NATURAL RESOURCES

West Sound Eelgrass Monitoring Program

Final report for WDFW19-13385

03/02/2021

PSEMP

PUGET SOUND ECOSYSTEM
MONITORING PROGRAM

WASHINGTON STATE DEPARTMENT OF
NATURAL RESOURCES
HILARY S. FRANZ | COMMISSIONER OF PUBLIC LANDS

DNR monitors abundance and depth distribution of native seagrasses to determine status and trends in greater Puget Sound through the Submerged Vegetation Monitoring Program (SVMP) (https://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/nearshore-habitat-eelgrass-monitoring).

The Submerged Vegetation Monitoring Program is a component of the Puget Sound Ecosystem Monitoring Program (PSEMP) (https://sites.google.com/a/psemp.org/psemp/home).

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The Nearshore Habitat Program is grateful to the Suquamish Tribe for initiating this project, and WDFW for providing funding for DNR to expand seagrass and macro algae monitoring in the area of interest. The following document is the final report for IAA 93-100143 / WDFW 19-13385 between DNR and WDFW.

The primary authors for this report are Bart Christiaen and Lisa Ferrier. Lauren Johnson and Melissa Sanchez played a critical role in the video data collection and post-processing for the work summarized in this report.

The Nearshore Habitat Program would like to give special recognition to Ian Fraser and Jim Norris of Marine Resources Consultants who played a significant role in the success of the project. Marine Resources Consultants showed great dedication and logged many hours of sea time collecting data for the project.

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Copies of this report may be obtained from:

http://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/nearshore-habitat-publications

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Contents

Executive summary

The Washington State Department of Natural Resources (DNR) manages 2.6 million acres of State-Owned Aquatic Lands for the benefit of current and future citizens of Washington State. DNR's stewardship responsibilities include protection of native seagrasses, such as eelgrass (*Zostera marina*), important components of nearshore ecosystems in greater Puget Sound. DNR monitors abundance and depth distribution of native seagrasses to determine status and trends in greater Puget Sound using towed underwater videography.

This report synthesizes results from eelgrass surveys conducted under an interagency agreement between DNR and the Washington Department of Fish and Wildlife (WDFW 19-13385). This agreement was initiated the Suquamish Tribe as part of NTA2018-0409. This effort supplements existing and planned future sampling by DNR's Submerged Vegetation Monitoring Program (SVMP), and significantly improves our understanding of eelgrass area and depth distribution in Central Puget Sound.

Key findings:

- In 2019 and 2020 DNR conducted a survey of eelgrass at 54 sites along the shoreline of the Kitsap Peninsula. This effort complements a series of surveys between 2014 and 2020 to assess eelgrass at 378 sites along the central basin of Puget Sound. The 2019 sampling effort expands the footprint of DNR's monitoring program to include the entire shoreline of the Colvos Passage. In 2020 DNR resurveyed previously sampled sites to assess trends in eelgrass area along the Kitsap Peninsula and Bainbridge Island.
- *Zostera marina* was found at 281 sites, and the non-native *Z. japonica* was found at 127 out of 378 sites sampled between 2014 and 2020. Eelgrass beds were found along most of the shorelines of the central basin, but were sparse or absent in Port Orchard, Dyes Inlet, Liberty Bay, and in the inner portion of Quartermaster Harbor. Eelgrass was also absent along heavily modified shorelines in Elliott Bay.
- Between 2014 and 2020, there was 1315 +/- 13 ha of eelgrass in the central basin of Puget Sound. This is 5.7% of our current best estimate of eelgrass area in greater Puget Sound (approximately 23,000 ha). Approximately 680 +/- 9 ha occurred along the shorelines of King County, and 635 +/- 10 ha was present along the shorelines of Kitsap County.
- Between 2018 and 2020, we revisited 35 sites along the Kitsap Peninsula that were previously sampled by DNR. In total there were 4 sites with declines, one site without eelgrass, and 30 sites where eelgrass did not significantly change over time.
- Multiple gradients in eelgrass depth distribution were evident throughout the study area. Eelgrass beds grew less deep in Port Orchard, the southern part of King County, and inside Quartermaster Harbor. These patterns likely reflect spatial gradients in water clarity.

1 Introduction

1.1 Eelgrass monitoring in Central Puget Sound

Eelgrass (*Zostera marina*) is a true flowering plant found in the marine environment. Eelgrass is a common species in the bays and estuaries of Puget Sound and it often forms dense meadows. Eelgrass provides many important and documented ecological functions. Eelgrass, along with other seagrasses, is an indicator of estuarine health (Dennison et al., 1993, Krause-Jensen et al., 2005; Orth et al., 2006). In Puget Sound, eelgrass plays a critical role for spawning Pacific herring (*Clupea harengus pallasi*), out-migrating juvenile salmon (*Onchorhynchus spp*) (Phillips, 1984; Simenstad, 1994), and waterbirds like the black brant (*Branta bernicla*) (Wilson & Atkinson, 1995) and the great blue heron (*Ardea erodias*) (Butler, 1995). Additionally, eelgrass was identified as a Vital Sign of ecosystem health by the Puget Sound Partnership because of its ecological importance and response to environmental change.

The West Sound Eelgrass Monitoring Program (NTA 2018-0409) is a collaboration between the Suquamish Tribe and DNR. This project is part of a larger multi-year survey of eelgrass in the Central Basin of Puget Sound (Figure 1). The larger study was initiated in 2014, by IAA 15-17 between the Suquamish tribe and DNR. In 2016, DNR collaborated with the City of Bainbridge Island to survey 24 sites along the shoreline of Bainbridge Island (IAA16-239). In the same year, DNR and the Suquamish Tribe amended IAA 15-17 to survey 50 additional sites. In 2017 and 2018, DNR sampled the entire shoreline of King County, including Vashon Island. This effort was partially funded through an agreement with King County, Department of Natural Resources and Parks, Wastewater Treatment Division (IAA 93-097520).

The West Sound Eelgrass Monitoring Program extends baseline sampling along the western shore of Colvos Passage south to Gig Harbor (25 sites), and resamples 29 previously sampled sites in the East Kitsap Study area. The monitoring provides eelgrass area and depth distribution estimates at all sites sampled. Sampling locations were selected to help meet the following objectives:

- To better characterize the status of eelgrass along the western shore of Colvos Passage, including providing a baseline for future year-to-year change assessment and long-term trend monitoring
- To observe conditions in specific area segments of Port Madison, Agate Pass, and Port Orchard Passage where a regionally important herring stock utilizes submerged vegetation as substrate for spawning

- To observe eelgrass conditions in critical areas where known change has occurred (e.g., Point Bolin, Battle Point)
- To estimate changes in eelgrass area and depth distribution along the upper Kitsap Peninsula and the eastern shore of Bainbridge Island.

The objectives support Regional Priority CHIN1 of the PSP Action Agenda - Protect all remaining salmon habitat, optimize and increase ecosystem function gain and improve region-wide accountability – by creating a balance sheet for habitat gain and loss in the study area.

This report summarizes results for NTA2018-0409, and compiles data from recent surveys into an eelgrass area and depth distribution in the central basin of Puget Sound. Partial results were previously published in Christiaen et al. (2018) and Christiaen et al. (2020). These reports contain more detailed information on site-level area and depth distribution, as well as long-term trends along the shoreline of King County.

1.2 Data access

The SVMP monitoring database and a User Manual are available through the DNR GIS data download web page. The User Manual (Dowty et al. 2019) includes a more detailed description of project methods than are included in this report. The data is also accessible through an online data viewer[1]. These resources are available at the following webpages:

https://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/puget-sound-eelgrass-monitoring-data-viewer

https://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/nearshore-habitat-publications

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[1] Note that data from 2020 will not be available for download until fall 2021

2 Methods

Field sampling was conducted using methods developed for DNR's Submerged Vegetation Monitoring Program (Christiaen et al. 2019). The SVMP is a regional monitoring program, initiated in 2000, designed to provide information of both the status and trends in native seagrass area in greater Puget Sound. This program uses towed underwater videography as the main data collection methodology to provide reliable estimates of eelgrass area for subtidal seagrass beds in places where airborne remote sensing cannot detect the deep edge of the bed. Video data is collected along transects that are oriented perpendicular to shore and span the area where native seagrasses (mainly eelgrass, *Zostera marina*) grow at a site. The video is later reviewed and each transect segment of nominal one-meter length (and one meter width) is classified with respect to the presence of *Zostera marina* and *Zostera japonica*.

2.1 Study area description

The study area for NTA2018-0409 stretches from Foulweather Bluff, on the northern tip of the Kitsap Peninsula, to Gig Harbor, including Bainbridge Island. It contains the less developed western shore of the central basin of Puget Sound, as well as Bainbridge Island, Port Orchard, Sinclair Inlet, Liberty Bay and Dyes Inlet and overlaps partly with the usual and accustomed fishing areas of the Suquamish Tribe. The Tribe has a vested interest in the preservation of eelgrass beds, and the many species that benefit from this valuable habitat, including Pacific Herring and juvenile salmonids. A regionally important herring stock utilizes submerged vegetation as substrate for spawning in the nearshore of Port Madison, Agate Pass, and Port Orchard Passage.

NTA2018-0409 is nested in a larger multi-year survey of eelgrass in the central basin of Puget Sound (Figure 1). The larger study was initiated in 2014, by IAA 15-17 between the Suquamish tribe and DNR. In 2016, DNR went into agreement with the City of Bainbridge Island to survey 24 sites along the shoreline of Bainbridge Island (IAA16-239). In the same year, DNR and the Suquamish Tribe amended IAA 15-17 to add 50 additional sample sites. In 2017 and 2018, DNR sampled the entire shoreline of King County, including Vashon Island. This study was partially funded through an agreement with King County, Department of Natural Resources and Parks, Wastewater Treatment Division (IAA 93-097520).

NTA2018-0409 complements this larger study in two ways. In 2019, DNR surveyed 25 sites along the west shore of the Colvos Passage between Southworth to Gig Harbor to establish baseline information on eelgrass at this location. In 2019 and 2020, DNR surveyed 29 sites, previously sampled as part of IAA 15-17 between DNR and the Suquamish Tribe, to estimate changes in eelgrass area and depth distribution along the upper Kitsap Peninsula and the eastern shore of Bainbridge Island. As a result of these studies, DNR has surveyed over 3800 transects at 378 sites in the Central Basin of Puget Sound.

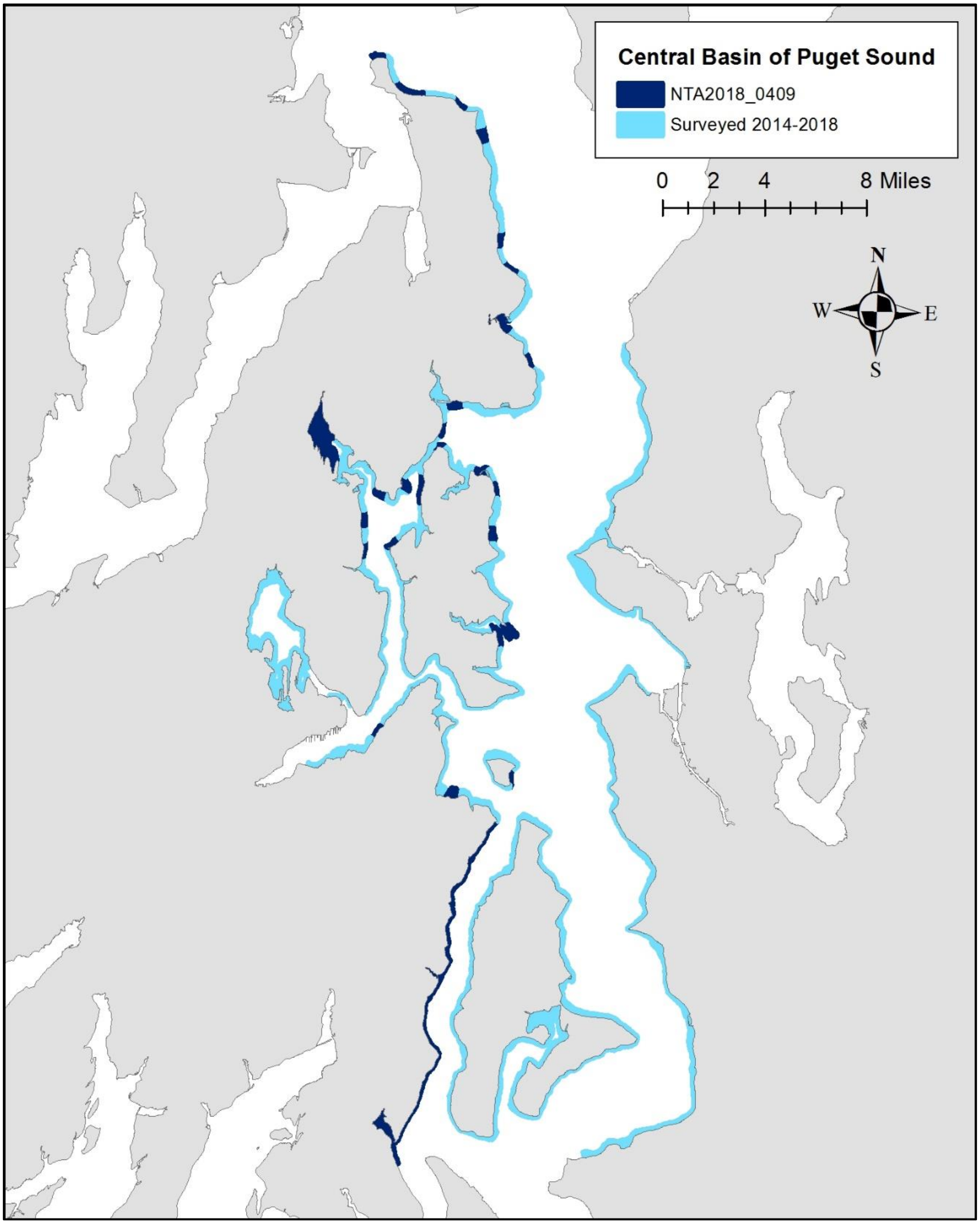

Figure 1: Eelgrass survey in the Central Basin of Puget Sound between 2014 and 2020. Light blue areas indicate sites sampled between 2014 and 2018. Dark blue indicates sites sampled part of NTA 2018-0409.

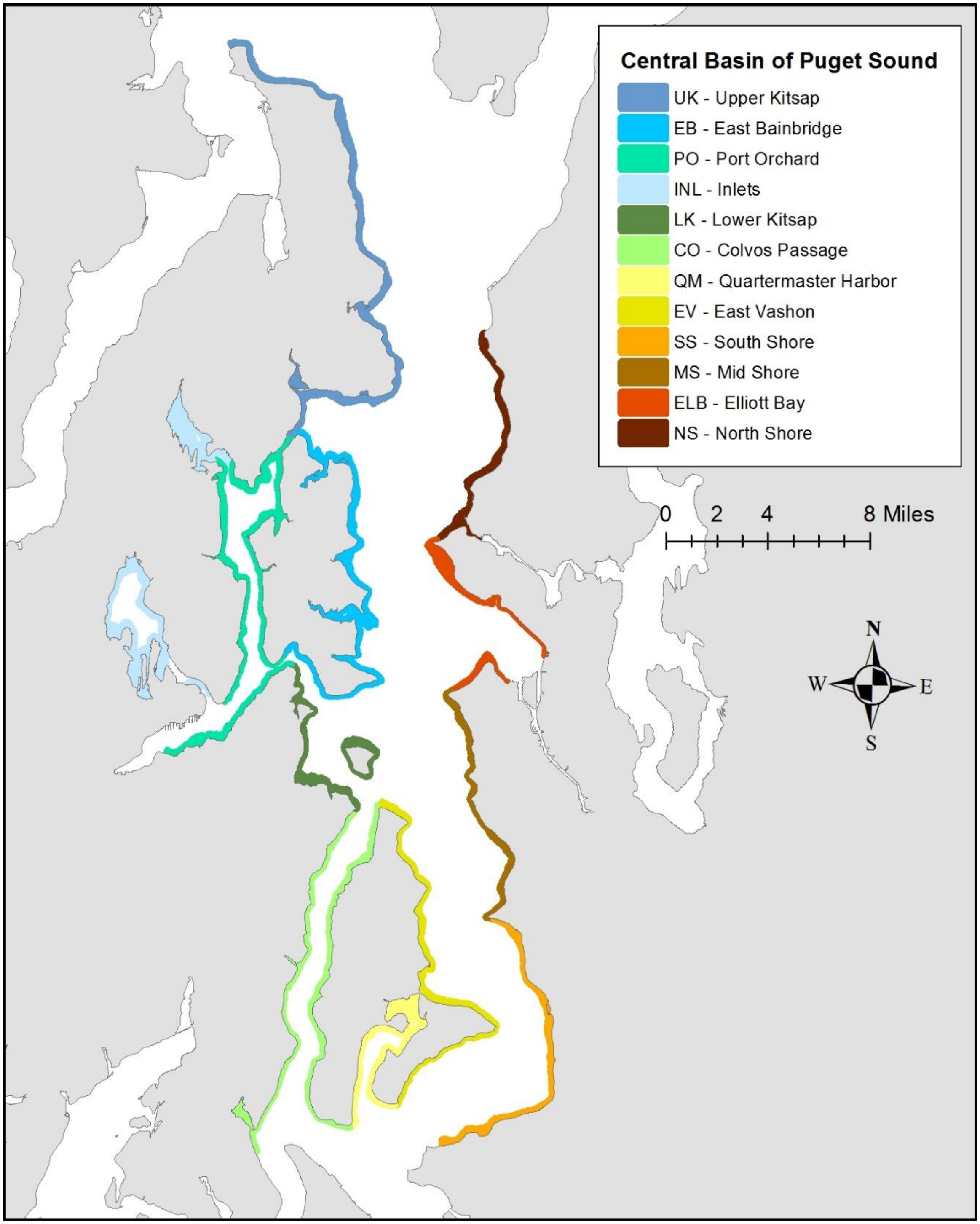

Figure 2: Eelgrass survey in the Central Basin of Puget Sound between 2014 and 2020. Colors indicate different zones as defined in Christiaen et al. (2018) and Christiaen et al. (2020).

2.2 Field sampling

Field sampling was conducted in July and August in 2019 and 2020 from the 11 m (36-ft) research vessel, the R/V Brendan D II, operated by Marine Resources Consultants (Figure 3). The equipment used for sampling is listed in Table 1. During sampling, the vessel deploys a weighted towfish with an underwater video camera mounted in a downward-looking orientation (Figure 4). The towfish is deployed directly off the stern of the vessel using a cargo boom and boom winch. During transect sampling, an MRC technician adjusts the position of the towfish using a hydraulic winch to fly the camera above the substrate. Parallel lasers mounted 10 cm apart on the towfish provide a scaling reference in the video image. A 500 watt underwater light provides illumination when needed.

Survey equipment simultaneously records the presence/absence of marine vegetation, position, depth and time of day. Time and position data are acquired using a differential global positioning system (DGPS) with ability to utilize satellite based augmentation services (SBAS). The antenna is located on top of the cargo boom directly above the towfish and camera, ensuring that the position data reflect the geographic location of the camera (Figure 4). Depth is measured using a Garmin Fishfinder 250 and a BioSonics MX habitat echo sounder. Both are linked to the differential global positioning system (DGPS) so that collected depth data is location and time specific.

A laptop computer equipped with a video overlay controller and data logger software integrates the DGPS data, user supplied transect information (transect number and site code), and the video signal at one second intervals. Video images with overlain DGPS data and transect information are simultaneously recorded on DVDs, and D/V hard drives. Date, time, position, and transect information are stored on the computer at one second intervals. A real-time plotting system integrates National Marine Electronic Association 0132 standard sentences produced by the DGPS, two depth sounders, and a user-controlled toggle switch to indicate presence of marine vegetation.

Additional information on field procedures and methodology can be found in the Quality Assurance Project Plan for NTA 2018-0409.

2.3 Site and sample polygons

Prior to field sampling, a site polygon was defined for each site, bounded by the -6.1 m MLLW bathymetry contour and the ordinary high water mark as described in the SVMP methods (Dowty et al. 2019). Fringe sites are 1000 m along the -6.1 m contour on the deep edge. Segment lengths vary for flats sites (e.g., depending on embayment size). In addition, we delineated sample polygons that span the entire length of the site and encompass all the eelgrass at that location.

At each site, underwater videography was used to sample the presence of eelgrass and other vegetation types along transects in a modified line-intercept technique (Norris et al. 1997). Video transects are oriented perpendicular to shore, and extend beyond the shallow and deep edges of the sample polygons. Sites are divided in 10 sections of similar length (strata). Transects were selected based on a stratified random (STR) approach with 1 randomly selected transect per stratum.

Table 1: Equipment on the R/V Brandon D II

Equipment	Manufacturer/Model
Differential GPS Unit	Hemisphere VS330 with Satellite Based Augmentation System (SBAS, sub-meter accuracy)
Echosounders	Primary: BioSonics Mx Habitat Echosounder Secondary: Garmin Fishfinder 250, 200 KHz 11o single-beam transducer
Underwater Camera	Ocean Systems Deep Blue SD (downward facing) Ocean Systems Deep Blue HD (forward facing)
Underwater Light	Deep Sea Power and Light Led SeaLite
Lasers	Deep Sea Power & Light (10 cm spread, red)
DVD Recorder	Sony RDR-GX7 + Intuitive Circuits TimeFrame Video Overlay Controller
Image Recording	3 Atomos Ninja 2 Digital Video Recorders, ProRes format + VideoLogix Proteus II Video Overlay Controller
Computer systems	Rugged laptop with Microsoft Office and Hypack Max hydrographic software (capable of accepting ESRI ArcGIS files). HP 4480 Color printer
Camera	Nikon Coolpix waterproof camera

2.4 Data processing

We classified presence/absence of eelgrass at one second intervals, based on observation of rooted shoots within the field of view (video sampling resolution of nominally 1 m^2). All eelgrass presence and absence data were recorded with corresponding spatial information. The fractional cover of eelgrass along transects was used to calculate site eelgrass area. The depth at which eelgrass grows along each transect was used to estimate maximum and minimum depth of eelgrass relative to Mean Lower Low Water (MLLW) at each site. The non-native *Z. japonica* was classified as well, but these data were not included in the calculation of eelgrass area and depth distribution[2].

All measured depths were corrected to the MLLW datum by adding the transducer offset, subtracting the predicted tidal height for the site and adding the tide prediction error (calculated using measured tide data from the National Oceanic and Atmospheric Administration website http://co-ops.nos.noaa.gov/data_res.html). The final corrected depth data were merged with eelgrass data and spatial information so the eelgrass observations had associated date/time, position and depth measurements corrected to MLLW datum.

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[2] *Z. japonica* typically grows at higher tidal elevations than *Z. marina*, and is often too shallow for the research vessel. We are not able to provide a good are estimate of this non-native seagrass based on our sample techniques.

Figure 3: All data were collected from the *R/V* Brendan D II, using towed underwater videography and depth sounding instrumentation.

Figure 4: The R/V Brendan D II is equipped with a weighted towfish that contains an underwater video camera mounted in a downward looking orientation, dual lasers for scaling reference, and underwater lights for night work (A). The towfish is deployed directly beneath the DGPS antenna attached to the A-frame cargo boom, ensuring accurate geographic location of the camera (B).

2.5 Data analysis

Data was analyzed with ArcGIS and R (R Core Team 2018). We used several R-packages, including “broom” (Robinson and Hayes 2018), “dplyr” (Wickam et al. 2018), “ggplot2” (Wickam 2016), “tidyr” (Wickam and Henry 2018), and “weights” (Pasek et al. 2018).

2.5.1 *Eelgrass area estimates*

We estimate the percentage seagrass cover within the site-sample polygon $\hat{\bar{p}}$ using a ratio estimator of the form (1), where l_i is the vegetated length of transect i, and L_i is the total length of transect i at a site with m transects. The ratio has an approximate variance of (2), with $\bar{L}$ the average length of transects the site (Cochran 1977)[3].

$$\hat{\bar{p}} = \frac{\sum_{i=1}^{m} l_i}{\sum_{i=1}^{m} L_i} \qquad (1)$$

$$Var_{\hat{\bar{p}}} = \frac{\sum_{i=1}^{m} \left(l_i - \hat{\bar{p}} L_i\right)^2}{(m-1)\, m\, \bar{L}^2} \qquad (2)$$

We estimate site seagrass area $\hat{X}$ by multiplying the percentage cover with the size of the sample polygon E (3). We then estimate the associated variance as (4).

$$\hat{X} = E\, \hat{\bar{p}} \qquad (3)$$

$$Var_{\hat{X}} = E^2 Var_{\hat{\bar{p}}} \qquad (4)$$

Site eelgrass area estimates were binned before visualizing values on regional maps using ArcGIS. The amount of eelgrass in the entire study area is then calculated as the sum of the individual site estimates, and the variance around this estimate is the sum of the variance estimates for the individual sites.

2.5.2 *Eelgrass depth distribution*

Eelgrass depth characteristics for each site were estimated using descriptive statistics (i.e., the 2.5th, 10th, 25th, 50th, 75th, 90th, and 97.5th percentile) for all eelgrass observations along all STR transects at a site. We calculated the range as the vertical width of the band that contains 95% of all eelgrass observations at a site. Maximum depth estimates were binned before visualizing values on regional maps using ArcGIS.

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[3] This formula may overestimate actual variance for stratified random samples and systematic samples, and is thus a conservative estimator of variance for these sampling schemes (McGarvey et al. 2016).

2.5.3 Trends in eelgrass area

We assessed trends in eelgrass area for 35 sites along the Kitsap Peninsula and Bainbridge Island. These sites were selected based on 2 criteria: they were sampled at least twice, and most recent sample dated from either 2018, 2019 or 2020.

At sites with more than 2 years of data, we used linear regression to assess trends over time. We used all site samples, regardless if they were collected by SRS or STR, and if they were new draw samples or repeats.

At sites with repeat transects, we visualized the patterns of gain and loss along individual transects by associating nearest points along paired transects in ArcGIS, and comparing presence/absence of eelgrass among both years. We used a paired t-test to assess mean change in the % vegetated fraction along repeat transects at individual sites, and visualized change in % cover at each site using boxplots.

3 Results

3.1 Overview of sample effort 2019-2020

In 2019 and 2020, a total of 565 transects were sampled at 54 sites along the Kitsap Peninsula. The locations of these sites are indicated on Figure 5 and Figure 6. In 2019, we sampled 25 sites along the Kitsap side of Colvos Passage to enhance a comprehensive survey of eelgrass along the central basin of Puget Sound. As a result, we have now sampled the entire shoreline of King County, and the eastern shore of the Kitsap Peninsula, as well Bainbridge Island. In 2019 and 2020, we revisited a 29 sites that were previously sampled as part of IAA15-17 between DNR and the Suquamish Tribe to assess change in eelgrass area between 2014 and 2020.

3.1.1 Seagrass species

There were two species of seagrass present in the study area: native eelgrass (*Z. marina*) and non-native dwarf eelgrass (*Z. japonica*). Both species prefer sandy and muddy substrates. Eelgrass is found between +1.4 m and -12.5 m relative to MLLW in greater Puget Sound. It is morphologically very plastic: its leaves can vary from 10-20 cm to well over 1.5 m long depending on the depth and location in greater Puget Sound. The non-native Z. japonica typically grows shallower than eelgrass. It is much smaller and has a different morphology of the leaf sheath and root system. It can be difficult to distinguish the species based on size alone because their size ranges overlap. DNR classifies presence/absence of Z. japonica from video observations, but at sites where we suspect this species to be present, we usually take a number of grab samples to confirm our observations based on the morphology of the leaf sheath.

Out of the 54 sites sampled in 2019 and 2020, there were 49 sites with *Zostera marina* (eelgrass), and 28 sites with *Z. japonica*. Out of all transects sampled in 2019 and 2020, there were 390 transects with *Zostera marina* and 119 transects with *Z. japonica* present. The locations of the individual transects are depicted on the figures in Appendix 1. *Z. japonica* did occur along the narrow shorelines of the Colvos Passage, but was usually present in low quantities. This may be partly due to the steep shoreline. *Z. japonica* tends to grow at higher tidal elevation than *Z. marina*, and has to compete with *Z. marina* at lower tidal elevations. This non-native species was more commonly found on Bainbridge Island and the upper part of the Kitsap peninsula.

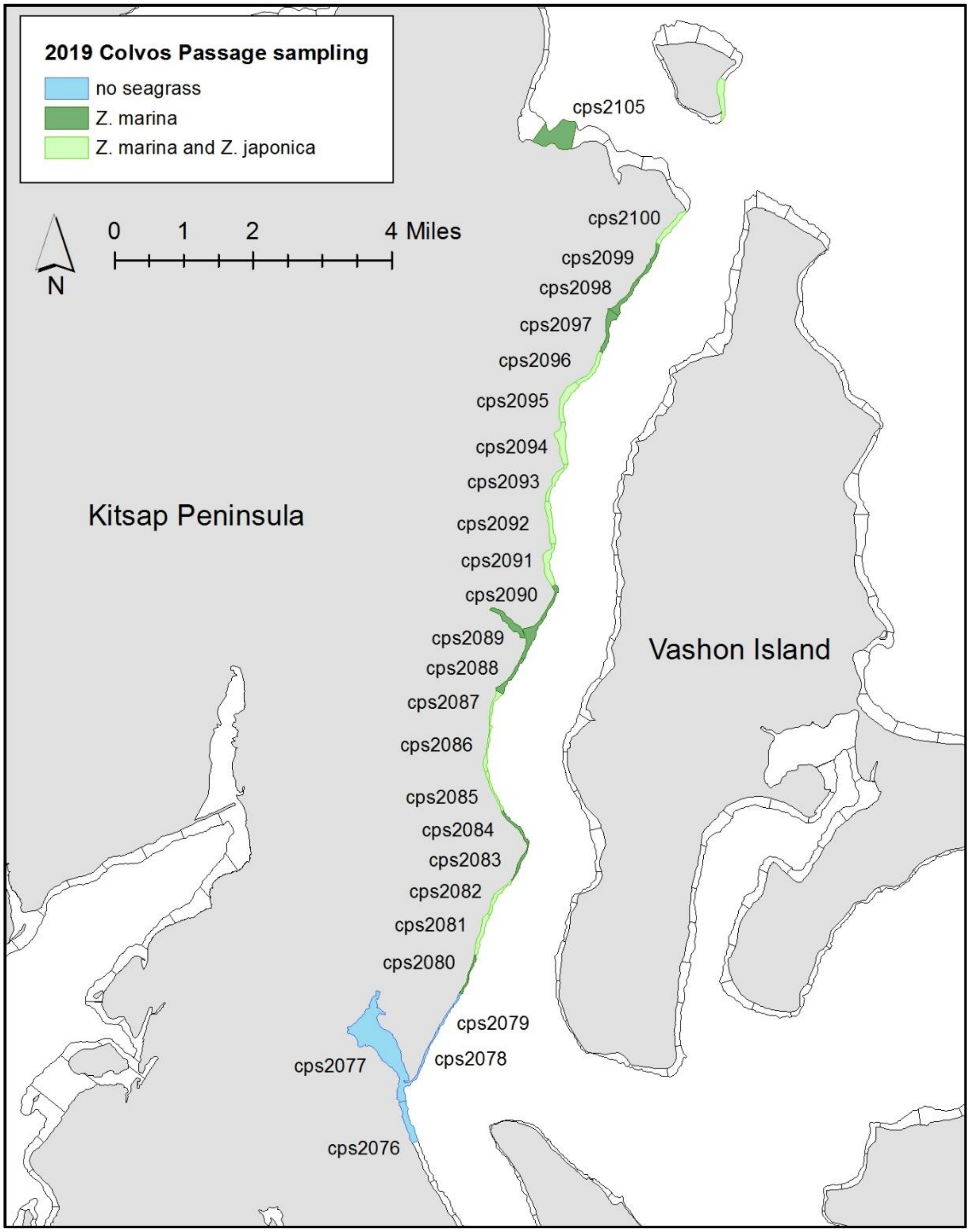

Figure 5: Location of sites sampled for NTA 2018-0409 in 2019

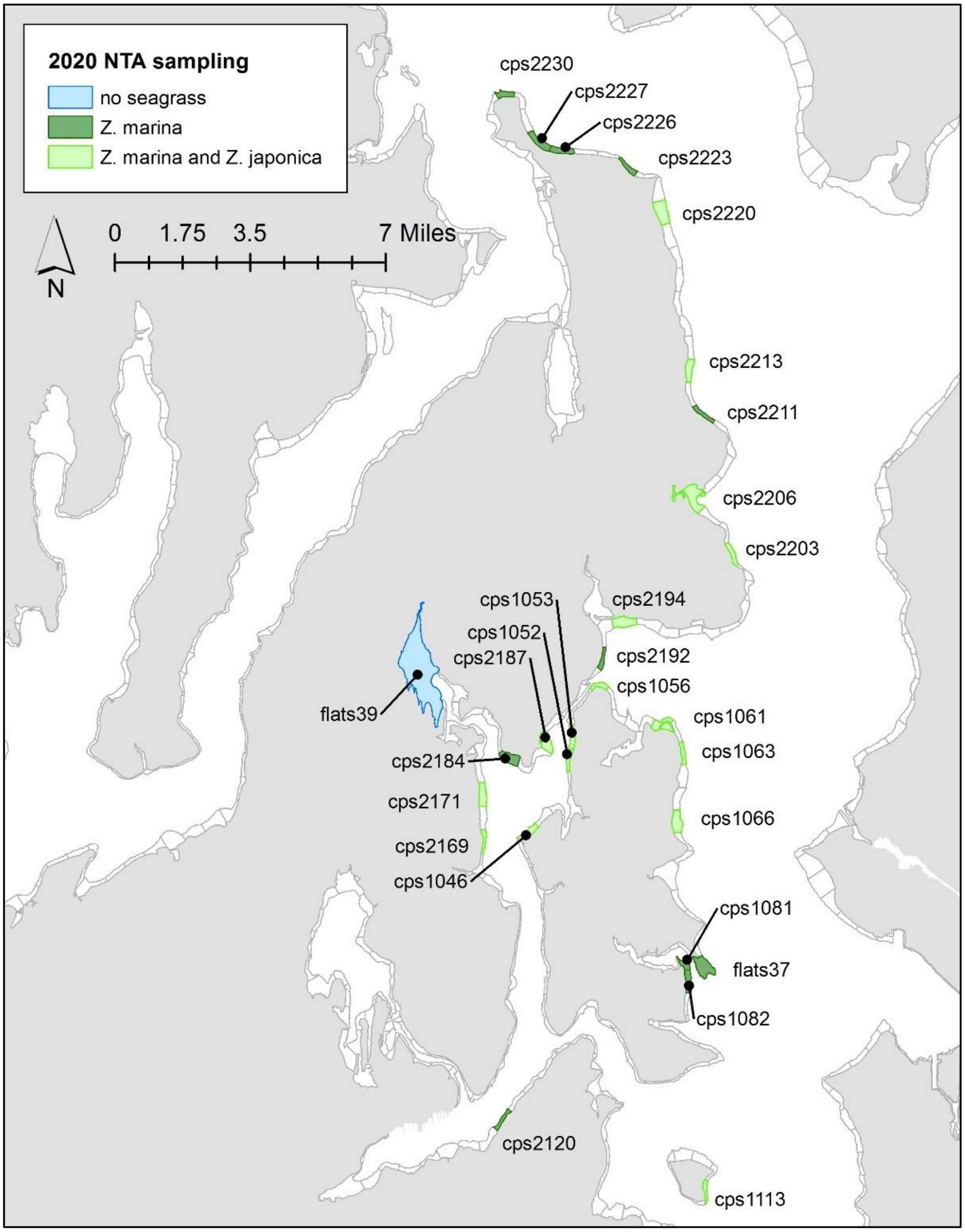

Figure 6: Location of sites sampled for NTA 2018-0409 in 2020

3.1.2 Eelgrass area and depth distribution

In 2019, we measured 48.7 +/- 5.6 ha of eelgrass along the 25 sites sampled on the western side of Colvos Passage. While eelgrass was commonly found, the majority of eelgrass beds were relatively small (Figure 7, Table 2): the median size of eelgrass beds was 1.68 ha (with a range of 0.35 to 6.7 ha). This is in part due to the steep bathymetry at most sites in the Colvos Passage. One additional site in Yukon Harbor, cps2105, had only trace eelgrass present. In 2020 we measured 193 ha of eelgrass at 28 sites spread throughout the Kitsap Peninsula and Bainbridge Island. The median size of eelgrass beds at these sites was 5.91 ha, with a range from 0.32 to 20.21 ha (Figure 7, Table 2). In general, the size of eelgrass beds was similar to previous sample efforts in 2014 (see section 3.3).

The depth distribution of eelgrass at each site sampled in 2019 and 2020 is shown in Table 3. The deepest observation of eelgrass was at -8.2m relative to MLLW (cps1061). The shallowest observation was +1.18m relative to MLLW (cps2206). We calculated 'eelgrass depth range' as the width of the vertical band that contains 95 % of eelgrass observations at a site. This range varied from 0.15m (at cps2105) to 5.76m (at cps1061), with an average of approximately 3.8m. There is a clear spatial pattern in eelgrass depth distribution. Maximum depth and eelgrass depth range become smaller along a gradient from Port Madison to Port Orchard.

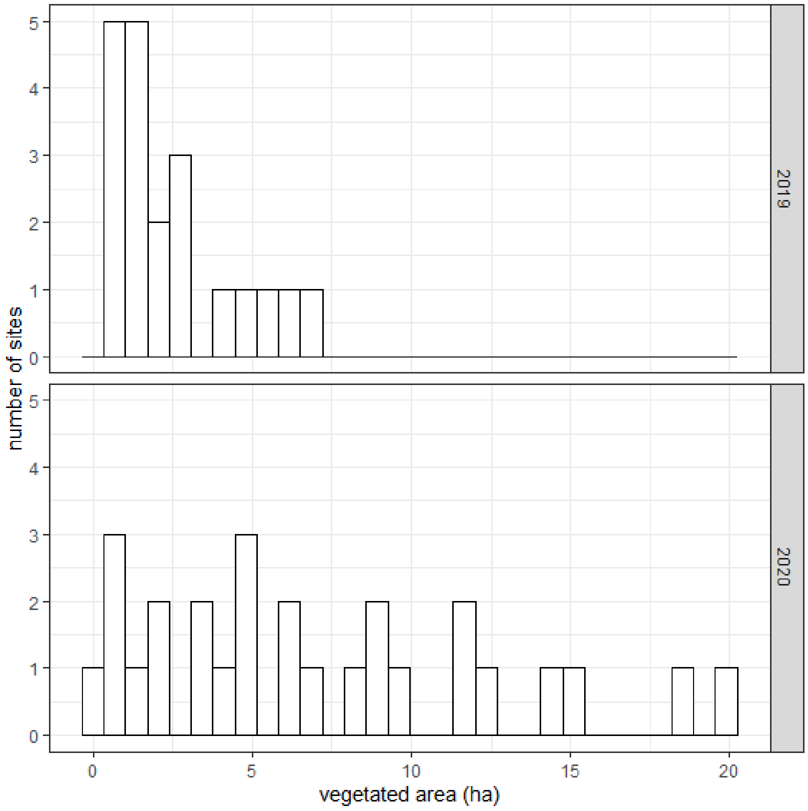

Figure 7: Distribution of eelgrass area at sites sampled for NTA 2018-0409 in 2019 and 2020.

Table 2: Number of transects, area of the sample polygon (ha), eelgrass area (ha), and standard error (ha) for 54 sites sampled as part of NTA 2018-0409.

site_code	year	date_samp_start	n_tran	fraction	sample_ha	veg_ha	veg_ha_se
cps2076	2019	18-Sep-19	9	0	0	0	0
cps2077	2019	18-Sep-19	11	0	0	0	0
cps2078	2019	18-Sep-19	10	0	0	0	0
cps2079	2019	18-Sep-19	10	0	0	0	0
cps2080	2019	18-Sep-19	10	0.091	3.98	0.36	0.2
cps2081	2019	19-Sep-19	10	0.2196	7.03	1.54	0.38
cps2082	2019	19-Sep-19	10	0.2141	5.92	1.27	0.39
cps2083	2019	19-Sep-19	10	trace	trace	trace	trace
cps2084	2019	19-Sep-19	10	0.1946	3.8	0.74	0.23
cps2085	2019	19-Sep-19	10	0.2545	4.7	1.2	0.33
cps2086	2019	19-Sep-19	10	0.3972	4.58	1.82	0.33
cps2087	2019	20-Sep-19	10	0.4903	5.37	2.64	0.3
cps2088	2019	20-Sep-19	10	0.1393	6.53	0.91	0.35
cps2089	2019	20-Sep-19	10	0.2664	11.54	3.08	0.7
cps2090	2019	23-Sep-19	10	0.0972	3.6	0.35	0.32
cps2091	2019	23-Sep-19	10	0.5461	10.92	5.96	0.54
cps2092	2019	23-Sep-19	10	0.5124	9.21	4.72	0.51
cps2093	2019	23-Sep-19	10	0.3854	6.99	2.69	0.66
cps2094	2019	23-Sep-19	10	0.4175	13.59	5.67	0.77
cps2095	2019	24-Sep-19	10	0.5466	12.26	6.7	0.62
cps2096	2019	24-Sep-19	10	0.2497	8.08	2.02	0.93
cps2097	2019	24-Sep-19	10	0.1701	8.22	1.4	0.52
cps2098	2019	25-Sep-19	10	0.1748	6.33	1.11	0.36
cps2099	2019	25-Sep-19	10	0.1017	5.01	0.51	0.17
cps2100	2019	25-Sep-19	10	0.428	9.38	4.02	0.96
cps2105	2019	21-Aug-19	19	trace	trace	trace	trace
cps1046	2020	25-Aug-20	11	0.0664	4.88	0.32	0.13
cps1052	2020	25-Aug-20	10	0.5654	8.41	4.76	0.54
cps1053	2020	25-Aug-20	10	0.5785	15.51	8.97	0.66
cps1056	2020	27-Aug-20	10	0.3843	8.09	3.11	0.54
cps1061	2020	27-Aug-20	10	0.3824	11.63	4.45	0.76
cps1063	2020	2-Sep-20	10	0.5041	14.09	7.1	0.68
cps1066	2020	2-Sep-20	10	0.3733	30.59	11.42	0.82
cps1081	2020	1-Sep-20	10	0.3184	11.45	3.64	0.68
cps1082	2020	31-Aug-20	10	0.584	16.01	9.35	1.45
cps1113	2020	21-Aug-20	10	0.5547	9.07	5.03	0.39
cps2120	2020	2-Sep-20	11	0.1918	5.01	0.96	0.19
cps2169	2020	24-Aug-20	10	0.2674	7.11	1.9	0.28
cps2171	2020	24-Aug-20	10	0.2989	13.42	0.86	0.26

site_code	year	date_samp_start	n_tran	fraction	sample_ha	veg_ha	veg_ha_se
cps2184	2020	25-Aug-20	10	0.153	9.31	1.43	0.58
cps2187	2020	25-Aug-20	10	0.4723	24.93	11.78	1.82
cps2192	2020	26-Aug-20	10	0.2245	9.53	2.14	0.75
cps2194	2020	27-Aug-20	10	0.2866	28.99	8.31	0.72
cps2203	2020	4-Sep-20	10	0.4407	13.47	5.94	1.25
cps2206	2020	3-Sep-20	13	0.3768	38.42	14.48	3.23
cps2211	2020	4-Sep-20	10	0.5975	9.89	5.91	0.26
cps2213	2020	7-Sep-20	10	0.6142	19.79	12.15	0.35
cps2220	2020	8-Sep-20	10	0.4631	43.65	20.21	0.62
cps2223	2020	11-Sep-20	11	0.4624	10.72	4.96	0.63
cps2226	2020	9-Sep-20	11	0.5806	15.65	9.09	0.94
cps2227	2020	9-Sep-20	12	0.8132	22.82	18.55	0.62
cps2230	2020	9-Sep-20	15	0.1063	9.35	0.99	0.36
flats37	2020	31-Aug-20	10	0.321	47.39	15.21	4.67
flats39	2020	28-Aug-20	12	0	0	0	0

Table 3: Depth distribution (m, MLLW) based on all observations of *Z. marina* at individual sites. Maxd is the deepest observation, mind is the shallowest observation, q025 is the 2.5th percentile of all eelgrass depth observations, q10 is the 10th percentile of all eelgrass depth observations, etc. The range is calculated as the difference between q025 and q975, and represents the width of the vertical band that contains 95% of eelgrass observations at a site. N is the number of video frames with eelgrass at a site.

site_code	year	maxd	q025	q10	q25	q50	q75	q90	q975	mind	range	n
cps2080	2019	-5.70	-5.29	-4.20	-3.05	-1.60	-1.06	-0.80	-0.64	-0.52	4.65	76
cps2081	2019	-4.97	-4.17	-3.19	-1.80	-0.88	-0.30	-0.01	0.15	0.33	4.32	285
cps2082	2019	-5.60	-4.98	-2.59	-1.29	-0.53	0.00	0.25	0.61	0.76	5.59	235
cps2083	2019	-2.16	-2.11	-1.95	-1.72	-1.56	-1.28	-1.21	-1.19	-1.18	0.92	9
cps2084	2019	-4.71	-4.47	-3.76	-2.98	-1.48	-0.85	-0.50	-0.11	0.01	4.36	138
cps2085	2019	-4.93	-4.06	-2.60	-1.47	-0.83	-0.36	-0.07	0.12	0.16	4.18	216
cps2086	2019	-5.34	-4.78	-3.71	-2.28	-1.20	-0.62	-0.30	-0.14	0.13	4.64	365
cps2087	2019	-5.83	-4.33	-3.12	-1.70	-0.96	-0.51	-0.30	-0.07	0.23	4.26	560
cps2088	2019	-5.02	-4.19	-3.43	-2.55	-1.37	-0.75	-0.68	-0.49	-0.41	3.70	179
cps2089	2019	-6.07	-4.07	-2.93	-1.77	-1.13	-0.89	-0.79	-0.55	0.05	3.52	569
cps2090	2019	-3.51	-3.34	-2.74	-1.57	-0.59	0.01	0.27	0.39	0.42	3.73	58
cps2091	2019	-4.99	-3.78	-2.98	-2.35	-1.66	-0.76	-0.12	0.24	0.61	4.03	1118
cps2092	2019	-4.56	-3.43	-2.77	-1.99	-1.21	-0.41	0.04	0.33	0.54	3.77	888
cps2093	2019	-5.23	-4.45	-3.29	-2.35	-1.48	-0.69	0.04	0.36	0.65	4.81	530
cps2094	2019	-5.44	-4.40	-3.39	-2.31	-1.37	-0.58	-0.31	0.05	0.57	4.45	1003
cps2095	2019	-5.01	-4.30	-3.41	-2.35	-1.59	-0.75	-0.33	0.02	0.25	4.31	1243
cps2096	2019	-5.85	-4.93	-3.94	-2.65	-1.62	-0.74	-0.17	0.30	0.48	5.24	366
cps2097	2019	-5.21	-4.46	-3.35	-2.21	-1.30	-0.81	-0.65	-0.51	-0.27	3.95	276

site_code	year	maxd	q025	q10	q25	q50	q75	q90	q975	mind	range	n
cps2098	2019	-4.47	-3.64	-2.89	-2.25	-1.36	-0.80	-0.27	-0.05	0.09	3.59	185
cps2099	2019	-3.09	-2.68	-2.13	-1.63	-1.10	-0.78	-0.64	-0.23	-0.22	2.45	70
cps2100	2019	-5.36	-4.28	-3.32	-2.23	-1.33	-0.56	-0.05	0.46	0.84	4.74	593
cps2105	2019	-1.79	-1.78	-1.75	-1.72	-1.68	-1.64	-1.64	-1.63	-1.63	0.15	13
cps1046	2020	-1.40	-1.40	-1.35	-1.21	-1.01	-0.79	-0.61	-0.58	-0.56	0.82	21
cps1052	2020	-4.23	-3.30	-2.83	-2.31	-1.35	-0.68	-0.48	0.00	0.16	3.30	839
cps1053	2020	-4.46	-3.88	-3.29	-2.50	-1.46	-0.60	-0.24	-0.06	0.21	3.82	1577
cps1056	2020	-4.29	-3.80	-3.20	-2.59	-1.70	-1.05	-0.56	0.26	0.52	4.06	696
cps1061	2020	-8.20	-5.96	-3.10	-1.55	-0.94	-0.74	-0.53	-0.20	0.19	5.76	974
cps1063	2020	-5.12	-4.03	-2.68	-1.62	-0.68	-0.01	0.29	0.65	0.97	4.68	1413
cps1066	2020	-5.27	-3.98	-3.13	-2.03	-0.28	0.09	0.33	0.47	0.71	4.45	1859
cps1081	2020	-5.08	-3.57	-2.41	-1.77	-1.20	-0.91	-0.63	-0.50	0.00	3.07	971
cps1082	2020	-5.32	-4.19	-3.46	-2.57	-1.65	-1.17	-0.73	-0.36	-0.06	3.83	1670
cps1113	2020	-5.23	-4.35	-3.78	-3.26	-2.59	-1.25	-0.39	0.09	0.33	4.43	1037
cps2120	2020	-3.45	-2.92	-2.44	-1.94	-1.56	-1.22	-0.97	-0.82	-0.70	2.10	235
cps2169	2020	-2.08	-1.94	-1.65	-1.41	-1.05	-0.66	-0.45	-0.29	-0.15	1.65	306
cps2171	2020	-1.39	-1.32	-1.11	-0.90	-0.64	-0.50	-0.38	-0.31	-0.28	1.01	161
cps2184	2020	-1.46	-1.18	-1.10	-0.97	-0.79	-0.63	-0.54	-0.43	-0.28	0.76	259
cps2187	2020	-4.41	-3.87	-3.27	-2.67	-1.79	-1.10	-0.29	-0.03	0.19	3.84	1889
cps2192	2020	-3.69	-3.40	-3.19	-2.78	-2.17	-1.30	-0.87	-0.48	-0.25	2.91	393
cps2194	2020	-3.73	-3.25	-2.59	-1.74	-0.74	-0.35	0.04	0.24	0.43	3.48	1077
cps2203	2020	-6.35	-5.22	-3.95	-2.73	-1.30	-0.23	0.13	0.41	0.60	5.63	1090
cps2206	2020	-4.15	-2.57	-1.76	-1.04	-0.49	-0.10	0.33	0.61	1.18	3.18	1874
cps2211	2020	-5.25	-4.43	-3.36	-2.39	-1.63	-0.93	-0.40	-0.14	0.04	4.29	1028
cps2213	2020	-4.95	-4.48	-3.92	-3.23	-2.14	-0.48	0.02	0.32	0.68	4.80	2047
cps2220	2020	-4.85	-3.88	-2.82	-2.08	-0.75	-0.11	0.21	0.48	0.91	4.36	2739
cps2223	2020	-5.84	-4.84	-3.37	-1.78	-0.87	0.15	0.50	0.68	0.87	5.52	1059
cps2226	2020	-6.62	-5.89	-4.79	-4.27	-3.68	-2.50	-1.61	-1.13	-0.80	4.76	1496
cps2227	2020	-6.40	-5.50	-4.92	-4.13	-3.26	-2.37	-1.33	-0.48	0.33	5.02	3069
cps2230	2020	-4.55	-4.00	-3.75	-3.34	-2.67	-1.97	-1.60	-1.12	-0.73	2.88	302
flats37	2020	-7.86	-5.08	-3.56	-2.97	-2.34	-1.73	-1.08	-0.80	-0.60	4.28	1074

3.2 Larger context: eelgrass area and depth distribution in the central basin of Puget Sound (data 2014-2020)

3.2.1 Seagrass species

Zostera marina occurred at 281 sites, and the non-native *Z. japonica* was found at 127 out of 378 sites sampled between 2014 and 2020 in the central basin of Puget Sound. Eelgrass beds were found along most of the shorelines of the central basin, but were sparse or absent in Port Orchard, Dyes Inlet, Liberty Bay, and in the inner portion of Quartermaster Harbor. Eelgrass was also absent along heavily modified shorelines in Elliott Bay. *Zostera japonica* was present at approximately 50% of sites sampled in most zones, except for Dyes Inlet, Liberty Bay, Elliott Bay and the northern shorelines of King County (Figure 8). *Zostera japonica* was present at only 25% of sites sampled in Port Orchard. *Zostera japonica* mostly occurred at sites with *Z. marina*. This suggests that both species have similar requirements in terms of habitat and substrate. While it was not possible to provide an accurate estimate of *Z. japonica* area due to sampling restrictions, the maps in Appendix 1 indicate that *Z. marina* was usually more abundant than *Z. japonica* at sites where both species were present.

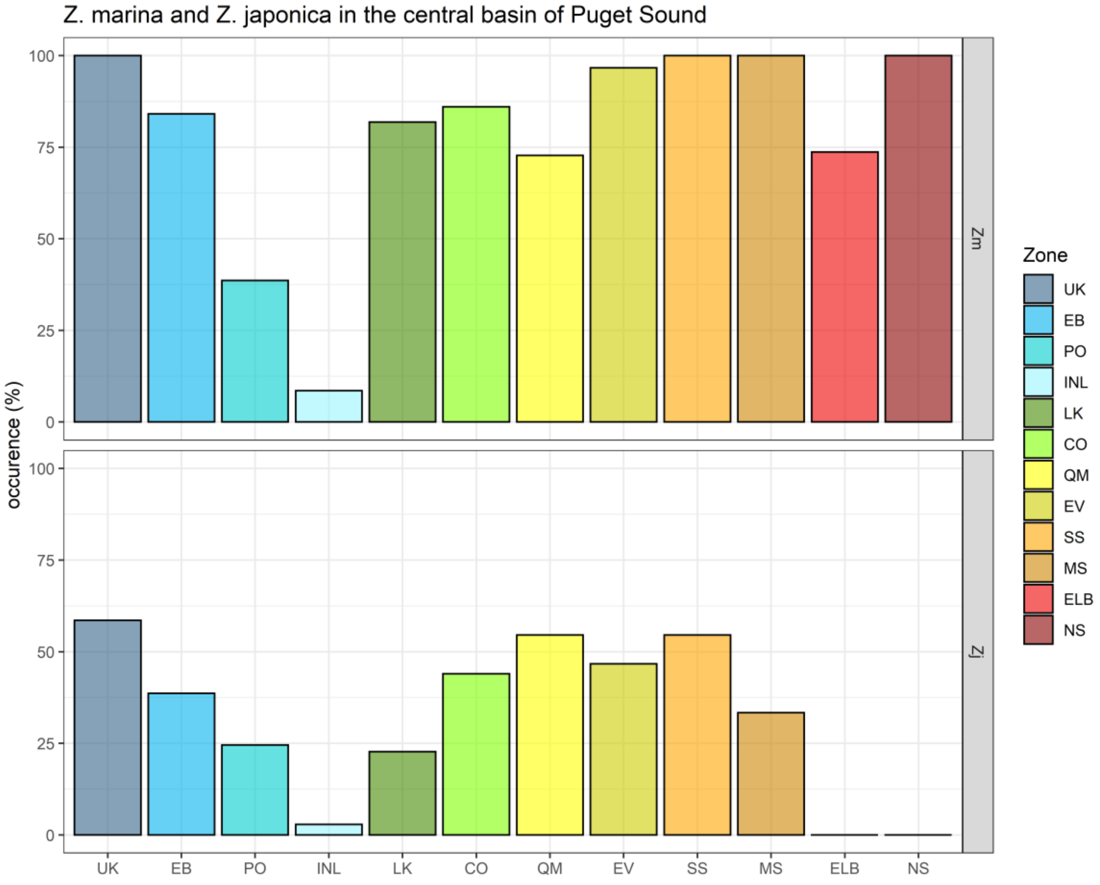

Figure 8: Percentage of all sites with *Z. marina* and *Z. japonica* in the central basin of Puget Sound (see Figure 2)

3.2.2 Area distribution

The eelgrass beds along the shoreline of the central basin of Puget Sound were relatively small (Figure 9). This is to be expected, as most of these beds grew on relatively narrow fringes of shoreline. Out of the 281 sites with eelgrass, 12 sites had trace amounts of eelgrass present, 50 sites had less than 1 ha of eelgrass, 112 sites had between 1 and 5 ha of eelgrass, 75 sites had between 5 and 10 ha of eelgrass, and 29 sites had between 10 and 20 ha of eelgrass. Only 3 sites had eelgrass beds that were larger than 20 ha (Figure 11). The largest eelgrass beds were found at cps2220 (South of Point No Point in the Upper Kitsap Peninsula), and at cps1688 and cps1689 (Magnolia Bluff, north of Elliott Bay). Overall, sites in the northern part of the study area had larger eelgrass beds as compared to sites in the southern part of the study area. The median size of eelgrass beds in the central basin of Puget Sound was approximately 3.64 ha (range 0.001 to 37.56 ha). This is similar to fringe sites throughout greater Puget Sound (median size 3.5 ha, range 0.001 – 75 ha).

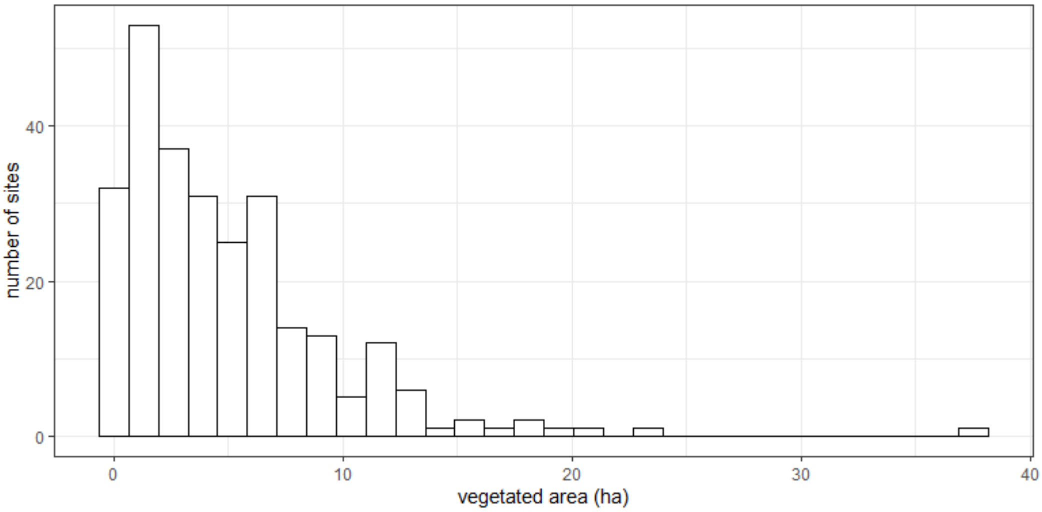

Figure 9: The size distribution of eelgrass beds at sites in the central basin of Puget Sound (ha). The majority of eelgrass beds in the study area were relatively small (< 10 ha)

We divided the central basin of Puget Sound into 12 zones (Figure 2) and estimated total eelgrass area in each of these zones based on the current sample of 378 sites (**Figure 10**). Given that we sampled the vast majority of sites within the study area, the degree of uncertainty associated with the estimates is relatively small, which is represented by the standard error in **Figure 10**. Note that Colvos Passage (zone CO) is split between Kitsap and King County. Between 2014 and 2020, there was 1315 +/- 13 ha[4] of eelgrass in the central basin of Puget Sound (**Figure 10**). This is 5.7% of our current best estimate of eelgrass area in greater Puget Sound (approximately 23,000 ha). Approximately 680 +/- 9 ha occurred along the shorelines of King County, and 635 +/- 10 ha was present along the shorelines of Kitsap County[5].

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[4] Mean +/- standard error

[5] Note that this includes a small part of Pierce County along the Colvos Passage

In Kitsap County, the majority of eelgrass occurred along the wider shorelines of the upper Kitsap Peninsula (zone UK) and along the eastern shores of Bainbridge Island (zone EB, see **Figure 10**). Eelgrass became progressively sparser inside Port Orchard, and as virtually absent in Dyes Inlet and Liberty Bay (zone INL). In King County, the majority of eelgrass grew on the mainland (North Shore – zone NS, Elliott Bay – zone ELB, Mid Shore – zone MS, and South Shore – zone SS) or on the eastern part of Vashon Island (zone EV). Eelgrass was less abundant in Quartermaster Harbor (zone QM) and along Colvos Passage (zone CO).

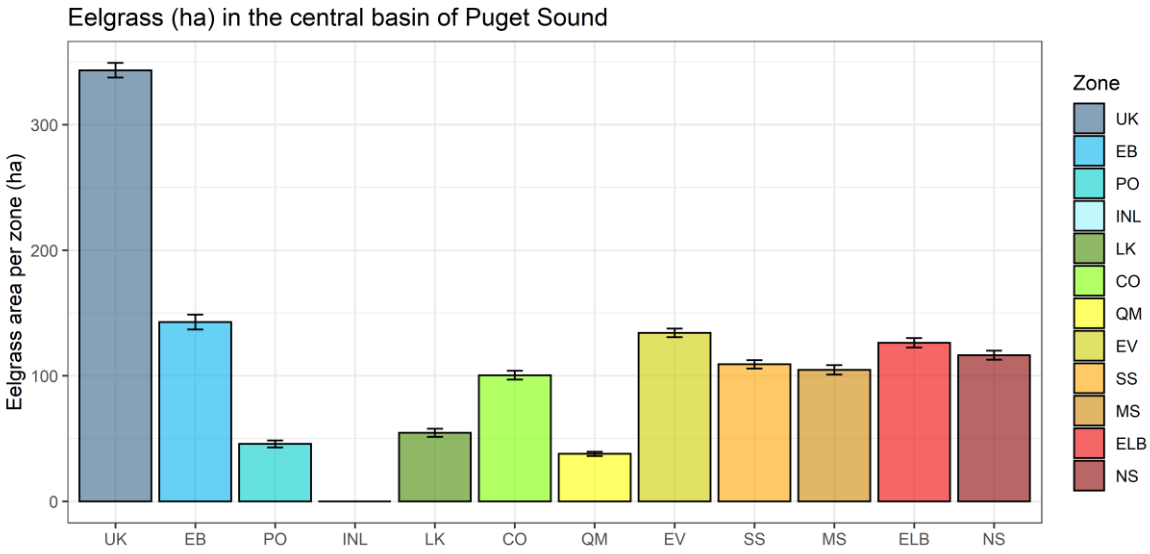

Figure 10: Estimates of eelgrass area along different central basin of Puget Sound zones (see Figure 2 for the geographic depiction of the different zones).

3.2.3 Depth distribution

The majority of eelgrass in the central basin of Puget Sound is found between 0 and -4.5m relative to MLLW, but eelgrass was found as shallow as +1.1m and as deep as -13.3m (MLLW)[6]. There were only 4 sites where eelgrass was found deeper than -10m (cps1669, cps1688, cps1723, and cps1072) and at those locations very few plants extended to this depth (Figure 12). In King County, eelgrass grew deepest at sites north of Brace Point (North Shore, Elliott Bay, and Mid Shore) and along the Colvos Passage. Some eelgrass beds with deep edges also occurred on the northeastern side of Vashon Island. South Shore and Quartermaster Harbor usually had eelgrass beds with smaller depth ranges. In Kitsap County the deepest eelgrass beds were found on Blake Island, the eastern side of Bainbridge Island in the upper Kitsap Peninsula. There was a clear gradient in maximum depth from the central channel towards Port Orchard and the mouth of Liberty Bay. At these locations, eelgrass was either absent or grew to very shallow depths.

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[6] Note that at some sites with *Z. japonica* there is some uncertainty on the upper limit of *Z. marina*, because these species can be hard to differentiate when they overlap.

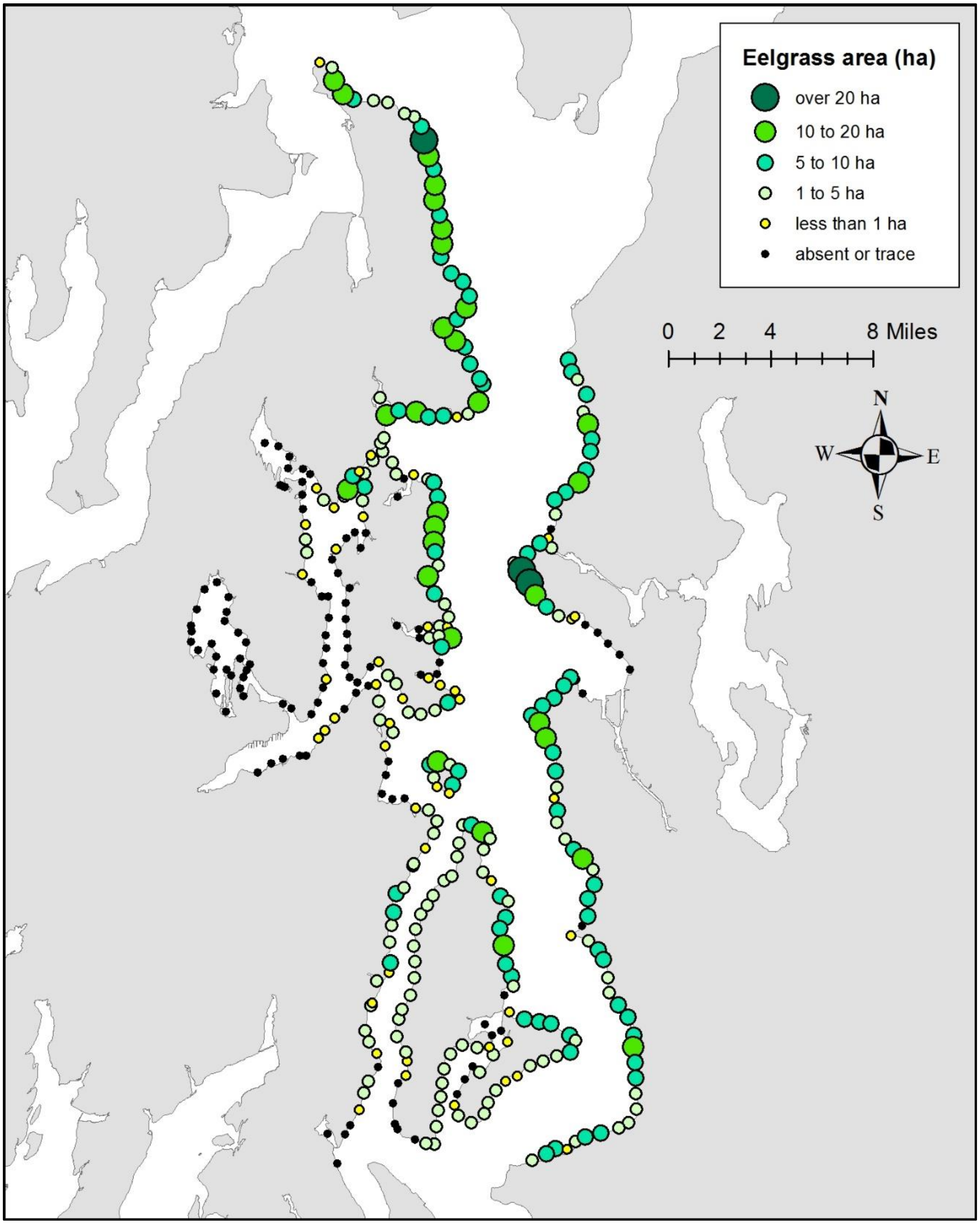

Figure 11: Size of eelgrass of at sites in the central basin of Puget Sound (ha). The majority of eelgrass beds in the study area were relatively small (< 10 ha).

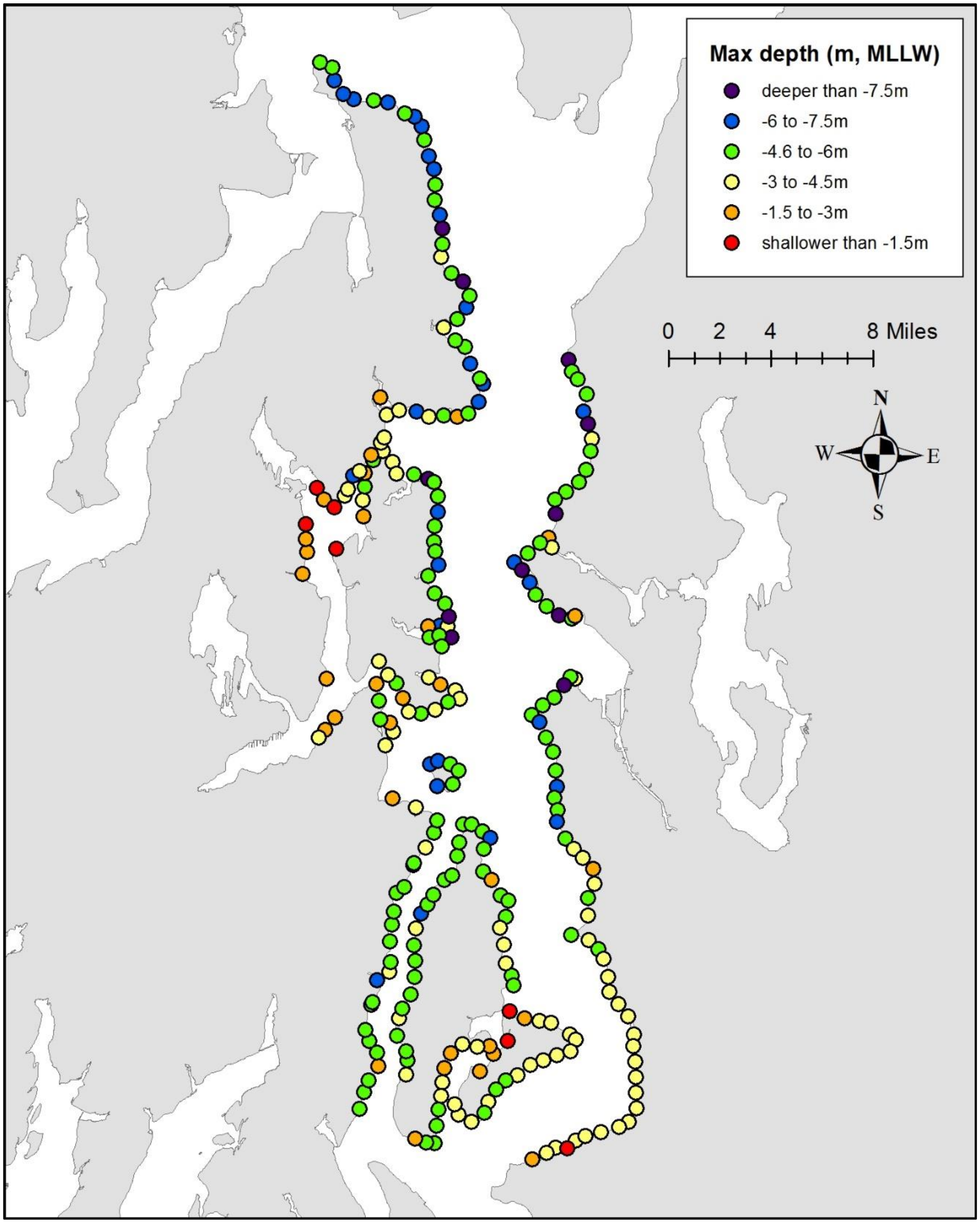

Figure 12: Maximum depth of eelgrass beds at sites in the central basin of Puget Sound (m, relative to MLLW).

3.3 Recent trends in eelgrass area

3.3.1 *Regressions*

Between 2018 and 2020, we revisited 35 sites that were previously sampled as part of IAA15-17 between DNR. Out of these sites, 16 have been sampled on more than two occasions. At these sites we tested for trends in site eelgrass area using a linear regression analysis (alpha = 0.05). We included all available information (including instances where sites were sampled with both SRS and STR). Note that most estimates were based on new draw SRS, which introduces some uncertainty to the trend analysis. At only one site (cps2105) there was a decline. At one site, eelgrass was never present (flats39). At the other 14 locations there was no linear trend over time (Figure 13). There were no sites with significant increases. At cps2218, an apparent trend was rejected because of potential misidentification between *Z. marina* and *Z. japonica*.

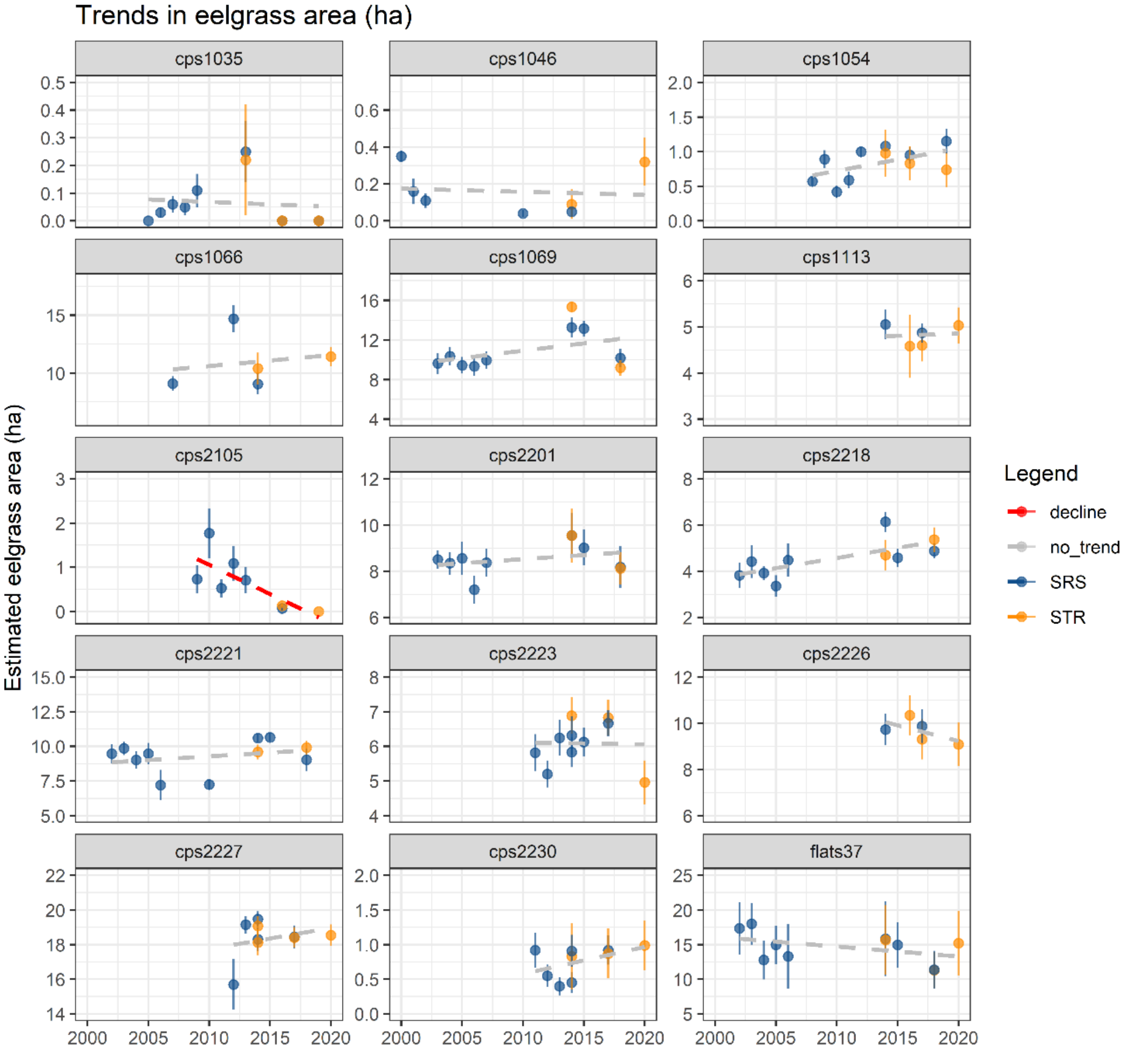

Figure 13: Linear regression of eelgrass area over time at sites for NTA2018-0409 that have been sampled on more than 2 occasions. Error bars are standard error. The color of the regression line indicates declines (red) or no trend (grey). Flats39 is not shown as eelgrass was never present at this location.

3.3.2 *Paired transect analysis*

In 2019 and 2020, we resurveyed previously sampled transects at 29 locations. We compared the vegetated fraction in 2019/2020 with values from a previous sample (2014, 2016 or 2017 depending on the site). We plotted the change in vegetated fraction per site (Figure 14) and tested if the mean change in vegetated fraction was different from zero using a paired t-test (alpha = 0.01). At 3 out of 29 sites eelgrass declined, and at 25 sites there was no change over time. At one site (flats39) no eelgrass was found. There were no sites with significant increases.

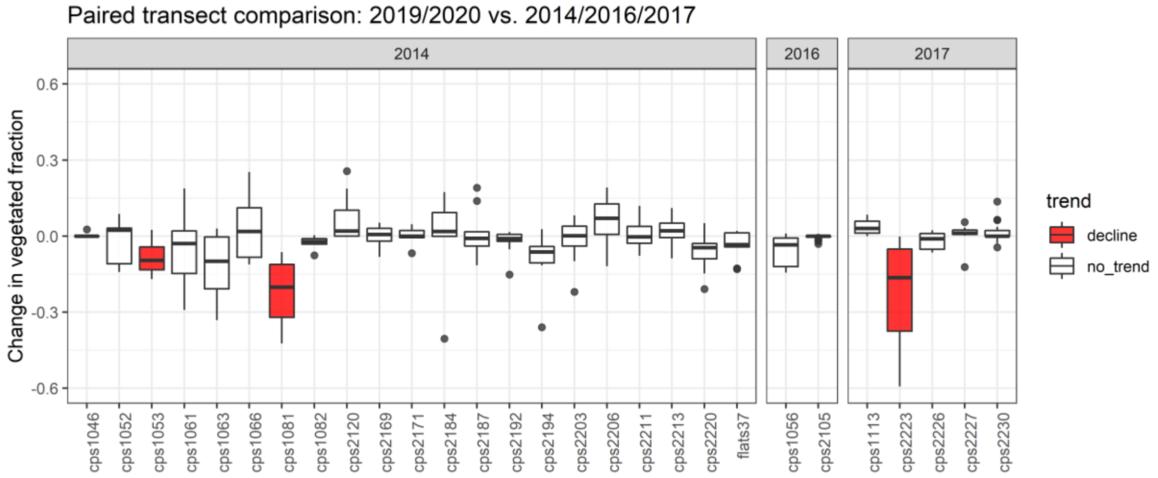

Figure 14: Boxplots of change in vegetated fraction along transects that were resampled over time, analyzed using paired t-tests (alpha = 0.01). Sites with declines in vegetated fraction are marked in red.

3.3.3 *Sites of interest*

The regression and paired transect analyses highlight different aspects of changes in eelgrass distribution. The regressions are based on all area estimates at a site. These analyses are less precise but they use all available information and encompass the entire time series at each site. Paired transect analyses are more precise since they compare changes in cover at the transect level, but they are limited to 2 years from the entire time series.

- At **cps2105** (Yukon Harbor), eelgrass has steadily declined over the last decade. There were only traces of eelgrass left in 2016 and 2019. At this location, declines in an already sparse seagrass bed were likely due to a thick layer of green macro-algae covering the substrate.
- At **cps1081** (Bill Point, Bainbridge Island) there has been loss of eelgrass in the intertidal between 2014 and 2020 (Figure 15). This site has only been sampled twice by DNR. More data is needed to assess if this decline is part of a longer term trend, or if it is inter-annual variation.

- At **cps2223** (South of Norwegian Point) eelgrass declined between 2017 and 2020. The decline was most pronounced at the northern part of the site (Figure 15). The regression analysis did not detect a longer term trend at this location (2011-2020).
- Between 2014 and 2020, there has been expansion of the Z. japonica bed at **cps1046**. There is no overlap with the small *Z. marina* bed, which is located immediately north of Battle Point.
- At **cps2184** (west of Point Bolin), the footprint of the eelgrass bed changed between 2014 and 2020. Total eelgrass area did not significantly change in this time period.

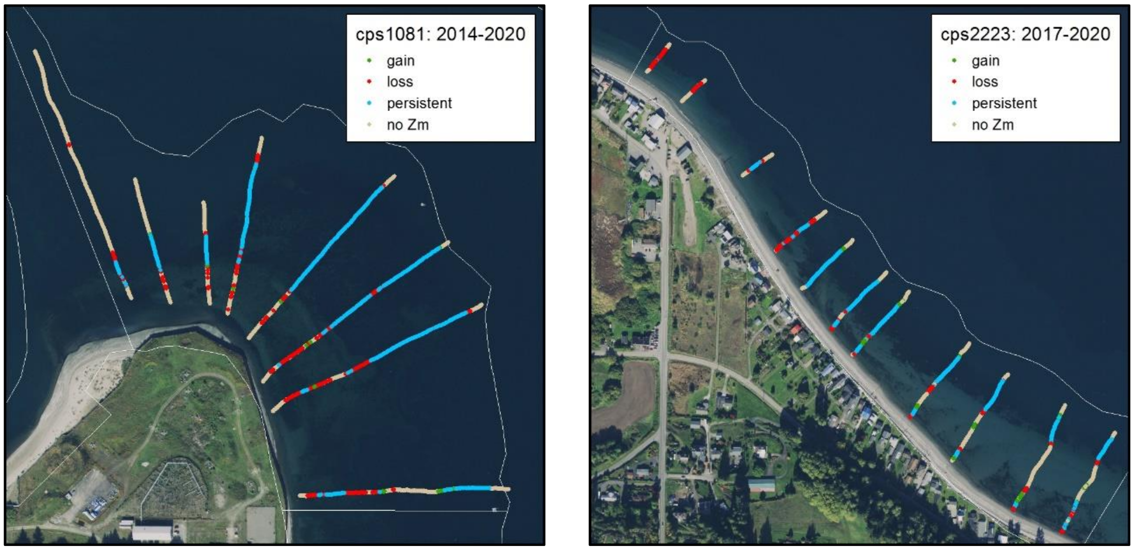

Figure 15: Left: loss of intertidal eelgrass at cps1081 between 2014 and 2020. Right: eelgrass decline at the northern part of cps2223.

4 Discussion

4.1 Importance of long-term monitoring

Eelgrass is an important but vulnerable component of nearshore ecosystems in Puget Sound. Seagrasses, such as eelgrass, can be damaged by a wide range of human actions, such as dredging, anchoring, construction of overwater structures, and the excessive input of nutrients and organic matter from coastal watersheds. They are often used as a bio-indicator of ecosystem health – both globally and within Puget Sound (Krause-Jensen et al. 2005, Orth et al. 2006, Mumford 2007). Large scale surveys, such as the 2014-20 survey in the central basin of Puget Sound, provide information on the spatial variability of eelgrass beds and form a high resolution baseline for assessing future change. In combination with data from other monitoring programs, these surveys provide insight on effects of potential stressors and the spatial extent of human disturbance.

4.2 Spatial patterns in area and depth distribution

4.2.1 Area distribution

Based on the site area estimates, we estimate that there is approximately 1315 ha of eelgrass on the shorelines of King County and Kitsap County in the central basin of Puget Sound. Approximately 680 +/- 9 ha occurred along the shorelines of King County, and 635 +/- 10 ha was present along the shorelines of Kitsap County (which includes a small section of Pierce County on western side of the Colvos Passage for the purpose of this report). The majority of eelgrass in the study area was found on narrow fringes of intertidal and subtidal land along the shoreline. This contrasts with the soundwide distribution pattern, where approximately 50% of eelgrass grows on flats sites (Christiaen et al. 2019).

In Kitsap County, almost 55% all eelgrass was found along the upper Kitsap Peninsula (343 ha) and approximately 22% of all eelgrass was found of the eastern shoreline of Bainbridge Island (~143 ha). The lower Kitsap Peninsula, Port Orchard, and Colvos passage each contained approximately 50 ha of eelgrass, and account for the remaining 23%. Only trace amount of eelgrass were found in Dyes inlet & eelgrass was absent from Liberty Bay. In King County, the majority of eelgrass was found along the mainland and the eastern shore of Vashon Island. Quartermaster Harbor accounted for only 5% of all eelgrass in King County (37.8 ha). Eelgrass became progressively more sparse towards the head of the embayment, and was completely absent from the inner Harbor.

Eelgrass beds provide important habitat to a wide range of vertebrate and invertebrate species, spawning substrate for Pacific herring, and nursery habitat for commercially important and endangered fish species such as rockfish and salmonids. Eelgrass beds within the study area provide spawning substrate for 3 different herring stocks: the Elliott Bay herring stock, the Quartermaster Harbor herring stock, and the Port Orchard/Madison herring stock (Sandell et al. 2019). Current spawning grounds correspond to sites with significant eelgrass beds at each of these locations.

4.2.2 Depth distribution

In the study area, eelgrass is found at depths between -13.3 and 1.1m relative to Mean Lower Low Water (MLLW). However, the vast majority of plants is found between 0 and -4.5m (MLLW). There were only 4 sites where eelgrass was found deeper than -10m (cps1669, cps1688, cps1723, and cps1072) and at those locations very few plants extended to this depth. In Kitsap County, eelgrass grew deepest along the northeastern Kitsap Peninsula, southeastern Kitsap Peninsula, Colvos Passage, and the eastern side of Bainbridge Island. Eelgrass did not grow as deep in Port Orchard and Sinclair Inlet, essentially disappeared when moving further west into Liberty Bay and Dyes Inlet. In King County, eelgrass grew to deeper extents in the northern parts of the study area and along Colvos Passage. It did not grow as deep in the southern section of the central channel. There also was a clear gradient in maximum depth throughout Quartermaster Harbor.

Seagrasses have relatively high light requirements because they support a large biomass of roots and rhizomes in relation to their size (Hemminga at al. 1998, Lee et al. 2007). In the Pacific Northwest, eelgrass requires on average 3 mol quanta m-2 day-1 for long-term survival (Thom et al. 2008). The maximum depth to which they grow is in part determined by the amount of light that filters through the water column, as well as the level of overgrowth by epiphytes and macroalgae (Dennison 1987). The ‘shallower’ deep edge of eelgrass beds along the shoreline of Federal Way (from Dash Point to Redondo Beach), could be caused by the Puyallup river plume, which is laden with sediment and highly turbid. The spatial patterns in the deep edge within Quartermaster Harbor and towards Port Orchard are suggestive of a gradient in water clarity. Other variables, such as water temperature or flushing rates, could also play a role.

4.3 Trends in eelgrass area

Based on data collected between 2018 and 2020, we were able to assess change over time for 35 sites previously sampled along the Kitsap Peninsula. One site never had eelgrass present (Liberty Bay). Out of the 16 sites that had been sampled on more than 2 occasions, only one site showed a significant trend over time (cps2105 – Yukon Harbor). At this location eelgrass gradually declined over time, and was virtually absent in 2019. At 29 sites, we were able to resurvey previously sampled transects. At 21 sites, the initial sample was from 2014, at 2 sites the initial sample was collected in 2016, and at 6 sites the initial sample dated from 2017. A paired transect analysis indicated that eelgrass declined at 3 locations: cps1081, cps1053 and cps2223. There were no significant trends at any of the other sites. At this point we have not determined the exact cause for the declines. However, we did document thick layers of green macroalgae at cps2105. Green algae blooms are often associated with eutrophication, and can have negative impacts on eelgrass and other biota in nearshore habitats (Burkholder et al. 2007).

4.4 Data use and availability

As a result of a series of interagency agreements between DNR, the Suquamish Tribe, the City of Bainbridge Island, WDFW, and King County, the shoreline of the central basin has become one of the most extensively sampled areas for eelgrass status in greater Puget Sound.

Surveying large, contiguous stretches of shoreline has generated detailed estimates of eelgrass area and depth distribution. These data provide a highly precise large area profile of the current extent of both eelgrass (*Z. marina*) and the non-native *Z. japonica*. It can serve as a baseline for future studies on trends in eelgrass area and depth distribution. Currently, additional analyses are underway to assess potential impacts of shoreline armor on intertidal eelgrass populations in central Puget Sound, as well as study on additional of marine vegetation, such as green algae, *Sargassum* and understory kelp.

Eelgrass abundance, distribution and depth data identify sensitive habitat areas for consideration in land-use planning. Given the recognized ecological importance of eelgrass, planning should explicitly consider the location of eelgrass beds, its environmental requirements and potential habitat.

All data presented in this report will be available online in the next distribution dataset of DNR’s Submerged Vegetation Monitoring Program (scheduled for 2021). For more information, visit http://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science

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6 Appendix 1: transect maps

Figure 16: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps2230, cps2227, and cps2226

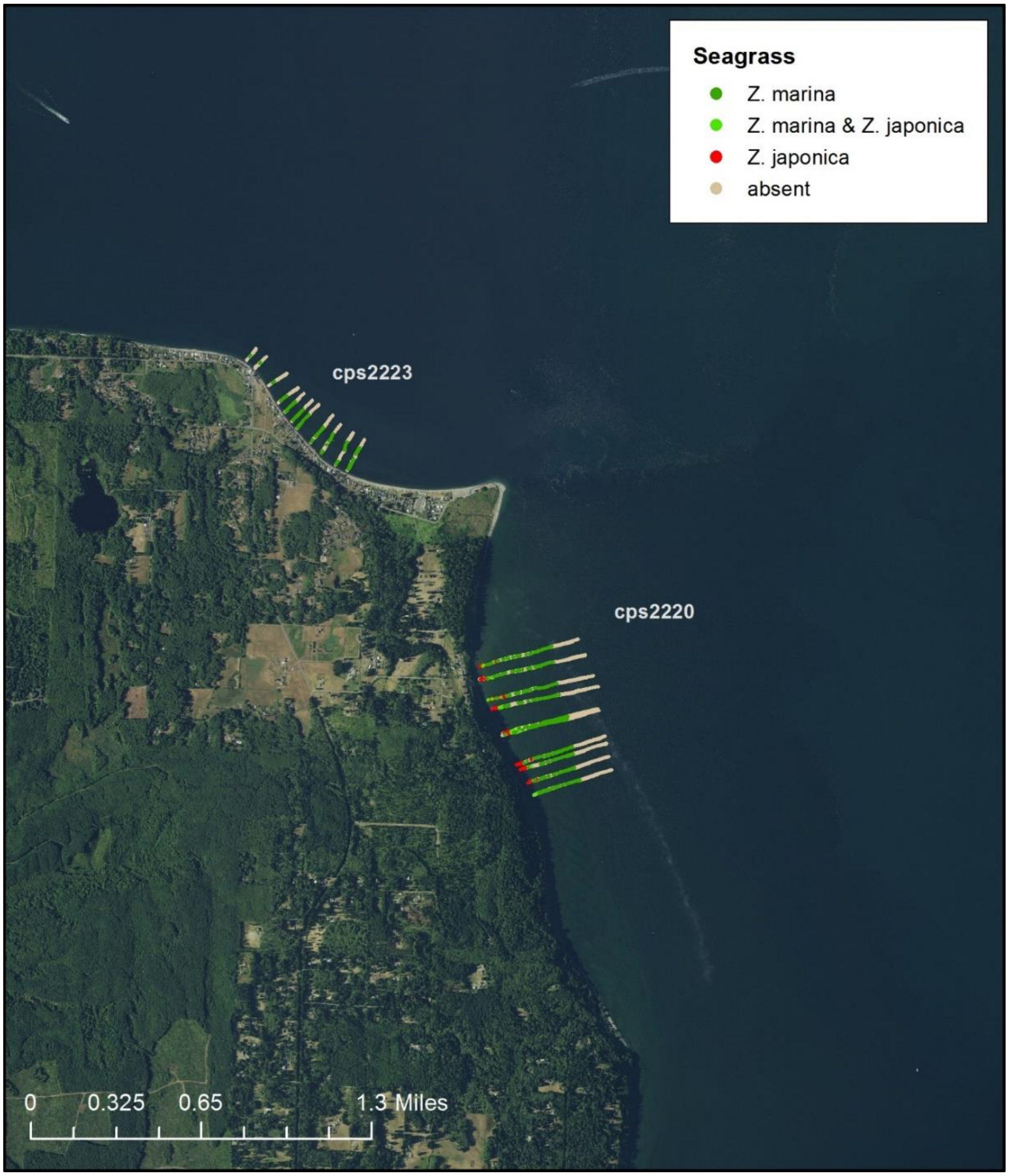

Figure 17: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps2223 and cps2220

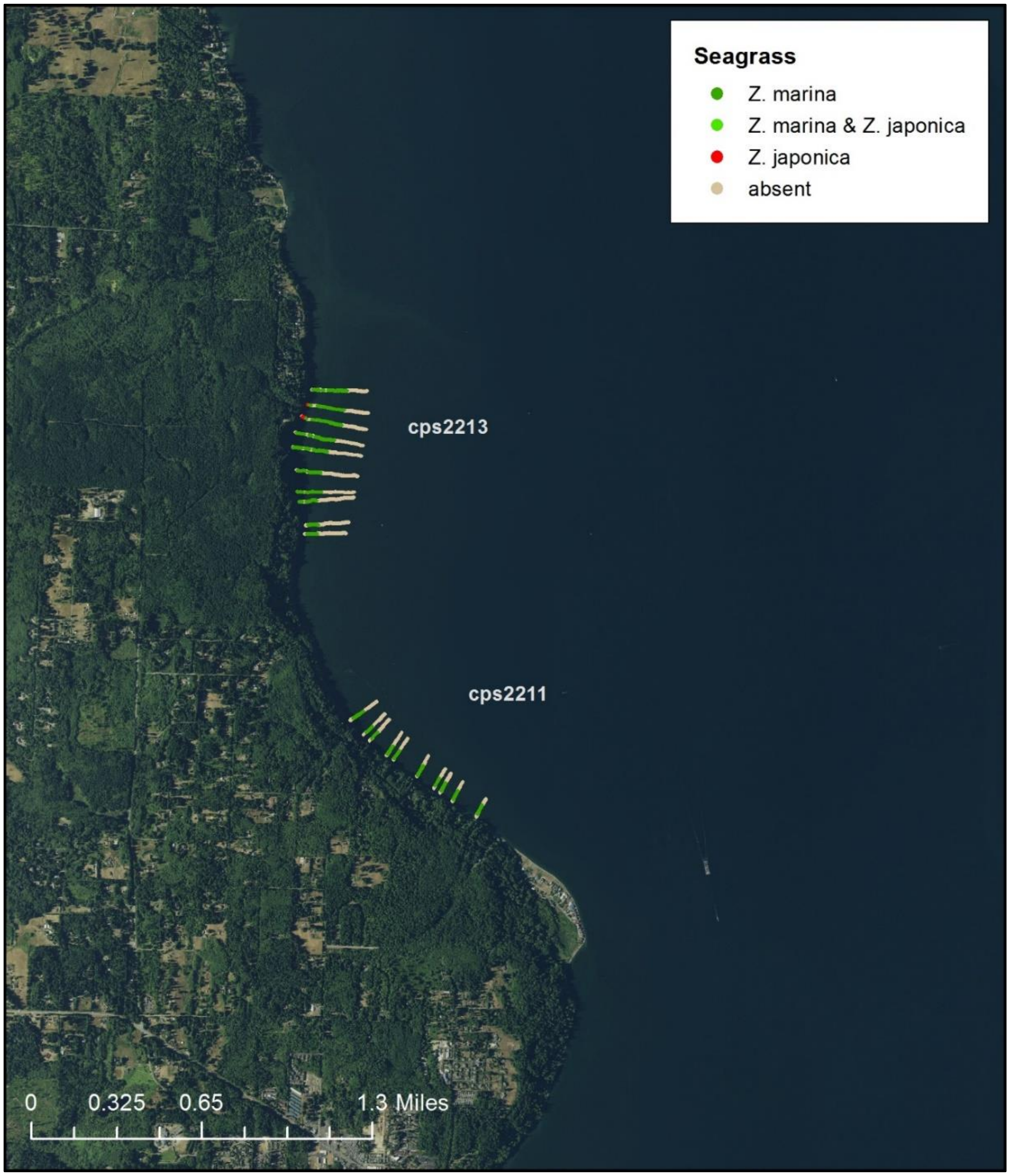

Figure 18: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps2213 and cps2211

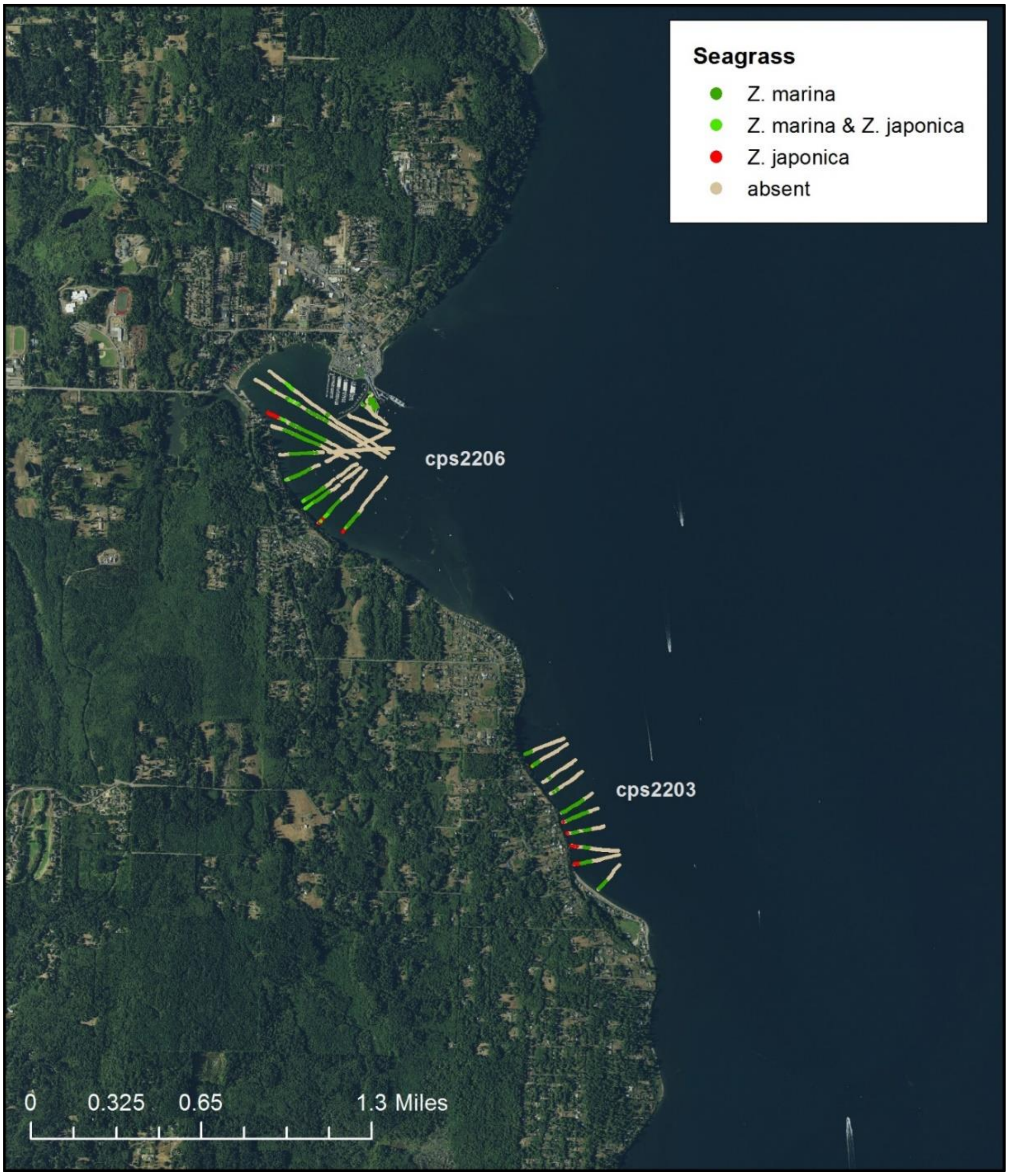

Figure 19: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps2206 and cps2203

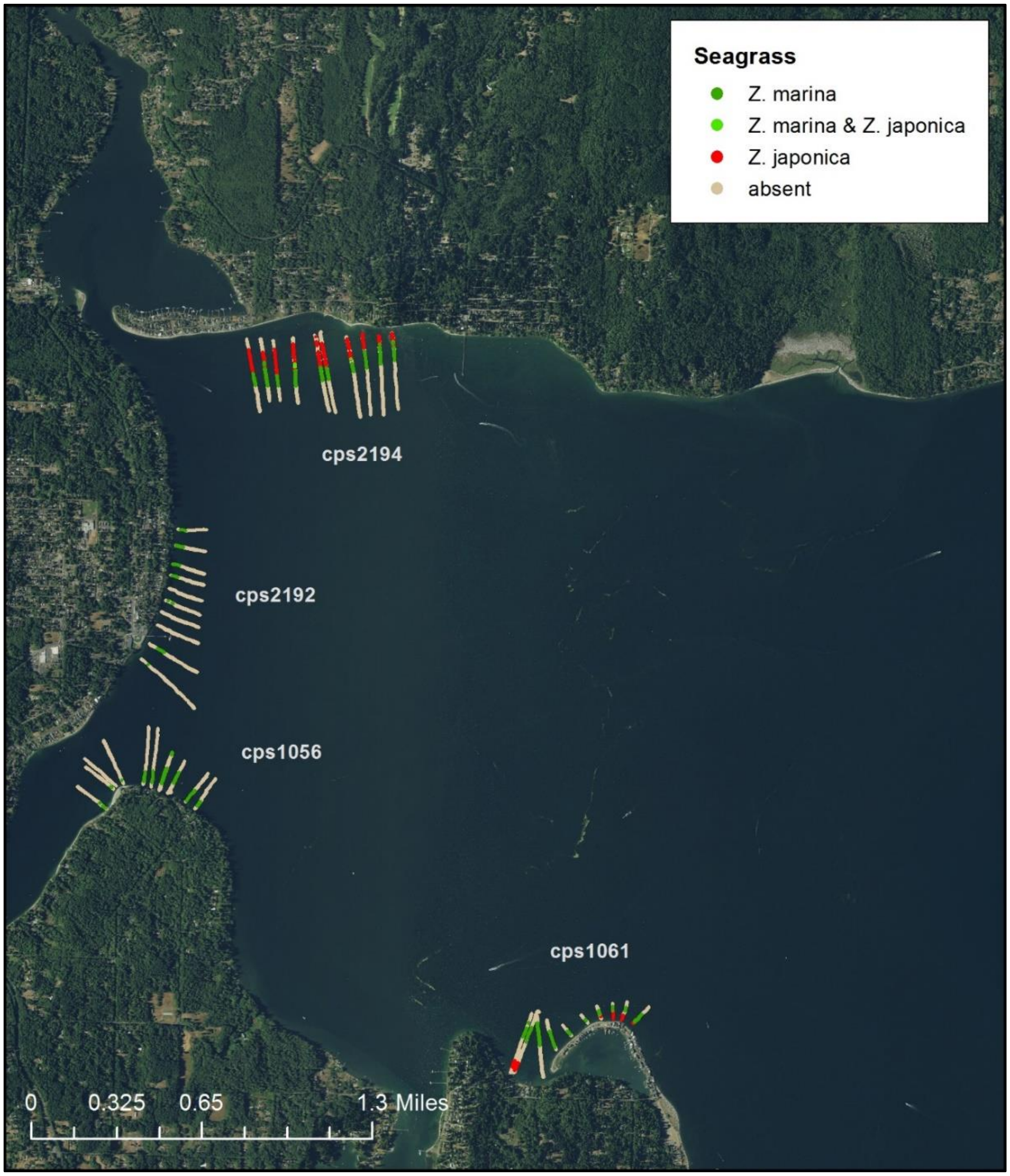

Figure 20: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps2194, cps2192, cps1056, and cps1061

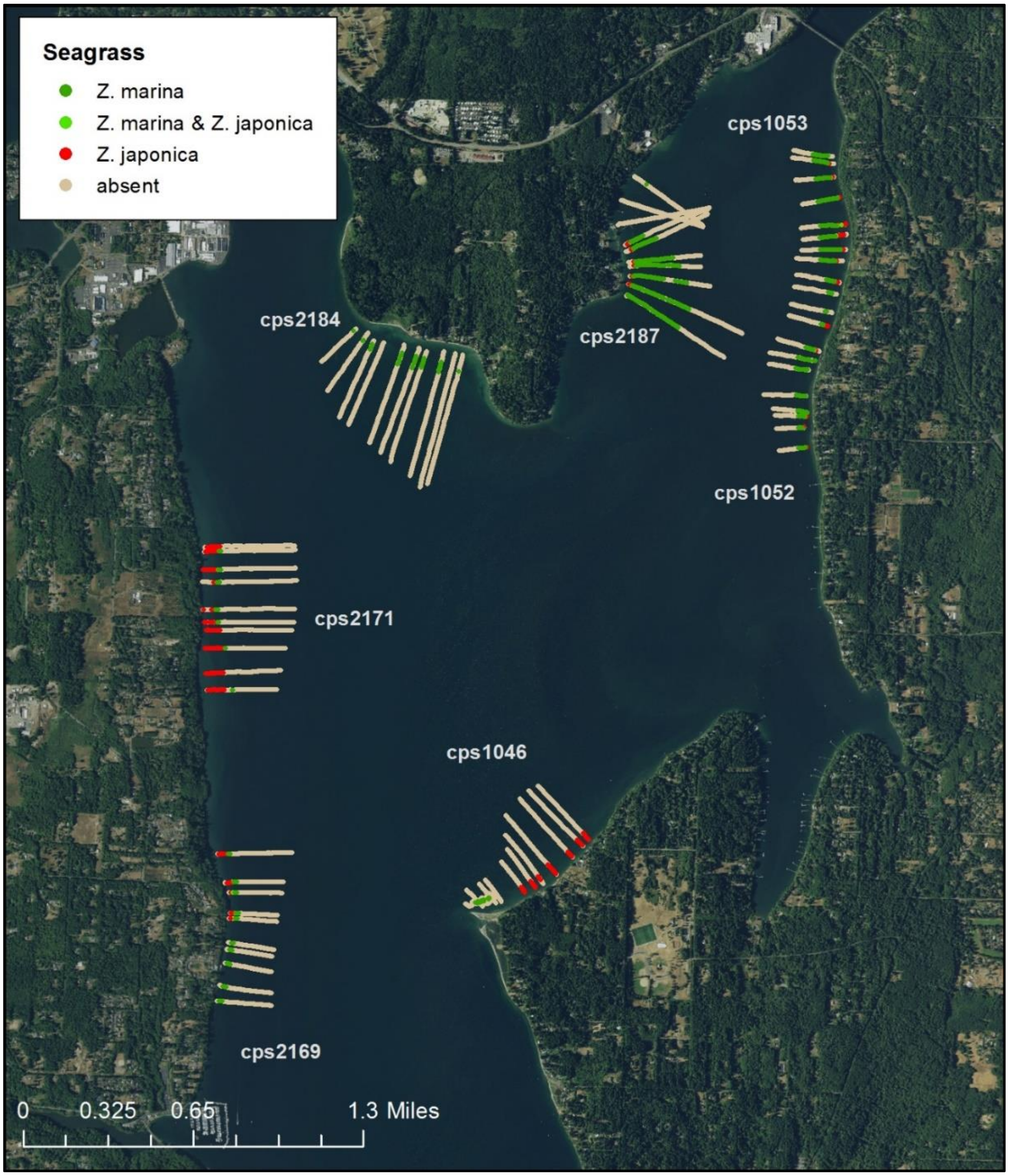

Figure 21: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps1046, cps1052, cps1053, cps2187, cps2184, cps2171, and cps2169

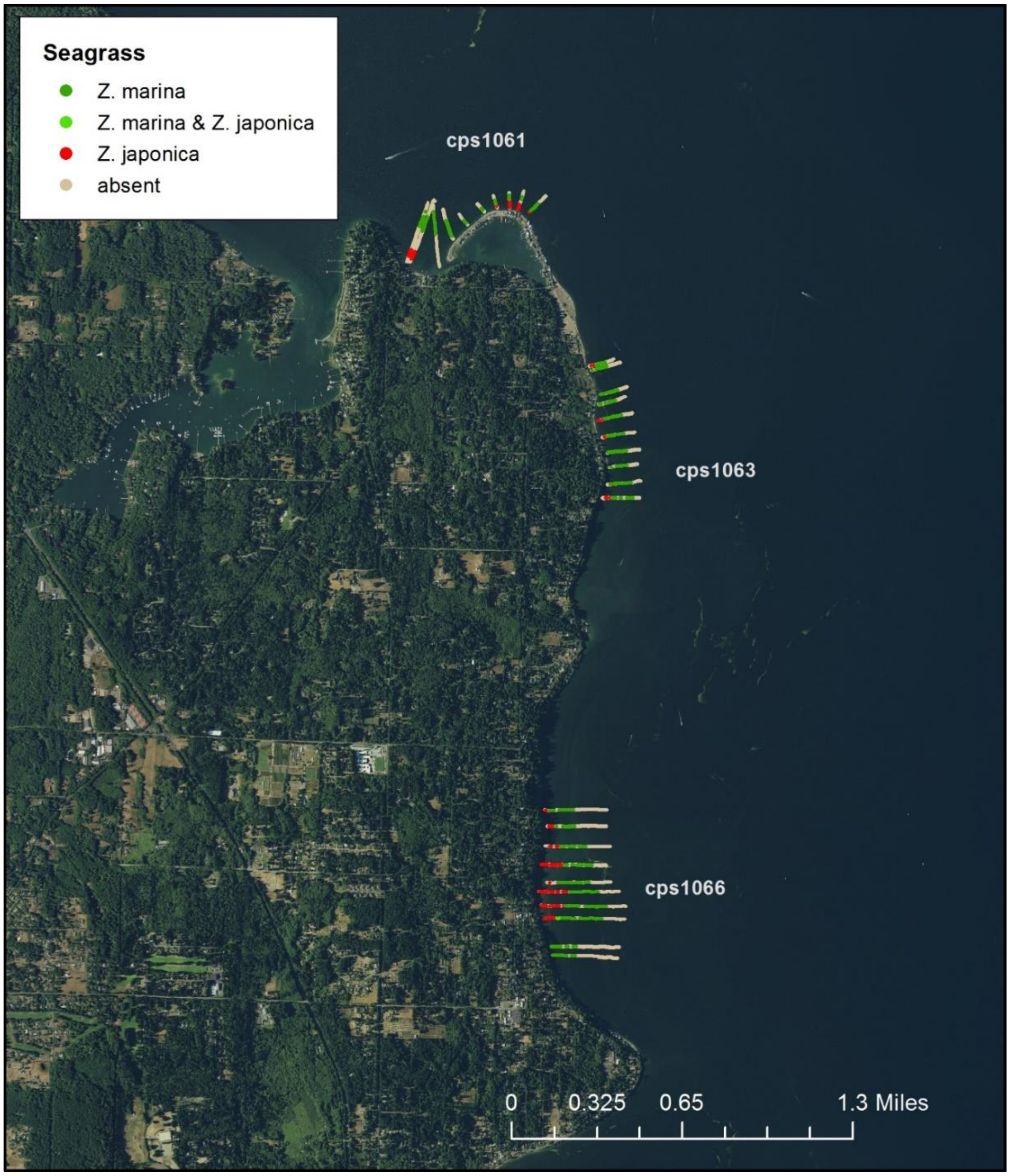

Figure 22: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps1061, cps1063, and cps1066

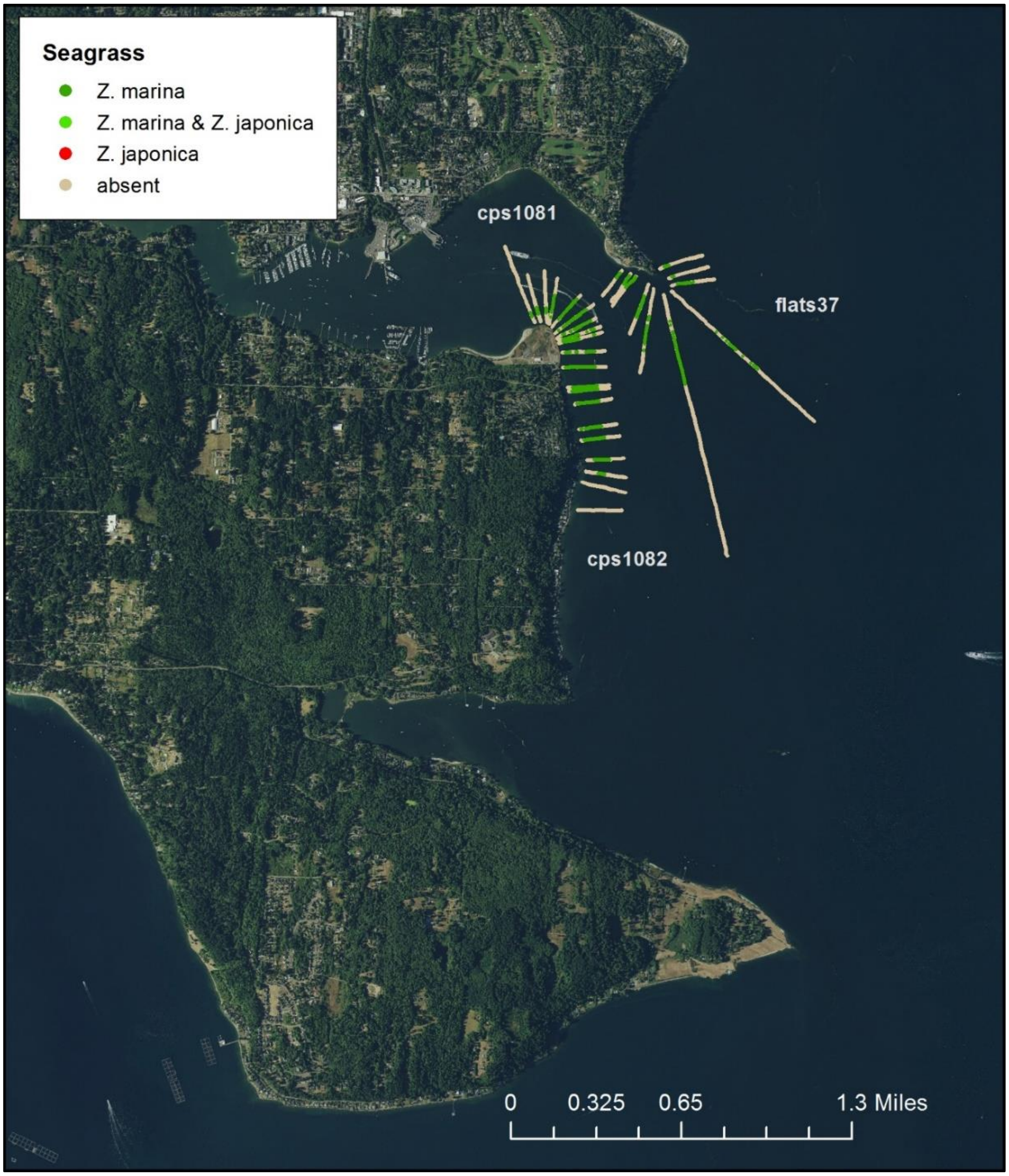

Figure 23: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at flats37, cps1081, and cps1082

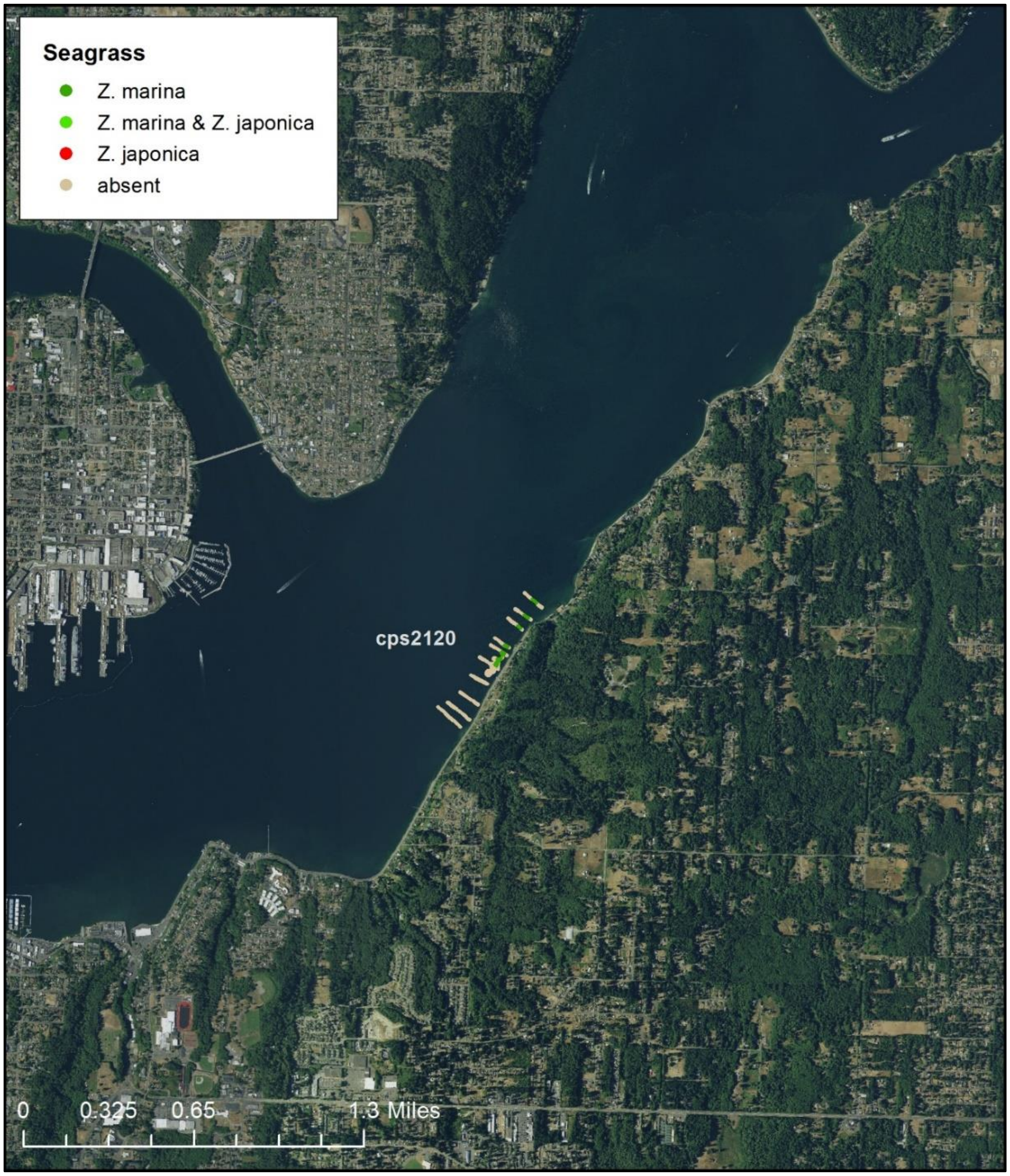

Figure 24: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps2120

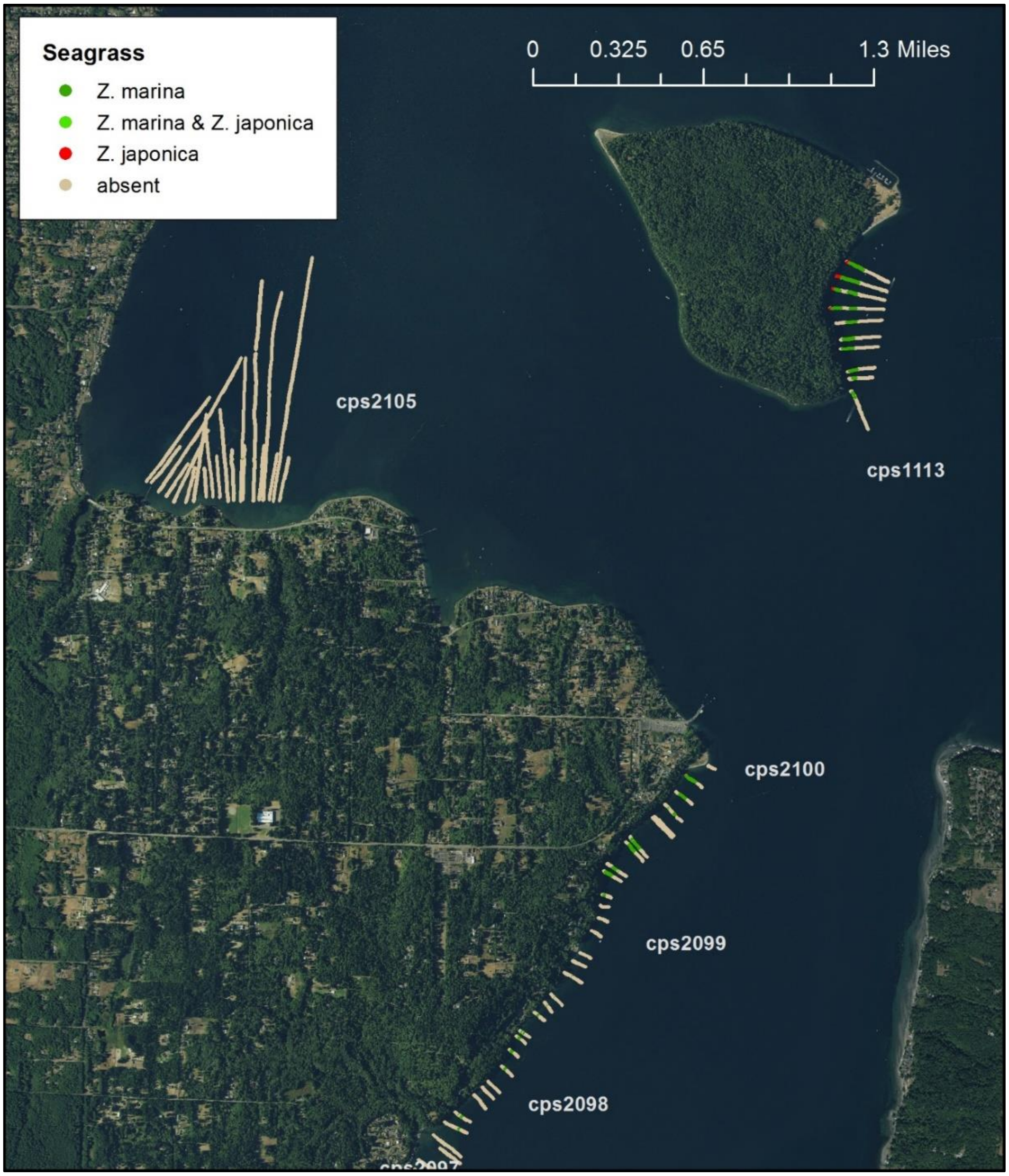

Figure 25: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps1113, cps2105, cps2100, cps2099, and cps2098

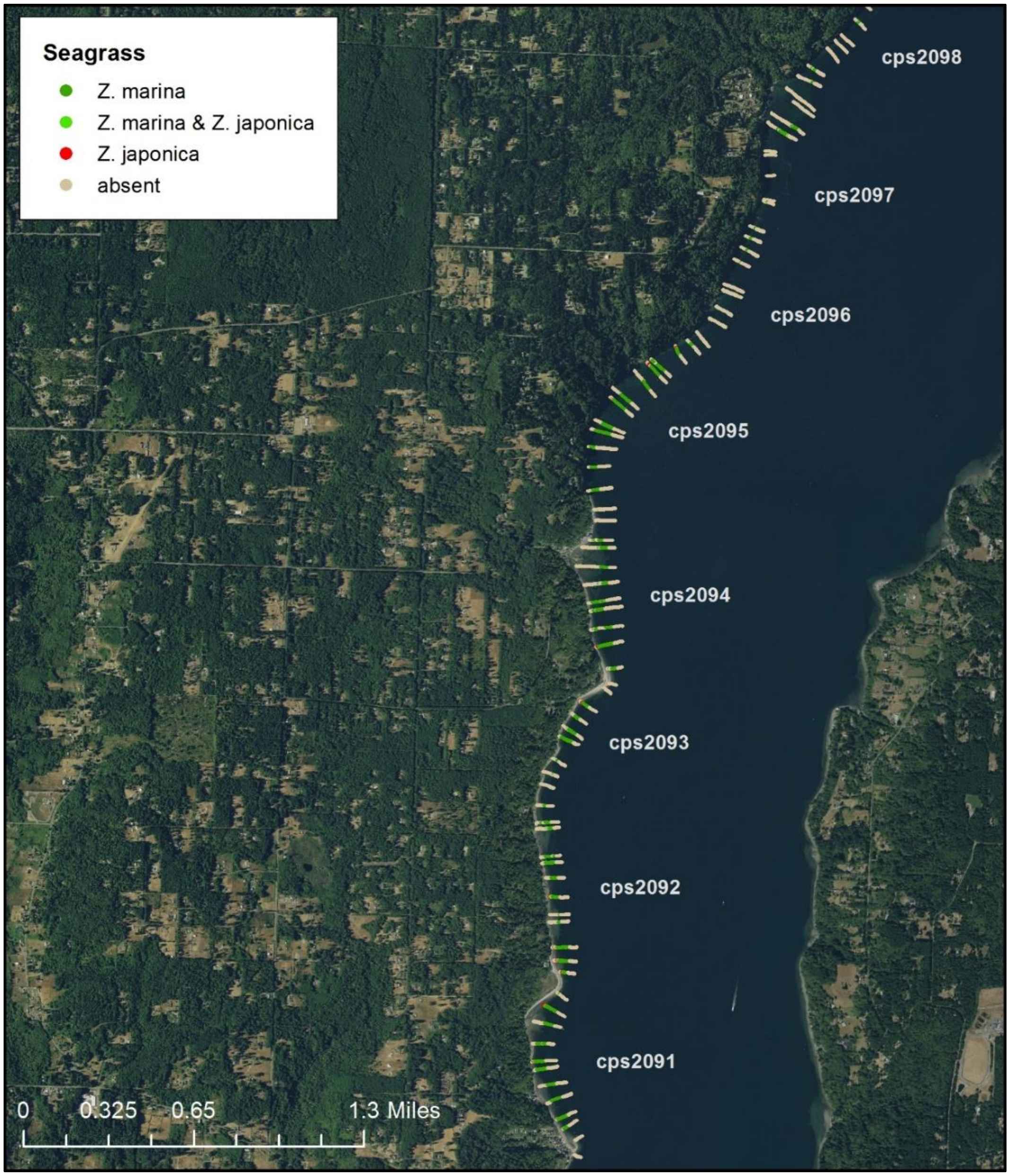

Figure 26: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps2098, cps2097, cps2096, cps2095, cps2094, cps2093, cps2092, and cps2091

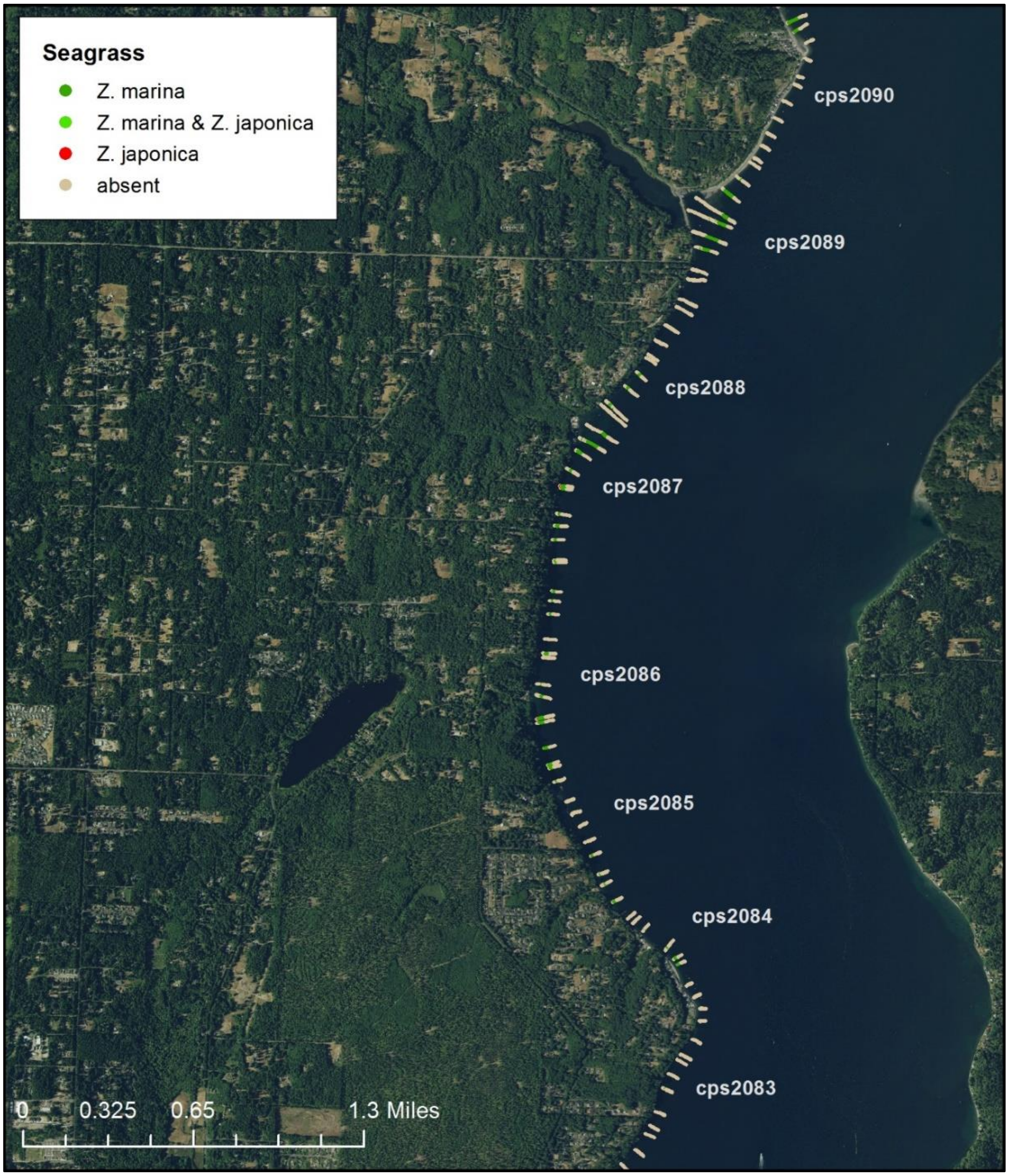

Figure 27: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps2090, cps2089, cps2088, cps2087, cps2086, cps2085, cps2084, and cps2083

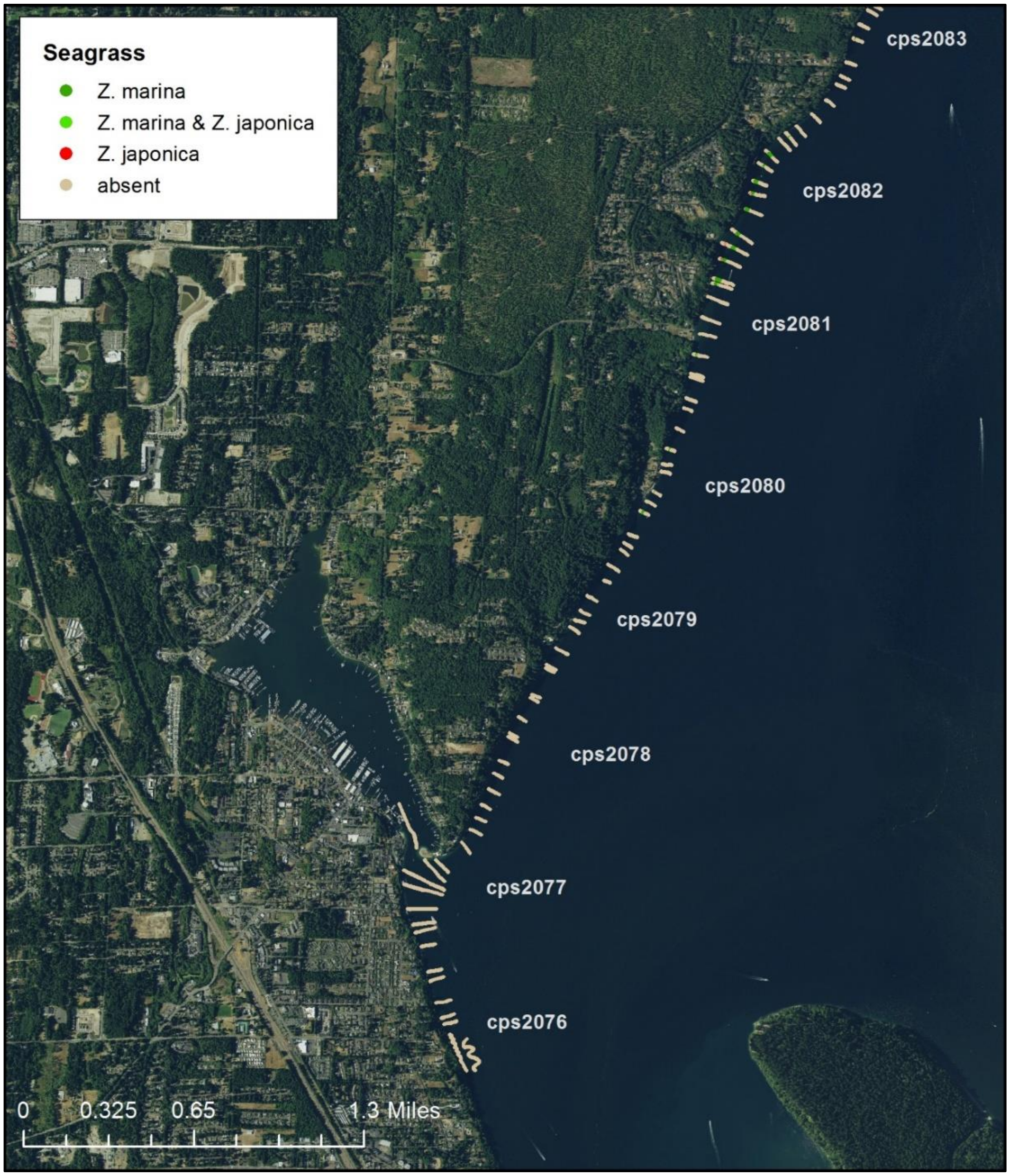

Figure 28: Presence/absence of *Z. marina* and *Z. japonica* along individual transects at cps2083, cps2082, cps2081, cps2080, cps2079, cps2078, cps2077, and cps2076