NATURAL RESOURCES

Eelgrass abundance and depth distribution in the East Kitsap Study Area

Final report to the Suquamish Tribe
DNR IAA 15-17
NWIFC CA PA-00J32201-0

---

30 June 2016

PUGET SOUND ECOSYSTEM MONITORING PROGRAM

WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES

The Nearshore Habitat Program supports the Washington State Department of Natural Resources' stewardship responsibilities for state-owned aquatic lands. It is also a component of the Puget Sound Ecosystem Monitoring Program (PSEMP) (http://sites.google.com/site/pugetsoundmonitoring/).

Cover Photo: *Zostera marina* and *Zostera japonica*, Photo by DNR

Eelgrass abundance and depth distribution in the East Kitsap Study Area

Final report to the Suquamish Tribe
DNR IAA 15-17
NWIFC CA PA-00J32201-0

---

30 June 2016

Bart Christiaen
Jeff Gaeckle
Lisa Ferrier

Nearshore Habitat Program
Aquatic Resources Division

PUGET SOUND ECOSYSTEM MONITORING PROGRAM

WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES

Acknowledgements

The Nearshore Habitat Program is part of the Washington State Department of Natural Resources' (DNR) Aquatic Resources Division, the steward for state-owned aquatic lands. Program funding is provided through DNR's Resource Management Cost Account. The Nearshore Habitat Program monitors and evaluates the status and trends of marine vegetation for DNR and the Puget Sound Partnership.

The following document fulfills deliverable 6.1 for Inter-Agency Agreement no. IAA 15-17 and NWIFC Cooperative Agreement PA-00J32201-0 between the Washington Department of Natural Resources and the Suquamish Tribe.

The principal authors of this report include Bart Christiaen, Jeff Gaeckle, and Lisa Ferrier. Several people played a critical role in the video data collection and post-processing for the work summarized in this report including Jessica Stowe and Evan Sutton.

The Nearshore Habitat Program would like to give special recognition to Ian Fraser and Jim Norris of Marine Resources Consultants who continue to play 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.

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement PA00J32201-0 to Northwest Indian Fisheries Commission. The Contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Washington State Department of Natural Resources
Aquatic Resources Division
1111 Washington St. SE
P.O. Box 47027
Olympia, WA 98504-7027

www.dnr.wa.gov

Copies of this report may be obtained from: http://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science

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*), an important nearshore habitat in greater Puget Sound. DNR monitors the status and trends of native seagrass abundance and depth distribution throughout greater Puget Sound using underwater videography.

In 2014, the Suquamish Tribe signed an interagency agreement with DNR to collect baseline eelgrass area and depth distribution data within their usual and accustomed fishing area, including 62 sample sites along the eastern Kitsap Peninsula and Bainbridge Island, using methods standardized by DNR's Submerged Vegetation Monitoring Program (SVMP). Monitoring was initiated on 9 September 2014, and ended on 29 October 2014. During this period of time, we sampled the 62 proposed sites and an additional 33 sites which were mainly located in Dyes Inlet.

In addition to estimating current status, this project establishes a baseline for future, periodic surveys to document trends in eelgrass area and depth distribution at both a site and regional (East Kitsap) scale. This effort supplements existing and planned future sampling by the SVMP, and significantly increases the certainty in local estimates of eelgrass area and depth distribution over what existing data from the Submerged Vegetation Monitoring Program can currently provide.

Key Findings:

- Out of the 95 sites sampled, there were 58 sites with *Zostera marina* and 38 sites with the non-native *Zostera japonica*. In 34 sites, both species were present. There was little overlap between species. *Z. japonica* tends to grow at higher tidal elevations compared to *Z. marina*.
- Out of the 95 sites sampled, there were 37 sites without eelgrass. Sites without eelgrass were predominantly located in Dyes Inlet, Liberty Bay, and Port Orchard Bay.
- Within the study area, eelgrass was most abundant along the eastern shore of the Upper Kitsap Peninsula.
- Eelgrass grew to greater maximum depths along the eastern shores of the upper Kitsap Peninsula and Bainbridge Island, as compared to Port Orchard and Sinclair Inlet.
- Over 75 % of all eelgrass in the study area grew between 0 and -3 m relative to Mean Lower Low Water (MLLW).

1 Introduction

Eelgrass (*Zostera marina*) provides a wide range of important ecosystem services. In Puget Sound, eelgrass offers spawning grounds for Pacific herring (*Clupea harengus pallasi*), out-migrating corridors for juvenile salmon (*Oncorhynchus* spp.) (Phillips 1984, Simenstad 1994), and important feeding and foraging habitats for waterbirds such as the black brant (*Branta bernicla*) (Wilson and Atkinson 1995) and great blue heron (*Ardea herodias*) (Butler 1995). In addition, eelgrass provides valued hunting grounds and ceremonial foods for Native Americans and First Nation People in the Pacific Northwest (Suttles 1951, Felger and Moser 1973, Kuhnlein and Turner 1991, Wyllie-Echeverria and Ackerman 2003). Eelgrass responds quickly to anthropogenic stressors such as physical disturbance, and reduction in sediment and water quality due to excessive input of nutrients and organic matter. This makes eelgrass an effective indicator of habitat condition (Dennison et al. 1993, Short and Burdick 1996, Lee et al. 2004, Kenworthy et al. 2006, Orth et al. 2006).

Since 2000, the Nearshore Habitat Program at the Washington State Department of Natural Resources has collected annual data on the status of eelgrass (*Zostera marina*) throughout Puget Sound as part of the Submerged Vegetation Monitoring Program (SVMP). The SVMP is one component of the broader Puget Sound Ecosystem Monitoring Program (PSEMP), a multi-agency monitoring program coordinated by the Puget Sound Partnership. The monitoring data is used to characterize the status of native seagrass and is one of 25 vital signs used by the Puget Sound Partnership to track progress in the restoration and recovery of Puget Sound (PSP 2014).

In 2014, The Suquamish Tribe signed an interagency agreement with DNR to collect baseline eelgrass area and depth distribution data within their usual and accustomed fishing area, including 62 sample sites along the east Kitsap Peninsula, using methods standardized by the SVMP. Monitoring was initiated on 9 September 2014, and ended on 29 October 2014. During this period of time, we sampled the 62 proposed sites and an additional 33 sites which were mainly located in Dyes Inlet.

This report summarizes the DNR sampling methods, and the eelgrass area and depth distribution results at the 95 sites in the East Kitsap Study area.

2 Methods

Field sampling was conducted using the methods of DNR's Submerged Vegetation Monitoring Program (SVMP). 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 East Kitsap study area is a subset of the SVMP study area, containing 219 sites. A total of 95 sites were sampled as part of this project (Figure 1). We divided the study area into 5 different zones: Upper Kitsap (UK), Eastern Bainbridge Island (EB), Port Orchard and Sinclair Inlet (PO), Dyes Inlet and Liberty Bay (INL) and Lower Kitsap (LK). All sites sampled for this report were located in UK, EB, PO and INL. Sites in LK will be sampled as part of a future effort. Sites are labeled according to the SVMP dataset. Each code starts with 3 letters (cps, which stands for Central Puget Sound), followed by 4 numbers. The sole exception are the tidal flats, which are coded as "flats" followed by 2 numbers. The location of each sampled site, as well as the zone to which they belong, are indicated on Figure 1.

2.2 Field sampling

2.2.1 Equipment

Field sampling was conducted in September and October 2014 from the 11 m research vessel *R/V* Brendan D II (Figure 3). The *R/V* Brendan D II was equipped with an underwater video camera mounted in a downward-looking orientation on a weighted towfish (Figure 4). Parallel lasers mounted 10 cm apart created two red dots in the video images for scaling reference. The towfish was deployed directly off the stern of the vessel using an A-frame cargo boom and hydraulic winch.

The weight of the towfish positions the camera directly beneath a DGPS antenna, ensuring that the data accurately reflected the geographic location of the camera (Figure 4). Time, differential global positioning system (DGPS) data, Garmin and BioSonics depth data were acquired simultaneously during sampling. Differential corrections were received from the United States Coast Guard public DGPS network using the WSG 84 datum. Table 1 lists the equipment used to conduct the video sampling and acquisition of eelgrass depth data.

2.2.2 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 (Berry et al. 2003, Figure 3). Fringe sites are 1000 m along the -6.1 m contour on the deep edge, while the segment lengths vary for flats sites (e.g., depending on embayment size). In addition, we delineated sample polygons, which encompass all the eelgrass at a site, based on reconnaissance prior to sampling. At each site, underwater videography was used to sample the presence of eelgrass 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. At 56 sites, transects were selected based on a stratified random approach with 1 transect per stratum (STR[1]). In addition, we repeated transects at 13 sites that were sampled in previous years (based on a simple random sample scheme, SRS), to look for changes over time. Sites where reconnaissance indicated that there was no appreciable eelgrass present (39 sites, mostly within Dyes Inlet) were sampled with meander transects only (Figure 2).

Table 1. Equipment and software used to collect underwater video and depth data

Equipment	Manufacturer/Model
Differential GPS	Trimble AgGPS 132 (sub-meter accuracy)
Depth Sounders	BioSonics DE 4000 system (including Dell laptop computer with Submerged Aquatic Vegetation software), Garmin FishFinder 250
Underwater Cameras	(2) SplashCam Deep Blue Pro Color (Ocean Systems, Inc.)
Lasers	Deep Sea Power & Light
Underwater Light	Deep Sea Power & Light RiteLite (500 watt)
Navigation Software	Hypack Max
Video Overlay Controller	Intuitive Circuits TimeFrame
DVD Recorder	Sony RDR-GX7
Digital Video Recorder	Sony DVR-TRV310 Digital8 Camcorder Datavideo DN-700 / DV Hard Disk Recorder

[1] For the stratified random sampling (STR), sites are divided in 10 sections of similar length (strata). In each of these sections, one transect is selected based on a simple random sample scheme (Figure 2). For the simple random sample scheme (SRS) a number of transects is randomly selected throughout the area where eelgrass is present at a site (Berry et al. 2003).

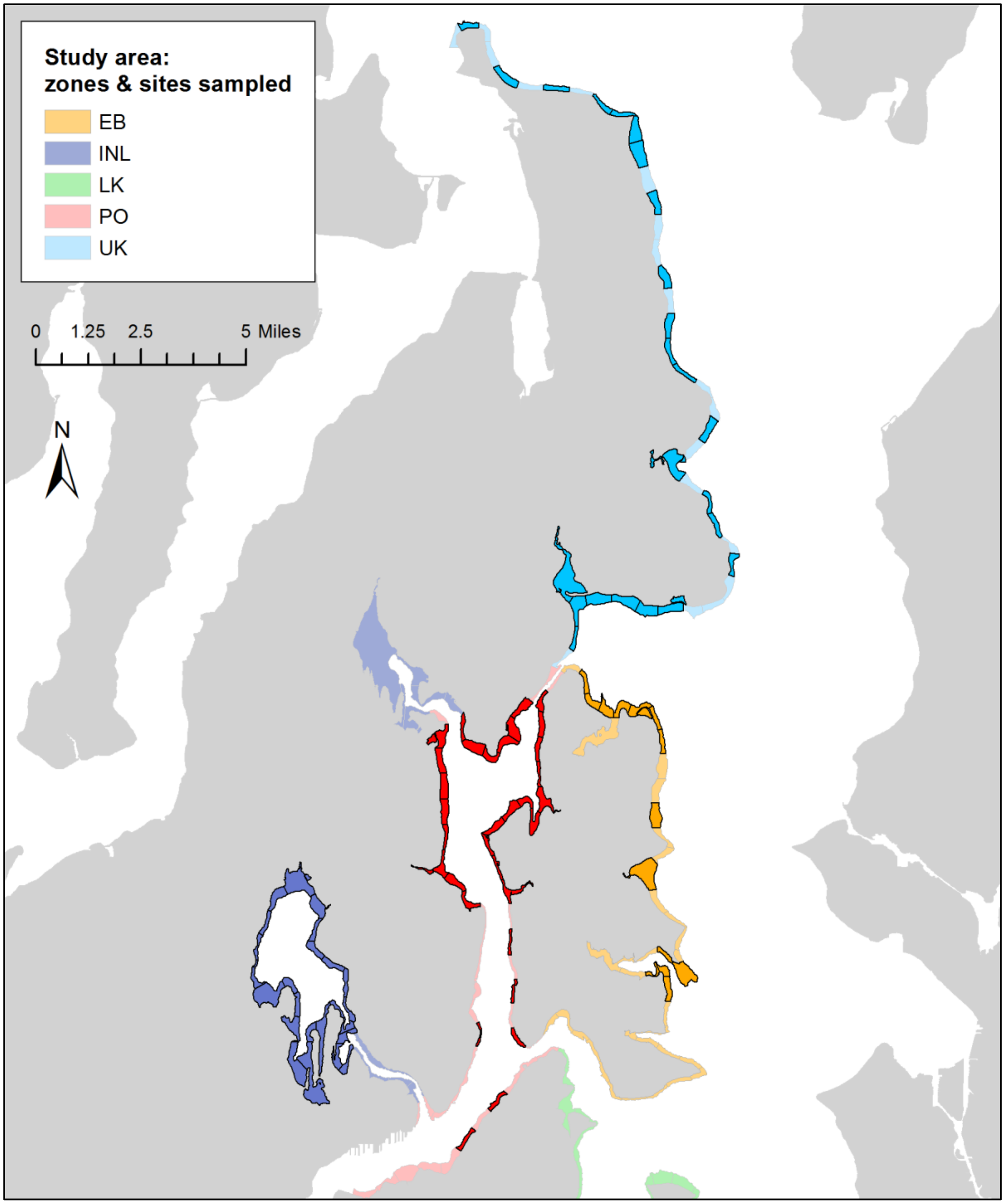


Figure 1: Overview of the East Kitsap study area. Zones are indicated by different colors: EB is East Bainbridge Island, INL is Liberty Bay and Dyes Inlet, LK is Lower Kitsap Peninsula, PO is Port Orchard and Sinclair Inlet, and UK stands for Upper Kitsap Peninsula. Sites that were sampled as part of IAA 15-17 are indicated in bold color.

2.3 Video processing and data analysis

2.3.1 Video processing

The video sampling resolution is nominally one square meter and eelgrass is categorized as present or absent based on the observation of rooted shoots within the video field of view. All *Z. marina* presence and absence classification results 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 mean maximum and minimum depth of eelgrass relative to Mean Lower Low Water (MLLW) within each sample polygon at each site.

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). These final corrected depth data were merged with eelgrass data and spatial information into a site database so the eelgrass observations had associated date/time, position and depth measurements corrected to MLLW datum.

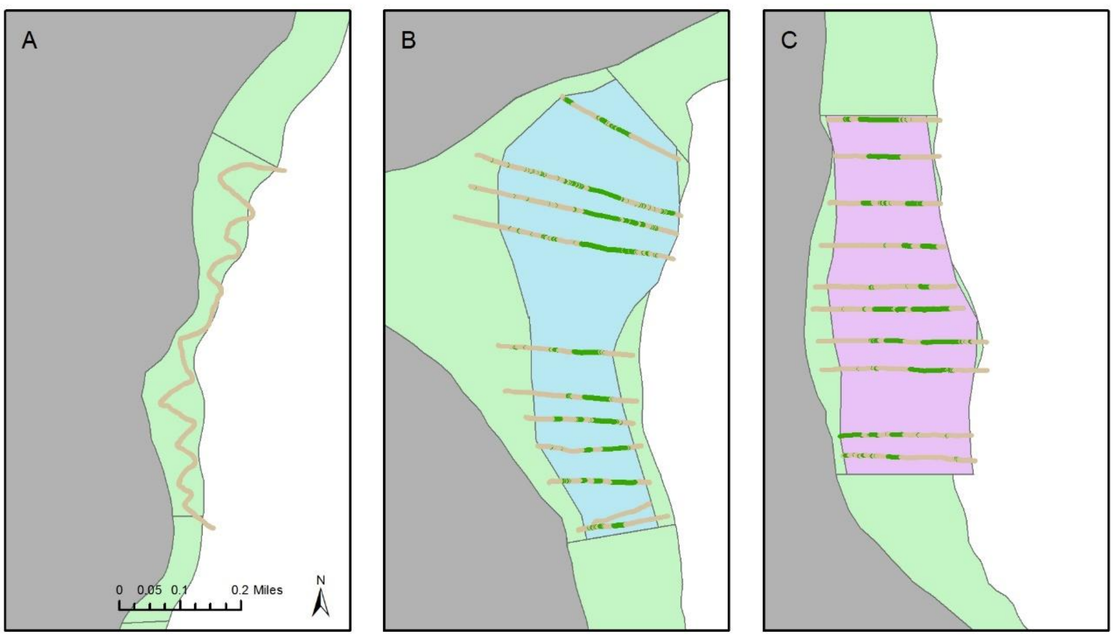


Figure 2: Different transect types: A. Meander transect at cps1106; B. Simple random transects at cps1069; C. stratified random transects with one unit per stratum at cps 1066. Green sections along transects indicate where eelgrass was present. The blue and purple polygons delineate the sample polygons at the sites.

Figure 3: Eelgrass (*Z. marina*) presence and depth distribution data were collected from the *R/V* Brendan D II using 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).

2.3.2 *Area calculations*

Eelgrass area at each site was calculated using ArcGIS software and the site database file in the following sequential steps:

1. Calculate the area within the sample polygon;
2. Calculate the fraction of eelgrass along each random line transect;
3. Calculate the mean fraction and associated variance[2], weighed by transect length;
4. Estimate the overall eelgrass area and variance at the site by extrapolating the mean fraction along random transects over the sample polygon area.

We used a statistical framework to provide estimates of total eelgrass area for each of the study area zones (EB, INL, PO, and UK). Sites in each of the zones were classified in 3 different strata depending on their characteristics (flats, narrow fringe or wide fringe). For each of the strata, results from a limited number of sites were extrapolated based on either total area (flats) or shoreline length (fringes) to estimate the total eelgrass area, and the uncertainty associated with these estimates (variance) in each of the zones. For more information on the statistical framework, see Berry et al. (2003) and the QAPP submitted for this project (Gaeckle 2014).

2.3.3 *Depth distributions*

Each random video transect that contained *Z. marina* had a minimum and maximum depth relative to MLLW. Minimum and maximum *Z. marina* depth characteristics for each site were described using descriptive statistics (i.e., means and ranges). For each site with *Z. marina* and *Z. japonica* present, we represented the depth distribution with a histogram of depths of all sample points where *Z. marina* or *Z. japonica* was detected at the site (Appendix 2).

The regional depth distribution of *Z. marina* was calculated as follows. For each site, *Z. marina* observations were binned according to their depth relative to MLLW in 0.5m bins. The number of observations in each depth bin was divided by the total number of *Z. marina* observations at the site. This fraction was multiplied by the estimated eelgrass area at the site to estimate the area of eelgrass in each depth bin at the site. In other words, we used the following formula to estimate eelgrass area in each depth bin at each site:

$$a_{jk} = A_j \frac{c_{jk}}{\sum_{k=1}^{n} c_{jk}}$$

Where a_{jk} is *Z. marina* area in each histogram bin (k) at site (j), c_{jk} is the count of observations per bin, and A_j is estimated eelgrass area at site j. Per-bin area estimates from sites were combined into a depth distribution for the entire study area.

[2] We calculate variance for both simple random samples and stratified random samples using the textbook variance estimator. 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).

2.3.4 *Repeat transect analysis*

Thirteen sites within the East Kitsap study area were sampled in previous years. At these sites, original transects were re-sampled and the vegetated fraction was compared with the previously sampled transects using a paired t-test:

1. Calculate the difference between the two vegetation fractions for each pair of transects (2014 result – result from previously sampled year)
2. Calculate the mean difference, D, of the vegetated fraction from all paired transects for each site
3. Calculate the standard error, SE, (standard deviation / square root of n)
4. Calculate the T statistic (D-0)/SE
5. Use t-distribution (evaluated with R software) to compare the value of the T statistic with the $t_{(n-1)}$ distribution, to test if D is significantly different from 0.

Before data-analysis, transect pairs were clipped using the same sample polygon. We tested the quality of the repeats by comparing total transect length of the paired transects. If transect length was different by more than 10%, the transect pair was removed from analysis.

3 Results

3.1 Seagrass species in the East Kitsap study area

Out of the 95 sites sampled there were 58 sites with *Z. marina* (eelgrass), 38 sites with the non-native *Z. japonica*, and 37 sites where seagrass was absent (Figures 6 and 7). Eelgrass is widespread along the eastern shoreline of the Kitsap Peninsula. All sites sampled between Foulweather Bluff and Point Jefferson, and all sites on the eastern side of Bainbridge Island contained eelgrass beds. Sites without eelgrass were predominantly located in Dyes Inlet, Liberty Bay, and Port Orchard Bay (Figure 7). There were three sites in Dyes Inlet with eelgrass present but only trace amounts.

Zostera japonica (Figure 5a) grows at higher tidal elevations than *Z. marina* (Figure 5b), and is often too shallow for the sample vessel. As such, our data are conservative estimates for the presence/absence of *Z. japonica*. Nevertheless, the data suggests that *Z. japonica* is common throughout the area. This species usually occurs at sites where *Z. marina* is present. Only 4 of the 95 sites sampled contained only *Z. japonica* but no *Z. marina* (Figures 6 and 7).

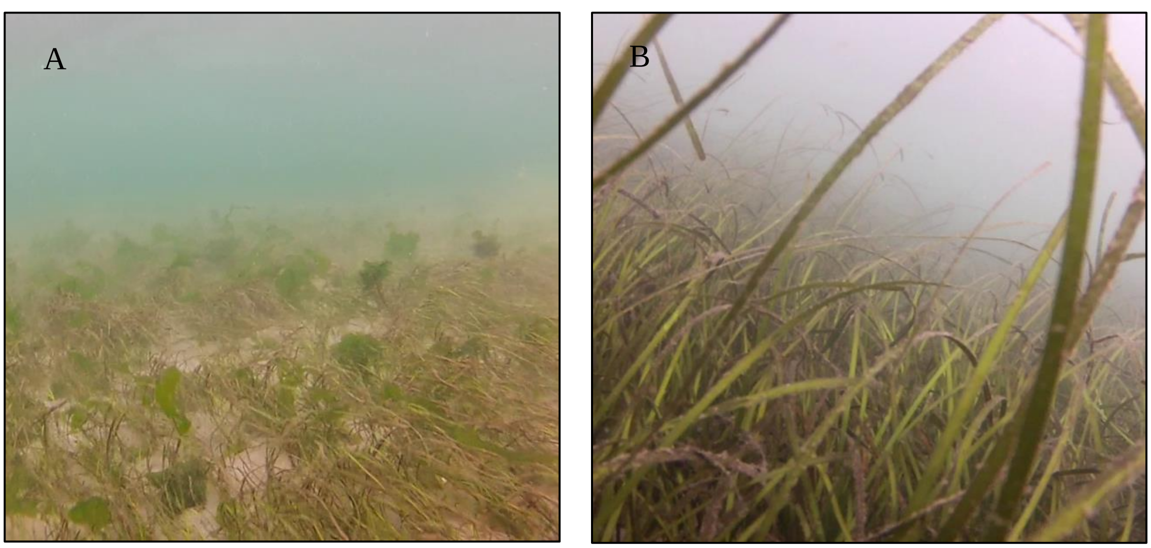


Figure 5: Examples of *Zostera japonica* (A) and *Zostera marina* (B) habitat in Central Puget Sound.

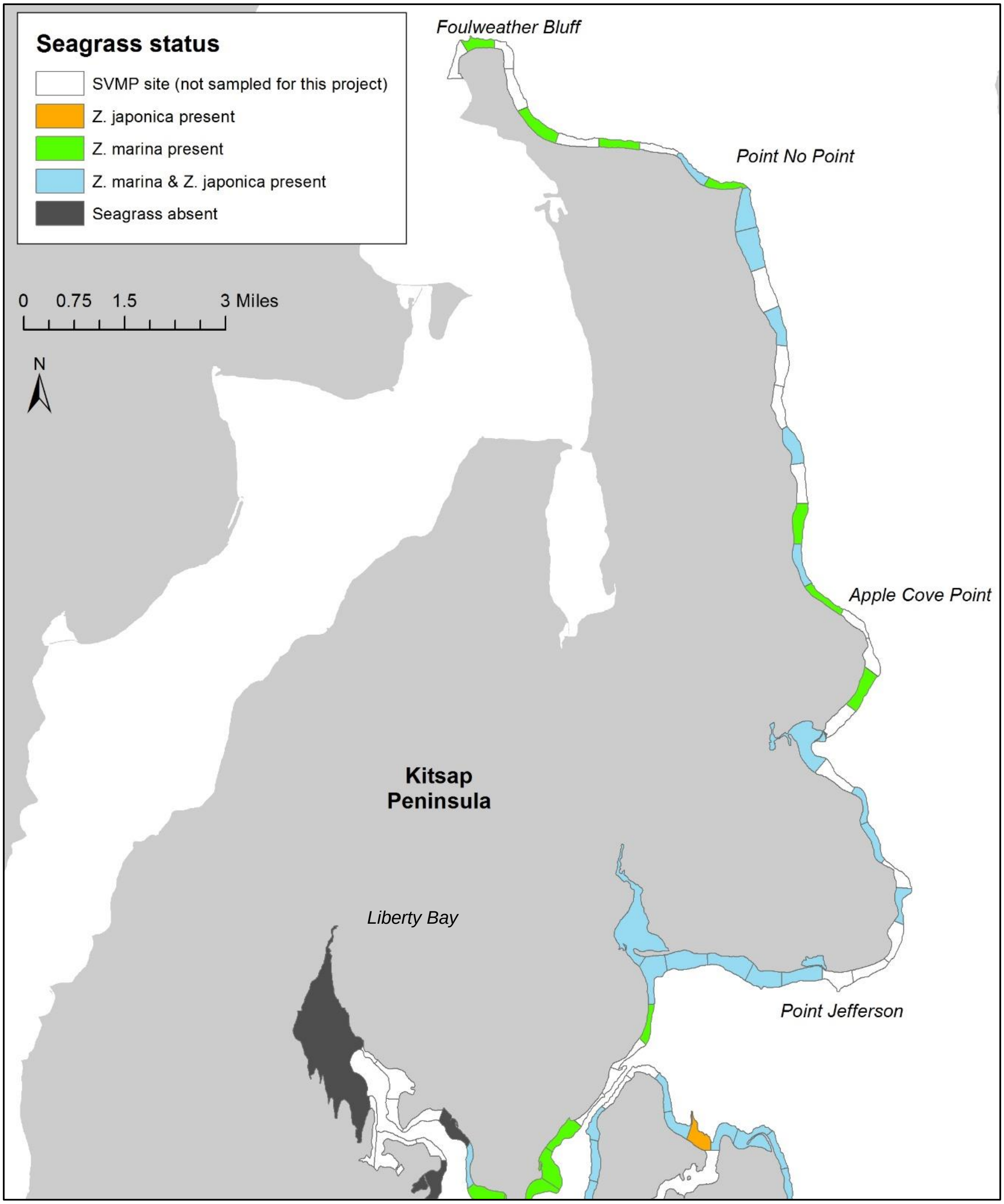


Figure 6: Seagrass status in the northern portion of the East Kitsap study area. Note: Liberty Bay was not sampled for this project. Results for Liberty Bay area are from a previous survey.

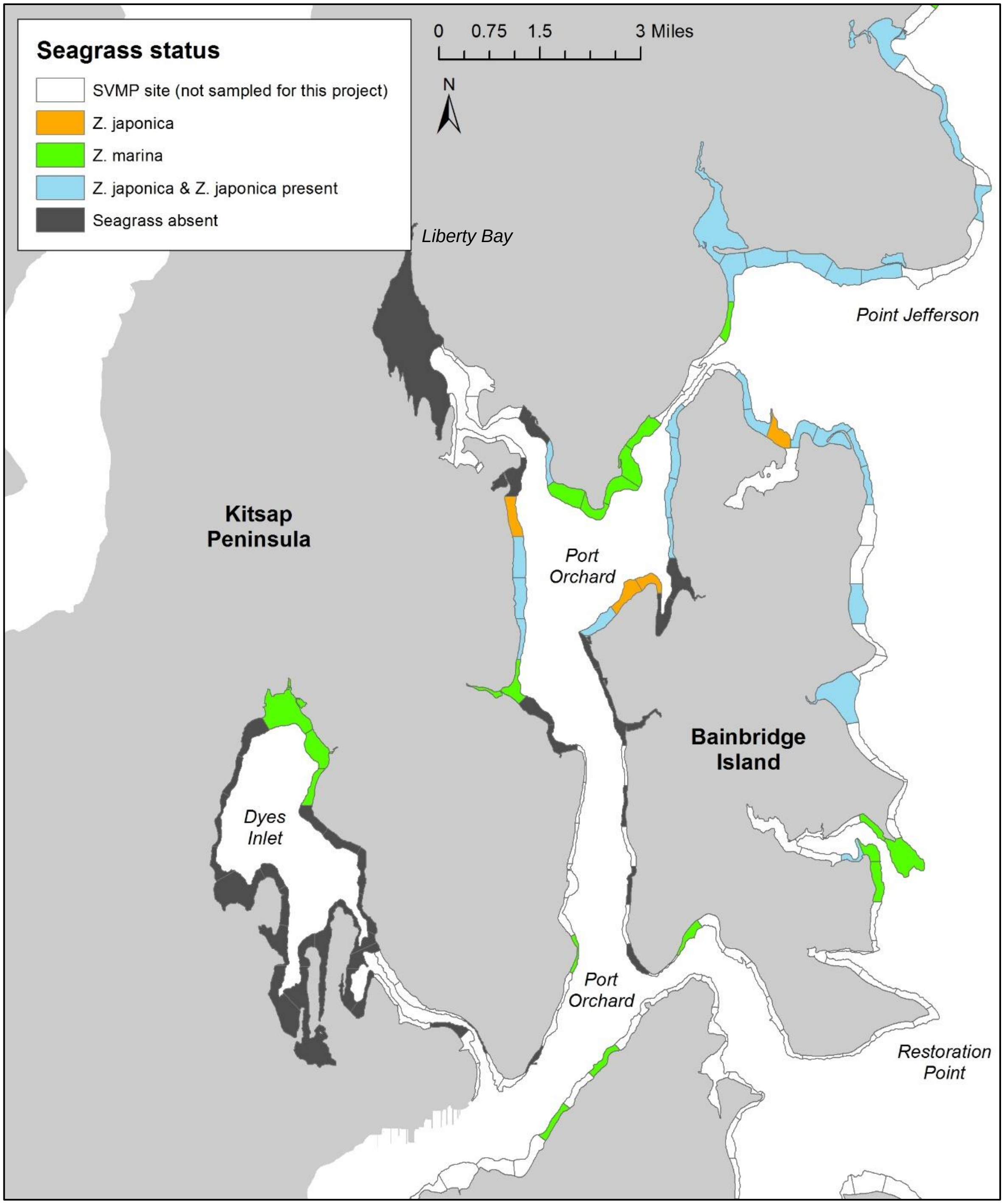


Figure 7: Seagrass status in the southern portion of the East Kitsap study area. Note: Liberty Bay was not sampled for this project. Results for Liberty Bay proper are from a previous survey.

3.2 Area estimates of eelgrass beds in the East Kitsap study area

The eelgrass beds in the East Kitsap study area are relatively small. This is to be expected, as most of these beds grow on relatively narrow fringes of shoreline. Out of the 58 sites with eelgrass, 3 sites have only trace amounts of eelgrass present, 11 sites have less than 1 ha of eelgrass present, 16 sites have between 1 and 5 ha of eelgrass present, 15 sites have between 5 and 10 ha present, and only 13 sites have eelgrass beds larger than 10 ha (Appendix 1). As such, the distribution of eelgrass area (ha) in the East Kitsap study area is skewed (Figure 8). The sites with the largest eelgrass beds are cps2220 (22.8 ± 0.78 ha), cps2227 (18.13 ± 0.75 ha), cps2193 (16 ± 1.35 ha), cps1069 (15.31 ± 0.57 ha) and flats37 (13.26 ± 3.51 ha). Overall, sites on the east side of Bainbridge Island and the Kitsap Peninsula have larger eelgrass beds than sites in Dyes Inlet, Sinclair Inlet or Port Orchard (Appendix 1).

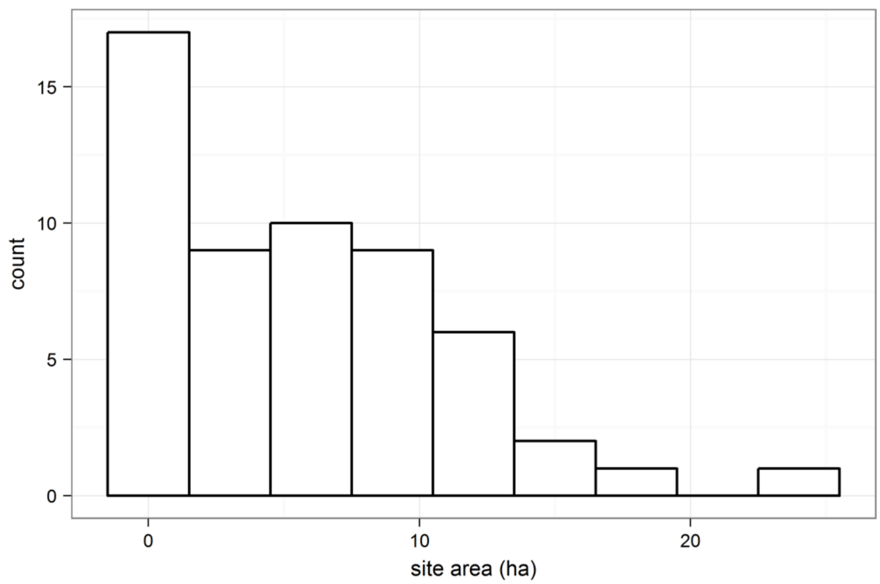


Figure 8: The size distribution of eelgrass beds at sites in the East Kitsap study area (ha). The majority of eelgrass beds in the study area is relatively small (< 10 ha).

We divided the East Kitsap study area into 5 zones and estimated total eelgrass area in each of these zones based on the current sample of 95 sites (Figure 9). Given that this is an extrapolation, there is a certain degree of uncertainty associated with the estimates, which is represented by the error bars in Figure 9. The upper part of the Kitsap Peninsula (UK) and the eastern part of Bainbridge Island (EB) have the greatest eelgrass area. Eelgrass is less prevalent within Port Orchard Bay (PO), and is almost completely absent within Dyes Inlet and Liberty Bay (INL). The southern end of the East Kitsap study area (LK on Figure 1) was not sampled as part of this project, and is not represented on Figure 9.

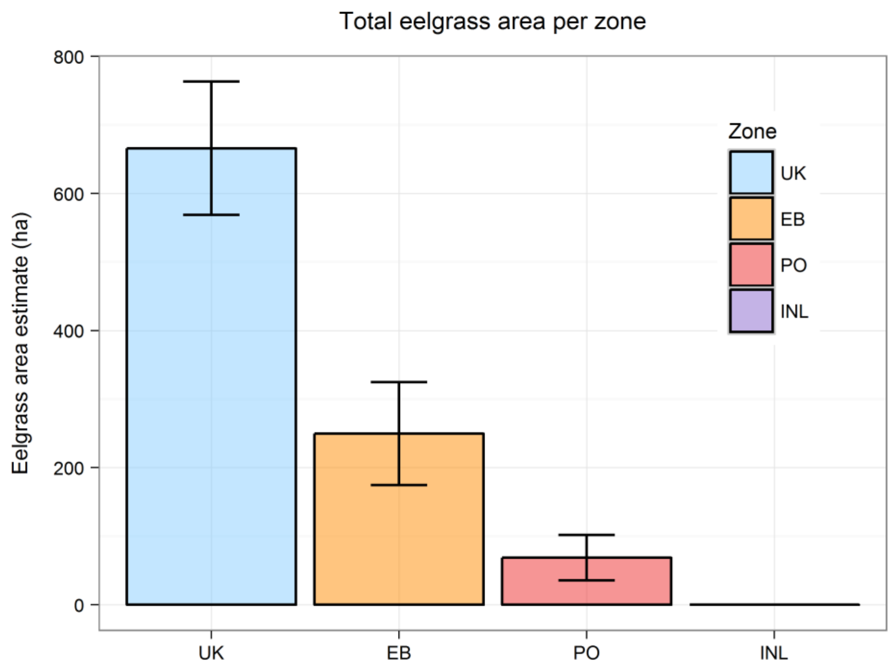


Figure 9: Estimates of total eelgrass area (ha) in 4 zones of the East Kitsap Study area. The error bars are 95% confidence intervals. Note: A trace amount of eelgrass was observed at three sites in Dyes Inlet.

3.3 Depth range of eelgrass beds in the East Kitsap study area

Eelgrass was observed between -7.5 and 1.3 m relative to mean lower low water (MLLW) in the East Kitsap study area. The shallowest observations are at sites cps2218, cps1063 and cps1066. The deepest observations were at cps2223, cps2201, and cps1066 (see Appendix 2). The optimal depth range for eelgrass is more limited: 75 % of all eelgrass in the study area grows between 0 and -3 m relative to MLLW (Figure 10).

We classify eelgrass as either intertidal or subtidal. We define the boundary between intertidal and subtidal as -1 m (relative to MLLW), which is a biologically relevant estimate of Extreme Low Tide depth in the Puget Sound region. For more information on this calculation, see Hannam et al. (2015). When comparing to this boundary, approximately 55 % of all eelgrass in the study area grows in the subtidal, while 45 % grows in the intertidal (Figure 10).

The non-native seagrass *Zostera japonica* is common in the study area and has a different depth distribution as compared to *Zostera marina*. It usually grows shallower, and is able to thrive in the intertidal habitats. Depth distributions for both species are listed in Appendix 2 for each individual site.

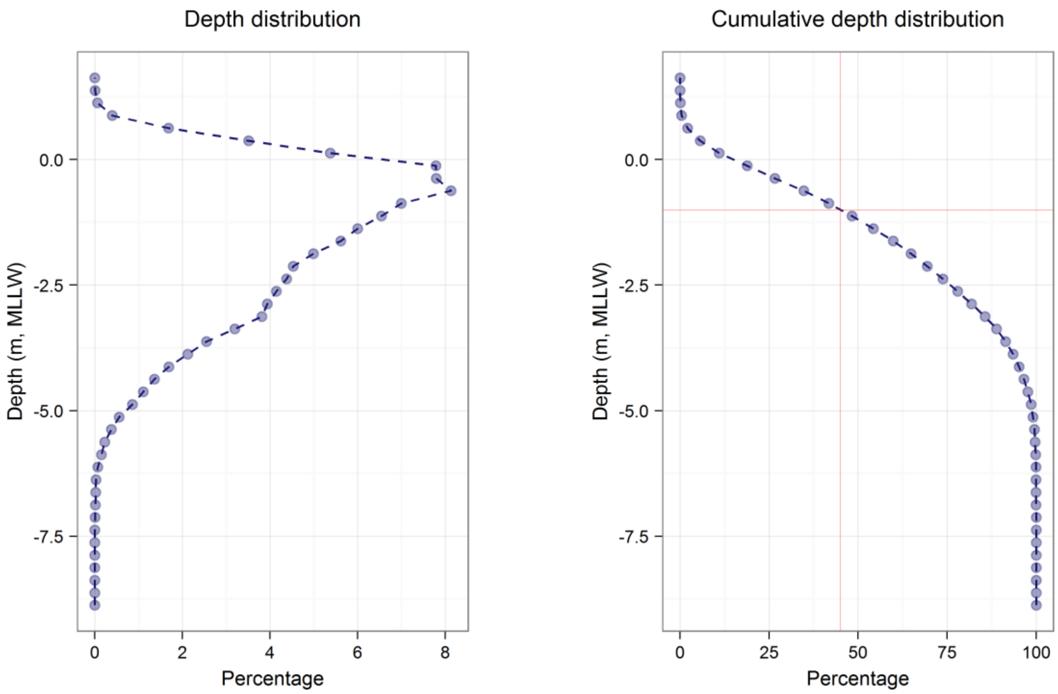


Figure 10: Depth distribution and cumulative depth distribution of eelgrass in the study area. The red lines indicate how much eelgrass grows in the intertidal vs. the subtidal.

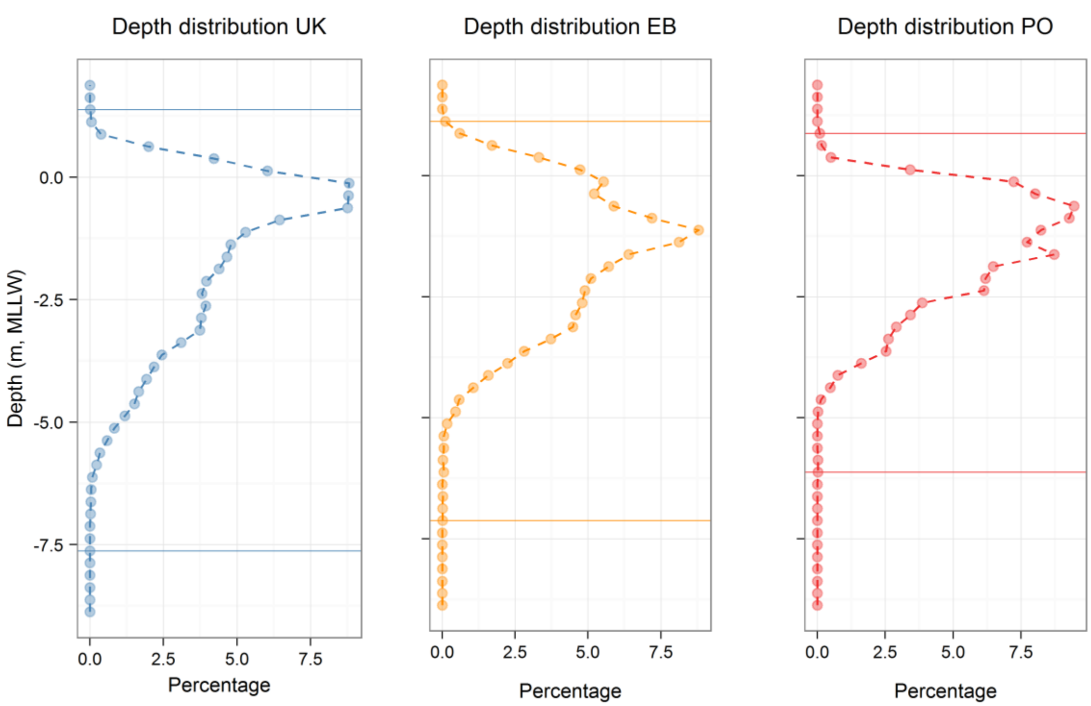


Figure 11: Depth distribution of eelgrass in three zones (UK, EB, and PO) of the study area. The horizontal lines indicate the shallowest and deepest observations of eelgrass in each of the zones.

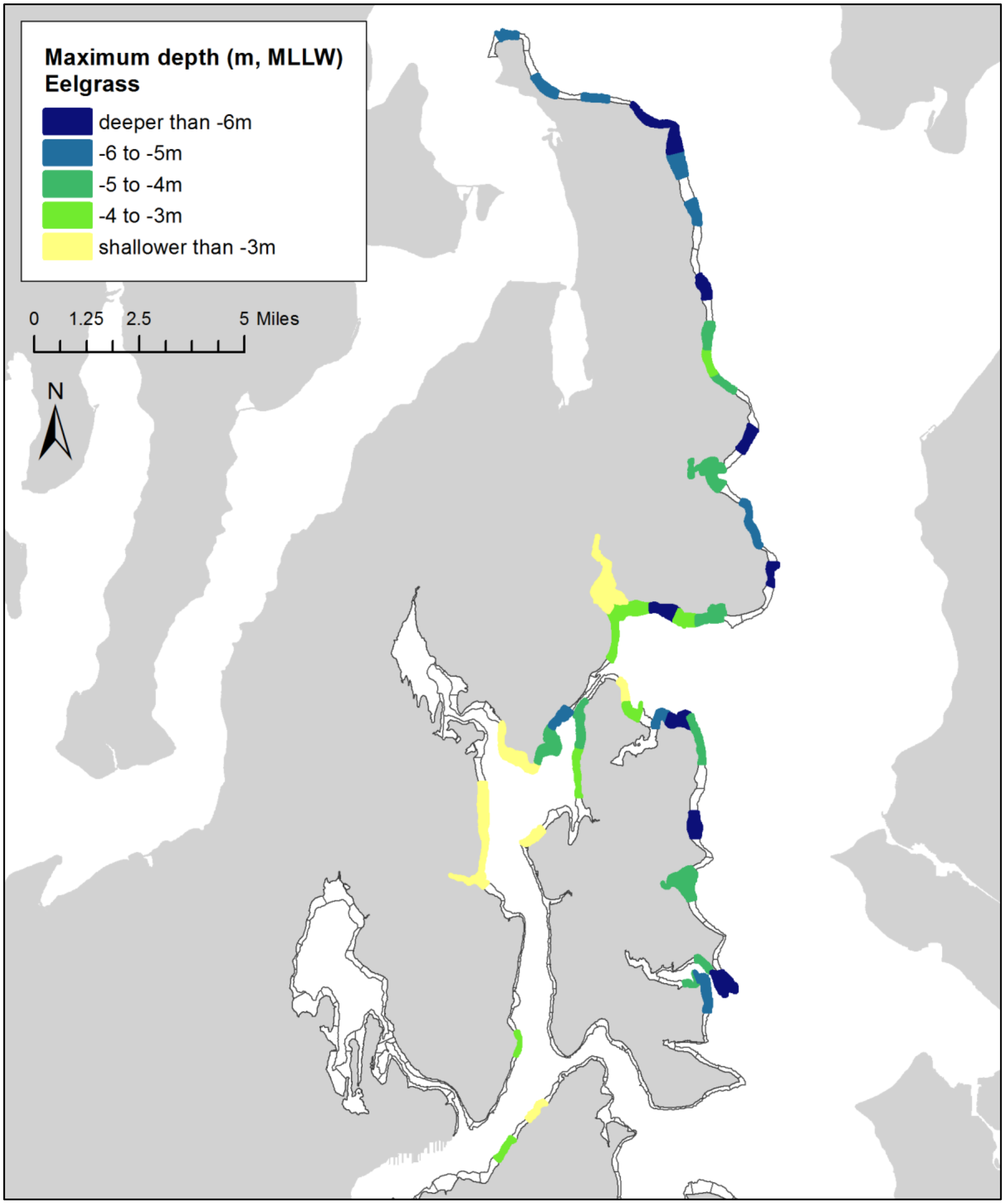


Figure 12: Maximum depth of eelgrass beds in the East Kitsap study area. Eelgrass tends to reach greater maximum depths in the Upper Kitsap and East Bainbridge zones. Maximum depth is not indicated for the sites with traces of eelgrass in Dyes Inlet.

There is high variability in the depth distribution and the maximum depth at which eelgrass is found among individual sites (Figure 12). Eelgrass has the widest depth range at sites in the Upper Kitsap Peninsula (UK), and the smallest depth range at sites within Port Orchard and Sinclair Inlet (PO). This is both due to the lower amount of intertidal eelgrass and the shallower maximum eelgrass depth at sites within Port Orchard (Figure 11). Despite the differences in depth range, the majority of eelgrass tends to grow in the same depth band (0 to -3 m, MLLW) in each of the three zones were eelgrass is present.

3.4 Change over time

Table 2 shows the results of the repeat transect analysis for 12 sites that were sampled previously by the SVMP. Four sites (cps2221, cps2218, cps1069 and cps1054) showed significant increases in eelgrass cover relative to previous years. The biggest change was at cps2221, where the increase was due to filling in of what previously observed as a patchy eelgrass bed. At the other sites, eelgrass beds did not change compared to the previously sampled year. It is important to consider that initial samples are not all from the same year. The time between the pairs of samples ranges from 1 to 8 years. There appears to be no direct relationship between the magnitude of the changes in vegetated fraction and the number of years before the site was resampled.

Table 2: Results of the paired t-tests, comparing the fraction of transects vegetated with *Zostera marina* over time. Positive values in mean change are increases, negative values are declines. Changes are considered significant if the p-value is less than 0.05. *At cps1066, it was difficult to distinguish between *Zostera marina* and the non-native *Zostera japonica*. We estimated change in total vegetated fraction (both species combined) for this site. At one previously sampled site (cps1046) there was not enough overlap between transects to make a valid change assessment.

Site code	Time between samples (years)	Mean change in vegetated fraction (%)	T statistic	df	p-value
cps2221	4	14.0	5.612	9	0.000
cps2218	8	6.2	2.334	10	0.042
cps1069	7	7.7	4.411	2	0.048
cps1054	2	2.7	2.170	13	0.049
flats37	8	2.9	2.163	8	0.063
cps2201	7	6.1	1.973	9	0.080
cps2227	1	1.1	1.886	7	0.101
cps1066*	2	4.2	1.408	8	0.111
cps2230	1	1.2	1.288	12	0.222
cps2208	2	1.0	1.274	10	0.231
cps2223	1	-1.8	-1.211	8	0.260
cps2215	4	-4.8	-0.869	9	0.407

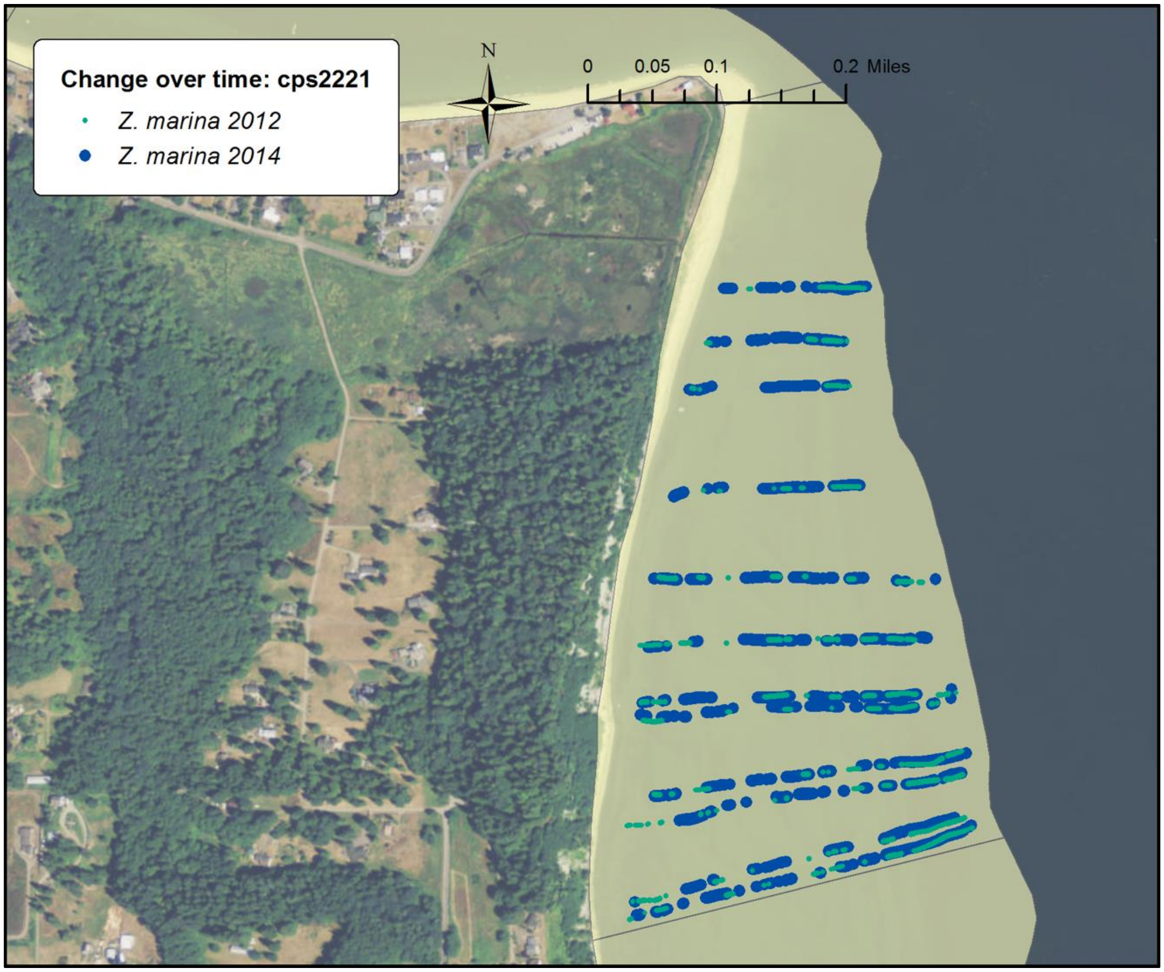


Figure 13: Increase in eelgrass cover at site cps2221. Transect results from 2014 have been indicated in bold, to highlight the difference in eelgrass presence along transects between 2012 and 2014.

4 Discussion

4.1 Eelgrass area in the East Kitsap study area

Based on extrapolation, we estimate that there is approximately 1000 ha of eelgrass in the study area. This is roughly one third of our current best estimate for eelgrass area in Central Puget Sound, and less than 5 % of all eelgrass in greater Puget Sound (Christiaen et al., 2016). The majority of eelgrass in the study area grows along narrow fringes of intertidal and subtidal land along the shoreline. This is very similar to other eelgrass habitat in Central Puget Sound, where more than 90 % of eelgrass grows on fringe sites.

At the majority of sites surveyed, eelgrass beds are relatively small (between 0 and 20 ha per 1000 m of shoreline). Small seagrass beds at fringe sites may provide different ecosystem services than contiguous seagrass beds growing on large flats sites. Large contiguous seagrass beds tend to have more stable nekton communities over time, as they provide enough habitat to sustain a wide variety of species (Hensgen et al., 2014), while smaller eelgrass beds on fringe sites are important for habitat connectivity. Small narrow seagrass beds also tend to be more dynamic than larger beds, as they are more vulnerable to disturbance from hydrodynamic forces (Koch 2001, Greve and Krause-Jensen 2005), and have a lower ability to recruit new shoots through both sexual and asexual reproduction (Greve and Krause-Jensen 2005).

When comparing trends in eelgrass cover at 12 sites in the East Kitsap Study area, the majority of sites appears stable, while four sites show increases in eelgrass cover in recent years. This is similar to other observations in greater Puget Sound, which suggests that recent years have been beneficial for seagrass growth (Christiaen et al. 2016).

4.2 Eelgrass depth limits in the East Kitsap study area

In the study area, eelgrass is found at depths between -7.5 and 1.3 m relative to Mean Lower Low Water (MLLW). This is very similar to other sites in Central Puget Sound, but is more restricted as compared to the depth distribution of eelgrass in near the San Juan Islands and the Strait of Juan de Fuca (Hannam et al. 2015). The majority of eelgrass in the study area grows between 0 and -3 m relative to MLLW.

Approximately 55 % of all eelgrass grows in the subtidal (deeper than -1 m, MLLW), and roughly 46 % of eelgrass grows deeper than the Extreme Low Tide Line[3]. This is slightly shallower than in greater Puget Sound as a whole, where approximately 62 % of all eelgrass grows subtidally (Hannam et al. 2015) and 50 % grows deeper than the Extreme Low Tide Line. The depth distribution of eelgrass has implications for the protection of this vulnerable plant. The Extreme Low Tide Line forms the boundary between tidelands and bedlands for a large part of Puget Sound. Virtually all bedlands in Washington are owned by the State, while only 29 % of Washington State's tidelands remain in public ownership (Ivey 2014). This suggests that a large proportion of eelgrass is found on state owned aquatic lands, which emphasizes the importance of continued stewardship activities by DNR.

When comparing the different zones within the study area, eelgrass tends to grow to greater depths at the Upper Kitsap Peninsula and the Eastern side of Bainbridge Island, as compared to Port Orchard Bay and Sinclair Inlet. Eelgrass essentially disappears when moving further West into Liberty Bay and Dyes Inlet. However, there is a lot of variability in maximum eelgrass depth among individual sites. This site-scale variability in depth limits is typical for eelgrass beds in greater Puget Sound (Hannam et al. 2015). The maximum depth of seagrass beds is often limited by the amount of light that is able to penetrate throughout the water column (Duarte 1991). As such, a reduction in the maximum depth of eelgrass beds is a possible indicator of water quality impairments (Burkholder et al. 2007). However, many factors can influence water clarity in areas such as Puget Sound, including sediment resuspension due to wave action and tidal currents. Other factors, such as substrate type and bathymetric slope can also influence where eelgrass grows at a site. Further research is needed to ascertain a potential link between water quality, light attenuation, and spatial patterns in the maximum depth extent of eelgrass beds in Puget Sound.

4.3 Zostera japonica in East Kitsap study area

The non-native seagrass *Zostera japonica* has been detected at approximately 40 % of all sites sampled in the East Kitsap study area. Similar to *Zostera marina*, this species tends to be more prevalent on the Upper Kitsap Peninsula and the Eastern side of Bainbridge Island than in Port Orchard Bay, Sinclair Inlet, Dyes Inlet or Liberty Bay. *Zostera japonica* grows higher in the intertidal as compared to *Zostera marina*, and at most sites in the study area there is little overlap in the depth distribution of both species (Appendix 2). This suggests that there is little competition between *Zostera marina* and *Zostera japonica*, and that these two species do not have negative effects on each other in areas where they do co-occur. (Shafer et al. 2014, Harrison 1982, Hahn 2003).

[3] For the purpose of designating ownership boundaries, the federal government defined the Extreme Low Tide line (ELT) as the line below which it might be reasonably expected that the tide would not ebb. In the Puget Sound area of Washington State this line is estimated by the federal government to be a point in elevation 4.5 ± 0.5 feet below the datum plane of MLLW (Ivey 2014).

4.4 Data use and availability

As a result of the 2014 effort for this project, the East Kitsap study area has become one of the most densely sampled areas for eelgrass cover in greater Puget Sound. Surveying large contiguous stretches of shoreline, has generated detailed estimates of eelgrass area (Appendix 1) and depth distribution (Appendix 2) for 95 out of the 217 sites within the study area. These data provide a good overview of the current extent of both eelgrass (*Zostera marina*) and the non-native *Zostera japonica*, and can be used as baseline for future studies on trends in eelgrass area and depth distribution.

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 made available online in the next distribution dataset of DNR’s Submerged Vegetation Monitoring Program (scheduled for January 2017). For more information, visit http://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science

5 References

Berry H.D., A.T. Sewell, S. Wyllie-Echeverria, B.R. Reeves, T.F. Mumford Jr., J. Skalski, R.C. Zimmerman, J. Archer. 2003. Puget Sound Submerged Vegetation Monitoring Project: 2000-2002 Monitoring Report. Nearshore Habitat Program, Washington State Department of Natural Resources. Olympia, WA.

Burkholder J.M., D. Tomasko, B.D. Touchette. 2007. Seagrasses and eutrophication. *Journal of Experimental Marine Biology and Ecology* 350: 46-72.

Butler R.W. 1995. The patient predator: Foraging and population ecology of the great blue heron, *Ardea herodias*, in British Columbia. *Occasional Papers for Canadian Wildlife Service* No. 86.

Christiaen B., P. Dowty, L. Ferrier, J. Gaeckle, H. Berry, J. Stowe, E. Sutton. 2016. Puget Sound Submerged Vegetation monitoring Program – 2014 Report. Nearshore Habitat Program, Washington State Department of Natural Resources. Olympia, WA.

Dennison W.C., R.J. Orth, K.A. Moore, J. C. Stevenson, V. Carter, S. Kollar, P. W. Bergstrom and R. A. Batiuk. 1993. Assessing water quality with submerged aquatic vegetation: habitat requirements as barometers of Chesapeake Bay health. *BioScience* 43(2):86-94.

Duarte C.M. 1991. Seagrass depth limits. *Aquatic Botany* 40: 363-377.

Felger R. and M.B. Moser. 1973. Eelgrass (*Zostera marina* L.) in the Gulf of California: discovery of its nutritional value by the Seri Indians. *Science* 181:355-356.

Gaeckle, J. 2014. Quality Assurance Project Plan for East Kitsap Eelgrass (*Zostera marina*) Monitoring Project. An agreement between Suquamish and the Washington State Department of Natural Resources per IAA 15-17 and NWIFC CA PA-00J32201-0. Pg. 53.

Greve T.M. and D. Krause-Jensen. 2005. Stability of eelgrass (*Zostera marina* L.) depth limits: influence of habitat type. *Marine Biology* 147:803-812.

Hahn D.R., 2003. Changes in community composition and ecosystem processes associated with biological invasions: impact of *Zostera japonica* in the marine intertidal zone. PhD dissertation, University of Washington, Dept. of Biology, Seattle, WA.

Hannam M.P., P. Dowty, B. Christiaen, H. Berry, L. Ferrier, J. Gaeckle, J. Stowe, E. Sutton. 2015b. Depth Distribution of Eelgrass in Greater Puget Sound. Nearshore Habitat Program, Washington Department of Natural Resources, Olympia, WA

Harrison P.G. 1982. Spatial and temporal patterns in abundance of two intertidal seagrasses, *Zostera Americana* den Hartog and *Zostera marina* L. *Aquatic Botany*12: 305-320.

Hensgen G.M., G. J. Holt, S. A. Holt, J. A. Williams, G. W. Stunz. 2014. Landscape pattern influences nekton diversity and abundance in seagrass meadows. Marine Ecology Progress Series 507: 139-152.

Ivey S. 2014. Aquatic land boundaries in Washington State. Washington Department of Natural Resources, Olympia, WA

Kenworthy W.J., S. Wyllie-Echeverria, R.G. Coles, G. Pergent and C. Pergent-Martini. 2006. Seagrass conservation biology: an interdisciplinary science for protection of the seagrass biome. pp. 595-623. *In*: Larkum AWD, Orth RJ, Duarte CM (eds). 2006. *Seagrasses: Biology, Ecology and Conservation*. Springer, Dordrecht, 691 pp.

Koch E.W. 2001. Beyond light: physical, geological, and geochemical parameters as possible submersed aquatic vegetation habitat requirements. *Estuaries* 24:1-17.

Kuhnlein H.V. and N.J. Turner. 1991. *Traditional plant foods of Canadian Indigenous Peoples: Nutrition, Botany and Use*. Gordon and Breach Science Publishers, Philadelphia. 633 pp

Lee K-S., F.T. Short and D.M. Burdick. 2004. Development of a nutrient pollution indicator using the seagrass, *Zostera marina*, along nutrient gradients in three New England estuaries. *Aquatic Botany* 78:197-216.

McGarvey R., P. Burch, J.M. Matthews. 2016. Precision of systematic and random sampling in clustered populations: habitat patches and aggregating organisms. Ecological Applications 26(1): 233-248.

Norris J.G., S. Wyllie-Echeverria, T. Mumford, A. Bailey, T. Turner. 1997. Estimating basal area coverage of subtidal seagrass beds using underwater videography. Aquatic Botany 58: 269-287.

Orth R.J., T.J.B. Carruthers, W.C. Dennison, C.M. Duarte, J.W. Fourqurean, K.L. Heck, A.R. Hughes, G.A. Kendrick, W.J. Kenworthy, S. Olyarnik, F.T. Short, M. Waycott and S.L. Williams. 2006. A global crisis for seagrass ecosystems. *BioScience* 56:987-996.

Phillips R.C. 1984. *The ecology of eelgrass meadows in the Pacific Northwest: a community profile*. U. S. Fish and Wildlife Service FSW/OBS-84/24. 85pp. Available online: http://www.nwrc.gov/library.html

PSP. 2014. *Puget Sound Vital Signs*. Puget Sound Partnership. Olympia WA.

Shafer D.J., J.E. Kaldy and J.L. Gaeckle. 2014. Science and Management of the Introduced Seagrass *Zostera japonica* in North America. *Environmental Management*. 53(1):147-162.

Short F.T. and D.M. Burdick. 1996. Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. *Estuaries* 19(3):730-739.

Simenstad C.A. 1994. Faunal associations and ecological interactions in seagrass communities of the Pacific Northwest coast, pp.11-17. *In*: Wyllie-Echeverria, S., A.M. Olson and M.J. Hershman (eds). 1994. *Seagrass Science and Policy in the Pacific Northwest: Proceedings of a Seminar Series*. U.S. Environmental Protection Agency, Seattle, WA. (SMA 94-1). EPA 910/R-94 004. 63 pp.

Suttles W.P. 1951. *Economic Life of the Coast Salish of Haro and Rosario Straits*. Ph.D. dissertation. University of Washington, Seattle, WA.

Wilson U.W. and J.B. Atkinson. 1995. Black Brant winter and spring-stages use at two Washington coastal areas in relation to eelgrass abundance. *The Condor* 97:91-98.

Wyllie-Echeverria S. and J.D. Ackerman. 2003. The seagrasses of the Pacific Coast of North America, pp.199-206. *In*: Green, E.P. and F.T. Short (eds) *The World Atlas of Seagrasses*. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, California. 298 pp.

6 Appendix 1: Site summaries

Table 3: Area of eelgrass beds (ha) in the East Kitsap study area, calculated from sites sampled with stratified random transects (2014 only). For sites with eelgrass, the shallowest and deepest observations are listed (depth in m relative to MLLW).

site_code	year	sample area (ha)	veg area (ha)	veg area se (ha)	shallowest observation (m)	deepest observation (m)
cps1037	2014	0	0	0	no data	no data
cps1039	2014	0	0	0	no data	no data
cps1041	2014	0	0	0	no data	no data
cps1043	2014	0	0	0	no data	no data
cps1044	2014	0	0	0	no data	no data
cps1045	2014	0	0	0	no data	no data
cps1046	2014	4.88	0.09	0.08	-0.56	-1.51
cps1047	2014	0	0	0	no data	no data
cps1048	2014	0	0	0	no data	no data
cps1049	2014	0	0	0	no data	no data
cps1050	2014	0	0	0	no data	no data
cps1051	2014	4.84	0.05	0.04	-0.21	-3.01
cps1052	2014	8.41	4.13	0.26	0.29	-3.94
cps1053	2014	15.7	10.1	0.6	0.83	-4.73

site_code	year	sample area (ha)	veg area (ha)	veg area se (ha)	shallowest observation (m)	deepest observation (m)
cps1054	2014	4.94	1	0.33	0.89	-5.08
cps1057	2014	7.26	1.78	0.53	0.68	-2.09
cps1058	2014	10.15	1.57	0.4	0.85	-3.45
cps1059	2014	0	0	0	no data	no data
cps1060	2014	11.05	0.7	0.27	-0.74	-5.54
cps1061	2014	11.45	4.33	0.81	0.41	-6.7
cps1062	2014	10.77	7.24	0.25	0.93	-4.45
cps1063	2014	14.12	8.55	0.7	1.18	-5.09
cps1066	2014	30.59	10.4	1.37	1.07	-7.2
cps1069	2014	36.87	15.31	0.57	0.75	-5.1
cps1080	2014	5.91	1	0.7	0.46	-5.03
cps1081	2014	11.45	6.36	0.88	0.15	-5.51
cps1082	2014	15.62	9.92	1.33	0.16	-5.45
cps1086	2014	0	0	0	no data	no data
cps1087	2014	0	0	0	no data	no data
cps1088	2014	0	0	0	no data	no data
cps1089	2014	0	0	0	no data	no data
cps1090	2014	0	0	0	no data	no data
cps1091	2014	0	0	0	no data	no data
cps1092	2014	0	0	0	no data	no data
cps1093	2014	0	0	0	no data	no data
cps1094	2014	0	0	0	no data	no data
cps1095	2014	0	0	0	no data	no data
cps1096	2014	0	0	0	no data	no data
cps1097	2014	0	0	0	no data	no data
cps1098	2014	0	0	0	no data	no data
cps1099	2014	0	0	0	no data	no data
cps1100	2014	0	0	0	no data	no data
cps1101	2014	0	trace	trace	no data	no data

site_code	year	sample area (ha)	veg area (ha)	veg area se (ha)	shallowest observation (m)	deepest observation (m)
cps1102	2014	0	trace	trace	no data	no data
cps1103	2014	0	trace	trace	no data	no data
cps1104	2014	0	0	0	no data	no data
cps1105	2014	0	0	0	no data	no data
cps1106	2014	0	0	0	no data	no data
cps1107	2014	0	0	0	no data	no data
cps2118	2014	8.02	0.26	0.14	-1.27	-2.39
cps2120	2014	5.01	0.79	0.28	-0.87	-3.01
cps2148	2014	0	0	0	no data	no data
cps2149	2014	0	0	0	no data	no data
cps2150	2014	0	0	0	no data	no data
cps2160	2014	4.12	0.41	0.21	-0.36	-2.93
cps2166	2014	0	0	0	no data	no data
cps2167	2014	0	0	0	no data	no data
cps2168	2014	9.49	0.65	0.47	-0.15	-2.25
cps2169	2014	7.11	1.91	0.26	-0.16	-2.2
cps2170	2014	11.36	1.16	0.29	-0.41	-1.64
cps2171	2014	13.42	0.79	0.29	0.75	-1.53
cps2172	2014	0	0	0	no data	no data
cps2173	2014	0	0	0	no data	no data
cps2183	2014	6.37	0.1	0.09	-0.08	-0.18
cps2184	2014	9.31	1.45	0.47	-0.22	-1.13
cps2185	2014	7.74	0.08	0.07	-0.93	-1.19
cps2186	2014	13.19	1.4	0.58	-0.01	-4.29
cps2187	2014	24.93	10.9	1.56	0.32	-4.68
cps2188	2014	18.19	6.4	1.39	0.28	-6.22
cps2192	2014	9.53	2.39	0.78	0.06	-4.09
cps2193	2014	30.71	16	1.35	0.24	-3.89
cps2194	2014	28.99	10.07	1.16	0.92	-3.74

site_code	year	sample area (ha)	veg area (ha)	veg area se (ha)	shallowest observation (m)	deepest observation (m)
cps2195	2014	34.03	11.55	0.81	1.02	-6.4
cps2196	2014	14.85	5.77	0.86	0.53	-3.88
cps2197	2014	16.14	5.98	0.91	0.61	-4.53
cps2201	2014	16.24	9.57	1.16	0.81	-7.43
cps2203	2014	13.47	6.13	1.2	0.86	-6.2
cps2204	2014	10.87	5.51	0.45	0.95	-5.85
cps2206	2014	38.42	12.29	2.82	0.86	-4.31
cps2208	2014	26.28	11.19	1.01	0.72	-6.5
cps2211	2014	9.89	6.05	0.35	-0.03	-5.24
cps2212	2014	12.49	7.8	0.25	0.66	-3.89
cps2213	2014	19.88	11.58	0.54	0.59	-5.28
cps2215	2014	20.48	7.57	0.56	0.83	-6.6
cps2218	2014	23.18	4.71	0.64	-1.33	-6.05
cps2220	2014	43.65	22.8	0.78	0.94	-5.68
cps2221	2014	27.97	9.38	0.61	0.94	-6.65
cps2222	2014	8.52	3.58	0.58	0.53	-6.33
cps2223	2014	10.8	6.88	0.53	1.02	-7.54
cps2225	2014	10.78	3.9	0.87	-0.27	-5.83
cps2227	2014	22.82	18.13	0.75	-0.07	-6.04
cps2230	2014	9.31	0.83	0.48	-0.37	-5.47
cps2890	2014	9.13	1.49	0.53	0.21	-5.15
flats37	2014	47.39	13.26	3.51	-0.52	-6.56
flats40	2014	69.78	3.13	1.53	0.49	-2.32

7 Appendix 2: Site maps

This appendix contains site maps for all sites sampled as part of IAA 15-17. Sites where either *Zostera marina* or *Zostera japonica* was detected include a graph with the depth distribution of both seagrass species (represented by a histogram of observations vs. depth). While the depth distribution of *Zostera marina* is accurate, and the distribution of *Z. japonica* is accurate within the depth range shown, the upper bound of the distribution of *Zostera japonica* may not be captured at some sites, because our research vessel could not reach the upper intertidal at some locations. At 4 sites (cps1090, cps2148, cps2149 & cps2150), GPS coordinates were not collected due to equipment malfunction. As such, these sites are not represented in the maps. At neither of these 4 sites eelgrass was present.

Site maps are grouped by zone and ordered from lowest to highest site code. For the location of individual sites, please refer to Figure 14 (Upper Kitsap Peninsula, page 37), Figure 15 (East Bainbridge, page 63), Figure 16 (Port Orchard, page 79), and Figure 17 (Dyes Inlet and Liberty Bay, page 113).

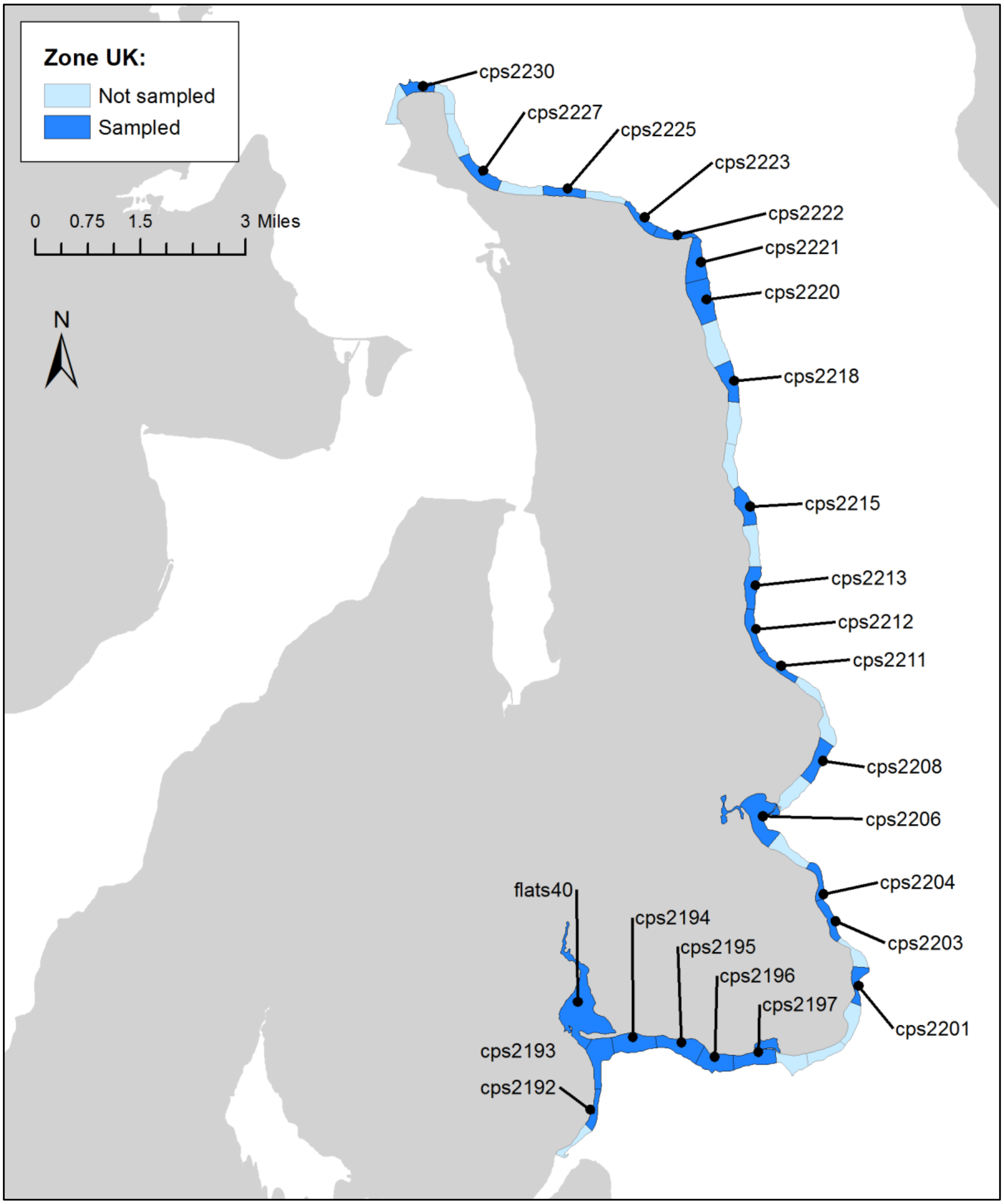
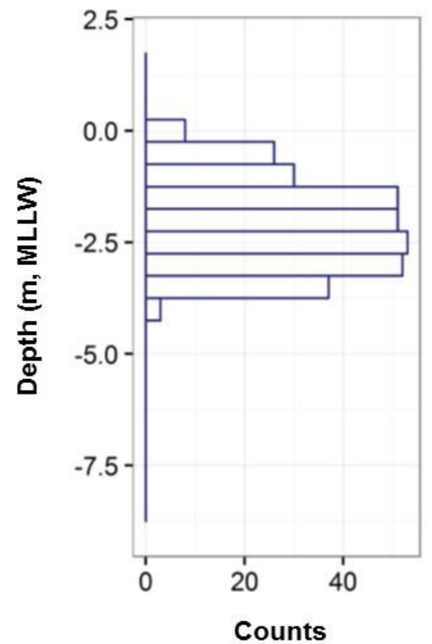
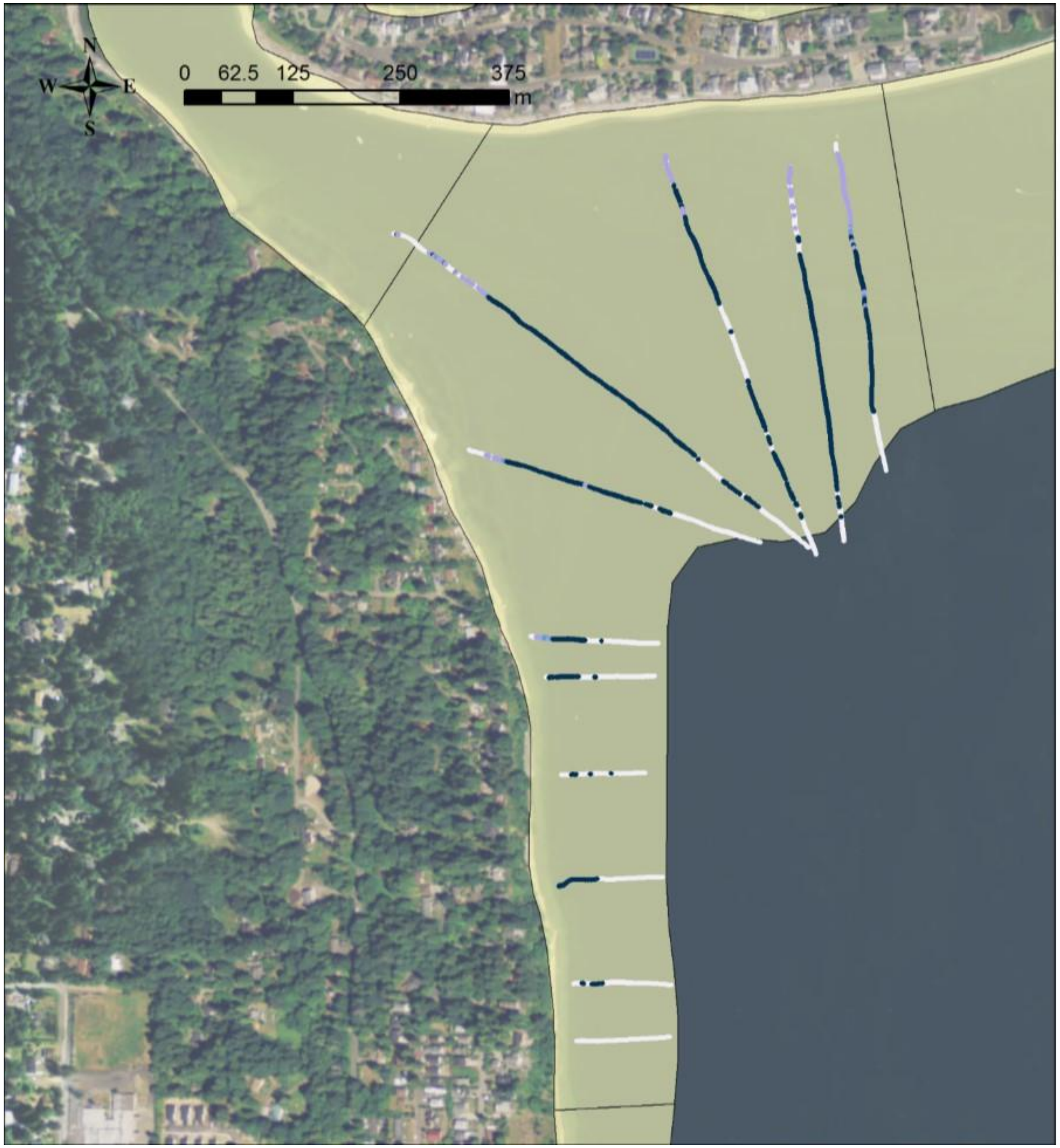


Figure 14: Northern section of the East Kitsap study area (Zone UK, or 'Upper Kitsap'). Sites that were sampled as part of IAA 15-17 are labeled and indicated in bold.

CPS2192

Depth distribution of *Z. marina*

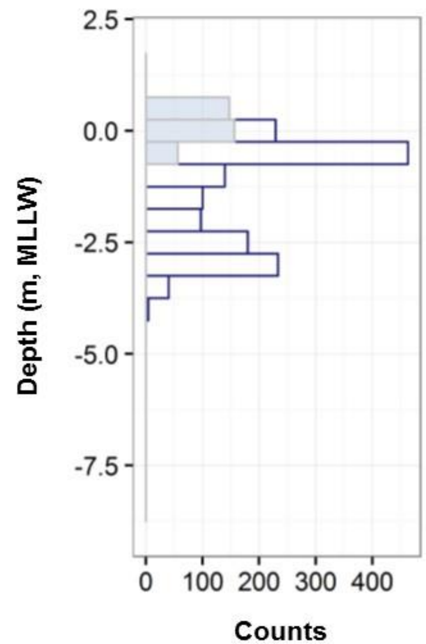


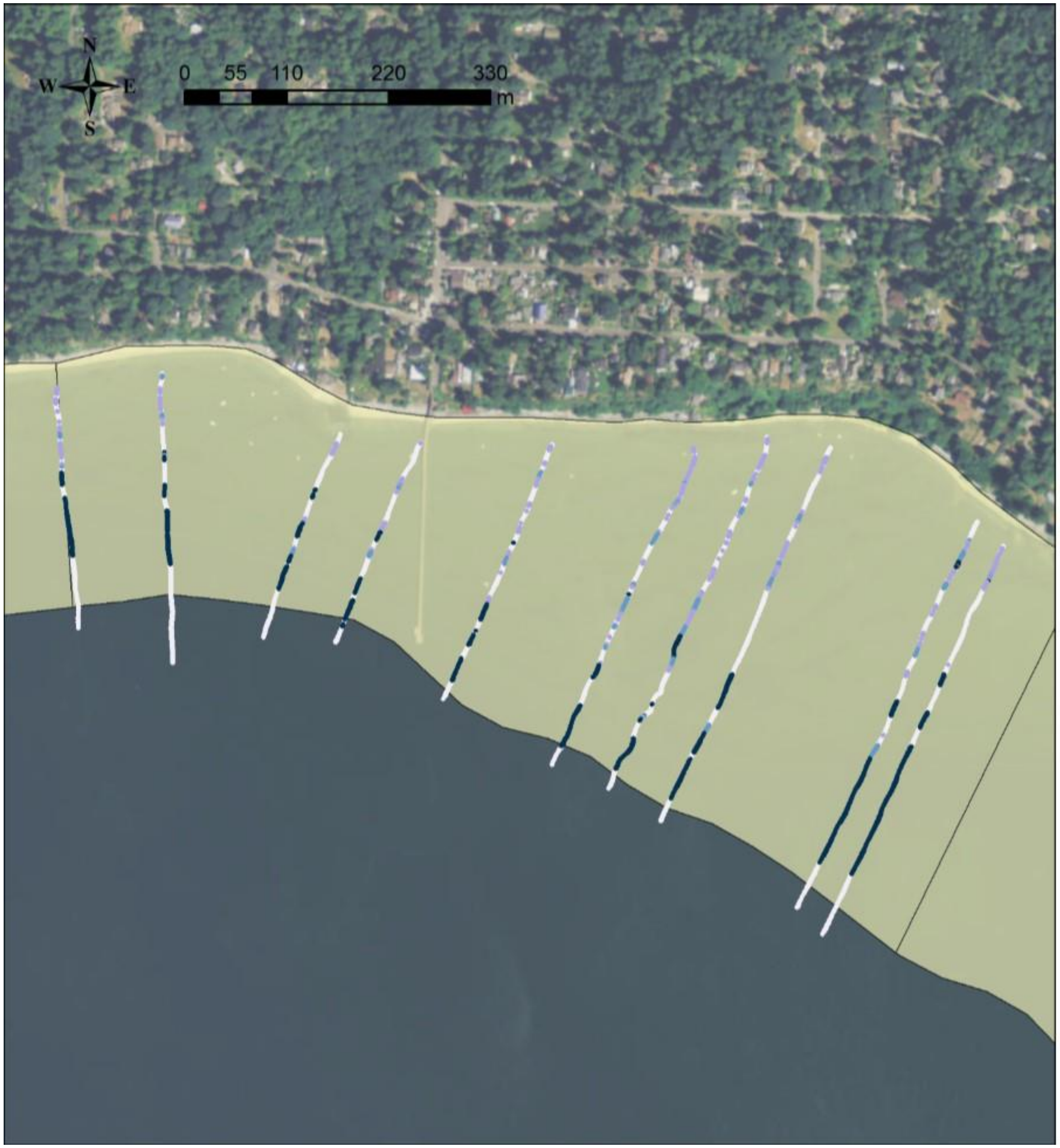


CPS2193

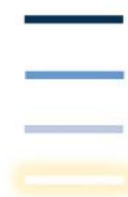
Z. marina
Z. marina & *Z. japonica*
Z. japonica
no seagrass

Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)

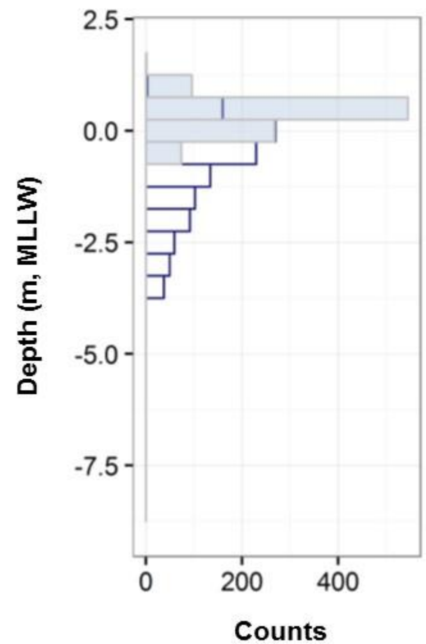


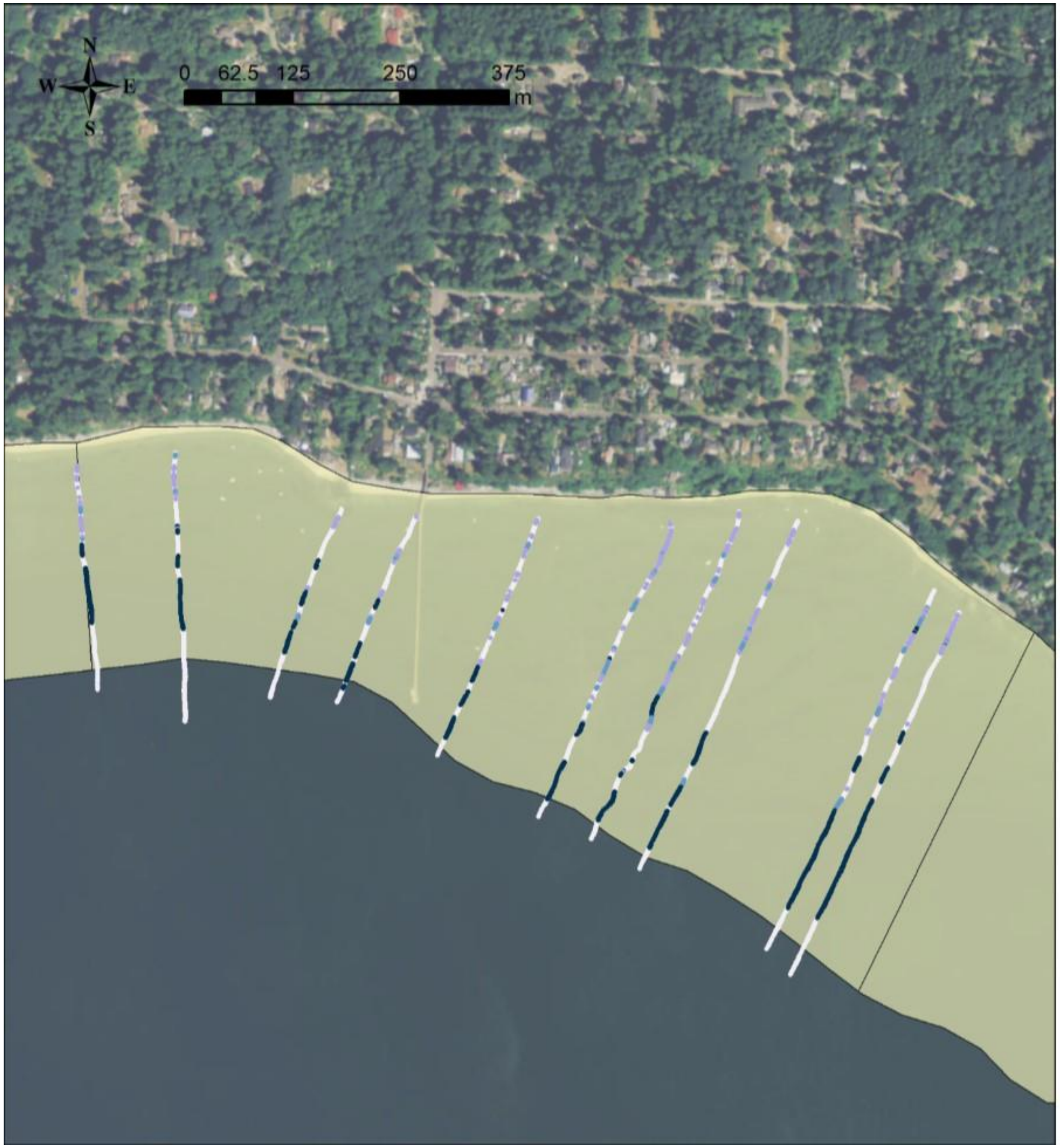


CPS2194



Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)





CPS2195

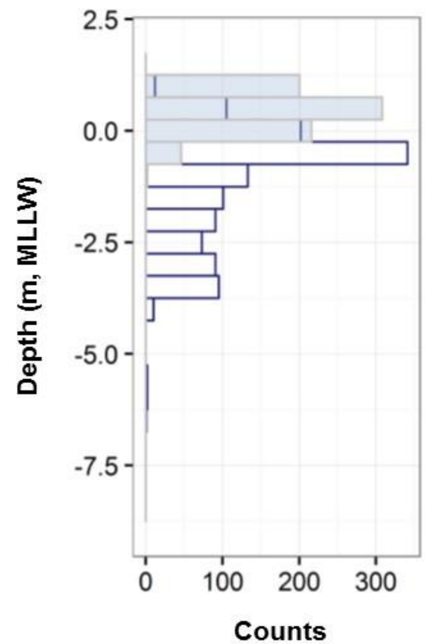
Z. marina

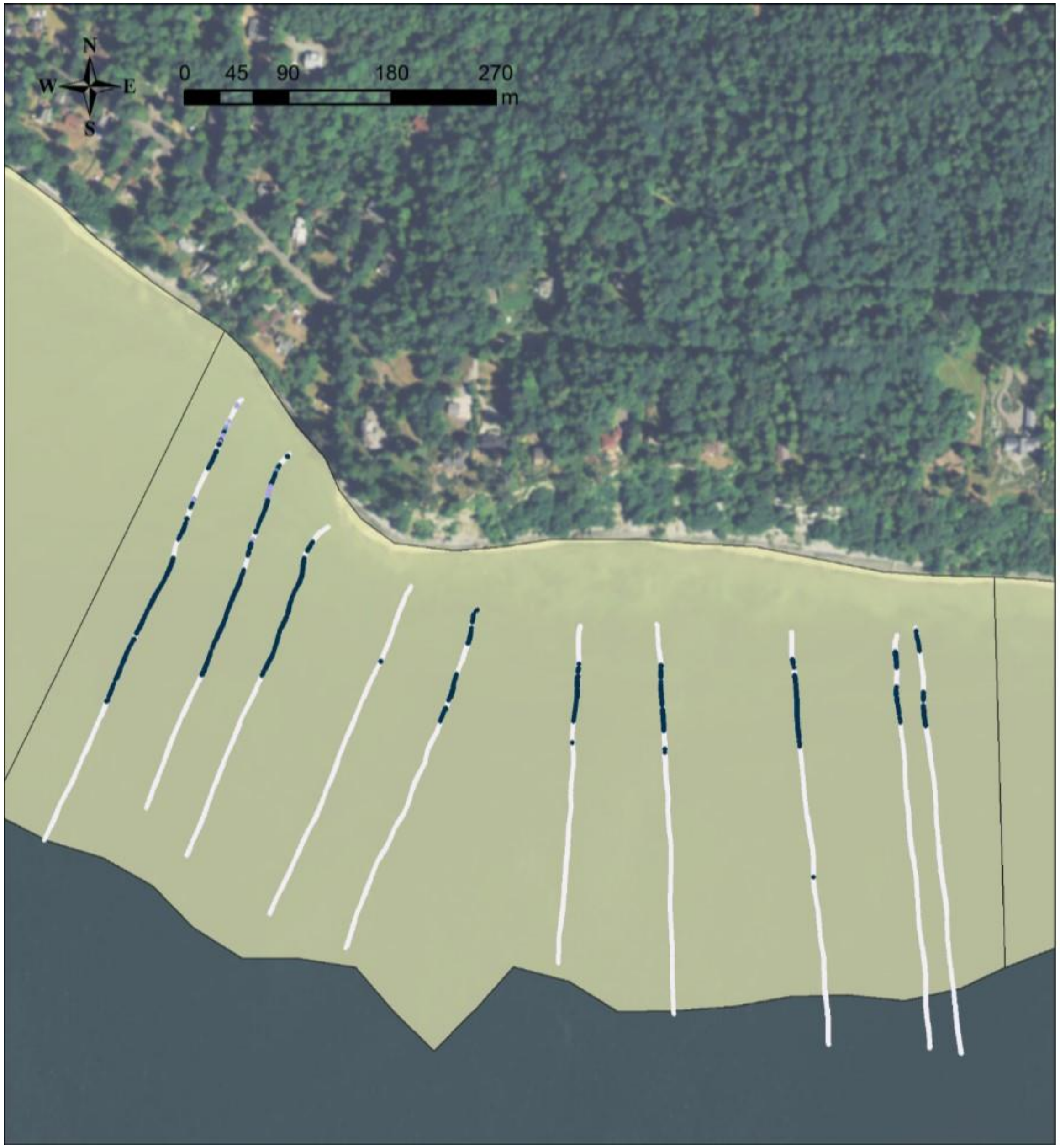
Z. marina & *Z. japonica*

Z. japonica

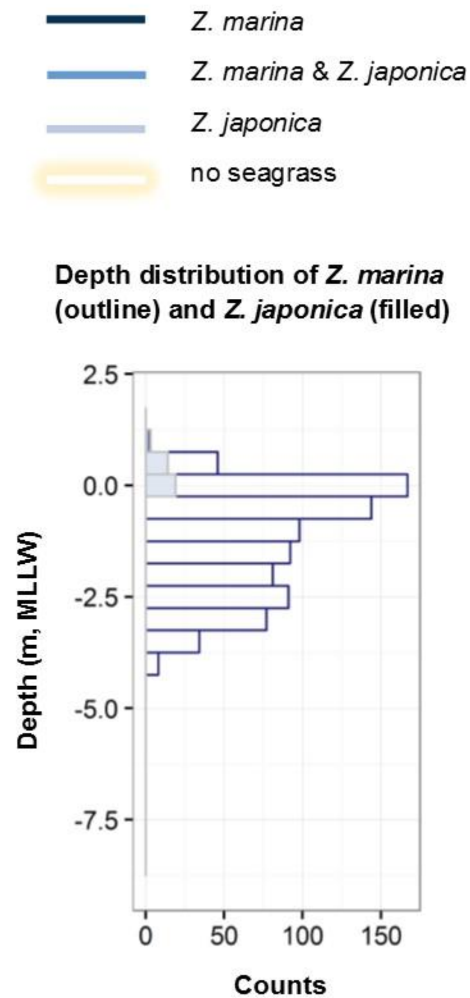
no seagrass

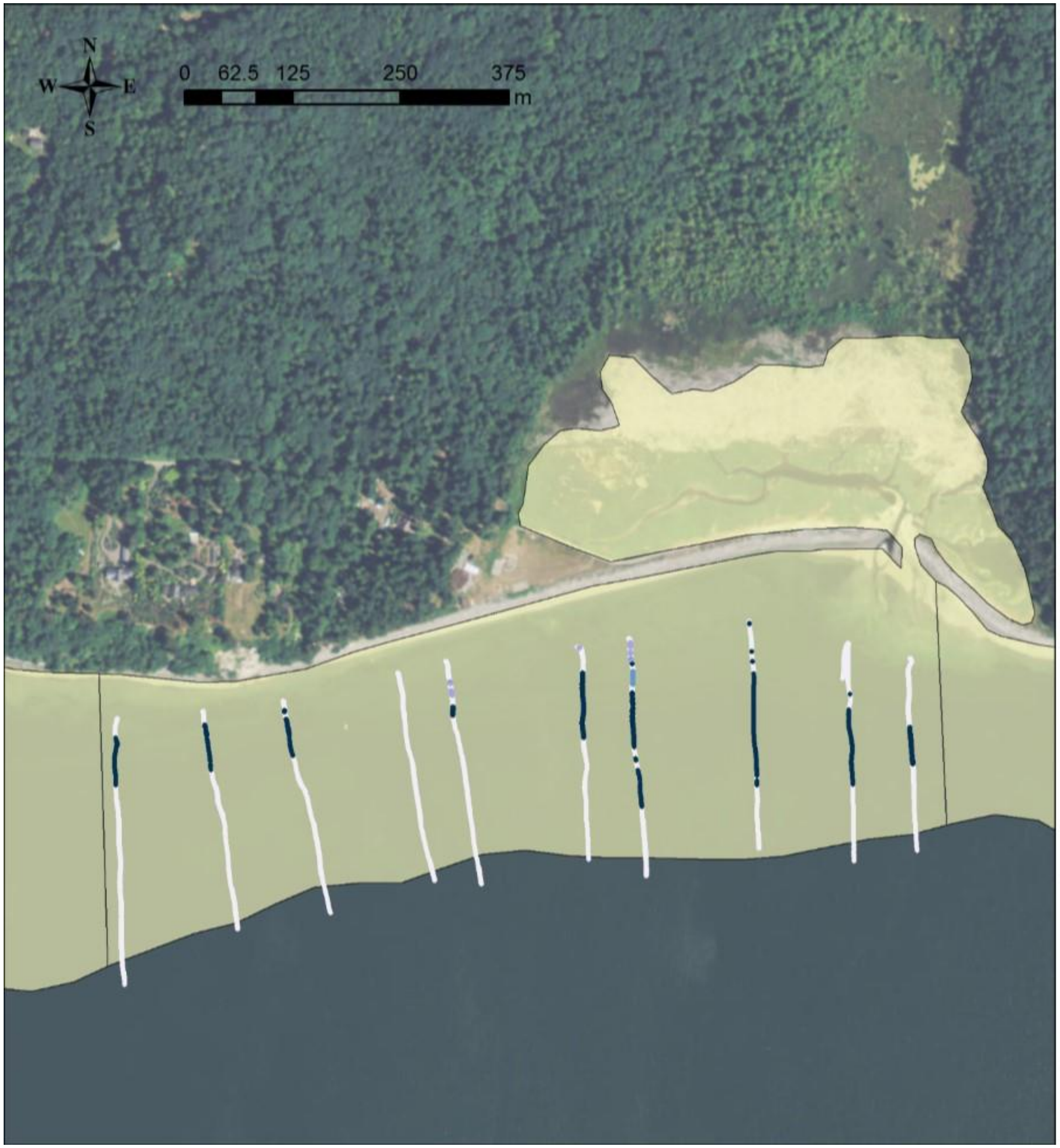
Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)




N
S
W
E
0
45
90
180
270
m

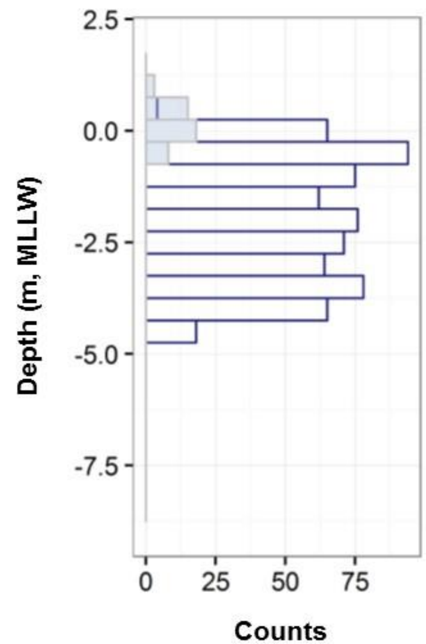
CPS2196

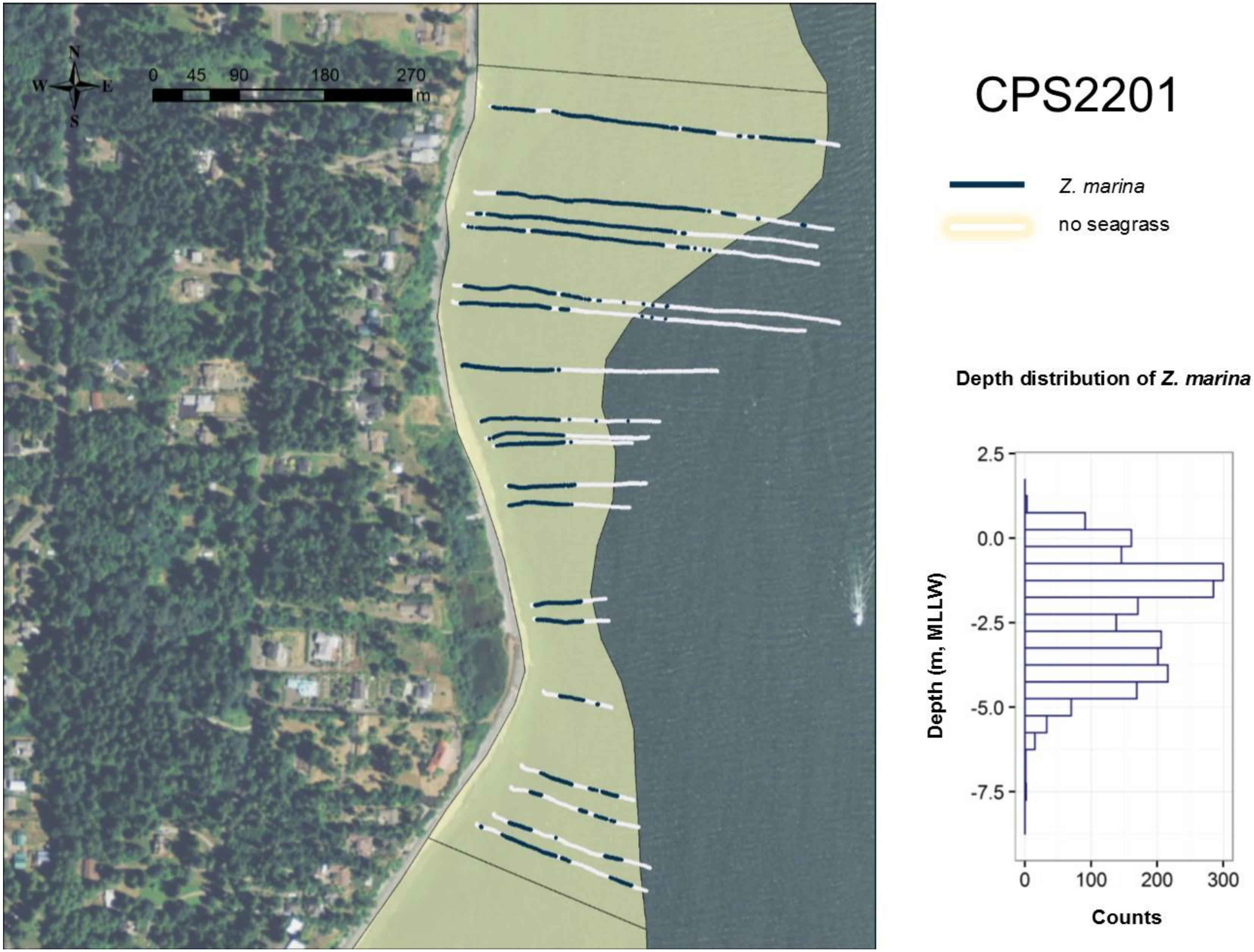

Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
50
100
150
Counts



CPS2197

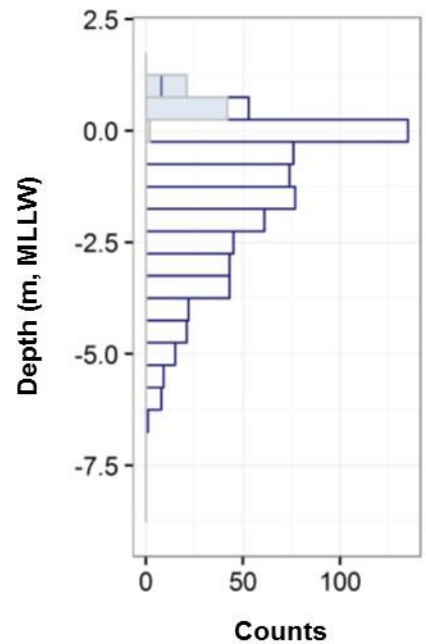
Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)




N
W
E
S
0 45 90 180 270
m
CPS2201
Z. marina
no seagrass
Depth distribution of Z. marina
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
100
200
300
Counts

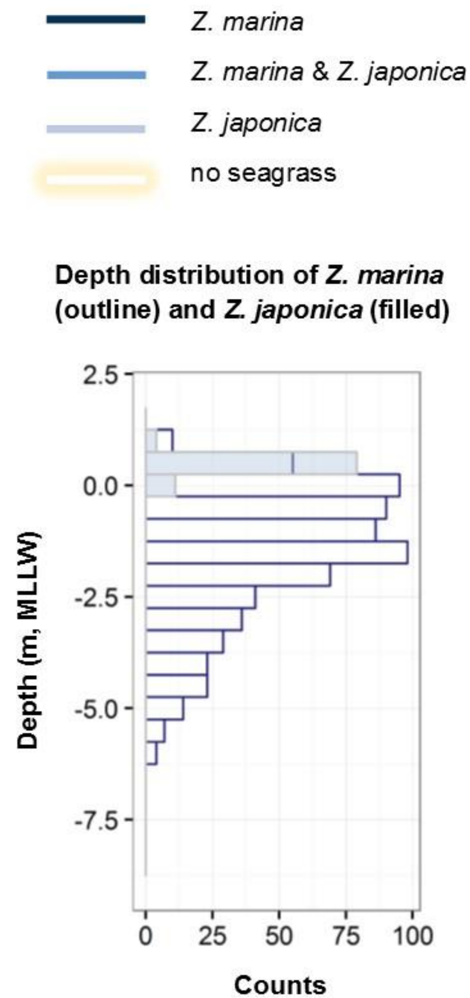
CPS2203

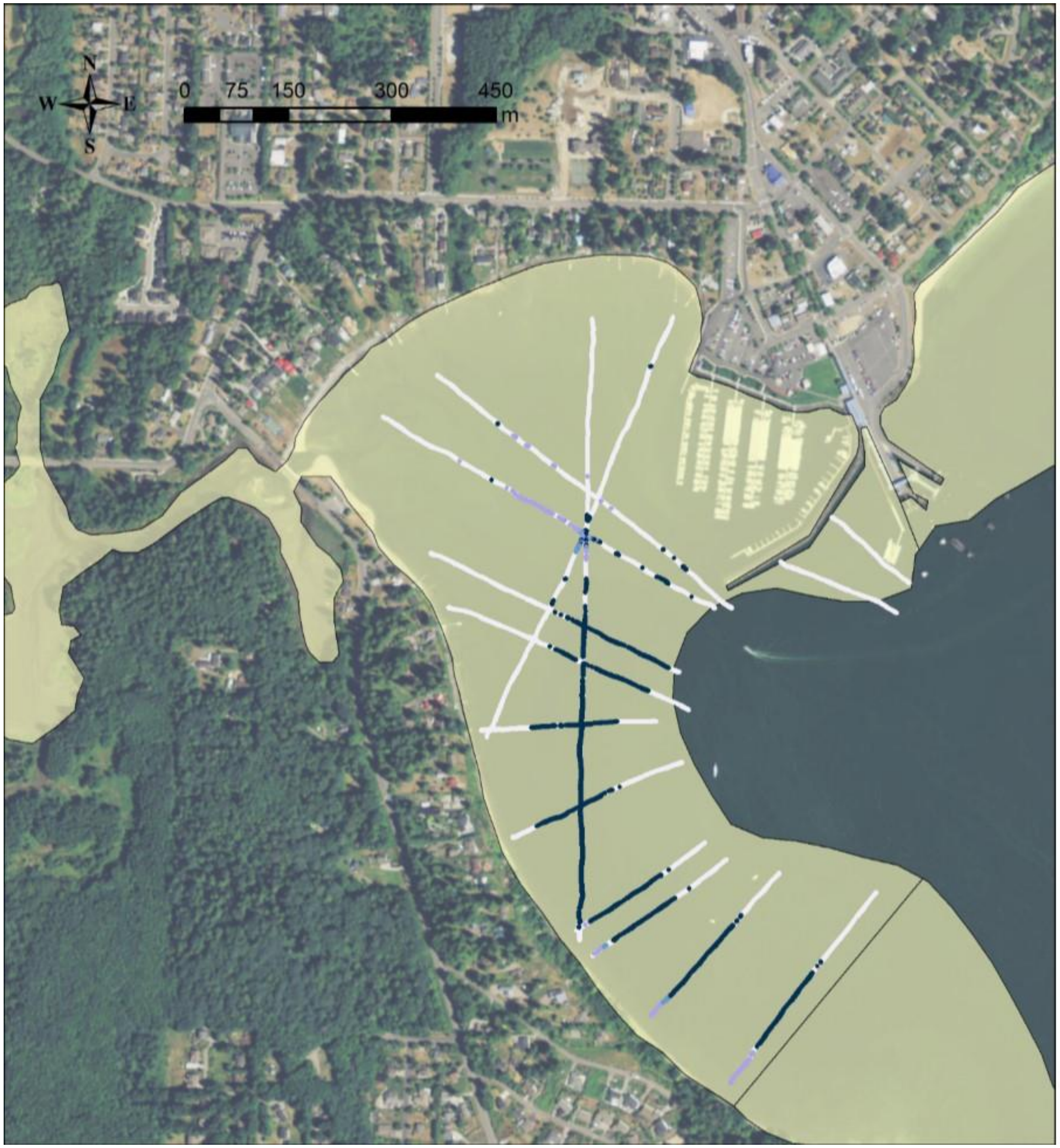
Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)




N
S
W
E
0 62.5 125 250 375
m

CPS2204

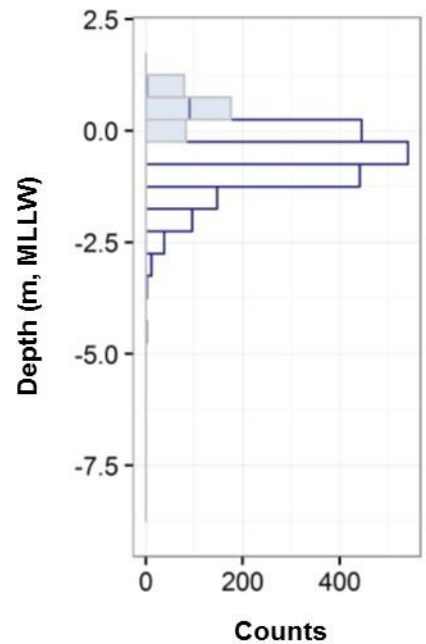

Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
25
50
75
100
Counts

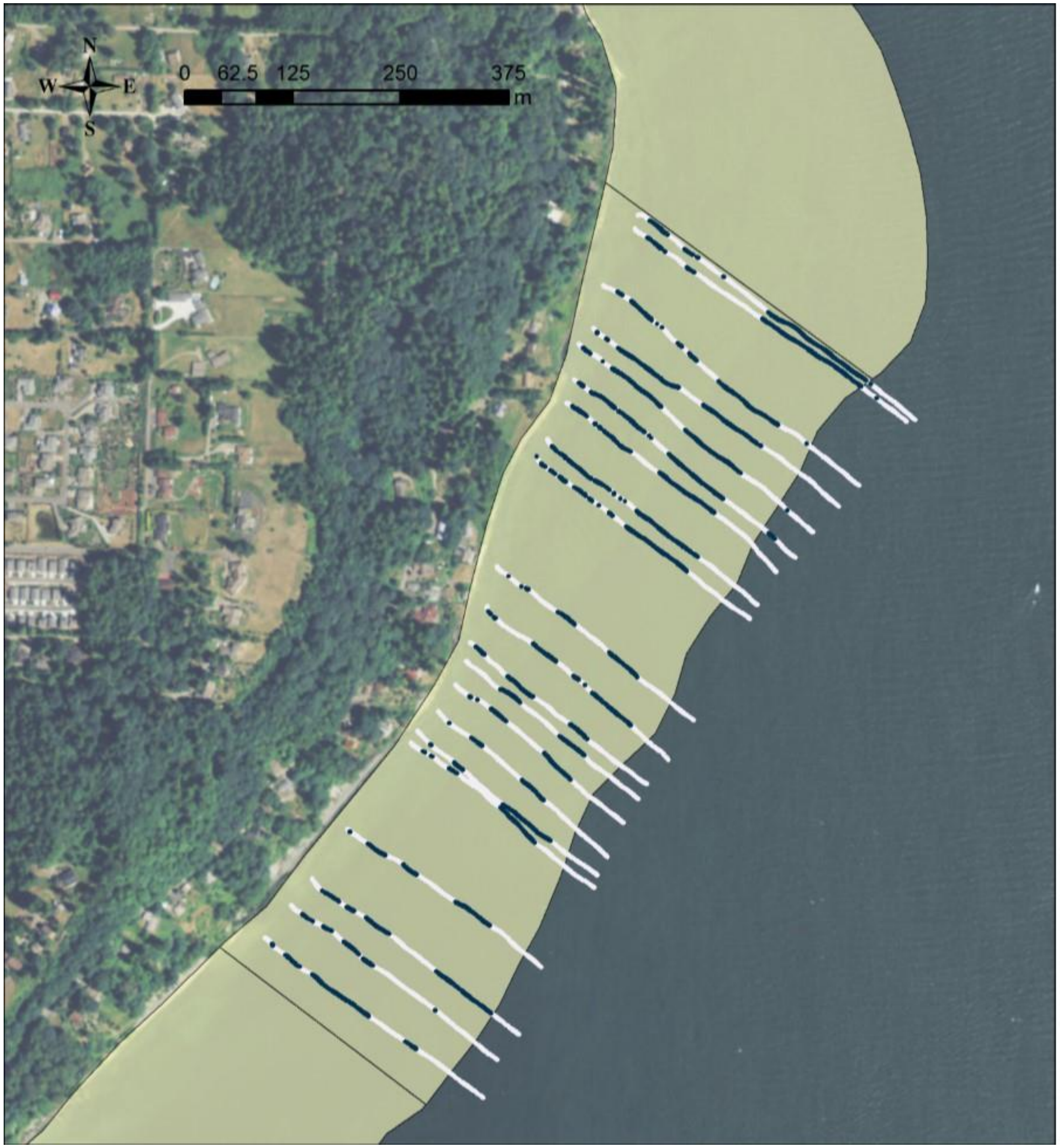


CPS2206

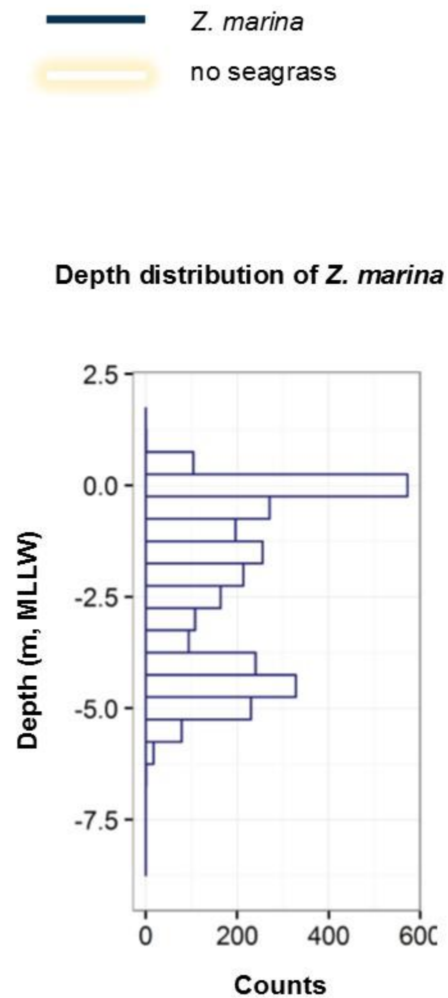
Z. marina
Z. marina & *Z. japonica*
Z. japonica
no seagrass

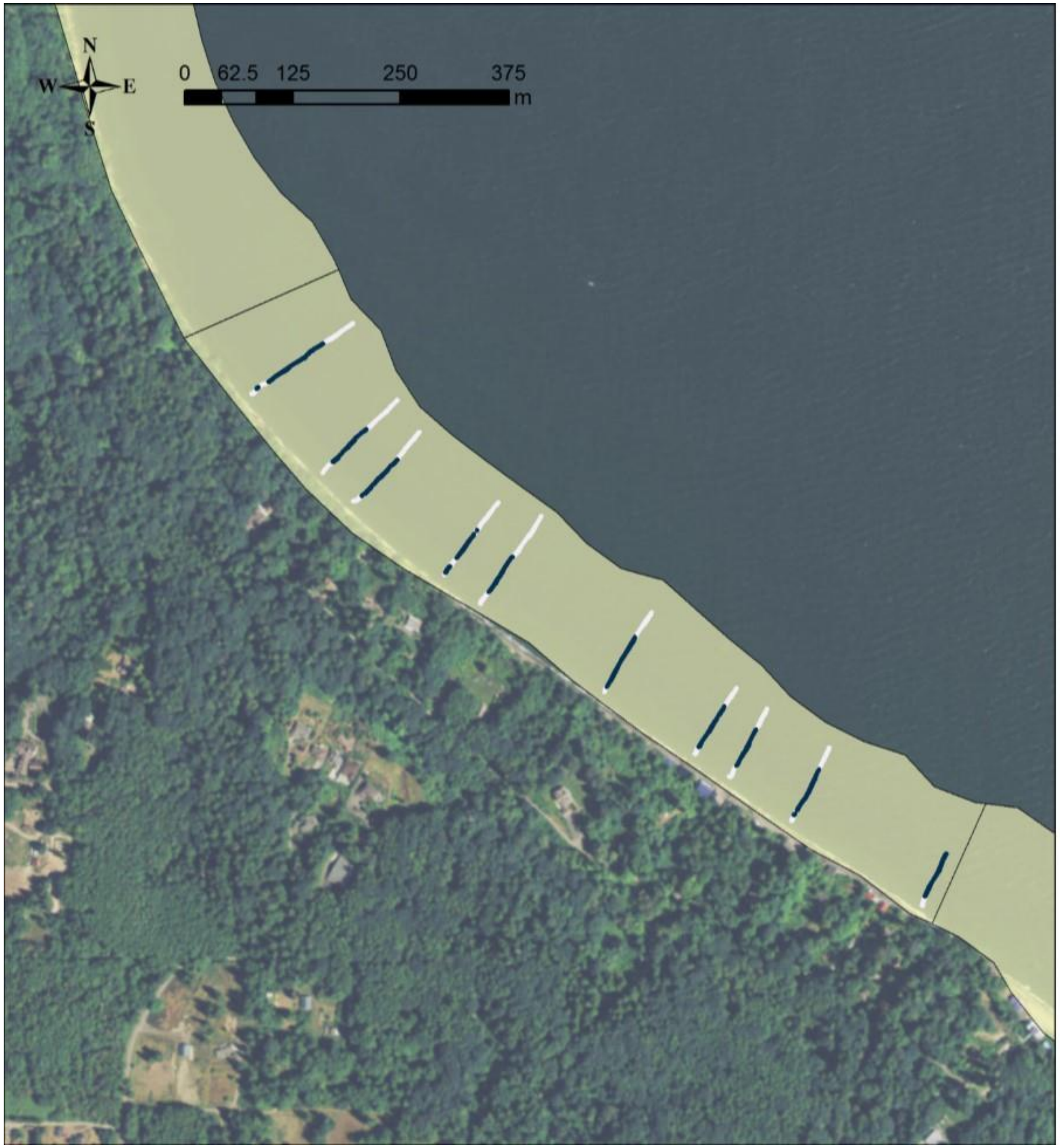
Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)




N
S
W
E
0
62.5
125
250
375
m

CPS2208


Z. marina
no seagrass
Depth distribution of Z. marina
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
200
400
600
Counts

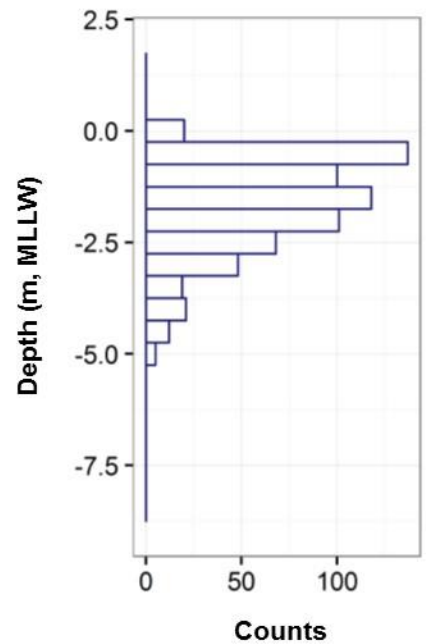


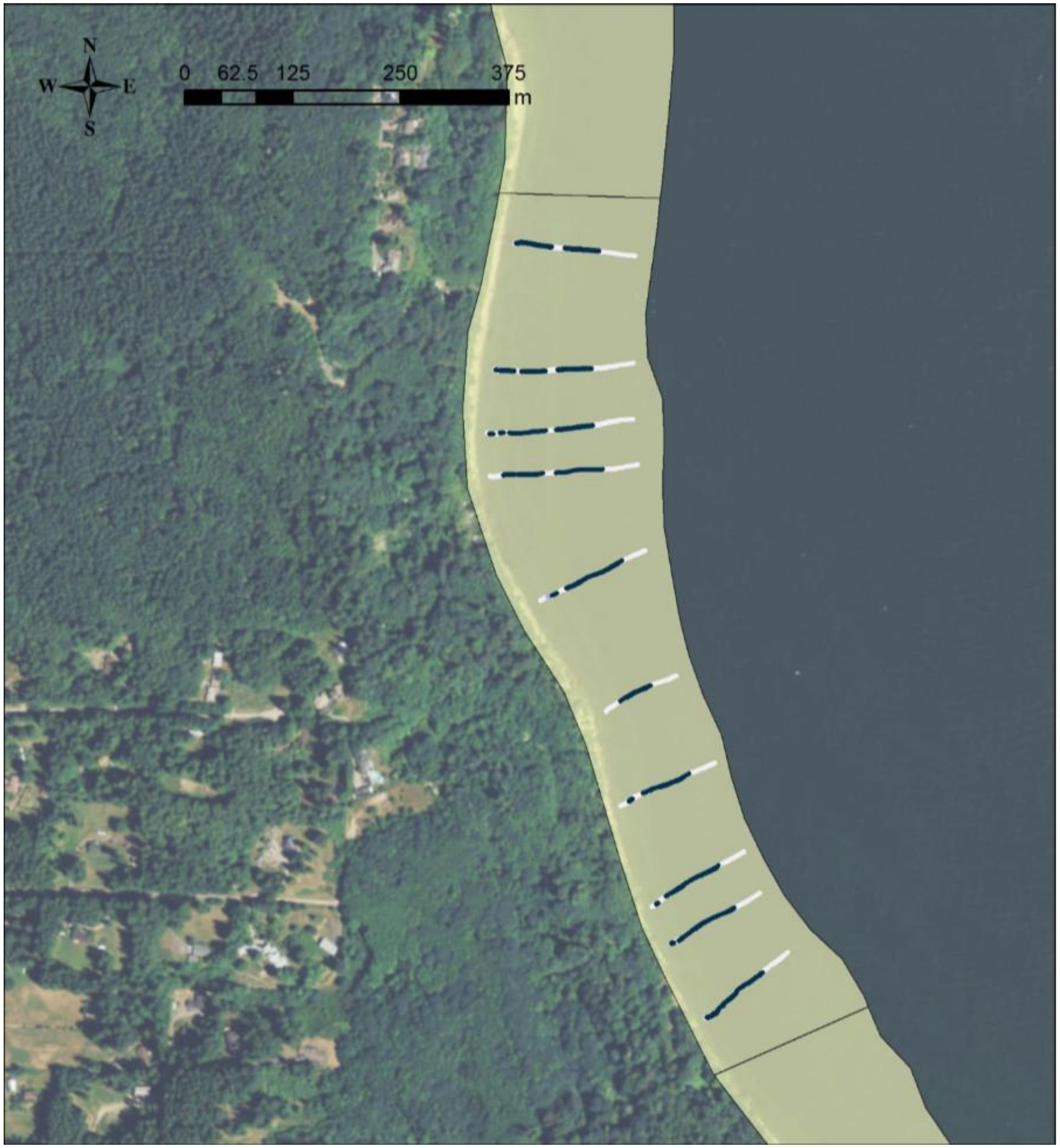
CPS2211

Z. marina

no seagrass

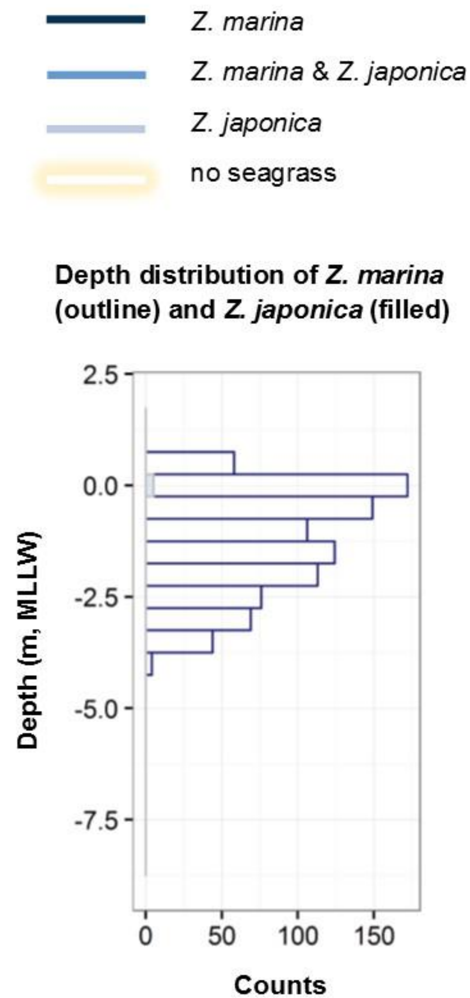
Depth distribution of *Z. marina*



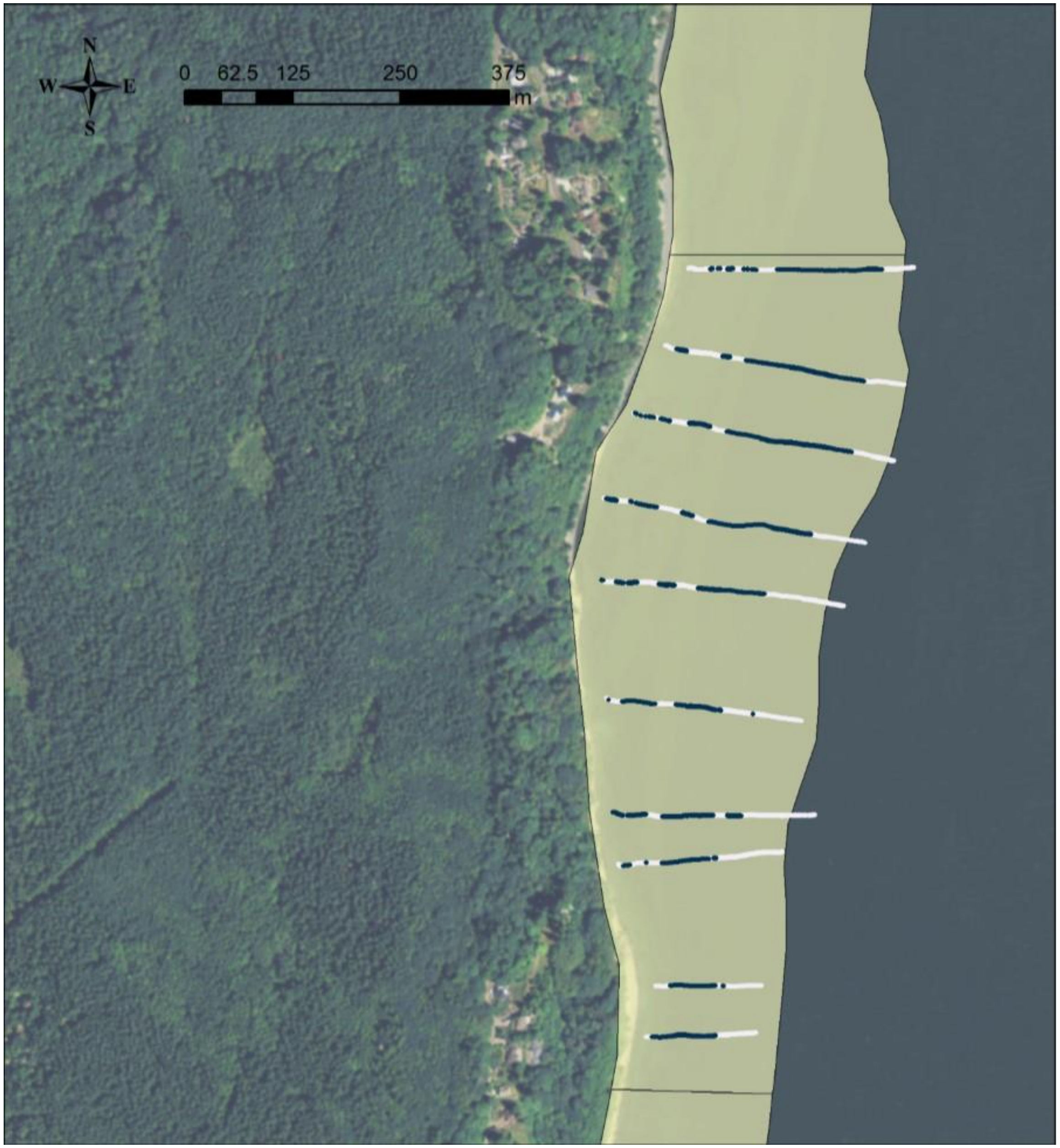


N
W
E
S
0
62.5
125
250
375
m

CPS2212

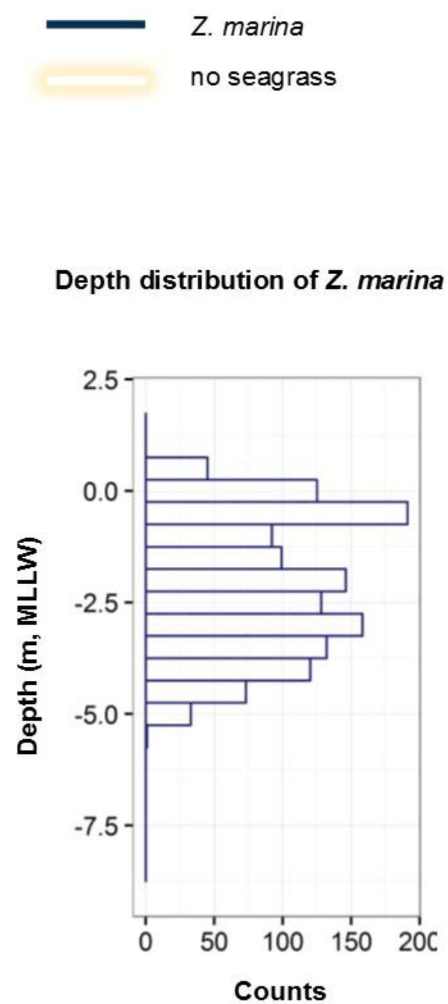


Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
50
100
150
Counts



N
W
E
S
0 62.5 125 250 375
m

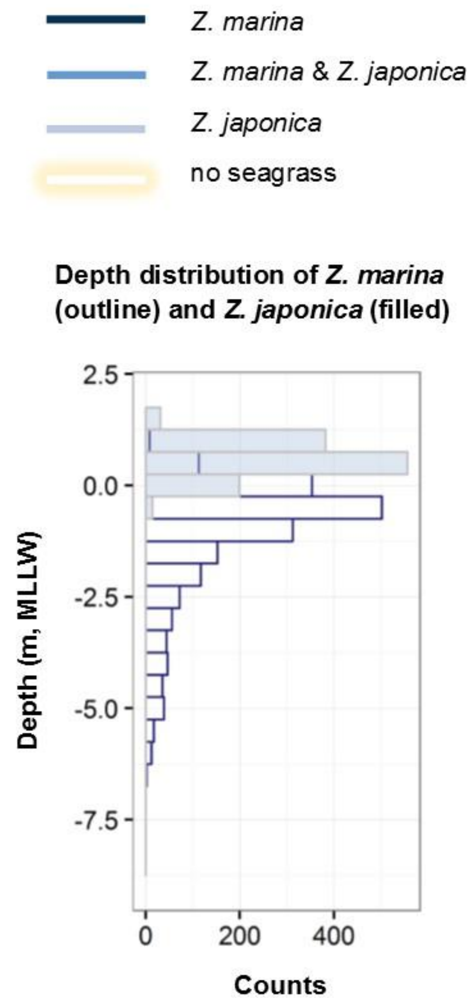
CPS2213

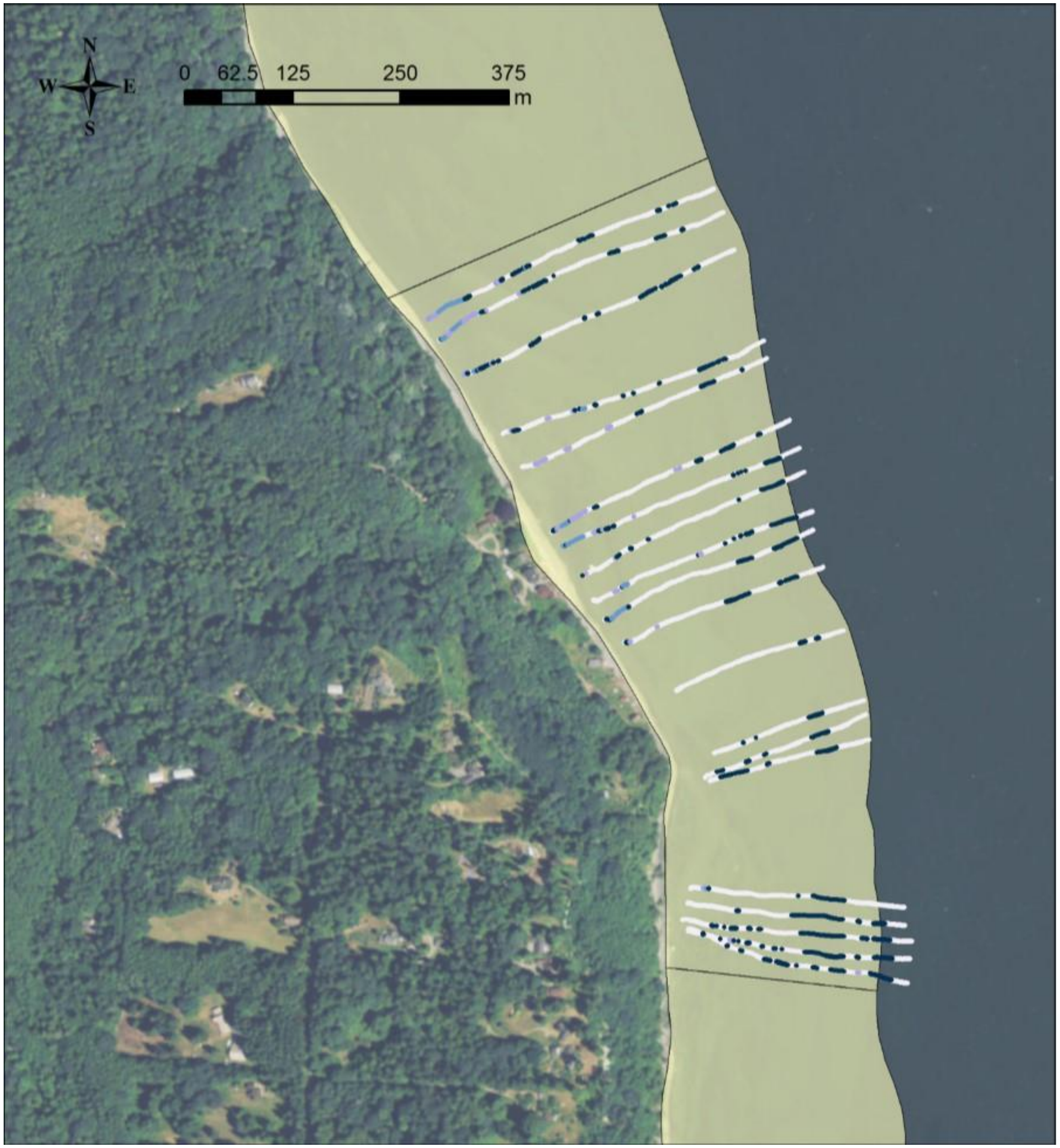


Z. marina
no seagrass
Depth distribution of Z. marina
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0 50 100 150 200
Counts


N
W
E
S
0 55 110 220 330
m

CPS2215


Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
200
400
Counts



CPS2218

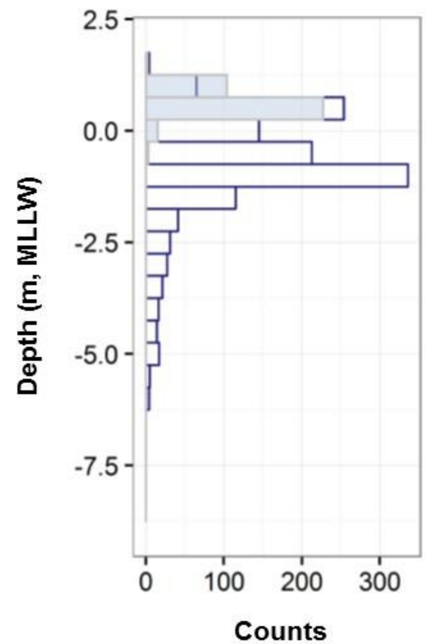
Z. marina

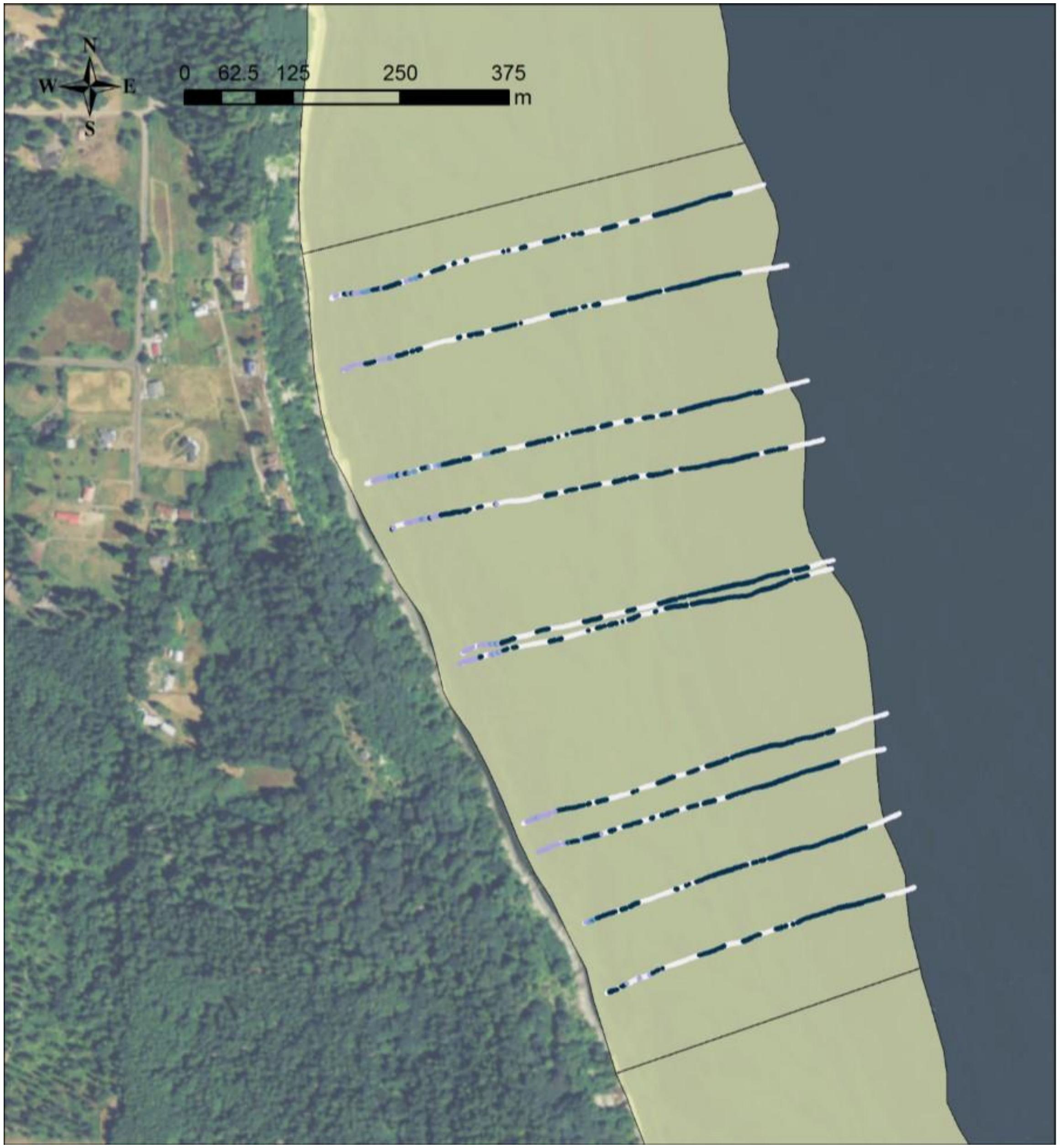
Z. marina & *Z. japonica*

Z. japonica

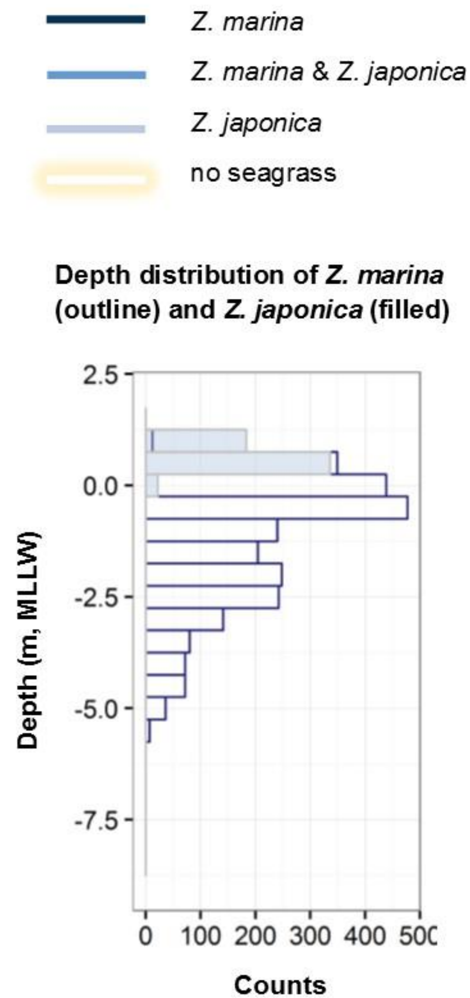
no seagrass

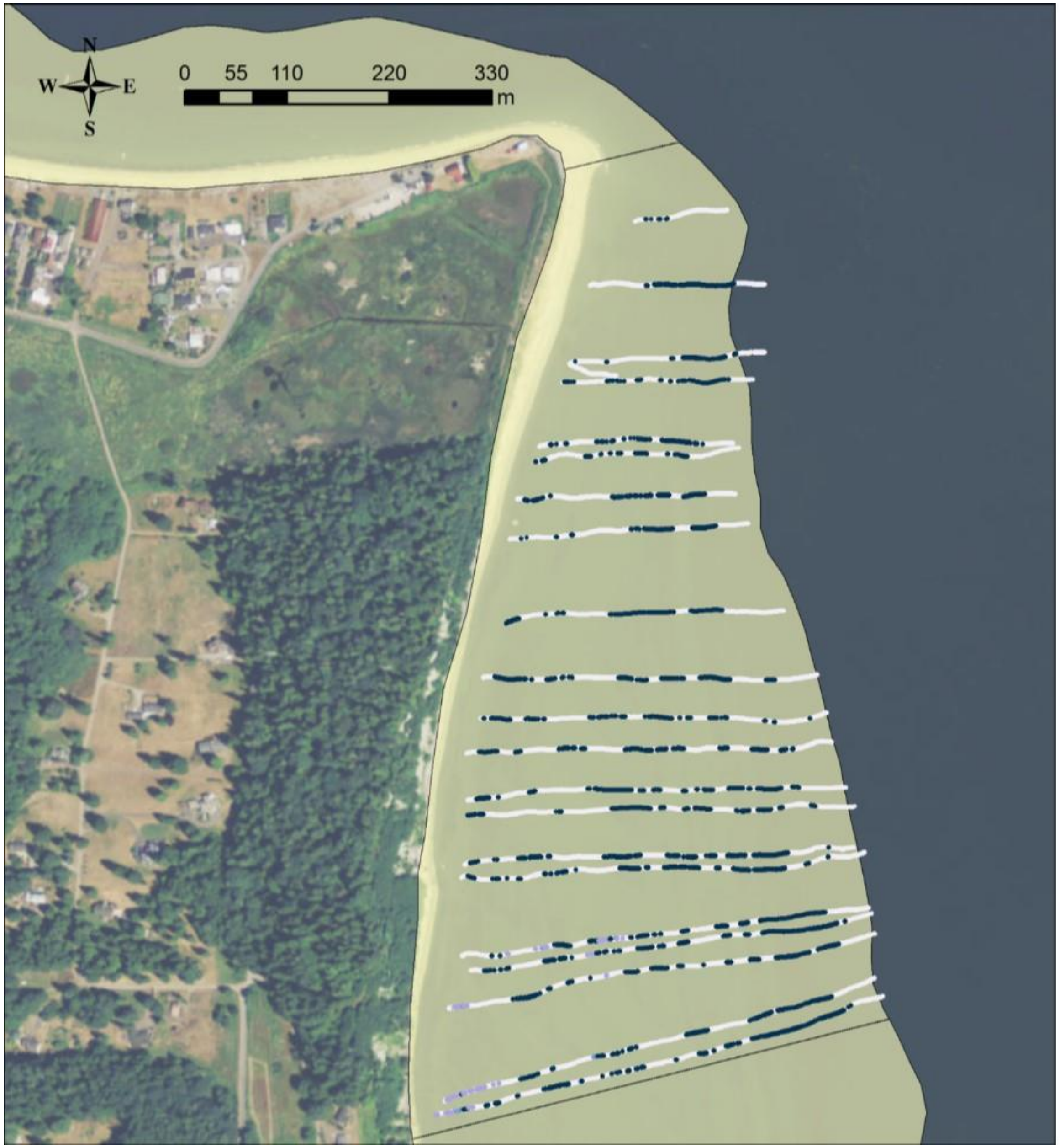
Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)




N
W
E
S
0 62.5 125 250 375
m

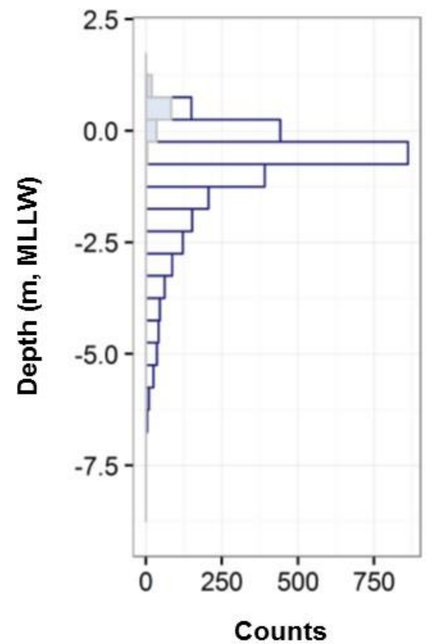
CPS2220

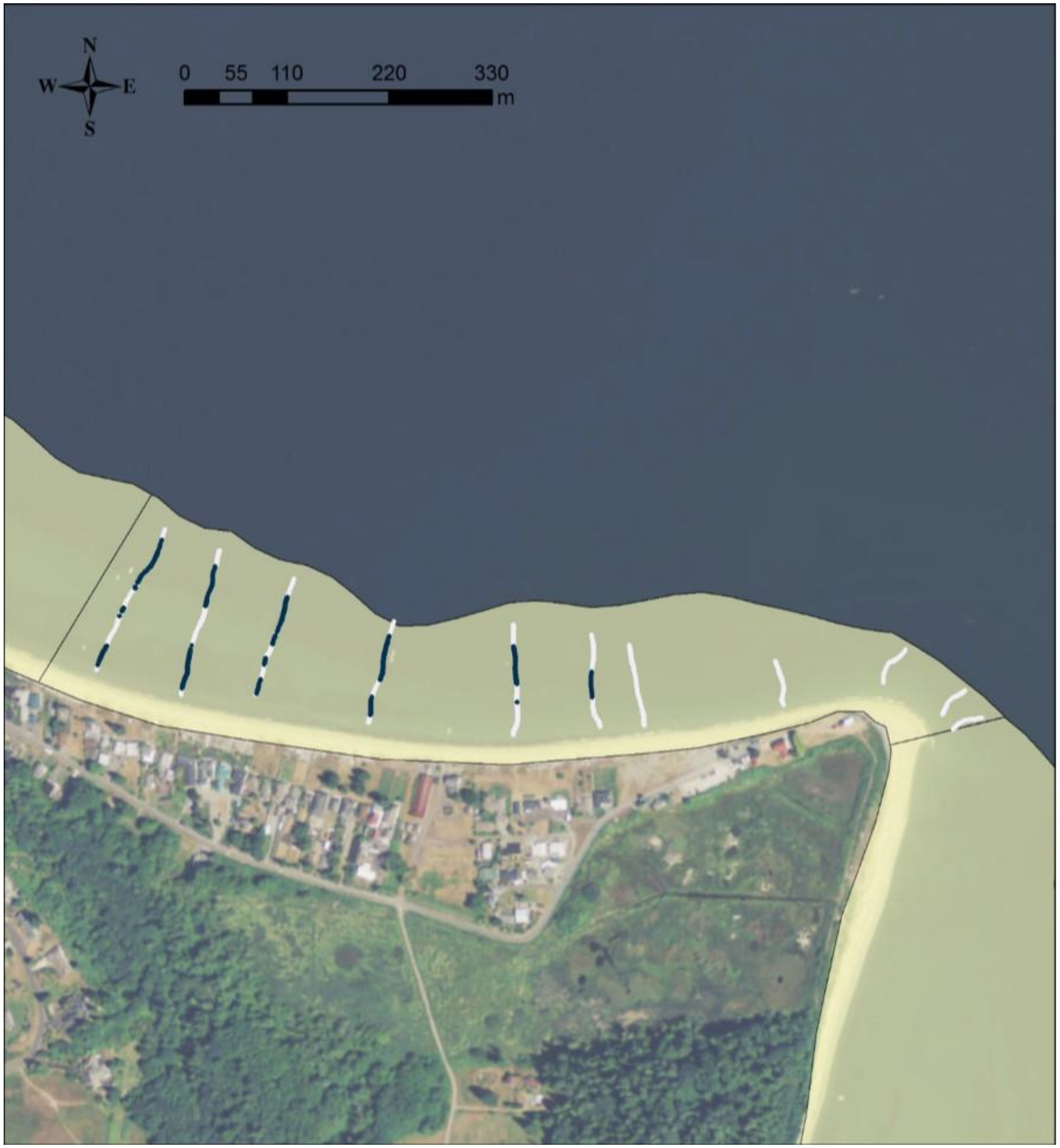

Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0 100 200 300 400 500
Counts



CPS2221

Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)

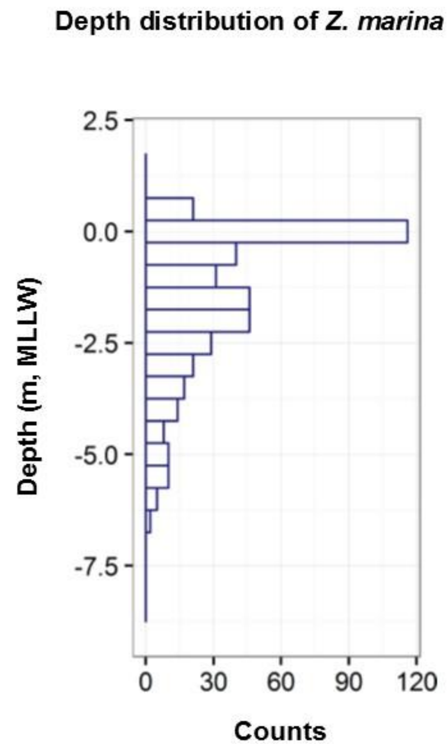




N
W
E
S
0 55 110 220 330
m

CPS2222

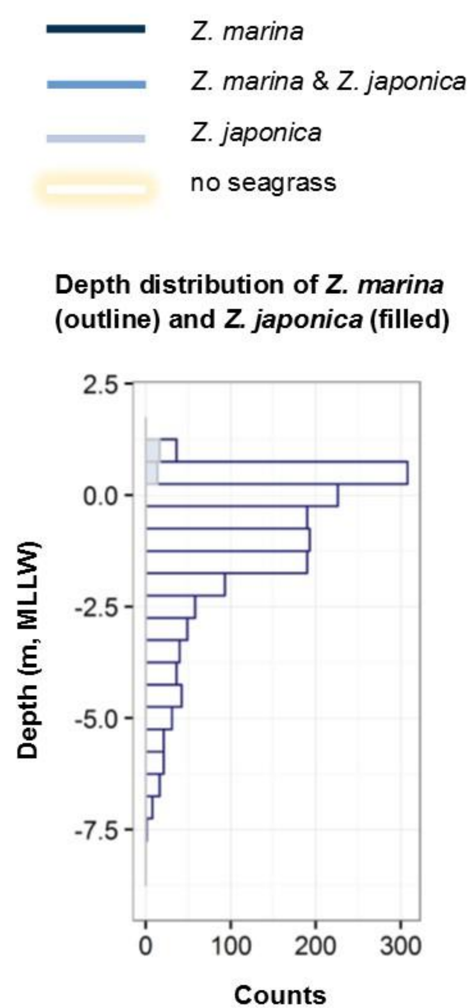
Z. marina
no seagrass

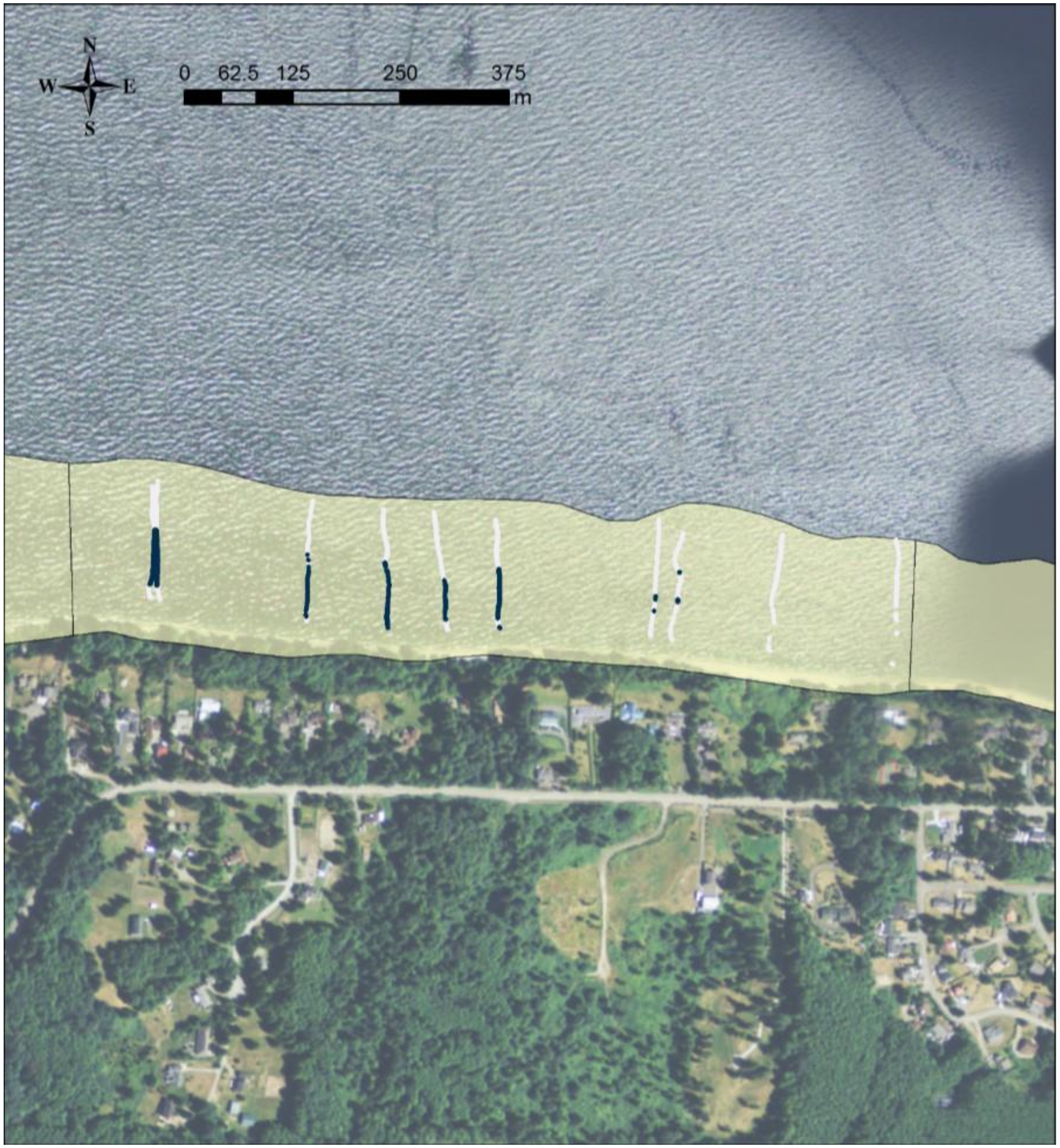


Depth distribution of Z. marina
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
30
60
90
120
Counts


N
W
E
S
0 45 90 180 270
m

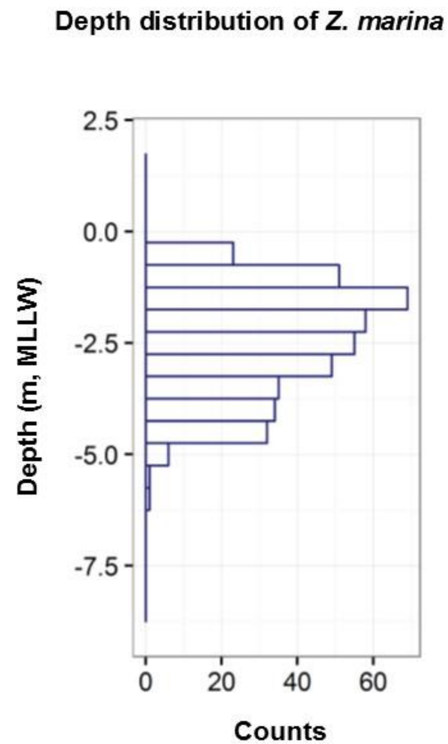
CPS2223

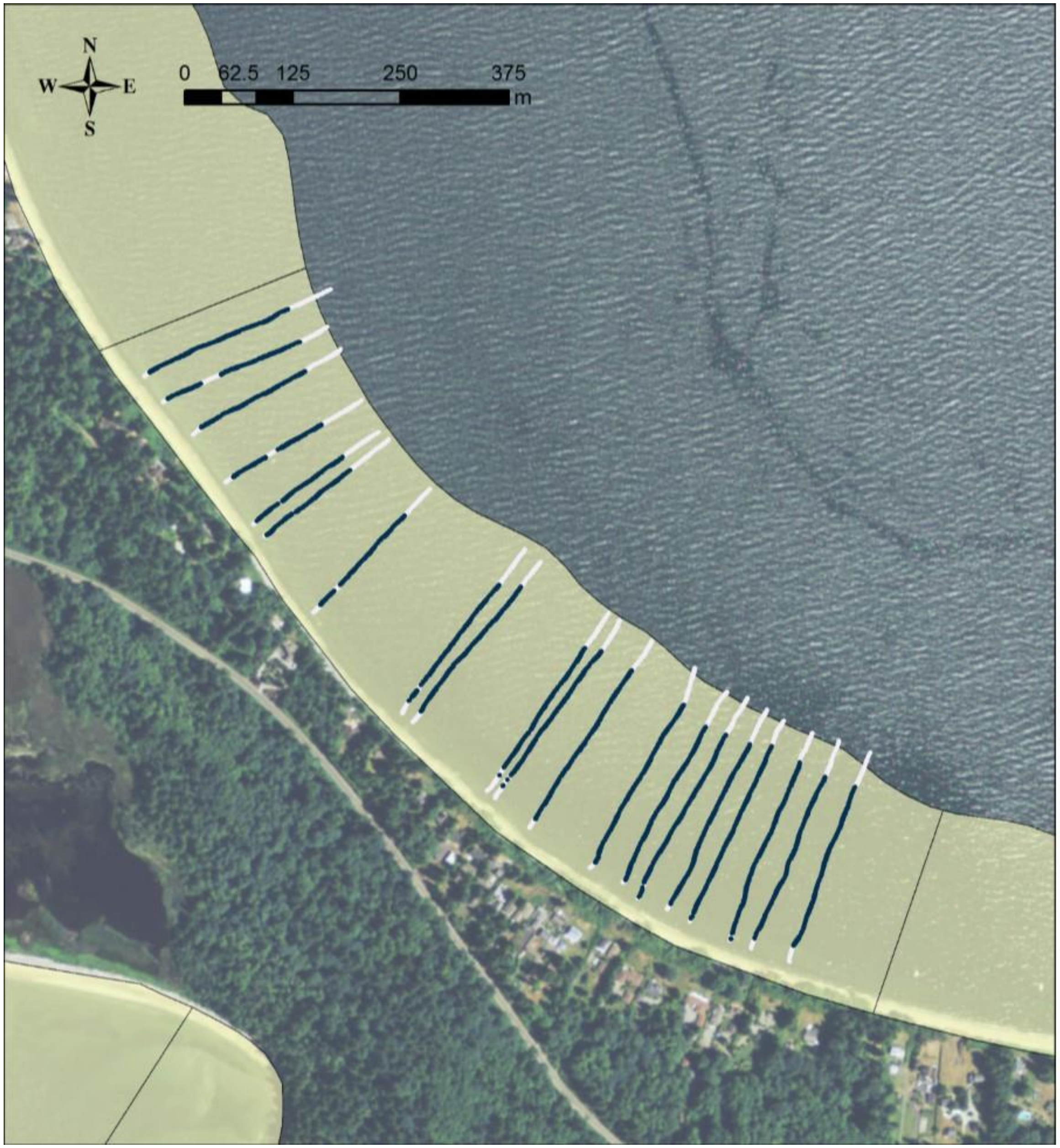

Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
100
200
300
Counts


N
W
E
S
0 62.5 125 250 375
m

CPS2225

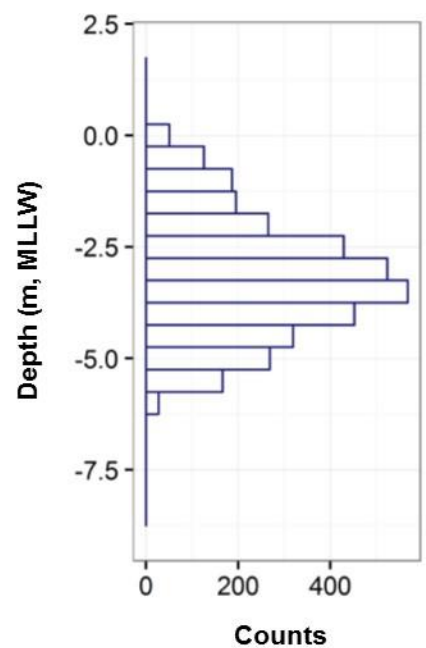
Z. marina
no seagrass

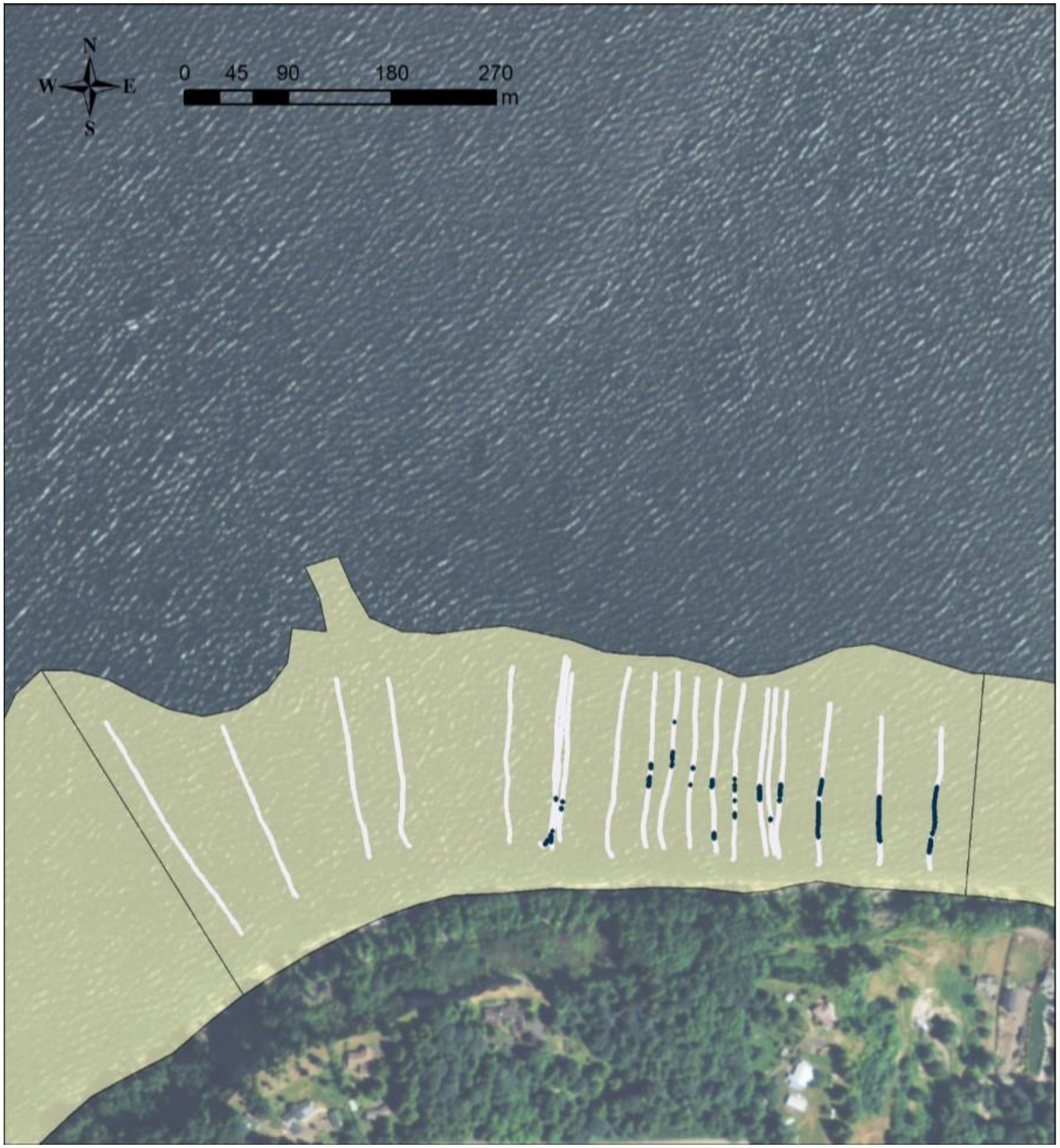

Depth distribution of *Z. marina*
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
20
40
60
Counts



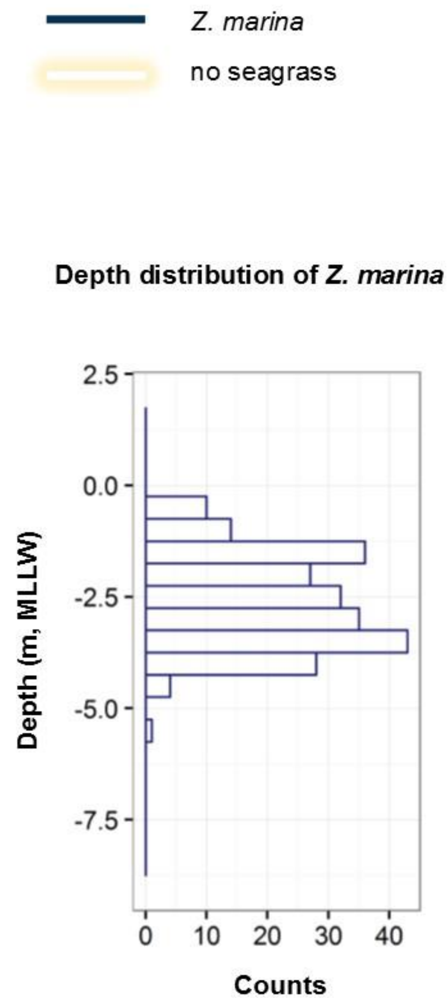
CPS2227

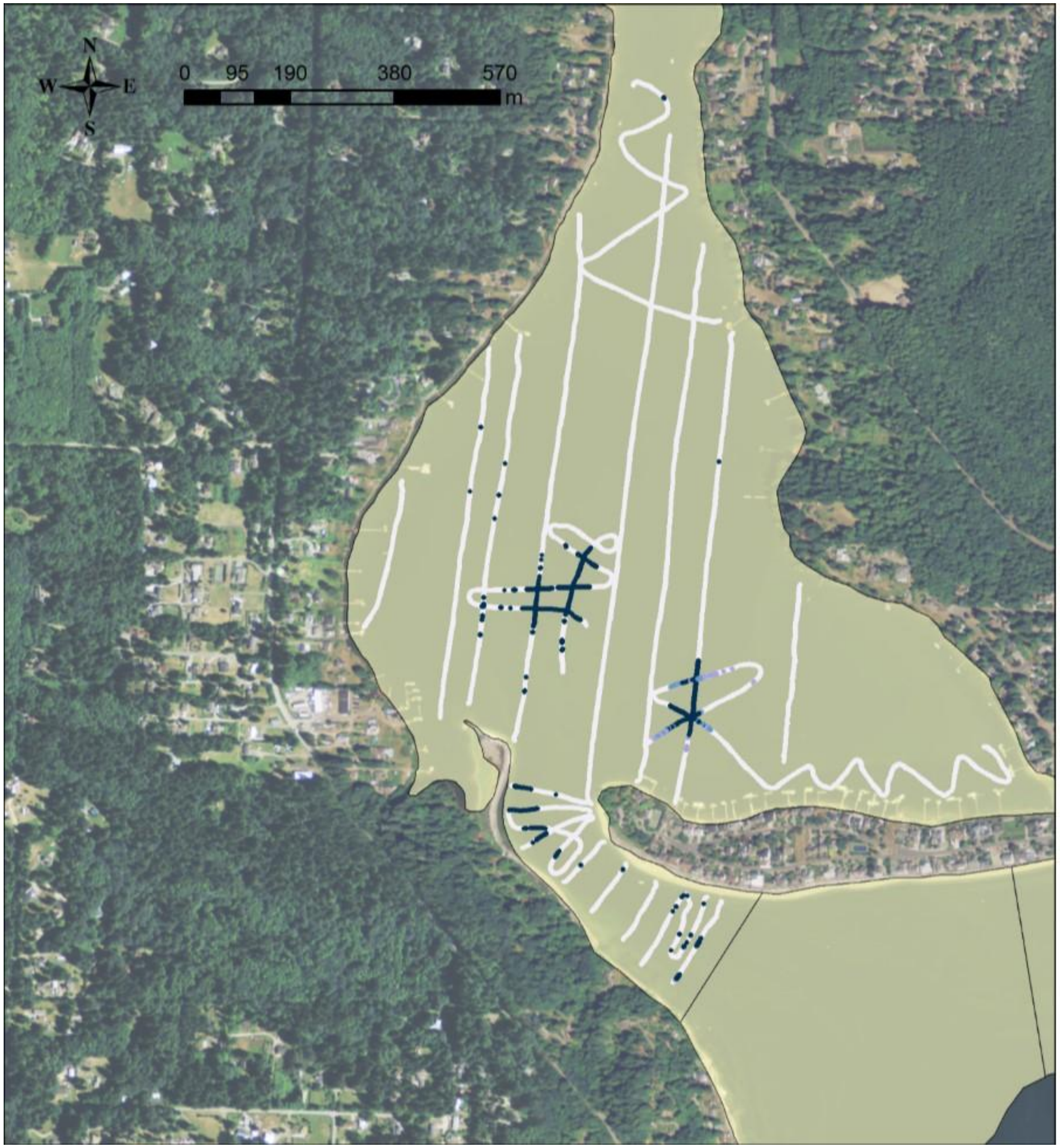
Depth distribution of *Z. marina*




N
W
E
S
0 45 90 180 270
m

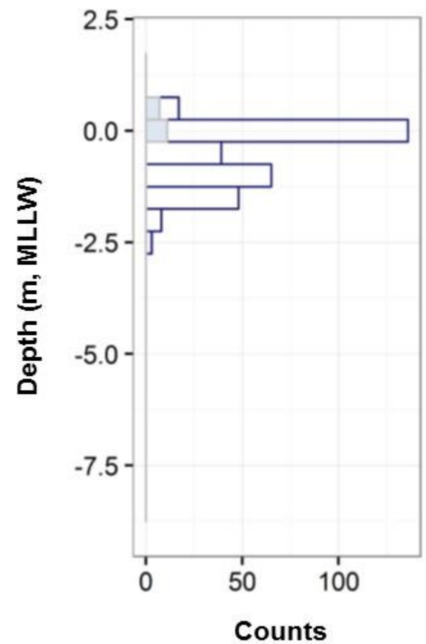
CPS2230


Z. marina
no seagrass
Depth distribution of Z. marina
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0 10 20 30 40
Counts



FLATS40

Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)



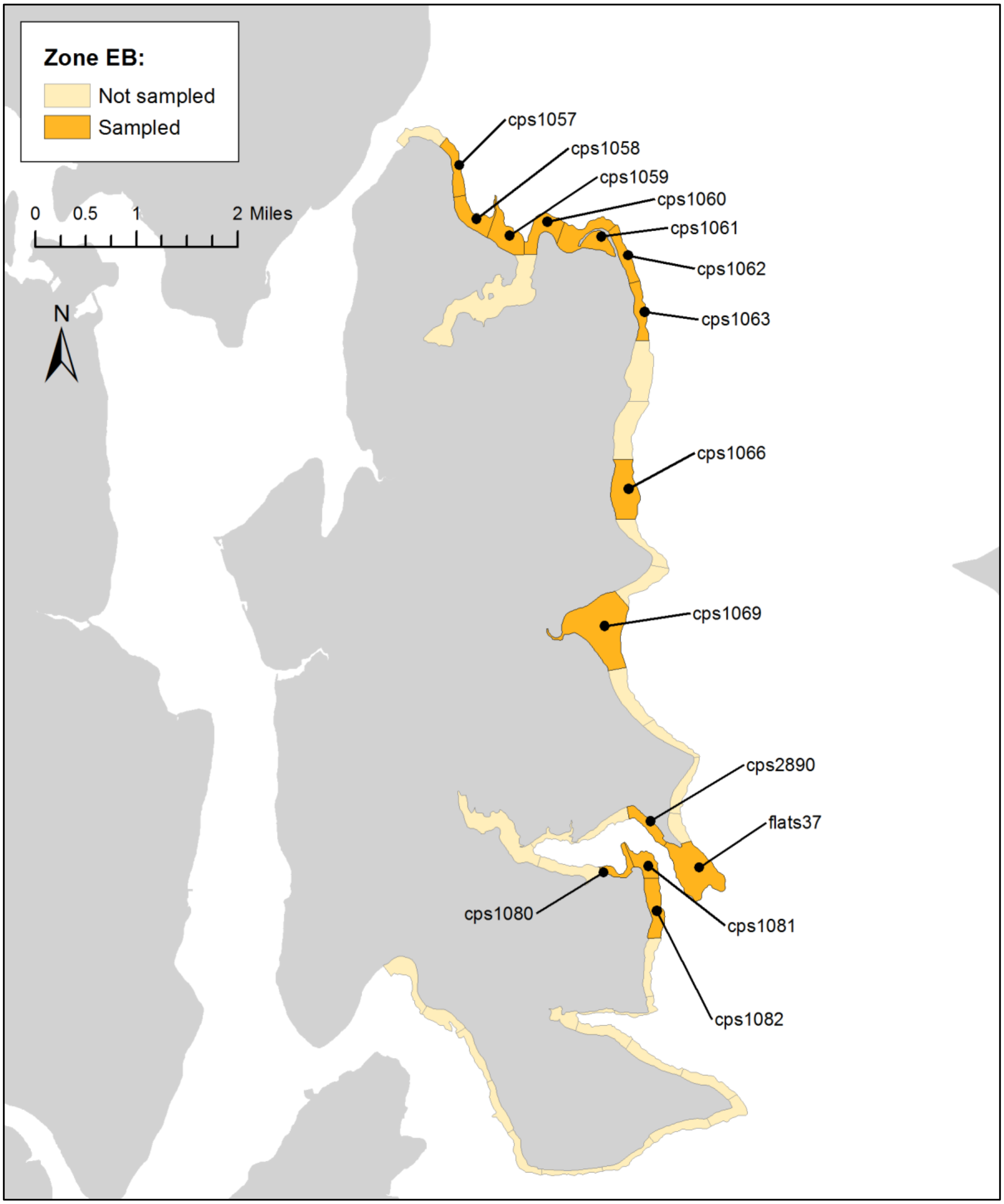
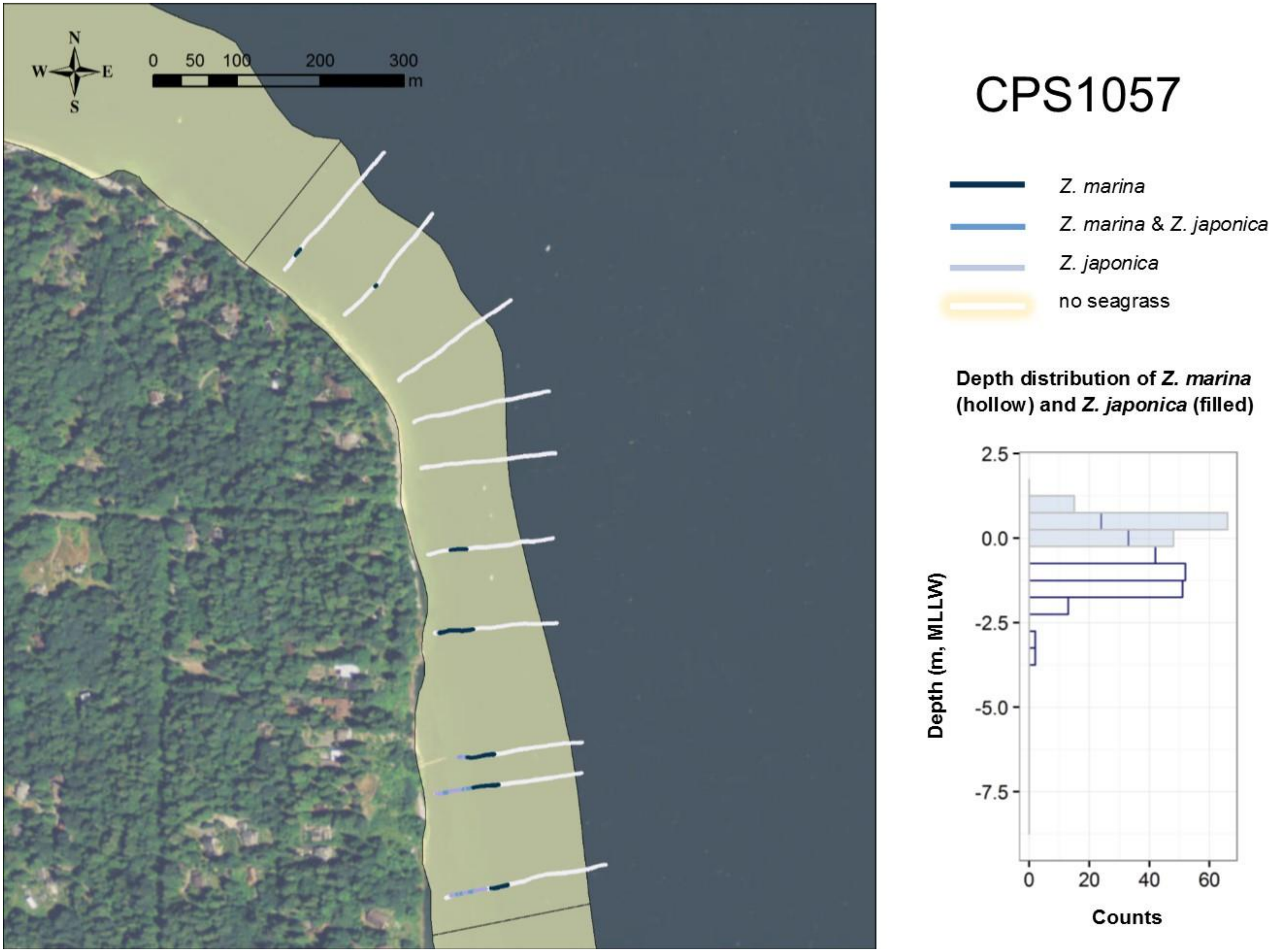
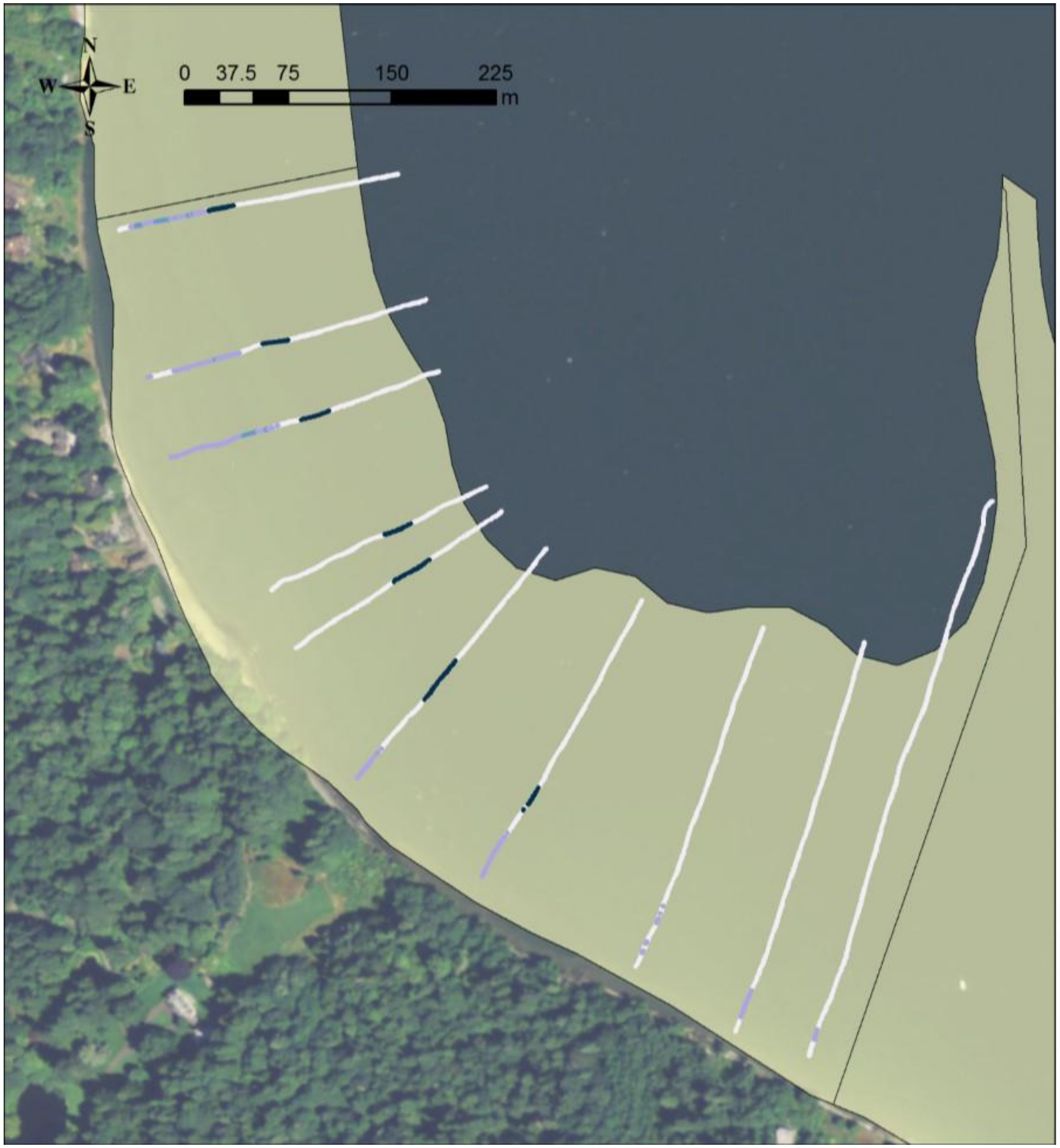


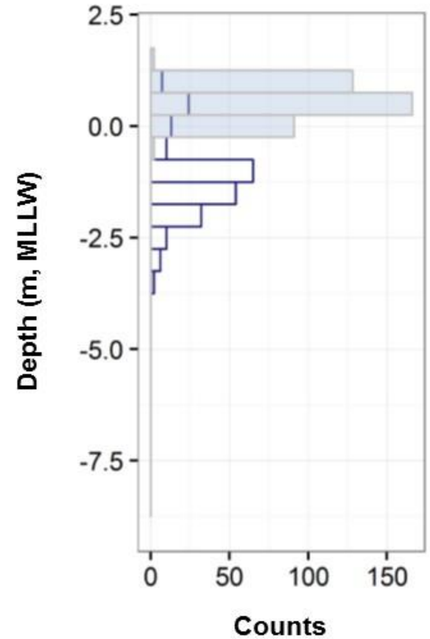
Figure 15: Eastern section of the East Kitsap study area (Zone EB, or 'East Bainbridge'). Sites that were sampled as part of IAA 15-17 are labeled and indicated in bold.


N
W
E
S
0 50 100 200 300
m
CPS1057
Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (hollow) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
20
40
60
Counts

CPS1058



N
W
E
S
0 37.5 75 150 225
m
Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass



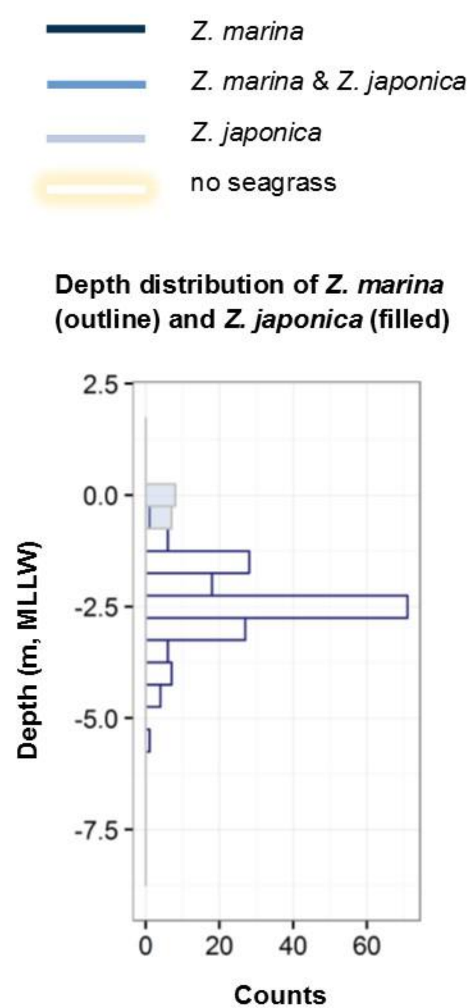
Depth distribution of Z. marina (outline) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
50
100
150
Counts

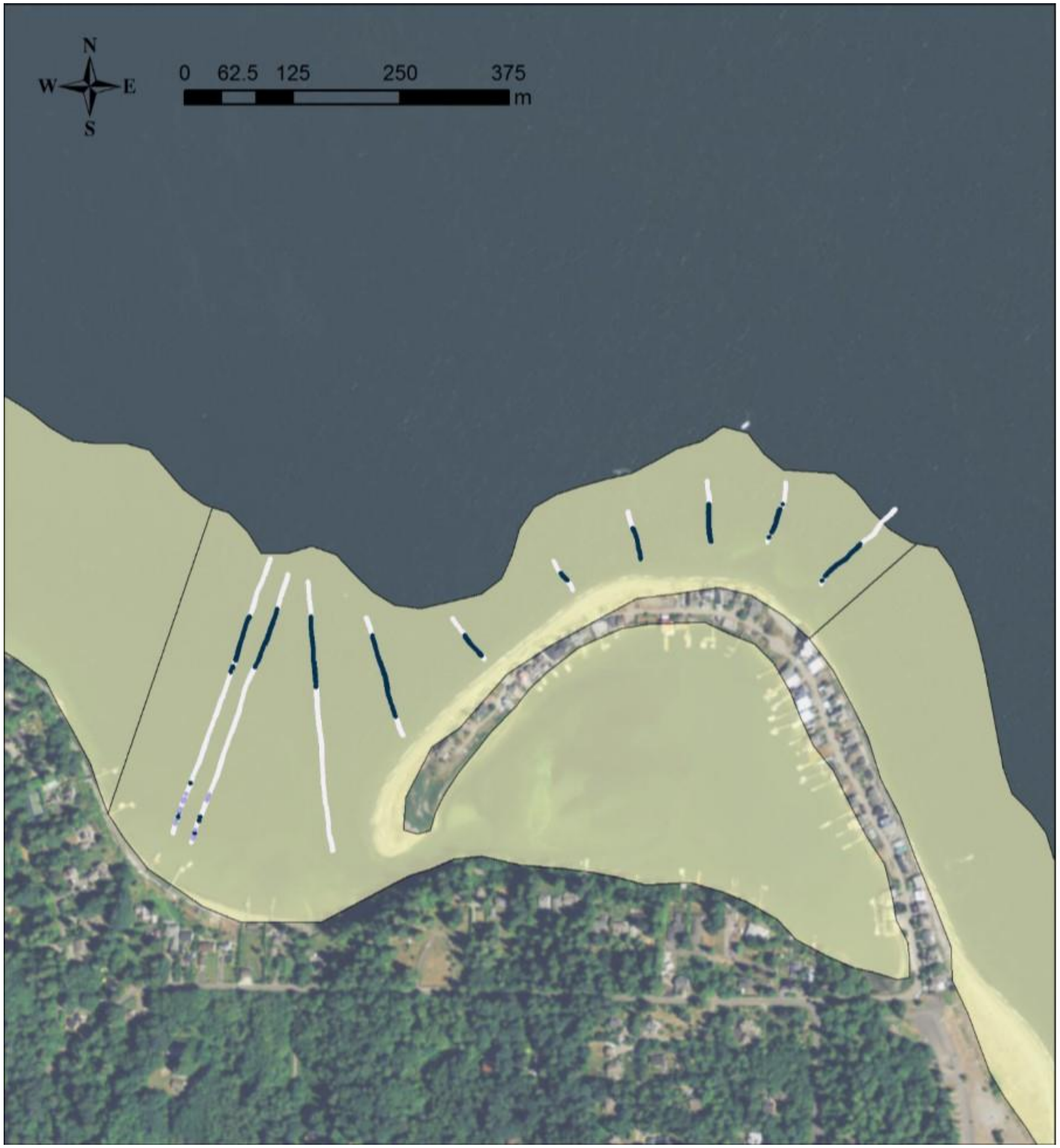
CPS1059

no seagrass

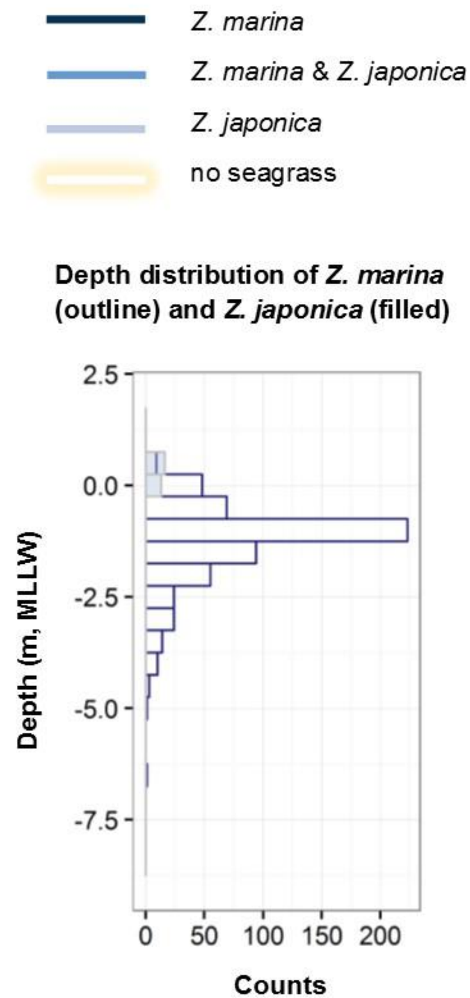

N
S
W
E
0 37.5 75 150 225
m

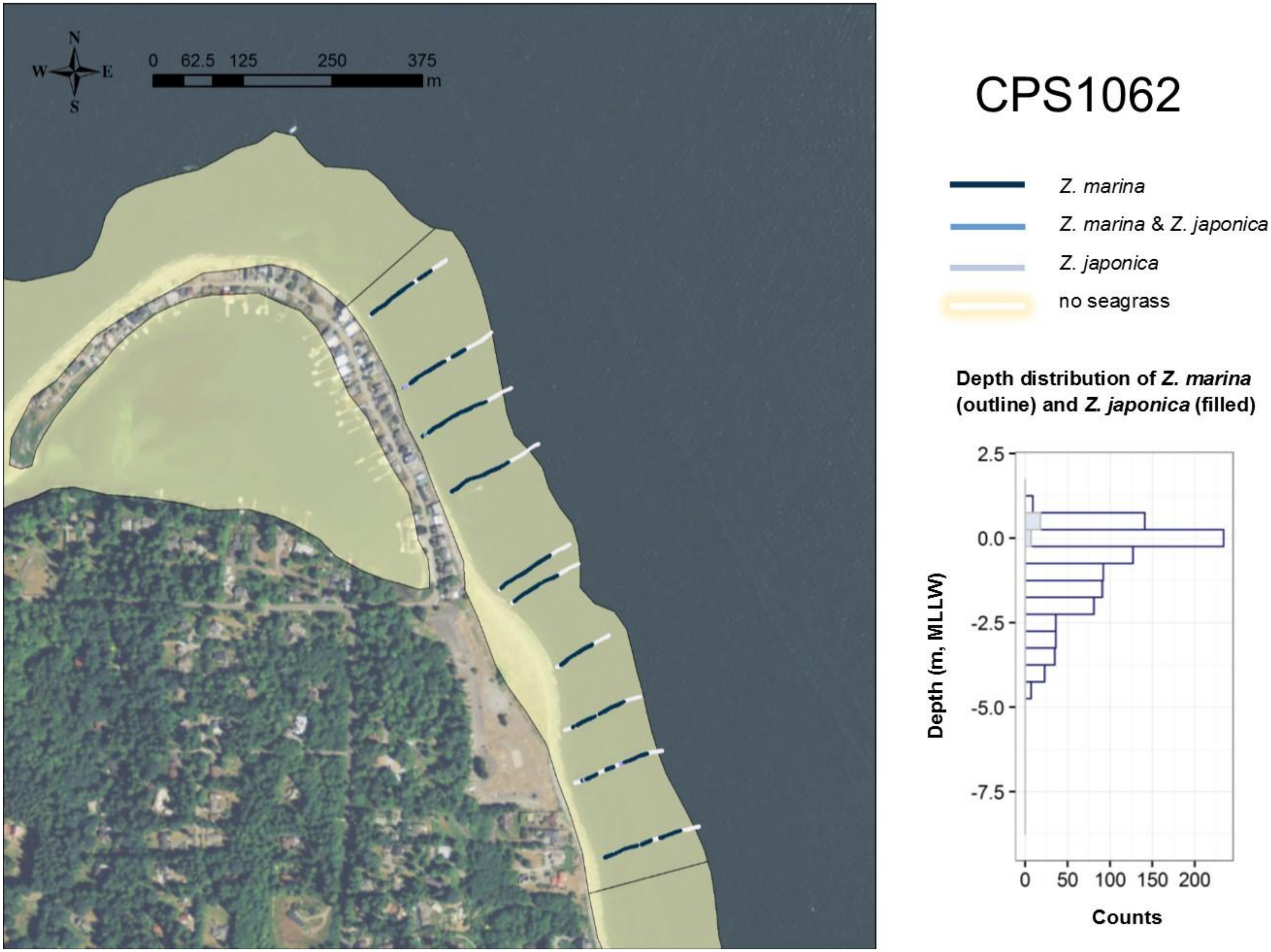
CPS1060


Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
20
40
60
Counts

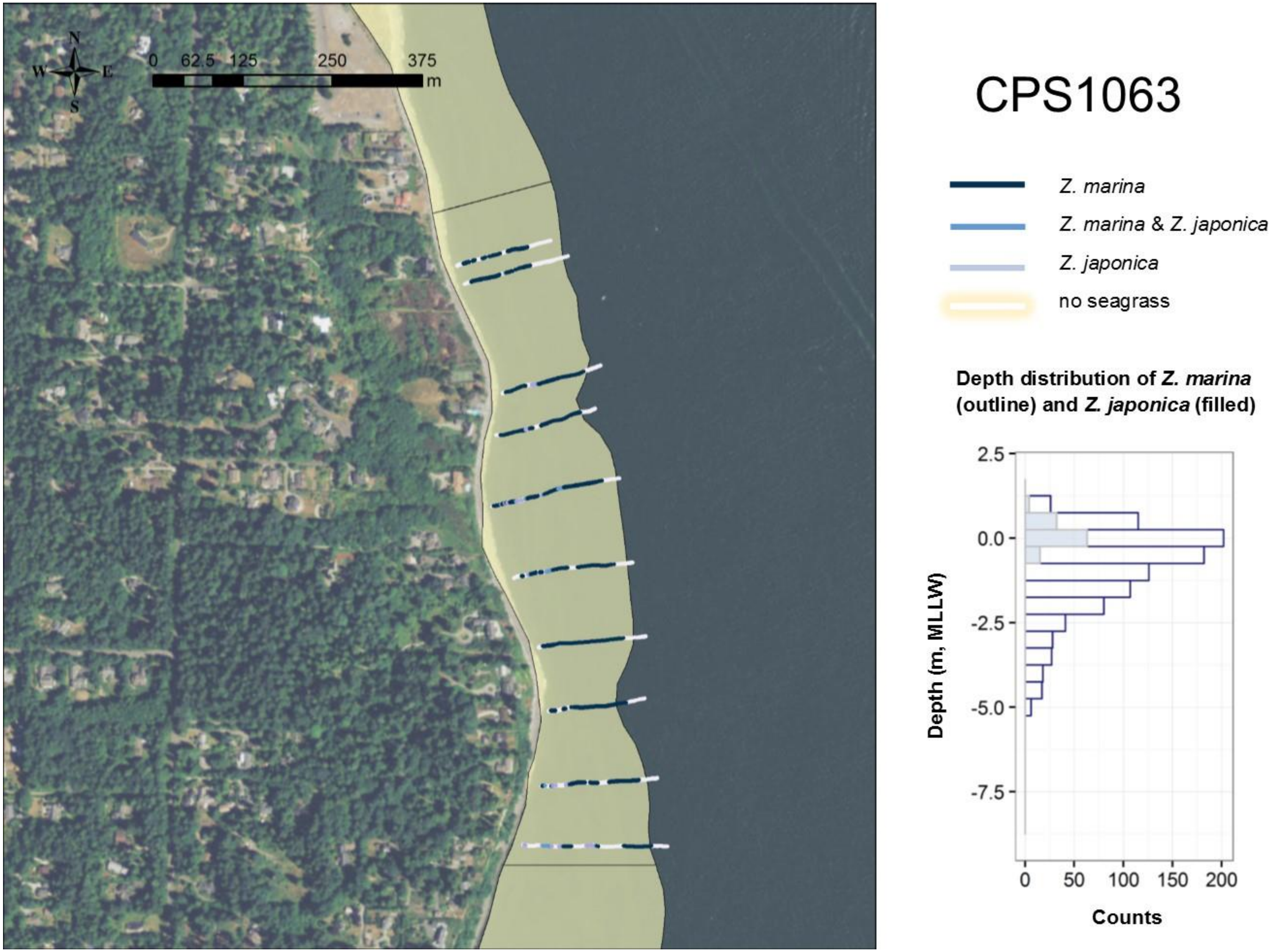

N
W
E
S
0 62.5 125 250 375
m

CPS1061


Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
50
100
150
200
Counts

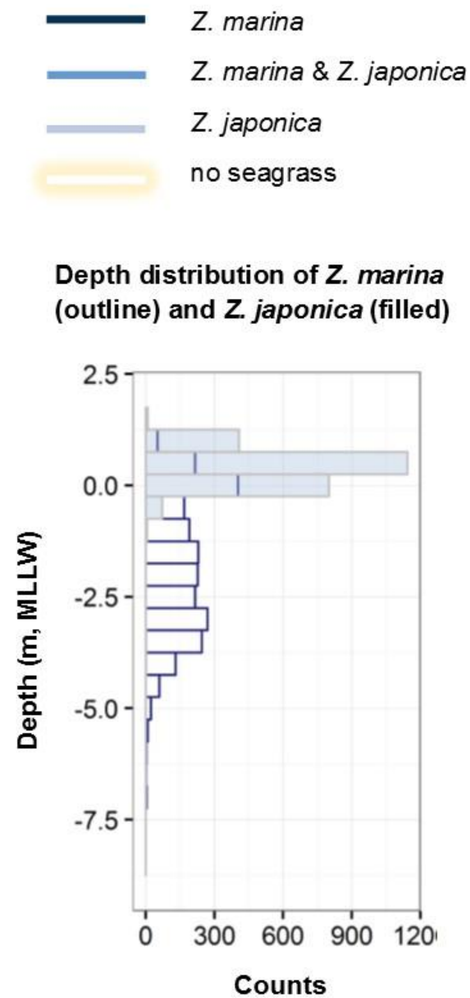

0 62.5 125 250 375
m
N
S
W
E
CPS1062
Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0 50 100 150 200
Counts

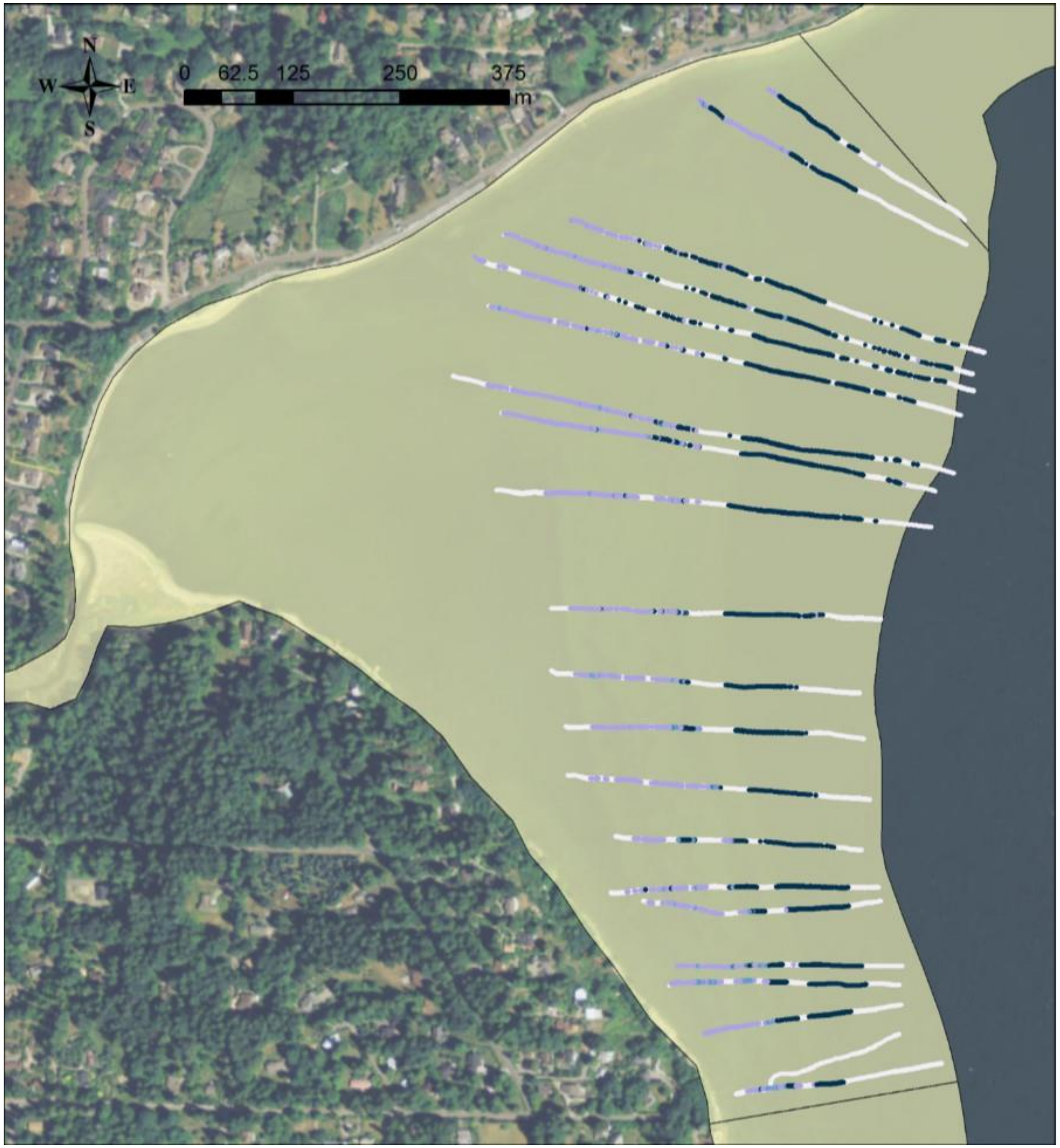
CPS1063


N
S
W
E
0
62.5
125
250
375
m
Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
50
100
150
200
Counts


N
S
W
E
0 62.5 125 250 375
m

CPS1066


Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
300
600
900
120
Counts



CPS1069

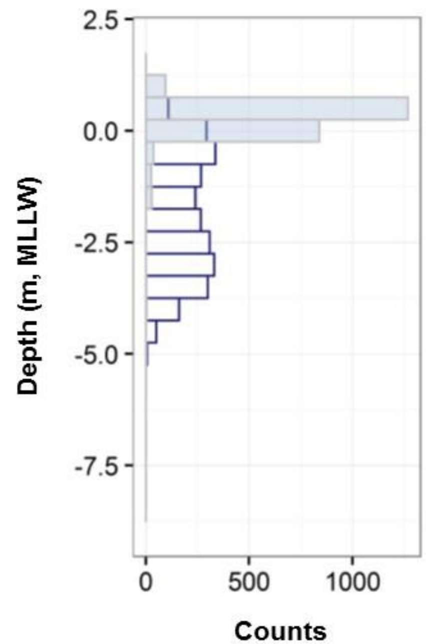
Z. marina

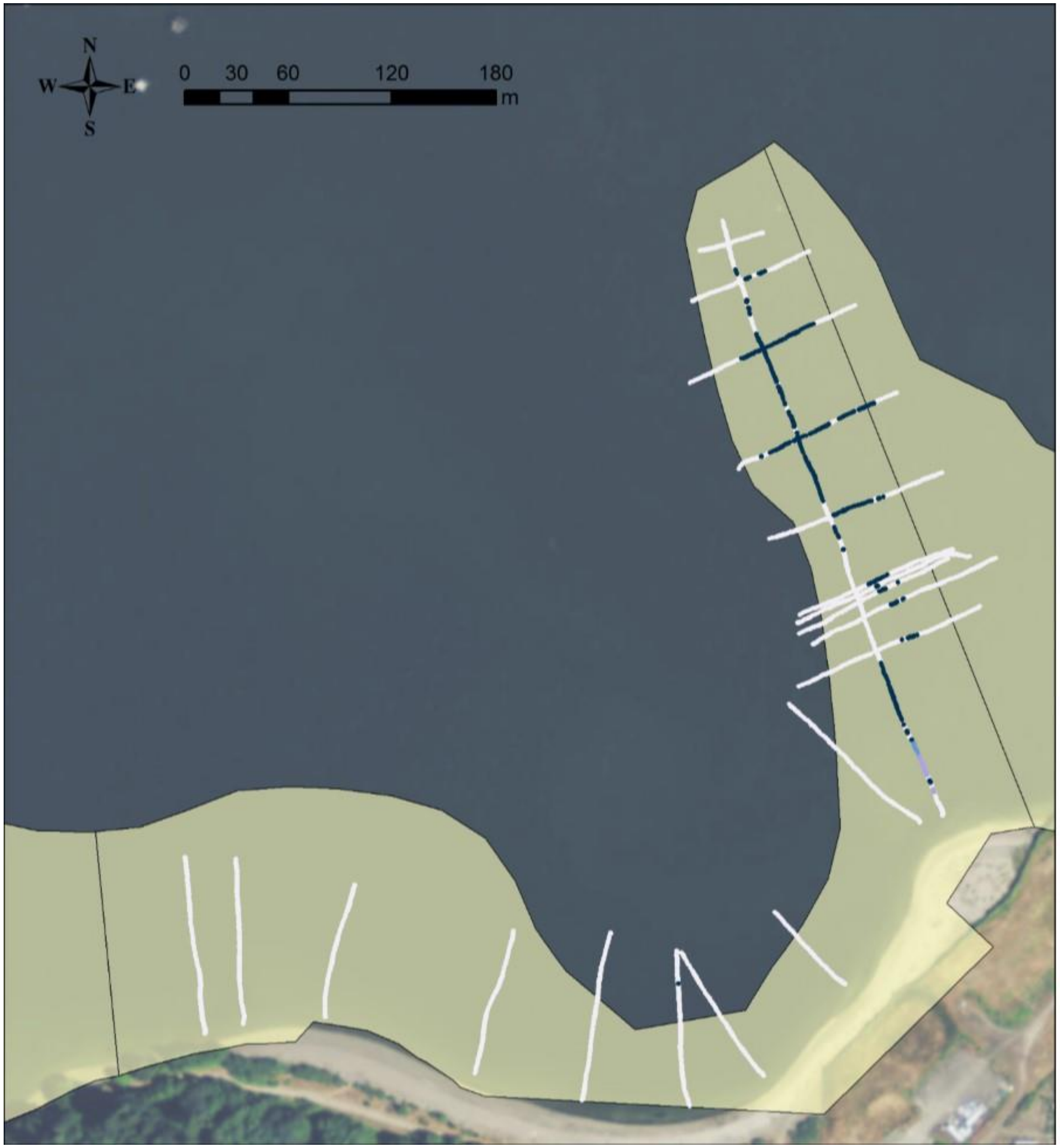
Z. marina & *Z. japonica*

Z. japonica

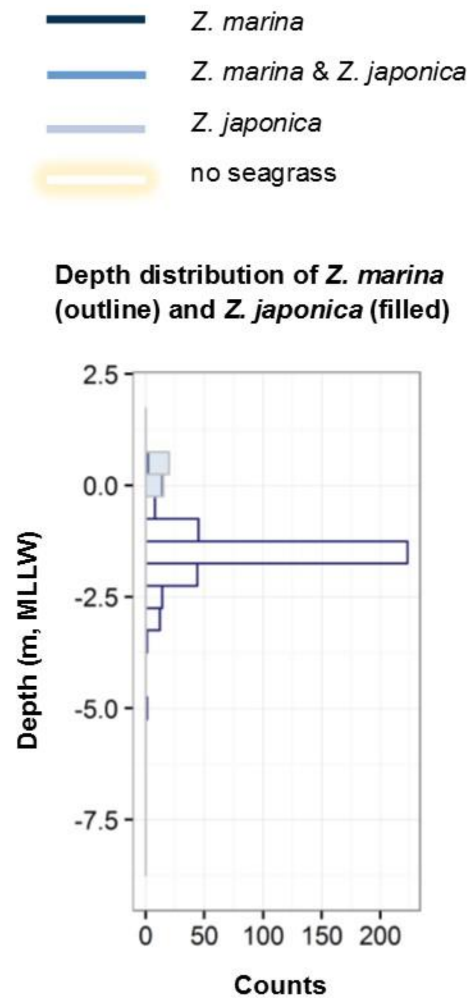
no seagrass

Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)



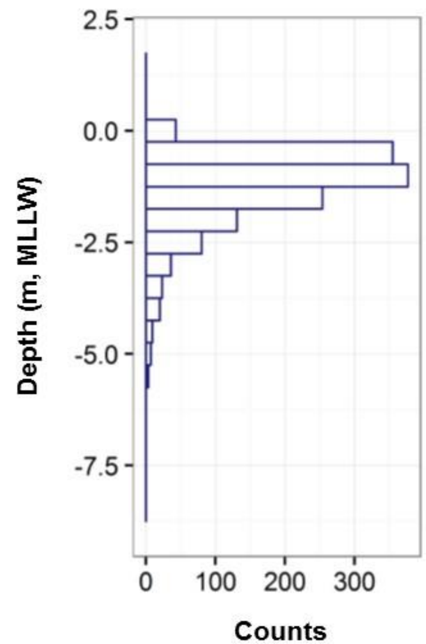

N
S
W
E
0 30 60 120 180
m

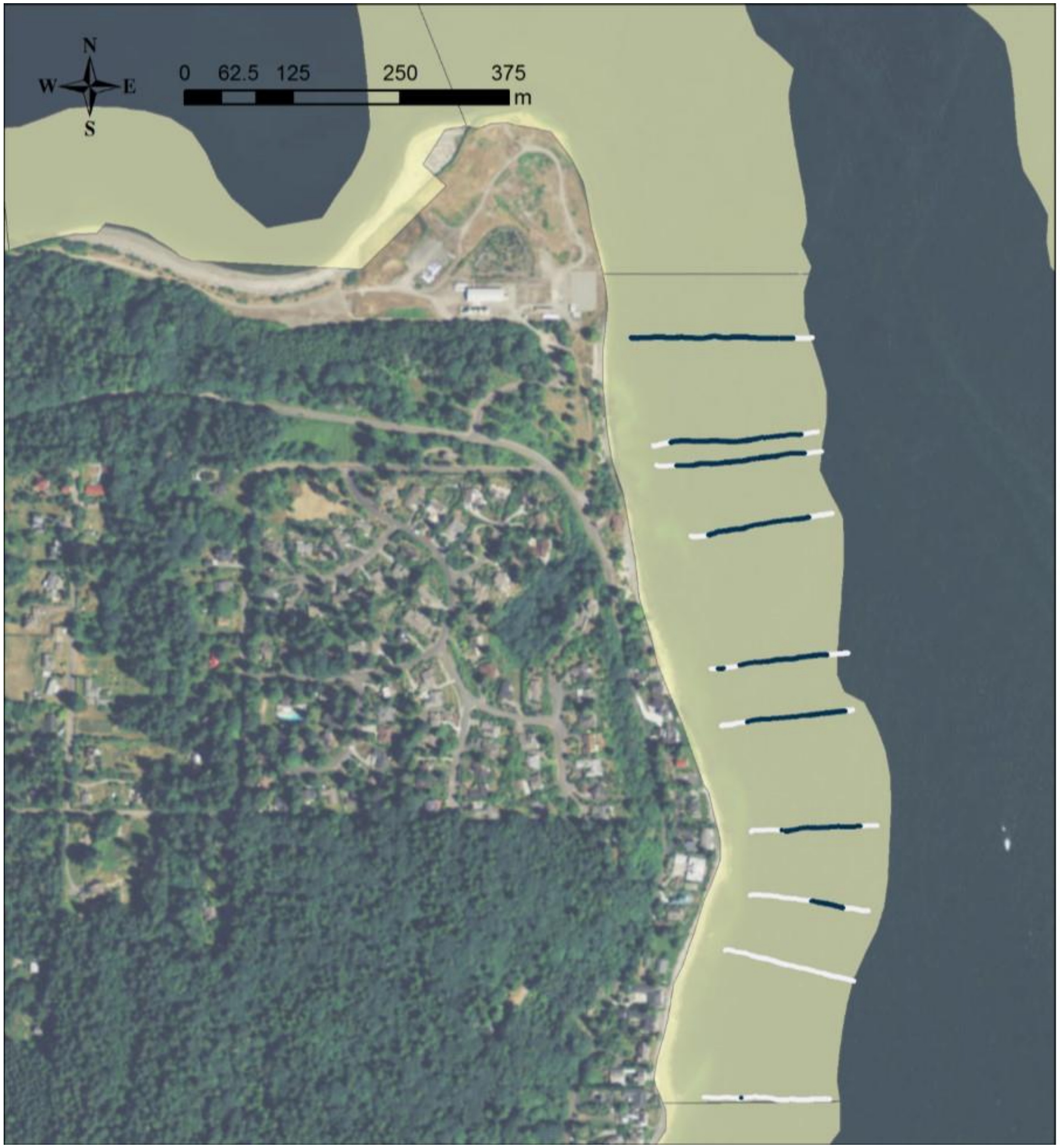
CPS1080


Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0 50 100 150 200
Counts

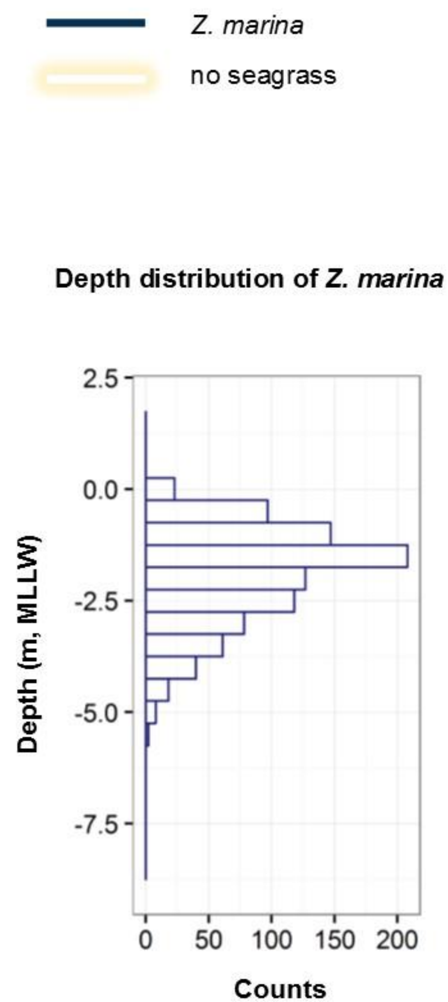
CPS1081

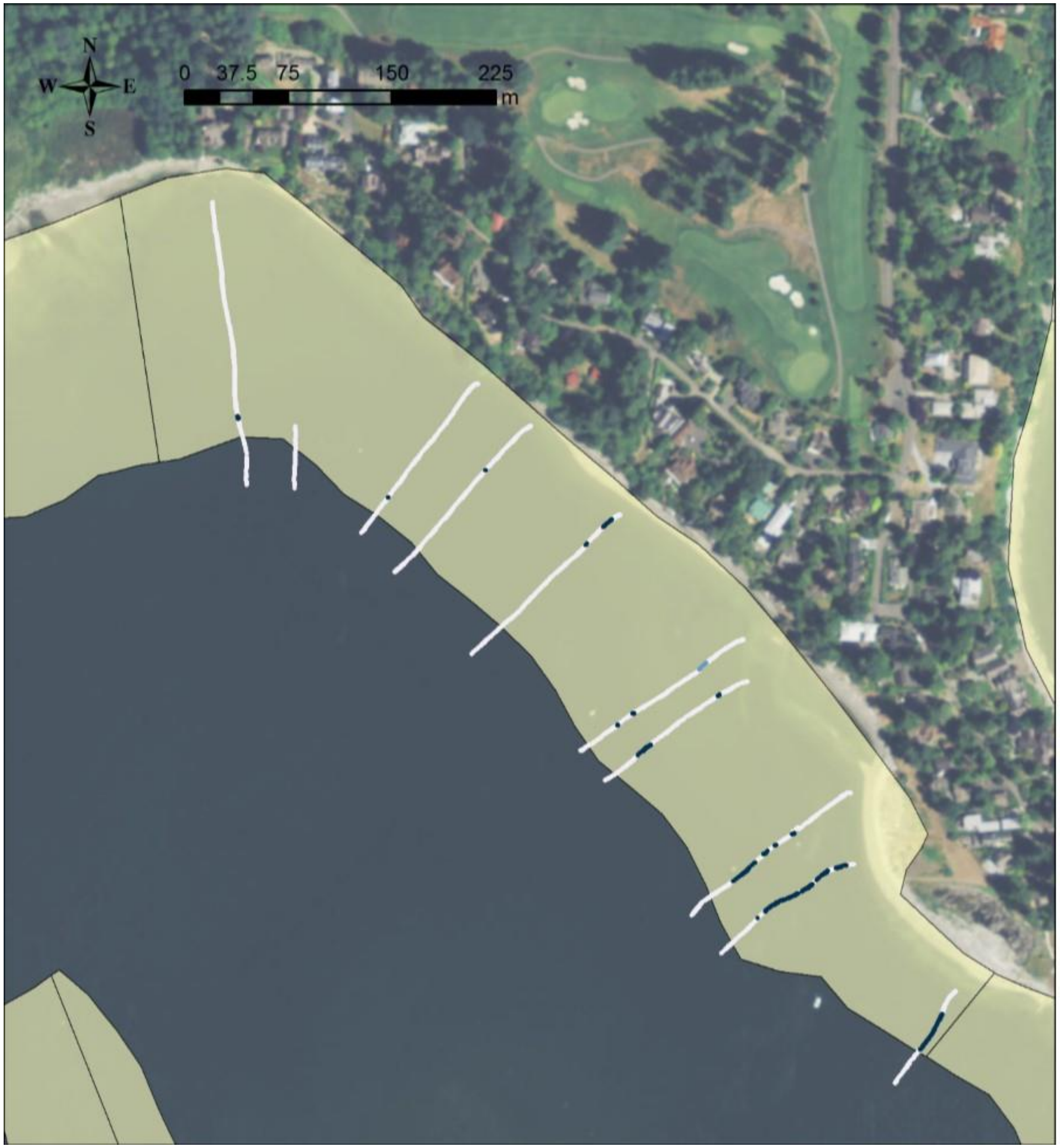
Depth distribution of *Z. marina*



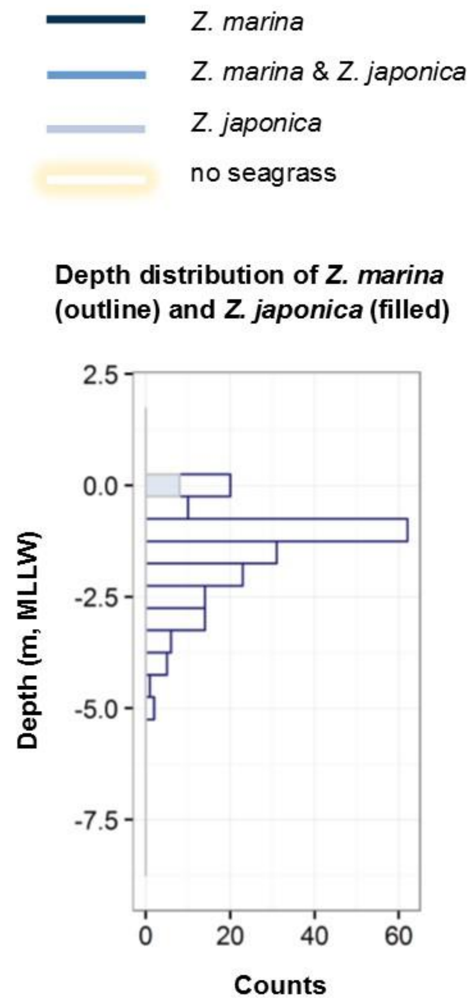

N
W
E
S
0 62.5 125 250 375
m

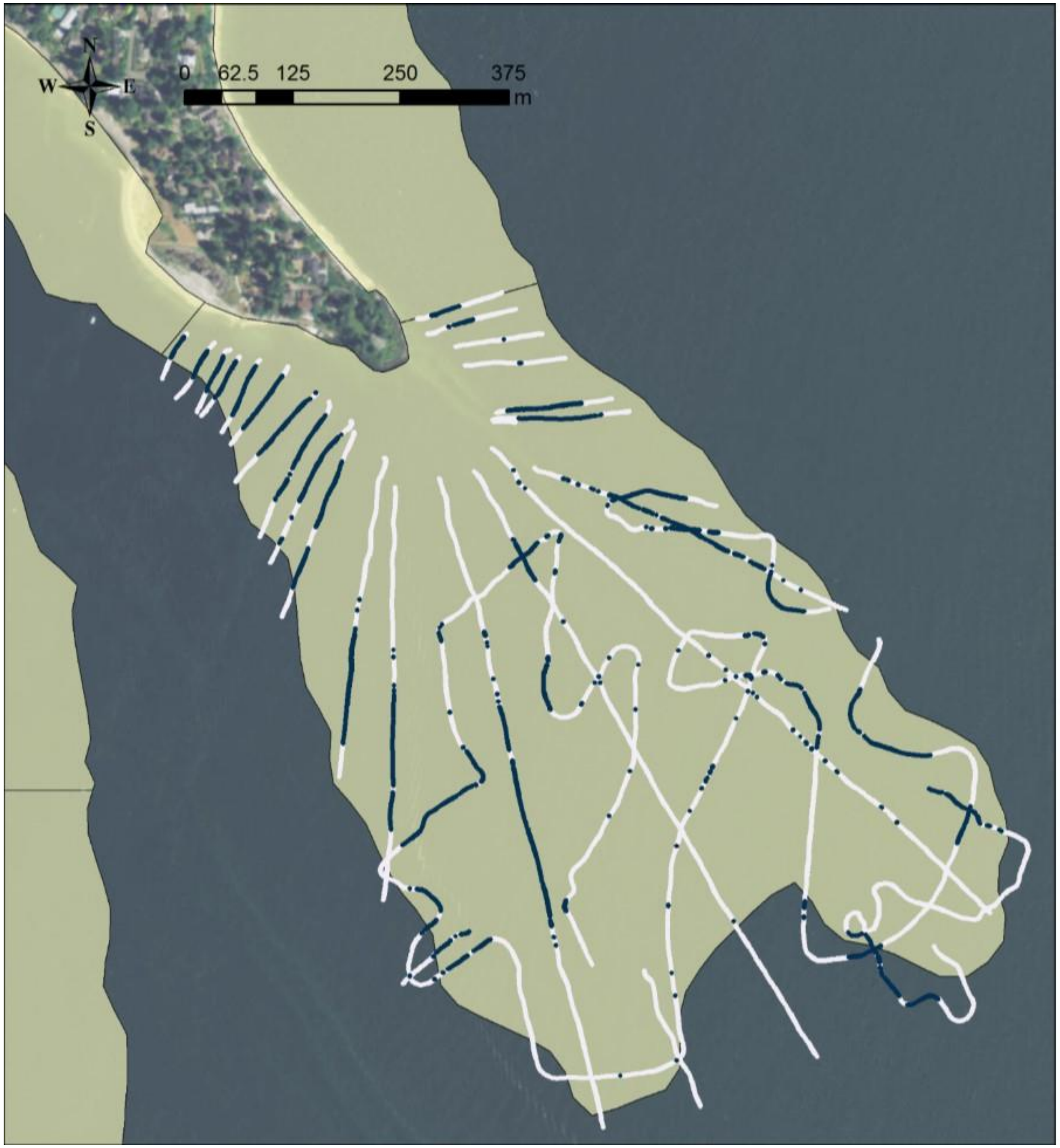
CPS1082


Z. marina
no seagrass
Depth distribution of Z. marina
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0 50 100 150 200
Counts

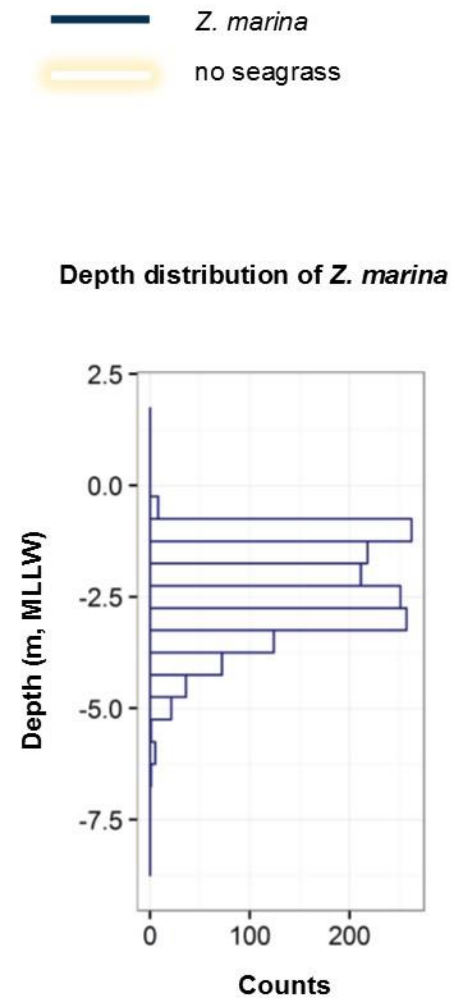

N
W
E
S
0 37.5 75 150 225
m

CPS2890


Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
20
40
60
Counts


N
W
E
S
0 62.5 125 250 375
m

FLATS37


Z. marina
no seagrass
Depth distribution of Z. marina
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
100
200
Counts

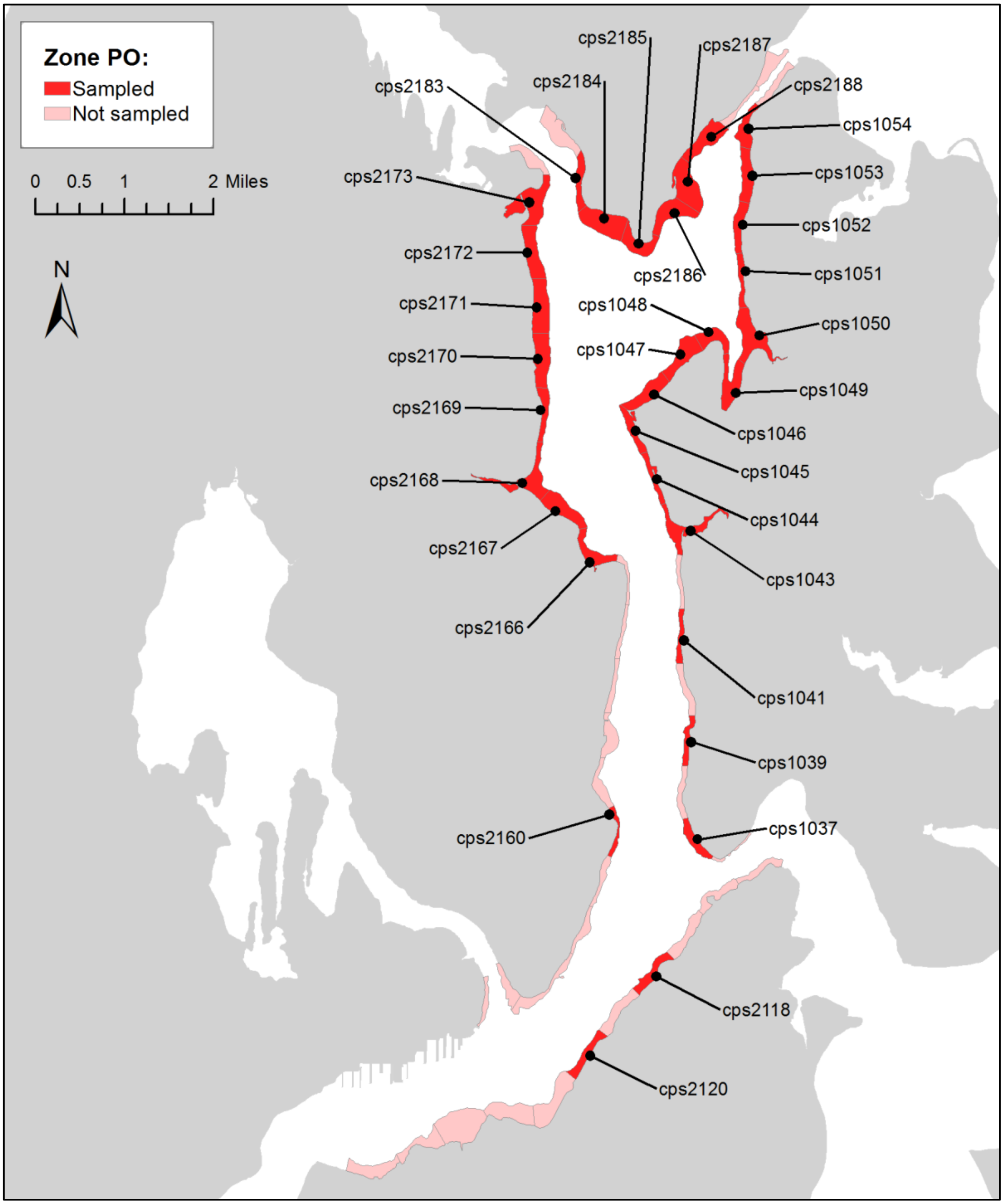
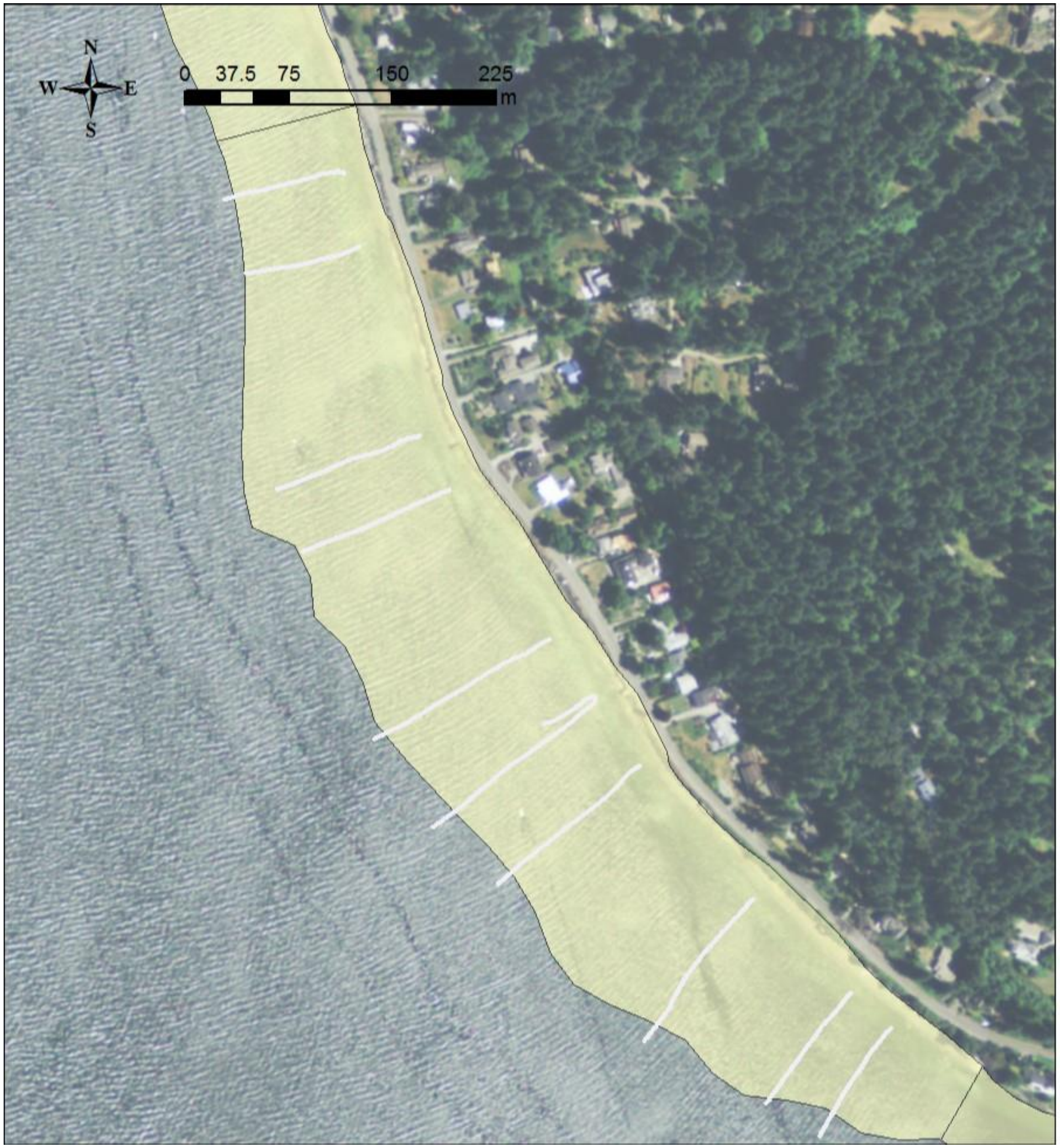
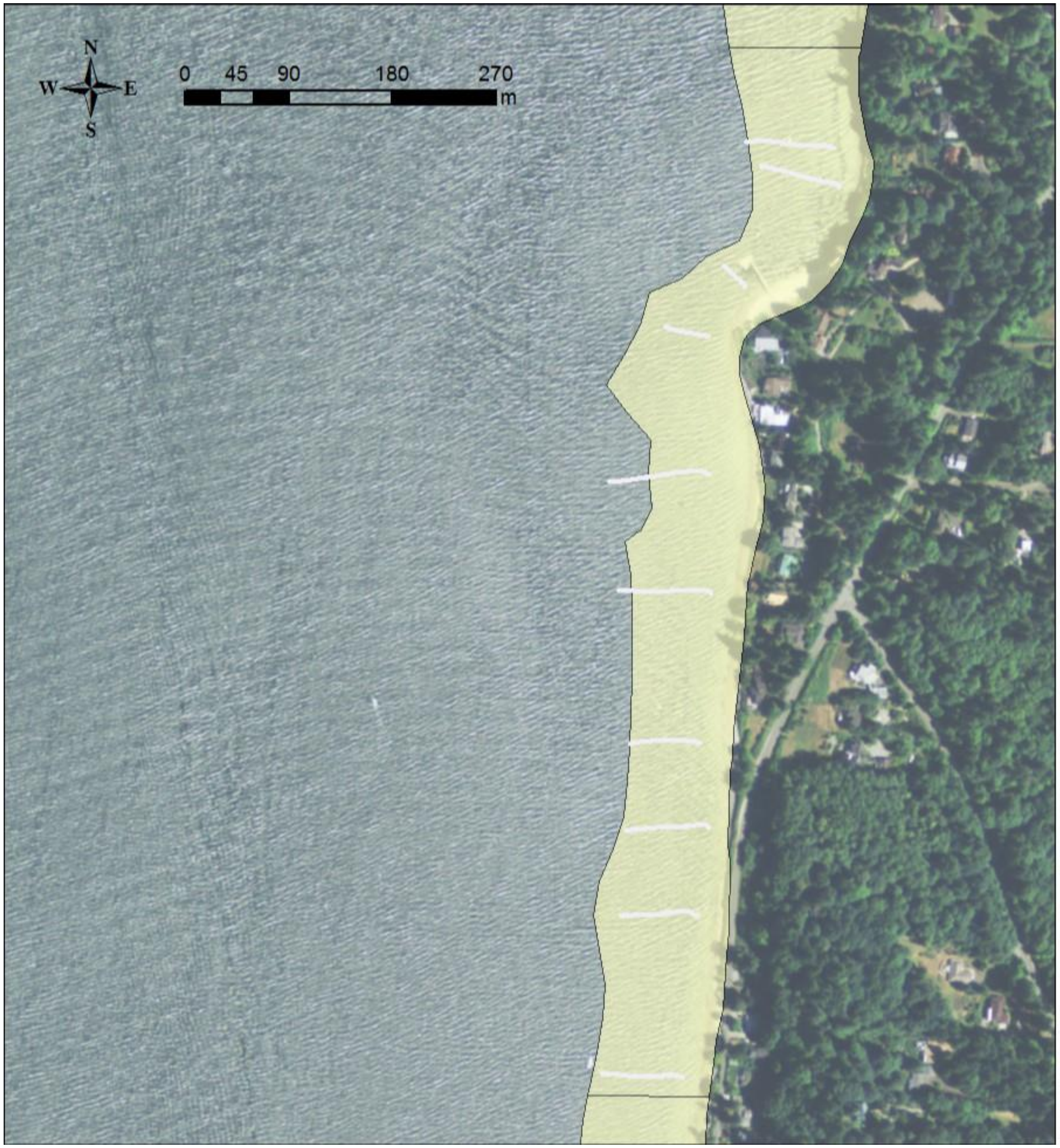


Figure 16: Mid-section of the East Kitsap study area (Zone PO, or 'Port Orchard & Sinclair Inlet'). Sites that were sampled as part of IAA 15-17 are labeled and indicated in bold.

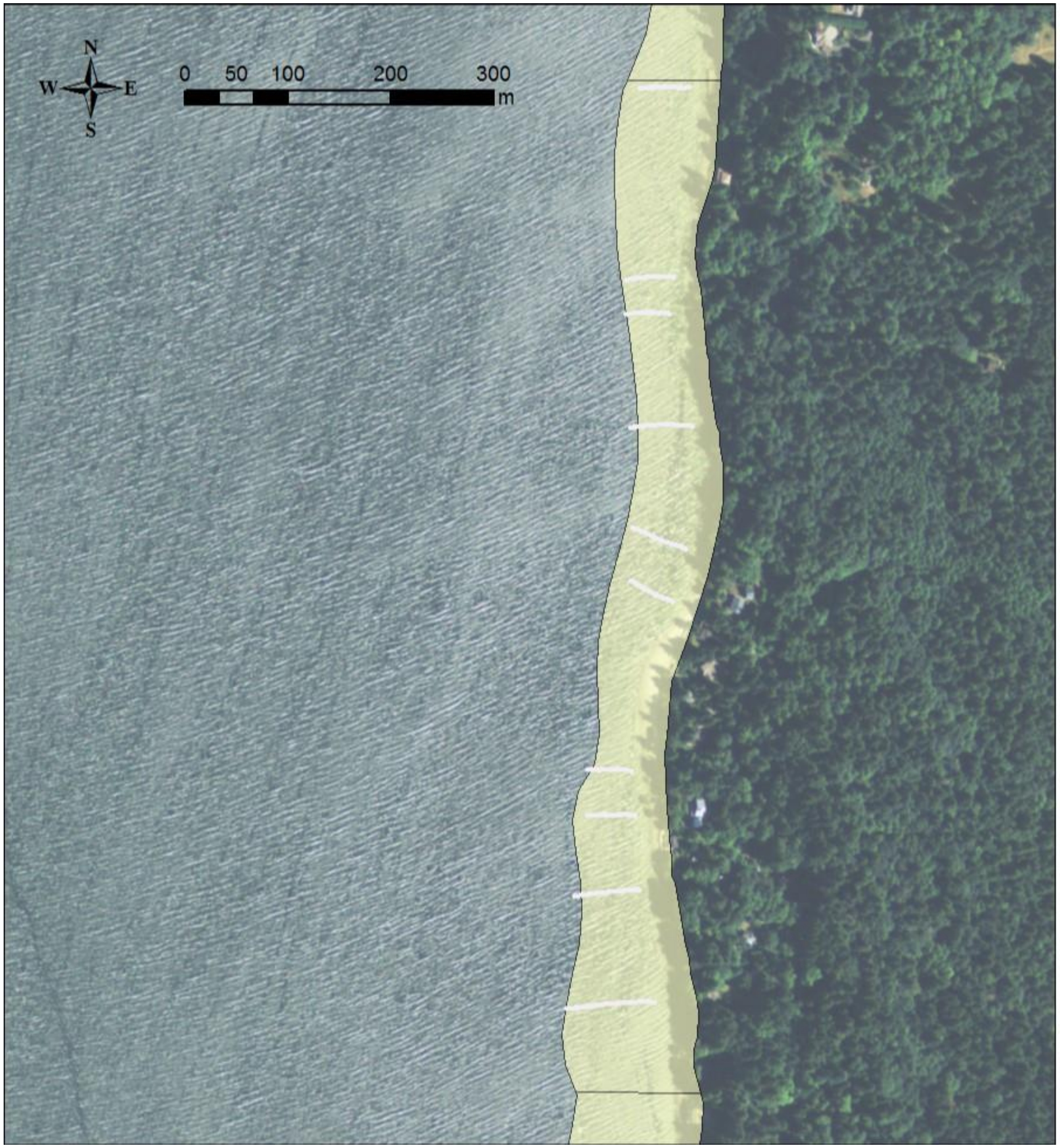


CPS1037

no seagrass



CPS1039



CPS1041

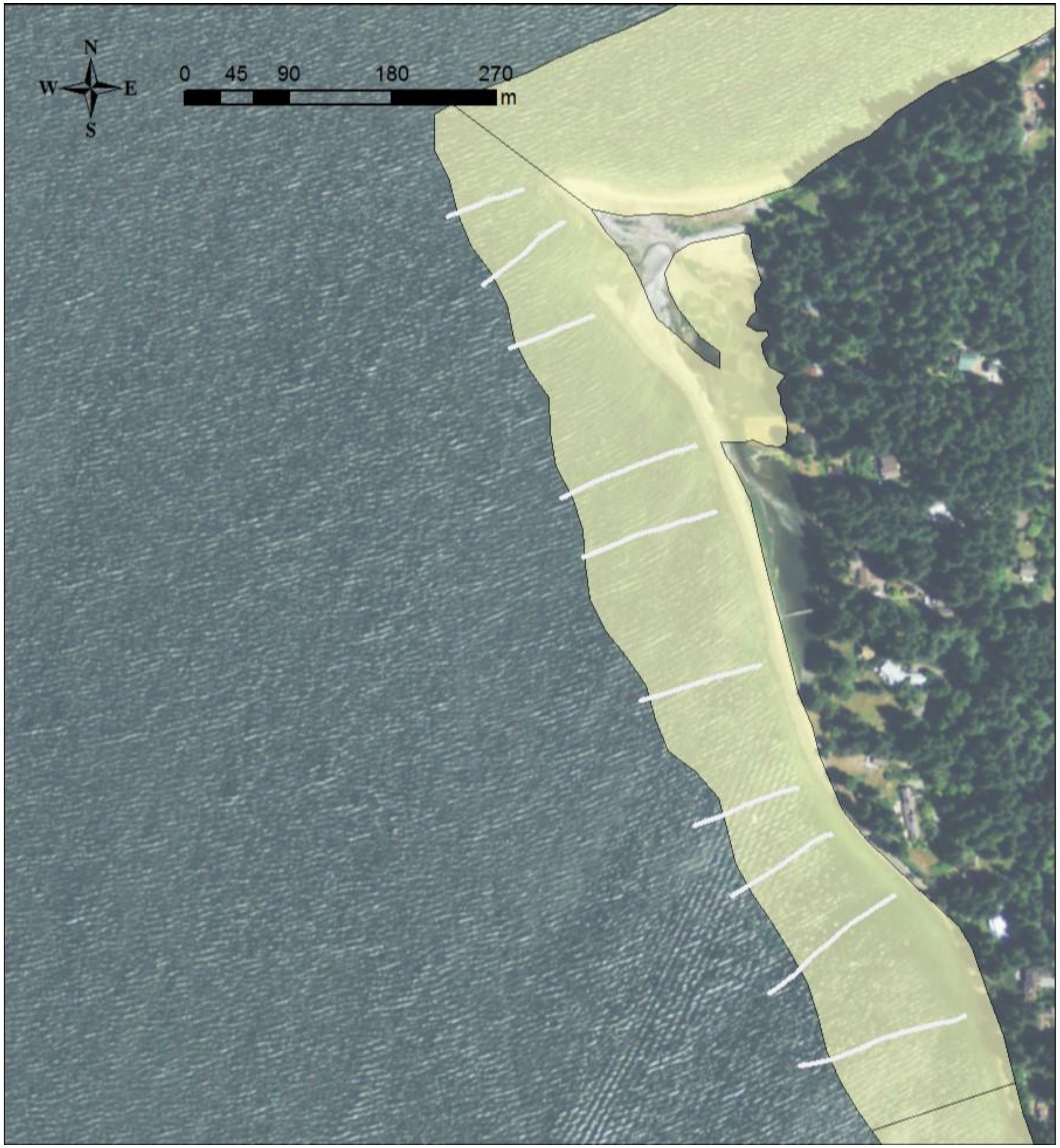
no seagrass

CPS1043

no seagrass

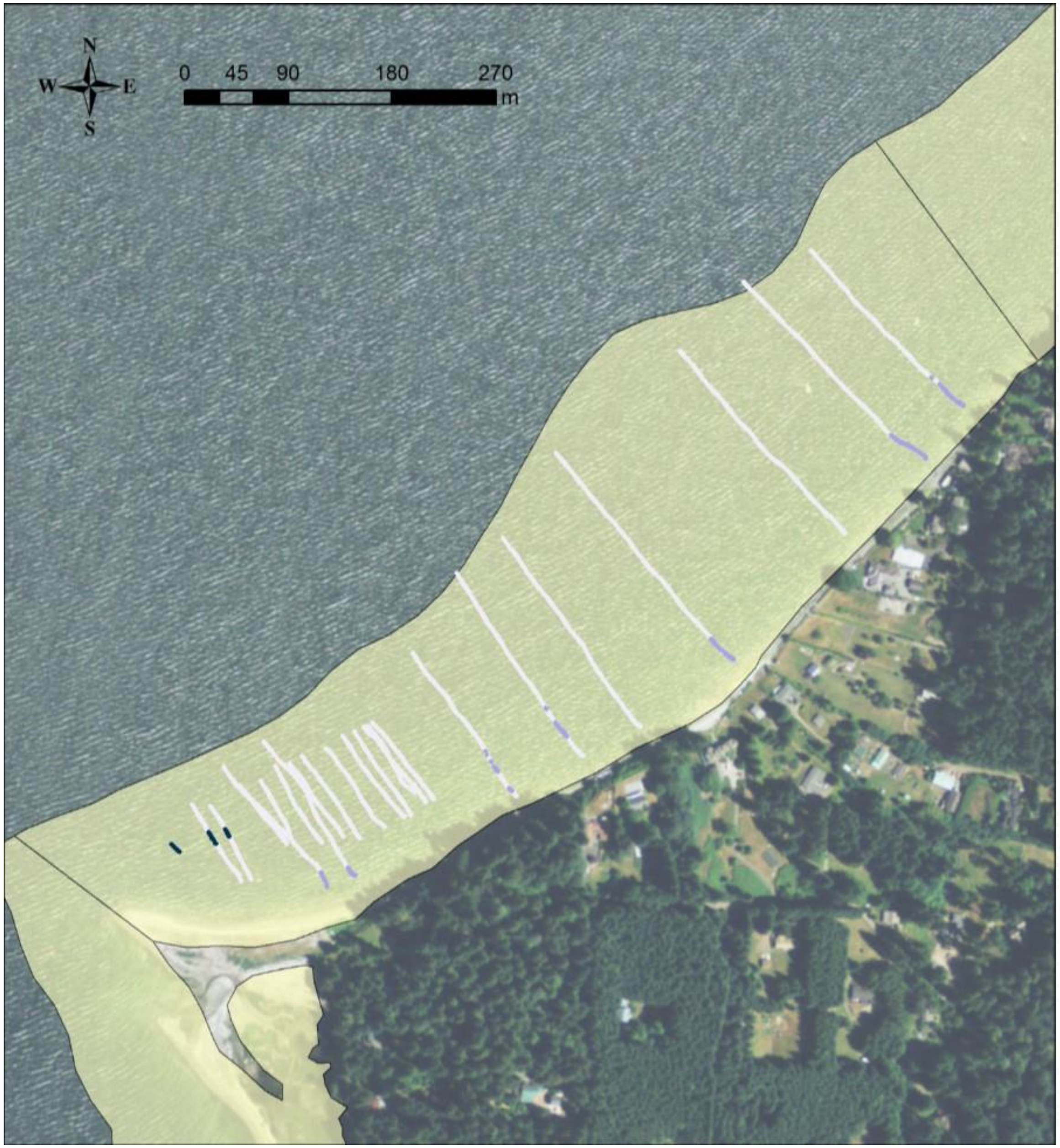
CPS1044

no seagrass



CPS1045

no seagrass



CPS1046

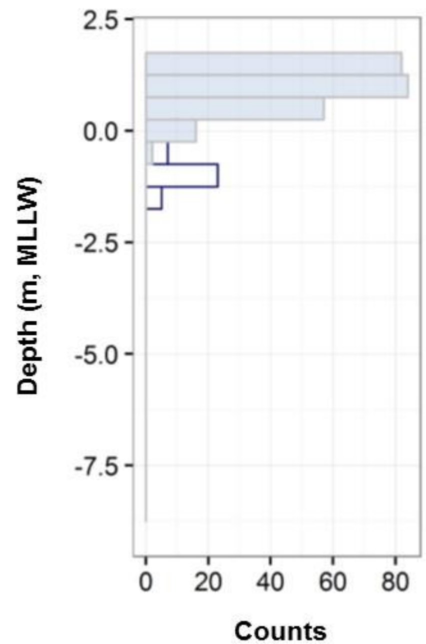
Z. marina

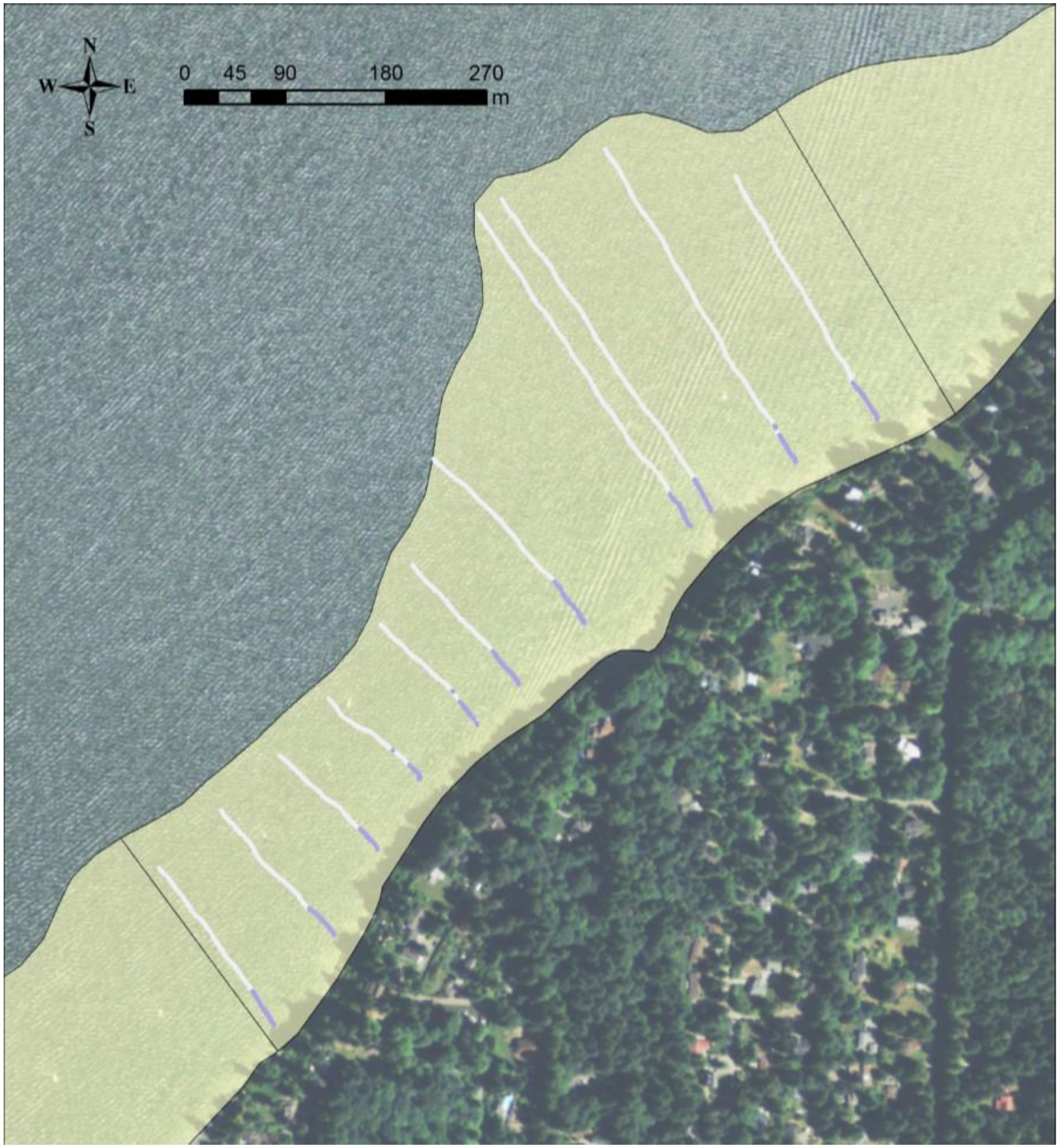
Z. marina & *Z. japonica*

Z. japonica

no seagrass

Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)

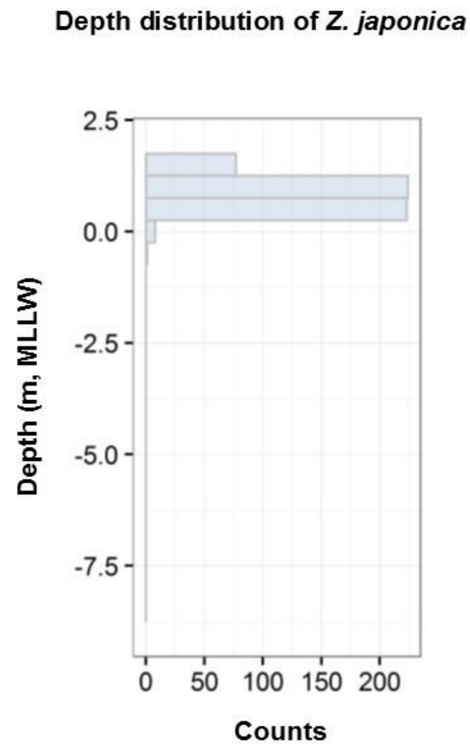


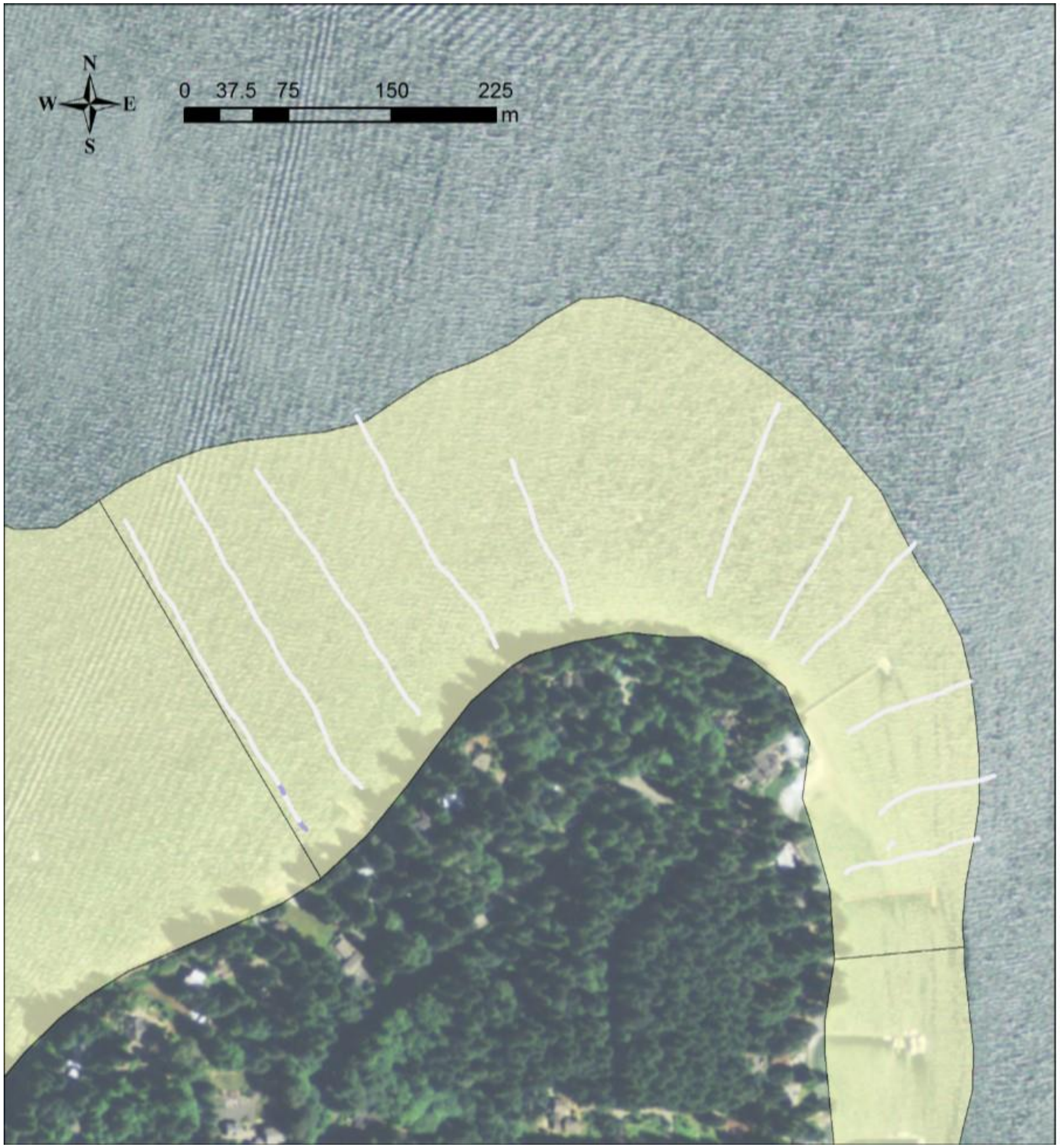


CPS1047

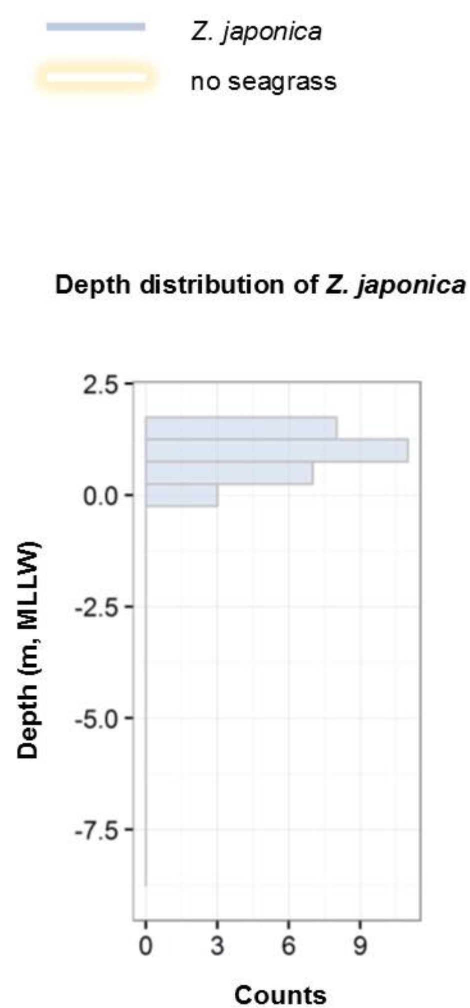
Z. japonica

no seagrass



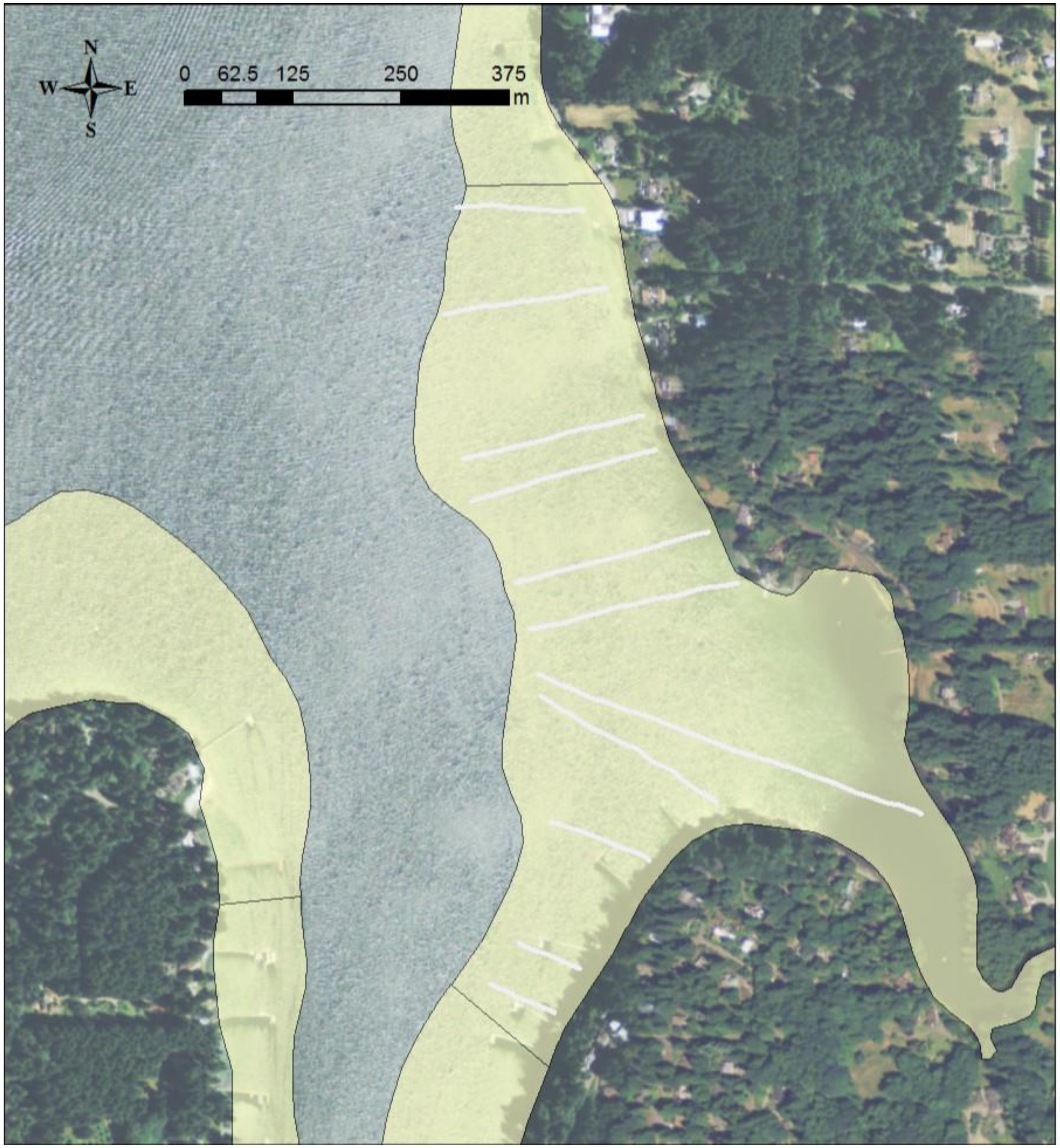

N
W
E
S
0 37.5 75 150 225
m

CPS1048


Z. japonica
no seagrass
Depth distribution of Z. japonica
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
3
6
9
Counts

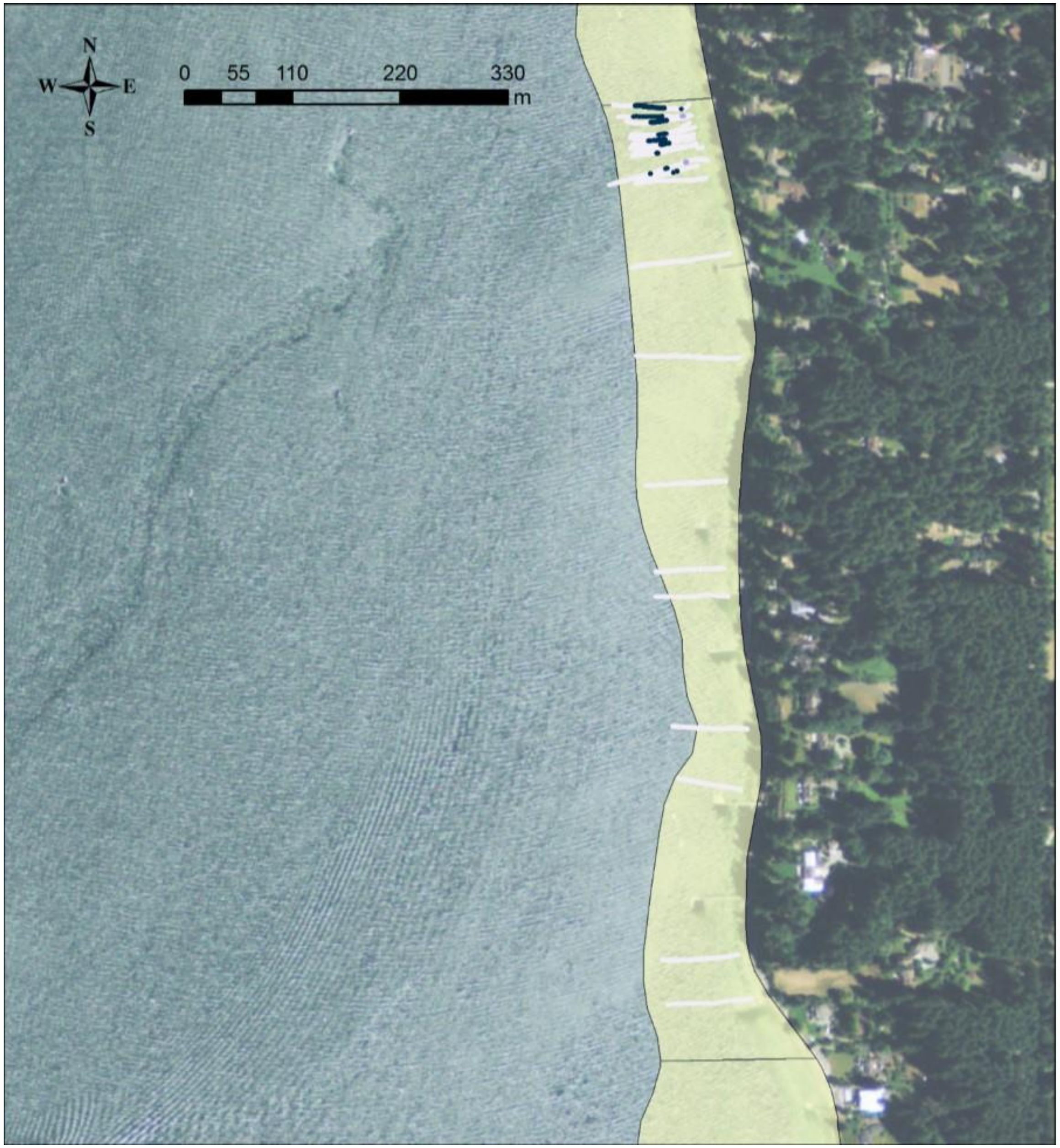
CPS1049

no seagrass



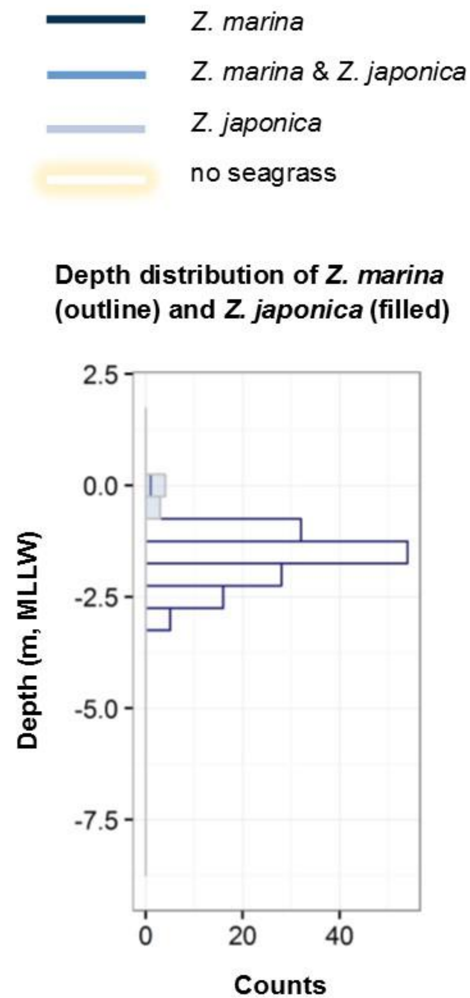
CPS1050

no seagrass



N
W
E
S
0 55 110 220 330
m

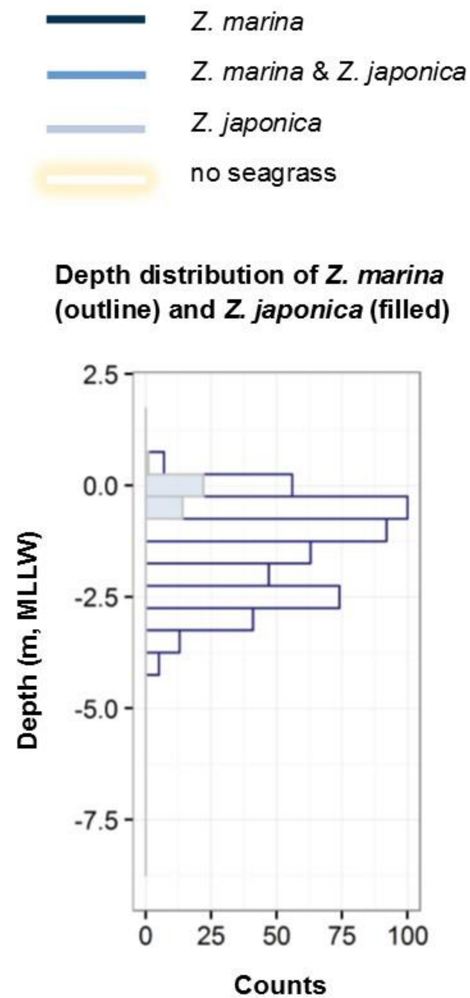
CPS1051



Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
20
40
Counts

CPS1052

N
W
E
S
0
55
110
220
330
m

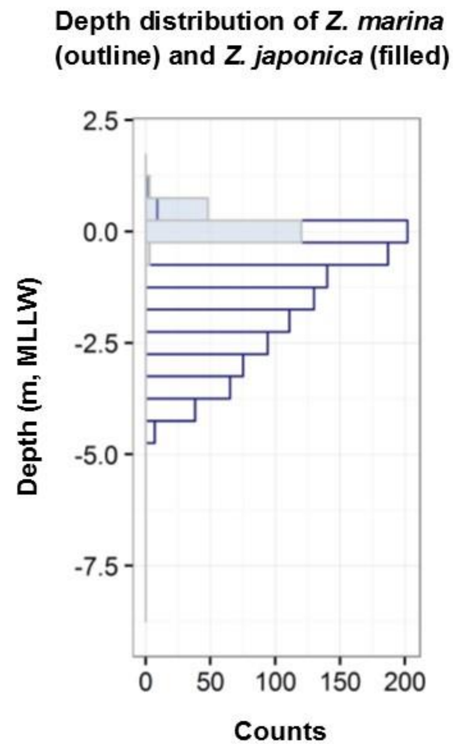


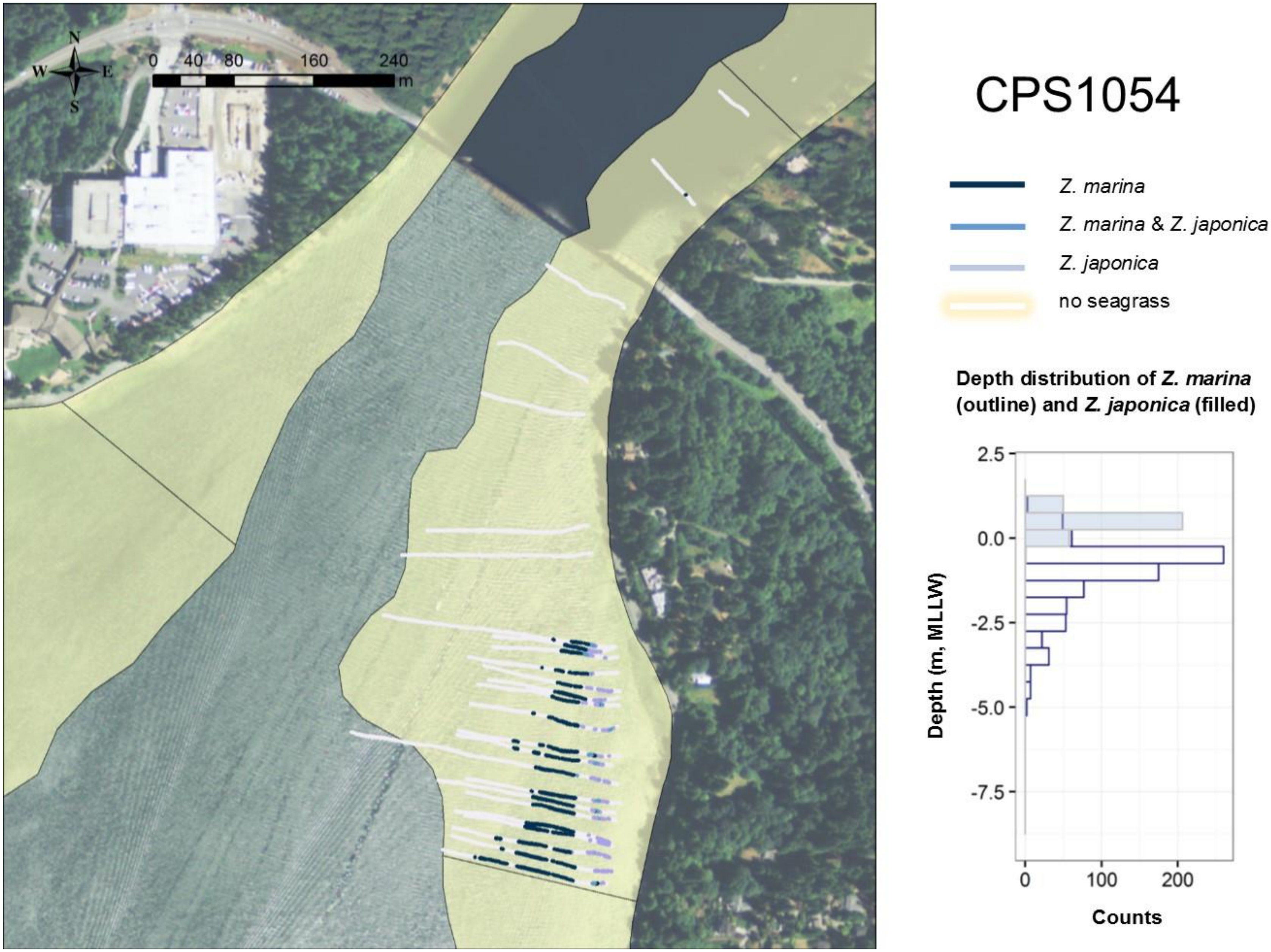
Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
25
50
75
100
Counts

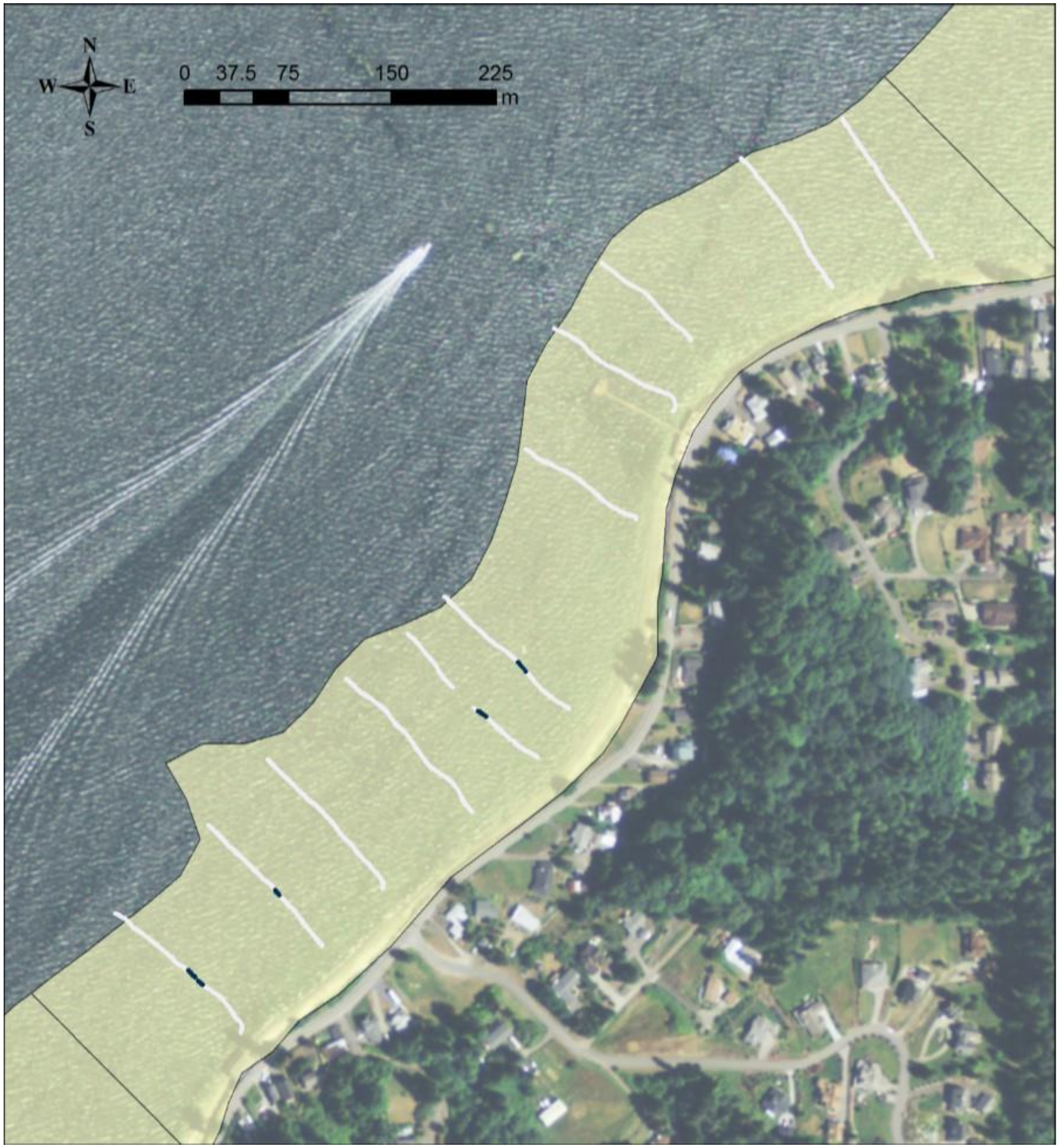

N
W
E
S
0 55 110 220 330
m

CPS1053


Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass

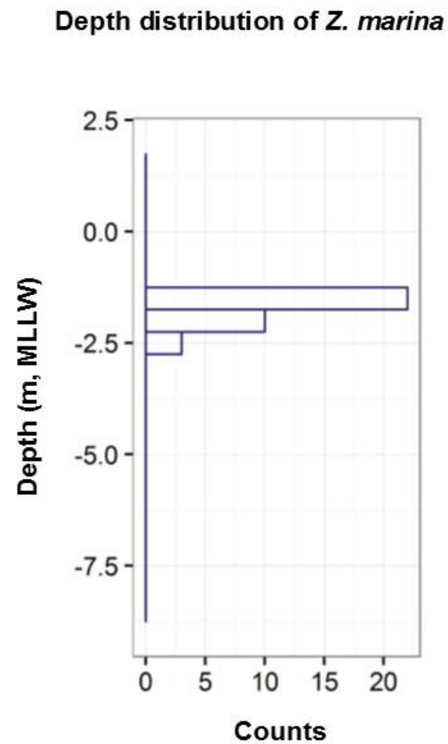

Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0 50 100 150 200
Counts

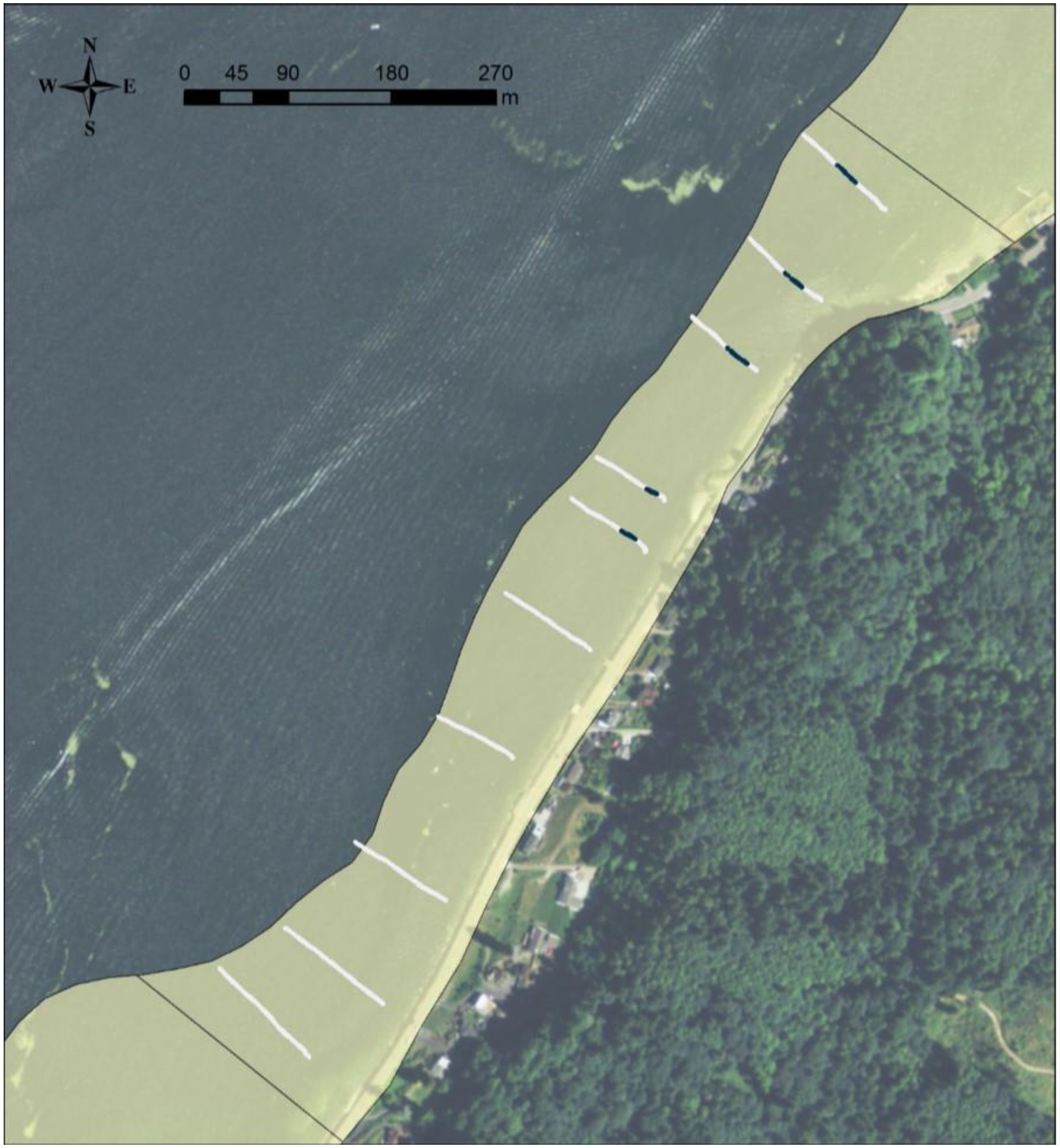

N
S
W
E
0
40
80
160
240
m
CPS1054
Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
100
200
Counts


N
S
W
E
0 37.5 75 150 225
m

CPS2118

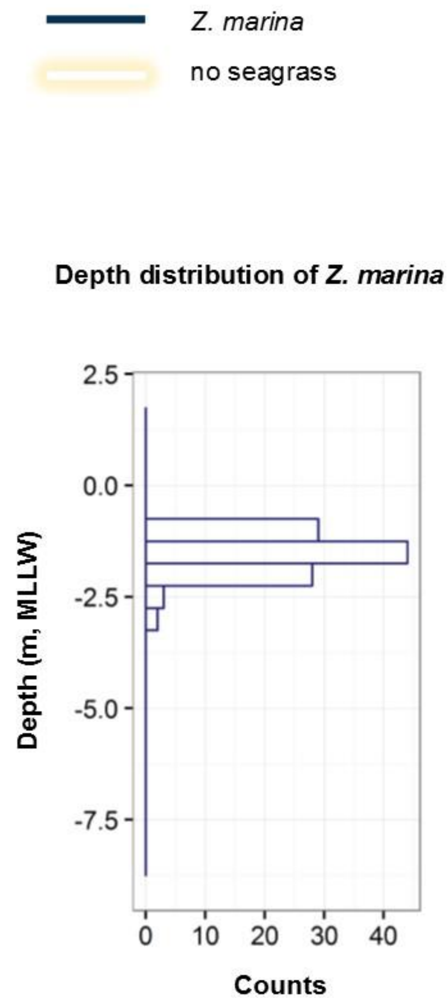
Z. marina
no seagrass


Depth distribution of Z. marina
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
5
10
15
20
Counts



N
S
W
E
0 45 90 180 270
m

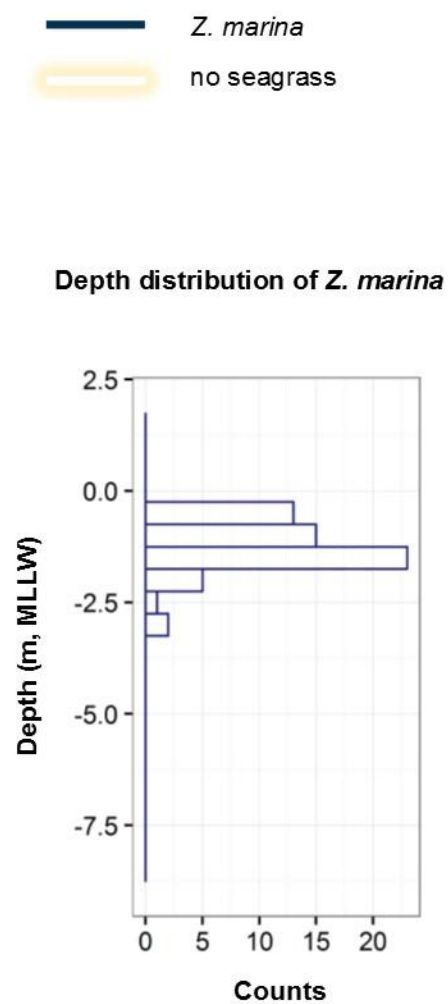
CPS2120



Z. marina
no seagrass
Depth distribution of Z. marina
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0 10 20 30 40
Counts


N
W
E
S
0 45 90 180 270
m

CPS2160


Z. marina
no seagrass
Depth distribution of Z. marina
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0 5 10 15 20
Counts

CPS2166

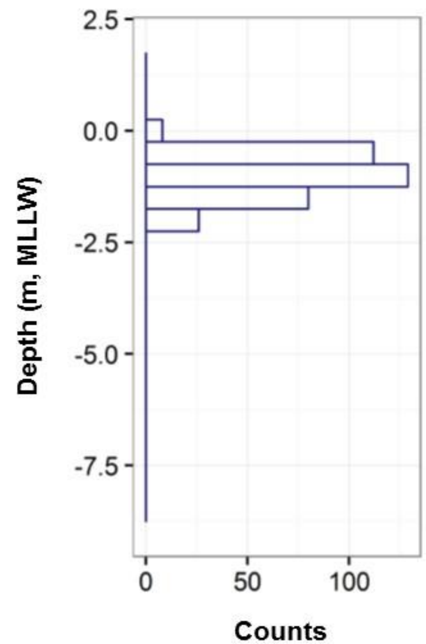
no seagrass

CPS2167

no seagrass

CPS2168

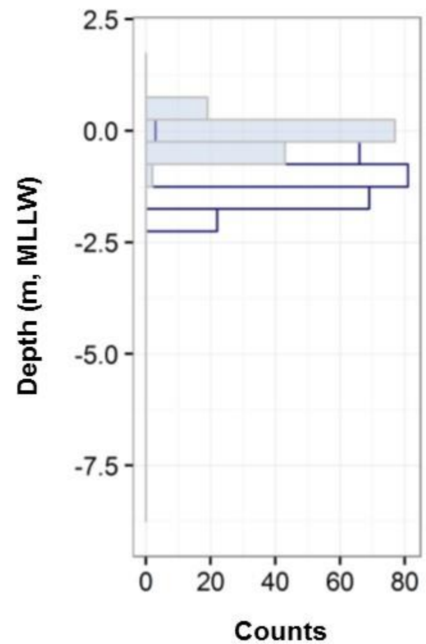
Depth distribution of *Z. marina*



CPS2169

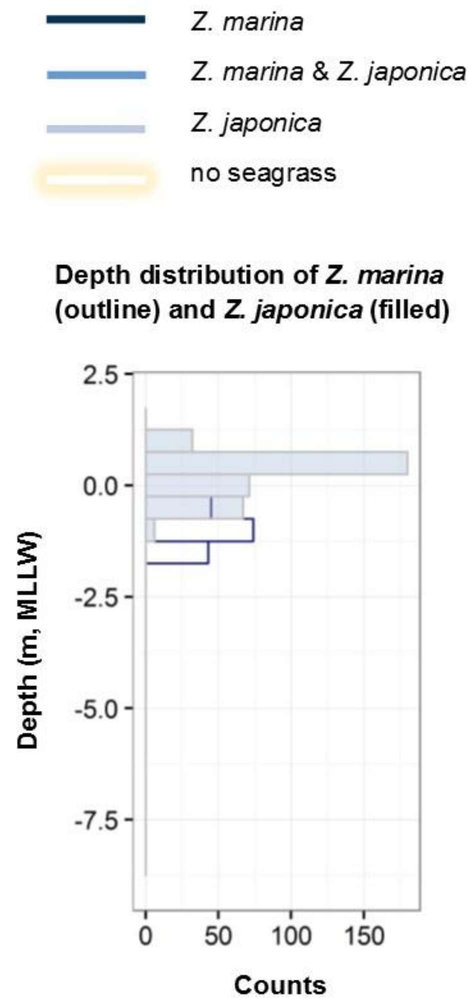
Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass

Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)



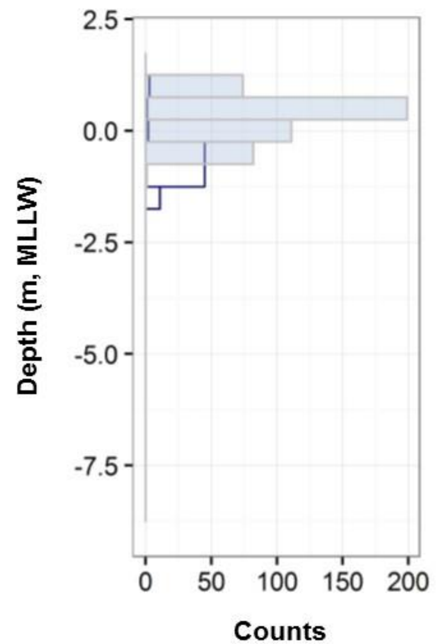

N
W
E
S
0
62.5
125
250
375
m

CPS2170


Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
50
100
150
Counts

CPS2171

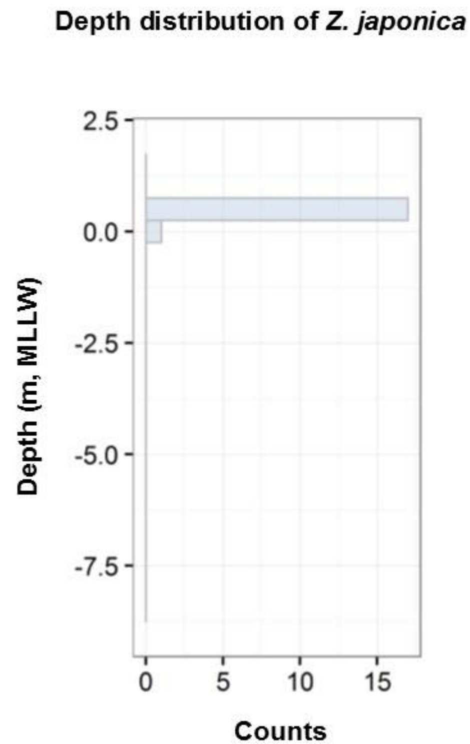
Depth distribution of *Z. marina* (outline) and *Z. japonica* (filled)




N
W
E
S
0
62.5
125
250
375
m

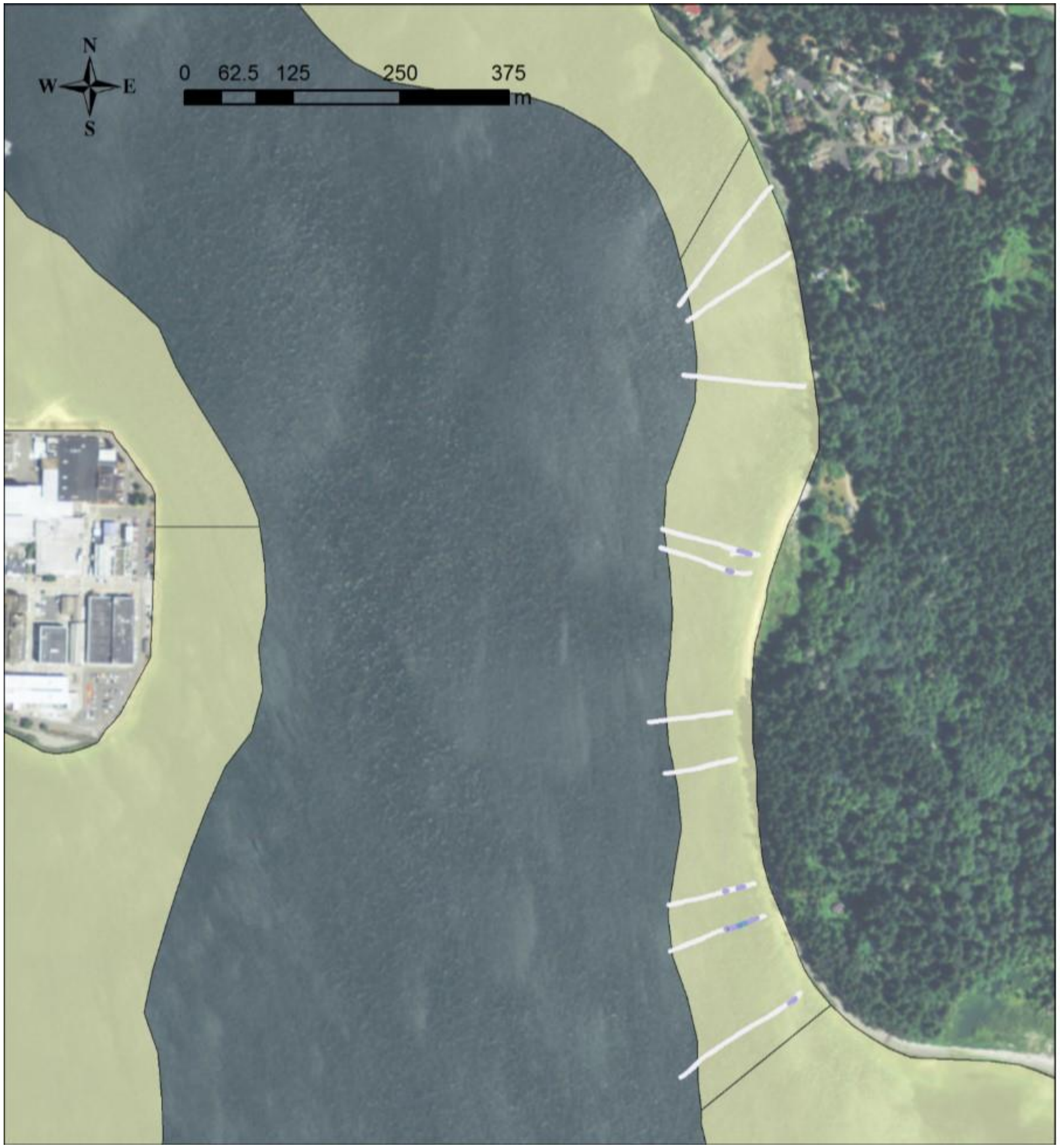
CPS2172

Z. japonica
no seagrass

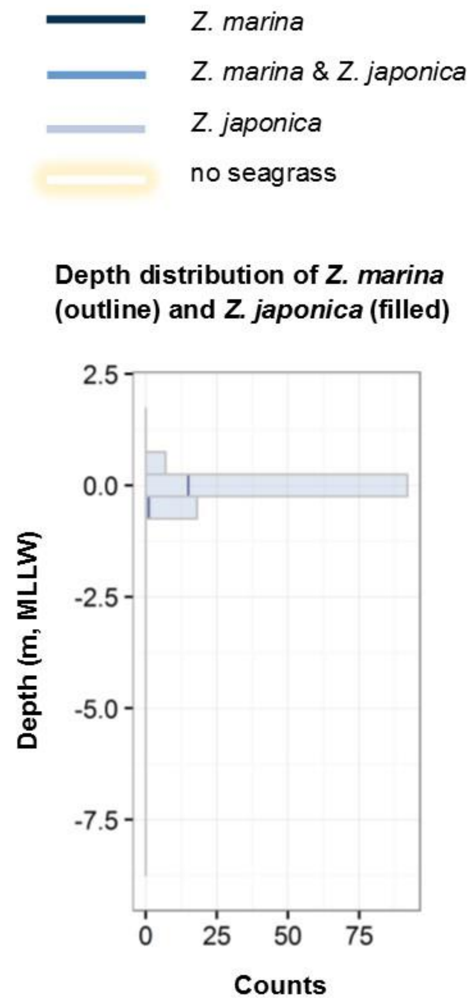

Depth distribution of Z. japonica
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
5
10
15
Counts

CPS2173

no seagrass


N
W
E
S
0
62.5
125
250
375
m

CPS2183

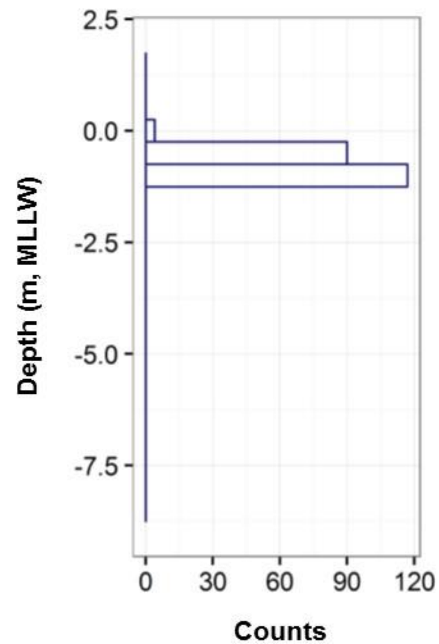

Z. marina
Z. marina & Z. japonica
Z. japonica
no seagrass
Depth distribution of Z. marina (outline) and Z. japonica (filled)
Depth (m, MLLW)
2.5
0.0
-2.5
-5.0
-7.5
0
25
50
75
Counts

CPS2184

Z. marina

no seagrass

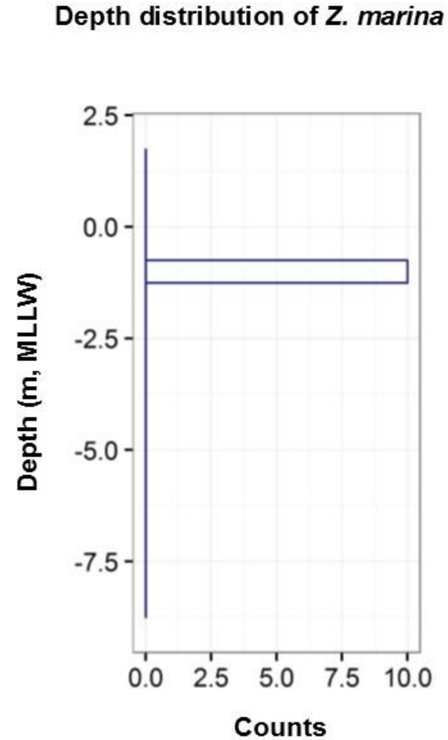
Depth distribution of *Z. marina*




N
S
W
E
0
37.5
75
150
225
m

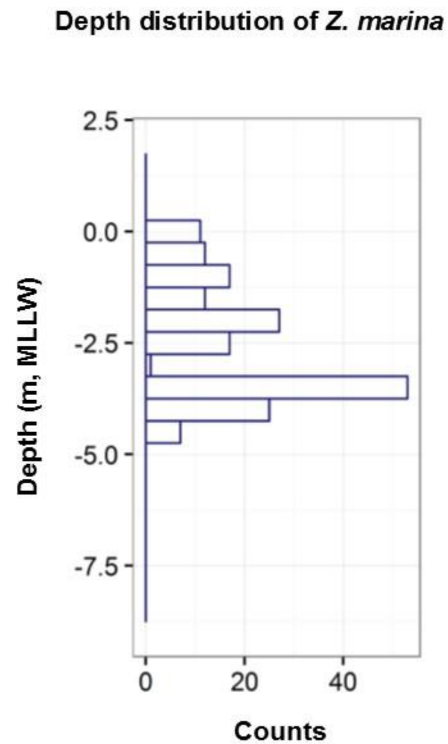
CPS2185

Z. marina
no seagrass


Depth distribution of Z. marina
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0.0
2.5
5.0
7.5
10.0
Counts

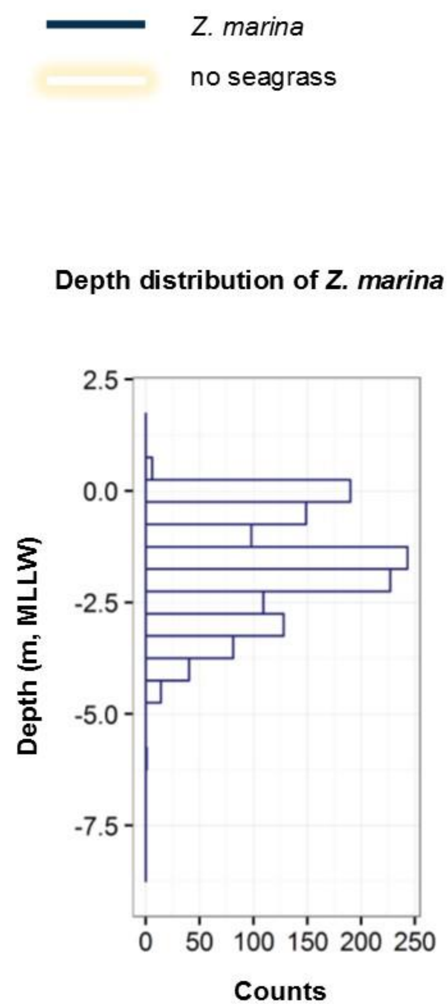
CPS2186


N
W
E
S
0 45 90 180 270
m
Z. marina
no seagrass


Depth distribution of Z. marina
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0
20
40
Counts

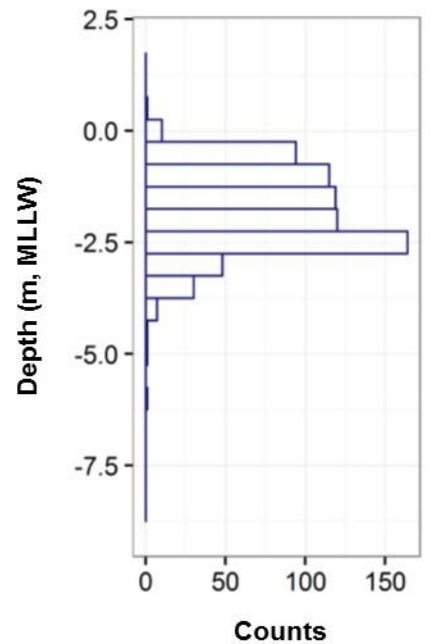

N
W
E
S
0 62.5 125 250 375
m

CPS2187


Z. marina
no seagrass
Depth distribution of Z. marina
2.5
0.0
-2.5
-5.0
-7.5
Depth (m, MLLW)
0 50 100 150 200 250
Counts

CPS2188

Depth distribution of *Z. marina*



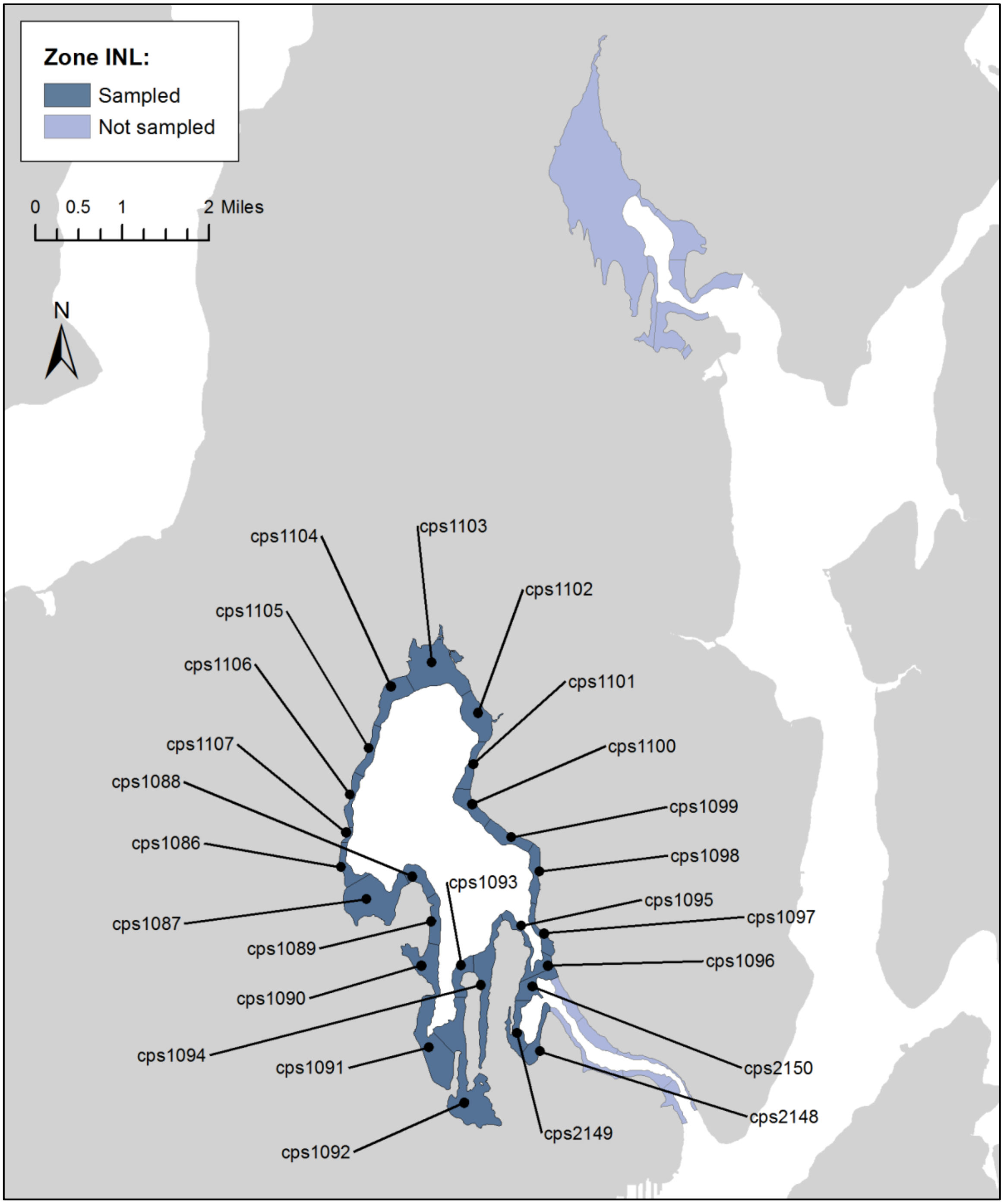
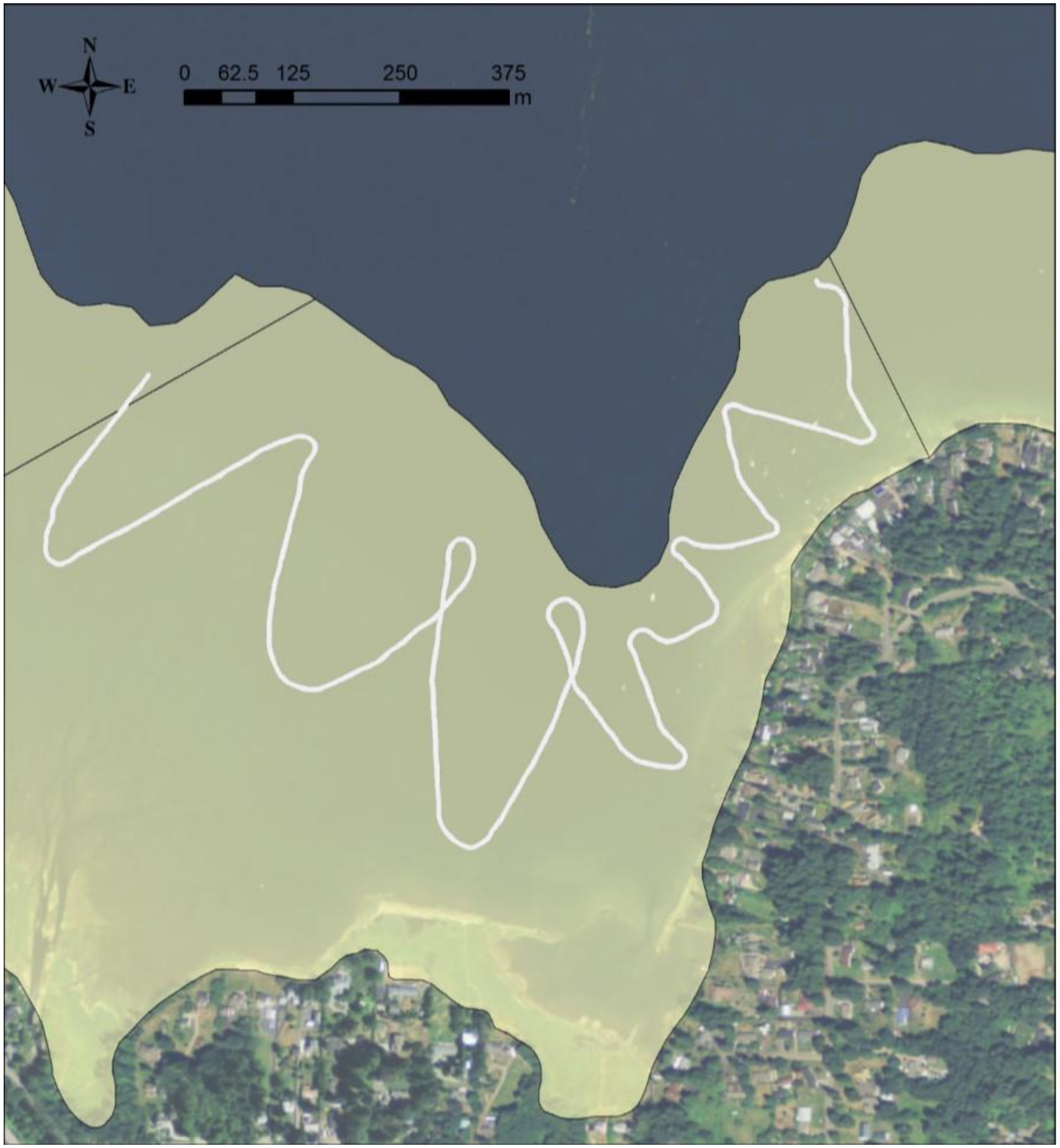


Figure 17: Inner section of the East Kitsap study area (Zone INL, or 'Liberty Bay and Dyes Inlet'). Sites that were sampled as part of IAA 15-17 are labeled and indicated in bold.

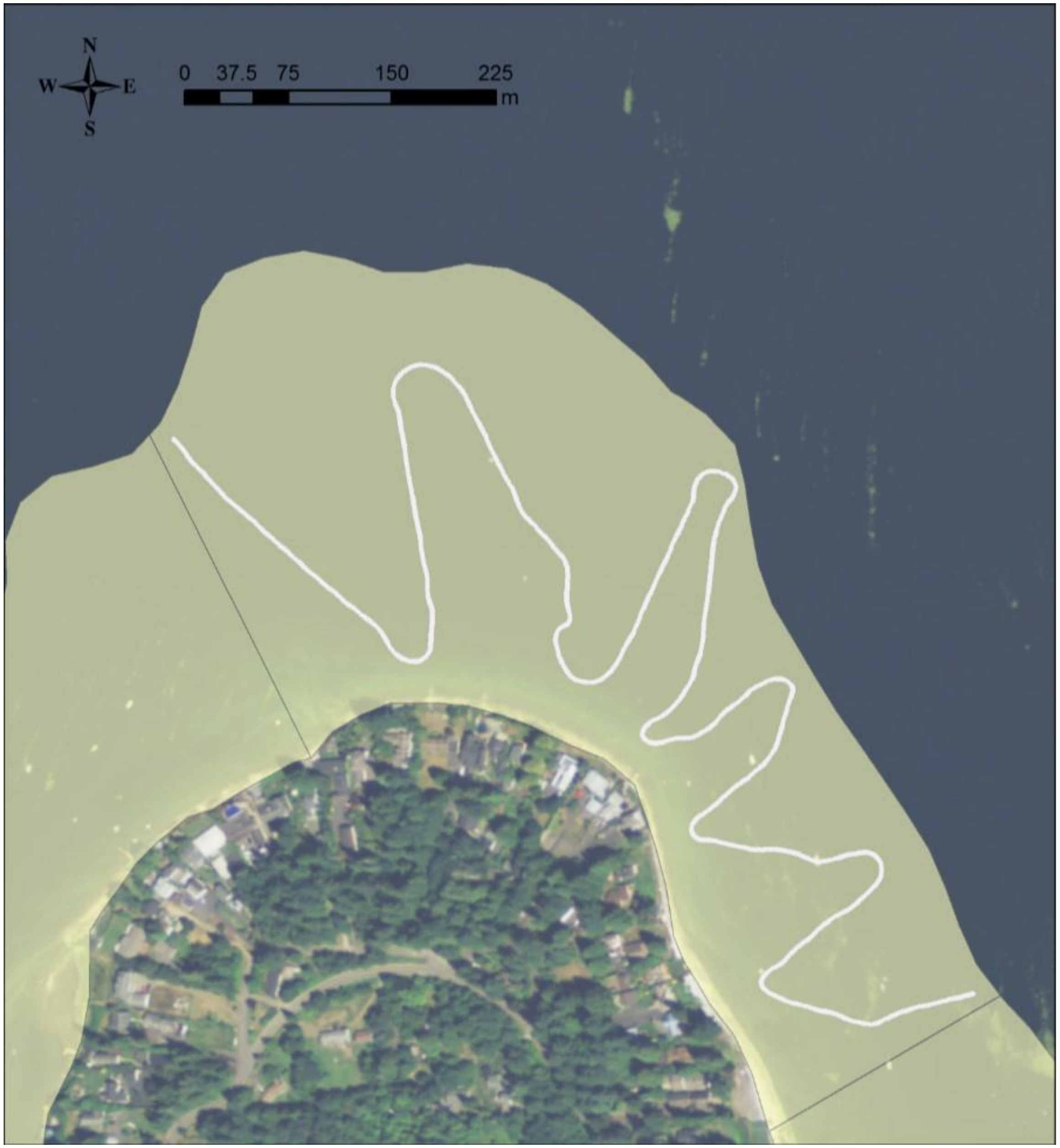
CPS1086

no seagrass



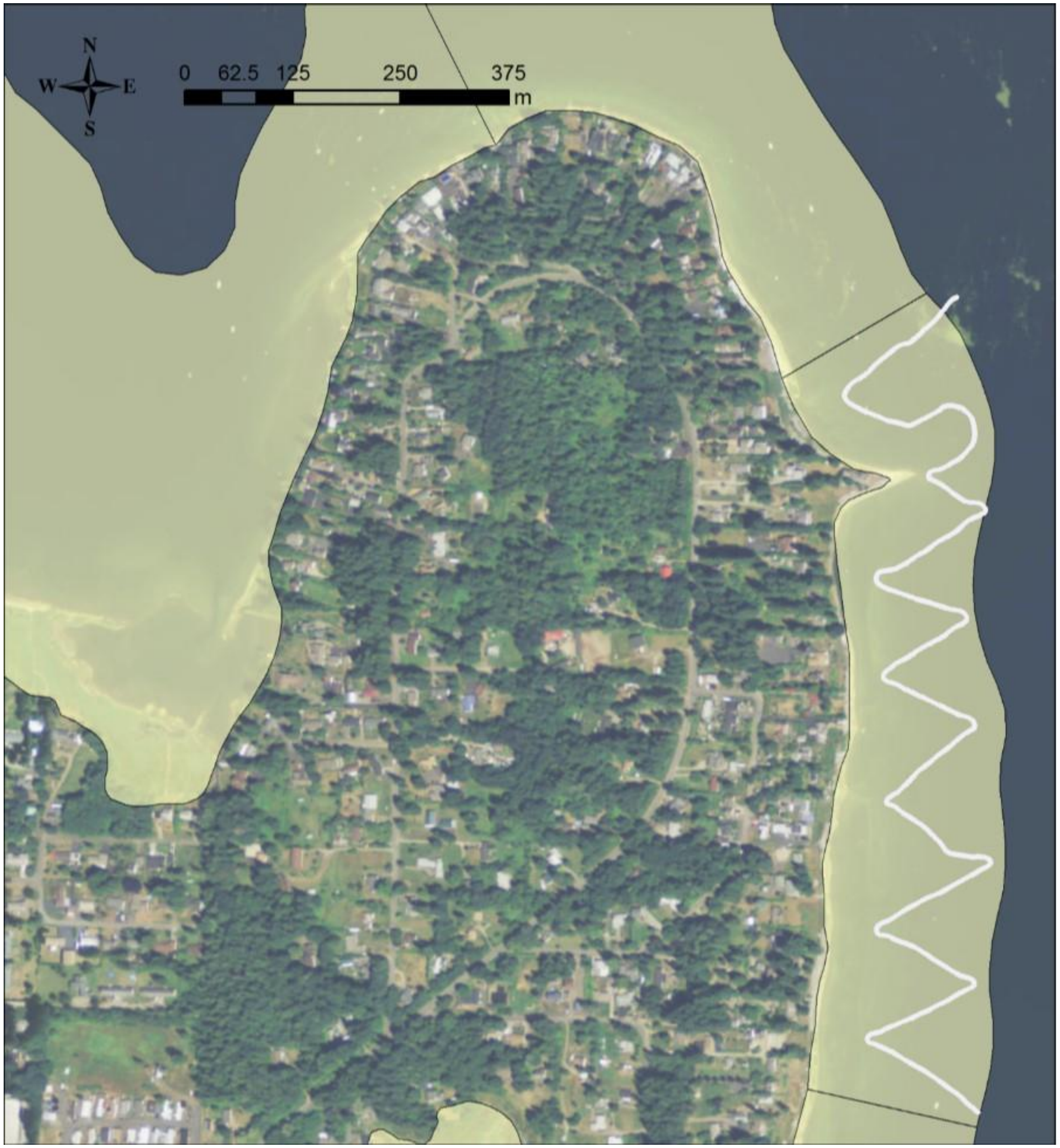
CPS1087

no seagrass



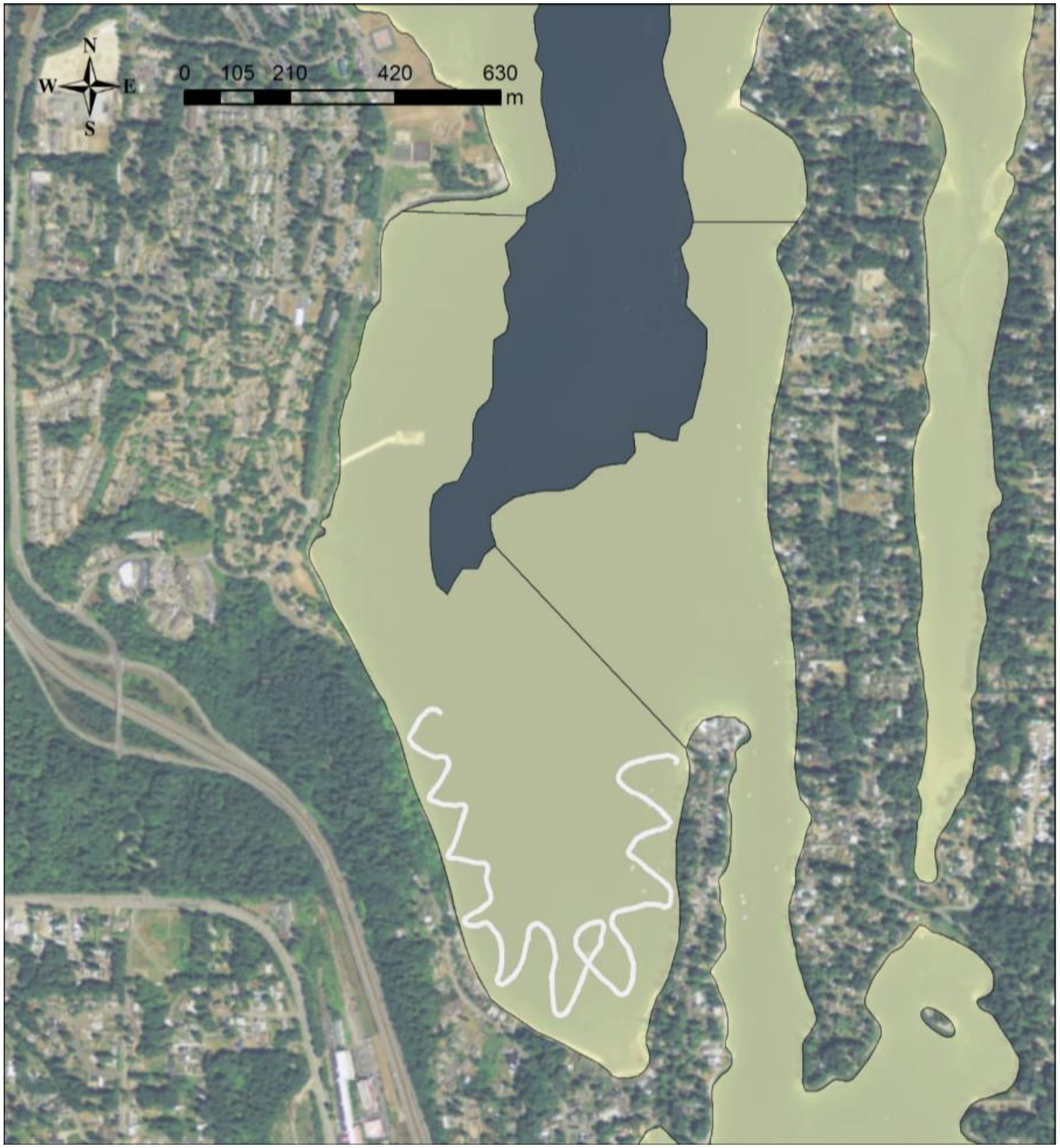
CPS1088

no seagrass



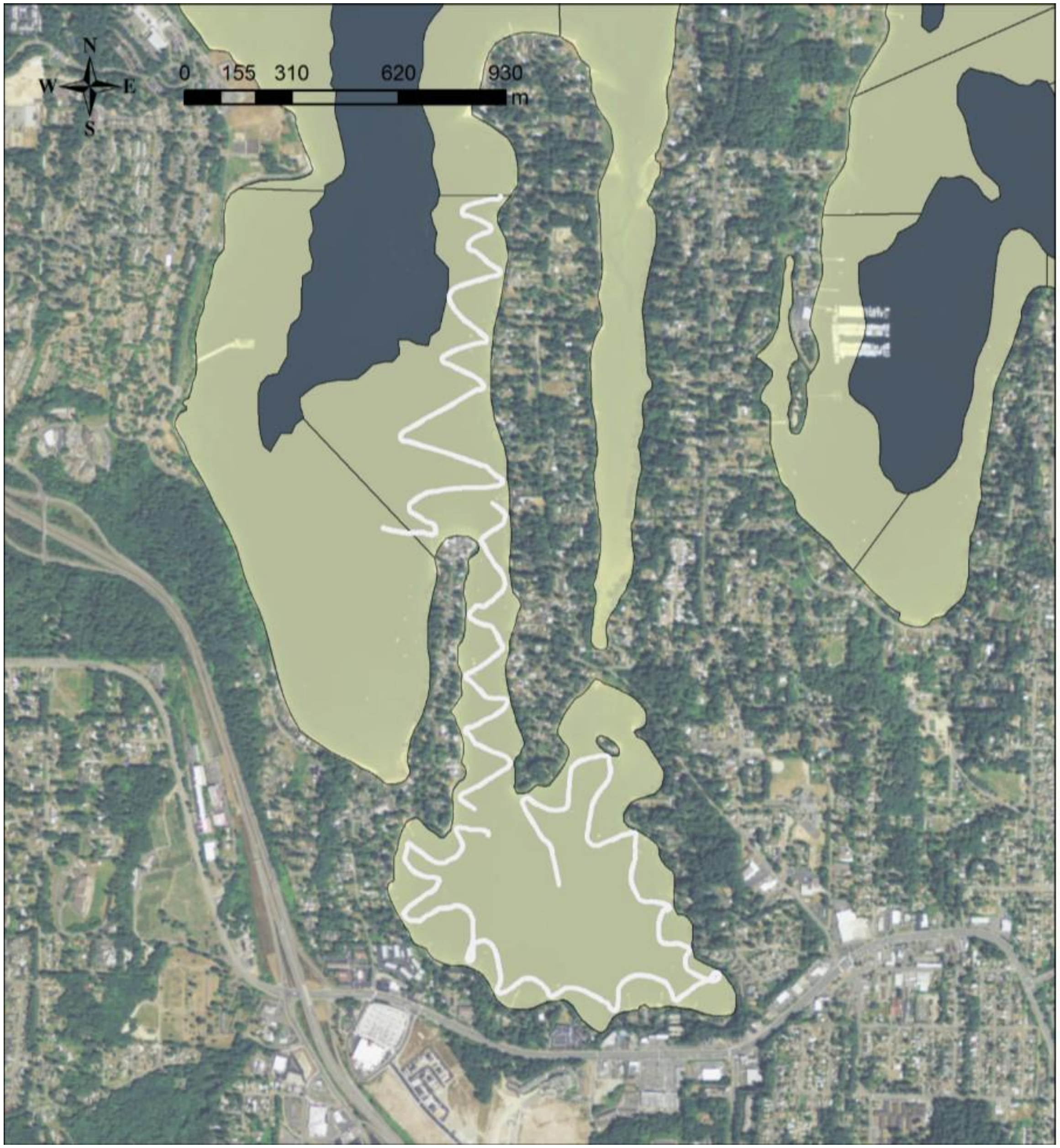
CPS1089

no seagrass



CPS1091

no seagrass



CPS1092

no seagrass

CPS1093

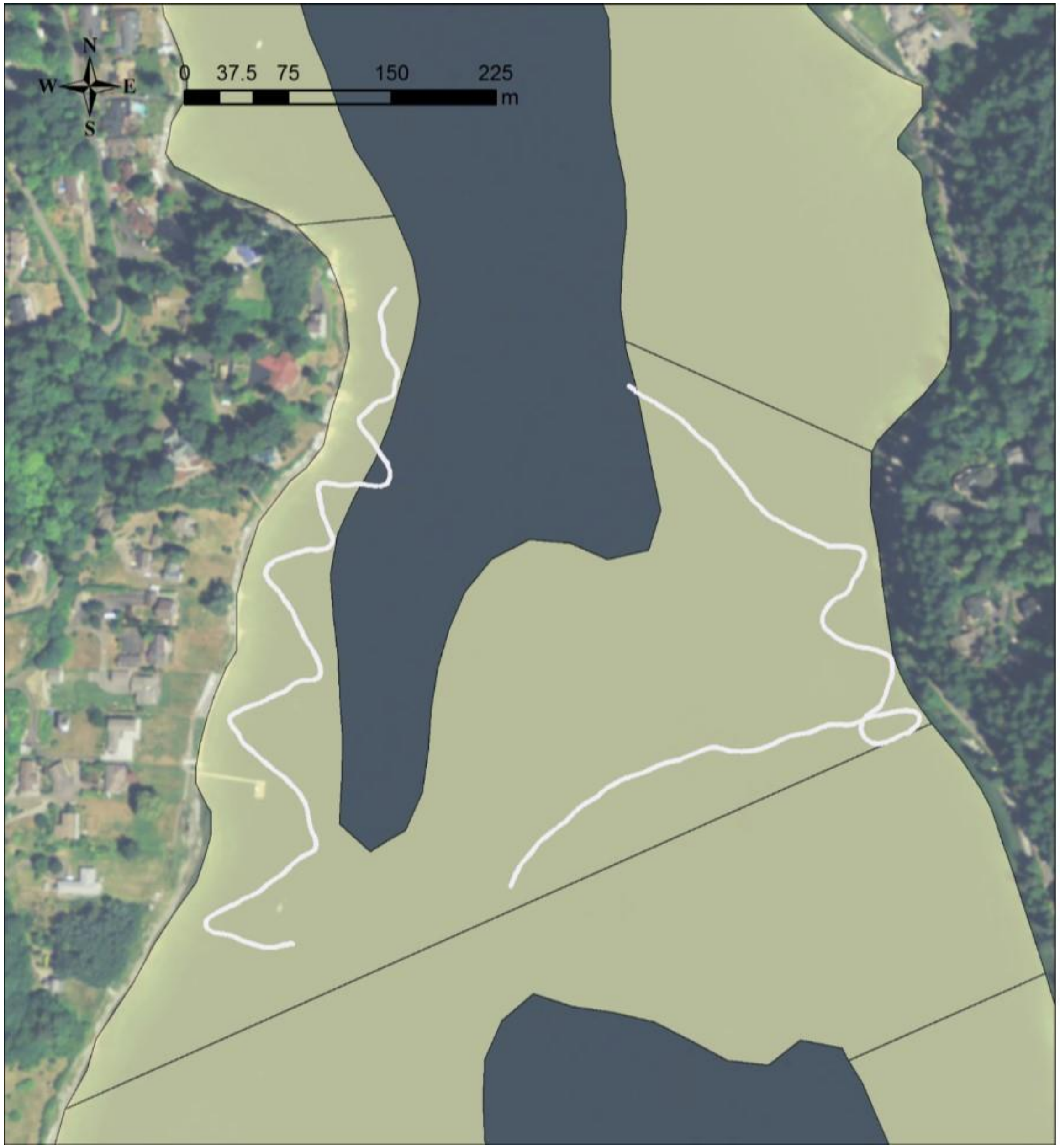
no seagrass

CPS1094

no seagrass

CPS1095

no seagrass



CPS1096

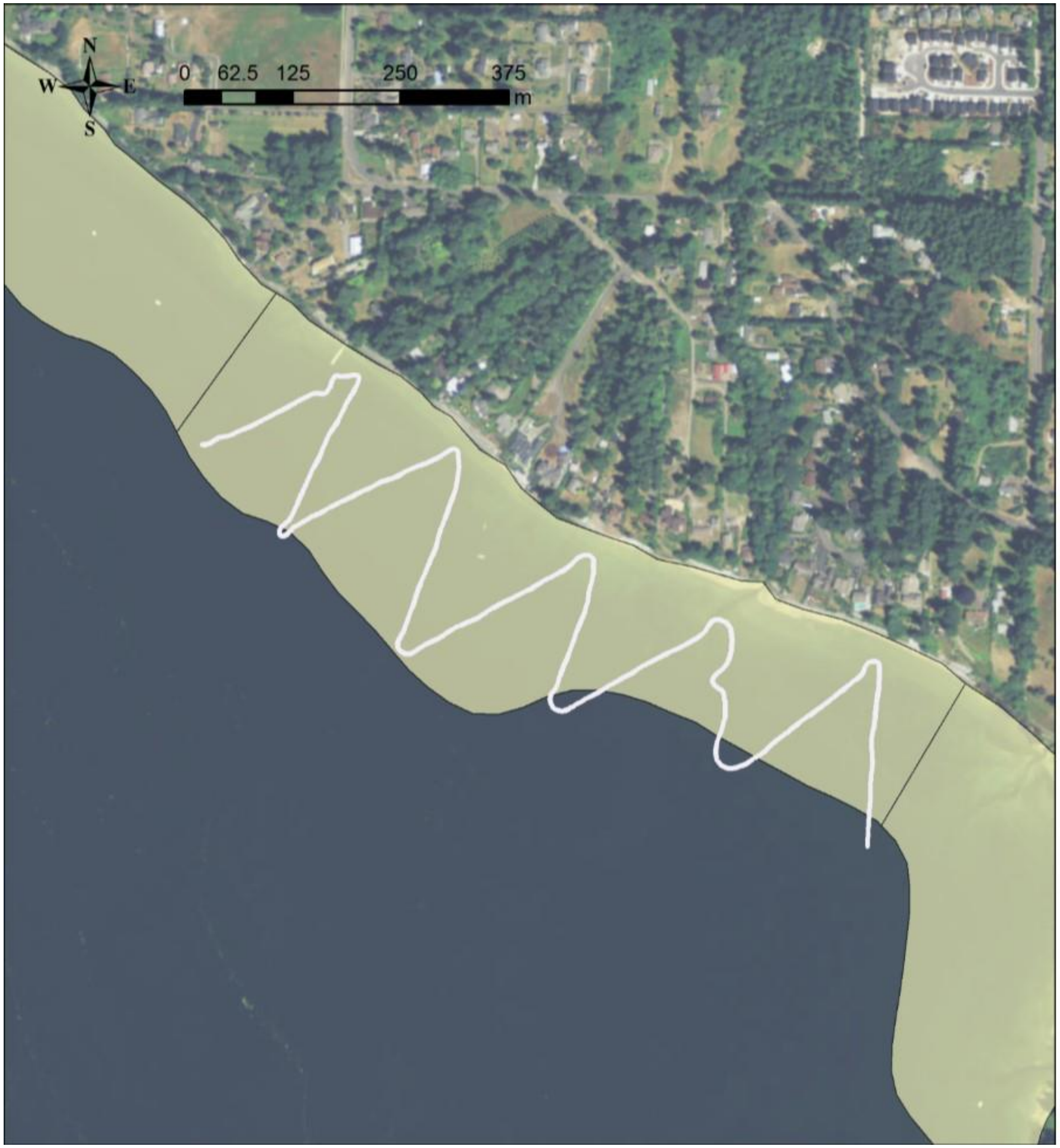
no seagrass

CPS1097

no seagrass

CPS1098

no seagrass



CPS1099

no seagrass

CPS1100

no seagrass

CPS1101

Z. marina

no seagrass

CPS1102

CPS1103

Z. marina

no seagrass

CPS1104

no seagrass

CPS1105

no seagrass

CPS1106

no seagrass

CPS1107

no seagrass