Appendix 3: Draft sub-basin report – San Juan Islands

Puget Sound Vital Signs Floating Kelp Canopy Indicator Status and Trends in the San Juan Islands Sub-basin

Last updated: May 27, 2022

Recent trend:	Insufficient data
Entire data record trend:	Insufficient data
Overall trend:	Concern

Executive Summary

Kelp forests play critical ecological and cultural roles in marine ecosystems. The Puget Sound Vital Signs track this important resource using the floating kelp canopy indicator. The indicator reports on status and trends of floating canopies in sub-regions throughout Washington State. This report presents assessment results for the San Juan Islands sub-basin, which spans 687.8 km (427.4 mi) of shoreline and includes islands in the San Juan Archipelago and Cypress Island (Fig. 1).

Data Summary:

Fixed-wing aerial images processed by the Samish Indian Nation from 2006, 2016, and 2019 and images collected by the Washington Department of Natural Resources from 2011 - 2021 at the Cypress Island Aquatic Reserve were analyzed. Indigenous Scientific Knowledge on floating canopy kelp collected by the Samish Indian Nation was also examined to assess multi-decadal trends. Independent studies of floating kelp in Neushul (1967), Berry and Mumford (2011), and Spencer (2006) were also considered.

Key findings:

- Floating kelp is common in the San Juan Island sub-basin, with beds covering approximately 800 acres (350 hectares) in 2006.
- Surveys in 2016 and 2019 indicate lower kelp abundance than what was measured in 2006 throughout the majority of the sub-basin. However, differences in collection methods across the 2006, 2016, and 2019 survey years indicate that results should be viewed with caution. Specifically, the 2016 and 2019 surveys did not account for tide elevation and currents, which have been shown to have a large effect on the amount of visible floating kelp.
- Annual surveys from 2010-2019 around Cypress Island (approximately 4.5% of the sub-basin resource) indicate stability in total abundance, as well as within most zones.

- Indigenous Scientific Knowledge gathered by the Samish Indian Nation suggests multiple zones of decline in the kelp area over decades.
- Other studies conducted at small spatial scales within the sub-basin suggest kelp area decline, one area of concern is San Juan Channel, on eastern San Juan Island.
- Multiple sources raise concerns about floating kelp status and trends; however these sources cover limited areas, limited time periods or rely on different methods/systems of knowing that cannot be combined with quantitative data. Notably, Indigenous Scientific Knowledge data from the Samish Indian Nation indicates more extensive floating kelp beds in the past compared to what was observed in 2006, 2016, or 2019. Other sources suggest losses in some areas, but data gaps preclude detailed assessment.

Priorities for Future Research and Monitoring

- The highest priority is to continue to collect comprehensive aerial data in the Cypress Island Aquatic Reserve annually and process San Juan County Aerial imagery when conducted. Currently, County flights are planned to occur every three years.
    - Upgrade San Juan County imagery to match methods used by Washington Department of Natural Resources. Priorities would be to conduct flights during low current and low tide conditions, use consistent image processing procedures, and conduct flights annually.
- Conduct additional research at locations that indicate losses
- Continue collaboration with Samish Indian Nation on aerial and Indigenous Scientific Knowledge
- Encourage re-sampling of Marine Resource Committee kayak kelp monitoring sites.

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1. Introduction

1.1 Floating kelp canopy area vital sign indicator

Kelp is an ecosystem engineer that provides habitat and food web support for myriad species of invertebrates, fishes, birds and mammals. In Puget Sound, for example, kelp forests are critical habitat for juvenile rockfish (Sebastes spp.), forage fish (including Pacific herring and surf smelt), as well as out-migrating juvenile and returning adult salmon (Love et al., 1991; Doty et al., 1995; Johnson and Schindler, 2009; Essington et al., 2018; Shaffer et al., 2020). Changes in kelp abundance can have cascading effects (Sunday et al., 2016). For more information on the ecological role of kelp, see The Knowledge Review in The Kelp Conservation and Recovery Plan (Calloway et al., 2020).

This document is a part of an effort to produce a *floating kelp canopy area* indicator for the Puget Sound Vital Signs. In 2020, the Puget Sound Partnership called for a new *floating kelp canopy area* indicator, in recognition that kelp forests are foundations for diverse and productive ecosystems. The indicator will fill a current gap in scientific information about the condition of floating kelp canopies. It will also serve as a communications tool for sharing information with the public. *Floating kelp canopy area* indicator results will be available on Puget Sound Info – Vital Signs in June 2023. Detailed indicator information will be available on the Puget Sound Floating Kelp Hub Site. Summarized indicator results will be presented on the web sites in a format targeted for broad audiences. In addition, three types of technical documents describe the indicator in detail: (1) indicator assessment procedures, (2) sub-basin reports, (3) dataset descriptions.

The *floating kelp canopy area* is presented in a three tiered hierarchical system – termed the "Blended Indicator". At the highest level is the integrated info-map which is presented on Puget Sound Info – Vital Signs and the Puget Sound Floating Kelp Hub Site. One step down is sub-basin summary pages which are linked from the info-map on the Hub site. From there users can access sub-basin reports. The purpose of sub-basin reports is to provide detailed information on the data, analyses, and results of kelp status and trends that are synthesized in the floating kelp canopy area indicator, including rationale for sub-basin trend designation.

1.2 Sub-basin overview

The San Juan Island sub-basin encompasses all of the nearshore areas in San Juan County and Cypress Island (Figure 1). This region features numerous rocky islands separated by deep channels. This geology coupled with large tidal exchanges creates strong currents. To the south the basin is bordered by the eastern Strait of Juan de Fuca which connects to the Pacific Ocean. To the north lies the southern Strait of Georgia including the mouth of the Fraser River in Canada. South and southwest facing shorelines are often subject to relatively strong winds and waves from prevailing storms. Floating and understory kelps are found throughout the sub-basin due to the combination of hard substrates, nutrient replete waters, and high currents. Bull kelp (*Nereocystis luetkeana*) is the only canopy forming kelp species and dominates many of the sub-basin's rocky shorelines.

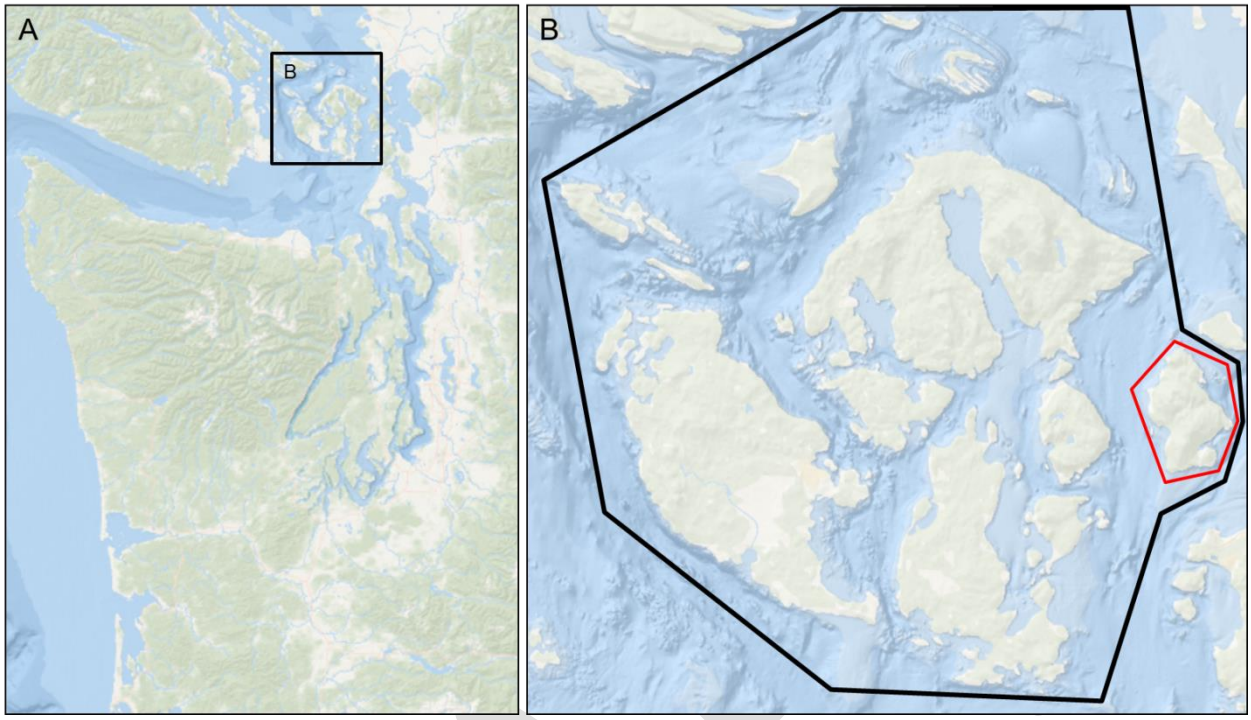


Figure 1: Western Washington State (A) with the San Juan Island sub-basin (B). Black polygon delineates San Juan Islands sub-basin. Samish Indian Nation aerial kelp data is collected along all shorelines in the sub-basin except those in the DNR Cypress Island aquatic reserve (red polygon).

2. Data, methods, and analyses

2.1 Overview

Data collection, summarization, and analysis followed general guidelines described in the floating kelp canopy area [guidelines and procedures document]. Below is a detailed description of how these guidelines were implemented for datasets in the San Juan Island Sub-basin.

2.2 Datasets analyzed for the indicator

Detailed dataset descriptions for the [Samish Indian Nation Aerial Kelp Survey Data] and [Washington Department of Natural Resources Cypress Island Aquatic Reserve aerial kelp surveys] are available on the Kelp Hub website. (Draft dataset descriptions can be found in Appendix 7 and Appendix 11.) Below is a summary of the datasets that are included in the San Juan Island Sub-basin.

Two data sources are used for indicator creation, the Samish Indian Nation Aerial Kelp Survey Data and Washington Department of Natural Resources Cypress Island Aquatic Reserve aerial kelp surveys.

1. Samish Indian Nation aerial kelp data includes surveys in 2004/2006, 2016 and 2019 and covers approximately 656.9 km (408.2 mi) or 95.5% of kelp area in the sub-basin.
2. DNR Cypress Island aquatic reserve aerial data data induces annual surveys from 2010 – 2019 and covers approximately 30.9 km (19.2 mi) or 4.5% of kelp area in the sub-basin.

2.3 Other datasets considered

In addition to the datasets above, we considered five additional datasets that include information on floating kelp canopy area.

- In 2019 the Samish Indian Nation collected and summarized Traditional Ecological Knowledge on the presence of floating kelp in their traditional territory including the San Juan Islands sub-basin. These data provide valuable insight into the past ecosystem state of the region.
- Neushul (1967) noted the presence of *Nereocystis* and understory kelp species near Brown Island in the late 1960s. This area was re-surveyed by WA DNR in 2018 (Christiaen B. personal communication).
- The San Juan County Marine Resources Committee conducted kayak monitoring of kelp beds in the sub-basin. However, these sites have not been surveyed since 2017.
- Erin Spencer (2006) explored changes in *Nereocystis* abundance on the eastern shores of San Juan Island, between Turn Rock and Point Caution.
- Berry and Mumford (2011) compared aerial photography-based surveys in 2004 and 2006 to historical Fertilizer Maps (Cameron 1915).

2.4 Time period designation

We followed the general guidelines for analysis time periods outlined in the floating kelp canopy area [guidelines and procedures document]. How these guidelines apply to the San Juan Islands sub-basin is described below.

Table 1: Definition of kelp status and trends analysis time periods for the San Juan Islands sub-basin.

Period	**Duration**
Recent	NA
Entire data record	NA
Overall	San Juan Islands: 2006, 2016, 2019 Cypress Island Aquatic Reserve: 2011 – 2021 Time periods encompassed in Other datasets considered

Following the general guidelines for kelp status time periods in the floating kelp canopy area [guidelines and procedures document] there is only sufficient data for an overall assessment of kelp condition. This is due to gaps in sampling frequency of existing Samish aerial and DNR Cypress datasets. Furthermore, the methods used on aerial photo flights in 2006, 2016, and 2019 surveys were inconsistent (see [Samish Indian Nation Kelp Aerial Survey] dataset description). The 2016 and 2019 surveys were not controlled for tides and currents. This precludes aerial comparisons, because tides and currents have been shown to have variable and large effects on the amount of visible kelp, ranging from 10% – 90% reduction in visible kelp (Britton-Simmons et al 2008).

2.5 Analysis

For both Samish Indian Nation aerial data and DNR Aquatic Reserve data from Cypress Island, GIS polygons of kelp bed area were obtained and plotted with GIS. For each year, kelp bed area was summed in 38 (Samish) and 9 (Cypress) unique nearshore zones. Zones were created following the guidelines used to create similar nearshore spatial units (also called "map-indecies") developed by DNR for the outer coast and Strait of Juan de Fuca. These units comprise approximately 5 to 15 km of shoreline and extend from the mean lower low water tide line (MLLW) to approximately 30m depth. Breaks between zones were created with consideration to overall size, consistency of physical parameters (e.g. shoreline type, substrate, exposure), and large geographical features such as bays, channels, and headlands. This created a single file for each dataset of kelp bed area by year by zone upon which all analyses and plotting was performed.

Kelp bed area for each dataset was assessed by plotting kelp bed area for each survey as raw values, as an anomaly from the whole dataset survey mean, and as a percentage of the maximum kelp area. Plots of raw values were made at three different spatial scales: 1) whole dataset, 2) summarized by reach, and 3) summarized by zone (Figure 2). Anomalies were calculated as the proportional difference in kelp bed area in a given year compared to the mean kelp bed area over the three survey years.

Year over year change in kelp bed area was assessed by regressing kelp bed area against survey year. From this regression, slope and p-values for each zone were extracted so that the direction and magnitude of change could be assessed. This information is visualized with bubble and slope plots. Bubble plots include a circle for each zone where the size of the circle is a function of the maximum proportional kelp bed area for the dataset (large circles are zones that have large kelp bed area). Circles are colored by the slope of the regression line and the p-value of that slope. Slopes where $p > 0.05$ are determined to have no change in kelp bed area over the surveys and are colored gray. Slopes where $p \leq 0.05$ are colored dark red for negative slopes and green for positive slopes. Slope plots display the estimated slope and error for each zone. Regression analysis was conducted over the all survey years for the Samish aerial data and for the recent time period (last 5 years: 2017 – 2021) and for the entire data record (10 years 2011 – 2021).

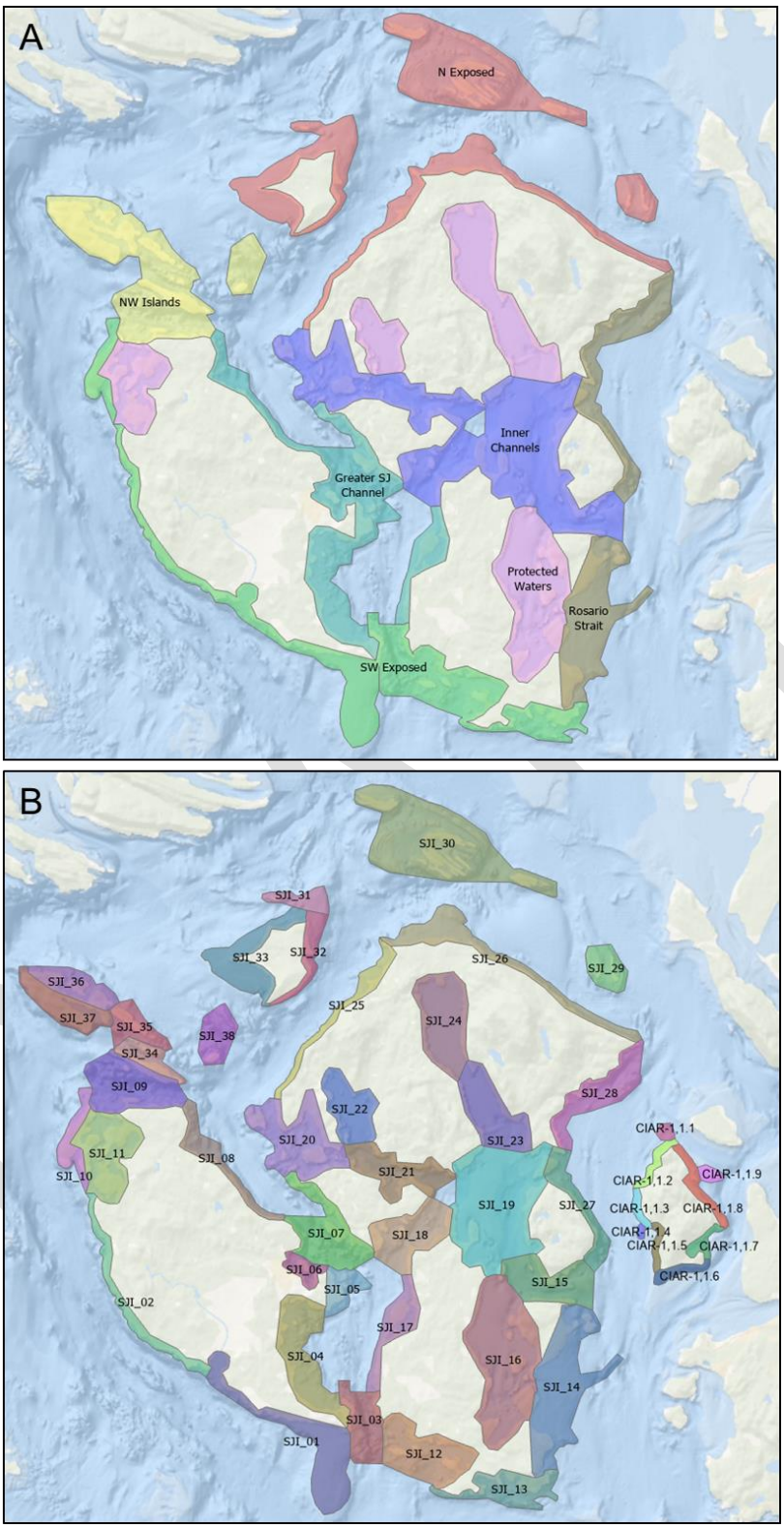


Figure 2: Reaches (A) and zones (B) of the San Juan Islands sub-basin. The protected waters reach (A) is composed of four smaller areas that are not spatially connected, but the kelp in these areas are summarized together. Note reaches are not defined for the DNR Cypress Island Aquatic Reserve.

3. Results

3.1 Abundance and distribution of floating kelp

3.1.1 Samish Indian Nation aerial data

The maximum amount of kelp detected in the San Juan Islands with the Samish Indian Nation aerial dataset was 324 hectares (800 acres) in 2006. Kelp detection in the sub-region decreased in 2016 and 2019, with the lowest kelp area detected in 2019 (Figure 3). Average kelp bed area per year was 233 +/- 86.9 sd hectares (575 acres +/- 214.6 sd). All Samish aerial data are presented as kelp bed area. The amount of kelp bed area varies greatly from survey-to-survey and at the reach and zone scale in Samish aerial data. Kelp bed area is most abundant in the SW Exposed reach which corresponds to zones SJI_01, SJI_02, SJI_03, SJI_12, and SJI_13. This is also where declines over the three surveys are most evident (Figure 4, 5).

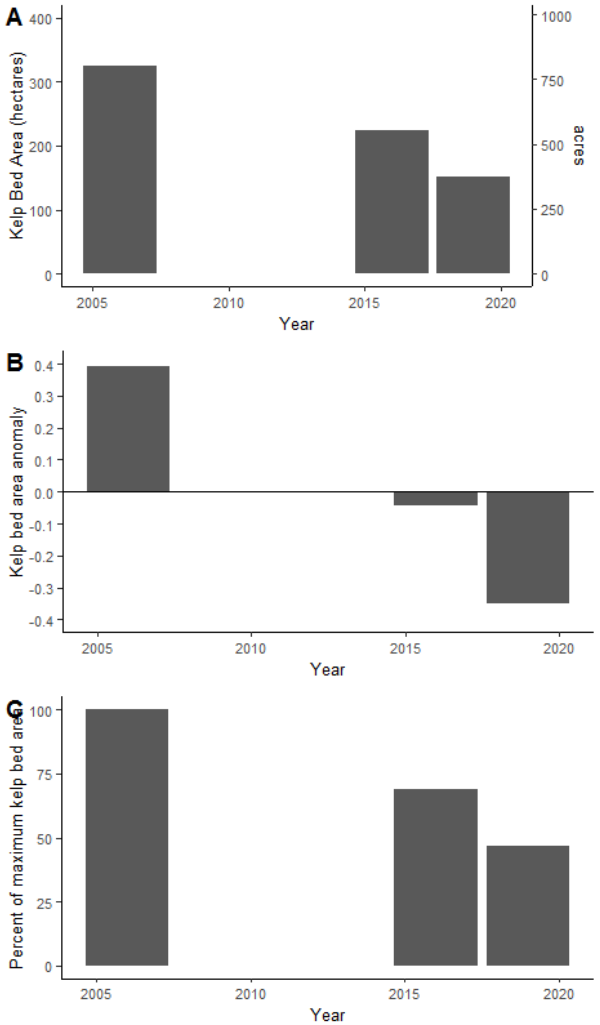


Figure 3: Kelp bed area (A), kelp bed area anomaly (B), and percent of maximum kelp bed area (C) summed in each year of the Samish Indian Nation aerial data collected in 2006, 2016, and 2019. Apparent changes should be interpreted with caution because the 2016 and 2019 aerial photography was not controlled for tides or currents, which are known to impact kelp detection.

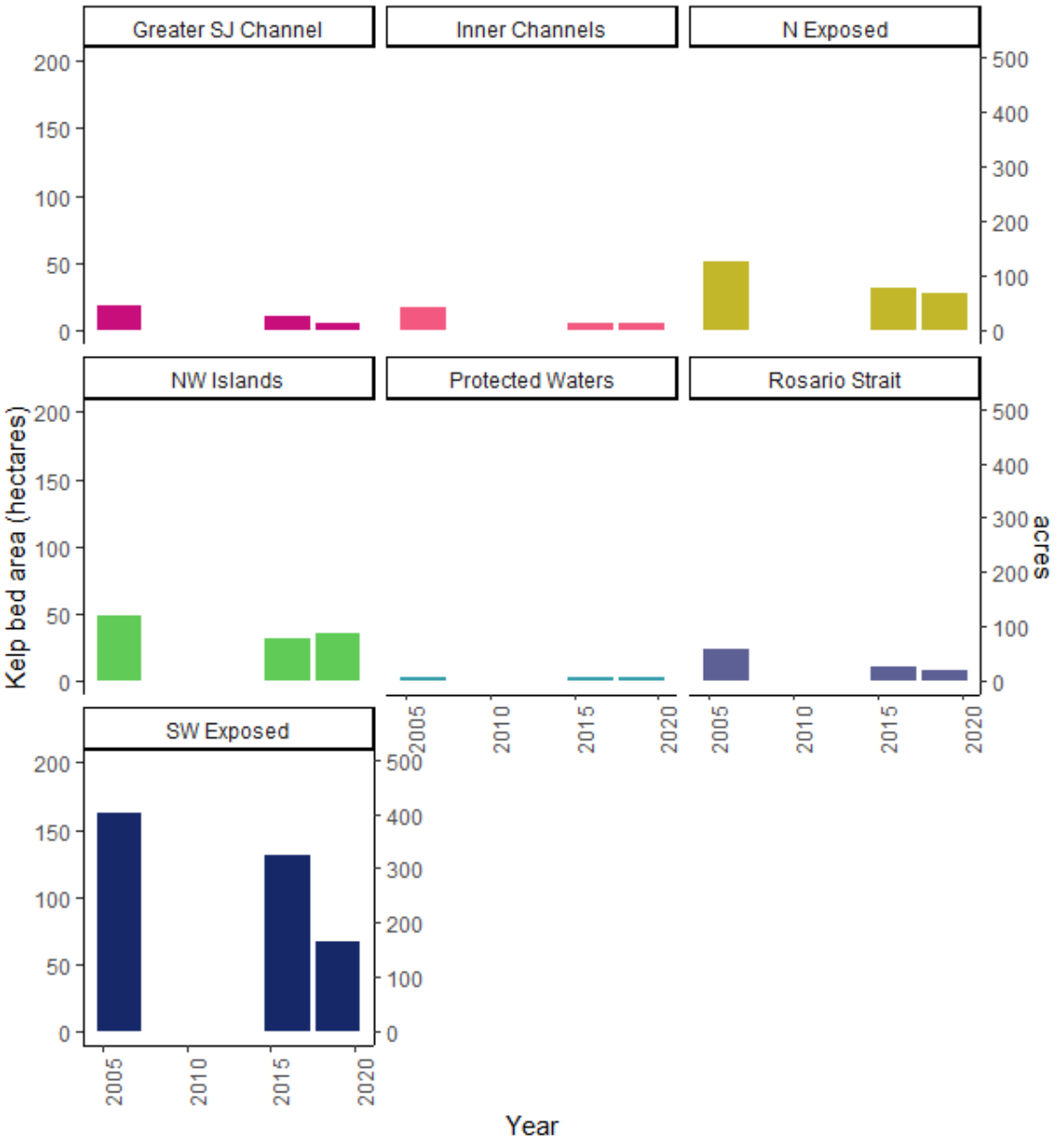


Figure 4: Kelp bed area summed by reach in the San Juan Islands sub-basin. Apparent changes should be interpreted with caution because the 2016 and 2019 aerial photography was not controlled for tides or currents, which are known to impact kelp detection.

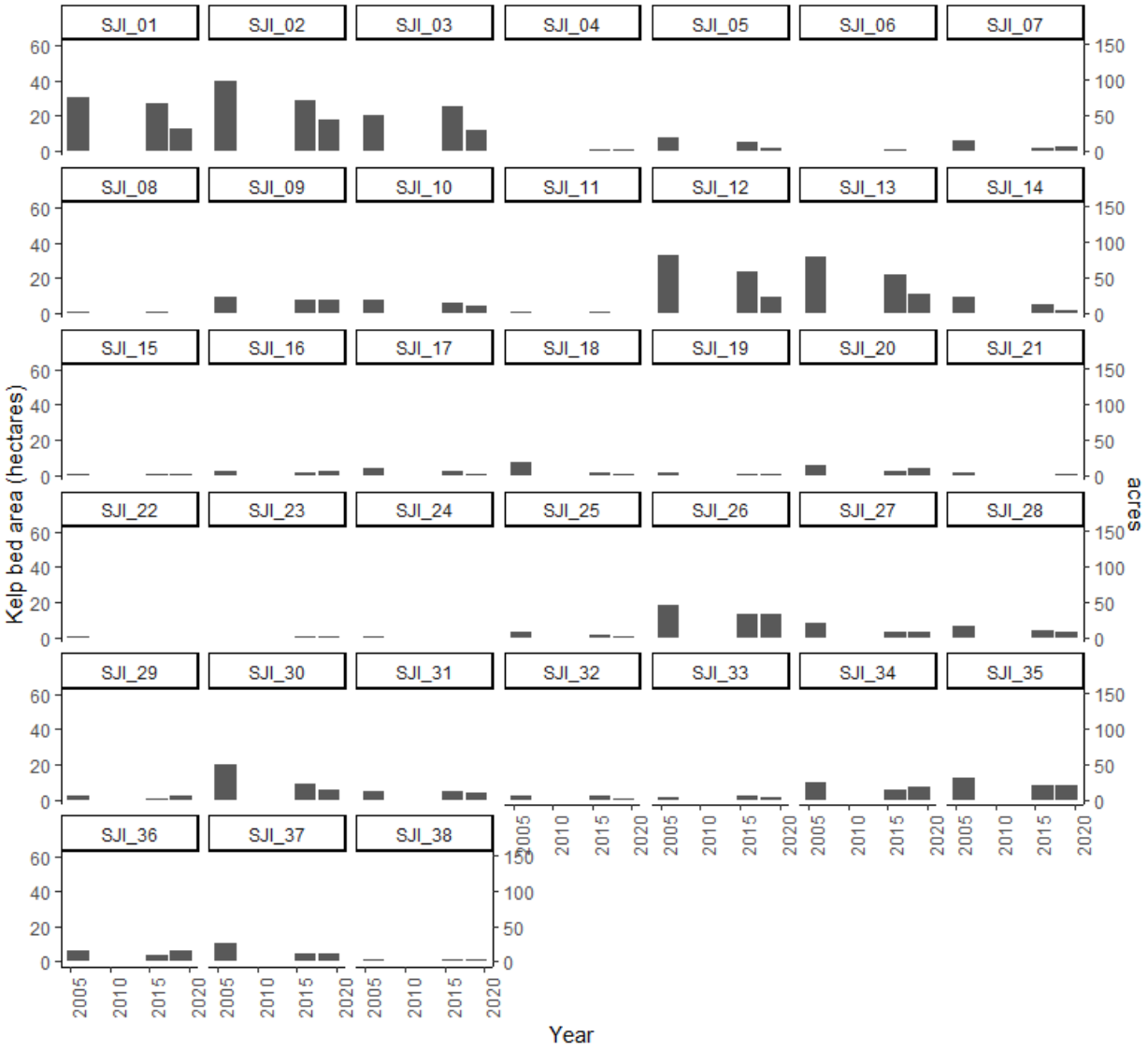


Figure 5: Kelp bed area summed by zone in the San Juan Islands sub-basin. Changes among years should be interpreted with caution because the 2016 and 2019 aerial photography was not controlled for tides or currents, which are known to impact kelp detection.

3.1.2 DNR Cypress Island Aquatic Reserve data

Kelp area in the Cypress Island Aquatic Reserve has varied year-to-year from 2010 to 2020 but has been largely consistent across the time span. In Cypress Island Aquatic Reserve, floating kelp area is reported in two ways: 1) As kelp *bed* area (comparable to the Samish Indian Nation aerial dataset), and 2) as kelp *canopy* area (comparable to COSTR data set which includes data for the Strait of Juan de Fuca [link]). We report both here. In summary, the canopy encompasses the area with bulbs, blades and stipes floating on the surface while the bed groups nearby plants and includes the gaps between them. All figures for this sub-basin are shown for bed area, to maintain comparability between the Samish Indian Nation aerial data set and the DNR Cypress Island Aquatic Reserve data set.

Cypress Island – Floating kelp bed area

The maximum floating kelp bed area detected in the Cypress Island Aquatic Reserve was 79.2 hectares (195.7 acres), which occurred in the year 2013 (Figure 6). The minimum kelp bed area detected in the Cypress Island Aquatic Reserve was 54.6 hectares (134.9 acres), which occurred in the year 2015. Average kelp bed area per year was 66.8 hectares [± 8.2 hectares s.d.].

Cypress Island – Kelp canopy area

The maximum kelp canopy area detected in Cypress Island Aquatic Reserve was 14.6 hectares (36.1 acres) in 2013. The minimum kelp canopy area detected in Cypress Island Aquatic reserve was 9.3 hectares (23.0 acres), which occurred in the year 2015. Average kelp canopy area per year was 12.7 hectares [± 1.9 hectares sd].

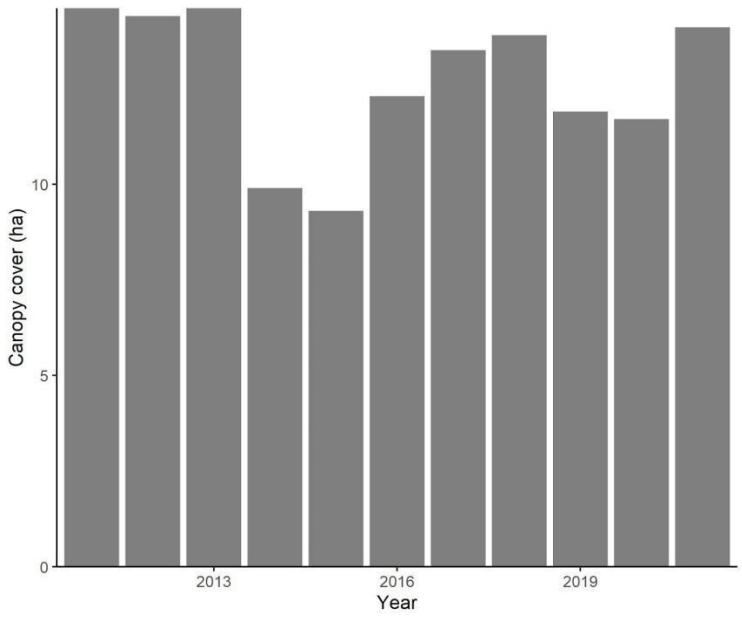


Figure 6: Kelp canopy area summed across all zones on the DNR Cypress Island Aquatic Reserve aerial data set from 2010 to 2021.

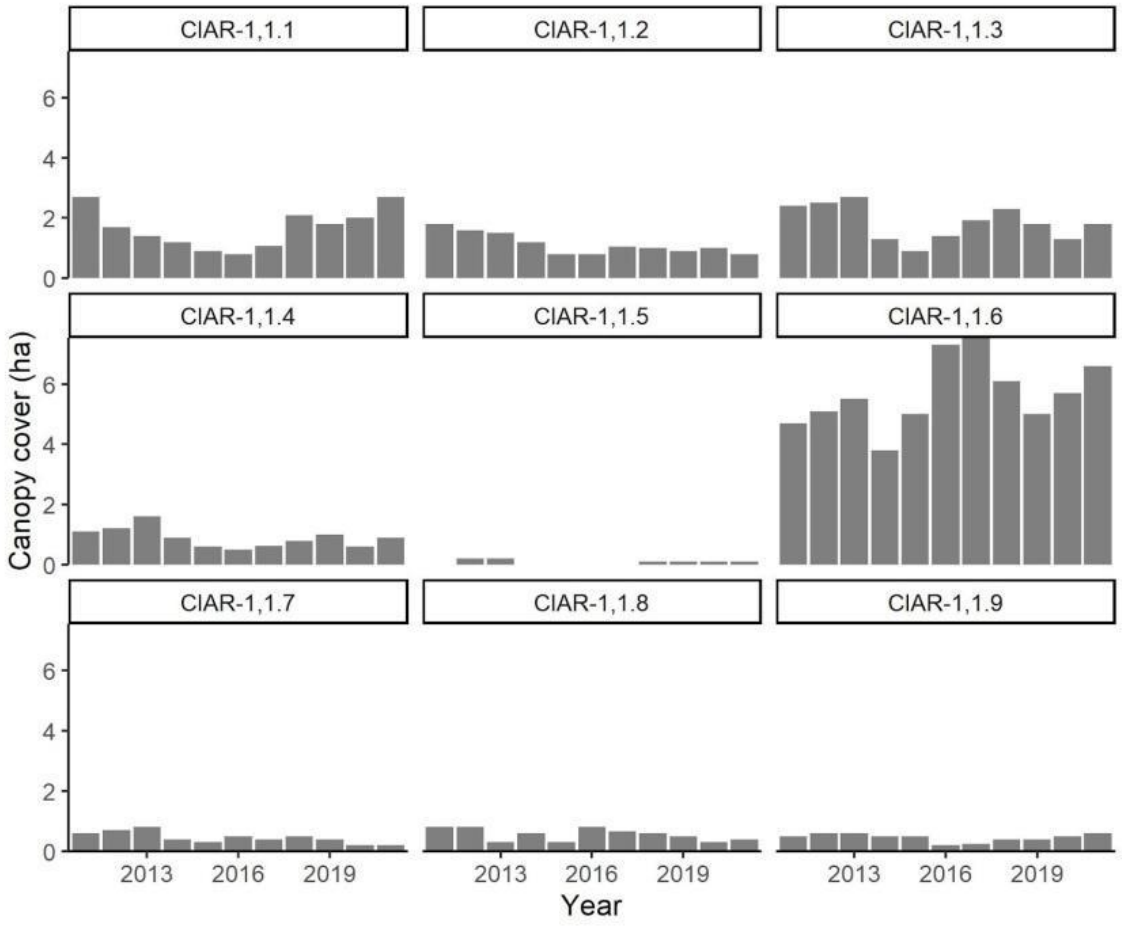


Figure 7: Kelp canopy area summed in zones on the DNR Cypress Island Aquatic Reserve aerial data set from 2010 to 2021.

3.2 Trends in floating kelp area

3.2.1 Samish Indian Nation aerial data

Six out of seven reaches and 32 out of 38 zones in the Samish aerial surveys showed no change in kelp abundance across all survey years. One each (SW Exposed) and 6 zones showed lower abundance in 2019, compared to 2006, however this difference could be due to sampling conditions (Figure 8 - 11). Kelp canopies in the most rapidly contracting zone (SJI_12, located near the western portion of southern Lopez Island) decreased at an average rate of 1.6 hectares (3.9 acres) per year (Fig. 13). These patterns are mirrored when kelp data are summarized at the reach level (Figure 8). These estimates of change must be interpreted with caution because the 2016 and 2019 estimates did not control for tides and currents, which are known to affect the canopy visibility.

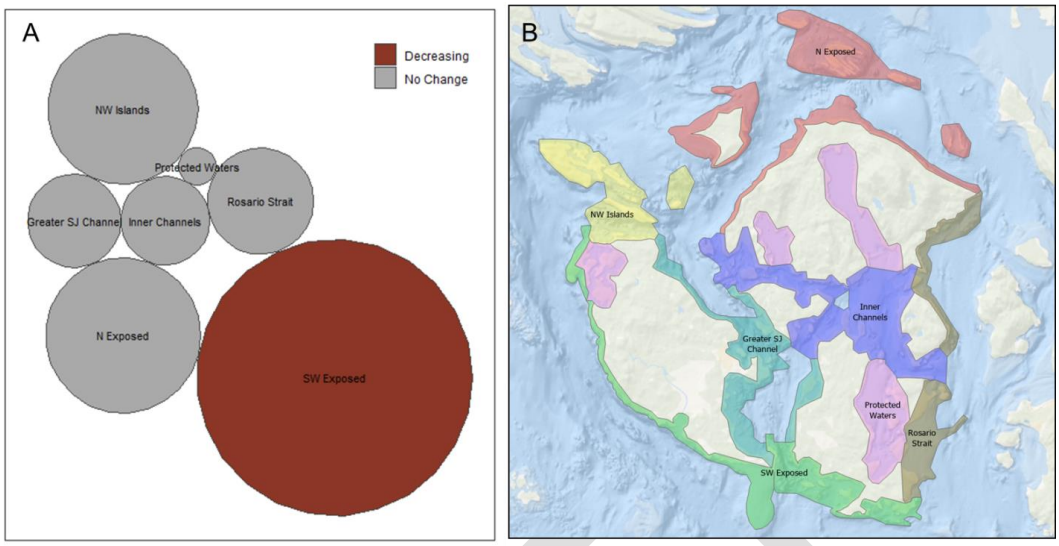


Figure 8: A: Bubble plot of reach level trends in kelp bed area from Samish aerial surveys across all survey years (2006, 2016, and 2019). These estimates of change must be interpreted with caution because the 2016 and 2019 estimates did not control for tides and currents, which are known to affect the canopy visibility. Circle size is the proportion of total kelp area of a given reach. B: Map of San Juan Island sub-basin with reaches of Samish aerial data. Same color polygons indicate the same reach.

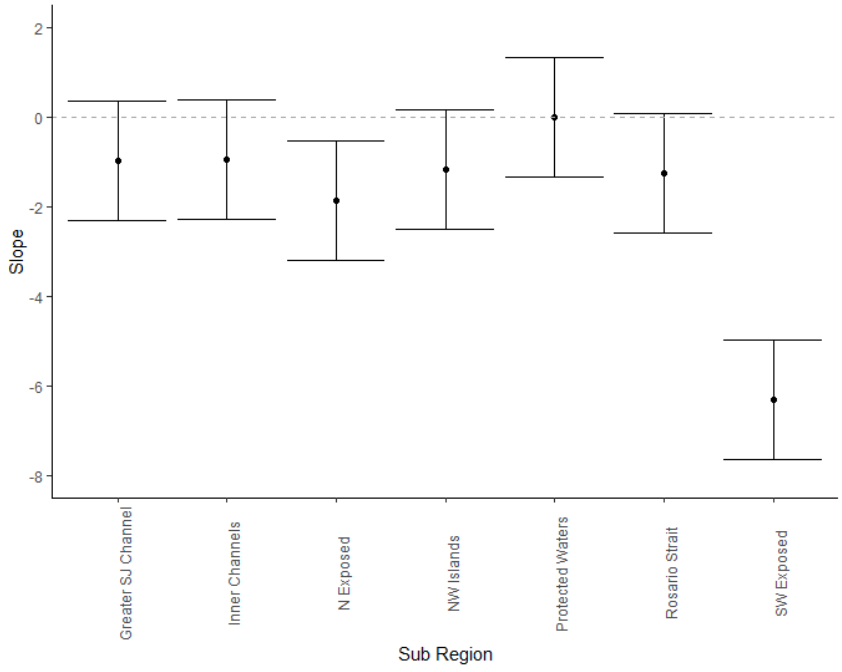


Figure 9: Slope plot of reach level trends in kelp bed area from Samish aerial surveys across all survey years (2006, 2016, and 2019). These estimates of change must be interpreted with caution because the 2016 and 2019 estimates did not control for tides and currents, which are known to affect the canopy visibility. Circle size is the proportion of total kelp area of a given zone.

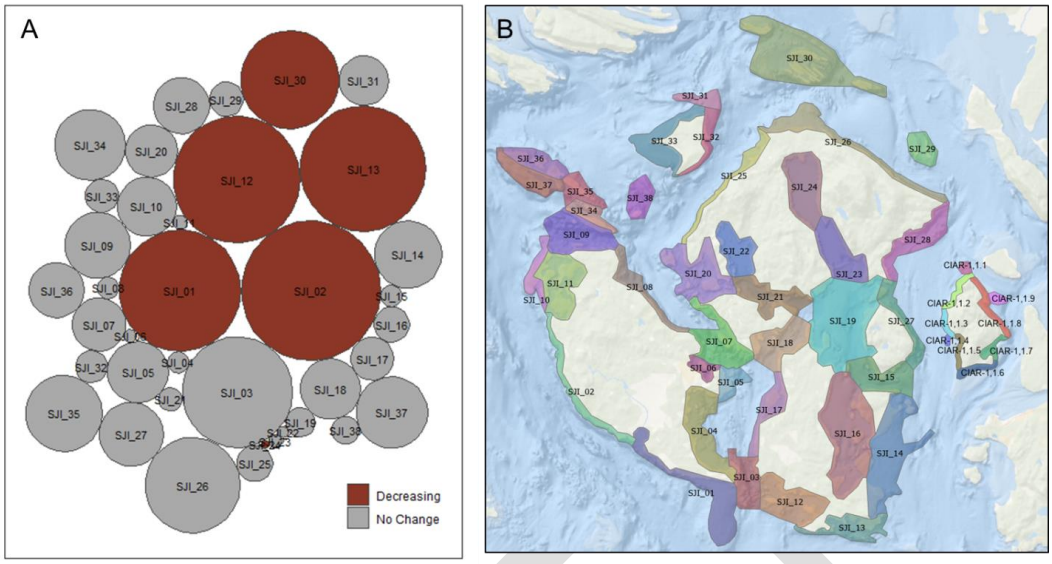


Figure 10: A: Bubble plot of zone level trends in kelp bed area from Samish aerial surveys across all survey years (2006, 2016, and 2019). These estimates of change must be interpreted with caution because the 2016 and 2019 estimates did not control for tides and currents, which are known to affect the canopy visibility. Circle size is the proportion of total kelp area of a given zone. B: Map of San Juan Island sub-basin with zones of Samish aerial data and Cypress Island. See Figure 12-14 for Cypress Island trends.

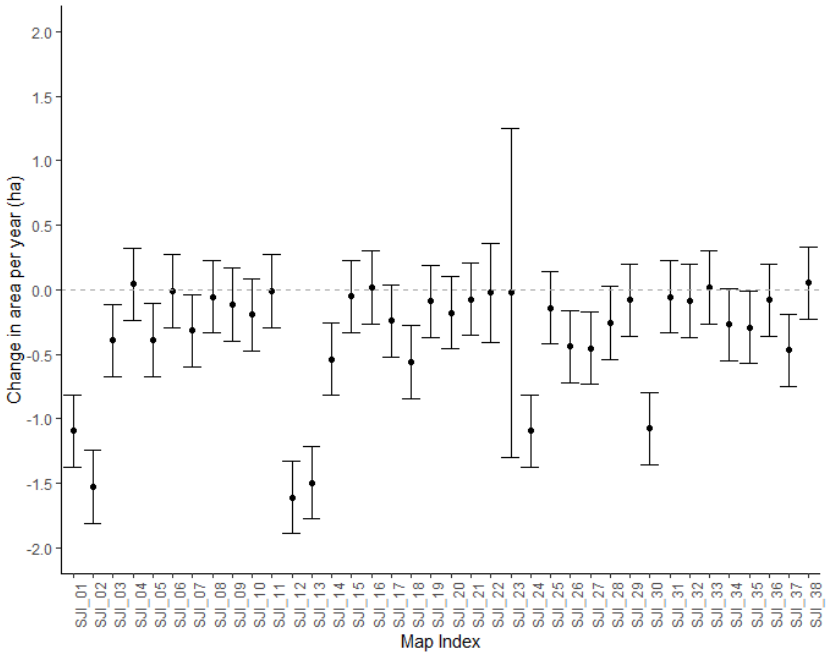


Figure 11: Slope plot of zone level trends in kelp bed area from Samish aerial surveys across all survey years (2006, 2016, and 2019). These estimates of change must be interpreted with caution because the 2016 and 2019 estimates did not control for tides and currents, which are known to affect the canopy visibility.

DNR Cypress Island Aquatic Reserve data

Seven out of nine zones (77%) in the Cypress Island Aquatic Reserve showed no evidence of a change in kelp bed area from 2010 to 2020, while two map indices showed evidence of decline (Figure 12). Kelp canopies in the most rapidly decreasing zone (CIAR1, 1.2) decreased at an average rate of 0.5 hectares (1.2 acres) per year across all survey years (Figure 13). However, trends across the last 5 years indicate increases in CIAR1 1.1 and CIAR1 1.5, with the remaining zones suggesting no trend (Figure 14 - 15).

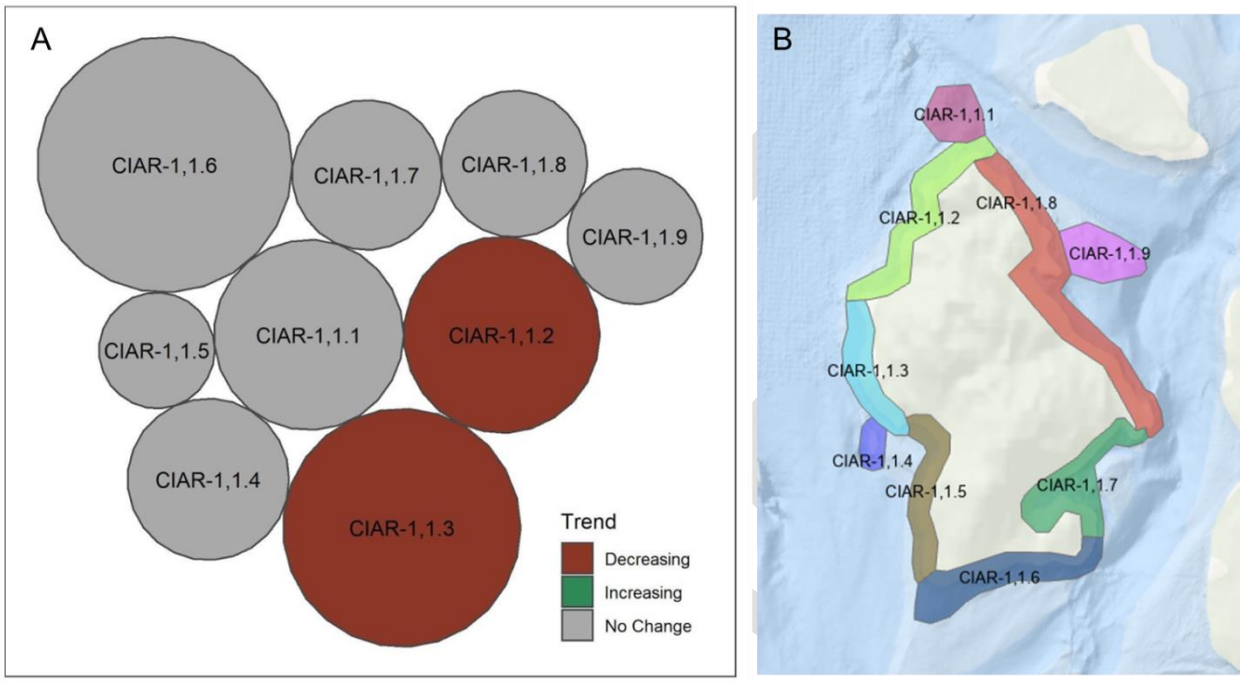


Figure 12: A: Bubble plot of zone level trends in kelp bed area from Cypress Island Aquatic Reserve across all survey years (2011 – 2021). B: Map of Cypress Island zones.

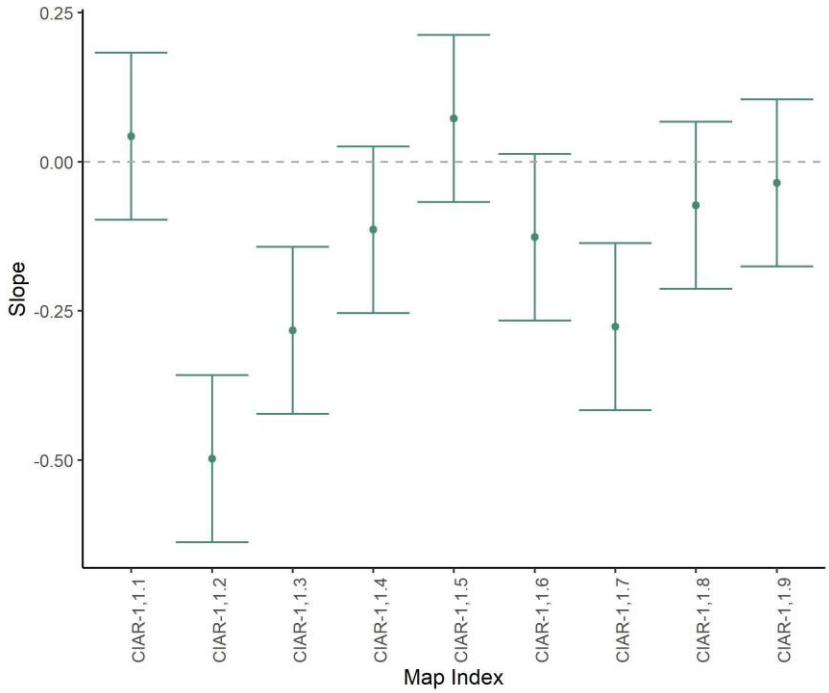


Figure 13: Slope plot of zone level trends in kelp bed area from Cypress Island Aquatic Reserve across all survey years (2011 – 2021).

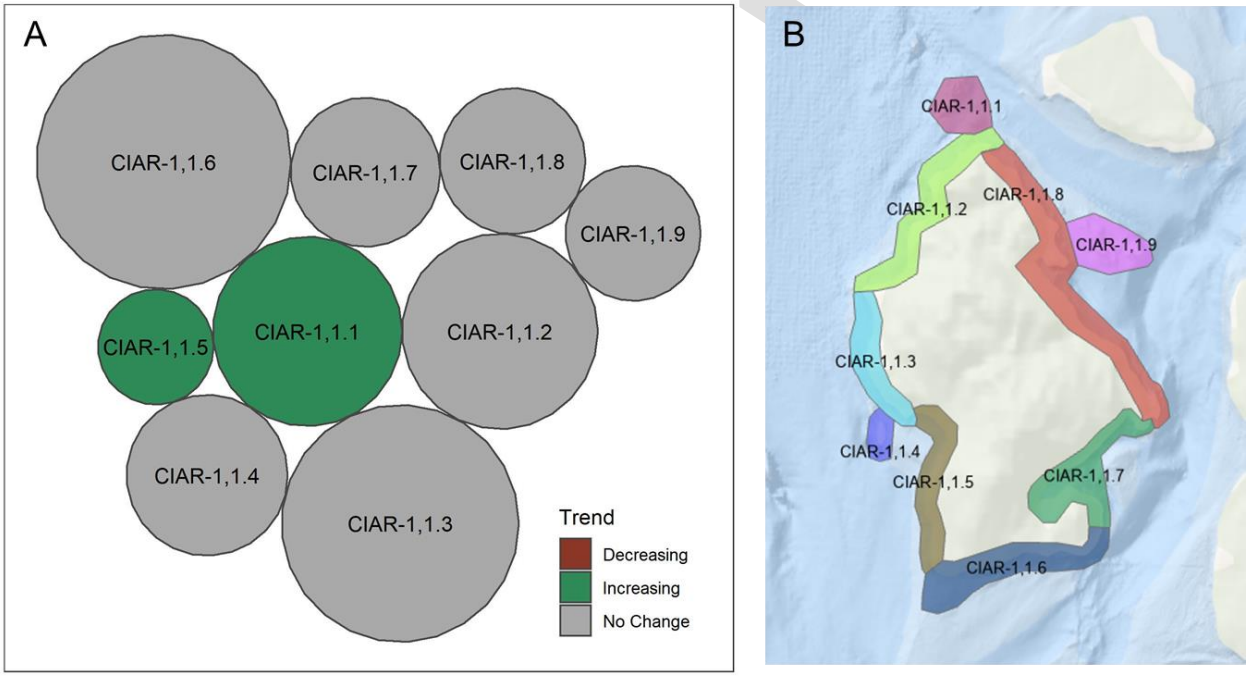


Figure 14: A: Bubble plot of zone level trends in kelp bed area from Cypress Island Aquatic Reserve from the last 5 years (2017 – 2021). B: Map of Cypress Island zones.

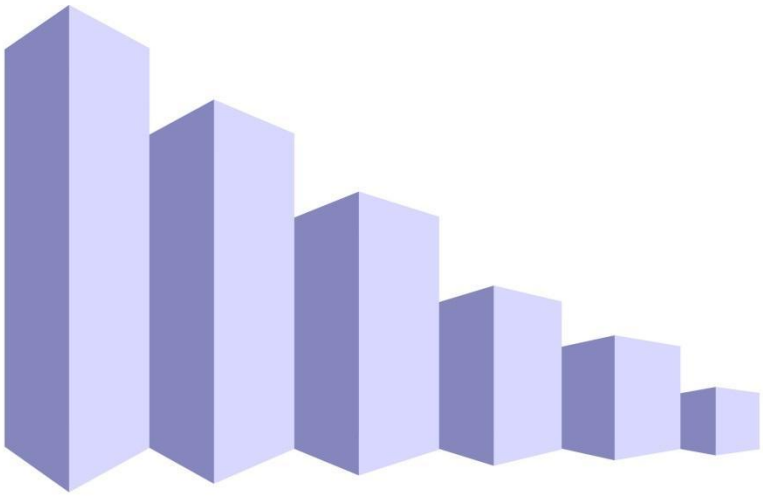


Figure 15: Slope plot of zone level trends in kelp bed area from Cypress Island Aquatic Reserve from the last 5 years (2017 – 2021). Currently not available.

3.3 Other datasets

- Mapping of Samish Indian Nation Indigenous Scientific Knowledge (ISK) identifies general areas within the sub-basin where Tribal fishermen fished near canopy-forming kelp beds (Figure 16). Multiple conspicuous differences existed between ISK and aerial survey data, suggesting both expansion and contraction at different sites. Notable areas where contemporary surveys observed substantially smaller floating kelp beds include the southeast portion of San Juan Island (Garrison Bay), east coast of Orcas Island (Deep Point to Lawrence Point), east Shaw Island (Picnic Cove to Hankin Point), and northwest Lopez Island (Flat Point to Upright Head). Notable areas of expansion are the shorelines around Stewart, Spieden Island, Patos, Sucia, and Matia Island, the outer shoreline of Henry Island (Kellett Bluff area), and southern shorelines of Cypress Island. However, given the methods by which ISK was collected, these maps likely reflect areas where elders had long-standing knowledge, rather than a comprehensive sub-basin assessment of where canopies occurred throughout the sub-basin. Areas with no kelp canopies mapped could indicate either that no kelp was present or that the elders did not use that area. No distinction between 'absent' and 'no data'' has been made. Note that Samish ISK data includes areas that are not a part of the San Juan sub-basin including Lummi Island, Guemes Island, shorelines near Anacortes, WA, Burrows and nearby islands, and Deception Pass. However, ISK data from these regions is useful for other sub-basins.
- DNR towed videography in the same vicinity as Neushul (1967) in addition to widespread anecdotal observations has noted that *Nereocystis* has been absent from Brown Island for at least a decade.
- The San Juan County Marine Resources Committee kayak monitoring sites are pending review, prior to inclusion in the dataset. Because the sites have not been surveyed since 2017, and major changes were not noted during the years they were surveyed, they are anticipated to be useful primarily for comparison to other datasets. A detailed dataset description of the Marine Resources Committee kelp surveys can be found [here].
- Erin Spencer (2006) noted disappearance of some beds of *Nereocystis* and changes in density relative to 1911-1912, but also noted substantial uncertainty related to methodological differences.

- Berry and Mumford (2011) identified the eastern shores of San Juan Island as an area with high probability of localized losses.

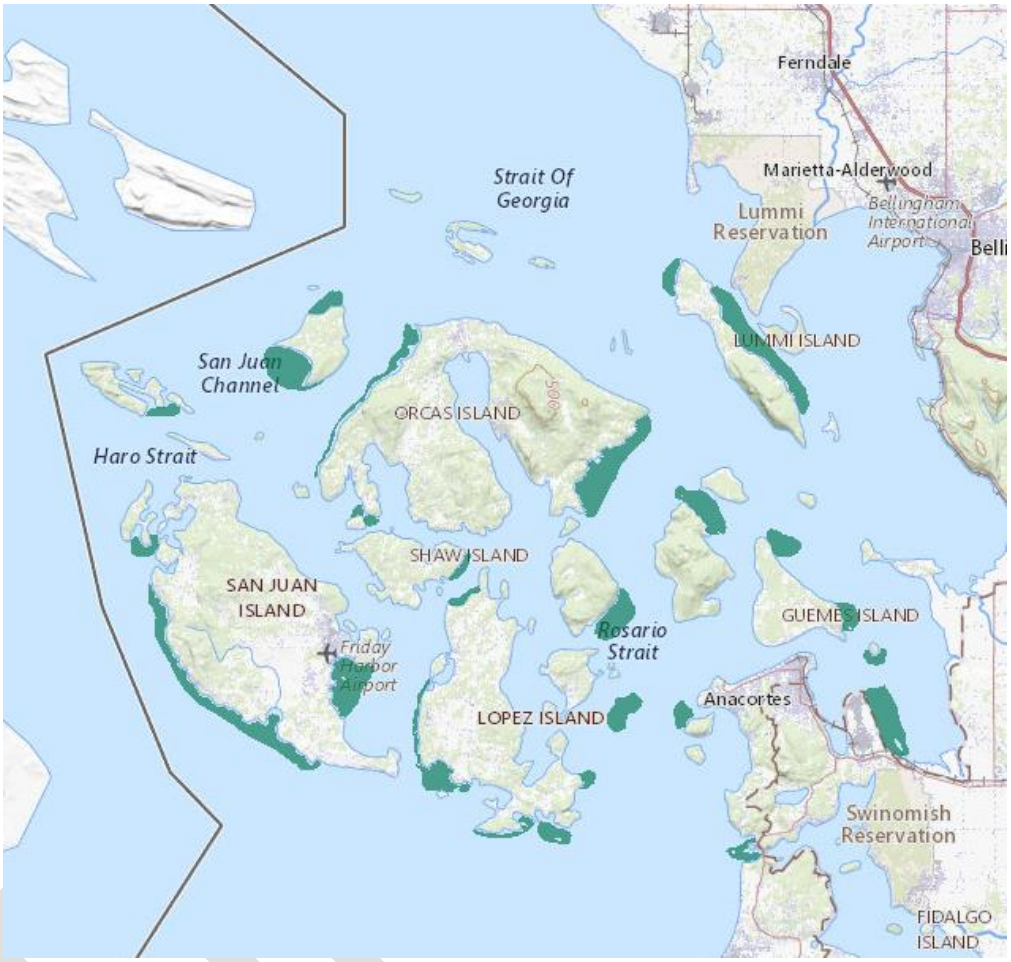
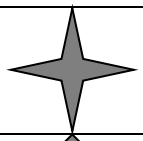
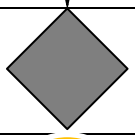
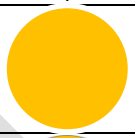
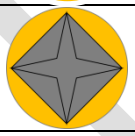


Figure 16: Indigenous Scientific Knowledge of kelp beds in the Samish Indian Nation traditional territory. Green shaded areas represent locations where two tribal fishermen drew where they remembered seeing Bull Kelp from their decades of fishing the waters surrounding the San Juan Islands. Elders denoted that kelp canopies were historically present.

3.4 Determination of sub-basin trend designation

Due to the substantial spatial and temporal data gaps, as well as methodological inconsistencies, it is not possible to conclusively assess floating kelp trends over the last 5 years or longer time spans in the San Juan sub-basin. Therefore, it is classified as *insufficient data* for recent and entire data record. The DNR Cypress Island data suggests stability based on annual surveys with consistent methods over the last 10 years, but this dataset comprises less than 5% of the sub-basin shorelines. Taking both aerial datasets into consideration in addition to results from other datasets there is the suggestion of loss of kelp canopy area over longer time periods. Therefore, the overall classification is *concern* for floating kelp canopies in the San Juan Islands sub-basin.

Table 2: Summary of floating kelp canopy area status and trend category designation for recent, entire data record time spans, and overall assessment.

Recent	Insufficient data	
Entire data record	Insufficient data	
Overall	Concern	
Indicator Classification	**Concern**	

4. Discussion

4.1 Datasets used in sub-basin assessment

Samish aerial and DNR Cypress aerial data provide a comprehensive survey of floating kelp canopy area for the years surveyed in the sub-basin. While the 2006 Samish aerial data and Cypress aerial data is collected following procedures that account for tide and currents, the 2016 and 2019 survey years of the Samish aerial data is not. This introduces substantial unaccounted error in the 2016 and 2019 surveys as visible floating kelp canopy area can be greatly affected by tide and current (Britton-Simmons et al. 2008, Cavanaugh et al. 2021).

Samish Indian Nation ISK kelp canopy area data provides a unique view of past kelp bed state in the sub-basin. The apparent abundance of kelp from this data is in stark contrast to recent aerial surveys and suggests that kelp bed area has substantially declined over many decades. These apparent differences highlight a need for consistent monitoring of kelp bed area in the sub-basin.

4.2 Potential drivers of observed kelp trends and linkages to ecosystem components

The nature of available data kelp data in the sub-basin presents considerable challenges when trying to ascribe potential drivers to observed patterns. However, it is important to note that the sub-basin constitutes the greatest extent of floating kelp shoreline in Washington State. Therefore, floating kelps make up a major nearshore habitat in the sub-basin and changes in its abundance are likely to have wide-reaching effects.

Like other floating kelp populations in the region, floating kelp in the San Juan Islands are susceptible to large scale and local climatic and physical drivers including the Pacific Decadal Oscillation, the Oceanic El Niño Index, and the North Pacific Gyre Oscillation, regional surface temperatures, and salinity. Of

particular note, there is a well-documented temperature and salinity gradient between the south and north of the sub-basin (Masson and Cummins 2000, Lowe et al. 2016). Southern areas (South and West San Juan Island, and South Lopez Island) are dominated by relatively cold and saline waters of the Strait of Juan de Fuca, whereas Northern areas (North Orcas Island, Sucia Island, Patos Island, Matia Island, Waldron Island, and Stuart Island) are dominated by warmer, fresher water from the Fraser River plume. This gradient connected with deep channels between islands, and strong tidal driven currents produce a dynamic physical environment that may influence floating kelp abundance. The apparent declines on the Southern margin of the sub-basin is surprising in that kelps should thrive in these waters compared to the Northern portion of the sub-basin where they may be more physiologically stressed. This further highlights that the observed decline in floating kelp in that reach may be a function of differences in sampling as the 2016 and 2019 data where not collected with regard to tide height and current.

Sea urchins are important grazers in kelp forest ecosystems (Watson and Estes, 2011) and are common in the sub-basin. However, direct grazing pressure by sea urchins on floating kelps is assumed to be low as sea urchins appear to rely on drift algae for consumption (Britton-Simmons et al. 2012). Other than records of commercial catch, there is little information on the population status and trends of sea urchins in the region. Other grazers including *Lacuna* sp. snails (Duggins et al. 2001), and kelp crabs (*Pugettia producta*) (Dobkowski 2017, Dobkowski et al. 2017) have been noted to consume kelp in the region. However the sub-basin scale impact of these grazers is unknown.

4.3 Priorities for future research and monitoring

This assessment of floating kelp resources in the San Juan Islands brings to light a series of research and monitoring priorities that could be undertaken, contingent upon available funding and resources:

- The highest priority is to continue to collect comprehensive aerial data in the Cypress Island Aquatic Reserve annually and process San Juan County Aerial imagery when conducted. Currently, County flights are planned to occur every three years.
- Upgrade San Juan County imagery to match methods used by Washington Department of Natural Resources. Priorities would be to conduct flights during low current and low tide conditions, use consistent image processing procedures, and conduct flights annually.
- Conduct additional research at locations that indicate losses such as the South and West shoreline of San Juan Island and South Lopez Island.
- Continue collaboration with Samish Indian Nation on aerial and Indigenous Scientific Knowledge
- Encourage re-sampling of Marine Resource Committee kayak kelp monitoring sites.

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