San Francisco Estuary Invasive *Spartina* Project
2019-2020 Monitoring and Treatment Report

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1. INTRODUCTION

Since the early 1970s, four non-native cordgrasses, including *Spartina alterniflora* (Atlantic smooth cordgrass), *S. densiflora* (Chilean cordgrass), *S. anglica* (English cordgrass), and *S. patens* (salt meadow cordgrass), were introduced to the San Francisco Estuary ('Estuary' or 'Bay' throughout this report). Each of these species is known to be invasive outside of its native range, and each has demonstrated varying degrees of invasiveness since establishing in the Estuary. *Spartina* species are closely related, and both *S. alterniflora* and *S. densiflora* subsequently hybridized with native *S. foliosa* (Daehler and Strong 1996; Ayres, Strong et al. 2003; Ayres, Grotkopp et al. 2008). Offspring of hybrid *S. alterniflora* x *foliosa* backcrossed with the parent species, producing an extremely robust and fertile "hybrid swarm," which invaded habitat throughout the Estuary, threatening the ecological integrity of the existing tidal wetlands and mudflats as well as the potential for future restoration efforts (Daehler and Strong 1996; Goals 1999; Ayres, Strong et al. 2003; State Coastal Conservancy 2003; Ayres, Zaremba et al. 2004; Ayres, Grotkopp et al. 2008). For further detail on each species of *Spartina* found in the Estuary, see **Appendix I**.

The San Francisco Estuary Invasive *Spartina* Project (ISP) was established in 2000 by the California State Coastal Conservancy (Conservancy), in partnership with the U.*S.* Fish and Wildlife Service (USFWS), in response to the invasion of non-native *Spartina*. Non-native *Spartina* had been determined to pose many serious threats to the Estuary, as was described in the ISP's Programmatic Environmental Impact Statement/Environmental Impact Report (PEIS/EIR; (State Coastal Conservancy 2003). Predicted impacts of non-native *Spartina* in the Estuary included the destruction or degradation of endangered species habitat, loss of mudflats that are vital for shorebird foraging, loss of urban flood control capacity, creation of mosquito-breeding areas by impounding water, corruption of salt marsh restoration efforts, and the possible eventual extinction of native *Spartina foliosa*. The purpose of the ISP is to implement a regional program to eradicate non-native *Spartina* species from the Estuary. This goal is being accomplished through a highly coordinated program of inventory mapping and treatment that is planned and supervised by ISP biologists and implemented on-the-ground by a bay-wide network of partners including dozens of landowners, resource agencies, contractors, grantees, and stakeholder groups throughout the nine county Bay Area.

The project has been supported over the years by a combination of state (74%), federal (22%), and local/other funds (4%) totaling $45M. The program expenditure for 2019 and 2020 seasons was approximately $5,530,000 with $4,100,000 of that for *Spartina* treatment and monitoring, $230,000 for Ridgway's rail monitoring, and $1,200,000 for habitat restoration through revegetation and construction of high tide refuge islands.

Working within limited annual windows of opportunity due to tides, stage of plant development, and presence of endangered species in the work area, the ISP conducts mapping and treatment of invasive *Spartina* annually throughout up to 70,000 acres of potential habitat.

Since 2008, inventory efforts have been conducted primarily on the ground or using various boats. Most sites are inventoried each year prior to treatment to allow thorough and focused mapping and potential collection of DNA samples, and to map precise current locations of invasive *Spartina* plants to inform treatment. Having the target plant locations identified and mapped in advance allows treatment crews to work more efficiently without having to hunt for all occurrences of non-native *Spartina* at the same time. It also enhances worker safety, reduces the amount of ground crews must cover, and reduces disturbance to the marsh. A relatively small number of sites with a substantial mudflat component are mapped during airboat treatment due to logistical concerns. Biologists map invasive *Spartina* plants they have detected as points, lines, or polygons using rugged handheld tablet PCs with Global Positioning System (GPS), spatially demarcating each feature. A cover class is assigned to each feature to record the density of live invasive *Spartina* within that feature's delineated boundary (see inset: Defining "Area").

Defining "Area"

The ISP uses the terms "net area" and "treatment area" to define the extent of non-native *Spartina*.

Net area refers to the size of the infestation if the space between stems were subtracted from the overall footprint of the plant or clump of plants. Net area is the metric typically used in botanical surveys.

Treatment area describes the area that will be directly affected by treatment. Treatment area is a separate measurement used for planning, and it is generally five to seven times greater than the net area of a given instance of invasive *Spartina*.

Unless otherwise noted in the text, all references to area in this report are net area.

During treatment, ISP biologists guide agency personnel or contracted herbicide applicators to each previously mapped invasive *Spartina* feature and update that feature on the tablet to record that day's treatment activity (e.g., "sprayed", "dug", "not treated", "sub-optimally treated" etc.). This methodology has been implemented by ISP since 2009, and it has greatly improved the ability to accomplish thorough treatment of sites in the limited amount of time available with the treatment crew(s) for a given day. For further detail on the methods employed by ISP for treatment, monitoring, and other work, please see **Appendix II**.

The ISP has made tremendous progress toward eradication since 2005 when inventory and treatment began throughout the San Francisco Estuary and in the neighboring coastal areas. Historic infestations have been reduced by 96% within the Estuary, completely eradicated from the Point Reyes National Seashore and Bolinas Lagoon, and very nearly eradicated from Tomales Bay. Since 2011, treatment restrictions had been in place at fourteen sub-areas[1], and

1 Prior to 2018, the fourteen sub-areas with treatment restrictions were consolidated as eleven sub-areas. A few of these sub-areas were split into multiple sub-areas to reflect changes to the treatment restrictions in 2018 per the Project's Section 7 consultation with the United States Fish & Wildlife Service.

at the beginning of the 2018 season, a minimum of 33 acres of non-native *Spartina* (80% of the Estuary total) remained untreated in those fourteen marshes. After Section 7 consultation with U.S. Fish & Wildlife Service in 2018, treatment was reinitiated in a subset of those marshes. During the 2018 inventory and treatment season, the ISP mapped a total of 38 net acres of non-native *Spartina*, which was a slight increase over recent years due to expansion in marshes where halted treatment and a couple wet winters after extended drought promoted growth. For further information on recent inventory and treatment activities, see Section 2 below and for a more complete history of the invasion and treatment activities around the Bay, see the 2012 ISP Monitoring and Treatment Report (Rohmer, Kerr et al. 2014), as well as the 2013-14, 2015-16, and 2017-18 Monitoring and Treatment Reports.

2. TREATMENT AND MONITORING COMPLETED 2019-2020

The ISP's activities and progress over the two-year period 2019-2020 are described in this section, first from a bay-wide perspective, and then in more detail for each of 12 reporting regions (see inset at right and **Figure 1**). The reporting regions are based on regions initially defined by USFWS for assessment of California Ridgway's rail (*Rallus obsoletus obsoletus*) populations. The reporting region boundaries also take into consideration natural and political landscape features, similarities in land management, geographic proximity and ecological connectedness of the treatment sub-areas, site access, and general impact of non-native *Spartina* invasion on the region. ISP uses these reporting regions to cohesively present treatment and monitoring data in a manner more suitable for correlation with California Ridgway's rail ("Ridgway's rail") data. Information presented here predominantly reflects data from the 2020 season, though activities from 2019 are included as needed and where specifically identified.

ISP Reporting Regions

Region 1. Marin
Region 2. San Francisco Peninsula
Region 3. San Mateo
Region 4. Dumbarton South
Region 5. Union City
Region 6. Hayward
Region 7. San Leandro Bay
Region 8. Bay Bridge North
Region 9. Suisun
Region 10. Vallejo
Region 11. Petaluma
Region 12. Outer Coast

2.1 Bay-wide Inventory

2.1.1 Bay-wide Inventory Methods

There are 70,000 acres of potential *Spartina* habitat within the ISP Project Area. Constraints including but not limited to staff availability, budget, a short growing season (June to November), and appropriate tide windows limit the Project's ability to complete inventory (and treatment) in all areas every year. To make the best use of available resources, ISP Managers begin planning for the upcoming season by setting priorities according to relative invasion pressure or other risk. ISP inventory priorities are established using the following criteria:

- historic presence of non-native *Spartina*,
- proximity to non-native *Spartina* seed sources,
- habitat suitability for colonization by non-native *Spartina,* and
- time since the area was thoroughly surveyed for non-native *Spartina*.

Prioritized sub-areas are assigned to one of four inventory categories: (1) complete inventory, (2) partial inventory, (3) coarse inventory, and (4) no inventory. Sub-areas prioritized for complete inventory typically have historic infestation or high risk of colonization, or several years have passed since the last thorough inventory and the sub-area requires reassessment. Partial inventory is conducted in portions of very large sub-areas where there are known isolated infestations. Coarse inventory is conducted in sub-areas with heavy infestations, i.e., where treatment is restricted due to permit requirements, or where treatment will be broad enough to not warrant a high level of inventory data detail. Coarse inventory may be conducted as a less-focused and detail-oriented form of standard inventory or by using a 25x25 meter grid method[2]. No inventory is conducted in low-priority sub-areas where there has not been historic infestation and risk of colonization is low, or where there has been a recent thorough inventory that concluded the sub-area was low risk.

A second round of inventory is frequently conducted late in the season at select sub-areas that are approaching local eradication. This additional assessment is critical to identify invasive *Spartina* plants that may not have been detected in the first round, usually because they were heavily impacted by prior treatment and were not yet sufficiently developed, had emerged after the initial inventory, or had suffered herbivory by geese. Sub-areas chosen for a second round are those approaching eradication. Many of these contain linear stretches of marsh that do not provide habitat for Ridgway's rails, and so they may be given initial treatment earlier in the season (e.g., prior to the end of rail nesting season). The early initial treatment allows enough time for plants to show treatment stress before the second treatment round, allowing for targeted and highly effective second round applications.

Factors impacting the 2019 and 2020 seasons were an increased inventory area as compared to 2018 due to an additional sub-area added in Suisun Bay, a relatively wet 2018 winter and 2019 spring, increased wildfires, and the 2020 COVID-19 pandemic. Not all sub-areas with known infestations were inventoried in 2018 due to limited time and resources, but inventory resumed at these marshes in 2019. After missing a season of treatment in 2018 and receiving relatively large amount of rain over the winter 2018 and spring 2019, these areas became disproportionately difficult to navigate and survey in 2019. Later that season the wildfires hit, which halted field work and served as a warning for the major cancellations of fieldwork that would be experienced in the much stronger wildfire season of 2020. The greatest unexpected impact to the 2020 season came from the massive West Coast wildfires that brought unhealthy smoke levels as measured by the Air Quality Index (AQI). This period of poor air quality lasted for approximately three weeks in August-September 2020 during the peak field season, with a few breaks, and resulted in many postponed days of field work for both inventory and treatment.

On top of these challenging factors, the health concerns surrounding the pandemic resulted in delays getting access to many properties, and in several partners that would otherwise provide airboat support (e.g., U.S. Fish & Wildlife Service, California Department of Food and Agriculture, East Bay Regional Park District) being unable to do so. This resulted in increased budget allotment for outside contractors (SOLitude Lake Management) to provide airboat support. It also resulted in several areas not getting inventoried as planned due to conflicts between availability of staff, appropriate tides, and weather.

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[2] The 25x25 meter grid method was developed by ISP in 2008. Mapping by grid follows the rationale that detailed locations of plants would neither inform current year treatment nor inventory for the following year, and the time saved mapping by grid can be better allocated to areas that will receive treatment.

Figures 1 and 2 show the location of the ISP reporting regions, inventory boundaries and status of survey completion for 2019 and 2020. **Appendix III** provides the level of inventory conducted at each ISP sub-area in 2019 and 2020. Timing of completed inventory is shown in **Table 1.**

2.1.2 Bay-wide Inventory Results

In 2019, a total of approximately 30,000 acres (44%) of the ISP project area was surveyed and 36.9 acres of invasive *Spartina* was mapped. In 2020, 34,000 acres (48%) were surveyed and 33.1 acres of invasive *Spartina* was mapped. This reflects a 96% reduction from peak levels in 2005, and a 10% reduction from 2019 levels (**Table 2**) and is comparable to the level detected in 2013 (Rohmer, Kerr et al. 2014). Of the remaining invasive *Spartina* in the Estuary, 25.7 acres (78%) of hybrid *S. alterniflora* is located within six sub-areas of Central San Francisco Bay where treatment has been restricted since 2010. The remaining 7.4 acres of hybrid *S. alterniflora* is in sub-areas where treatment is authorized, and 2.5 acres of those acres were treated in 2020 for the first time since 2010 (**Section 3.2**).

All but 2.7 m^2 of invasive *Spartina* mapped in 2020 was hybrid *S. alterniflora* (**Table 3**), 99.7% of which was located in four reporting regions (listed here in decreasing order of cordgrass cover):

- Region 6: Hayward – 18.4 acres
- Region 7: San Leandro Bay – 11.3 acres
- Region 3: San Mateo – 2.8 acres
- Region 4: Dumbarton South – 0.4 acres

The three most infested regions (regions 6, 7, and 3) each contain sub-areas that had some level of treatment restriction in place until 2018. Regions 6 and 7 continue to have treatment restrictions in place at some sub-areas; infestation in these restricted sub-areas accounts for 25.7 acres (78%) of the Bay total. An additional 7.4 acres of hybrid *S. alterniflora* were found in the sub-areas that were re-authorized for treatment between 2018 and 2020, of which 2.5 acres was treated in 2020 for the first time since 2010. The infestation in Region 4 has decreased the most rapidly in recent years; it has dropped 90% since 2017 when it contained over 4 acres of hybrid *S. alterniflora*. **Figure 3** summarizes and shows the distribution of all invasive *Spartina* by Region.

The distribution of non-native *Spartina* by species within each reporting region and sub-area is shown in **Figures 4-6**.[3] **Figure 4** shows the widespread distribution of hybrid *S. alterniflora*. The greatest presence (net cover and/or abundance) of hybrid *S. alterniflora* continues to be concentrated in reporting regions 3, 4, 6, and 7 in Central and South Bay; low levels persist in all other reporting regions except for Region 12 where it has not been detected since 2018. Note

[3] Please note that the representation of *Spartina* in maps is not to scale in this small (8.5" x 11") report, but is meant to show location and distribution. For more detailed information on invasive *Spartina* occurrences, the ISP prepares finer scale accurate maps and GIS data with site partners.

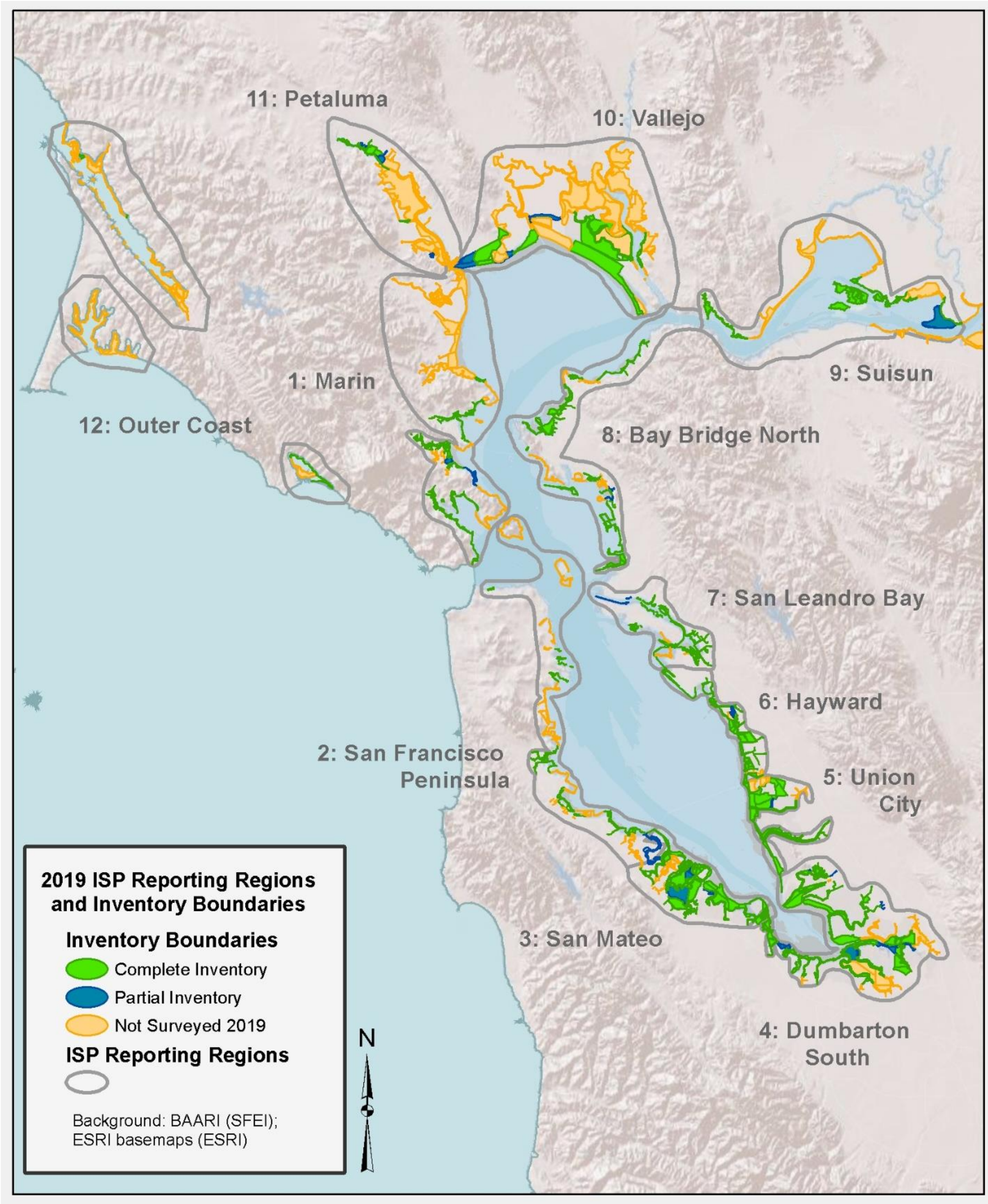

Figure 1. ISP Reporting Regions and 2019 survey efforts throughout San Francisco Bay Estuary.

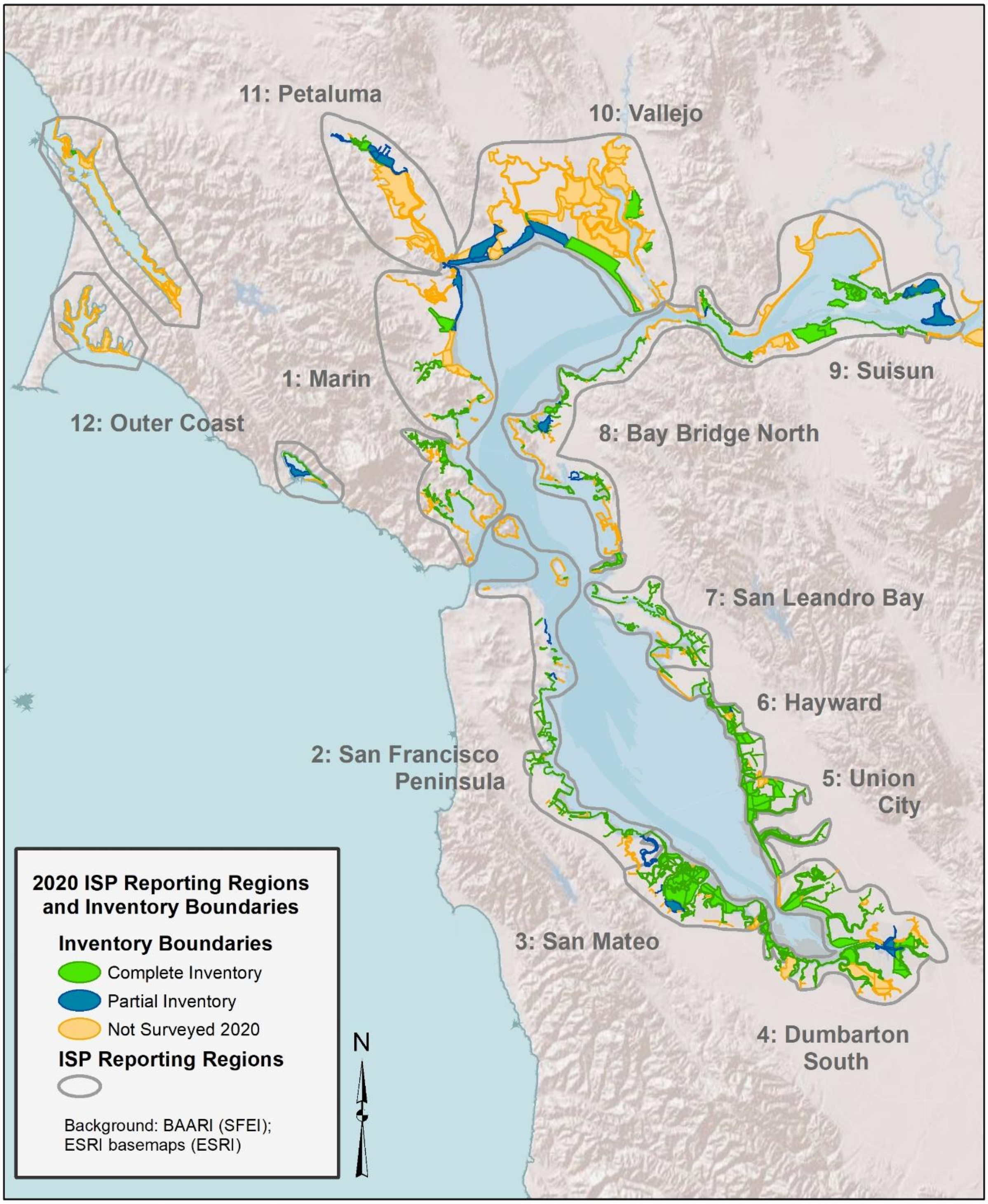

Figure 2. ISP Reporting Regions and 2020 survey efforts throughout San Francisco Bay Estuary

also in Figure 3 that Region 5 currently supports one of the lowest levels of infestation in the Estuary, even though it was the site of the original introduction, hybridization, and peak infestation of hybrid *S. alterniflora*. **Figure 5** shows that Region 1, the source of the *S. densiflora* infestation, is where that species population remains the greatest and that Region 12 is the only other region with detections in 2020. **Figure 6** is a combined map showing distribution of the remaining two species, *S. patens* and S. *anglica*, as well as hybrid *S. densiflora* x *foliosa*, all of which occur only as small, isolated populations in regions 1, 2, and 9.

Second rounds of inventory were conducted in both 2019 and 2020. In 2019 there were 52 sub-areas with prior invasion history where no non-native *Spartina* was found, and in 2020 there were 45. Invasive *Spartina* was re-detected in twelve sub-areas in 2020 where none had been found in 2019, though they were all small plants less than 1m^2 and were subsequently treated (**Table 4**). The number of “zero detect” sub-areas steadily increased every year since secondary

Table 1. Inventory timing for *Spartina* by species in 2019 and 2020

***Spartina* species**	**Time frame of 2019 inventory**	**Time frame of 2020 inventory**
hybrid *S. alterniflora*	June 26, 2019 - December 12, 2019	June 12, 2020 – November 13, 2020
S. patens	May 21, 2019 - September 19, 2019	Not surveyed by ISP 2020
S. densiflora and hybrids (I)	June 3, 2019 - June 27, 2019	June 3, 2020 - June 30, 2020
S. densiflora and hybrids (II)	December 30, 2019 - February 20, 2020	January 5, 2021 - January 18, 2021*
S. densiflora and hybrids (III)	n/a	February 23, 2021 - February 24, 2021
S. anglica	June 5, 2019 - July 5, 2019	June 9, 2020 - July 9, 2020

*one sub-area surveyed February 19, 2021 after USFWS Covid-19 protocol approvals in place

Table 2. Summary of Invasive *Spartina* Mapped in 2019 and 2020

# Sub-Areas	Potential Invasive *Spartina* Habitat (ac)	Proportion of Acreage Authorized for Full Treatment	Net Cover 2019 (ac)	Net Cover 2020 (ac)	Change Since 2019 (ac)	% Change Since 2019	Peak Year	Peak Amount (ac)	% Change Since Peak	% Remaining since Peak
220	**69,170**	**99.6%**	**37.0**	**33.1**	**-3.9**	**-10.5%**	**2005**	**805**	**-95.9%**	**4.1%**

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Table 3. Summary of invasive *Spartina* Mapped in 2019 and 2020 by Species and Treatment Authorization Status

Spartina species	Net Cover 2020	Net Cover 2019	Change Since 2019	% Change Since 2019	Peak Year	Peak Amount	Change Since Peak	% Change Since Peak	% Remaining since Peak
S. alterniflora* x *foliosa									
Sub-areas with 2020 Full Treatment Authorized	7.40 ac.	12.30 ac.	-4.90 ac.	-39.8%	2005	714.39 ac.	-706.99 ac.	-99.0%	1.0%
Sub-areas with 2020 Treatment Restrictions	25.70 ac.	24.60 ac.	+1.10 ac.	+4.5%	2005	73.19 ac.	-47.49 ac.	-64.9%	35.1%
TOTAL	33.10 ac.	36.90 ac.	-3.80 ac.	-10.3%	2005	787.59 ac.	-754.49 ac.	-95.8%	4.2%
S. densiflora	0.80 m^2	1.87 m^2	-1.07 m^2	-57.2%	2005	4.17 ac.	-4.1698 ac.	-99.995%	0.005%
S. densiflora* x *foliosa	0.65 m^2	2.05 m^2	-1.40 m^2	-68.3%	2005	347.82 m^2	-347.17 m^2	-99.8%	0.2%
S. anglica	0.14 m^2	0.53 m^2	-0.39 m^2	-73.6%	2006	382.66 m^2	-382.52 m^2	-99.96%	0.04%
S. patens	0.38 m^2	4.70 m^2	-4.32 m^2	-91.9%	2005	0.65 ac.	-0.6499 ac.	-99.99%	0.01%

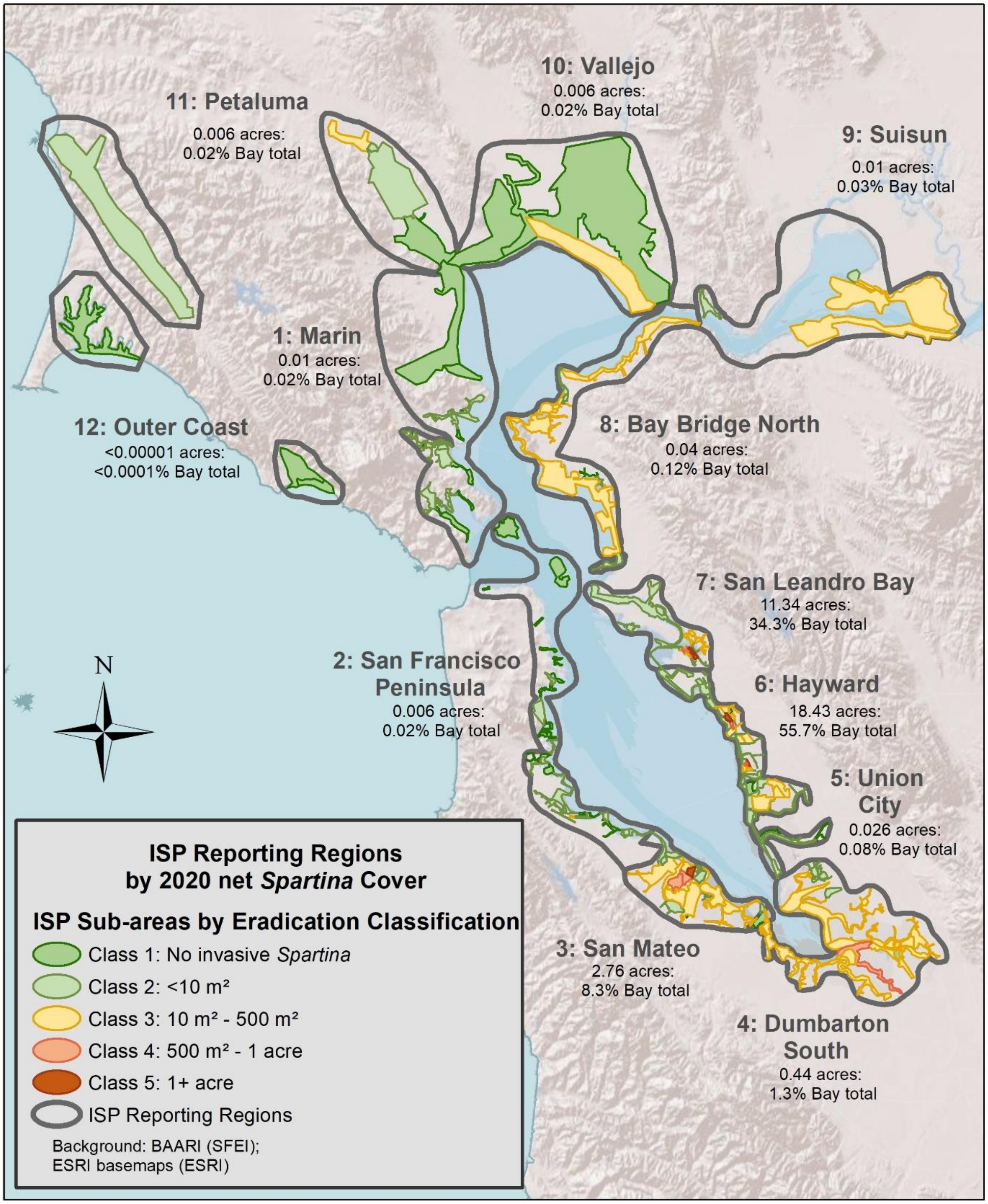

Figure 3. Net Area and Percentage of Bay Total of Non-native *Spartina* by ISP Reporting Region and Classification of Non-native Spartina Eradication by Sub-area.

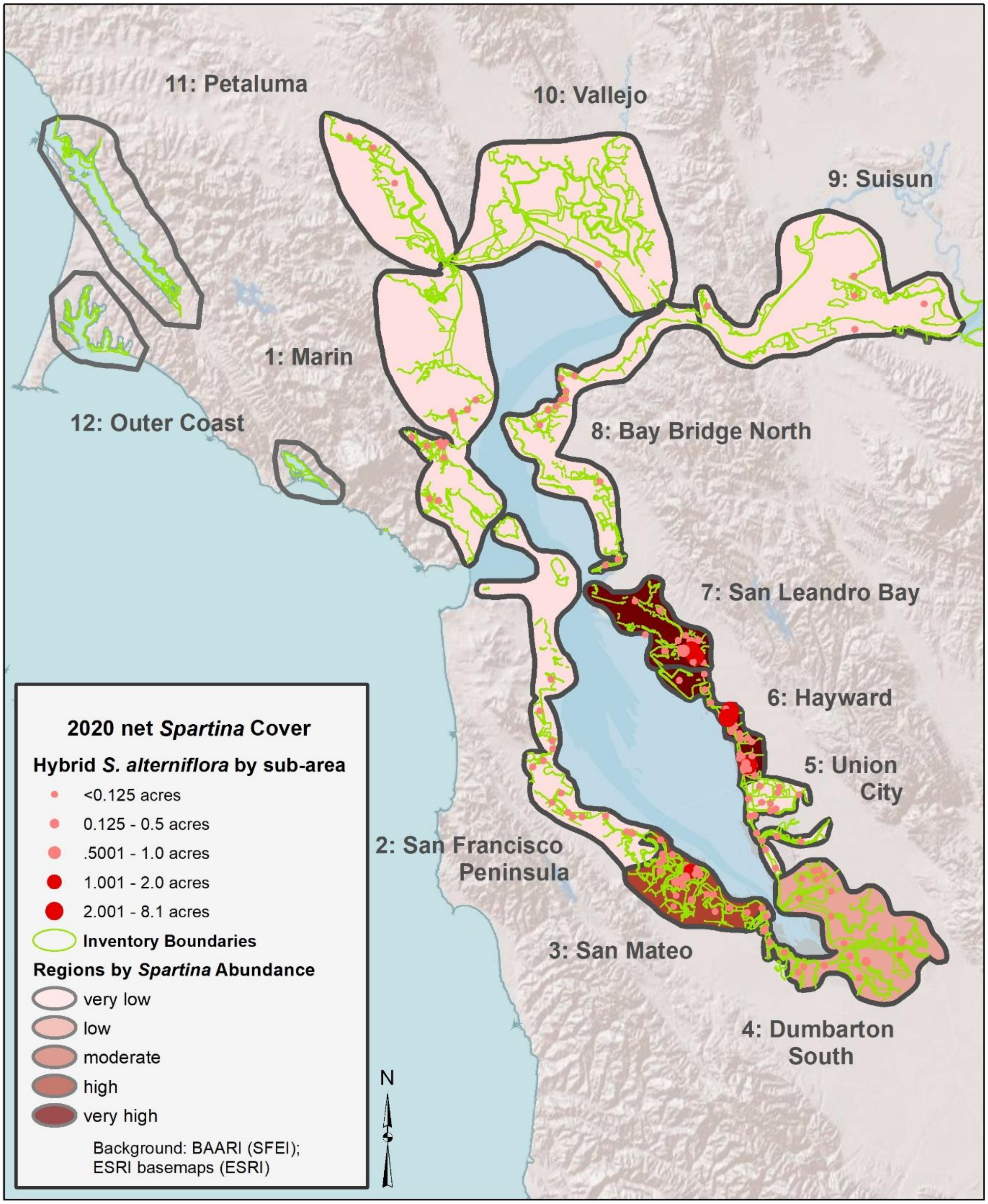

Figure 4. 2020 hybrid *Spartina alterniflora* x *foliosa* presence throughout San Francisco Bay Estuary by ISP Reporting Region and sub-area

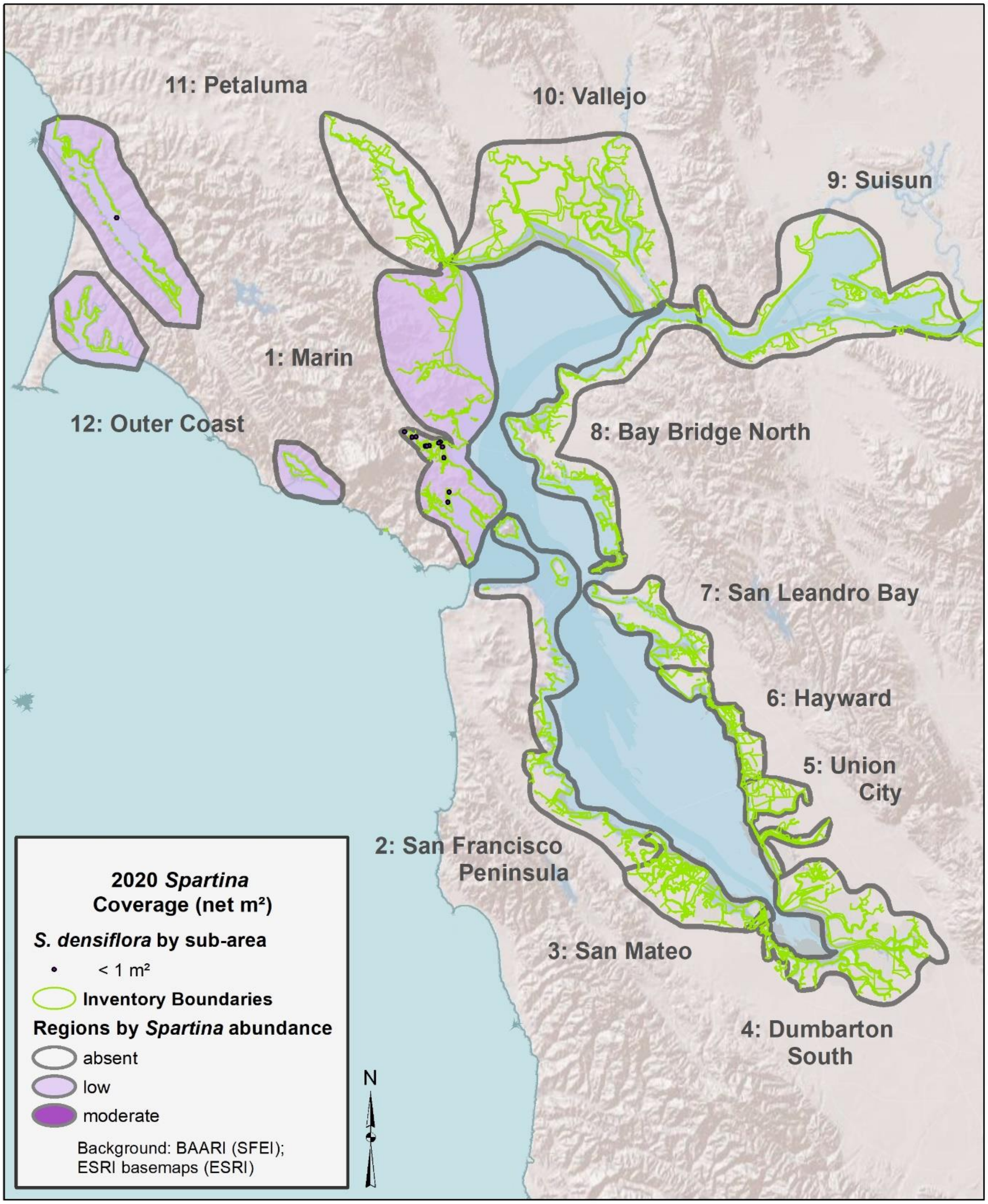

Figure 5.2020 *Spartina densiflora* presence throughout San Francisco Bay Estuary by ISP Reporting Region and sub-area.

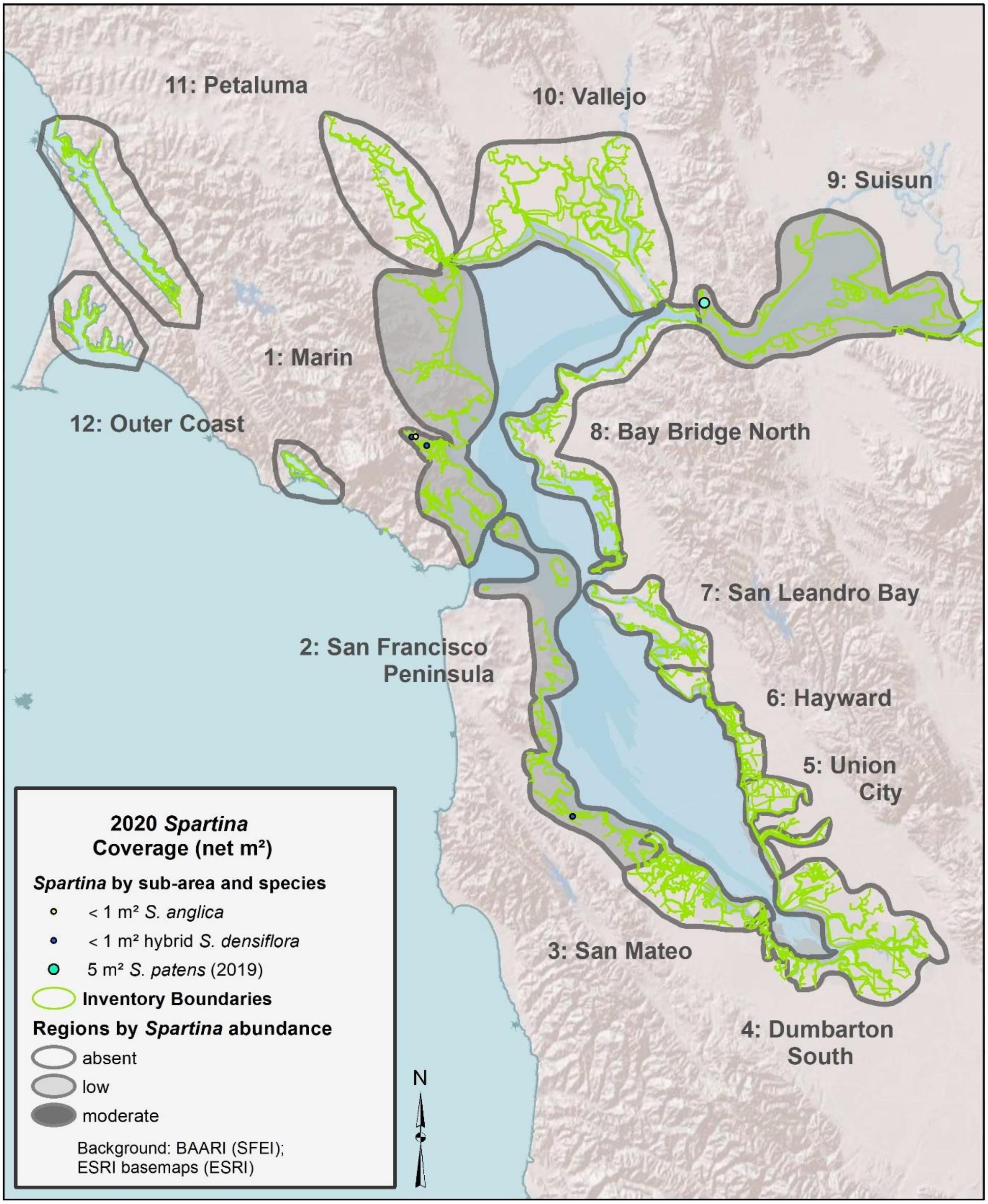

Figure 6. 2020 hybrid *Spartina densiflora* x *foliosa*, *S. anglica*, and *S. patens* presence throughout San Francisco Bay Estuary by ISP Reporting Region and sub-area.

Table 4. Sub-areas with historic infestation in which no invasive *Spartina* of any kind was detected in either 2019 or 2020

Sub-areas that maintained "Zero-detect" Status for both 2019 and 2020

Region	Code	Sub-area	Region	Code	Sub-area
1	03a	Blackie's Creek (above bridge)	2 (cont.)	18d	Inner Harbor
	03b	Blackie's Creek Mouth		18f	Confluence Marsh
	04d	Piper Park West		18g	San Bruno Marsh
	23c	Loch Lomond Marina		19b	Sierra Point
	23f	Paradise Cay		19c	Oyster Cove
	23k	Sausalito		19d	Oyster Point Marina
	23l	Starkweather Park		19g	Seaplane Harbor
	23m	Novato		19m	Fisherman's Park
	23n	Triangle Marsh and shoreline		19r	Anza Lagoon
	23o	China Camp	3	19s	Maple Street Channel
2	12a	Pier 94	4	02n	SF2
	12b	Pier 98 / Heron's Head		15a.7	Pond 17
	12c	India Basin	5	01d	Upper Channel - Union City Blvd to I-880
	12d	Hunters Point Naval Reserve	10	26a	White Slough / Napa River
	12f	Candlestick Cove		26c	Sonoma Creek
	12g	Crissy Field		26d	Sonoma Baylands
	12h	Yerba Buena Island	11	24d	Lower Petaluma River - Downstream of San Antonio Creek
	12i	Mission Creek	12	25b	Limantour Estero
	18a	Colma Creek		25c	Drakes Estero
	18b	Navigable Slough		25d	Bolinas Lagoon, North
	18c	Old Shipyard		25e	Bolinas Lagoon, South

Sub-areas achieving its initial year of "Zero detect" in 2020

Region	Code	Sub-area	2019 net m^2	2020
1	04k	Boardwalk No. 1 (Arkites)	0.02	zero detect
2	19o	San Mateo Creek / Ryder Park	1.37	zero detect
5	01f	Pond 3 - AFCC	0.01	zero detect
	13i	Eden Landing - Pond 10	0.01	zero detect
8	22d	Stege Marsh	0.12	zero detect

Sub-areas that were "Zero detect" in 2019 but were re-infested in 2020

Region	Code	Sub-area	2019	2020 net m^2
1	04e	Larkspur Ferry Landing Area	zero detect	0.48
	04l	Murphy Creek	zero detect	0.07
	23h	Strawberry Point	zero detect	0.13
2	18h	San Bruno Creek	zero detect	0.19
	19a	Brisbane Lagoon	zero detect	0.01
	19e	Oyster Point Park	zero detect	0.21
	19f	Point San Bruno	zero detect	0.02
	19j	Easton Creek Mouth	zero detect	0.19
3	19q	Foster City	zero detect	4.34
5	13c	Old Alameda Creek South Bank	zero detect	2.06
	13g	Upstream of 20 Tide Gates	zero detect	1.32
	13h	Eden Landing - North Creek	zero detect	1.92

rounds were implemented in 2014, with 25 sub-areas in 2014 to 52 sub-areas in 2019, before dropping for the first time to 45 sub-areas in 2020.

The graph in **Figure 7** illustrates bay-wide trends of invasive *Spartina* over the years. Since the peak infestation of 805 acres in 2005, cover has dropped to 33.1 acres in 2020. In 2019, inventory was conducted by grid (mentioned above) at all restricted treatment sub-areas. Inventory was not conducted in 2018 or 2020 at the sub-areas where treatment was not authorized; all 2020 data for these sub-areas are carryovers from the 2019 inventory. **Figure 8** shows the distribution of invasive *Spartina* change from 2005 (when treatment began) to 2020.

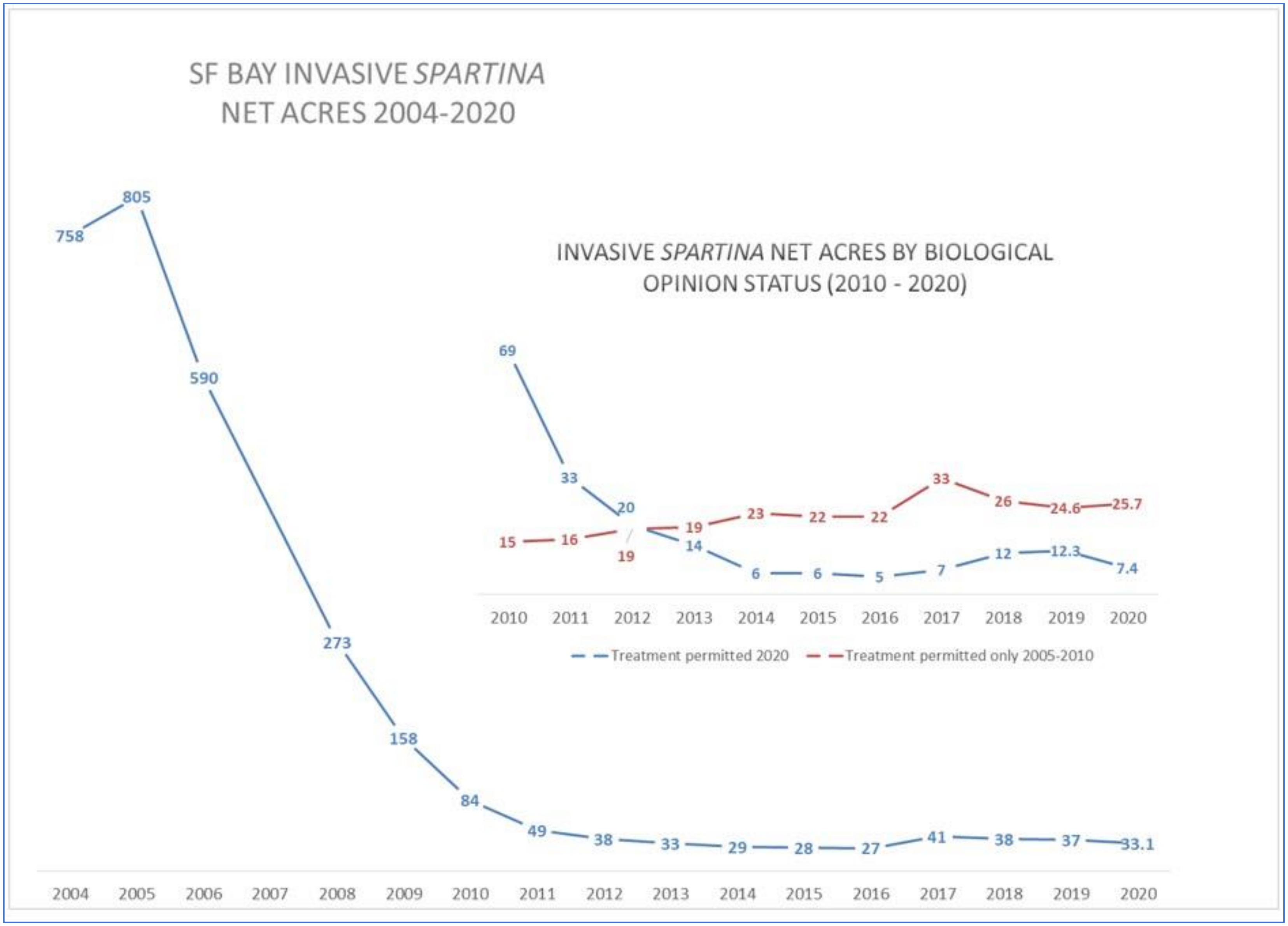

Figure 7. Bay-wide trend of invasive *Spartina* from 2004-2020 by net cover (acres) and treatment authorization since 2010

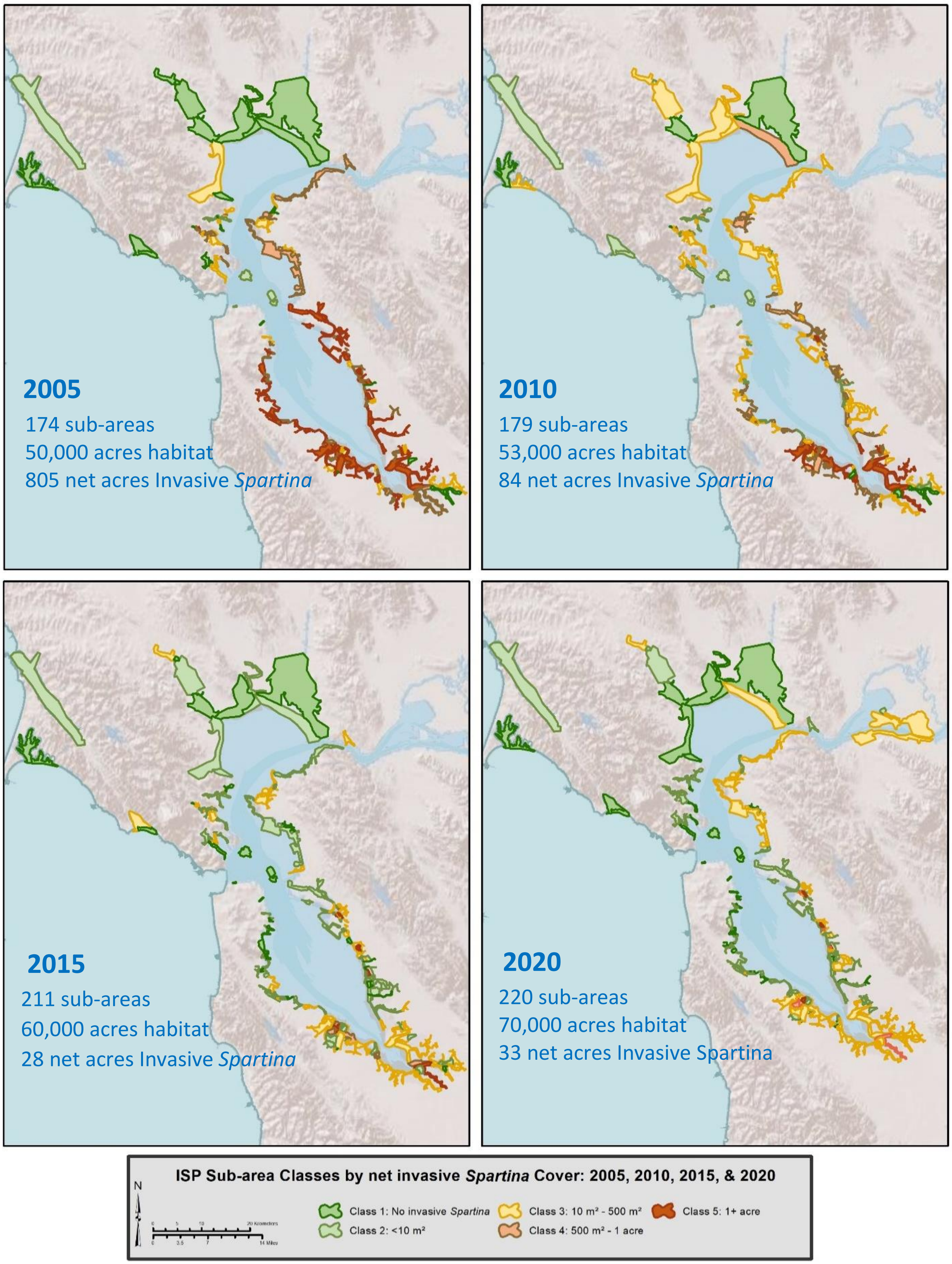

Figure 8. Progression of Invasive *Spartina* cover in the San Francisco Estuary tidal marsh habitat between 2005 and 2020.

2.2 Regional Inventory and Treatment

Section 2.1 introduced the ISP Reporting Regions as part of a discussion of bay-wide trends in invasive *Spartina* cover and treatment. This section provides additional detail by Reporting Region. **Table 5** provides a summary by region, and the following sections provide additional details.

2.2.1 Region 1: Marin

The Marin Region (Region 1) is composed of 32 sub-areas in Marin County and extends from the Golden Gate Bridge north to the mouth of the Petaluma River. It includes several large, contiguous tracts of marsh, most notably those in the Novato Creek, Corte Madera Creek and Las Gallinas Creek Watersheds. Relative to regions in the Central and South Bays, the Marin Region never had a very sizeable infestation in terms of acreage, but instead had many small infestations scattered throughout the marshes and tidal channels. Four non-native *Spartina* species are present (*S. alterniflora* x *foliosa* hybrids, *S. densiflora*, *S. densiflora* x *foliosa* hybrids, and *S. anglica*), the majority occurring in the Corte Madera Creek Watershed. Creekside Park (04g) on upper Corte Madera Creek is the original introduction site for both *S. densiflora* and *S. anglica* to the Estuary. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 9, Figure 10,** and **Table 6.** Treatment dates and methods are included in Table 6**.**

The ISP inventoried part or all of 31 of 32 sub-areas in this region in 2019 and all 32 in 2020 – on foot when the shoreline was accessible, supplemented by kayak on difficult shorelines and upstream portions of the watershed. The Novato (23m) sub-area, which includes Hamilton Wetlands and Gallinas Creek, was not inventoried in 2019 due to low infestation, but it was again partially surveyed in 2020 either by airboat or on foot.

Four sub-areas were only partially inventoried in 2020 due to low infestation pressure and/or access complications due to COVID-19. These include Bothin Marsh (23j), Sausalito (23k), Novato (23m), and China Camp (23o). The portions of these sub-areas that were inventoried included areas with instances of hybrid *S. alterniflora* detected within the last three years and those areas with highest invasion pressure. All sub-areas with historic detections of *S. densiflora* were surveyed for that species in both the summer and winter inventory rounds in 2019 and 2020. In February 2020, a third round of inventory and treatment for *S. densiflora* was conducted at multiple sub-areas for the first time in a single season, the dates of which are shown in Table 6.

The ISP mapped a total of 25 m^2 of non-native cordgrass of four species in the Marin Region in 2020. This reflects a 19 m^2 (43%) reduction from 2019 inventory and a reduction of 6.1 acres (>99%) since peak infestation in 2005.

Table 5. Summary of 2020 Invasive *Spartina* Cover by Reporting Region

Region #	Region Name	# Sub-Areas	Potential Invasive *Spartina* Habitat (ac)	Proportion of Region Acreage Authorized for Full Treatment	Net Cover 2020 (ac)	% Bay-wide Total	Change Since 2019 (ac)	% Change Since 2019	Peak Year	Peak Amount (ac)	Change Since Peak (ac)	% Change Since Peak	% Remaining since Peak
1	Marin	32	4,150	All	0.006	0.02%	-0.005	-42.8%	2005	6.1	-6.09	-99.9%	0.1%
2	SF Peninsula	35	1,151	All	0.006	0.02%	-0.02	-72.7%	2004	125.5	-125.47	-99.99%	0.01%
3	San Mateo	26	5,630	All	2.755	8.3%	-1.37	-33.2%	2004	134.8	-132.0	-98.0%	2.0%
4	Dumbarton South	25	9,693	All	0.439	1.3%	-0.54	-55.1%	2008	39.5	-39.1	-98.9%	1.1%
5	Union City	21	3,375	All	0.026	0.1%	-0.01	-26.3%	2004	233.1	-233.0	-99.99%	0.01%
6	Hayward*	30	1,493	88%	18.433	55.7%	-2.2	-10.7%	2005	225.9	-207.5	-91.8%	8.2%
7	San Leandro Bay*	20	483	85%	11.338	34.3%	+0.3	2.7%	2006	84.6	-73.3	-86.6%	13.4%
8	Bay Bridge North	13	1,705	All	0.040	0.1%	-0.02	-27.9%	2009	6.5	-6.4	-99.4%	0.6%
9	Suisun	5	11,977	All	0.010	0.03%	+0.004	66.6%	2005	0.65	-0.6	-98.5%	1.5%
10	Vallejo	4	20,789	All	0.006	0.02%	+0.005	661.7%	2009	0.32	-0.3	-98.0%	2.0%
11	Petaluma	4	5,696	All	0.006	0.02%	+0.002	53.4%	2007	0.15	-0.1	-96.1%	3.9%
12	Outer Coast	5	3,028	All	0.0000005	0.000001%	-6.79451E-07	-58.3%	2007	0.05	-0.048	-99.999%	0.001%
ALL	**SFB Estuary**	**220**	**69,170**	**99.6%**	**33.1**	100%	**-3.9**	**-10.5%**	**2005**	**805**	**-771.9**	**-95.9%**	**4.1%**

* This region has treatment restrictions in multiple sub-areas in 2020. The amount of the region that is authorized for full treatment is calculated by area in column 5.

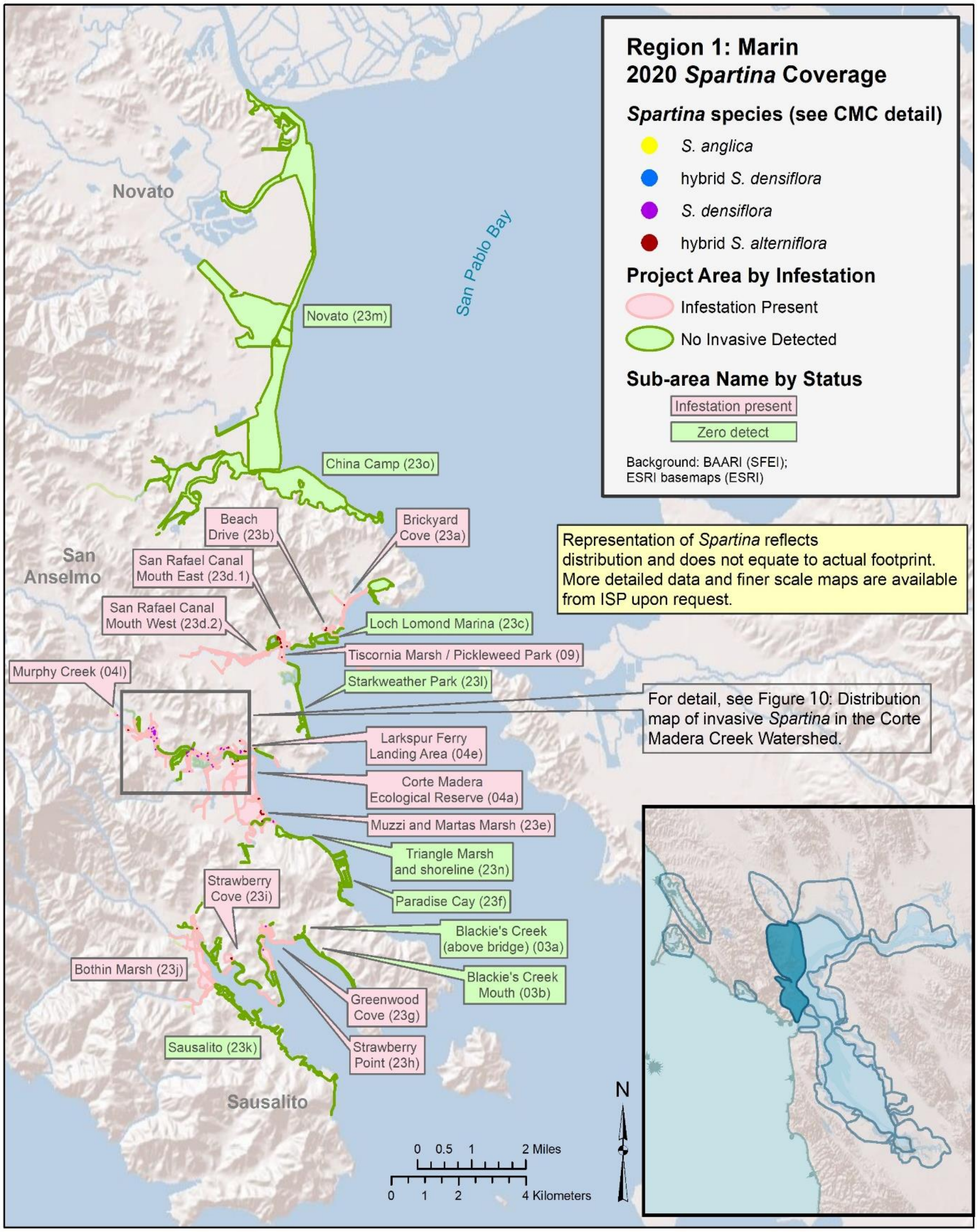

Figure 9. Distribution of invasive *Spartina* in 2020 across the 32 sub-areas of Reporting Region 1: Marin. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive Spartina are labeled in green

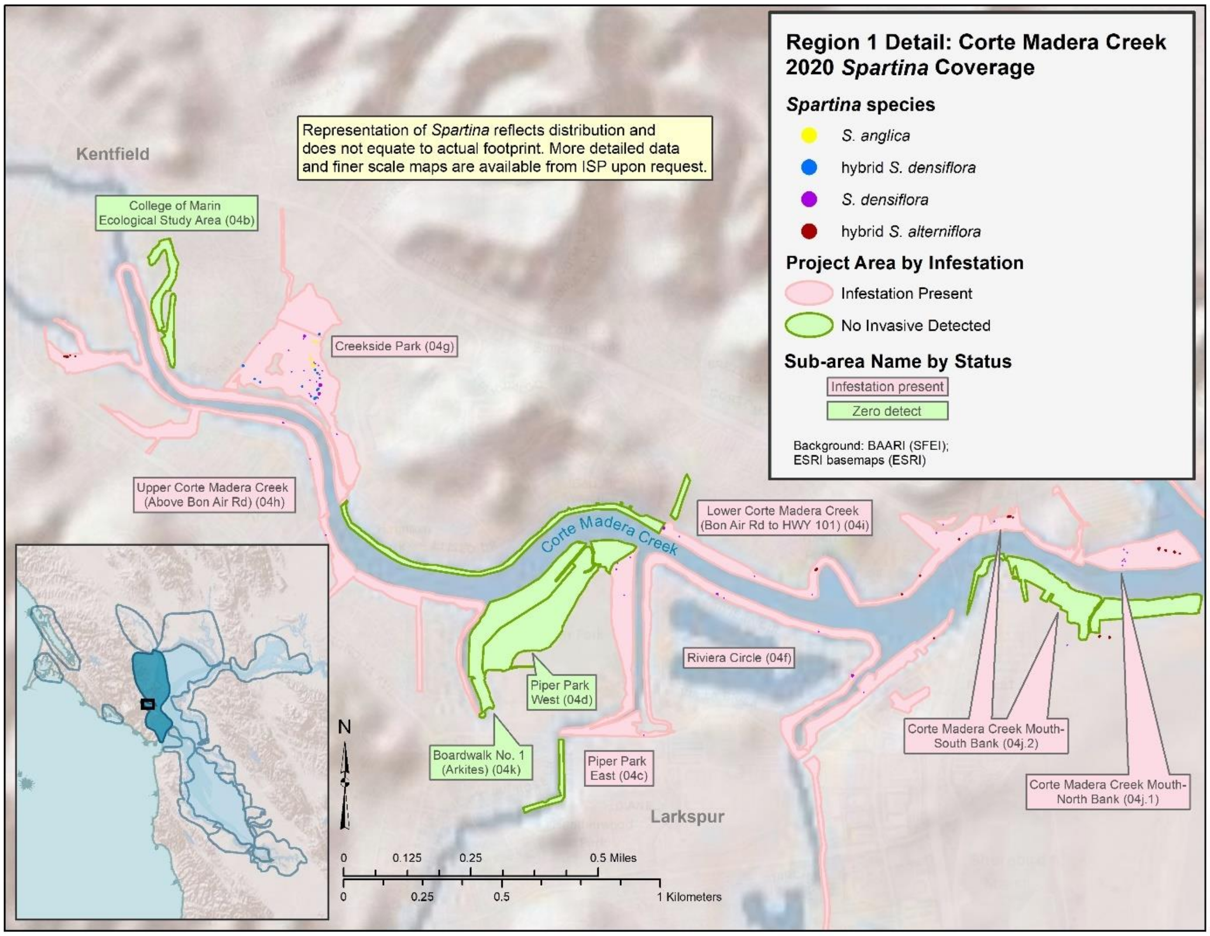

Figure 10. Distribution of invasive *Spartina* in 2020 within the Corte Madera Creek Watershed of ISP's Marin Region.

A total of 23 m^2 of hybrid *S. alterniflora* was mapped throughout 14 sub-areas of the region. Only five sub-areas had infestations larger than 1 m^2 net cover and they account for 88% of the regional infestation: Tiscornia/Pickleweed Park (09), Beach Drive (23b), San Rafael Canal Mouth East (23d.1), Muzzi & Marta's Marsh (23e), and Strawberry Cove (23i). Only a handful of Marin marshes have ever been heavily infested by hybrid *S. alterniflora*, but eradication efforts are complicated by the landscape of intricate, privately owned shorelines, which also support abundant *S. foliosa*. The ISP and the Friends of Corte Madera Creek Watershed have adapted inventory methods to address these areas, including shifting to ground surveys from kayak surveys conducted from the creek, which enables more thorough detection, but which requires extensive landowner coordination to gain access to private properties. Virtually all treatment in Region 1 now involves very small-scale spot applications of imazapyr, so work has been conducted by backpack sprayer in recent years.

Table 6. Summary of 2020 invasive *Spartina* mapped and treated by sub-area within Reporting Region 1: Marin.

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species					All Invasive *Spartina* Cover				
											Net Area Decline	
			anglica	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	2020 Net Area	2020 Treat-ment Area	Peak Year	Since Peak	Since 2019
REGION 1: MARIN												
03a: Blackie's Creek (above bridge)	2 years with No Invasive Spartina (2019-2020)			0		0	0	0	0	2005	100%	n/a
03b: Blackie's Creek Mouth	4 years with No Invasive Spartina (2017-2020)			0		0	0	0	0	2005	100%	n/a
04a: Corte Madera Ecological Reserve	9/4; 2/23/21 (COI)	Dug, Backpack		0		0.7 m²	0.002 m²	0.7 m²	21 m²	2005	>99%	Increase (0.6 m²)
04b: College of Marin Ecological Study Area	No Invasive Spartina 2020			0		0	0	0	0	2004	100%	100%
04c: Piper Park East	1/5/21 (COI)	Dug		0		0	0.009 m²	0.009 m²	0.2 m²	2005	>99%	77%
04d: Piper Park West	2 years with No Invasive Spartina (2019-2020)			0		0	0	0	0	2005	100%	n/a
04e: Larkspur Ferry Landing Area	11/11; 12/21	Backpack		0		0.5 m²	0	0.5 m²	15 m²	2005	>99%	n/a
04f: Riviera Circle	6/18 (COI); 1/14/21 (COI)	Dug, Backpack		0		0	0.1 m²	0.1 m²	1 m²	2005	>99%	24%
04g: Creekside Park	6/9 (COI); 8/14; 12/8; 1/5/21 (COI)	Dug, Backpack	0.14 m²	0.62 m²		0	0.1 m²	0.8 m²	16 m²	2005	>99%	66%
04h: Upper Corte Madera Creek (Above Bon Air Rd)	6/8 (COI); 7/22; 1/6/21 (COI)	Dug, Backpack		0.004 m²		0.1 m²	0.01 m²	0.2 m²	4 m²	2006	>99%	86%
04i: Lower Corte Madera Creek (Bon Air Rd to HWY 101)	6/8 (COI); 6/10 (COI); 7/22; 8/14; 11/11, 12/21; 1/6/21 (COI); 2/23/21 (COI)	Dug, Backpack		0.01 m²		0.3 m²	0.1 m²	0.4 m²	13 m²	2005	>99%	90%
04j.1: Corte Madera Creek Mouth - North Bank	6/8 (COI); 7/22; 9/22; 1/8/21 (COI)	Dug, Backpack		0		0.4 m²	0.1 m²	0.5 m²	30 m²	2007	>99%	43%
04j.2: Corte Madera Creek Mouth - South Bank	7/22; 11/11; 1/6/21 (COI)	Dug, Backpack		0		0.1 m²	0.009 m²	0.1 m²	5 m²	2007	>99%	90%
04k: Boardwalk No. 1 (Arkites)	No Invasive Spartina 2020			0		0	0	0	0	2006	100%	100%
04l: Murphy Creek	1/6/21 (COI)	Dug		0		0	0.07 m²	0.07 m²	0.3 m²	2007	>99%	n/a
09: Tiscornia Marsh / Pickleweed Park	9/7; 10/15; 11/11; 12/21	Backpack		0		3 m²	0	3 m²	91 m²	2004	99%	39%
23a: Brickyard Cove	9/7	Backpack		0		0.3 m²	0	0.3 m²	20 m²	2008	>99%	Increase (0.2 m²)
23b: Beach Drive	9/7; 9/10	Backpack		0		6 m²	0	6 m²	114 m²	2006	>99%	Increase (0.1 m²)
23c: Loch Lomond Marina	2 years with No Invasive Spartina (2019-2020)			0		0	0	0	0	2004	100%	n/a
23d.1: San Rafael Canal Mouth East	9/15	Backpack		0		7 m²	0	7 m²	416 m²	2007	98%	30%
23d.2: San Rafael Canal Mouth West	9/25	Backpack		0		0.2 m²	0	0.2 m²	13 m²	2004	>99%	55%
23e: Muzzi and Martas Marsh	9/4; 9/22; 11/11; 2/23/21 (COI)	Dug, Backpack		0		2 m²	0.02 m²	2 m²	152 m²	2007	>99%	77%
23f: Paradise Cay	3 years with No Invasive Spartina (2018-2020)			0		0	0	0	0	2005	100%	n/a
23g: Greenwood Cove	6/17 (COI); 1/18/21 (COI)	Dug		0		0	0.02 m²	0.02 m²	0.2 m²	2006	>99%	Increase (0.01 m²)
23h: Strawberry Point	6/30 (COI)	Dug		0		0	0.1 m²	0.1 m²	0.3 m²	2005	>99%	n/a
23i: Strawberry Cove	9/4	Backpack		0		2 m²	0	2 m²	118 m²	2007	>99%	Increase (0.6 m²)
23j: Bothin Marsh	9/4	Backpack		0		0.06 m²	0	0.06 m²	2 m²	2006	>99%	94%
23k: Sausalito	6 years with No Invasive Spartina (2015-2020)			0		0	0	0	0	2004	100%	n/a
23l: Starkweather Park	5 years with No Invasive Spartina (2016-2020)			0		0	0	0	0	2006	100%	n/a
23m: Novato	5 years with No Invasive Spartina (2016-2020)			0		0	0	0	0	2006	100%	n/a
23n: Triangle Marsh and shoreline	2 years with No Invasive Spartina (2019-2020)			0		0	0	0	0	2007	100%	n/a
23o: China Camp	4 years with No Invasive Spartina (2017-2020)			0		0	0	0	0	2010	100%	n/a
REGION 1 TOTAL			0.14 m²	0.634 m²		23 m²	0.8 m²	25 m²	0.3 acres	2005	>99%	43%

The Marin infestation of *S. densiflora* remains the largest in the Estuary, because this region was the original introduction site, and this species was detected in only one other region in 2020 (Region 12: Outer Coast). In 2020, *S. densiflora* was detected in 12 of the 32 sub-areas. The ISP mapped a total of 0.80 m^2 cover, which amounts to 99.8% of the 2020 bay-wide total and reflects a 57% reduction from 2019 inventory. Every instance of *S. densiflora* found in 2019 and 2020 was subsequently treated by manual removal. Hybrid *S. densiflora × foliosa* was found in three sub-areas (down from eight sub-areas in 2018 and seven in 2019) and totaled 0.8 m^2 of net cover. All instances were either dug, sprayed, and/or tarped in 2020. See section **3.3** for more details on *S. densiflora* and hybrid *S. densiflora*.

The Marin Region is also the only region where *S. anglica* has ever been detected. It was again found in a single historical sub-area, Creekside Park (04g) in 2020. The nine instances of this species amounted to 0.14 m^2 net cover, all of which were treated in 2020. Imazapyr treatment of the remaining *S. anglica* detections was delayed by about 1.5 months after a couple citizens contacted Marin County after seeing their IPM application notice posted at Creekside Park. The ISP Treatment Program Manager worked with Marin County Parks to answer questions from the concerned citizens and produced some educational signage that was subsequently posted at the site. The signage explained the careful, detailed IPM strategy, and the long history of volunteer work of Friends of Corte Madera Creek at the site. Treatment of *S. anglica* requires a small amount of herbicide due to the plant being rhizomatous and therefore impossible to effectively remove by digging without doing substantial and long-lasting damage to the substrate. Surveys for Ridgway's rails conducted by the ISP and Point Blue Conservation Science (PBCS) have shown a stable population trend in the Marin Region, with an increase in rail detections at surveyed sub-areas between 2019 and 2020, and an overall increase over five years at the same sub-areas (Wood 2019, 2020; McBroom 2020).

The Marin Region contains several large intact native marshes that support Ridgway's rail populations that are not expected to be impacted by the removal of the remaining non-native *Spartina*. With the abundance of native marsh, the ISP has not targeted Region 1 for significant habitat enhancement, except for nine constructed high tide refuge islands installed at the Corte Madera Ecological Reserve to provide resilience against sea level rise. In addition, ISP and Friends of Corte Madera Creek have planted *Grindelia stricta* for nesting substrate and cover at Creekside Park, where the large infestation of multiple non-native *Spartina* species had displaced many native marsh plants.

The low invasion pressure in this region and the locally abundant *S. foliosa* have allowed the ISP to harvest plant material for amplification in nursery propagation beds and outplanting to other regions that do not have suitable native cordgrass propagule sources. The ISP currently maintains propagation beds at The Watershed Nursery of genetically-verified *S. foliosa* from four Marin County marshes, including Strawberry Cove (23i), Coyote Creek (a part of Bothin Marsh [23j]), Starkweather Park (23l), and Upper Gallinas Creek (a part of Novato [23m]). Plants from these beds have been outplanted into five regions: Region 2: San Francisco Peninsula, Region 5: Union City, Region 6: Hayward, Region 7: San Leandro Bay, and Region 10: Vallejo.

2.2.2 Region 2: San Francisco Peninsula

The San Francisco Peninsula Region (Region 2) extends from the Golden Gate Bridge south to the San Mateo Bridge and includes 35 sub-areas. Once very heavily infested by hybrid *S. alterniflora*, successful treatment has largely returned the shorelines to mudflat, as they were prior to invasion. The three most prominent marsh habitats in the region are found at the confluence of Colma Creek and San Bruno Creek (site 18) in South San Francisco, the shoreline of the San Francisco International Airport (SFO, 19h), and the mouth of Seal Slough (19p) in San Mateo County. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 11** and **Table 7**. Treatment dates and methods are included in Table 7.

Multiple sub-areas were not inventoried in 2019 due to several consecutive years of being "Zero detect". Areas not inventoried included Mission Creek (12i), Candlestick Cove (12f), Brisbane Lagoon (19a), Sierra Point (19b), Oyster Cove (19c), Oyster Point Marina (19d), Oyster Point Park (19e), Anza Lagoon (19f), Fisherman's Park (19m), and portions of Pier 94 (12a), Seaplane Harbor (19g), Mills Creek Mouth (19i), Easton Creek Mouth (19j). Every sub-area in this region was surveyed again in 2020. Inventory at three sub-areas (India Basin [12c], Hunters Point Naval Reserve [12d], and Yerba Buena Island [12h]) was limited to the zones that were assessed to contain suitable habitat for *Spartina*. The remaining 32 sub-areas were surveyed thoroughly on foot in 2020 and 26 m^2 of non-native cordgrass was mapped, all of which was hybrid *S. alterniflora* except for 0.01 m^2 of hybrid *S. densiflora*. This is a reduction of 67 m^2 (72%) from 2019 infestation, and the current footprint represents 0.005% of the peak 125.5-acre infestation in 2004 (**Table 7**).

Hybrid *S. alterniflora* is now scarce or absent in most sub-areas in the San Francisco Peninsula Region, with 20 of the sub-areas being "zero detect" (**Table 5**) in 2020. Seventy-nine percent of the total remaining non-native *Spartina* in the region is in a single sub-area, Sanchez Marsh (19k). Small re-infestations were detected in 2020 at several of the sub-areas that were not inventoried in 2019, which highlights the need to continue inventory in "zero detect" marshes until all local infestation pressure is removed.

Sanchez Marsh contains the largest remaining infestation in the region, but it has been steadily decreasing in area due to intensified inventory and treatment efforts over the last five years. It requires airboat treatment, which is complicated by the need to get an airboat cage under a footbridge at the eastern end of the hydrologically connected Burlingame Lagoon (19l). Morning tides are low enough to allow this access with sufficient time to treat only early in the treatment season.

Sanchez Marsh is the only remaining marsh in Region 2 where hybrid *S. densiflora* was found. A single plant totaling 0.01 m^2 net cover was detected in both 2019 and 2020, and it was tarped in 2020. Sanchez Marsh and Burlingame Lagoon also historically contained *S. densiflora*, but this species has not been detected in either marsh since 2018 and 2016, respectively, despite being inventoried twice a year for *S. densiflora*.

The urban shoreline in the San Francisco Peninsula Region offers little habitat for Ridgway's rails. A single rail was detected in 2019 at SFO (19h) and a total of two rails were detected in 2020 at the Seal Slough sub-areas (19p.1 and 19p.2). These three sub-areas are the only marshes in the region where rails have been detected during ISP rail surveys in the past five years. The major reduction in hybrid *S. alterniflora* in the San Francisco Peninsula Region since 2005 resulted in reduced numbers of California Ridgway's rails, because there was little native habitat available after the successful control effort. Most areas that were invaded by hybrid *S. alterniflora* in the region were at low elevations that did not support native tidal marsh vegetation prior to invasion and are now restored to mudflats.

The San Francisco Peninsula bay edge is heavily urbanized with very few opportunities to enhance habitat that could support sustainable Ridgway's rail populations. The ISP's habitat enhancement efforts have been limited to three sub-areas within the Colma Creek/San Bruno complex. ISP partnered with an SFSU graduate student (Whitney Thornton) to reintroduce *S. foliosa* along Colma Creek (18a) and in San Bruno Marsh (18g) from 2011-13, and has continued planting efforts at San Bruno Marsh and at Confluence Marsh (18f) from 2016-21. The planting effort has focused on re-establishing the narrow fringe of native *S. foliosa* that was present near the mouth of Colma Creek prior to hybrid *S. alterniflora* invasion.

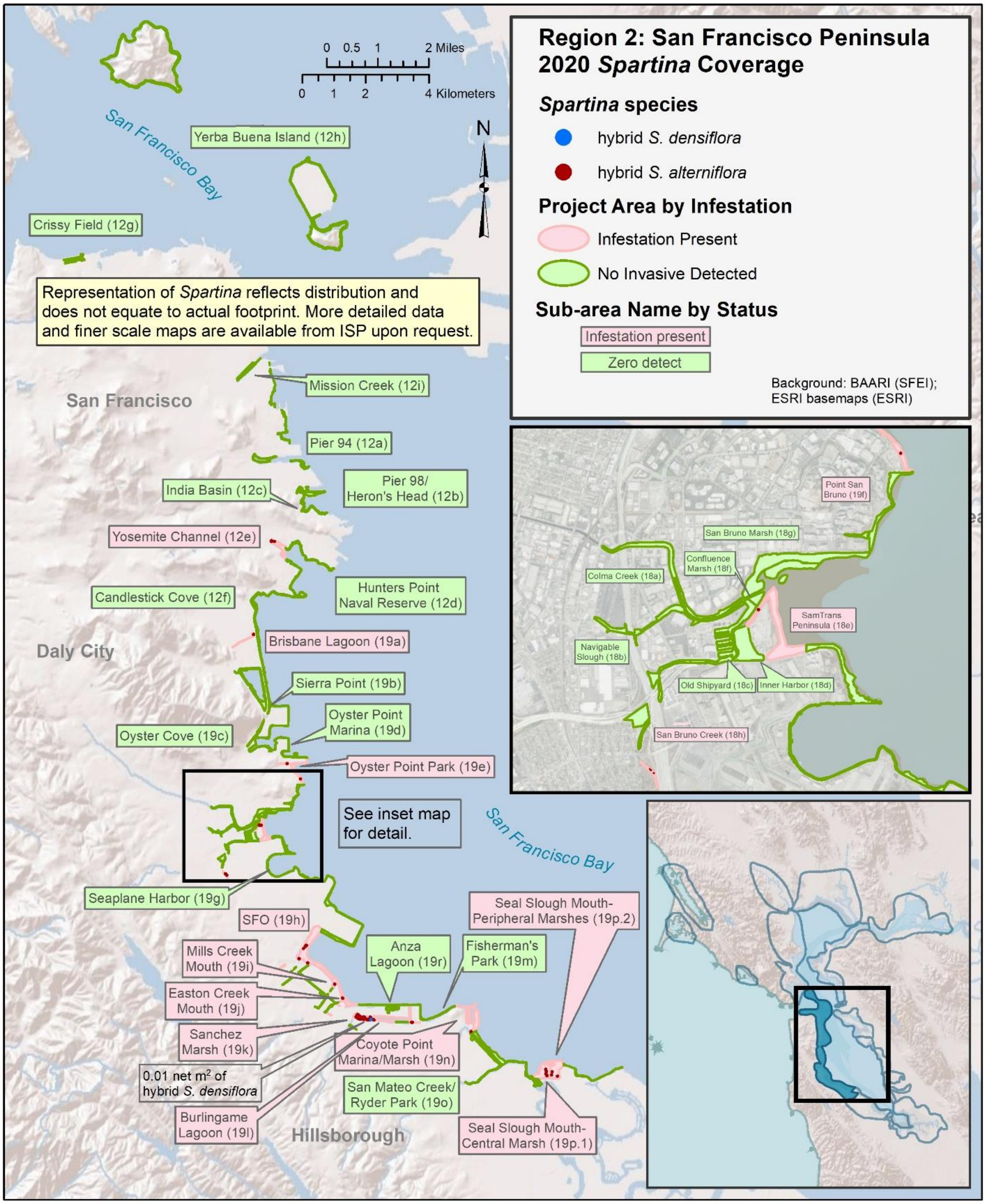

Figure 11. Distribution of invasive *Spartina* in 2020 across the 35 sub-areas of Reporting Region 2: San Francisco Peninsula. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive *Spartina* are labeled in green.

Table 7. Summary of 2020 invasive Spartina mapped and treated by sub-area within Reporting Region 2: San Francisco Peninsula.

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species					All Invasive *Spartina* Cover				
											Net Area Decline	
			anglica	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	2020 Net Area	2020 Treat-ment Area	Peak Year	Since Peak	Since 2019
REGION 2: SAN FRANCISCO PENINSULA												
12a: Pier 94	**5 years with No Invasive Spartina (2016-2020)**		0			0	0	0	0	2005	100%	n/a
12b: Pier 98 / Heron's Head	**3 years with No Invasive Spartina (2018-2020)**		0			0	0	0	0	2008	100%	n/a
12c: India Basin	**7 years with No Invasive Spartina (2014-2020)**		0			0	0	0	0	2005	100%	n/a
12d: Hunters Point Naval Reserve	**4 years with No Invasive Spartina (2017-2020)**		0			0	0	0	0	2008	100%	n/a
12e: Yosemite Channel	9/3	Backpack	0			0.2 m²	0	0.2 m²	7 m²	2004	>99%	Increase (0.08 m²)
12f: Candlestick Cove	**6 years with No Invasive Spartina (2015-2020)**		0			0	0	0	0	2006	100%	n/a
12g: Crissy Field	**7 years with No Invasive Spartina (2014-2020)**		0			0	0	0	0	2008	100%	n/a
12h: Yerba Buena Island	**7 years with No Invasive Spartina (2014-2020)**		0			0	0	0	0	2006	100%	n/a
12i: Mission Creek	**7 years with No Invasive Spartina (2014-2020)**		0			0	0	0	0	2009	100%	n/a
18a: Colma Creek	**3 years with No Invasive Spartina (2018-2020)**		0			0	0	0	0	2005	100%	n/a
18b: Navigable Slough	**4 years with No Invasive Spartina (2017-2020)**		0			0	0	0	0	2006	100%	n/a
18c: Old Shipyard	**2 years with No Invasive Spartina (2019-2020)**		0			0	0	0	0	2006	100%	n/a
18d: Inner Harbor	**7 years with No Invasive Spartina (2014-2020)**		0			0	0	0	0	2006	100%	n/a
18e: Sam Trans Peninsula	7/29	Backpack	0			0.002 m²	0	0.002 m²	0.3 m²	2004	>99%	75%
18f: Confluence Marsh	**4 years with No Invasive Spartina (2017-2020)**		0			0	0	0	0	2004	100%	n/a
18g: San Bruno Marsh	**2 years with No Invasive Spartina (2019-2020)**		0			0	0	0	0	2004	100%	n/a
18h: San Bruno Creek	7/30	Backpack	0			0.2 m²	0	0.2 m²	7 m²	2006	>99%	n/a
19a: Brisbane Lagoon	6/23	Backpack	0			0.008 m²	0	0.008 m²	0.3 m²	2006	>99%	n/a
19b: Sierra Point	**6 years with No Invasive Spartina (2015-2020)**		0			0	0	0	0	2004	100%	n/a
19c: Oyster Cove	**5 years with No Invasive Spartina (2015-2020)**		0			0	0	0	0	2006	100%	n/a
19d: Oyster Point Marina	**6 years with No Invasive Spartina (2015-2020)**		0			0	0	0	0	2006	100%	n/a
19e: Oyster Point Park	6/23	Backpack	0			0.2 m²	0	0.2 m²	6 m²	2005	>99%	n/a
19f: Point San Bruno	6/23	Backpack	0			0.02 m²	0	0.02 m²	0.4 m²	2005	>99%	n/a
19g: Seaplane Harbor	**3 years with No Invasive Spartina (2018-2020)**		0			0	0	0	0	2004	100%	n/a
19h: SFO	9/21	Backpack, Airboat	0			3 m²	0	3 m²	166 m²	2004	>99%	77%
19i: Mills Creek Mouth	9/21	Backpack, Airboat	0			0.09 m²	0	0.09 m²	3 m²	2005	>99%	34%
19j: Easton Creek Mouth	9/21	Backpack, Airboat	0			0.2 m²	0	0.2 m²	6 m²	2004	>99%	n/a
19k: Sanchez Marsh	7/24; 10/27 (R2); 12/18	Dug, Backpack, Airboat	0.01 m²			20 m²	0	21 m²	884 m²	2004	>99%	72%
19l: Burlingame Lagoon	7/24; 10/27 (R2)	Dug, Backpack	0			1 m²	0	1 m²	104 m²	2004	>99%	Increase (0.4 m²)
19m: Fisherman's Park	**9 years with No Invasive Spartina (2012-2020)**		0			0	0	0	0	2005	100%	n/a
19n: Coyote Point Marina / Marsh	11/10	Backpack	0			0.04 m²	0	0.04 m²	2 m²	2004	>99%	Increase (0.03 m²)
19o: San Mateo Creek / Ryder Park	**No Invasive Spartina 2020**		0			0	0	0	0	2006	100%	100%
19p.1: Seal Slough Mouth - Central Marsh	8/14	Backpack	0			0.2 m²	0	0.2 m²	8 m²	2004	>99%	97%
19p.2: Seal Slough Mouth - Peripheral Marshes	8/14	Backpack	0			0.2 m²	0	0.2 m²	25 m²	2004	>99%	90%
19r: Anza Lagoon	**5 years with No Invasive Spartina (2016-2020)**		0			0	0	0	0	2004	100%	n/a
REGION 2 TOTAL			0.01 m²			26 m²	0	26 m²	0.3 acres	2004	>99%	73%

2.2.3 Region 3: San Mateo

The San Mateo Region (Region 3) consists of 26 sub-areas on the western South Bay shoreline between the San Mateo and Dumbarton Bridges. Control of hybrid *S. alterniflora* in this region is essential to protect some large historic tracts of native marsh (Greco Island [02f, 02h]), extensive tracts of restored marsh (Bair Island [02c, 02d, 02k, 02m, 02o]), and remaining large commercial salt ponds that are slated for restoration to tidal habitat. This region was heavily impacted by hybrid *S. alterniflora* invasion, which colonized the shoreline and marshes, and quickly invaded newly breached areas undergoing restoration to tidal marsh. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 12** and **Table 8**. Treatment dates and methods are included in Table 8.

All 26 sub-areas in the San Mateo Region were inventoried in 2019, though three on Bair Island Ecological Reserve with known infestations (B2 North South [02c.2], Pond B3 [02m], and Central Bair [02o]) were only partially surveyed due to time constraints. In 2020, all 26 sub-areas were inventoried on foot, although a 57-acre portion of Inner Bair (02l) was not completed due to extreme weather conditions.

Inventory in 2020 was conducted primarily on foot, often with assistance from boats (kayak, Whaler, Achilles inflatable boat, or airboat) for access. Two sub-areas (Pond B3 [02m] and Central Bair [02o]) were surveyed solely by airboat with assistance from Solitude Lake Management and San Mateo County Mosquito and Vector Control District, respectively. Inventory and treatment were conducted simultaneously at these two sub-areas, resulting in coarser data than would be normally collected during a purely inventory-focused survey. B2 North East (02c.1b) was mapped by grid in 2019 and 2020 and was treated by helicopter both years. 2018 was the first year of full treatment of B2 North East since 2010, after which treatment was restricted under the project's Biological Opinion (see Section 3.3 for more information on resuming treatment at formerly restricted sites).

A total of 2.8 net acres of hybrid *S. alterniflora* was mapped in the San Mateo Region, a 1.4-acre (33%) reduction since 2019 (Figure 10, Table 8). Region 3 has the third largest remaining infestation in the Estuary behind Region 6: Hayward and Region 7: San Leandro Bay, where there continue to be treatment restrictions on most of the remaining hybrid *S. alterniflora* infestations.

Three sub-areas within the Bair Island Ecological Reserve (B2 North East (02c.1b), B2 North South (02c.2), and Pond B3 (o2m)) maintain an infestation of greater than 0.25 acre: and collectively account for 89% of the region's remaining infestation. B2 North East continues to have by far the largest remnant infestation (1.7 acres net cover) and accounts for 62% of the region total. Full treatment of B2 North East was restricted between 2012 and 2017, and only one sub-lethal aerial application of herbicide was allowed annually to curb seed production (the intent being to maintain aboveground vegetation for Ridgway's rail habitat). Since full treatment resumed in 2018, the sub-area has seen steady annual declines in infestation level.

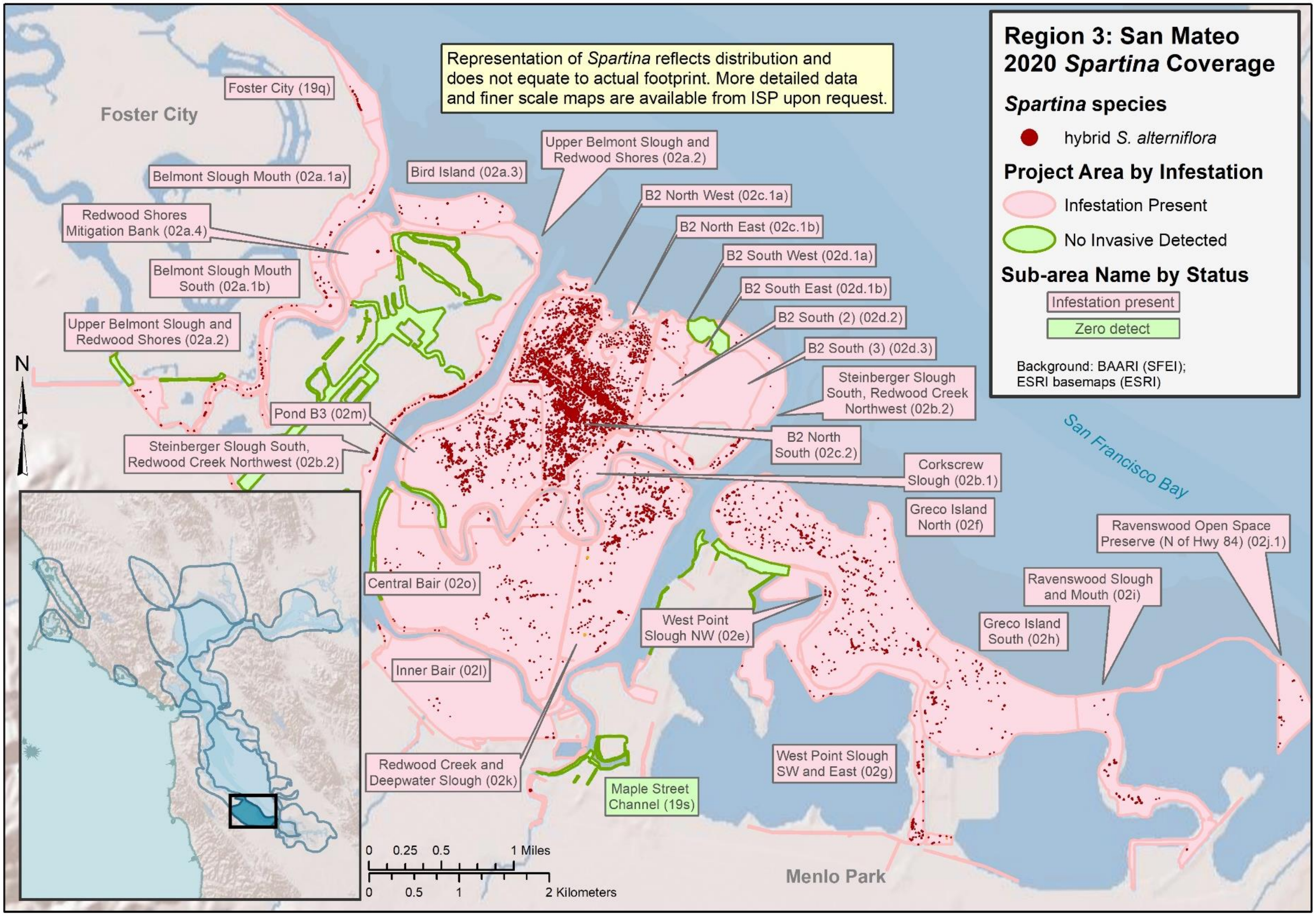

Figure 12. Distribution of invasive *Spartina* in 2020 across the 26 sub-areas of Reporting Region 3: San Mateo. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive *Spartina* are labeled in green.

Table 8. Summary of 2020 invasive *Spartina* mapped and treated by sub-area within Reporting Region 3: San Mateo.

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species: *anglica*	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	All Invasive *Spartina* Cover: 2020 Net Area	2020 Treat-ment Area	Peak Year	Net Area Decline: Since Peak	Since 2019
REGION 3: SAN MATEO												
02a.1a: Belmont Slough Mouth	8/24; 9/8	Truck, Backpack, Airboat		0		2 m²	0	2 m²	179 m²	2004	>99%	86%
02a.1b: Belmont Slough Mouth South	8/12	Truck, Backpack, Airboat		0		4 m²	0	4 m²	221 m²	2004	>99%	71%
02a.2: Upper Belmont Slough and Redwood Shores	8/12	Truck, Backpack, Airboat		0		24 m²	0	24 m²	956 m²	2004	>99%	58%
02a.3: Bird Island	8/24; 9/8-9/9	Backpack		0		4 m²	0	4 m²	243 m²	2006	>99%	58%
02a.4: Redwood Shores Mitigation Bank	10/14	Backpack		0		0.1 m²	0	0.1 m²	3 m²	2015	99%	55%
02b.1: Corkscrew Slough	8/22; 8/24; 9/22; 11/11	Backpack, Airboat		0		57 m²	0	57 m²	0.3 acres	2004	99%	66%
02b.2: Steinberger Slough South, Redwood Creek Northwest	7/24; 9/8-9/9; 10/19; 11/11; 11/23	Backpack, Airboat		0		160 m²	0	160 m²	0.9 acres	2004	>99%	14%
02c.1a: B2 North West	8/12; 8/22; 10/21	Backpack, Airboat		0		293 m²	0	293 m²	2.3 acres	2005	>99%	46%
02c.1b: B2 North East	8/19	Airboat, Aerial: Broadcast		0		1.7 acres	0	1.7 acres	24.2 acres	2005	93%	33%
02c.2: B2 North South	10/7-10/9; 10/21-10/22; 11/7; 11/9; 11/11; 11/23	Backpack, Airboat		0		0.4 acres	0	0.4 acres	12 acres	2006	96%	51%
02d.1a: B2 South West	10/22	Backpack		0		5 m²	0	5 m²	194 m²	2004	>99%	60%
02d.1b: B2 South East	10/22	Backpack		0		0.1 m²	0	0.1 m²	5 m²	2004	>99%	Increase (0.05 m²)
02d.2: B2 South (2)	10/22	Backpack		0		4 m²	0	4 m²	170 m²	2006	>99%	Increase (2 m²)
02d.3: B2 South (3)	10/22; 11/11	Backpack		0		4 m²	0	4 m²	198 m²	2009	>99%	Increase (2 m²)
02e: West Point Slough NW	11/23	Backpack, Airboat		0		8 m²	0	8 m²	114 m²	2005	>99%	Increase (3 m²)
02f: Greco Island North	8/24; 9/9; 9/23-9/24; 10/7; 10/10; 11/23	Backpack, Airboat		0		216 m²	0	216 m²	1 acres	2008	>99%	50%
02g: West Point Slough SW and East	7/27; 9/9; 9/23; 10/8	Backpack, Airboat		0		35 m²	0	35 m²	0.3 acres	2005	>99%	74%
02h: Greco Island South	9/9; 9/23	Backpack, Airboat		0		14 m²	0	14 m²	617 m²	2005	>99%	76%
02i: Ravenswood Slough and Mouth	10/6-10/7	Backpack		0		15 m²	0	15 m²	644 m²	2004	>99%	25%
02j.1: Ravenswood Open Space Preserve (N of Hwy 84)	9/23; 11/11	Backpack		0		3 m²	0	3 m²	125 m²	2006	>99%	Increase (2 m²)
02k: Redwood Creek and Deepwater Slough	8/24; 9/8; 9/22; 9/24; 11/23	Backpack, Amphibious vehicle, Airboat		0		272 m²	0	272 m²	1.6 acres	2009	98%	37%
02l: Inner Bair	8/21	Backpack		0		3 m²	0	3 m²	91 m²	2006	>99%	70%
02m: Pond B3	6/30; 8/27-8/28; 9/26; 10/10; 11/23	Airboat		0		0.4 acres	0	0.4 acres	2.3 acres	2014	5%	Increase (336 m²)
02o: Central Bair	7/10; 8/10-8/11; 11/23	Airboat		0		61 m²	0	61 m²	0.3 acres	2016	41%	11%
19q: Foster City	9/3	Backpack		0		4 m²	0	4 m²	59 m²	2004	>99%	n/a
19s: Maple Street Channel	2 years with No Invasive Spartina (2019-2020)			0		0	0	0	0	2011	100%	n/a
REGION 3 TOTAL				0		2.8 acres	0	2.8 acres	46.2 acres	2004	98%	34%

The only sizeable increase in infestation area in the San Mateo Region was at Pond B3, where the net cover of hybrid *S. alterniflora* increased by 340 m^2 in 2020. This increase, however, was largely a result of a shift in inventory timing. Early in 2020, biologists assessed the sub-area and found habitat potentially suitable for nesting Ridgway's rail, and as a result, inventory and treatment had to be scheduled later in the season than in previous years. This delay allowed for additional plant growth and resulted in increased detection of hybrid *S. alterniflora*. Consequently, inventory and treatment at this location will continue to be conducted later in the season in future years.

Most treatment in this region must be conducted using airboats, either applying imazapyr herbicide directly from the spray rig or, for areas beyond the reach of the hose, deploying personnel with backpack sprayers. ISP partners conducted 22 days of airboat treatment within the San Mateo Region in 2020.

The San Mateo Region historically contained small, isolated populations of *S. densiflora* in several sub-areas, though none was detected in either 2019 and 2020. The largest infestation was historically in Maple Street Channel (19s), where the presence of homeless encampments complicated access and treatment. The most recent detection of *S. densiflora* was within this sub-area in 2018, and it was manually removed.

Annual surveys for Ridgway's rails by the ISP and Don Edwards National Wildlife Refuge (DENWR) indicate stable numbers in the region. The number of rails detected increased by about 1% between 2019 and 2020, and the current number is about the same as that of 2015 (McBroom 2020). At the formerly restricted sub-area B2 North East (02c.1b), however, Ridgway's rail numbers have declined by about 35% since full treatment was initiated in 2018, with most of the decline occurring between 2019 and 2020. Because the overall trend in the region remains stable, rails may be moving from B2 North East into adjacent sub-areas with higher quality habitat.

With abundant *S. foliosa* within most sub-areas and hybrid *S. alterniflora* persisting throughout the region, native cordgrass has not been considered for planting in this region. Habitat enhancements to date have included construction of high tide refuge islands and planting extensive *Grindelia stricta*. Both types of enhancement are intended to provide Ridgway's rails with taller vegetative cover for protection from predators. High tide refuge islands, intended to provide cover during extreme tide events, have been constructed at seven sub-areas: two along Belmont Slough (02a.1-2), one on Bird Island (02a.3), four in Corkscrew Slough (02b.1), nine within B2 North (02c.1a-b), and four in Deepwater Slough (02k). Additionally, the ISP has installed approximately 37,600 *Grindelia stricta* plants across seven sub-areas.

2.2.4 Region 4: Dumbarton South

The Dumbarton South Region (Region 4) includes 25 sub-areas and is comprised of all tidal wetlands south of the Dumbarton Bridge. The region includes newly breached restoration sites, salt evaporator ponds that are slated for restoration to tidal marsh, large expanses of marsh protected and managed by the USFWS as part of San Francisco Bay Don Edwards National Wildlife Refuge (DENWR), and fringe marsh that provides connectivity between the larger habitat areas. Much of this region is a focus for restoration by the South Bay Salt Pond Restoration Project (SBSPRP), and control of invasive *Spartina* here is key to the SBSPRP achieving its long-term goals. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 13** and **Table 9**. Treatment dates and methods are included in Table 9.

All 25 sub-areas of the Dumbarton South Region were inventoried in 2019 and 2020, though the furthest upstream extents of Guadalupe Slough (15a.3) and Alviso Slough (15a.4) were not surveyed either year, and the furthest upstream extents of Coyote Creek-Alameda County (05f) and Coyote Creek to Artesian Slough (15a.5) were only surveyed in 2020. Island Pond A21 (part of the 05i sub-area) was thoroughly surveyed in 2019, but only the historic infestation zone was thoroughly surveyed in 2020. In 2020 two other sub-areas, Dumbarton/Audubon (05b) and Cooley Landing East (16.2), received a coarser level of inventory in order accommodate challenging timeframes at other marshes due to hazardous air quality and restrictions from COVID-19.

In 2019, ISP began coordinating with the San Jose-Santa Clara Regional Wastewater Facility to launch an airboat from their onsite boat ramp along upper Artesian Slough, which connects to Coyote Creek east of the Amtrak train bridge. This bridge precluded access by airboat in previous years. In 2019, Solitude Lake Management provided airboat assistance for inventory and treatment in Island Ponds A19 and A20 and along stretches of Coyote Creek, which had previously been accessible only by ISP's on boat. In 2020, airboat assistance was increased for more thorough survey of these areas and for inventory of Pond A17 (15a.7).

Hybrid *S. alterniflora* is the only species of non-native cordgrass that has been found in the Dumbarton South Region, and in 2020, ISP mapped a total of 0.44 acre, a 0.54-acre (55%) reduction since 2019. The hybrid *S. alterniflora* infestation in the Dumbarton South Region amounts to 1.3% of the Estuary total, placing this region as the fourth most infested behind Hayward, San Leandro Bay, and San Mateo Regions.

Three sub-areas, Calaveras Marsh (05a.1), Alviso Slough (15a.4), and Cooley Landing East (16.2), maintain a combined 0.25-acre infestation, 59% of the region total. In 2020, each of these sub-areas reflected reductions of greater than 50% compared to 2019 level of infestation. These three sub-areas and five others together have represented the largest infestations in Region 4 for many years. Since 2016, infestation at each of these sub-areas has substantially decreased: Alviso Slough (87% reduction), Calaveras Marsh (88%), Cooley Landing East (91%), Palo Alto

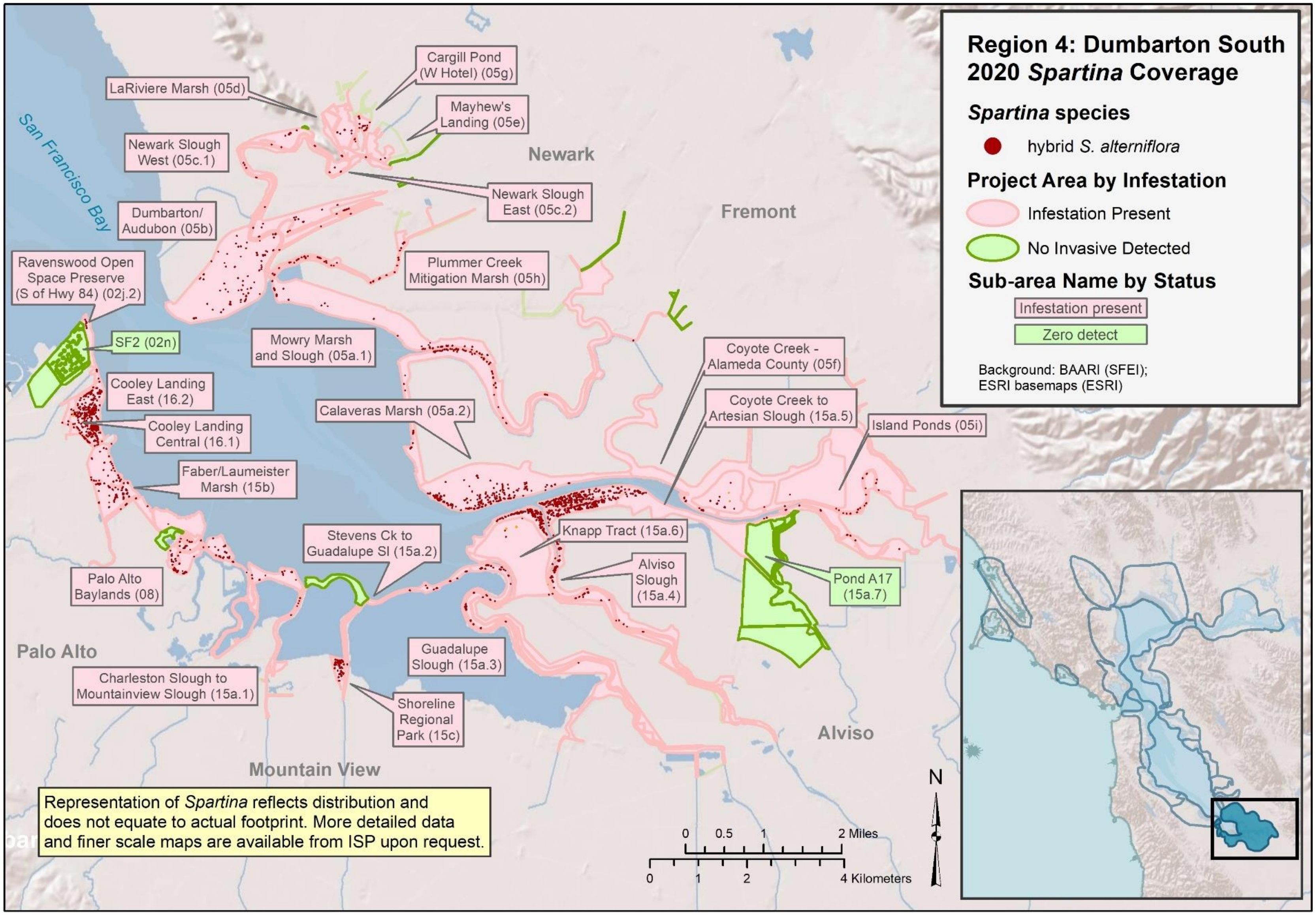

Figure 13. Distribution of invasive *Spartina* in 2020 across the 25 sub-areas of Reporting Region 4: Dumbarton South. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive *Spartina* are labeled in green.

Table 9. Summary of 2020 invasive *Spartina* mapped and treated by sub-area within Reporting Region 4: Dumbarton South.

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species					All Invasive *Spartina* Cover				
											Net Area Decline	
			anglica	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	2020 Net Area	2020 Treatment Area	Peak Year	Since Peak	Since 2019
REGION 4: DUMBARTON SOUTH												
02j.2: Ravenswood Open Space Preserve (S of Hwy 84)	9/23	Backpack		0		12 m^2	0	12 m^2	183 m^2	2006	>99%	56%
02n: SF2	3 years with No Invasive Spartina (2018-2020)			0		0	0	0	0	2013	100%	n/a
05a.1: Mowry Marsh and Slough	7/23; 8/11; 9/23; 10/5; 10/7; 10/22; 11/12	Backpack, Airboat		0		95 m^2	0	95 m^2	0.3 acres	2008	>99%	61%
05a.2: Calaveras Marsh	7/27; 10/9-10/10; 11/12	Backpack, Amphibious vehicle, Airboat		0		242 m^2	0	242 m^2	0.9 acres	2007	>99%	67%
05b: Dumbarton/Audubon	7/23; 8/13; 9/23; 10/5; 10/7; 10/12; 11/14	Backpack, Airboat		0		64 m^2	0	64 m^2	0.4 acres	2006	>99%	68%
05c.1: Newark Slough West	9/24	Backpack, Airboat		0		12 m^2	0	12 m^2	428 m^2	2004	>99%	10%
05c.2: Newark Slough East	9/24	Backpack, Airboat		0		8 m^2	0	8 m^2	119 m^2	2005	>99%	Increase (8 m^2)
05d: LaRiviere Marsh	10/7	Backpack		0		4 m^2	0	4 m^2	117 m^2	2006	>99%	Increase (0.3 m^2)
05e: Mayhew's Landing	10/7	Backpack		0		0.5 m^2	0	0.5 m^2	13 m^2	2004	>99%	54%
05f: Coyote Creek - Alameda County	9/22; 9/25; 11/25	Backpack, Airboat		0		34 m^2	0	34 m^2	768 m^2	2008	80%	Increase (32 m^2)
05g: Cargill Pond (W Hotel)	8/21; 11/6 (R2)	Backpack		0		6 m^2	0	6 m^2	267 m^2	2010	>99%	54%
05h: Plummer Creek Mitigation Marsh	10/22; 12/18	Backpack		0		1 m^2	0	1 m^2	65 m^2	2011	>99%	Increase (0.3 m^2)
05i: Island Ponds	9/22; 9/25	Airboat		0		10 m^2	0	10 m^2	179 m^2	2017	94%	73%
08: Palo Alto Baylands	8/26; 9/8; 10/5; 10/28	Truck, Backpack, Airboat		0		112 m^2	0	112 m^2	846 m^2	2009	98%	42%
15a.1: Charleston Slough to Mountainview Slough	8/13	Backpack		0		16 m^2	0	16 m^2	161 m^2	2004	>99%	46%
15a.2: Stevens Ck to Guadalupe Sl	8/13	Backpack		0		15 m^2	0	15 m^2	209 m^2	2008	99%	39%
15a.3: Guadalupe Slough	9/25			0		50 m^2	0	50 m^2	0.3 acres	2008	98%	Increase (13 m^2)
15a.4: Alviso Slough	7/24; 7/28-7/29; 8/10; 9/21-9/22; 10/22	Backpack, Airboat		0		589 m^2	0	589 m^2	3.3 acres	2007	94%	52%
15a.5: Coyote Creek to Artesian Slough	9/22; 11/25	Backpack, Airboat		0		144 m^2	0	144 m^2	0.4 acres	2017	82%	Increase (104 m^2)
15a.6: Knapp Tract	9/25	Airboat		0		12 m^2	0	12 m^2	132 m^2	2017	44%	Increase (11 m^2)
15a.7: Pond 17	No Invasive Spartina ever detected			0		0	0	0	0	n/a	n/a	n/a
15b: Faber / Laumeister Marsh	9/9; 9/15; 10/19	Backpack		0		49 m^2	0	49 m^2	988 m^2	2008	97%	53%
15c: Shoreline Regional Park	8/26	Backpack		0		29 m^2	0	29 m^2	604 m^2	2006	>99%	75%
16.1: Cooley Landing Central	8/24; 9/21; 10/23	Truck, Backpack, Airboat		0		52 m^2	0	52 m^2	668 m^2	2008	>99%	64%
16.2: Cooley Landing East	8/24; 8/26; 9/21; 10/23	Truck, Backpack, Airboat		0		219 m^2	0	219 m^2	1.3 acres	2008	>99%	72%
REGION 4 TOTAL				0		0.4 acres	0	0.4 acres	8.3 acres	2008	99%	55%

Baylands (84%), Mowry Marsh and Slough (65%), Dumbarton/Audubon (88%), Cooley Landing Central (89%), Faber/Laumeister (72%). Together, these sub-areas experienced a reduction off 2.7 acres of hybrid *S. alterniflora* cover over the last four years.

The access to the upper reaches of Coyote Creek facilitated by increased airboat assistance resulted in discovery of new patches of hybrid *S. alterniflora* 3 kilometers further upstream than previously detected. In total, an additional 136 m^2 net cover was mapped between the two adjacent Coyote Creek sub-areas. Detection of hybrid *S. alterniflora* in these upstream zones prompted plans for more thorough surveys of the area moving forward, followed quickly by treatment before the hybrid gets more established. Low rainfall in 2020 facilitated detection of hybrid *S. alterniflora* in the brackish upstream areas by greatly reducing the thick stands of native Alkali bulrush (*Bolboschoenus)* that normally grow there; however, the drought conditions are also expected accelerate colonization of these areas by hybrid *S. alterniflora*.

The Dumbarton South Region includes some of the highest quality Ridgway's rail habitat in the Estuary. Surveys conducted by ISP, PBCS, and DENWR have shown an increase in detections of +22% between 2019 and 2020, and a more moderate +2% annual change over the previous five years. Marshes in this region generally have abundant *S. foliosa*, however, there is opportunity to enhance available habitat cover with *G. stricta* plantings and high tide refuge islands. ISP and partners have constructed two high tide refuge islands at Cooley Landing (16.2), eight at Palo Alto Baylands (08), and six at Dumbarton/Audubon (05b), and planted over 8,400 *G. stricta* at Dumbarton/Audubon (05b).

2.2.5 Region 5: Union City

The Union City Region (Region 5) extends along the East Bay shoreline from the San Mateo Bridge to the Dumbarton Bridge, and includes 21 sub-areas. This region includes the original introduction site for *S. alterniflora* to San Francisco Bay – Pond 3 adjacent to the north bank of the Alameda Flood Control Channel (AFCC; 01f, also known as Ecology Marsh). Planted *S. alterniflora* later hybridized with native *S. foliosa* and eventually resulted in the bay-wide spread of their highly invasive progeny. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 14** and **Table 10**. Treatment dates and methods are included in Table 10.

Of the 21 sub-areas in this region, 19 were inventoried thoroughly in 2019; Eden Landing-Pond E10 (13i) was surveyed partially, and only in the area that has tidal exchange, and Upstream of 20 Tide Gates (13g) was not inventoried. Upstream of 20 Tide Gates was not surveyed in 2019 because it had not had any detected infestation since 2015 and the salinity there favors brackish vegetation. In 2020 all 21 sub-areas were thoroughly surveyed. Most inventory was completed on foot, though the young restoration site, Eden Landing Ponds-E8A, E9, and E8x (13m), was surveyed by a combination of airboat, kayak, jon boat, and on foot.

Leading up to 2019, multiple sub-areas within Eden Landing Ecological Reserve (ELER) experienced several years of increase in hybrid *S. alterniflora* cover. These increases were attributed to ELER's location directly south of, and hydrological connection to the Cogswell Complex (Region 6), where two sub-areas restricted from treatment between 2011 and 2018 contained some of the largest infestations in the bay. Consultation with U.S. Fish and Wildlife Service in 2018 resulted in re-authorization for treatment at several portions of the Cogswell Complex, and those treatments seem to have effectively reduced propagule loading into Region 5 (see **Section 3.2** for further detail on **Restricted Treatment Sites**). Most detections in this region are of newly colonized plants on previously unvegetated mudflats, which, incidentally, is the same phenomenon seen when these sites were first breached for restoration in the mid-2000s. Each of the sub-areas still contain open mudflat where sediment has not sufficiently accreted to support most native vegetation.

In 2020, a total of 0.02 acres net cover of hybrid *S. alterniflora* was detected and treated. This represents 0.08% of the bay wide infestation, and a 25% reduction from 2019 regional infestation. Of the region total, 89% is found within three sub-areas: Eden Landing-North Creek Marsh (13k), Eden Landing-North Creek Marsh (13l), and Eden Landing-Ponds E8A, E9, and E8X (13m). All of these areas are former salt ponds restored to tidal flow since 2006.

The thorough inventory of Upstream of 20 Tide Gates in 2020 resulted in discovery of one 1.3 m^2 patch of hybrid *S. alterniflora* that was subsequently treated.

Annual surveys for Ridgway's rails have shown an increasing trend in the number of rails detected at sub-areas surveyed by ISP and DENWR in the Union City Region (McBroom 2020). Between 2019 and 2020, there was a 96% increase in detections, nearly doubling the number

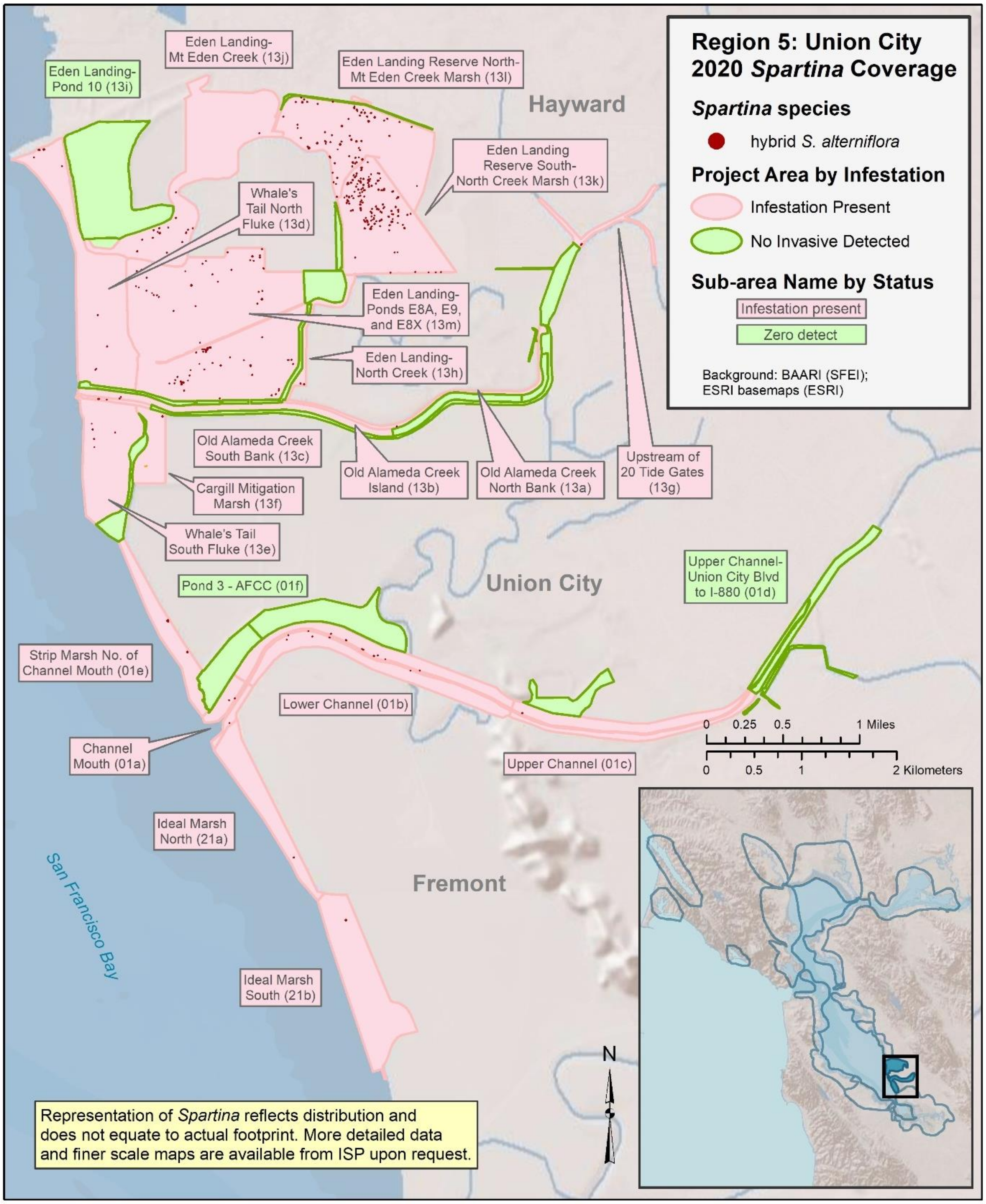

Figure 14. Distribution of invasive *Spartina* in 2020 across the 21 sub-areas of Reporting Region 5: Union City. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive *Spartina* are labeled in green.

Table 10. Summary of 2020 invasive *Spartina* mapped and treated by sub-area within Reporting Region 5: Union City

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species					All Invasive *Spartina* Cover				
											Net Area Decline	
			anglica	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	2020 Net Area	2020 Treat-ment Area	Peak Year	Since Peak	Since 2019
REGION 5: UNION CITY												
01a: Channel Mouth	8/21	Backpack		0		0.1 m²	0	0.1 m²	4 m²	2004	>99%	60%
01b: Lower Channel	8/21; 11/6 (R2)	Backpack		0		2 m²	0	2 m²	21 m²	2004	>99%	80%
01c: Upper Channel	8/21; 11/6 (R2)	Backpack		0		0.5 m²	0	0.5 m²	15 m²	2004	>99%	78%
01d: Upper Channel - Union City Blvd to I-880	4 years with No Invasive Spartina (2017-2020)			0		0	0	0	0	2005	100%	n/a
01e: Strip Marsh No. of Channel Mouth	8/21; 10/8	Backpack		0		0.6 m²	0	0.6 m²	14 m²	2004	>99%	67%
01f: Pond 3 - AFCC	No Invasive Spartina 2020			0		0	0	0	0	2005	100%	100%
13a: Old Alameda Creek North Bank	10/23	Backpack		0		0.04 m²	0	0.04 m²	1 m²	2005	>99%	37%
13b: Old Alameda Creek Island	10/8	Backpack		0		0.04 m²	0	0.04 m²	2 m²	2005	>99%	97%
13c: Old Alameda Creek South Bank	10/8	Backpack		0		2 m²	0	2 m²	35 m²	2005	>99%	n/a
13d: Whale's Tail North Fluke	8/27; 10/7; 11/11	Backpack		0		1 m²	0	1 m²	48 m²	2005	>99%	27%
13e: Whale's Tail South Fluke	10/8	Backpack		0		0.4 m²	0	0.4 m²	9 m²	2005	>99%	27%
13f: Cargill Mitigation Marsh	10/8; 12/21	Backpack		0		0.3 m²	0	0.3 m²	15 m²	2004	>99%	Increase (0.2 m²)
13g: Upstream of 20 Tide Gates	10/23	Backpack		0		1 m²	0	1 m²	18 m²	2005	>99%	n/a
13h: Eden Landing - North Creek	9/15	Backpack		0		2 m²	0	2 m²	30 m²	2007	>99%	n/a
13i: Eden Landing - Pond 10	No Invasive Spartina 2020			0		0	0	0	0	2008	100%	100%
13j: Eden Landing - Mt Eden Creek	8/27	Backpack		0		5 m²	0	5 m²	179 m²	2009	>99%	66%
13k: Eden Landing Reserve South - North Creek Marsh	8/7; 9/15; 9/21	Backpack		0		50 m²	0	50 m²	0.4 acres	2009	88%	12%
13l: Eden Landing Reserve North - Mt Eden Creek Marsh	8/25; 8/27	Backpack		0		26 m²	0	26 m²	781 m²	2010	84%	35%
13m: Eden Landing - Ponds E8A, E9, and E8X	8/7; 10/23	Backpack, Airboat		0		13 m²	0	13 m²	436 m²	2014	62%	Increase (1 m²)
21a: Ideal Marsh North	8/21	Backpack		0		0.5 m²	0	0.5 m²	14 m²	2005	>99%	22%
21b: Ideal Marsh South	10/13	Backpack		0		0.6 m²	0	0.6 m²	17 m²	2006	>99%	64%
REGION 5 TOTAL				0		105 m²	0	105 m²	0.8 acres	2004	>99%	26%

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of rails detected from 25 rails to 49 rails. An increase in rail detections is also evident in a +7% five-year trend. The rise in rail numbers is most evident at sub-areas where the ISP Restoration Program has focused revegetation efforts.

The objective of the ISP Restoration Program in this region is to establish native rail habitat where control efforts have removed or precluded hybrid *S. alterniflora*. To date, the program has installed more than 220,000 plantings across twelve sub-areas along the Alameda Flood Control Channel (1a, 1b, 1c) and within the Eden Landing Ecological Reserve (13b, 13d, 13e, 13f, 13h, 13j, 13k, 13l, 13m), Along the Alameda Flood Control Channel, the site of the original introduction of *S. alterniflora*, control has been extremely effective, making possible the reintroduction of *S. foliosa* to restore the band of native cordgrass that existed prior to the hybrid *S. alterniflora* invasion. As part of the SBSPRP, multiple former salt ponds within the Eden Landing Ecological Reserve were restored to tidal action. As there was no local source population for *S. foliosa*, the ISP conducted extensive active planting to speed up revegetation and provide habitat. Planted *S. foliosa* has established and expanded extensively in this region, now covering acres of tidal wetlands at appropriate elevations, especially in the former salt ponds. The amount of *S. foliosa* present in the region resulting from plantings is orders of magnitude greater than the minor amount of remaining hybrid *S. alterniflora*. Ridgway's rails are now present in increasing numbers at North Creek Marsh, a former salt pond that was targeted with extensive active plantings over several years. In 2018 there were zero birds detected at North Creek Marsh, and in 2021 there were 13.

2.2.6 Region 6: Hayward

The Hayward Region (Region 6) extends from the San Mateo Bridge to Oakland Airport on the east side of the San Francisco Bay. The region is heavily urbanized and consists of 30 sub-areas clustered around three relatively young but sizeable restoration marsh complexes: Robert's Landing, Oro Loma, and Cogswell Marsh. Cogswell Marsh (20m-o) is the oldest and was restored in 1980. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 15** and **Table 11**.

Treatment at three sub-areas, Cogswell Marsh B Main (20n.3), North Marsh (20f) and Citation Marsh Central (20d.2b), has been halted since 2011 out of concern for local Ridgway's rail populations. Another six sub-areas were restricted from treatment in 2011 but were re-authorized in 2018 after consultation with U.S. Fish and Wildlife Service. Treatment restrictions in this region allowed many years of unchecked expansion of hybrid *S. alterniflora*, with spread into adjacent marshes and reversal of progress toward eradication in many sub-areas.

Twenty-nine of the 30 sub-areas in the Hayward Region were inventoried on foot in 2019 and 26 sub-areas were inventoried on foot in 2020. The three sub-areas with continued treatment restriction, and Citation Marsh Upper (20d.2a), where treatment was mostly restricted until 2020, were surveyed by grid in 2019 and not at all in 2020. Due to extremely tall and dense plants that precluded successful movement through the marsh during inventory, portions of each marsh did not get completed in 2019 and data was carried over and reported from the previous survey by grid in 2017.

A total of 18.4 net acres of non-native cordgrass, all hybrid *S. alterniflora*, was detected in 2020 (**Figure 15**). This accounts for 56% of the Estuary total and places Region 6 as the most heavily infested region, a fact largely due to the extensive historic treatment restrictions. The area covered is expected to decrease substantially over the next two years as treatment continues in the formerly restricted sub-areas in the Robert's Landing and Cogswell Complexes, and as the effect of the 2020 treatment of 2.6 net acres in Citation Marsh Upper is realized.

Every sub-area in this region contained hybrid *S. alterniflora* in both 2019 and 2020, and though annual treatment keeps infestation levels low in many sub-areas, their proximity to sub-areas where treatment is restricted makes eradication impossible while the restrictions are in place. Annual inventory and treatment remain necessary to ensure that these marshes and mudflats do not evolve into hybrid *S. alterniflora* meadows and further impact the Estuary with increased propagules.

The number of California Ridgway's rail detected in the Hayward Region increased by 16% between 2019 and 2020, and by 17% between 2015 to 2020 (McBroom 2020). The increasing trend can likely be attributed to the expansion of non-native cordgrass at the sub-areas where treatment was restricted in 2011. Although six of these sub-areas were authorized for treatment in 2018, rail response to the re-initiation of treatment of non-native cordgrass was not yet apparent in the 2020 rail survey results. As the vegetative structure continues to change

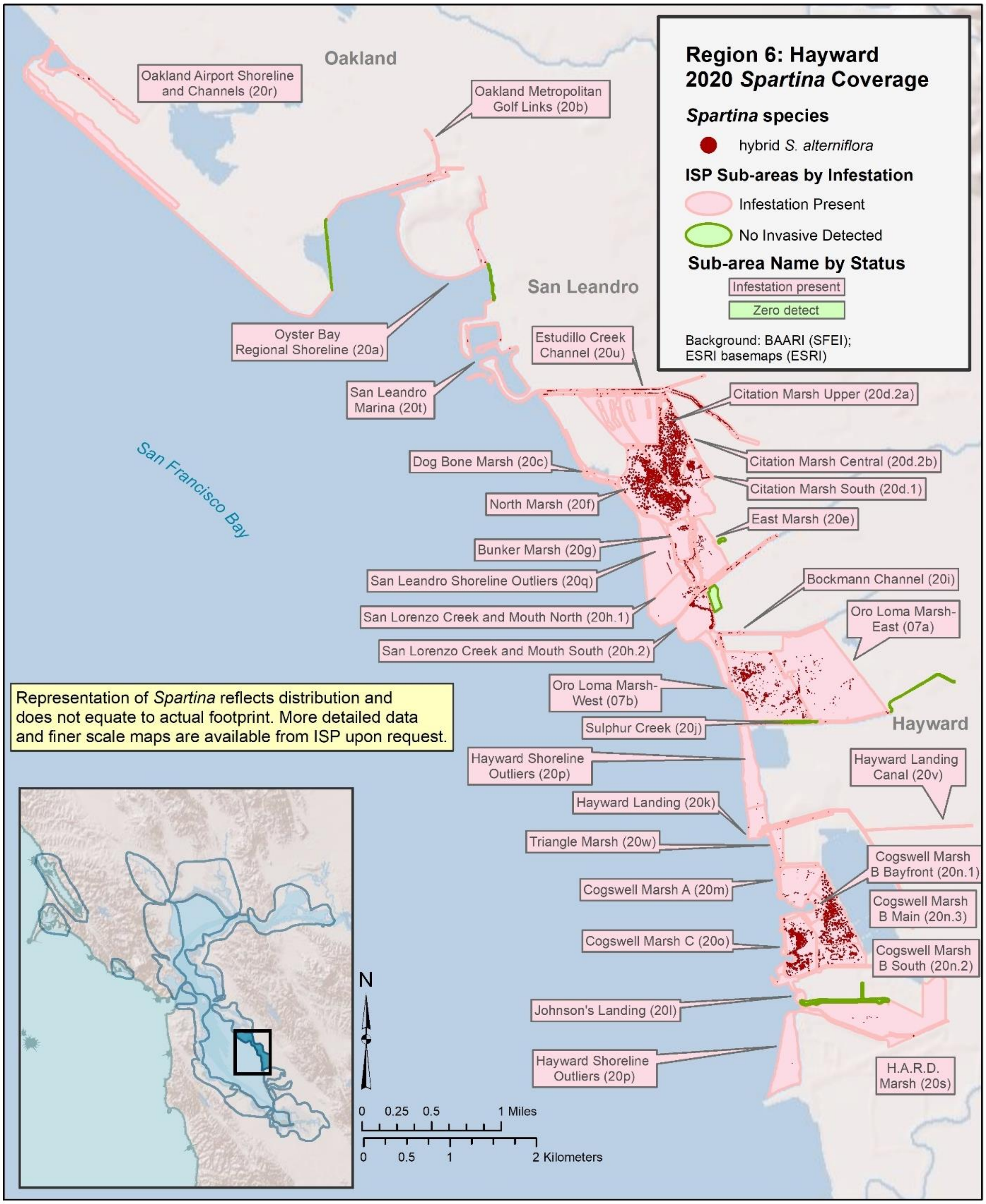

Figure 15. Distribution of invasive *Spartina* in 2020 across the 30 sub-areas of Reporting Region 6: Hayward. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive *Spartina* are labeled in green.

Table 11. Summary of 2020 invasive Spartina mapped and treated by sub-area within Reporting Region 6: Hayward

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species					All Invasive *Spartina* Cover				
											Net Area Decline	
			anglica	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	2020 Net Area	2020 Treat-ment Area	Peak Year	Since Peak	Since 2019
REGION 6: HAYWARD												
07a: Oro Loma Marsh - East	11/9-11/10; 12/21	Backpack, Airboat		0		22 m^2	0	22 m^2	443 m^2	2008	>99%	63%
07b: Oro Loma Marsh - West	11/9-11/10	Backpack, Airboat		0		129 m^2	0	129 m^2	0.5 acres	2005	>99%	0%
20a: Oyster Bay Regional Shoreline	7/15; 11/6 (R2)	Backpack		0		2 m^2	0	2 m^2	82 m^2	2004	>99%	85%
20b: Oakland Metropolitan Golf Links	7/15; 11/6 (R2)	Backpack		0		0.4 m^2	0	0.4 m^2	14 m^2	2009	>99%	Increase (0.01 m^2)
20c: Dog Bone Marsh	7/14; 11/6 (R2)	Backpack		0		0.3 m^2	0	0.3 m^2	19 m^2	2006	>99%	64%
20d.1: Citation Marsh South	10/22	Truck, Backpack		0		100 m^2	0	100 m^2	0.4 acres	2004	98%	30%
20d.2a: Citation Marsh Upper	8/20-8/21; 9/3-9/4; 9/23; 10/7-10/9; 10/21; 11/10; 12/2	Truck, Backpack		0		2.6 acres	0	2.6 acres	25.1 acres	2006	56%	Increase (137 m^2)
20d.2b: Citation Marsh Central	No Treatment Authorized since 2010			0		3.5 acres	0	3.5 acres	22.1 acres	2006	49%	Increase (7 m^2)
20e: East Marsh	10/23; 11/10	Backpack		0		3 m^2	0	3 m^2	105 m^2	2006	>99%	94%
20f: North Marsh	No Treatment Authorized since 2010			0		8.1 acres	0	8.1 acres	45.8 acres	2006	55%	n/a (Not mapped 2020)
20g: Bunker Marsh	8/21; 10/23; 11/10	Truck, Backpack, Amphibious vehicle		0		0.3 acres	0	0.3 acres	2.6 acres	2004	98%	80%
20h.1: San Lorenzo Creek and Mouth North	10/21; 11/10	Backpack		0		3 m^2	0	3 m^2	81 m^2	2004	>99%	71%
20h.2: San Lorenzo Creek and Mouth South	10/21; 10/23; 11/10	Backpack		0		47 m^2	0	47 m^2	0.3 acres	2004	>99%	31%
20i: Bockmann Channel	7/28	Backpack		0		2 m^2	0	2 m^2	57 m^2	2004	>99%	35%
20j: Sulphur Creek	7/28	Backpack		0		6 m^2	0	6 m^2	97 m^2	2004	91%	Increase (6 m^2)
20k: Hayward Landing	8/12	Backpack		0		0.7 m^2	0	0.7 m^2	28 m^2	2004	>99%	Increase (0.3 m^2)
20l: Johnson's Landing	7/28	Backpack		0		0.2 m^2	0	0.2 m^2	3 m^2	2005	>99%	Increase (0.2 m^2)
20m: Cogswell Marsh A	8/12; 10/13 (R2)	Backpack		0		4 m^2	0	4 m^2	162 m^2	2005	>99%	67%
20n.1: Cogswell Marsh B Bayfront	9/8; 9/21	Truck, Backpack		0		731 m^2	0	731 m^2	3.7 acres	2005	98%	77%
20n.2: Cogswell Marsh B South	9/22	Truck, Amphibious vehicle		0		135 m^2	0	135 m^2	0.5 acres	2005	>99%	85%
20n.3: Cogswell Marsh B Main	8/19	**Aerial Broadcast for Seed Suppression**		0		3.6 acres	0	3.6 acres	35.2 acres	2005	90%	n/a (Not mapped 2020)
20o: Cogswell Marsh C	9/21-9/22	Truck, Backpack, Amphibious vehicle		0		464 m^2	0	464 m^2	1.4 acres	2005	>99%	69%
20p: Hayward Shoreline Outliers	7/28; 8/12	Backpack		0		0.9 m^2	0	0.9 m^2	20 m^2	2008	>99%	73%
20q: San Leandro Shoreline Outliers	11/10	Backpack		0		2 m^2	0	2 m^2	40 m^2	2006	>99%	23%
20r: Oakland Airport Shoreline and Channels	10/21	Backpack		0		2 m^2	0	2 m^2	122 m^2	2006	>99%	87%
20s: H.A.R.D. Marsh	7/28; 8/12; 10/13 (R2); 11/10	Backpack		0		1 m^2	0	1 m^2	48 m^2	2006	>99%	94%
20t: San Leandro Marina	7/14; 11/6 (R2)	Backpack		0		0.4 m^2	0	0.4 m^2	12 m^2	2009	>99%	Increase (0.1 m^2)
20u: Estudillo Creek Channel	7/16	Truck, Backpack		0		69 m^2	0	69 m^2	0.3 acres	2010	91%	28%
20v: Hayward Landing Canal	8/12	Backpack		0		2 m^2	0	2 m^2	36 m^2	2006	>99%	Increase (0.7 m^2)
20w: Triangle Marsh	7/28; 8/12	Backpack		0		2 m^2	0	2 m^2	29 m^2	2007	86%	52%
REGION 6 TOTAL				0		18.4 acres	0	18.4 acres	138.4 acres	2005	91%	11%

Note: several sub-areas in this Region were inventoried by grid in 2019 only and not all in 2020. Inventory data for 2020 reported for the following sub-areas reflect those of 2019 hybrid *S. alterniflora* that was not treated in 2019: Citation Marsh Upper (20d.2a), Citation Marsh Central (20d.2b, North Marsh (20f), and Cogswell Marsh B Main (20n.2) with the treatment of non-native cordgrass, rail numbers are likely to decline until native *S. foliosa* can be restored to the formerly restricted sub-areas.

The large amount of hybrid *S. alterniflora* remaining in this region has delayed the reintroduction of *S. foliosa* at sub-areas with treatment restrictions. The ISP Restoration Program has cautiously tested planting *S. foliosa* at sub-areas with relatively less invasion pressure near restricted treatment sub-areas with the goal of enhancing suitable habitat prior to resuming control efforts in the future. Sub-areas that have undergone some level of *S. foliosa* planting include Oro Loma Marsh-East (07a), H.A.R.D. Marsh (20s), Triangle Marsh (20w), and Cogswell Marsh A (20m). Habitat enhancements in this region have also included planting *Grindelia stricta* and constructing high tide refuge islands. To date, over 45,000 *Grindelia* plants have been installed (sometimes paired with *Distichlis spicata*), across twelve sub-areas, and a total of 13 high tide refuge islands have been installed in Cogswell Marsh B South (20n.2), Cogswell Marsh B Main (20n.3), Cogswell Marsh C (20o), and Bunker Marsh (20g).

2.2.7 Region 7: San Leandro Bay

The San Leandro Bay Region (Region 7) is an exceptionally urbanized portion of the East Bay that extends north from the Oakland Airport to the Bay Bridge. Its 20 sub-areas consist of long, thin tidal areas along rip-rap shorelines and open mudflats, punctuated by fragmented areas of marsh habitat. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 16** and **Table 12**. Treatment dates and methods are included in Table 12**.**

This region contains three sub-areas where treatment has not been conducted since 2010 out of concern for the local Ridgway's rail population: Arrowhead Marsh East (17c.2), MLK New Marsh (17h), and Fan Marsh Main (17j.2). All sub-areas in this region were mapped on foot or by boat. The sub-areas where treatment is restricted were inventoried by grid in only 2019 and not in 2020, and in those cases, 2019 data has been carried over and reported in 2020 for summary. Hybrid *S. alterniflora* was the only non-native cordgrass species found in Region 7, with a net cover of 11.3 acres in 2020, which reflects a 3% increase over 2019 levels.

Ninety-eight percent of hybrid *S. alterniflora* found in Region 7 is located in the three un-treated sub-areas and in Arrowhead Marsh West (17c.1), which is directly adjacent to Arrowhead Marsh East, from which it receives annual influx of propagules. The limited increase in infestation at treatment-restricted sites suggests that hybrid *S. alterniflora* levels may be reaching maximum amounts and plateauing here.

The infestation in Region 7 comprises 34.4% of the total amount of invasive *Spartina* remaining in the Estuary. Every sub-area in the San Leandro Bay Region contained invasive *Spartina* in both 2019 and 2020. Annual treatment in the San Leandro Bay Region by ISP facilitates the control of the proliferation of hybrid *S. alterniflora*, but constant establishment of new plants from nearby seed sources makes it unlikely that any sub-area will achieve zero detect status while treatment restrictions remain in place.

The number of Ridgway's rail detected during surveys declined by 23% between 2019 and 2020, to a level on par with numbers detected in the region in 2015 (McBroom 2020). Two previously restricted sub-areas were permitted for treatment in 2018, however, the decline since 2019 at these two sub-areas accounts for less than a third of the overall decline in the region. Sub-areas where treatment is still restricted also exhibited fewer detections of Ridgway's rails during 2020 surveys. The high level of hybrid *S. alterniflora* infestation in San Leandro Bay marshes has supported a local high-density Ridgway's rail population for the past two decades, and the lack of appropriate native marsh structure in these marshes makes the rails here dependent upon hybrid *S. alterniflora*.

Opportunities for rail habitat enhancement in this region are limited by treatment restrictions at three key marshes, Arrowhead West (17c.1), MLK New Marsh (17h), and Damon Marsh (17d.4). The presence of uncontrolled hybrid *S. alterniflora* significantly increases the risk of *S. foliosa* plantings becoming infested and then requiring treatment. As a result, the ISP Restoration Program has so far limited efforts to enhance habitat in this region. From 2011 to

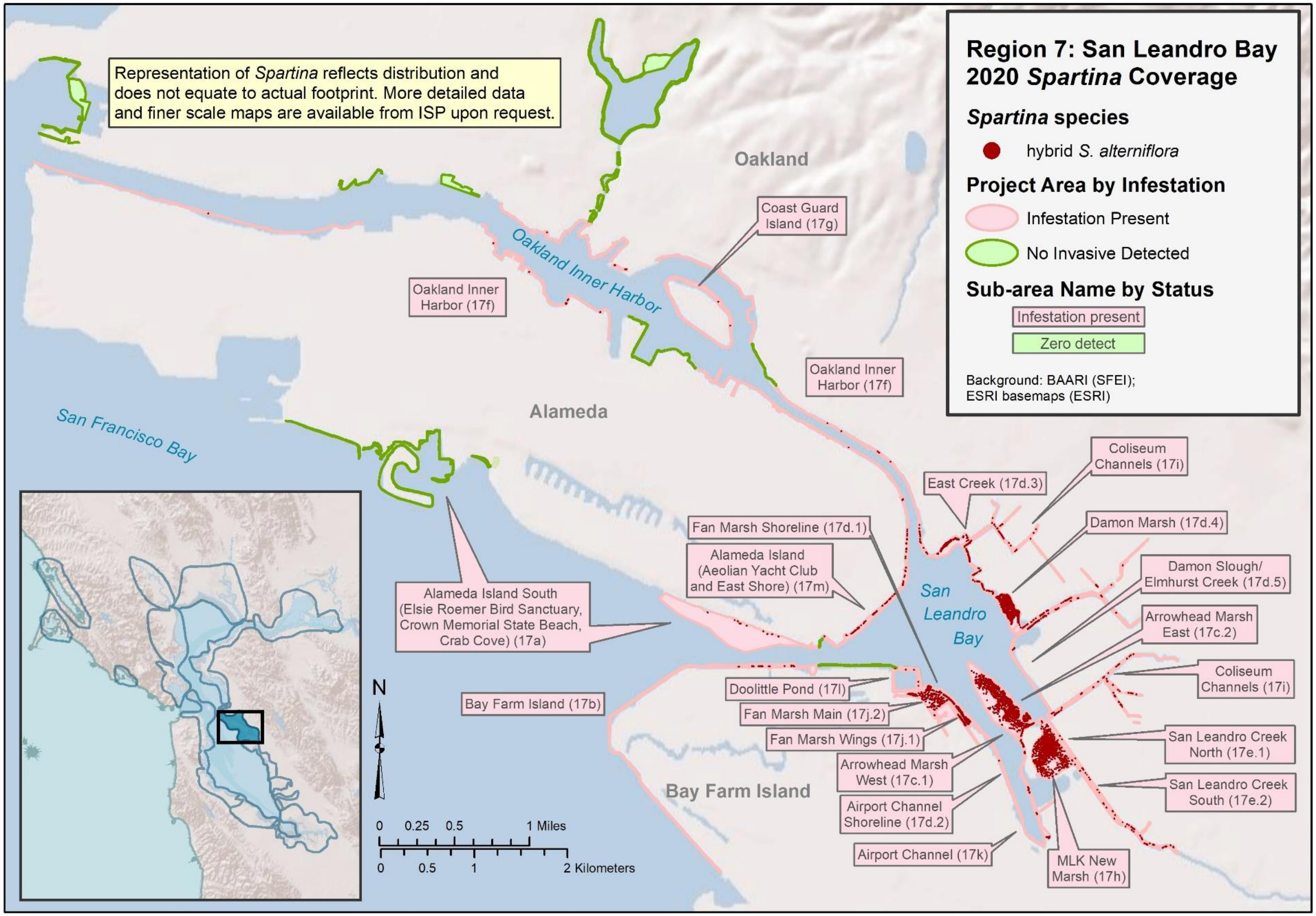

Figure 16. Distribution of invasive *Spartina* in 2020 across the 20 sub-areas of Reporting Region 7: San Leandro Bay. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive *Spartina* are labeled in green.

Table 12. Summary of 2020 invasive *Spartina* mapped and treated by sub-area within Reporting Region 7: San Leandro Bay

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species					All Invasive *Spartina* Cover				
											Net Area Decline	
			anglica	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	2020 Net Area	2020 Treat-ment Area	Peak Year	Since Peak	Since 2019
REGION 7: SAN LEANDRO BAY												
17a: Alameda Island South (Elsie Roemer Bird Sanctuary, Crown Memorial State Beach, Crab Cove)	8/7; 10/26 (R2)	Backpack	0			2 m²	0	2 m²	73 m²	2006	>99%	Increase (0.6 m²)
17b: Bay Farm Island	8/7	Backpack	0			2 m²	0	2 m²	82 m²	2005	>99%	40%
17c.1: Arrowhead Marsh West	8/18-8/19	Backpack, Airboat	0			0.7 acres	0	0.7 acres	8.4 acres	2005	93%	Increase (0.3 acres)
17c.2: Arrowhead Marsh East	**No Treatment Authorized since 2010**		0			4.4 acres	0	4.4 acres	20.2 acres	2006	73%	n/a (Not mapped 2020)
17d.1: Fan Marsh Shoreline	7/13	Airboat	0			58 m²	0	58 m²	788 m²	2004	>99%	Increase (42 m²)
17d.2: Airport Channel Shoreline	7/13-7/14	Backpack	0			73 m²	0	73 m²	741 m²	2005	>99%	Increase (57 m²)
17d.3: East Creek	7/13	Backpack	0			20 m²	0	20 m²	685 m²	2004	>99%	51%
17d.4: Damon Marsh	11/5	Amphibious vehicle, Airboat	0			485 m²	0	485 m²	1.4 acres	2006	98%	19%
17d.5: Damon Slough / Elmhurst Creek	7/13-7/14	Backpack	0			6 m²	0	6 m²	260 m²	2005	>99%	73%
17e.1: San Leandro Creek North	7/13	Backpack	0			2 m²	0	2 m²	33 m²	2005	>99%	46%
17e.2: San Leandro Creek South	7/13	Backpack	0			9 m²	0	9 m²	262 m²	2005	>99%	4%
17f: Oakland Inner Harbor	7/15; 7/30; 8/13; 10/15	Backpack, Airboat	0			1 m²	0	1 m²	62 m²	2007	>99%	73%
17g: Coast Guard Island	10/15	Backpack	0			0.3 m²	0	0.3 m²	10 m²	2007	>99%	56%
17h: MLK New Marsh	**No Treatment Authorized since 2010**		0			5.2 acres	0	5.2 acres	25.6 acres	2006	30%	n/a (Not mapped 2020)
17i: Coliseum Channels	7/15	Backpack	0			21 m²	0	21 m²	471 m²	2005	>99%	59%
17j.1: Fan Marsh Wings	7/14	Backpack	0			10 m²	0	10 m²	335 m²	2005	>99%	34%
17j.2: Fan Marsh Main	**No Treatment Authorized since 2010**		0			0.9 acres	0	0.9 acres	8.7 acres	2006	88%	n/a (Not mapped 2020)
17k: Airport Channel	7/13-7/14	Backpack, Airboat	0			1 m²	0	1 m²	34 m²	2005	>99%	14%
17l: Doolittle Pond	7/13	Backpack	0			0.7 m²	0	0.7 m²	21 m²	2004	>99%	62%
17m: Alameda Island (Aeolian Yacht Club and East Shore)	8/7	Backpack	0			6 m²	0	6 m²	283 m²	2006	>99%	58%
REGION 7 TOTAL			0			11.3 acres	0	11.3 acres	65.4 acres	2006	87%	3% increase (0.3 acres)

Note: several sub-areas in this Region were inventoried by grid in 2019 only and not all in 2020. Inventory data for 2020 reported for the following sub-areas reflect those of 2019 hybrid *S. alterniflora* that was not treated in 2019: Arrowhead Marsh East (17c.2), Damon Marsh (17d.4), MLK New Marsh (17h), and Fan Marsh Main (17j.2).

2016, more than 3,000 *Grindelia* plantings were installed at the key marshes. *Spartina foliosa* has been planted at Elsie Roemer (17a), with caution due to the high risk of re-infestation. Additionally, a total of five high tide refuge islands were constructed in 2012-13 within MLK New Marsh and Arrowhead West to provide potential protective cover for rails during extreme high tides when they are most exposed to predators.

2.2.8 Region 8: Bay Bridge North

The Bay Bridge North Region (Region 8) is composed of 13 sub-areas including all East Bay shoreline marshes north of the Bay Bridge and southwest of the Carquinez Strait. This region is typified by riprap shorelines and fragmented marshes with little or no room for expansion due to urban development to their upland edge. The exceptions are intact historic Whittel Marsh (10a) and Giant Marsh (10c), and the large and partially brackish Wildcat Marsh (22a) and San Pablo Marsh (22b). The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 17** and **Table 13**. Treatment dates and methods are included in **Table 13**.

ISP surveyed all 13 sub-areas in both2019 and 2020, though portions of Hoffmann Marsh (22e) and Richmond/Albany/Pinole Shoreline (22f) were not surveyed due to low invasion pressure. All inventory was completed on foot, except for the shorelines and ponds adjacent to Wildcat Marsh (22a), which were surveyed by kayak. In 2020 a total of 0.04 acres of hybrid *S. alterniflora* was found in Region 8, which represents 0.12% of the Estuary total and a 28% reduction from 2019 levels. Sub-areas adjacent to the future Giant Marsh Living Shorelines Project area (Southern Marsh [10b], Giant Marsh [10c], Breuner Marsh Restoration [10d], and Breuner Marsh (Rheem Creek) [22c]) contained a total of 18 m^2 in 2020 and received a second round of treatment by early October to speed up local eradication.

Stege Marsh (22d) achieved zero detect status for the first time in 2020, after multiple years of regularly finding and treating small, isolated patches of hybrid *S. alterniflora*. Stege is the first major site within the Two Points Complex (Site 22) to reach the zero-detect milestone aside from Hoffman Marsh (22e), that only had a very small infestation at its peak. The Two Points Complex represents an important location in the Estuary as the gateway to the North Bay on the eastern shoreline, north of which the ISP has been able to keep any infestations to minor levels and has eliminated many. Stege Marsh, albeit relatively small in total area, contains a great deal of native *S. foliosa* and high-quality habitat at a low tidal elevation and has developed unique hybrid morphologies at higher elevations on the marsh plain. These factors have complicated identification of hybrid *S. alterniflora* plants and made achieving local eradication very challenging.

Spartina densiflora has been present in this region since it was first detected here in 2004, having been manually removed from four sub-areas: Whittel Marsh (10a), Southern Marsh (10b), Giant Marsh (10c), and Richmond/Albany/Pinole Shoreline (22f). No *S. densiflora* was detected in any sub-area in the Bay Bridge North Region between 2014 and 2018, when a single plant was found and removed from Whittel Marsh. No *S. densiflora* was detected in this region in either 2019 or 2020. Persistent inventory monitoring must continue for several years since *S. densiflora* seed bank can remain viable for an estimated five years.

Surveys for Ridgway's rails in the Bay Bridge North Region have been conducted by a coalition of survey organizations including ISP, PBCS, Avocet Research and Associates (ARA), and East Bay Regional Park District (EBRPD). Collectively, results from these surveys have shown stable

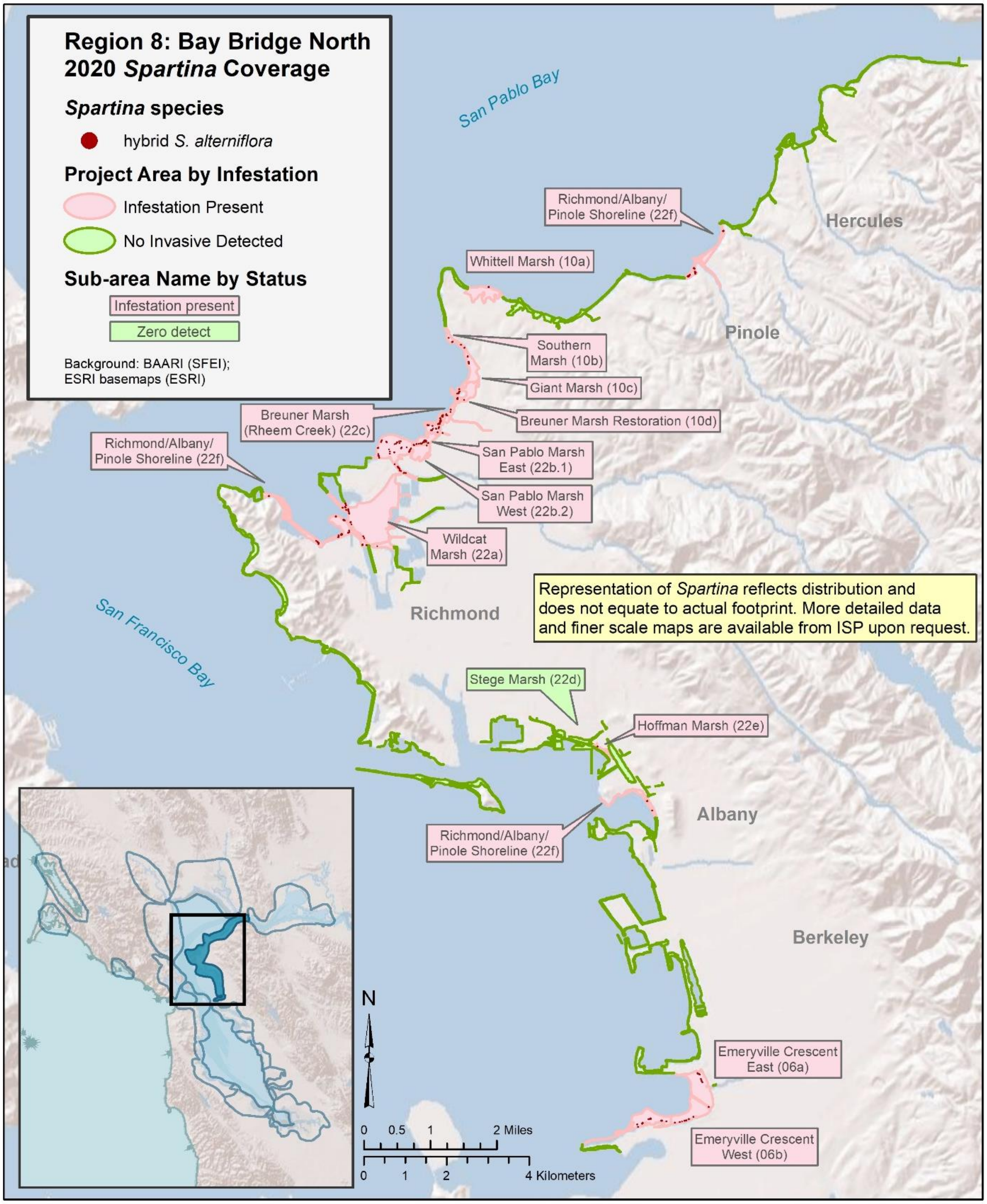

Figure 17. Distribution of invasive *Spartina* in 2020 across the 13 sub-areas of Reporting Region 8: Bay Bridge North. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive *Spartina* are labeled in green.

Table 13. Summary of 2020 invasive *Spartina* mapped and treated by sub-area within Reporting Region 8: Bay Bridge North.

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species					All Invasive *Spartina* Cover				
											Net Area Decline	
			anglica	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	2020 Net Area	2020 Treatment Area	Peak Year	Since Peak	Since 2019
REGION 8: BAY BRIDGE NORTH												
06a: Emeryville Crescent East	8/13	Backpack	0			3 m²	0	3 m²	129 m²	2005	>99%	66%
06b: Emeryville Crescent West	8/13; 9/18	Backpack	0			5 m²	0	5 m²	286 m²	2004	>99%	71%
10a: Whittell Marsh	9/8	Backpack	0			29 m²	0	29 m²	118 m²	2005	96%	Increase (29 m²)
10b: Southern Marsh	9/8; 10/8 (R2)	Backpack, Airboat	0			2 m²	0	2 m²	35 m²	2010	>99%	Increase (2 m²)
10c: Giant Marsh	9/8	Backpack, Airboat	0			3 m²	0	3 m²	22 m²	2005	>99%	Increase (2 m²)
10d: Breuner Marsh Restoration	9/8	Backpack	0			0.01 m²	0	0.01 m²	2 m²	2016	>99%	97%
22a: Wildcat Marsh	10/8; 11/14	Backpack, Airboat	0			20 m²	0	20 m²	698 m²	2010	99%	72%
22b.1: San Pablo Marsh East	9/29; 10/8	Backpack, Airboat	0			12 m²	0	12 m²	538 m²	2009	>99%	62%
22b.2: San Pablo Marsh West	9/16-9/17; 10/8	Backpack, Airboat	0			13 m²	0	13 m²	471 m²	2006	>99%	46%
22c: Breuner Marsh (Rheem Creek)	9/8; 10/8 (R2)	Backpack, Airboat	0			13 m²	0	13 m²	443 m²	2009	>99%	78%
22d: Stege Marsh	No Invasive Spartina 2020		0			0	0	0	0	2009	100%	100%
22e: Hoffman Marsh	9/30	Backpack	0			0.1 m²	0	0.1 m²	2 m²	2004	>99%	66%
22f: Richmond / Albany / Pinole Shoreline	8/6; 8/11; 10/1 (R2)	Backpack	0			62 m²	0	62 m²	0.3 acres	2004	97%	Increase (54 m²)
REGION 8 TOTAL			0			163 m²	0	163 m²	0.9 acres	2009	>99%	28%

numbers (+3% increase) between 2019 and 2020. Most of this region is highly urbanized, riprap shoreline or steep upland edge with few opportunities for tidal marsh habitat enhancement. The two largest marshes in this region, Wildcat Marsh (22a) and San Pablo Marsh (22b), have high quality habitat and extensive *S. foliosa* and *G. stricta* throughout. Consequently, to date, the ISP Restoration Program has not planned any habitat enhancements in this region, except to support the Giant Marsh Living Shorelines Project and test plantings of cordgrass in areas where the marsh is substantially eroding due to wave energy, both in combination with oyster reefs and plantings alone.

2.2.9 Region 9: Suisun

The Suisun Region (Region 9) is bounded on the west by the Carquinez Strait and extends east approximately to Antioch, where the salinity level transitions to freshwater within the San Joaquin-Sacramento Delta. The Suisun Region consists of five sub-areas including Southampton Marsh (11) and four sub-areas further east in Suisun Bay: Point Buckler (27a), MOTCO Islands (27b), Honker Bay (27c), and MOTCO Mainland (27d) that was added in 2020. An infestation by hybrid *S. alterniflora* was discovered on Point Buckler in 2016, resulting in the extension of this Region to the east to incorporate most of Suisun Bay. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 18** and **Table 14**. Treatment dates and methods are included in Table 14.

Southampton Marsh was surveyed thoroughly on foot and by kayak in 2019 and 2020 for hybrid *S. alterniflora* and *S. patens* and only for hybrid *S. alterniflora* in 2020. Since virtually all remaining hybrid *S. alterniflora* is within a few pockets along the channels and on the fringe, ISP tried a new inventory approach, shifting to both a walking and kayak survey that would maximize visibility. Only 0.5 m^2 of hybrid *S. alterniflora* was detected and subsequently treated, some based on previous DNA identification.

Point Buckler, MOTCO Islands, and Honker Bay were primarily inventoried by whaler with foot support where possible. MOTCO Mainland was surveyed by kayak for the first time in 2020. The extensive side channels and back sloughs of MOTCO Islands and Honker Bay have never been fully inventoried due to difficulty of access and the sheer amount of ground to cover; each year new areas are explored and assessed, often resulting in new detection of isolated patches of hybrid *S. alterniflora*. The long rocky shoreline of the Carquinez Strait provides minimal opportunity for *Spartina* establishment and is surveyed every few years so that resources can be focused elsewhere with more infestation pressure. This stretch was mostly surveyed by kayak in 2020.

ISP has experienced an increasing frequency of high winds while conducting field work around the Bay Area in recent years. In 2020, the ISP faced significant challenges conducting inventory and treatment in Suisun Bay, where the high fetch as the winds cross the open water can make it risky for boat operation. In 2020, high winds forced events scheduled in May to be delayed several times into October, almost causing the ISP to miss the treatment window for the season before the plants senesce.

In 2020, the mapped hybrid *S. alterniflora* in the eastern sub-areas of the Suisun Region all showed slight increases over 2019 levels. MOTCO Mainland was surveyed for the first time in 2020 and 15 m^2 of hybrid *S. alterniflora* was discovered. In most cases, increase of *S. alterniflora* was largely the result of a having conducted a more extensive inventory over a greater area. This portion of the estuary was added to ISP's Monitoring Plan in 2016, and then increased in size and survey effort in 2017 (see **Section 3.4** for further discussion). Inventory effort has increased each year since then as part of an adaptive inventory strategy to access more of the back sloughs and hidden shorelines. As a result, previously undetected clones were

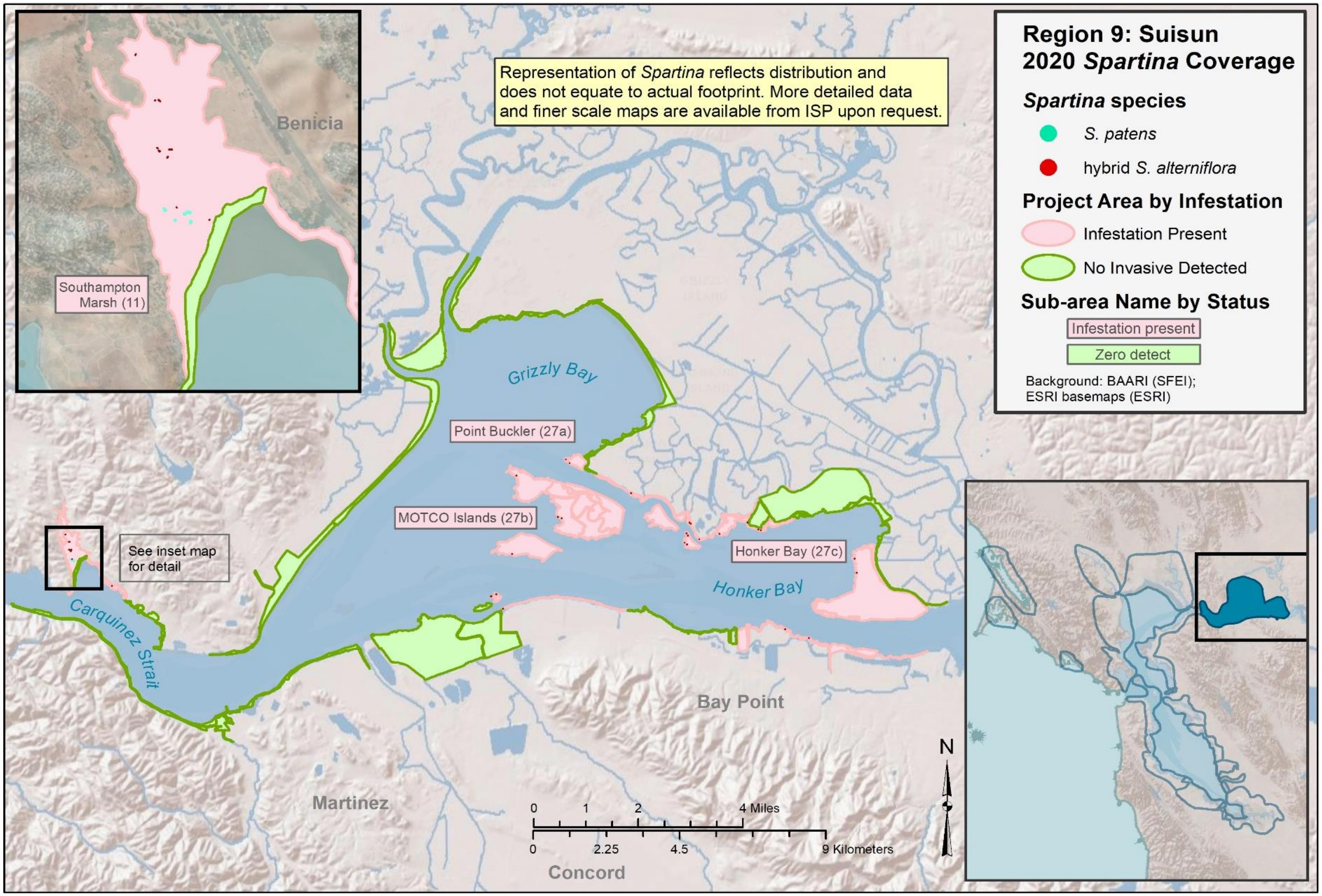

Figure 18. Distribution of invasive Spartina in 2020 in the five sub-areas of Reporting Region 9: Suisun. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive Spartina are labeled in green.

Table 14. Summary of 2020 invasive *Spartina* mapped and treated by sub-area within Reporting Region 9: Suisun.

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species: *anglica*	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	All Invasive *Spartina* Cover: 2020 Net Area	2020 Treat-ment Area	Peak Year	Net Area Decline: Since Peak	Since 2019
REGION 9: SUISUN												
11: Southampton Marsh	9/23	Backpack	~2 m²			0.5 m²	0	2 m²	60 m²	2005	>99%	79%
27a: Point Buckler	10/12	Backpack	0			0.3 m²	0	0.3 m²	16 m²	2016	>99%	Increase (0.3 m²)
27b: MOTCO Islands	10/9; 10/12; 10/13	Backpack	0			11 m²	0	11 m²	294 m²	2017	96%	Increase (2 m²)
27c: Honker Bay	10/12; 10/13; 11/9	Backpack	0			11 m²	0	11 m²	267 m²	2018	41%	Increase (7 m²)
27d: MOTCO Mainland	9/9; 11/19	Backpack	0			15 m²	0	15 m²	209 m²	2020	n/a	n/a
REGION 9 TOTAL			~2 m²			39 m²	0	41 m²	846 m²	2005	98%	67% increase (16 m²)

found in areas that had never been inventoried before, many of which were on the shorelines of Honker Bay. The original infestation that had been found and treated in 2016 and 2017 responded strongly to treatment and has shown dramatic declines.

Southampton Marsh (11), a part of the Benicia State Recreation Area, is the only location in the Estuary where *S. patens* has been documented, and it has persisted there since at least the early 1960s. In 2019, ISP staff mapped and treated a total of 5 m^2 of *S. patens*, all outside of the "interactions zone" where *S. patens* and the endangered plant *Chloropyron molle* ssp. *molle* (CHMOMO) co-exist. In early 2020, CDFW changed the structure of the rare plant permit such that staff from U.S. Department of Agriculture-Agricultural Research Services (ARS) now conduct all *S. patens* mapping – previously ARS mapped *S. patens* only within the CHMOMO interaction zones, and ISP had mapped the rest of the site. In 2020, about 2m^2 of *S. patens* was treated across the site. Almost all the remaining *S. patens* is within the interaction zones with CHMOMO, and it is also near areas of black rail detections. While the *S. patens* infestation is down to eradication levels, the various exclusion zones associated with CHMOMO and black rail are slowing progress.

Very few organizations conduct rail surveys in this region and data are sparse. OEI conducted surveys for the Military Ocean Terminal Concord (MOTCO) in 2020 at several offshore islands (including portions of ISP sub-area 27b), and no Ridgway's rails were detected. In general, the Suisun Region, with its extensive brackish and freshwater marshes, has a very low density of Ridgway's rails. The nominal infestation by and treatment of invasive cordgrass is not anticipated to have any impact on local rail populations.

The ISP Restoration Program has not implemented habitat enhancements within this region. California Department of Parks & Recreation manages a successful *Lepidium latifolium* treatment program at Southampton Marsh aimed at protecting and restoring the native channel bank vegetation (e.g., *Grindelia stricta*).

2.2.10 Region 10: Vallejo

The Vallejo Region (Region 10) is comprised of four sub-areas and covers the northern portion of San Pablo Bay, bounded by the mouth of the Petaluma River to the west and the City of Vallejo to the east, and extending eight miles inland to the north. Due to the region's large size and limited invasion pressure over much of its extent, it is not surveyed in entirety each year, and methods vary depending on resources. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 19** and **Table 15**. Treatment dates and methods are included in Table 15.

The entirety of the San Pablo Bay bayfront was surveyed by airboat in both 2019 and 2020. Interior portions of White Slough/Napa River (26a), Sonoma Creek (26c), and Sonoma Baylands (26d) were also surveyed by airboat in 2019 with airboat support from San Pablo Bay National Wildlife Refuge (SPBNWR) staff. Limited availability of airboat support in 2020 due to COVID-19 led to most interior portions of these sub-areas not getting inventoried in 2020. The historic infestations at Sonoma Creek were inventoried on foot both years, and those at American Canyon and White Slough (both part of 26a) were kayaked thoroughly in 2020. Mare Island (26b) was also inventoried on foot both years for *S. densiflora* and hybrid *S. alterniflora*. The expansive White Slough/Napa River sub-area (26a) is under very low invasion pressure by non-native *Spartina* and has not been inventoried in full since 2015 when it was thoroughly inventoried by airboat with the assistance of SPBNWR staff.

The total net area of non-native *Spartina* mapped in Region 10 was 25 m^2, all of which was hybrid *S. alterniflora* located in the San Pablo Bay NWR and Mare Island (26b) sub-area. This reflects an increase of 22 m^2 over 2019 levels and is due almost entirely to the discovery of one new clone in the northwest-most corner of the marsh, approximately 300 meters from a known clone along Sonoma Creek that was present up until 2019.

The San Pablo Bay NWR and Mare Island sub-area has also historically contained both *S. densiflora* and hybrid *S. densiflora*, though neither have been detected here since 2018. Persistent inventory monitoring will continue for at least two more years in order to confirm local eradication of *S. densiflora*, which can maintain a viable seed bank for an estimated five years.

In January 2015 Cullinan Ranch was breached and is being restored to tidal marsh. In 2019 the site was inventoried by airboat and *S. foliosa* establishment was documented. This new restoration marsh will be assessed and inventoried periodically to ensure that no populations of invasive *Spartina* establish and threaten its development.

Annual rail surveys by PBCS and San Pablo Bay NWR show an increasing trend in rail detections over the past five years, as younger restoration marshes mature and develop. There is extensive *S. foliosa* throughout the Region, and it has quickly colonized and become established in various restoration projects. The ISP Restoration Program has planted *S. foliosa* on 59 constructed islands and other elevated features located within the Sears Point-Dickson Unit

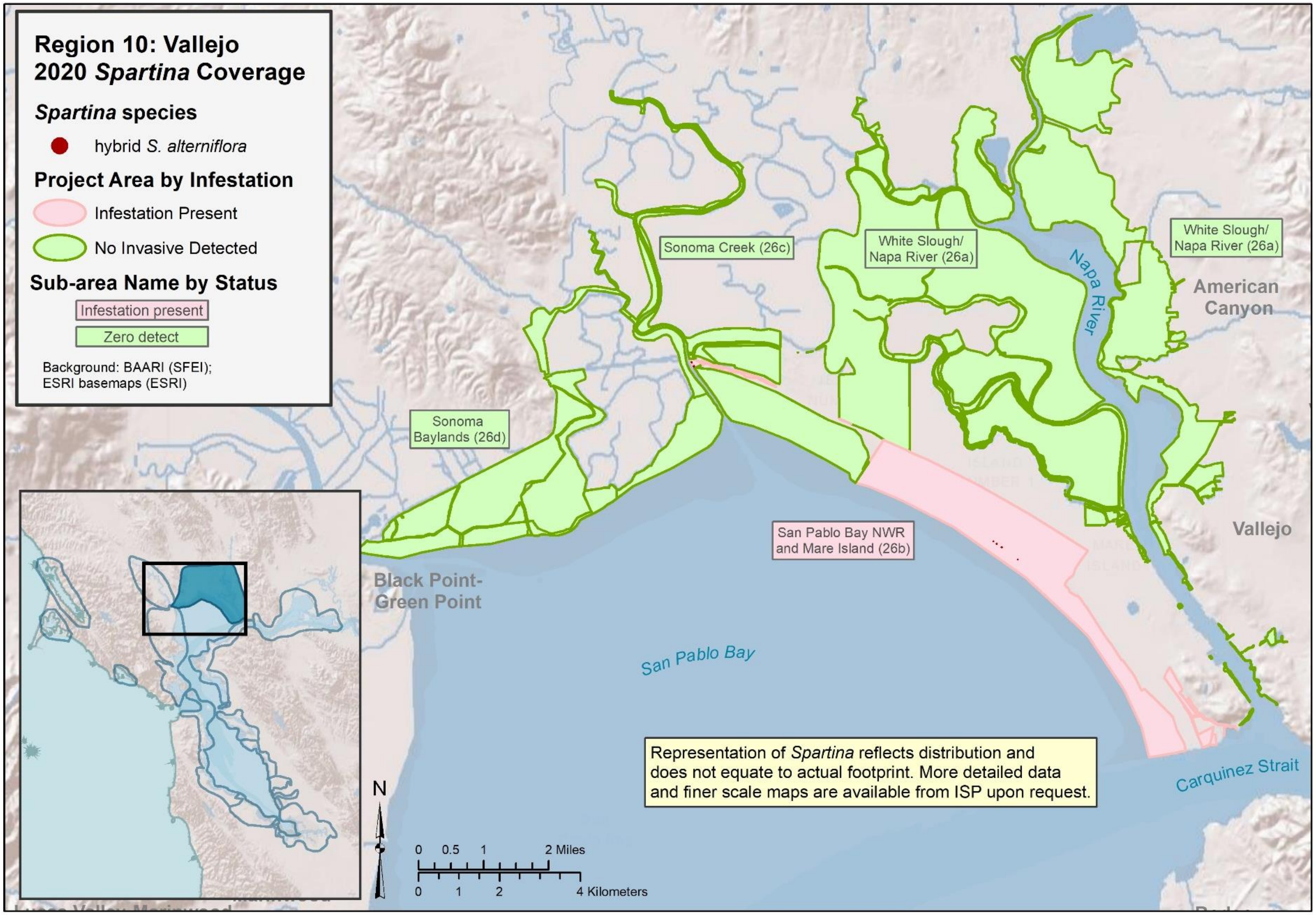

Figure 19. Distribution of invasive Spartina in 2020 across the four sub-areas of Reporting Region 10: Vallejo. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive Spartina are labeled in green.

Table 15. Summary of 2020 invasive *Spartina* mapped and treated by sub-area within Reporting Region 10: Vallejo.

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species					All Invasive *Spartina* Cover				
											Net Area Decline	
			anglica	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	2020 Net Area	2020 Treat-ment Area	Peak Year	Since Peak	Since 2019
REGION 10: VALLEJO												
26a: White Slough / Napa River	**11 years with No Invasive Spartina (2010-2020)**		0			0	0	0	0	2008	100%	n/a
26b: San Pablo Bay NWR and Mare Island	6/12; 10/6	Dug, Backpack	0			25 m²	0	25 m²	333 m²	2009	98%	Increase (22 m²)
26c: Sonoma Creek	**2 years with No Invasive Spartina (2019-2020)**		0			0	0	0	0	2010	100%	n/a
26d: Sonoma Baylands	**10 years with No Invasive Spartina (2011-2020)**		0			0	0	0	0	2008	100%	n/a
REGION 10 TOTAL			0			25 m²	0	25 m²	333 m²	2009	98%	725% increase (22 m²)

restoration project at the San Pablo Bay NWR. These interior features within the restoration site were planted to speed up vegetation establishment to help reduce erosion observed there by project partners, SFSU (Margot Buchbinder), San Francisco Bay NERR, SPBNWR, and Sonoma Land Trust. The ISP Restoration Program has collected *S. foliosa* plant material from several of the fringe marsh areas along the Napa River for amplification in propagation beds at a nursery. Propagated *S. foliosa* from this region has been planted in four other Regions: Region 2: San Francisco Peninsula, Region 5: Union City, Region 6: Hayward, and Region 7: San Leandro Bay.

2.2.11 Region 11: Petaluma

The Petaluma Region (Region 11) is composed of four sub-areas and includes the wetlands lining the tidal portions of the Petaluma River and its tributaries in Marin and Sonoma Counties, from downtown Petaluma to the river's mouth in northwestern San Pablo Bay. The historic infestation of hybrid *S. alterniflora* in this region peaked in 2007 at 0.15 acre, and has been fairly localized to the upper reaches of the Petaluma River. It is suspected that hybrid *S. alterniflora* was introduced here by propagules transported via uncleaned dredge or construction equipment. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 20** and **Table 16**. Treatment dates and methods are included in Table 16.

All four of this region's sub-areas were inventoried at least in part in both 2019 and 2020. The southern two sub-areas, Petaluma Marsh (24c) and Lower Petaluma River-Downstream of San Antonio Creek (24d) were only surveyed in specific portions in either year. These two sub-areas are often surveyed with the assistance of an airboat, but that was not available for either year, so very limited amounts were accessed. In 2019 thorough inventory was completed in the Mira Monte Marina Restoration Marsh and Bahia Restoration Marsh, both at the request of landowners, and Port Sonoma Marina was assessed and partially inventoried on foot both years. No invasive *Spartina* was found in any of these areas, a finding supported by the collection of DNA samples that consistently returned native *S. foliosa* results. All areas of known or historic infestation in the region were thoroughly surveyed; interior channels where no hybrid *S. alterniflora* has ever been detected were not surveyed.

The 2020 inventory of this region yielded 24 m^2 of hybrid *S. alterniflora* and no other non-native cordgrass species (Figure 20, Table 16). This represents a 58% increase from 2019 levels, most of which is attributed to the discovery of several new clones further upstream than had been detected in previous years. Most of the infestation (>87%) was within 24a (Upper Petaluma River-Upstream of Grey's Field), and no invasive *Spartina* of any species has ever been found in the lower portions of Petaluma River.

The infestation in the Petaluma Region exists along the narrow shoreline of upstream Petaluma River; while most of the rails in the region are detected further downstream, within Lower Petaluma River-Downstream of San Antonio Creek (24d). Surveys for Ridgway's rails within Region 11 are conducted by PBCS, which detected over 200 Ridgway's rails in the Petaluma Region during surveys in 2019 and 2020 (Wood 2019, 2020). Based on their survey results, rail populations in the region generally appear stable or increasing.

No ISP habitat enhancements have been implemented in Region 11 because the northern reaches of the Petaluma River have abundant *S. foliosa* and *G. stricta* throughout the extensive tidal marsh habitat. ISP's Restoration Program has collected *S. foliosa* from Port Sonoma Marina for amplification in nursery propagation beds. Native cordgrass collected from this region has been planted into five Reporting Regions: Region 2: San Francisco Peninsula, Region 5: Union City, Region 6: Hayward, Region 7: San Leandro Bay, and Region 10: Vallejo.

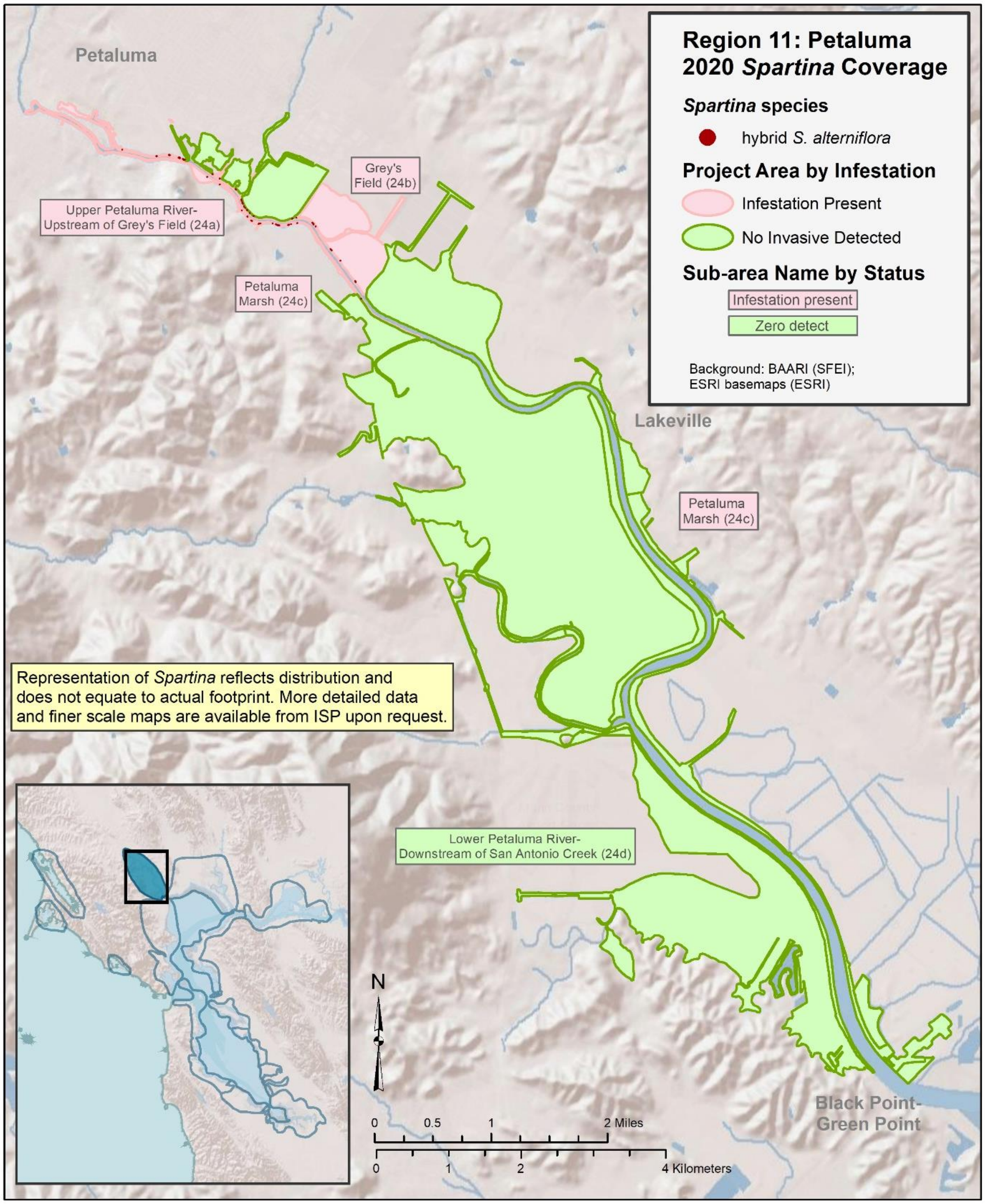

Figure 20. Distribution of invasive *Spartina* in 2020 across the four sub-areas of Reporting Region 11: Petaluma. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive *Spartina* are labeled in green.

Table 16. Summary of 2020 invasive *Spartina* mapped and treated by sub-area within Reporting Region 11: Petaluma.

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species: *anglica*	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	All Invasive *Spartina* Cover: 2020 Net Area	2020 Treat-ment Area	Peak Year	Net Area Decline: Since Peak	Since 2019
REGION 11: PETALUMA												
24a: Upper Petaluma River - Upstream of Grey's Field	8/7; 10/21 (R2)	Backpack, Airboat		0		21 m²	0	21 m²	546 m²	2007	96%	Increase (13 m²)
24b: Grey's Field	8/7	Backpack, Airboat		0		0.02 m²	0	0.02 m²	0.09 m²	2009	>99%	97%
24c: Petaluma Marsh	8/7	Backpack, Airboat		0		3 m²	0	3 m²	83 m²	2010	89%	55%
24d: Lower Petaluma River - Downstream of San Antonio Creek	No invasive Spartina ever detected			0		0	0	0	0	n/a	n/a	n/a
REGION 11 TOTAL				0		24 m²	0	24 m²	629 m²	2007	96%	Increase (9 m²)

2.2.12 Region 12: Outer Coast

The Outer Coast Region (Region 12) includes the geographically isolated watersheds on the western side of Marin County. This region is composed of remote coastal estuaries and bays, most within Point Reyes National Seashore, several of which have been colonized by hybrid *S. alterniflora*. The 2020 distribution and abundance of invasive *Spartina* within each sub-area is presented in **Figure 21** and **Table 17**. Treatment dates and methods are included in Table 17.

Of the five sub-areas in Region 12, three were at least partially inventory in 2019 and 2020. Bolinas Lagoon North (25d) and South (25e) were inventoried on foot in both years, and Tom's Point/Tomales (25a) was partially surveyed for *S. densiflora* only in both years. Limantour Estero (25b) and Drakes Estero (25c) have not been surveyed since 2018 due to conflicts between available tides and suitable weather in 2019, and then access restrictions due to COVID-19 and wildfires in 2020. Because of very low invasion pressure and difficult access, thorough boat survey has not been conducted at Limantour Estero(25b) or Drakes Estero (25c) for six years. Tom's Point/Tomales (25a) was partially surveyed for *S. densiflora* only.

Invasive *Spartina* currently occurs in the Outer Coast Region in only one instance: *S. densiflora* in one small marsh, Tom's Point (part of 25a) (Figure 21, Table 17). Hybrid *S. alterniflora* was present in Bolinas Lagoon, North until 2018, but was not detected in either 2019 or 2020 for the first time since treatment here began in 2014.

Spartina densiflora persisted at Tom's Point in 2020 with a single seedling totaling 0.02 m^2 of cover; no *S. densiflora* plants have been found at Hog Island Oyster Company since 2015. ISP conducts two rounds of surveys at both marshes each year to ensure that all detections are removed before they can set seed. With virtually no re-invasion potential since these sites are far removed from other infestations, it is simply a matter of time until the *S. densiflora* seed bank is exhausted and local eradication achieved.

With the removal of the infestation at Bolinas Lagoon North, the Outer Coast Region has been free of hybrid *S. alterniflora* since 2018. All other previous occurrences of hybrid *S. alterniflora* had already been removed from the region, with no invasive *Spartina* being found in Drakes Estero since 2012, Limantour Estero since 2011, and Bolinas Lagoon, South since 2012 (all achieving local eradication status after three years of zero detection).

Ridgway's rails do not occur in the region, as their observed geographic range is limited to the tidal marshes of the San Francisco Estuary, except for occasional fall and winter observations along the Outer Coast. As such, no annual Ridgway's rail surveys have been conducted in the Outer Coast Region. No ISP habitat enhancements have been implemented in this region to date.

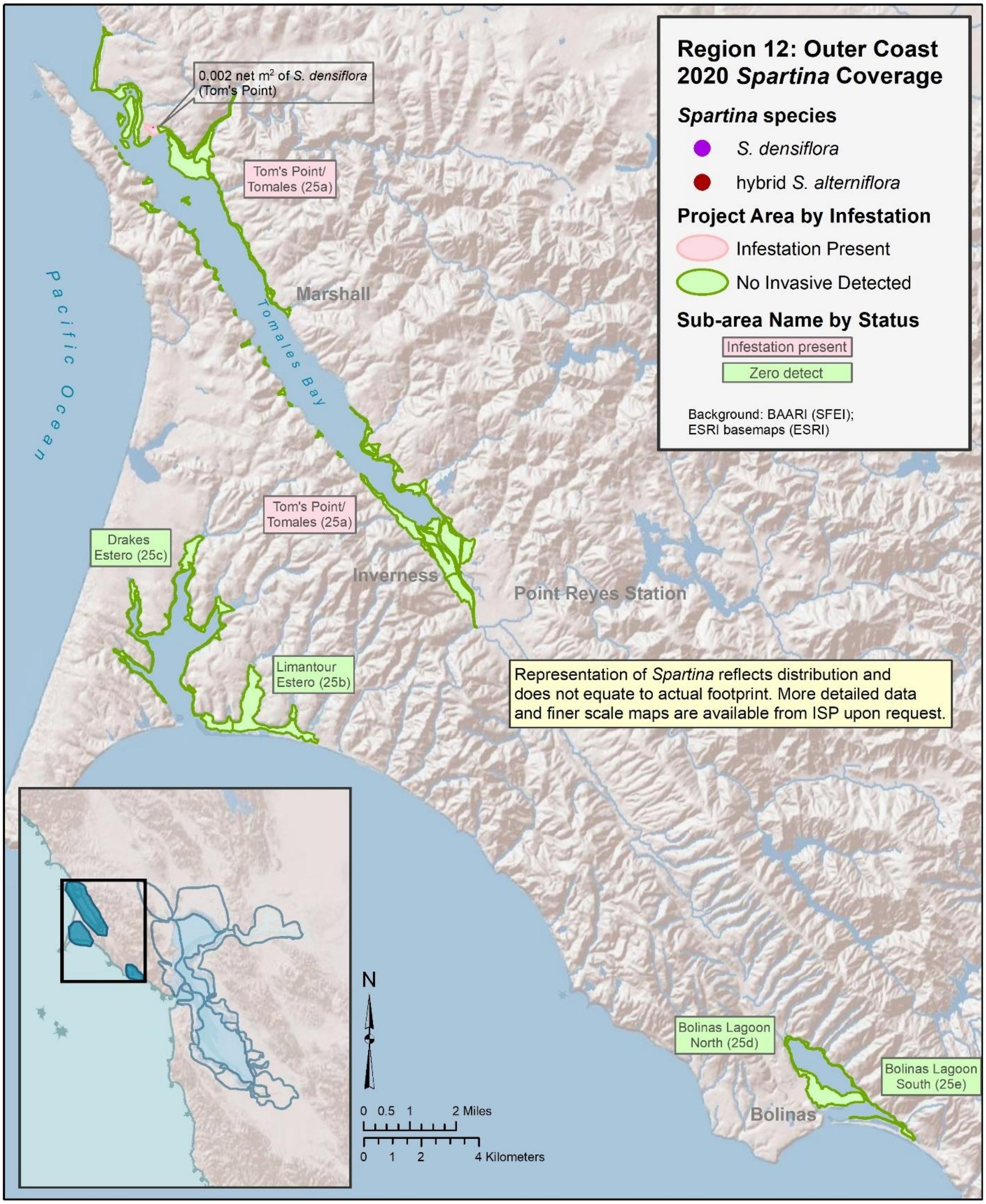

Figure 21. Distribution of invasive *Spartina* in 2020 across the five sub-areas of Reporting Region 12: Outer Coast. Sub-areas with current infestation are labeled in pink, while those with no detection of invasive *Spartina* are labeled in green.

Table 17. Summary of 2018 invasive *Spartina* mapped and treated by sub-area within Reporting Region 12: Outer Coast.

Split Sub-Area	2020 Treatment Dates	2020 Treatment Method	2020 Net *Spartina* Coverage By Species					All Invasive *Spartina* Cover				
											Net Area Decline	
			anglica	*patens*	*densiflora x foliosa*	*alterniflora x foliosa*	*densiflora*	2020 Net Area	2020 Treat-ment Area	Peak Year	Since Peak	Since 2019
REGION 12: OUTER COAST												
25a: Tom's Point, Tomales	1/11/21 (COI)	Dug		0		0	0.002 m²	0.002 m²	0.008 m²	2010	>99%	58%
25b: Limantour Estero	**9 years with No Invasive Spartina (2012-2020)**			0		0	0	0	0	2010	100%	n/a
25c: Drakes Estero	**8 years with No Invasive Spartina (2013-2020)**			0		0	0	0	0	2007	100%	n/a
25d: Bolinas Lagoon, North	**2 years with No Invasive Spartina (2019-2020)**			0		0	0	0	0	2012	100%	n/a
25e: Bolinas Lagoon, South	**9 years with No Invasive Spartina (2013-2020)**			0		0	0	0	0	2004	100%	n/a
REGION 12 TOTAL				0		0	0.002 m²	0.002 m²	0.008 m²	2007	>99%	58%

3. SPECIAL TOPICS

3.1 Large Scale Restoration and the South Bay Salt Pond Restoration Project

The San Francisco Estuary suffered great losses in tidal marsh habitat since the turn of the 20th century due to diking and land conversion for agriculture, urban development, and commercial salt production. In the last 40 years there has been a concerted effort to restore many of these areas to tidal marsh to support wildlife, urban welfare, and Estuary health. Most progress in this effort over the last 20 years has been undertaken by the State Coastal Conservancy (SCC), U.S. Fish and Wildlife Service (USFWS) and California Department of Fish and Wildlife (CDFW), most frequently in conjunction with the South Bay Salt Pond Restoration Project (SBSPRP), the largest tidal marsh restoration effort on the West Coast. **Figure 22** shows the location of these large-scale projects. These restorations efforts have coincided with the infestation of hybrid *S. alterniflora*, which has required collaboration to achieve restoration goals.

As its name suggests, SBSPRP is focused on the South Bay and mostly on the lands that were acquired from Cargill Salt in 2003. **Figure 23** shows an example of marsh development at the easternmost Island Pond (A19) in 2021, with abundant native *Spartina foliosa* establishing in the southern portion. Other large scale tidal restoration work has also been completed by USFWS, CDFW, the Conservancy, and other partners in other portions of the Estuary. In 2015,

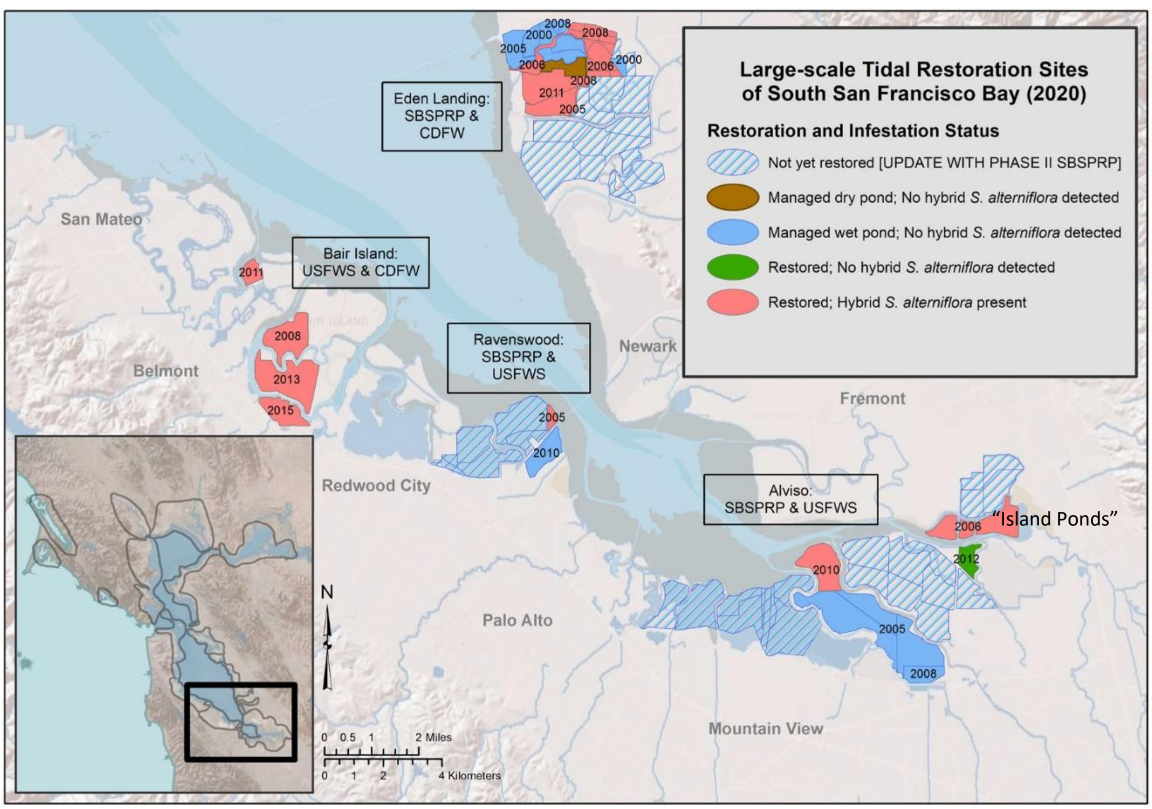

Figure 22. Large-scale Tidal Marsh Restoration Sites of the South San Francisco Bay (2020)

Figure 23. Abundant native Spartina foliosa establishment in Island Pond A19 along Coyote Creek.

two large tracts, Sears Point Restoration (part of sub-area 26d) and Cullinan Ranch (not yet included in a sub-area), in the Napa/Sonoma Marshes were breached and comprise 2,400 acres of young tidal marsh now included in San Pablo Bay NWR. In 2014 the Conservancy led a project to restore the 648-acre former Hamilton Airforce Base (partially in sub-area 23m) to tidal exchange along the Novato shoreline. Similarly in South Bay, though outside of SBSPRP, USFWS has also opened several former ponds on Bair Island as part of Don Edwards NWR over the last 15 years, including Pond B3 (02m), Central Bair (02o), and most recently Inner Bair Restoration (02l) in 2015.

Because greater than 98% of the remaining infestation is in Central and South Bay, restoration projects in the North Bay have so far been free from infestation, but they are still monitored by ISP regularly to ensure their protection. The restoration projects of the South Bay, however, have nearly all been colonized by hybrid *S. alterniflora*, and many quite extensively. They require thorough annual inventory and treatment to control the infestation and support the projects' restoration goals. Since 2011, more than 1,900 acres of diked salt ponds in the South Bay have been breached and restored to tidal marsh, expanding the potential habitat for hybrid *S. alterniflora* and thus the area monitored and treated by the ISP (see Figure 22). Phase I of the SBSPRP was completed in 2017. Phase II began in 2019, and after delays from the pandemic, is expected to begin new breach construction in 2021.

The ISP and SBSPRP coordinate regularly to anticipate future breaches, prepare the areas as much as possible (e.g., increase focus in adjacent sites to reduce threat of infestation by hybrid *S. alterniflora*), and to develop short- and long-term monitoring needs.

3.2 Phased Plan for Resuming Treatment at Previously Restricted Sites

In 2018, ISP and Coastal Conservancy staff worked with USFWS biologists at Don Edwards National Wildlife Refuge to prepare an update to the 2012 ISP Biological Assessment (BA). The BA informed a new interagency Section 7 consultation, and the ISP received a five-year Biological Opinion (BO) in October 2018 that covered a suite of invasive plant management and restoration activities from 2018-2022. The BA included a Phased Plan for resuming full treatment or seed suppression at a subset of infested sub-areas that haven't been permitted for this work since 2010, and the new BO subsequently authorized these activities. In 2018 USFWS reevaluated treatment restrictions once detections of Ridgway's rail had increased sufficiently for three consecutive years over an established baseline at consistently surveyed marshes. **Figure 24** shows the distribution of these sub-areas where either full treatment or seed suppression is permitted to occur as of 2018, as well as the sub-areas that continue with the prior level of restrictions (no treatment of the hybrid *S. alterniflora*). The 25.7 acres of hybrid S. alterniflora in the sub-areas that remain treatment-restricted account for 78% of the total remaining invasive *Spartina* in the Estuary (33.1 acres) as of their most recent coarse mapping in 2019. These sub-areas are inventoried every other year and were not inventoried in 2020.

The approach of phasing in treatment serves as the first steps in resuming management of hybrid *S. alterniflora* within four marsh complexes where treatment had been restricted since 2011, while minimizing negative impacts to populations of Ridgway's rail. A key component of the Phased Plan approach is revegetation after hybrid *S. alterniflora* has been reduced to acceptable levels that would not threaten those revegetation efforts. The restoration work begins with native marsh gumplant (*Grindelia stricta*) to provide vertical structure along channel banks that can serve as nesting substrate and refugia from predators during high tides. Once the hybrid *S. alterniflora* has been virtually removed from the sub-area, native *S. foliosa* can be reintroduced at the lower tidal elevations to vegetate the channels and bayfront. The infestation was very heavy in all of these sub-areas and extirpated the native cordgrass; revegetation with *S. foliosa* is required to establish essential rail habitat more rapidly than would occur with passive recruitment. The absence of native *S. foliosa* at all but one of these Phased Plan sites means that eradication can progress on a faster trajectory than at more complex marshes with abundant *S. foliosa*, and the ISP will begin restoration plantings and enhancements when appropriate. Revegetation completed to date in these and adjacent marshes are summarized within the sections above for Region 3: San Mateo, Region 6: Hayward, and Region 7: San Leandro Bay.

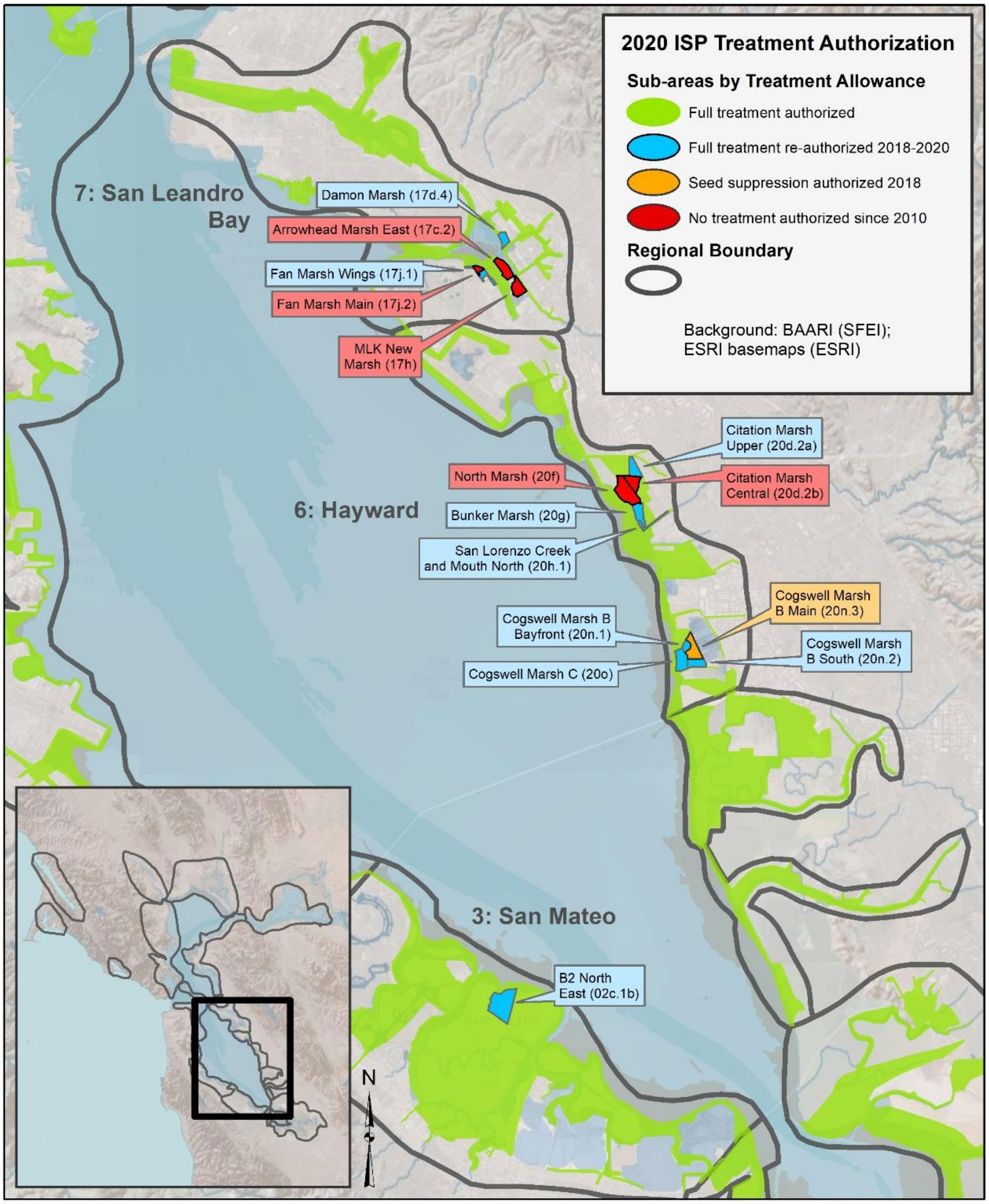

Figure 24. Baywide Invasive Spartina Treatment History

To facilitate resumed treatment, the phased plan necessitated the addition of four new sub-areas (Fan Marsh Wings [17j.1], Citation Marsh Upper [20d.2a], Cogswell Marsh B Bayfront [20n.1], and Cogswell Marsh B South [20n.2]) resulting from additional splits to the previously restricted sites. These sub-areas are permitted for phased, full treatment in the current BO, along with the five additional previously restricted sites: B2 North East (02c.1b), Damon Marsh (17d.4), Bunker Marsh (20g), San Lorenzo Creek & Mouth North (20h.1), and Cogswell Marsh C

(20o). There are still five sub-areas that continue to have no treatment permitted as treatment is phased back into the previously restricted areas: Arrowhead Marsh East (17c.2), MLK New Marsh (17h), Fan Marsh Main (17j.2), Citation Marsh Central (20d.2b), and North Marsh (20f). An addition sub-area, Cogswell B Main (20n.3), is authorized for seed suppression only. These restricted sites are all clustered in two nodes along the East Bay shoreline, within San Leandro Bay and Robert's Landing, serving to reduce the impacts from uncontrolled hybrid *Spartina* seed dispersal out to the Estuary.

Resuming treatment at the previously restricted sub-areas will require an increased investment for inventory in future years. These sub-areas and those that maintain treatment restrictions have been surveyed biennially by 25m x 25m grid since 2015 to allow inventory efforts to be focused in other marshes that would inform treatment in a given year. This "grid" inventory approach is coarser and less costly and provides the general distribution and abundance of non-native cordgrass without the level of detail required to relocate individual plants for treatment purposes. Grids were utilized again in 2019 to inform the Treatment Program in these sub-areas that would be broadly treated, but also to update the inventory data for those sub-areas that continue to not be treated. As treatment progresses, more detailed inventory will be needed to document the dwindling infestations, and so more extensive surveys will need to be conducted. The marshes that will not be treated will continue to be inventoried biennially by grid until treatment authorizations change and more detail is needed to inform treatment.

The current five-year ISP BO was received late in the 2018 Treatment Season, and it was not feasible to resume treatment in all of the now-permitted areas that season. Limitations included the number of appropriate tide windows remaining in that growing season, available vegetation management contractor time, and some of the target hybrid *S. alterniflora* was already senescing for the year (reducing herbicide uptake and translocation). In 2019, treatment resumed at most of the permitted sites not treated in 2018. Full treatment began at Bunker Marsh (20g) and Cogswell Marsh B Bayfront (20n.1) for the first time since 2010, and treatment for seed suppression began at Cogswell Marsh B Main (20n.3) using a dilute solution of imazapyr applied by helicopter to arrest plant development while maintaining aboveground biomass for Ridgway's rail. The seed suppression treatments will reduce the potential for re-infestation of neighboring full treatment marshes while minimizing indirect impacts to Ridgway's rail.

At the time, the ground-based treatment of Bunker Marsh (20g) in 2019 was the largest mobilization since the early days of the ISP, covering 11 solid treatment acres at the site using a Marshmaster amphibious tracked vehicle on the central marsh plain, and hauling hose out from a truck staged along the adjacent upland perimeter **(Figure 25).** The bayfront of Cogswell Marsh B contains a substantial infestation at the edge of the huge meadows that had not been treated since 2010. In 2018 Cogswell Marsh B Bayfront (20n.1) was split from Cogswell Marsh B Main (20n.3) to allow treatment that might contain the proliferation of hybrid seed out into the Estuary and adjacent restoration marshes. Inventory in 2019 at these sub-areas documented

Figure 25. Thick stands of marsh gumplant (*Grindelia stricta*) line the channels of Bunker Marsh one year after resuming full treatment. These ISP plantings were protected from being overrun by hybrid *S. alterniflora* over several years by annually treating a three-meter buffer, until adjacent meadows of hybrid *Spartina* are eliminated. This strategy assures high-quality Ridgway's rail refugia following removal of the hybrid *Spartina*.

greatly reduced infestation levels after that single application the previous year. Ground-based treatment was conducted by backpack, truck or Marshmaster at Fan Marsh Wings (17j.1), San Lorenzo Creek & Mouth North (20h.1), Cogswell Marsh B South (20n.2) and Cogswell Marsh C (20o), as well as airboat and truck treatment at Damon Marsh, and full concentration aerial treatment at B2 North East on Bair Island **(Figure 26)**.

Treatment of Citation Marsh Upper (20d.2a) resumed in 2020 for the first time since 2010 and was conducted entirely on the ground (**Figure 27)**. This was the largest ground-based mobilization in the entire history of the ISP. At the start of the project in 2005-2007, many marshes with this significant an infestation received broadcast helicopter treatment for 2-3 seasons before on the groundwork was initiated, but the proximity of Citation Marsh Upper to the housing development at Heron Bay precluded treatment by helicopter. Ground-based work was never conducted at this scale in one year at a single sub-area at the beginning of the project but was scaled up in a stepwise manner over several seasons. The current approach benefitted from technology that that was unavailable at the start of the ISP Treatment Program, including Intelli-Spray rigs with the capability of hauling out up to 850 feet of hose from a truck staged in the adjacent upland. Eleven full days were required to complete treatment here, which was achieved by hauling two long hoses (one 850 ft. and the second 600 ft.) from the spray rig out into the marsh and using a jon boat as a bridge across the major western channel.

Figure 26. Bair Island B2 Northeast had numerous hybrid *Spartina* clones scattered across the marsh plain when ttreatment resumed in 2019. Potentially devastating full invasion of a dense meadow was circumvented by applying “seed suppression” applications that left some standing plants but substantially reduced spread by seed.

Figure 27. Treatment resumed at Citation Marsh Upper in 2020, requiring eleven days of ground-based treatment over the course of the first season.

Full treatment continued at all other Phased Plan sites in 2020 including Bair Island B2 Northeast, Cogswell Marsh C, Cogswell Marsh B South, Cogswell Marsh B Bayfront, Bunker Marsh, Damon Marsh, Fan Marsh Wings, and San Lorenzo Creek Mouth North, as well as seed suppression at Cogswell Marsh B Main. The efficacy observed from treatment at Cogswell Marsh B South has been remarkable, a drop of 85% net cover after just two years. This progress has already allowed a shift to smaller scale backpack and truck work, no longer needing to deploy the Marshmaster to this site. Infestation has also been greatly reduced at Cogswell Marsh C, though not to the extent of Cogswell Marsh B South. Cogswell Marsh C has extensive fringe hybrid *S. alterniflora* in the southern cove, which was largely senesced in the first year of resuming treatment in 2018, making 2020 only the second season (although it still resulted in a 69% drop since 2019). Cogswell Marsh B Bayfront showed a 77% reduction after the partial treatment in the first year (2019). Cogswell Marsh A, which has been under continuous treatment, is likely benefitting from the ISP resuming treatment at the adjacent areas of Cogswell, showing a 67% reduction in net cover last year. Cogswell Marsh A was approaching eradication levels when treatment restrictions began in 2011, and already contains some of the ISP's earliest reintroductions of *S. foliosa*. Efficacy from resuming treatment at Bunker Marsh in 2019 was probably the most astounding drop after just a single treatment in the history of the ISP. Hybrid *S. alterniflora* cover was reduced by 80%, and quite a few Ridgway's rail are still being detected there (16 in 2021), probably benefitting from the *G. strictas* ISP installed in the early years of the ISP Restoration Program that have been maintained.

While Damon Marsh has shown a substantial hybrid *S. alterniflora* reduction since treatment resumed, it has not improved as much as some other locations, likely due to abundant hybrid propagules from the remaining fully restricted sites in San Leandro Bay. Fan Marsh Wings, formerly a restricted site, is down to 10 m^2 net cover, which is probably as low as it can be expected to get until treatment at adjacent Fan Marsh Main resumes.

3.3 *Spartina densiflora* Eradication Progress

ISP has been successful in maintaining its expected trajectory for *Spartina densiflora* eradication as the seedbank becomes locally exhausted with recurring treatment. ISP experience has shown that *S. densiflora* seed appears to remain viable for at least five years, and over the last five years ISP has detected and removed increasingly fewer occurrences of this species. During this timeframe virtually all detected *S. densiflora* plants were found and removed prior to their setting seed, which has led to greatly reduced infestation pressure. Still, very small numbers of detections occur at these isolated marshes for years despite twice annual survey and removal. This continuing low level of infestation by *S. densiflora* seems to be attributed to the historical seedbank that had developed onsite during the years before management implemented.

All *S. densiflora* infestation sub-areas receive inventory and concurrent manual removal twice each year. This occurs in early summer (normally early to mid-June), when *S. densiflora* is more detectable because it is flowering, and in winter (normally January), when it is more detectable because it remains green while many other marsh plants are more gray/brown with dormancy.

In 2020 when a *S. densiflora* seedling or young plant was detected and removed, it was often the only one found in a given sub-area (**Figure 28**). The original introduction site for *S. densiflora*, Creekside Park in Kentfield, which also contained the largest infestation in the Estuary at its peak, experienced a drop in detections into the single digits for the first time in June 2020 with only nine plants detected. However, detections can fluctuate at low levels for several years, even though ISP is virtually eliminating seed dispersal and is therefore not allowing the seedbank to be replenished.

Figure 28. A single seedling of *Spartina densiflora* (indicated by white arrows) manually removed at Tom's Point in January 2021, illustrating the challenge faced by ISP biologists to detect the last recruitment from the seedbank before it can set seed and set back the clock on eradication.

Spartina densiflora was detected and removed from 13 sub-areas in 2020, while another 20 sub-areas had reached zero detection for at least one season. A total of 0.8 m^2 of *S. densiflora* was detected and removed throughout the entire Estuary, down from 1.9 m^2 in 2019 and 6.2 m^2 in 2018. A total of 65 seedlings or small plants was detected and removed over the course of the 2020-2021 season. In March 2021, ISP added a third round of inventory and treatment for *S. densiflora*, at a few of the largest historical infestations and while the surrounding marsh vegetation was still in winter condition, which increases detectability rates. This additional round of inventory yielded a few more detections of plants that were immediately removed. Interestingly, no additional detections were found at Creekside Park in this third round, illustrating what a thorough and comprehensive survey ISP biologists had conducted in the previous winter and summer rounds of inventory.

Also in 2020, ISP implemented a new eradication strategy for hybrid *S. densiflora* that was approved by USFWS in the most recent amendment to the project's 2018 Biological Opinion. Hybrid *S. densiflora* is a novel hybrid between the native *S. foliosa* and the introduced *S. densiflora* and was recognized relatively early in the existence of the project. This early detection of the cross fertilization allowed the Treatment Program to get control of it quite quickly, so it never advanced to having a widespread presence in the Estuary. This is fortunate because it can thrive in areas with greater frequency and duration of inundation, potentially expanding the negative impacts of the *S. densiflora* invasion into a wider range of tidal zones. It has also been harder to kill than *S. densiflora* and often survives digging due to its rhizomatous growth habit (a genetic contribution of its *S. foliosa* parent, whereas *S. densiflora* is a discretely rooted bunchgrass that can be effectively dug without stimulating vegetative growth).

Hybrid *S. densiflora* has also rebounded following herbicide application, sometimes after a season or more has passed since treatment. While herbicide has been effective at eliminating larger stands of hybrid *S. densiflora* over the years, and digging was successful on many smaller patches, ISP has also experienced numerous instances where either or both methods were unsuccessful. This led to adopting a new treatment strategy for hybrid *S. densiflora* that ISP had successfully implemented on small, isolate patches of hybrid *S. alterniflora* in Point Reyes National Seashore, tarping. Treatment by tarping not only blocks sunlight from reaching the plant to arrest photosynthesis, but also solarizes the substrate, heating the rhizomes intolerable levels.

The remaining detections of hybrid *S. densiflora* around the Estuary were treated with imazapyr for a final time back in August 2020. In December 2020, all detected patches were first mowed flush to the substrate with hedge clippers, then tarped by covering them with thick, black geotextile fabric that was staked firmly to the substrate **(Figure 29)**. The tarps varied slightly in size and the total tarp footprint for all occurrences covered in December 2020 throughout the Estuary was approximately 20 m^2, with the average size being 80 cm X 80 cm (0.64 m^2). These treatments by tarping will be monitored periodically and will remain in place for about one year and will be maintained/repair as needed.

Figure 29. Tarped hybrid *Spartina densiflora* at Creekside Park six months after installation in December 2020. White arrows point to tarps covering *S. densiflora* plants.

Most of the new treatment approach for hybrid *S. densiflora* (11 of the 14 detections [79%]) was conducted at Creekside Park, where these hybrids have had the longest time to develop and build a stable root mass. Other detections were tarped at Sanchez Marsh (the only hybrid *S. densiflora* in the South Bay), and two along Lower Corte Madera Creek (one residential property along Lucky Drive, and a public area along the Bay Trail off S. Eliseo). In the winter round for *S. densiflora*, an additional 12 patches of hybrid *S. densiflora* were found in Creekside Park, almost all on historic footprints that had been absent for several seasons. The drought conditions may have been optimal for this "species" to reemerge; *S. densiflora* has also been observed to flourish during drought years. All these additional hybrid *S. densiflora* detections were tarped in January 2021.

4. CONSIDERATIONS FOR 2021

At the start of the 2021 ISP Inventory Monitoring and Treatment Season, more of the general population is fully vaccinated and restrictions throughout California are expected to be lifted on June 15. As a result, we expect that Covid-19 may not have as much impact on our field work in 2021 as it did in 2020, although there are concerning variants that may change this, and staff health and safety will continue to be top priorities. There will likely be fewer disruptions than experienced in the first year of the pandemic when the best available science on precautions and risk reduction were constantly evolving. By the time the hybrid *S. alterniflora* season started in late June 2020, the ISP had been working around the pandemic for a few months and had developed safety protocols that allowed much of our field work to occur normally. Our biggest changes and inconveniences, aside from wearing masks, and maintaining social distancing when congregating at points through the field day, were not being able to carpool and having the OEI office closed causing planning and some training work to be conducted remotely at home. We anticipate that we may be free from even these final two challenges in 2021. The Bay Area is entering the second year of the current drought, and 2021 is one of the driest years on record. The fires of the 2020 season postponed many days of field work out of concern for staff and partner safety while working in dangerously poor air quality. With the extreme drought, fire danger for 2021 is high, so the likelihood of work postponements from unhealthy AQI for the upcoming season is high as well. ISP also learned in the most recent multi-year drought that despite daily tidal interactions with salt water, we can expect both the native and invasive *Spartina* to respond to the low rainfall, often in ways that make the job of monitoring and treatment more difficult. Some *Spartina* will likely not produce any aboveground biomass, especially higher in the marsh where the substrate receives less frequent tidal inundation; ISP biologists already saw this to a minor degree in the first drought year of 2020. Obviously, one cannot map or treat hybrid *S. alterniflora* that is not producing any aboveground evidence of its existence. Imazapyr is a systemic herbicide that requires actively growing plants on which to conduct the foliar application, which is subsequently taken up by the leaves and translocated to the roots. When hybrid *S. alterniflora* is experiencing drought, it also tends not to grow as vigorously, which can make it hard to differentiate from *S. foliosa*, especially in the more cryptic morphs. The drought-related challenges described above can slow our progress towards exhausting any seedbank as well eliminating remnant rhizomes mature plants. However, the low rainfall does tend to bring some short-term benefits such as reduced seed set and recruitment, limiting the number of target plants and potentially making both mapping and treatment burden less time consuming.

Finally, the phenological timing can also be impacted by the low rainfall, potentially compacting the growing season into an even shorter window of opportunity within our already tight windows related to environmental permitting constraints such as Ridgway's rail breeding season. While we expected hybrid *S. alterniflora* to senesce earlier in 2020, we did not see this phenomena manifest across much of the Estuary. While drought generally can cause earlier plant senescence, it is hard to predict how the timing of the target plants in each region will change in response to drought, and how that may impact our upcoming monitoring and treatment season.

During pre-season 2020 *Spartina* Assessment Planning Team meetings, ISP managers chose a North Bay focus, and have reaffirmed our prioritization of this portion of the Estuary for 2021 as well. Aside from a handful of sites in the Richmond area (Wildcat/San Pablo/Rheem), every North Bay sub-area contains less than $10m^2$ or is at zero detection. The ISP uses several tools to give sites a greater focus, and one is to ensure that the primary inventory survey is conducted at an optimal phenology for detecting hybrid *S. alterniflora*. With over 200 historically infested sub-areas to monitor and limited time each season to have optimal hybrid detection, ISP managers need to make choices as to which sites receive those most valued time slots. Another tool is to use Round 2 (R2) inventory and follow-up treatment, which has been shown to drive sub-areas approaching local eradication to zero detection more rapidly. In order to accommodate two rounds of inventory and treatment during the growth season, focus sites need to be surveyed earlier in the season for the first round to allow for sufficient time to pass so undetected plants during that R1 can grow and be detected during the R2. These first rounds are slightly before optimal detection windows, which is necessary to balance the workload over all the relevant sites in a given season. Within the South Bay, as in 2020, ISP plans to approach the largest infestations with a coarse level of inventory and treatment to allow resources to be allocated to reaching local eradication throughout the rest of the Estuary where that goal is closer in the near term. Certain sites will be rotated into more optimal inventory and treatment timing, especially for any that have been relegated to sub-optimal slots in recent seasons. As detailed above in the regional descriptions (Section 2.2), many of the larger infestation sites showed substantial reductions in 2020, so some of those will be elevated in the rotation to push that envelope further.

ISP partners will continue treatment at the formerly restricted sites that have been permitted in the 2018-2022 Biological Opinion, including Citation Marsh Upper for the second season. Others will be treated for the third season since treatment restrictions were lifted in 2018 (full treatment of Bunker Marsh and Cogswell Marsh B Bayfront, and Cogswell Marsh B Main by seed suppression), and a longer list of sub-areas for the fourth consecutive season (B2 North East, Cogswell Marsh B South, Cogswell Marsh C, San Lorenzo Creek Mouth North, Damon Marsh, and Fan Marsh Wings).

Finally, the California Invasive Plant Council (Cal-IPC) received a grant from the SF Bay Restoration Authority that will fund much of ISP's work and also contains an enhanced outreach component. This is exciting because there has not been dedicated funding towards this important aspect of the project since the early years of ISP. There will be a series of presentations to local Weed Management Areas (WMAs), as well as presentations planned for other Bay Area natural resource management entities and agencies involved with tidal marsh restoration around the Estuary. Cal-IPC will be expanding outreach to Conservation Corps and volunteer audiences in disadvantaged communities.

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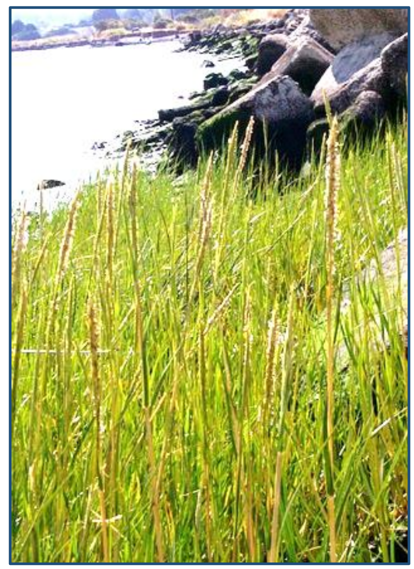
ISP Target Species Descriptions

There are one native and four non-native species of cordgrass in the San Francisco Estuary. The native species, Pacific cordgrass (*Spartina foliosa*), is avoided during treatment and is conserved by controlling the invasive species that can displace or genetically assimilate it. Key aspects of the cordgrass species found in the Estuary are contrasted below. All species and hybrids are perennial, salt-tolerant grasses that spread both sexually and asexually. The roles these species play in their native habitats give ecologists an indication of their potential to alter the salt marsh ecosystem of San Francisco Bay.

NATIVE: PACIFIC CORDGRASS (*SPARTINA FOLIOSA*)



California's only native cordgrass, *S. foliosa*, grows in a narrow range of the tidal spectrum due to its relatively short stature and intolerance for drought. *Spartina foliosa* is a vital component of the salt marsh plant community, occurring at the lowest intertidal elevation of any native macrophyte. This lower tidal marsh zone occurs at the upper elevation of the mudflat and along channel banks and benches. Native cordgrass is also found scattered throughout the next zone in the elevational gradient, the middle tidal marsh zone, or pickleweed (*Salicornia virginica*) marsh plain. *Spartina foliosa's* slender leafy shoots seldom exceed five feet in height including seed heads, with most shoots ranging from approximately one to three feet tall. Cordgrass height correlates with its tolerance of submersion, and as such *S. foliosa* can occupy only a limited range in the lower and middle tidal marsh zones (Cain and Harvey 1983). Its leaves and stems wither in fall and are shed in winter, as the clones die back to the mud substrate.

Spartina foliosa is particularly valued as habitat for the endangered California Ridgway's rail (*Rallus obsoletus obsoletus*), which spends most of its time foraging for food within, or close to, the protective canopy of cordgrass. California Ridgway's rails can move within S*. foliosa* stands, and they spend most of their time under cover of the cordgrass foliar canopy, usually selecting prey items such as benthic and aquatic invertebrates inhabiting the cordgrass stands and their edges. The benthic invertebrate community found in the substrate at the base of *S. foliosa* is also an important food source to a variety of other consumers including both resident and migratory shorebirds.

While it was widely recognized that hybrid *S. alterniflora* (discussed next) could potentially threaten the existence of native *S. foliosa*, control of the hybrids began sufficiently early that *S. foliosa* still anchors thousands of acres of tidal marsh throughout the Estuary. Most of the North Bay was relatively unimpacted by hybrid *S. alterniflora*, and more than 99% of the cordgrass in the remnant marshes throughout the Estuary is still intact *S. foliosa*. However, *S. foliosa* was assimilated into the hybrid swarm, and even locally extirpated, in some of the largest infestations around South San Francisco Bay, including the Alameda Flood Control Channel (Site 1) and Eden Landing (Site 13). These sites are the focus of an extensive reintroduction effort by the Conservancy that began in 2010, to establish stands of *S. foliosa* that will begin to disperse seeds throughout these sites, leveraging the investment in direct planting.

ATLANTIC SMOOTH CORDGRASS (*SPARTINA ALTERNIFLORA*) AND ITS HYBRIDS

Atlantic smooth cordgrass is unique among the world's cordgrass species in terms of its growth potential and ecological breadth. *Spartina alterniflora* is genetically very similar to *S. foliosa*, but the two species have significant differences. In size, growth rate, pollen and seed production, culm (stem) density and ecological tolerances, *S. alterniflora* is more robust than *S. foliosa* (Smart and Barko 1978; Boyer, Callaway et al. 2000). The San Francisco Estuary population of *S. alterniflora* was introduced from seed collected in Maryland in the early-1970s to aid in a dredge spoils stabilization and marsh restoration experiment (Faber 2000). Genetic similarity to *S. foliosa* allowed multiple hybridization and eventual backcrossing events that produced the "hybrid swarm" that has posed the most widespread and intrusive threat to the Estuary (Daehler and Strong 1997). Pollen production, higher fertility, greater tolerance for both inundation and drought, and increased timeframe for flowering make these hybrids a prominent threat to native cordgrass through outcompetition, pollen swamping, and hybrid assimilation (Rhymer and Simberloff 1996; Ayres, Garcia-Rossi et al. 1999; Anttila, King et al. 2000; Levin, Neira et al. 2006).

Hybrid *S. alterniflora* was well established and widely distributed in the Central and South Bay at the start of the ISP Control Program, but has been reduced by 95% bay-wide, down to 38 net acres[1] since its peak of 805 net acres in 2005.

> When stands of *S. foliosa* are displaced by hybrid *S. alterniflora*, not only does the biomass of the benthic invertebrates decline by more than 70%, the benthic community also shifts from surface feeders to belowground feeders that are inaccessible to foraging birds (Levin et. al. 2006).

[1] The ISP uses the terms "net area" and "treatment area" to define the extent of non-native *Spartina*. *Net area* refers to the size of the infestation if the space between stems were subtracted from the overall footprint of the plant or clump of plants. Net area is the metric typically used in botanical surveys. *Treatment area* describes the area that will be directly affected by treatment. Treatment area is a separate measurement used for planning, and it is general 2 to 3 times greater than the net area of given instance of invasive *Spartina*.

CHILEAN CORDGRASS (*SPARTINA DENSIFLORA*) AND ITS HYBRID WITH PACIFIC CORDGRASS (*S. FOLIOSA*)

Chilean cordgrass (also called dense-flowered cordgrass) is a distinctive cordgrass species native to South America that grows as a bunchgrass in the middle marsh plain, eventually forming tussocks and meadows (Spicher and Josselyn 1985; Kittelson and Boyd 1997). *Spartina densiflora* was introduced to California in Humboldt Bay by dry ship ballast containing propagules from South American ports that traded lumber (Spicher and Josselyn 1985). Thought for most of the 20th century to be a form of Pacific cordgrass, *S. densiflora* was deliberately transplanted to a salt marsh restoration project at Creekside Park (4g) along Corte Madera Creek in Marin County in the 1970s. Within the salt marshes fringing Corte Madera Creek, it became a locally-dominant component of the middle and high salt marsh vegetation, displacing even robust pickleweed.

While the bulk of the *S. densiflora* invasion has been contained within Marin around the Corte Madera Creek watershed, other populations have been detected and largely eliminated in Redwood City (19s), Point Pinole Regional Shoreline (Site 10), Burlingame (19k & 19l), Tom's Point (25a) in Tomales Bay, and the shoreline of San Pablo Bay National Wildlife Refuge (26b). Most of the novel population establishments appear to have been the result of active planting by anonymous parties. When established in close proximity to *S. foliosa*, *S. densiflora* has produced infertile hybrids with the native cordgrass that spread solely via vegetative growth (Ayres, Zaremba et al. 2008).

By 2016, the population of *S. densiflora* had been reduced to 24 m^2 Estuary-wide, and 12.5 m^2 of the hybrid between *S. foliosa* and *S. densiflora* remained; both are reductions of more than 95% since the peak years for each. These successful reductions have been achieved through dedicated implementation of an adaptive Integrated Vegetation Management (IVM) strategy that includes multiple treatment methods. Because of the unique biology of this form of *Spartina*, any single-tool approach would have been ineffective. The efficacy of herbicide treatment (using imazapyr) varies widely between large plants and small plants, as well as between pioneering individuals and established stands. The seed bank viability of *S. densiflora* is estimated at 3 to 5 years (as compared to 1 to 1.5 years for *S. alterniflora*), which increases the time required for full eradication, even after an infestation is effectively reduced to just a few individuals. With these additional challenges, it is fortunate that *S. densiflora* appears to be somewhat limited in its ability to disperse around the San Francisco Bay ecosystem, and that the infestation has never approached the scale of hybrid *S. alterniflora*, which both consistently responds well to imazapyr treatment and has shorter seed viability.

ENGLISH CORDGRASS (*SPARTINA ANGLICA*)

English cordgrass is an aggressive invader of mudflats and salt marshes in Britain, New Zealand, Australia, and the Pacific Northwest, and thrives in cool temperate climates. It originated in Britain as a fertile hybrid derived from introduced Atlantic smooth cordgrass and common cordgrass (*S. maritima*). It was introduced to the San Francisco Estuary at Creekside Park (4g) along Corte Madera Creek in Marin

County, along with Chilean cordgrass (*S. densiflora*), in 1976. Unlike Atlantic smooth cordgrass and Chilean cordgrass, this species failed to disperse from its point of introduction to expand the infestation beyond Creekside Park. It may be at or near its southern climatic limit on the Pacific Coast in the Estuary.

Spartina anglica is nearly eradicated from San Francisco Bay, and it is not known to occur in any other location in California. The ISP mapped just 8.3 m^2 of *S. anglica* in 2016. There are several factors that contributed to this infestation lingering longer than might be expected given its relatively small size and presence at only a single ISP site. *Spartina anglica* flowers and sets seed in early summer, slightly later than *S. densiflora* but far ahead of hybrid *S. alterniflora*. This phenology did not allow for treatment ahead of seed dispersal prior to 2008, when ISP was first permitted to enter the sites before California clapper rail breeding season ends on September 1. In addition, there were several other years where either delayed permits (2011 and 2012 Biological Opinions) or political concerns (delays with Marin County finalizing its revised IPM Policy in 2009) caused the implementing ISP partner, Friends of Corte Madera Creek Watershed, to miss the optimal treatment window for that year. Finally, the remaining *S. anglica* at Creekside Park is often found growing as a short understory to the native *S. foliosa* that lines the main channel, which limited the full detection of the target plants, and the desire to preserve as much of the native cordgrass as possible further complicated the matter.

SALT-MEADOW CORDGRASS (*SPARTINA PATENS*)

In its native range on the Atlantic coast, salt-meadow cordgrass is naturally restricted to the well-drained high salt marsh and relatively moist sandy depressions at or above tidal influence. However, in the San Francisco Estuary, it has thrived along channel banks and on the pickleweed plain. *Spartina patens* arrived in the Estuary by the early 1960s in Southampton Marsh (Site 11; Benicia State Recreation Area), as evidenced by a sample present in the California Academy of Science's collection from circa 1962. At the initiation of treatment by ISP and the California Department of Parks and Recreation (State Parks), 0.65 net acre of salt-meadow cordgrass was present in large, discrete patches at Southampton Marsh. In 2014, the net cover was only 75 m^2, and treatment was reinitiated after three years of hiatus due to complications related to the presence of three special status species. In 2016 a total of 35 m^2 of net cover was mapped by ISP biologists.

Spartina patens has spread into an area of Southampton Marsh that supports a population of an endangered annual hemi-parasitic plant, soft bird's-beak (*Chloropyron molle* ssp. *molle,* formerly *Cordylanthus mollis ssp. mollis*). The treatment approach initially approved and used in this area of the marsh was to treat the *S. patens* stands with herbicide in the late fall, after the soft bird's beak had produced seed and senesced, so that the treatment would not negatively affect the soft bird's beak population. However, *S. patens* itself flowers in May at that location, and by the time herbicide was applied in October, the *S. patens* plants had also already produced seed and begun senescing. When a plant senesces it is no longer able to uptake and translocate the herbicide, processes that are necessary to kill the plant. It soon was clear that no additional headway was being made toward eradication of *S. patens*.

In 2011, the ISP worked with rare plant researcher Brenda Grewell (USDA-ARS) and State Parks to develop a new eradication plan to address the shortcomings of the earlier plan. The new plan permits limited, temporary impacts to *C. molle* ssp. *molle e* so that the *S. patens* can be treated effectively, and may include collecting and banking seed from the hemi-parasite to sow once *S. patens* has been eradicated and native host plants reestablished.

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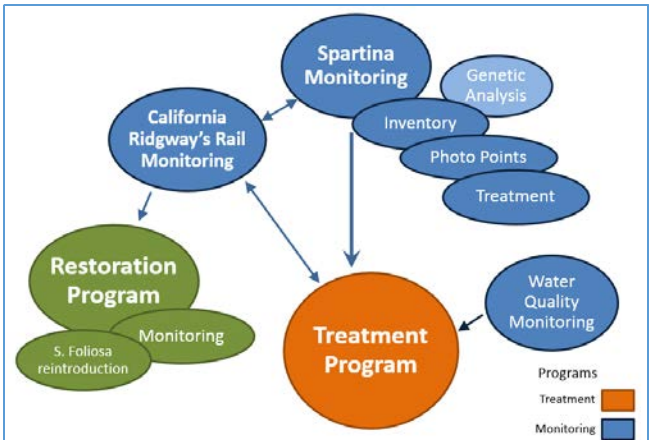
Invasive *Spartina* Project Programs

The ISP is comprised of three broad programs–treatment, monitoring, and restoration, which coordinate closely to achieve the ISP goals. Monitoring is comprised of several programs including *Spartina* inventory monitoring, treatment monitoring, California Ridgway's (formerly "clapper") rail monitoring, and water quality monitoring. Important tools within the monitoring programs are genetic sampling and analysis of *Spartina,* and photo point monitoring. The many programs work together to assure and document an effective regional treatment effort, while protecting water quality, wildlife, and the ecosystem structure. The status of each of the program areas is provided below.



Invasive Spartina Project Programs and Components

TREATMENT PROGRAM

The Treatment Program coordinates a multitude of contractors, agencies, landowners, and staff to plan and conduct annual treatment of the various non-native *Spartina* species found throughout the Estuary. Pilot efforts to test herbicide methods and coordination mechanisms began in 2004, when the total known footprint of non-native *Spartina* was at that time 758 acres. In 2005, the ISP partners began coordinated, Estuary-wide treatment. Treatment initially focused on large infestations and areas where partners were most ready to begin work, and expanded to include the total of sites in 2006 and 2007. Aerial broadcast treatment by helicopter at several of the large hybrid *Spartina* monocultures of the central and south bay soon effectively reversed the spread of hybrid *Spartina* and established control over the infestations. Once continuous meadows of hybrid *Spartina* at sites like Alameda Flood Control Channel (Site 1), Eden Landing Ecological Reserve (Site 13) in Union City, and Seal Slough (19p) in San Mateo, were reduced to a patchy distribution of plants across each site, the herbicide methods were shifted away from broadcast spray to use of amphibious tracked vehicles on the mudflats and marsh plain, and hauling hose from trucks staged on surrounding levees to accessible marshes. Smaller infestations were treated by applicators with backpack sprayers walking through the marsh, as well as by manual removal of isolated seedlings. *Spartina densiflora*, a species that grows in a bunchgrass form and doesn't spread significantly by rhizome, was effectively controlled by a strategic combination of herbicide application and digging (see Chilean Cordgrass description in Appendix 1).

After several years of regionally coordinated control work, the character of the infestations had changed. Very large meadows of non-native *Spartina* were rare, replaced by sparse infestations spread over larger areas that were more difficult to locate and access. New outlier populations were being discovered in more remote areas of the Estuary. By 2008, the ISP began to experiment with utilizing airboats on the open mud to allow treatment during low tide, thus maximizing herbicide dry time. The airboats were also used to deploy personnel with backpacks onto the marsh plain of islands and other sites that were inaccessible by land. By 2009, this approach was employed for treatment throughout Don Edwards San Francisco Bay National Wildlife Refuge (DENWR), and by 2012 there were as many as four airboats on a given day working on hybrid *Spartina* treatment around the Estuary. While the use of airboats in this way is essential for accessing difficult areas at this stage, the vast majority of herbicide treatment is conducted by trained personnel walking through the marsh with backpack herbicide sprayers.

Similarly, there have been shifts in methodology for *S. densiflora* treatment. By 2012, all sites were using manual removal as the primary technique, with only two sites still requiring an early season application of herbicide to stop seed production until digging could be implemented after California Ridgway's rail breeding season. Mowing was also an important technique used early on in combination with other treatment methods at sites with meadows of *S. densiflora*, but the reductions achieved through the successful implementation of the adaptive IPM strategies allowed Friends of Corte Madera Creek to discontinue mowing in 2012. Control methods used in 2016 are listed by sub-area in each of the Reporting Region tables in the accompanying report.

MONITORING PROGRAM

Inventory Monitoring

The ISP began Estuary-wide inventory monitoring of invasive *Spartina* in 2000, with annual monitoring of all known infestation sites beginning in 2004. The original geographic scope of inventory monitoring was limited to the bayward side of most major highways (Hogle 2008). Since 2006, all potential invasive *Spartina* habitat identified within the San Francisco Estuary and tidal tributaries, Bolinas Lagoon, Point Reyes National Seashore, and Tomales Bay has been surveyed by ISP biologists or its partners. This includes annual surveys over 50,000 acres of tidal marsh and mudflat throughout the Estuary and Outer Coast areas. The inventory area is shown in Section 2.1 of the 2014 Monitoring and Treatment Report. While the area inventoried covers some large remnant marshes as well as many fringe marshes, it also includes miles of flood control channels and many small fragmented marshes, channels and drainage ditches in a matrix of highly urbanized land use.

Inventory monitoring is conducted for two purposes: to track change in the extent and net cover of the infestation over time for analyzing and reporting, and to locate and map patches of invasive *Spartina* to inform management and coordination of Treatment Program operations. The ISP typically completes inventory of sites prior to treatment (generally from May through October) to allow for the most efficient use of time and personnel during limited treatment windows. Minimizing time in the marsh during treatment also serves to minimize potential disturbance to marsh plants and animals. Data is collected using global positioning system (GPS) and managed using a Geographic Information System (GIS).

Since 2008, all monitoring has been conducted on the ground or by helicopter for select large and remote sites where large patches of infestation persist. Ground mapping is done mostly on foot, but also by kayak and motorized boats when surveying islands, extensive shorelines, and lengthy waterways. 2012 was the last year that ISP conducted monitoring by helicopter due to its inherent decrease in precision as compared to ground mapping. As of 2013, all sites previously monitored by helicopter have been reduced to a lower status of infestation level and warrant more detailed ground mapping.

A history of the evolution of the ISP Monitoring Program between 2000 and 2012 (Zaremba and Hogle, in progress) is also available on the ISP website (http://www.spartina.org/project.htm).

Genetic Sampling and Analysis

Genetic analysis is a necessary tool for all of the ISP programs. *Spartina* leaf samples are collected and genetically analyzed to distinguish plants with native vs. non-native ancestry. Staff collect leaf samples from *S. foliosa* and hybrid *S. alterniflora* to verify identification of select plants, guide treatment practices, and keep an eye on new or changing plant morphologies. A genetic sampling plan is developed internally each season to address questions posed by the Treatment and Restoration programs and assure efficient use of limited laboratory resources. Samples are shipped to a commercial laboratory for extraction, and then sent to the UCLA Human Genomics Laboratory, where they are analyzed using Simple Sequence Repeats (SSRs; aka "microsatellites") and scored. The laboratory used fifteen SSR loci during the 2018 monitoring season. The ISP analyzes the data from UCLA using the software package Structure (Pritchard Lab, Stanford University) to determine, for every sampled plant, the likelihood of it being descended from *S. alterniflora* ancestry. The ISP incorporates these results into the program's GIS layers for further analysis and for reference in the field during future treatment and inventory events. Over 6,500 plants have been collected and analyzed in this manner since 2010, allowing the identification and treatment of many otherwise morphologically indistinct hybrid *S. alterniflora* plants throughout the Estuary.

More information regarding the genetic sampling program is available in the Monitoring Program Quality Assurance Document (http://www.spartina.org/project_documents/QAD_2009_Update_All.pdf) and the ISP *Spartina* Monitoring Program Approach report referenced above.

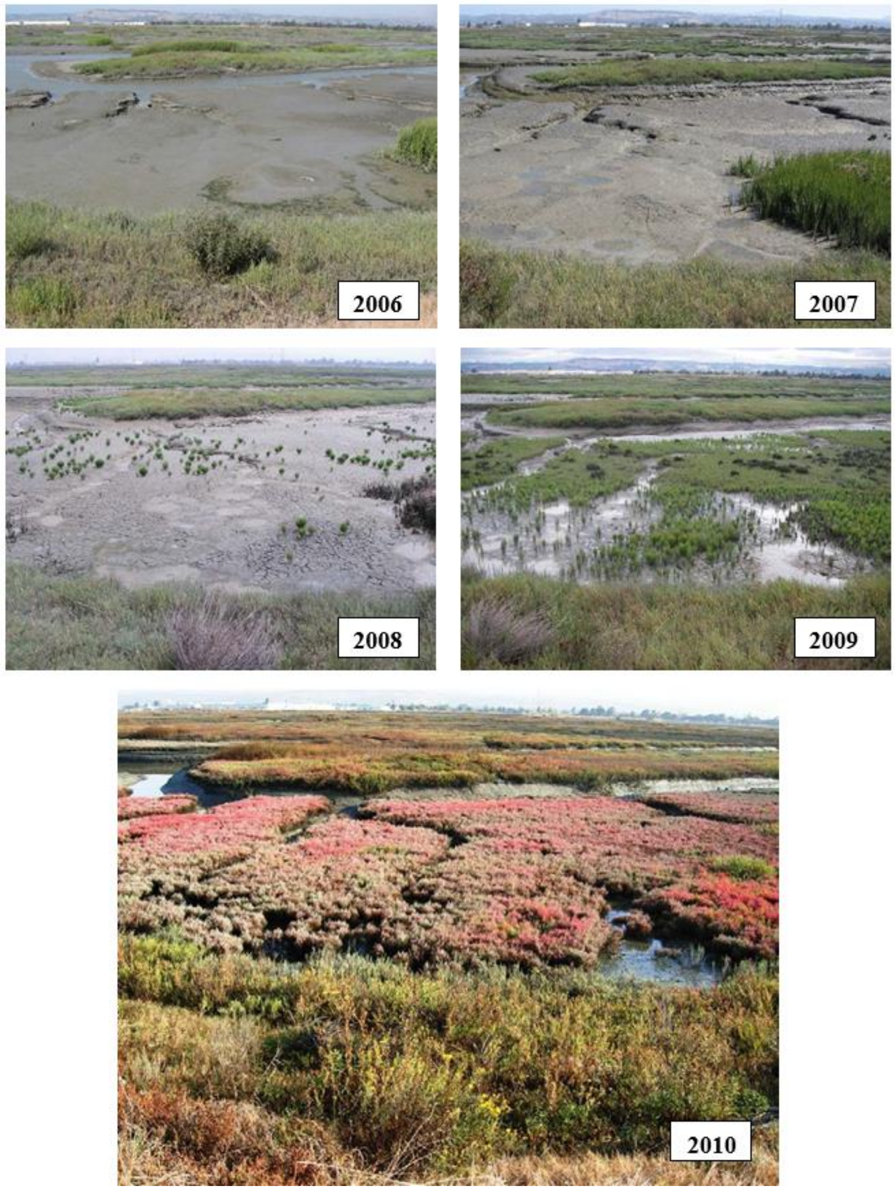
Photo Point Monitoring

Another tool used by the Treatment and Monitoring Programs is photo point monitoring. The ISP established and has maintained 93 permanent locations within 51 sub-areas from which staff take consistent photos twice annually to qualitatively monitor marsh changes between seasons and years. Photo points are used to inform the extent of the next treatment effort and to visually document the changes in vegetation occurring at the sites. Visible changes often include rapid disappearance of large areas of non-native *Spartina* within one to three seasons of treatment, passive (and frequently rapid) establishment of native vegetation, and expansion or "rebounding" of hybrid *Spartina* populations when treatment is missed or restricted for one or more seasons.

The intra- and inter-annual visual comparisons of marsh composition are useful to the ISP for monitoring treatment efficacy and for presenting local trends to outside parties. These photos are especially useful to illustrate different marsh trajectories when comparing sites with continuous full treatment with those where treatment was absent or incomplete, as has happened since 2011 in 11 sub-areas a result of permit restrictions. An example of photo point data is provided on the **next page.** Also, all ISP Photo Point photos are available on the web, through Google Maps and Picasa Web Albums, at http://maps.google.com/maps/ms?ie=UTF8&hl=en&msa=0&msid=212795091225976478689.00049ce382daadf691d97&t=h&z=10.

Treatment Monitoring

The ISP began monitoring all treatment events in 2009. Treatment monitoring involves pairing ISP personnel with the agency or private contractor treatment crews to accomplish the following important objectives: (1) assure protection of California Ridgway's rails and other sensitive species during treatment activities; (2) enhance conservation of native *S. foliosa* that may be present by delimiting it in no-treatment areas for the crew; (3) substantially improve the ability for crews to locate and target plants for treatment by leading them to less obvious plants requiring treatment; and (4) document completed treatment in real time at the patch level. As previously mapped *Spartina* locations are revisited, ISP staff update the map features using GPS data loggers to reflect the day's treatment action (e.g. "treated," "not treated," "sub-optimally treated" etc.). This data is uploaded daily to the ISP's ArcGIS geodatabase for use in the field the next day. Accompanying treatment crews also allows ISP staff to identify, mapping, and concurrently record treatment of patches of invasive *Spartina* that had not been detected during initial inventory monitoring. Treatment monitoring is perhaps the most important of the ISP's new programmatic initiatives, allowing ISP partners to gain ground on the remaining substantial infestations in the West Bay, and greatly accelerating the rate at which eradication may be achieved at all sites.



An example of photo point monitoring data showing habitat transition over several years.

Since the timing of inventory and treatment overlap from mid-July through November, the ISP hires additional seasonal staff to conduct treatment monitoring at suitable sites – that is, at sites where native *Spartina* is not present, where hybrid *Spartina* has been recently mapped by more experienced staff, or where native and hybrid morphologies are sufficiently distinct to allow the interns to make consistently correct determinations. More experienced biologists are thus reserved to inventory and monitor treatment at more complex sites.

California Ridgway's Rail Monitoring

Implementation of *Spartina* control measures requires annual breeding season surveys of the endangered California Ridgway's rail (*Rallus obsoletus obsoletus*) in marshes affected by the invasion and management of non-native *Spartina*. Annual breeding season surveys provide a standardized measure of Ridgway's rail presence and distribution in marshes throughout the Estuary. This information guides the

ISP in the planning, permitting, and implementation of treatment strategies and helps to minimize the impacts of *Spartina* control on rail populations. Results from California Ridgway's rail surveys help determine the time of year in which ISP monitoring staff and treatment contractors will enter a site so as to not disturb birds present during their breeding season, and are used by USFWS and others for making decisions regarding the ISP program.

Water Quality Monitoring

The application of herbicide for *Spartina* control is covered under the Statewide General National Pollutant Discharge Elimination System (NPDES) Permit for Application of Aquatic Pesticides for Aquatic Weed Control in Waters of the United States (General Permit No. CAG990005; www.swrcb.ca.gov/water_issues/programs/npdes/docs/aquatic/permit.pdf). To obtain coverage under this permit, each grantee or other ISP partner that will be applying herbicide must submit a Notice of Intent (NOI) to comply with the terms of the General Permit and an annual fee to the Regional Water Quality Control Board (RWQCB). The permit requires preparation of an Aquatic Pesticide Application Plan (APAP) that includes a Water Quality Monitoring Plan (WQMP), which must be updated annually as needed. The ISP arranged with the State Water Resources Control Board and the San Francisco Bay RWQCB to allow the ISP to prepare and implement a programmatic APAP and WQMP on behalf of the ISP partners who submitted NOIs. The ISP prepared a programmatic APAP in 2006 and updated it in 2015, which is available on the ISP website at http://www.spartina.org/documents/2015_ISP_APAP_wAppendices.pdf.

As with many substances, there are no State or Federal numeric water quality objectives or limits established for imazapyr herbicide; therefore, concentrations are compared to tested toxicity and effects levels found in the literature. In 2013, concentrations of imazapyr herbicide measured immediately following treatment events were two to four orders of magnitude below those reported in the literature as a concern to humans or the animals that inhabit the tidal marsh ecosystem. Imazapyr is not persistent in the aquatic environment because it is rapidly degraded by sunlight; thus, as expected, the one-week post-treatment samples with any residual herbicide detected showed a mean reduction of 91.4% of the treatment event levels. Details regarding sampling and analysis methods and the monitoring results are provided in the 2017 Water Quality Monitoring Report (Kerr 2013).

The ISP commissioned a focused review of imazapyr herbicide in 2005, prior to adopting it into the Treatment Program. The review, *The use of Imazapyr Herbicide to Control Invasive Cordgrass (Spartina spp.) in the San Francisco Estuary: Water Quality, Biological Resources, and Human Health and Safety (Leson & Associates 2005)*, is on the ISP website at www.spartina.org/project_documents. The Conservancy's findings under CEQA may be found at www.spartina.org/2005Addendum.htm.

RESTORATION PROGRAM

The Restoration Program was initiated in 2011 to rapidly establish habitat features to benefit California Ridgway's rails in areas where recent removal of non-native *Spartina* has caused decreases in Ridgway's rail habitat. The plan for the program is contained in the California Clapper Rail Habitat Enhancement, Restoration and Monitoring Plan (Olofson Environmental, Inc. 2012). As part of the plan, the Conservancy and other regional ISP partners are employing several habitat enhancement methods including construction of high tide refuge islands, deployment of artificial floating nesting islands, and extensive revegetation, focusing on native tidal marsh plant species that provide foraging, breeding, and high tide refuge cover.

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