South Bay Salt Pond Restoration Project

Restoring the Wild Heart of the South Bay

Habitat Evolution Mapping Project

Decadal Update

2019 & 2021

Final Report

October 26th, 2022

BRIAN FULFROST & ASSOCIATES

Habitat Evolution Mapping Project

Decadal Update (2019 & 2021)

Final Report

South Bay Salt Pond Restoration Project

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Executive Summary

This report details and summarizes the final results of the decadal update (2019 and 2021) to the original Habitat Evolution Mapping Project (HEMP). HEMP mapped the marshes and mudflats south of the San Mateo bridge yearly between 2009 and 2011. This update ("HEMP2") to that project, is a two-year project designed to understand the current status of these habitats, and to map and quantify the changes over the last decade. The goals of the update are to better inform the South Bay Salt Pond Restoration Project (SBSP), and its partners and stakeholders, about the status of marsh and mudflat habitats within the study area and assess changes to these habitats since the first study a decade ago.

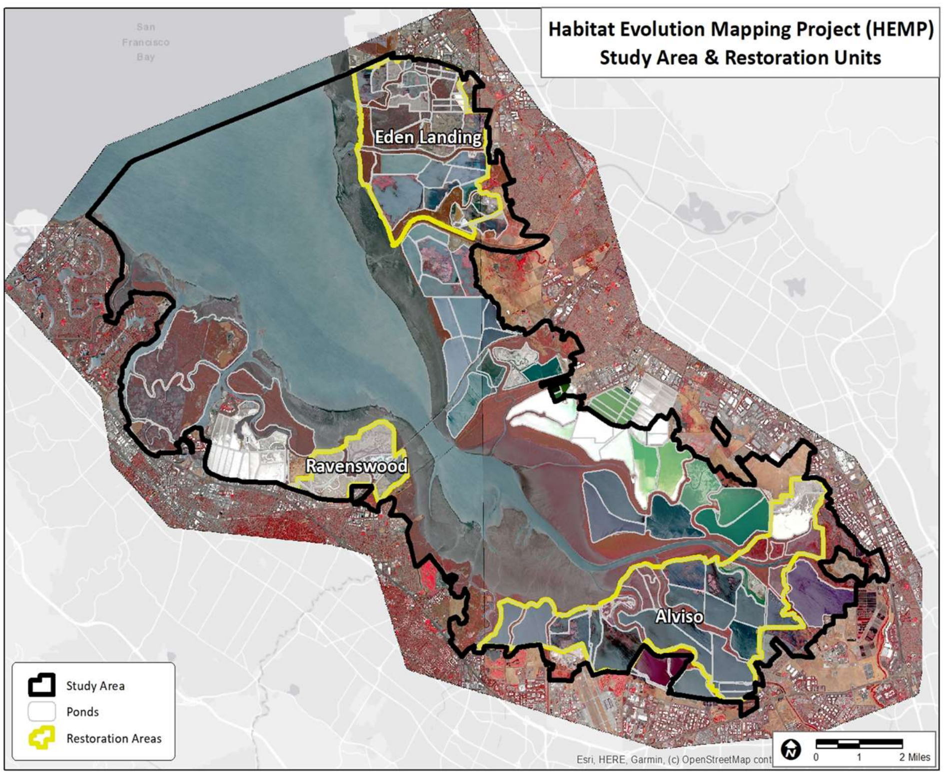
Habitat datasets produced from the HEMP2 study and presented in this report provide the SBSP Project Management Team (PMT) and its partners an important resource for quantifying and visualizing the distribution and extent of tidally influenced salt, brackish and freshwater marshes, as well as tidal mudflats, within the study area (see Map 1). In combination with the results from the first phase of HEMP (Fulfrost, B., Thomson, D., 2012), the datasets also allow the PMT and its partners and stakeholders to better understand how tidal marshes have evolved over the last decade (2009-2019). We cannot assess changes to mudflats for this same period since we were unable to use the mudflat data from the previous report as a good baseline. However, we now have mudflat distribution and extent from 2016 (Fulfrost, B., 2017), and have applied these same methods to the 2019 imagery.

This final report summarizes both the recent results produced from HEMP2 (2019 and 2021) and provides a high-level change analysis with the original HEMP1 study (2009-2011). Both sections provide acreage summaries (in tables, figures, and maps) for each year at various geographic scales (study area, restoration unit, and restored pond) and a brief discussion of changes to the relevant habitats.

Since 2009, there has been an overall increase in both salt and brackish marsh throughout the study area (see Table 30 and Figure 27). There was a 20% increase (95 acres) in Alkali Bulrush between 2009 and 2021, though the acreages have fluctuated and appear to be cyclical. Despite acreage fluctuations for some habitats between years, the marshes and mudflat south of the San Mateo bridge appear relatively "stable" between 2009 – 2021, in that the relative proportions between different habitat types have not changed significantly. Some notable exceptions are detailed in this report.

Salt marsh species (low, mid, and high combined) grew by a modest 3% between 2009 and 2021. However, the amount of growth varied between low, mid, and high marsh. The acreage of low salt marsh species (Cordgrass and Cordgrass /- Pickleweed) more than doubled (from 444 to 904 acres) and has trended up, despite a small relative decrease in 2021. The total acreage of Pickleweed has remained nearly identical between 2009 and 2021 (7355 to 7315 acres). At the same time, Pickleweed has increased significantly within restored ponds and restoration units. For example, there was a 35% increase in Pickleweed within Alviso and a 32% increase within Eden Landing during this same time period. High salt marsh species (Pickleweed /- Gumplant and Alkali Heath) in 2019/2021 are +/- 10% of the acreages from 2009. The acreages of Gumplant are identical for both 2009 and 2021 (179) while Alkali Heath dropped 18% (from 238 to 193 acres). This resulted in a 10% overall decrease in the acreage of high marsh species (from 435 to 390 acres) between 2009 and 2021. However, in 2019 there were 479 acres of high marsh species, indicating a 10% increase between 2009 and 2019.

Within many restored ponds (e.g., A21, A20, E8A, North Creek Marsh), there has been significant growth in salt (or brackish) marsh vegetation when compared to the entire study area. At the same time, some restored ponds, many which were opened to tidal action after 2011, had much less relative growth than other ponds (most notably E9, A6, A17, and Outer Bair) between the time period of the two studies. While the most significant floral colonization and growth of vegetation in many of the restored ponds occurred over the eight years between the end of HEMP1 (2011) and the beginning of HEMP2 (2019), the rate of vegetative growth within many restored ponds increased over the two years between 2019 and 2021*, suggesting that areas of these ponds may have reached an elevation conducive to vegetation establishment*. However, we cannot say whether the increased rate of floral colonization will continue or if it represents an interannual spike in growth. There is also ongoing evidence of continued marsh expansion outside of restored ponds, including Calavares Marsh, the fringe marsh above pond A6, and Ogilvie Island. However, there is also evidence of marsh erosion in some locations, including up to 50 meters feet at Whales Tail and 10 meters at the mouth of Ravenswood Slough.



Map 1: Habitat Evolution Mapping Project - Study Area

Overall, the tidal mudflats directly facing the bay (i.e., not within ponds or sloughs) south of the San Mateo appear to be relatively unchanged from 2016. Although mudflats decreased by 5% between 2016 and 2019 (18,435 to 17,542 acres), they have a similar extent and distribution, and appear to be accreting more than eroding. The contour of MLLW provided by the USGS from 2005 (Jaffee, B. & Foxgrover, A., 2006), also shows a general spatial correspondence with the current (2019) extent. Although tidal mudflats directly exposed to the bay remain relatively unchanged since 2016, there are some locations with evidence of accretion and/or erosion. There is also a decrease in the acreage of mudflats within many restored ponds due to floral colonization. In fact, 617 acres of mudflats were colonized by Pickleweed, Cordgrass, Cordgrass/-Pickleweed, or Alkali Bulrush between 2019 and 2021.

The acreage of Pepperweed dropped by 86% between 2009 and 2021 (see Table 30). Although we have concluded that some of this reduction of Pepperweed might be mapping as other classes (Ruderal or

Spearscale), it cannot alone account for the degree of change. Pepperweed density appears to be significantly less in 2021 than it was in 2009. During this same period, the acres of Spearscale have nearly quadrupled (from 57 to 211 acres).

The trends in habitat acreages and distributions vary at different geographic (and temporal) scales. As a result, the trend for a specific habitat at the study area wide scale might not be the same degree or direction of trend as a given restoration unit or restored pond (or marsh). For example, acreage differences between 2021 and 2019 might be indicative of interannual changes and not necessarily longer temporal trends. Decreases in a number of habitat types at the study area or restoration unit scale over the two-year period of the study can mask the longer-term trends of growth over the 12 years between the two studies. When doing this comparison, we contextualized the change over time in acreage of a given habitat by looking at a single year as part of a time series of all years. For all habitats (except mudflats) there are yearly 'snapshots' for five years over a twelve-year period (2009-2021). Due to tidal differences at the time image acquisition, the data only include two yearly snapshots for mudflats for the entire study area: 2016 (Fulfrost, B., 2017) and 2019.

There also can be correlative environmental, climatic, and anthropogenic factors influencing biotic and abiotic distributions that are not accounted for in this study. These Include but are not limited to temperature, precipitation, tidal changes, sediment accretion/erosion, soil and water salinity, and the restoration itself. We encourage the use of these datasets to inform other studies and help elucidate any role these factors might have in vegetation/habitat distributions, the evolution of marshes in the south bay, and the important role they play in habitat for obligate fauna.




Section 1. Habitat Types

We mapped 19 unique habitat types (see Table 1), including twelve tidal marsh vegetation types at both the a*lliance* and a*ssociation* scale. These are the various biotic (e.g., "Pickleweed") and abiotic (e.g., "mud") land cover classes that are mapped as part of the project. The 12 tidal marsh habitat classes include: 7 salt marsh, 3 brackish, and 2 freshwater vegetation specific habitat types. There are 2 additional 'upland' classes (Pepperweed and Ruderal) and 5 abiotic classes (mudflat, mudflat w/ biofilm, bare earth, wrack, and water). Descriptions for each habitat type are included in Appendix 1.

Within the context of this report, "habitats" refer to the mapped classes of vegetation alliances (or associations), tidal mudflats, and other abiotic classifications (e.g., bare earth). Our vegetation classifications are based on rules of dominance, co-dominance, and sub-dominance, that follow the same set of guidelines found in the Manual of California Vegetation (Sawyer, J.O., T. Keeler-Wolf, and J. M. Evens. 2009). Although these vegetation classifications are useful unto themselves, they are also primarily used as proxies for estuarine habitats. These habitats include salt marsh (low, "mid" high, and high), brackish marsh, freshwater marsh, and tidal mudflats. We continue to use common names for these habitats as they are the most inclusive and the most easily understood and avoid any issues differentiating localized differences in species (e.g., *Schoenoplectus californicus* vs *Schoenoplectus acutus*) as well as any difference between endemic or invasive hybrids (e.g., *Spartina foliosa* vs *Spartina alterniflora*).

There is a single classification for Pickleweed (this can include *Sarcocornia pacifica* or *Salicornia europaea*). We did not map *Sarcocornia pacifica* separately from *Salicornia europaea* separately from each other since we had difficulty distinguishing these sperate species in HEMP1. However, in our Cordgrass /- Pickleweed classification, which represent low (to mid marsh transition), it is more likely that the Pickleweed contains at least some *Salicornia europaea*. At the same time, our Pickleweed classification is more likely to contain *Sarcocornia pacifica* (see Appendix 1). The spectral similarity of Gumplant with other habitats (e.g., Alkali Bulrush), as well as its distribution pattern (often along channels), combine to make it difficult to differentiate it from surrounding vegetation. It is for this reason we map "Gumplant" as an association of Pickleweed. Along with Gumplant, Alkali Heath (Frankenia salina) is often an important indicator of high marsh.

Table 1: Habitat Classifications

Habitat Type		Alliance	Mapped Habitats (19) [Alliance /- Association]
Salt Marsh (7)	Salt Marsh – low (MTL-MHW)	Cordgrass	**Cordgrass**
			Cordgrass /- Pickleweed
	Salt Marsh – "mid" (MHW-MHHW)	Pickleweed	**Pickleweed**
			Saltgrass
			Pickleweed /- Jaumea
	Salt Marsh – high (MHHW)	Alkali Heath	**Alkali Heath**
		Pickleweed /- Gumplant	**Pickleweed /- Gumplant**
Brackish Marsh (3)		Alkali Bulrush	**Alkali Bulrush**
		Spearscale	**Spearscale**
		*Pepperweed**	***Pepperweed****
Freshwater Marsh (2)		Freshwater Bulrush	**Freshwater Bulrush**
		Cattails	**Cattails**
Upland (2)		Alkali Grasses	**Alkali Grasses**
		Ruderal	**Ruderal**
Non-Vegetated (5)		Mudflat	**Mudflat**
			Mudflat with Biofilm
		Wrack	**Wrack**
		Bare Earth	**Bare Earth**
		Water	**Water**

**Pepperweed was not included in the 'Brackish Marsh' habitat category when acreages were calculated.*

We used the same habitat classifications mapped in the first phase of the project (2009-2011), with some exceptions. In 2019 and 2021, we mapped *mostly* at the vegetation alliance level. One conclusion from the first HEMP study (09-11), was that we achieved our best results at the vegetation alliance level. Although we collected detailed ground truthing data down to individual plant species (and even assigned these locations vegetation associations), we mapped habitats mostly at the alliance level since the accuracy of many habitat associations (e.g., Alkali Bulrush /- Pickleweed) between 2009 and 2011 were below acceptable levels. This is not true for all habitats. Habitat associations (e.g., Pickleweed /- Gumplant) that were essential for differentiating low, "mid", and high salt marsh were included in both studies. For detailed descriptions of each habitat classification see Appendix 1.

Section 2. Results (2019 and 2021)

We have reviewed, quantified, and summarized the final results at three main geographic scales in order to make them easier to interpret. These geographic scales include study area wide, South Bay Salt Pond Restoration Project restoration unit (Alviso, Eden Landing, and Ravenswood), and either by restored pond (e.g., A6) or 'select' marsh (e.g., Faber/Laumeister). This section presents results from 2019 and 2021. An additional section (see below) presents a high-level change analysis comparing HEMP2 (2019 &2021) with HEMP1 (2009-2011).

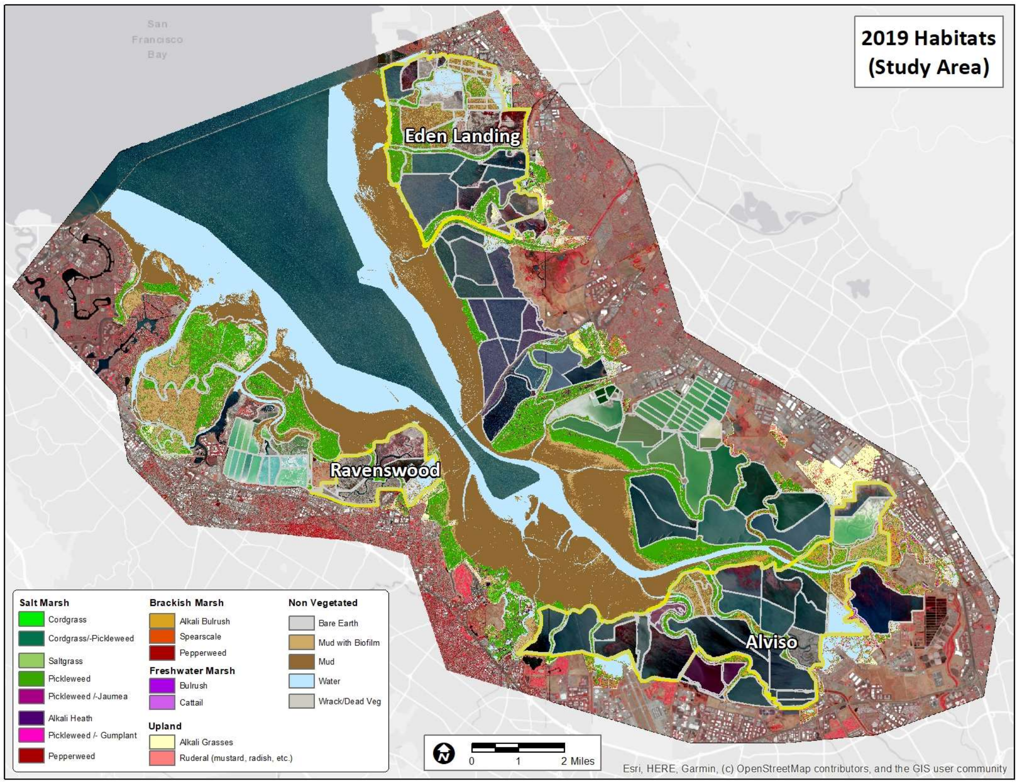
This report also summarizes acreages by both mapped habitat classification (see Table 3) as well as by habitat type (e.g. salt marsh, brackish marsh, and freshwater marsh - see Table 2 and Figure 1). The 'salt marsh' category has also been further subdivided into low, "mid" marsh, and high marsh (see Table 1). The results of our accuracy assessment demonstrate that the overall accuracy of all mapped habitats is very high for both years at the vegetation alliance level (2021: 84%; 2019: 85%) and still very good at the vegetation association level (2021: 78%; 2019: 80%).

Overall, despite fluctuations between years and across habitat type, mapped vegetation communities within tidal marshes have remained relatively stable, especially within fringe marshes along sloughs and marshes that already are well established. In order to better understand changes between years and the distribution of these changes, we calculated "difference" rasters between 2019 and 2021 for specific habitats. These rasters included the distribution of one habitat (e.g., Mudflat) for a given year (e.g., 2019) and then populate those cells with the habitat classes for another year (e.g., Pickleweed in 2021). These 'difference' rasters were essential in identifying and quantifying the floral colonization of mudflats and for understanding other habitat changes between years.

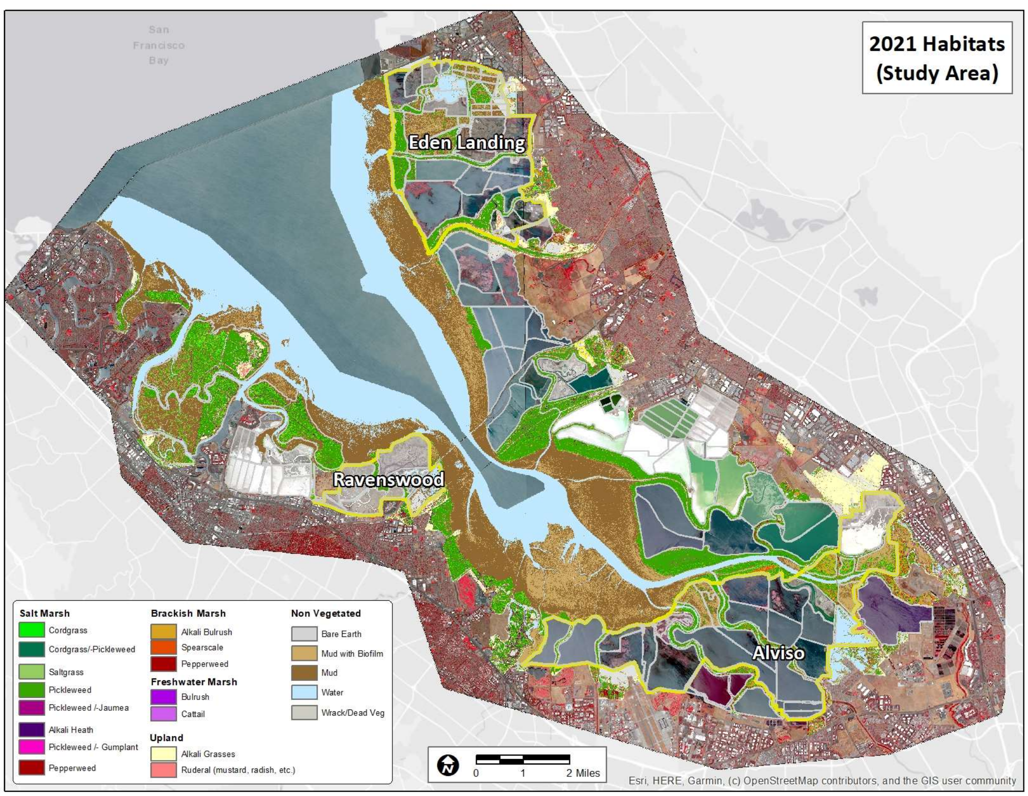
Notes for Interpreting Tables and Figures

The reader should be aware that changes in acreage of mapped habitats from year to year could result from a number of factors that are not necessarily changes to the distribution, extent, or total acreage of habitats. This can include (but is not limited to): phenological differences (and their impact on plant distribution), precipitation levels, differences in amount and patterning of dead vegetation, as well as difference in tide level.

We did not include water or mudflats in when comparing our acreage totals for the entire study area since the mudflats and related water levels in 2009-2011 were taken at various tidal levels. This also accounts for the differences in total acreages for each year (see Table 2 and Figure 1). Differences in acreages of water (and to a lesser degree mudflats) for the SBSP restoration units over time are at least partially due to these differences in tidal levels at the time of satellite overpass.



Map 2: Habitat Map (2019)



Map 3: Habitat Map (2021)

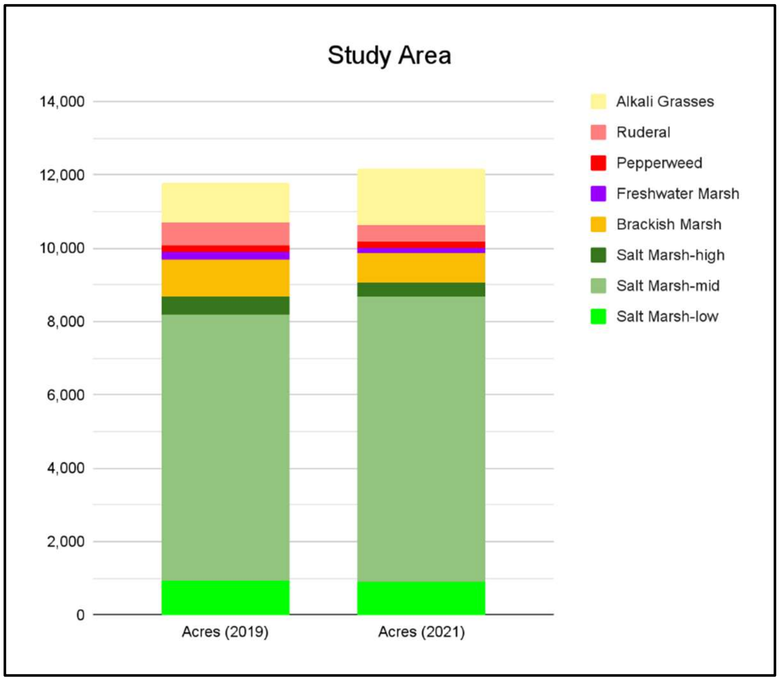


Figure 1: Acreage by Habitat Type for Study Area (2019 & 2021)

Table 2: Acreage by Habitat Type for Study Area (2019 & 2021)

Study Area			
Habitat Type		Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	926	903
	Salt Marsh-mid	7,277	7,785
	Salt Marsh-high	479	390
	Brackish Marsh	1,009	789
	Freshwater Marsh	206	146
	Pepperweed	194	153
	Ruderal	608	468
	Alkali Grasses	1,092	1,540
	Biotic total	**11,792**	**12,174**
abiotic habitats	Mudflat	17,542	16,014
	Wrack (or dead veg)	775	37
	Bare Earth	1,032	1,863
	Water	11,417	12,478
	Abiotic total	**30,766**	**30,393**
	Grand Total	**42,557**	**42,567**

2.1 Study Area

Salt Marsh

Overall, there was a 7% increase in mid salt marsh (Pickleweed, Jaumea, and Saltgrass) between 2019 and 2021 (see Figure 1 and Table 2). There were approximately 617 acres of salt marsh species (Pickleweed, Cordgrass, and Cordgrass/-Pickleweed) that directly colonized mudflats between 2019 and 2021. Eighty-nine percent (550 acres) of this floral colonization happened within restored ponds and marshes. The vast majority (508 acres) of mudflats were colonized by Pickleweed in 2021 and an additional 109 acres colonized by Cordgrass (or Cordgrass /-Pickleweed). Around 26 acres of Alkali Bulrush also colonized what were mudflats in 2019. These four vegetation classes account for a 643 acres reduction in mudflat alone between 2019 and 2021. There were also about 60 acres of mudflats in the bay or sloughs that were colonized by the same salt marsh vegetation classes. This includes the mudflat on the southside of Calavares marsh, the mudflat above Pond A6, and the mudflat on the east side of Ogilvie Island (see Figures 38, 44, and 46).

There was also a 2% decrease in low salt marsh (Cordgrass and Cordgrass/-Pickleweed), which is small enough to be either interannual variability, phenological difference between years, and/or expected differences in mapped distributions between years.

There was a notable decline in Gumplant (43%) between the two years (from 349 to 197 acres) with a coincident 37% increase in Alkali Heath, resulting in a 18% net decrease of high salt marsh (see Table 3). Although this appears to be a significant reduction, there is also evidence (from out accuracy assessment and extensive QA), that the distribution and extent of Gumplant in 2021 might be a better estimate than 2019, where there is evidence of overmapping within the mid salt marsh. When looking at this decrease in context of all mapped years (see Table 31), the acreage of Gumplant is the same for 2009 and 2021 (179 acres) but also similar for 2010 (279) and 2019 (249) with acreages for 2011 likely anomalous. It is possible these similarities reflect some cyclical trend in the florescence and the mapped distribution of Gumplant, rather than a long-term reduction.

Table 3: Acreage by Mapped Habitat for Study Area (2019 & 2021)

Study Area		
Mapped Habitat	**Acres (2019)**	**Acres (2021)**
Alkali Bulrush	792	568
Alkali Grasses	1,092	1,540
Alkali Heath	130	193
Bare Earth	1,032	1,863
Freshwater Bulrush	102	15
Cattails	104	131
Cordgrass	595	534
Cordgrass/-Pickleweed	331	369
Mudflat without Biofilm	14,656	11,187
Mudflat with Biofilm	2,886	4,828
Pepperweed	194	153
Pickleweed	6,963	7,315
Pickleweed /- Gumplant	349	197
Pickleweed /- Jaumea	201	185
Ruderal	608	468
Saltgrass	113	285
Spearscale	216	221
Water	11,417	12,478
Wrack	775	37
Upland	29	20
Grand Total	**42,587**	**42,587**

Gumplant acreages (197 acres) from 2021 over the entire study area are likely a better estimate of its extent and distribution than 2019, since the extent and distribution of Gumplant (along channels and in elevated locations) appears to be less accurate than in 2019, although this is not true in all locations (e.g., Faber/Laumeister). In 2021, our accuracy assessment indicates Gumplant is mapping very well (80% producer's accuracy; 100% user's accuracy). Our extensive iterative QA process provided some qualitative confirmation of this, especially the significant reduction of mis mapping Gumplant within the mid marsh plain in 2019 and the improvement in mapping Gumplant along channels (in 2021) where it was not (and should have been) mapping in 2019. After careful review of both years, we believe that we are overmapping Gumplant within the mid marsh plain at various locations in 2019. This appears to be happening throughout the study area, including (but not limited to) in parts of La Riviere marsh and Newark slough, within Mowry marsh/slough, and parts of Alameda Flood Control Channel (AFCC).

Brackish Marsh

There was a 28% decrease (224 acres) in Alkali Bulrush between 2019 and 2021 (see Table 2). Although this appears to be a large reduction in brackish marsh within the study area, at least some proportion of the reduction can likely be attributed to both phenological and tidal differences at time of satellite flyover. Even though it is a perennial, Alkali Bulrush appeared to be dead or senescing (actual decomposition - see Kantrud, Harold A., 1996) in many locations we visited in the field around the time of image acquisition in

June 2021. According to Kantrud (1996, p. 15.), *Scirpus Maritimus* decomposes up to 85% while *Scirpus Robustus* does not. The 'Alkali Bulrush' classification does *not* distinguish between these two species, but one can assume that locations where Alkali Bulrush was "senescing" in 2021 are *Scirpus Maritimus*. In addition, all mapped marshes in 2021 had only received one third (~5 inches) of the rainfall that had fallen when compared to the time of satellite acquisition in 2019 (~16 inches). This reduction in rainfall could be correlated to the reduction in acreages in Alkali Bulrush and possibly contributed to the much larger fluorescence (and larger acreage) captured in 2019. At the same time, our accuracy assessment (67% User's Accuracy) for 2021 indicates that we might be *overmapping* Alkali Bulrush although our ground truthing and expert QA would indicate otherwise. (Note: The Producer's Accuracy for Alkali Bulrush is much higher at 95% indicating that when surveying in the field at a location of Alkali Bulrush it is almost certainly going to be accurately mapped as Alkali Bulrush). As a result, we have concluded that there was certainly a decrease in the acreage of Alkali Bulrush between 2019 and 2021, but only time will tell if this represents 'normal' interannual differences related to season, precipitation, or other environmental factors rather than a longer-term trend. If we set aside the acreage of Alkali Bulrush from 2019 (792), the acreages from 2021 (568) are greater than all other years (2009-11) and represent a 20% increase since 2009. This means that between the time of first study (2009-2011) and the second study (2019-2021), there is still a trend toward growth in Brackish marsh.

Variation in alkali bulrush decomposition between years likely contributed to the decrease in Alkali Bulrush acreages. This variation likely also led to a corresponding increase in pickleweed mapping in 2021 in areas where these habitats are mixed (see Figure 2), especially within and around the Alviso Restoration unit. In fact, at approximately 50% of the locations where Alkali Bulrush were no longer mapping, these locations were mapped as Pickleweed in 2021. An additional 11% mapped as Spearscale in 2021.

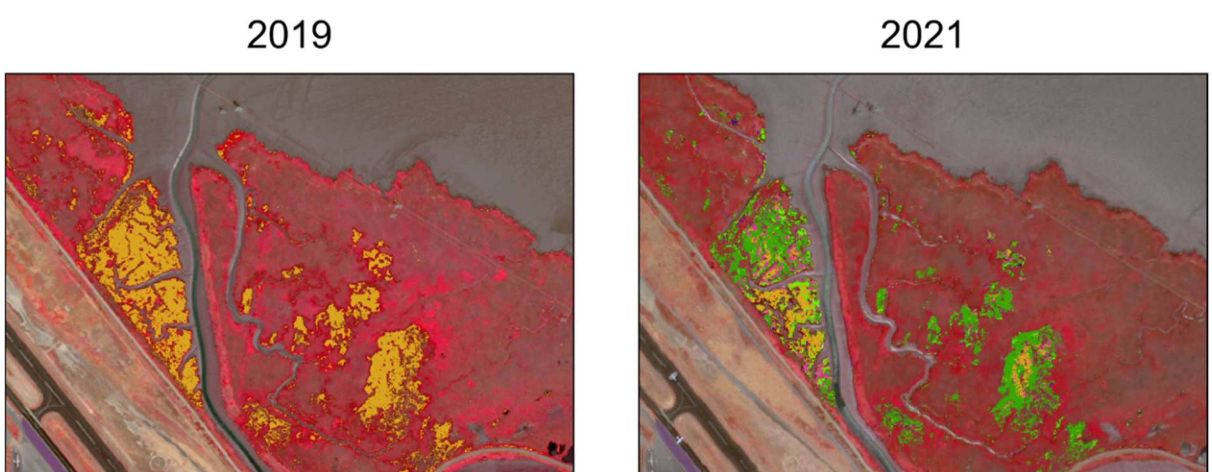


Figure 2: Example of Alkali bulrush (orange) phenological variation between 2019 and 2021 in Palo Alto Baylands which led to mapped habitat differences with pickleweed (green). These differences were verified in multiple locations in the field.

Freshwater Marsh

There was a 29% reduction in Freshwater Marsh habitats between 2021 and 2019 (see Table 2). At least a part of this decrease is likely due to the significant drop in precipitation by the day of image acquisition between years (from 16.43 in 2019 to 5.32 in 2021). The Freshwater Bulrush habitat class dropped to 15 acres in 2021 from 102 acres in 2019. Although there has been a general trend towards decreasing acreages of Freshwater Bulrush over the five years of the two mapping projects (excluding 2010), we have still concluded (based on the accuracy assessment and our review of ground truthing photos and surveys) that Freshwater Bulrush is significantly undermapping in 2021 as either Cattails or Alkali Bulrush. At the same time, there was 26% increase in Cattails between 2019 and 2021. Although this reflects a longer-term trend since 2009 of increasing acreages of Cattails (see Table 3), it is likely that this increase includes mis mapped Freshwater Bulrush.

Pepperweed

Between 2019 and 2021, there was a 21% decrease in Pepperweed over the entire study area. We provide a more detailed discussion of Pepperweed in the change analysis section below where we compare the results with HEMP1 (2009-11).

Alkali Grasses

There was a 41% increase (448 acres) in Alkali Grasses between 2019 and 2021. More than half of these acres of alkali grasses (304) mapped as other habitats in 2019 were found in five specific locations. These locations include: an upland area just east of the muted part of Mt Eden Marsh, Warm Springs, the upland portion of Outer Bair, the southwestern part of lagoon in the Palo Alto Baylands, and the upland part of the Don Edwards HQ. The vast majority of these locations were mapping as either wrack/dead vegetation or ruderal in 2019.

Abiotic

The graphs included in the report only display biotic classes. We have done this, so it is easier to see the trends over time in the biotic (i.e., vegetative) classes. The abiotic classes can vary greatly from year to year, depending on a range of factors, including tide, precipitation, phenology, and other environmental conditions, and when added to the graphs, can obscure important trends to highlight. For restored ponds, increases in biotic classes often are correlated with decrease in mudflats. We have included acreages for all abiotic classes in our mapped class and habitat type tables.

This report highlights the acreages and changes in mudflats within the various sections listed below by different management units (e.g., Alviso Restoration Unit, Pond A6, etc.). Depending on the area being compared, the mudflat acreages are not always comparable to other years (e.g., study area wide mudflats acres for 2021); however, other units (restored ponds and restoration units) can be compared, although they can have varying amounts of water based on tidal levels for that year. The Mudflat section (see below) quantities acreages and changes for relevant years (2016 and 2019) over time for the entire study area.

We have included a brief discussion here of the other abiotic classes (bare earth, wrack/dead vegetation, and water) to clarify differences in acreage numbers between years. Both Bare Earth and Wrack/Dead-Vegetation can map from one class to the other depending on conditions at the time of image acquisition. These two abiotic classes can also map as Alkali Grasses, or in some cases even Ruderal, depending on environmental conditions including precipitation. As a result, big changes in numbers of these three abiotic classes (bare earth, wrack, and water) and these two biotic classes (alkali grasses and to a lesser degree ruderal), are not necessarily meaningful. We have included a brief discussion here to clarify these changes.

Bare Earth

There was an 81% increase (831 acres) in bare earth between 2019 and 2021. Around 364 acres (41% of the increase) of bare earth mapped in 2021 had been water in 2019. A large proportion of this is actual conversion (or differences related to tide gauges) of ponds within the study area, including 134 acres in ponds south of A2E. An additional 264 acres (32% of the increase) are locations in Foster City by the shoreline that mapped as Wrack/Dead-Vegetation in 2019. The remaining increase include a lot of locations along levees throughout the study area which were also mapped as Wrack/Dead-Vegetation in 2019. Part of this difference can be attributed to the active removal of vegetation along levees and/or the reduced precipitation in 2021.

Wrack / Dead Vegetation

Based on our review of the results for both years, the 2019 imagery made it easier to map wrack throughout the study area during the lowest tides. The 'wrack line' is not as apparent in the 2021 imagery. Even though we expected to see a reduction in wrack in 2021 due to the higher tide compared to 2019, wrack did not map effectively in 2021, and as a result, there was a 95% decrease (738 acres) in wrack between 2019 and 2021. Certainly, some of this reduction was due to the higher tide, as a large amount of wrack appears along the shoreline at low tide. However, by far the largest proportion of the wrack/dead vegetation class in 2019 is actually dead vegetation, which is mapped as alkali grasses or bare earth in 2021. Although most wrack in 2019 is actually 'dead vegetation', there is still a significant amount creating a 'wrack line' in multiple locations (see Figure 3), which is not as apparent in 2021.

2019

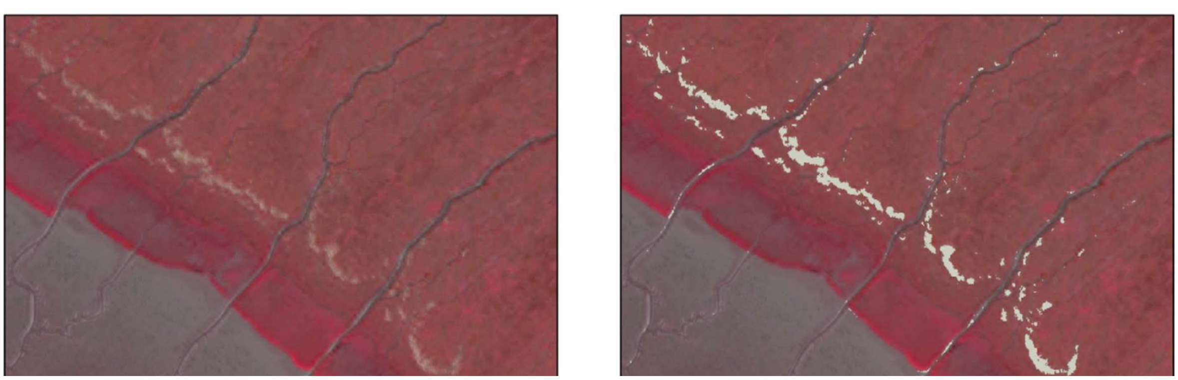


Figure 3: Wrack line mapped for 2019. On the left is the False Color image. On the right, the 'wrack line' (white/cream color), taken from the final 2019 habitats data, has been overlain on the false color image for comparison.

2.2 Restoration Units

In addition to summarizing the results for the entire study area we have also included acreage values by SBSP restoration unit (see Table 4 and Table 5), restored ponds, and select marshes (see below). These acreage values mostly exclude ponds with water or undergoing enhancement. We have also included summaries below of the results for restored ponds (e.g., Island Ponds, A6, E9/E8A), and select marshes (e.g., Bair Island). For a comparison with HEMP1 (2009-11) see the Change Analysis section below.

Table 4: Acreage by Habitat Type for Study Area (2019 & 2021)

Habitat Type		Alviso		Ravenswood		Eden Landing	
		Acres (2019)	Acres (2021)	Acres (2019)	Acres (2021)	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	63.5	134.8	4.7	2.4	75.1	53.4
	Salt Marsh-mid	568.8	597.2	77.3	76.5	809.8	976.6
	Salt Marsh-high	51.0	26.2	4.5	1.9	25.8	45.3
	Brackish Marsh	226.7	214.1	0.1	0.0	14.2	4.2
	Freshwater Marsh	24.9	21.0	0.0	0.0	0.2	0.5
	Pepperweed	25.0	21.2	0.6	0.0	5.6	2.6
	Ruderal	36.4	15.1	6.0	2.0	51.6	85.7
	Alkali Grasses	34.2	49.8	6.9	17.5	64.2	104.3
	Biotic total	**1,030.5**	**1,079.5**	**100.2**	**100.4**	**1,046.5**	**1,272.6**
abiotic habitats	Mudflat	795.3	820.8	46.0	90.0	1,126.9	1,010.8
	Wrack (or dead veg)	82.0	3.6	13.9	0.3	94.2	0.7
	Bare Earth	107.7	183.9	100.3	109.4	172.0	258.4
	Water	526.9	454.6	152.7	113.0	388.8	285.7
	Abiotic total	**1,511.9**	**1,462.9**	**313.0**	**312.8**	**1,781.8**	**1,555.6**
Grand Total		**2,542.4**	**2,542.4**	**413.2**	**413.2**	**2,828.3**	**2,828.2**

Table 5: Acreage for Mapped Habitats by Restoration Unit (2019 & 2021)

Mapped Habitat	Alviso		Ravenswood		Eden Landing	
	Acres (2019)	Acres (2021)	Acres (2019)	Acres (2021)	Acres (2019)	Acres (2021)
Alkali Bulrush	197.0	171.8	0.1	0.0	14.0	3.8
Alkali Grasses	34.2	49.8	6.9	17.5	64.2	104.3
Alkali Heath	3.3	8.7	0.9	0.4	6.7	19.0
Bare Earth	107.7	183.9	100.3	109.4	172.0	258.4
Freshwater Bulrush	15.0	0.5	0.0	0.0	-	0.1
Cattails	9.9	20.5	0.0	0.0	0.2	0.5
Cordgrass	49.8	87.4	3.0	1.1	41.8	20.4
Cordgrass/-Pickleweed	13.7	47.4	1.7	1.3	33.3	33.0
Mudflat without Biofilm	365.7	274.9	37.0	81.2	732.0	557.8
Mudflat with Biofilm	429.6	545.9	9.0	8.8	394.9	453.1
Pepperweed	25.0	21.2	0.6	0.0	5.6	2.6
Pickleweed	558.2	586.4	75.4	71.6	790.2	956.2
Pickleweed /- Gumplant	47.7	17.4	3.6	1.5	19.1	26.3
Pickleweed /- Jaumea	7.9	4.3	1.0	2.9	9.6	3.9
Ruderal	36.4	15.1	6.0	2.0	51.6	85.7
Saltgrass	2.7	6.5	0.8	2.0	10.1	16.4
Spearscale	29.7	42.4	0.0	0.0	0.2	0.4
Water	526.9	454.6	152.7	113.0	388.8	285.7
Wrack	82.0	3.6	13.9	0.3	94.2	0.7
Grand Total	**2,542.4**	**2,542.4**	**413.2**	**413.2**	**2,828.3**	**2,828.2**

2.3 Eden Landing

At Eden Landing, there appears to be significant floral colonization of mudflats within restored ponds between 2019 and 2021 (see Figure 4 and Table 6). There was a 21% increase (166 acres) in pickleweed between 2019 and 2021 (see Table 7). The majority (147 acres) of this growth in pickleweed within Eden Landing was mapped as mudflat in 2019, indicating a significant amount of floral colonization of mudflats within that time period. Approximately 64% of the growth of pickleweed colonizing mudflats occurred in E9, E8A/E8X, Mt Eden Creek Marsh, and North Creek Marsh. Twenty-six percent (~38 acres) of the floral colonization happening at Eden was within E8A or E8X (see Figures 5 & 6), while an additional eight percent (~ 12 acres) of pickleweed was within E9 (see Figure 7). Eighteen percent (~26 acres) of the growth of pickleweed was within North Creek Marsh and an additional twelve percent (~17 acres) of the growth of pickleweed was within Mt Eden Creek marsh (mostly in the tidal part). If, as the accuracy assessment shows (see Table 26), we are undermapping Cordgrass in some locations, it is likely a fractional percentage (~10-15%) of this pickleweed growth is Cordgrass (or Cordgrass /- Pickleweed). It also is possible that the rate of floral colonization has 'sped up' (as compared to 2009-2011) in some locations, since the relative increase in floral colonization between 2019 and 2021 appears to be greater than between 2011 and 2019.

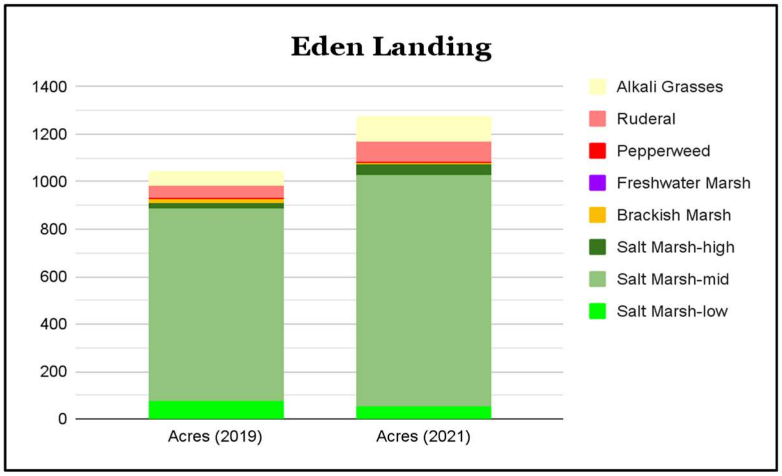


Figure 4: Acreage by Habitat Type for Eden Landing (2019 & 2021)

Table 6: Acreage by Habitat Type for Eden Landing (2019 & 2021)

Eden Landing			
	Habitat Type	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	75.1	53.4
	Salt Marsh-mid	809.8	976.6
	Salt Marsh-high	25.8	45.3
	Brackish Marsh	14.2	4.2
	Freshwater Marsh	0.2	0.5
	Pepperweed	5.6	2.6
	Ruderal	51.6	85.7
	Alkali Grasses	64.2	104.3
	Biotic total	**1,046.5**	**1,272.6**
abiotic habitats	Mudflat	1,126.9	1,010.8
	Wrack (or dead veg)	94.2	0.7
	Bare Earth	172.0	258.4
	Water	388.8	285.7
	Abiotic total	**1,781.8**	**1,555.6**
	Grand Total	**2,828.3**	**2,828.2**

Table 7: Acreage by Mapped Habitat for Eden Landing (2019 & 2021)

Mapped Habitat	Eden Landing	
	Acres (2019)	**Acres (2021)**
Alkali Bulrush	14.0	3.8
Alkali Grasses	64.2	104.3
Alkali Heath	6.7	19.0
Bare Earth	172.0	258.4
Cattails	0.2	0.5
Cordgrass	41.8	20.4
Cordgrass/-Pickleweed	33.3	33.0
Mudflat without Biofilm	732.0	557.8
Mudflat with Biofilm	394.9	453.1
Pepperweed	5.6	2.6
Pickleweed	790.2	956.2
Pickleweed /- Gumplant	19.1	26.3
Pickleweed /- Jaumea	9.6	3.9
Ruderal	51.6	85.7
Saltgrass	10.1	16.4
Spearscale	0.2	0.4
Water	388.8	285.7
Wrack	94.2	0.7
Total	**2,828.3**	**2,828.3**

There was a 53% reduction (~20 acres) in Cordgrass between 2019 and 2021 (see Table 7). Part of this reduction is due to the higher tide in 2021 when compared to 2019, since some locations could have been inundated by more water relative to 2019. However, this does not explain this large of a change. At the same time, 26 acres of the locations mapped as Cordgrass in 2019 are mapped as Pickleweed in 2021. A little more than half (~15 acres) of these locations where Cordgrass is now mapped as Pickleweed are either in North Creek or Mt Eden Creek marshes. At least a part of the reduction in Cordgrass is a result of undermapping Cordgrass (as Pickleweed) at some locations in 2021. However, it is also possible that the growth in Pickleweed indicates continued accretion within the restored ponds, and a shift towards mid marsh in these locations

There was a 73% reduction (from ~14 acres to ~4 acres) in Alkali Bulrush between 2019 and 2021. This significant difference is at least partly a phenological difference between years as well as the likely correlated drop in precipitation between years. Rainfall by the time of satellite overpass in June 2021 (5.32 inches) was less than a third of what it had been by June 2019 (16.43 inches). It is also possible that there is an increased salinity within Eden Landing as sediment accretes in the restored ponds and is being colonized with salt marsh species (primarily Pickleweed and Cordgrass).

There was a 40 acre increase in Alkali Grasses between 2019 and 2021 at Eden Landing. Approximately 88% (35 acres) of this mapped as wrack/dead vegetation in 2019. The majority of this change is likely senescent vegetation (i.e., grasses) that in 2021 were fluorescing and mapped as alkali grasses. Despite the reduction in rainfall between years at the time of satellite flyover (from 26 to 5 inches), this is most likely simply due to phenological differences between years. Approximately 25% of this change at these locations (where wrack is now mapped as alkali grasses) occurred in the upland portion of Pond E1C. A large proportion of the remaining areas of change are distributed along paths or levees. This trend is the same when we look at acreages for the entire study area (see Table 2). The shift to alkali grasses from wrack, bare earth, or even ruderal, are likely simply normal interannual and/or inter seasonal differences, and in most cases are simply differences in phenology on the dates of imagery acquisition in 2019 and 2021.

There was also a 48% (~28 acres) increase in ruderal vegetation (radish, mustard, iceplant, sea lavender) between 2019 and 2021 (see Table 6). In addition to areas that mapped consistently as Ruderal between years, more than half of the areas mapped as Ruderal in 2021, were mapped as Alkali Grasses or Wrack/Dead Vegetation in 2019. This 'shift' between classes is to be expected due to differences in phenology and to a lesser degree overlap of vegetation between classes. However, this could also indicate a shift in these upland grass locations to more ruderal vegetation types. The largest proportion of the increase in Ruderal vegetation (up to 20 acres or 75% of the increase) were in locations that were mapped as Pickleweed in 2019, and perhaps indicate a reduction in salinity or land conversion of some type at these locations. It is also likely that we were at least partially overmapping pickleweed in these locations in 2019 since such a large shift is unlikely to occur within 2 years. These locations are largely within disturbed parts of Alameda Flood Control Channel (AFCC), an area with a mix of salinities and lots of ruderal intrusion.

Ponds E8A/E8X

Between 2019 and 2021, there was a growth of ~35 acres of Pickleweed within E8A and an additional ~2 acres in E8X (see Table 8 and Table 9). The area of change (including both Pickleweed and Cordgrass) between 2019 and 2021 within E8A (38.6 acres) and within E8X (3.1 acres) is shown as light green in Figure 5 and Figure 6, respectively. This was nearly identical to the amount of reduced mudflat within both ponds. This indicates a 64% increase in salt marsh vegetation (see Table 8), indicating active floral colonization of mudflats within these ponds during the time period of the study.

Table 8: Acreage by Habitat Type for E8A (2019 & 2021)

E8A (acres)			
	Habitat Type	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	3.77	5.94
	Salt Marsh-mid	56.52	93.29
	Salt Marsh-high	0.60	0.57
	Brackish Marsh	1.53	0.26
	Freshwater Marsh	0.00	0.00
	Pepperweed	0.11	0.04
	Ruderal	0.18	1.10
	Alkali Grasses	0.09	1.00
	Biotic total	**62.79**	**102.21**
abiotic habitats	Mudflat	183.50	148.12
	Wrack (or dead veg)	1.22	0.00
	Bare Earth	4.65	3.93
	Water	13.04	10.94
	Abiotic total	**202.41**	**162.99**
	Grand Total	**265.20**	**265.20**

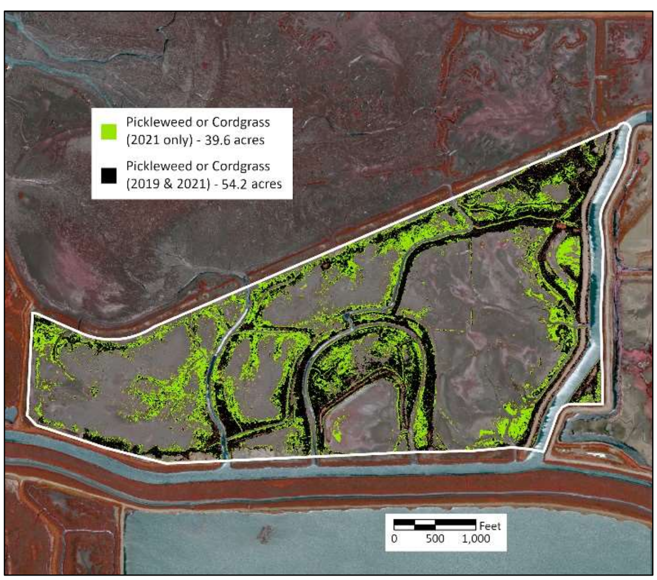


Figure 5: Mapped mudflat floral colonization for E8A

Map 4a-b: Mapped habitats for E9/E8A/E8X (2019 & 2021)

Table 9: Acreage by Habitat Type for E8X (2019 & 2021)

E8X			
	Habitat Type	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	0.40	0.69
	Salt Marsh-mid	2.89	5.21
	Salt Marsh-high	0.06	0.01
	Brackish Marsh	0.15	0.23
	Freshwater Marsh	0.00	0.00
	Pepperweed	0.00	0.00
	Ruderal	0.00	0.01
	Alkali Grasses	0.00	0.02
	Biotic total	**3.50**	**6.17**
abiotic habitats	Mudflat	23.20	20.95
	Wrack (or dead veg)	0.00	0.00
	Bare Earth	0.13	0.04
	Water	0.51	0.20
	Abiotic total	**23.85**	**21.18**
	Grand Total	**27.35**	**27.35**

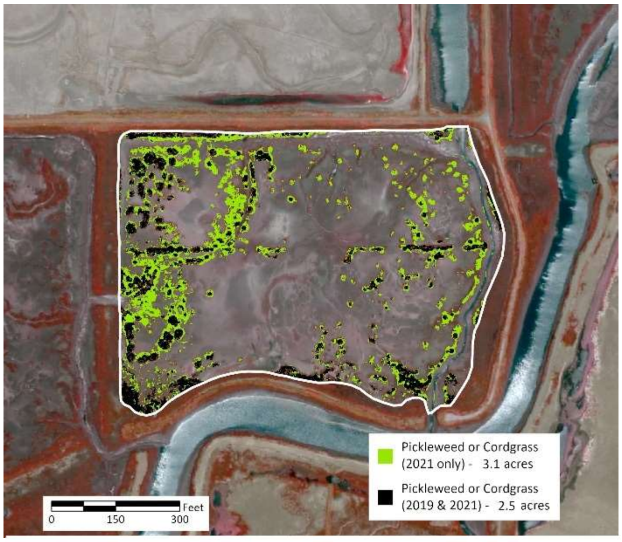


Figure 6: Mapped mudflat floral colonization for E8X

Pond E9

There was also significant floral colonization of mudflats within E9. Between 2019 and 2021, low salt marsh (e.g., Cordgrass) more than doubled, from 1.5 to 3.5 acres, as did mid salt marsh (e.g., Pickleweed), from ~9 to 21 acres (see Table 10 and Maps 4a-b). The total area of change (i.e., floral colonization of mudflats by salt marsh species) between years is shown as green in Figure 7.

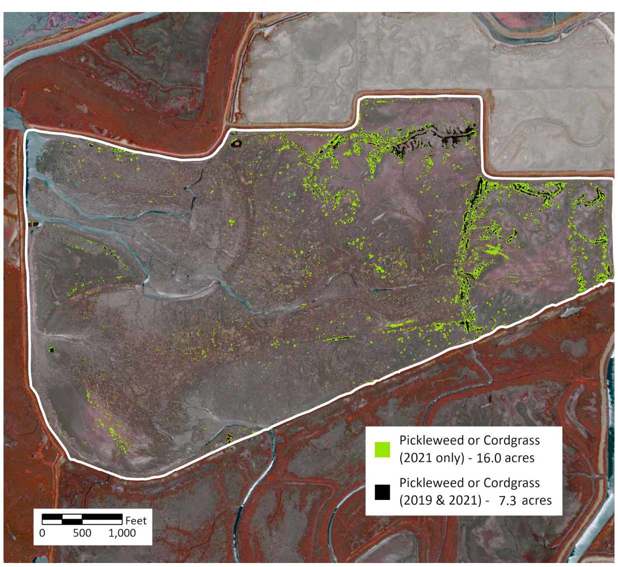


Figure 7: Mapped mudflat floral colonization for E9

Table 10: Acreage by Habitat Type for E9 (2019 & 2021)

E9			
	Habitat Type	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	1.50	3.56
	Salt Marsh-mid	8.87	20.81
	Salt Marsh-high	0.29	0.15
	Brackish Marsh	0.20	0.53
	Freshwater Marsh	0.00	0.00
	Pepperweed	0.01	0.02
	Ruderal	0.01	0.14
	Alkali Grasses	0.00	0.07
	Biotic total	**10.89**	**25.29**
abiotic habitats	Mudflat	347.15	333.60
	Wrack (or dead veg)	0.06	0.00
	Bare Earth	0.41	0.53
	Water	6.79	5.88
	Abiotic total	**354.42**	**340.02**
	Grand Total	**365.30**	**365.30**

North Creek Marsh

In North Creek Marsh, there was significant growth of salt marsh within the restored pond between 2021 and 2019 (see Figure 8 and Table 11). Pickleweed doubled from approximately 35 to 70 acres during this time period (see Maps 5a-b). Twenty-five acres of this increase can be attributed to direct floral colonization of mudflats, However, 10 acres of pickleweed mapped in 2021, was mapped as Cordgrass (or Cordgrass /- Pickleweed) in 2019. This is certainly at least partially due to undermapping of Cordgrass within the marsh (due to a combination of phenology, tide, and radiometric differences). It could also possibly indicate continued accretion of sediment within the pond and a consequent transition from low to mid marsh in these locations. It is likely that these 10 acres of pickleweed in 2021 is a combination of Cordgrass, Cordgrass /- Pickleweed, and Pickleweed. Overall, there was a reduction of about 4.5 acres of Cordgrass within the entire marsh between 2019 and 2021. This indicates that, in addition to 10 acres of Cordgrass being mapped as Pickleweed in 2021, Cordgrass was *also* potentially colonizing other locations and/or was more fluorescent in 2021 at certain locations when compared to 2019 at the time of satellite acquisition. The area of change between is shown in Figure 9, with areas where Pickleweed has colonized mudflats between 2019 and 2021 shown in light green (~29 acres) and areas that were mapped as pickleweed in both years shown in black (~42 acres).

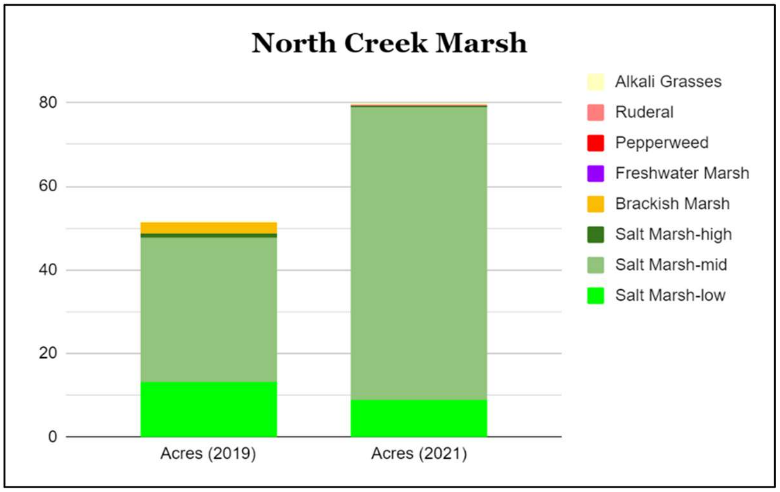
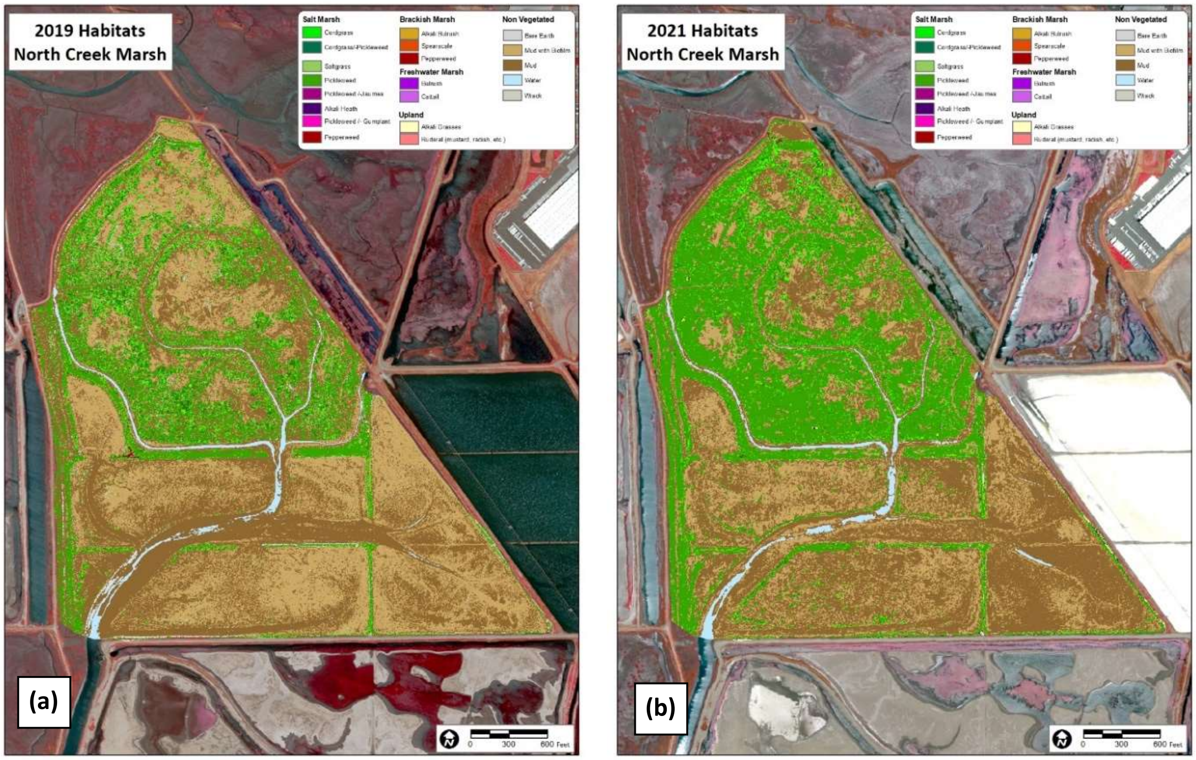


Figure 8: Acreage by Habitat Type for North Creek Marsh (2019 & 2021)

Table 11: Acreage by Habitat Type for North Creek Marsh (2019 & 2021)

North Creek Marsh			
Habitat Type		**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	13.11	8.86
	Salt Marsh-mid	34.51	70.09
	Salt Marsh-high	1.20	0.25
	Brackish Marsh	2.55	0.16
	Freshwater Marsh	0.00	0.00
	Pepperweed	0.07	0.09
	Ruderal	0.12	0.26
	Alkali Grasses	0.02	0.22
	Biotic total	**51.57**	**79.94**
abiotic habitats	Mudflat	162.08	136.85
	Wrack (or dead veg)	0.30	0.01
	Bare Earth	0.72	0.48
	Water	6.41	3.79
	Abiotic total	**169.50**	**141.13**
	Grand Total	**221.07**	**221.07**



Map 5a-b: Mapped habitats for North Creek Marsh (2019 & 2021)

Figure 9: Mapped mudflat floral colonization for North Creek Marsh

Mt Eden Creek Marsh

Overall, there was approximately 23 acres of increase in pickleweed within Mt Eden Creek Marsh between 2019 and 2021. Seventeen acres of this was pickleweed that had colonized on what was mudflat in 2019. However, unlike North Creek Marsh, the conversion of mudflat to pickleweed is not as straightforward. It appears mudflat was expanding in some locations while being colonized by vegetation in others, resulting in an overall reduction of about 4 acres of mudflat overall between years. About 6 acres of this new pickleweed had been mapped as Cordgrass in 2019. This is certainly at least partially due to undermapped of Cordgrass within the marsh (due to a combination of phenology, tide, and radiometric differences). It could also possibly indicate continued accretion of sediment within the pond and a consequent transition from low to mid marsh in these locations. The locations of floral colonization of mudflats are shown in Figure 11, with areas where pickleweed colonized mudflats in 2021 shown in light green (~16 acres) and areas that were mapped as pickleweed in both years shown in black (~15 acres).

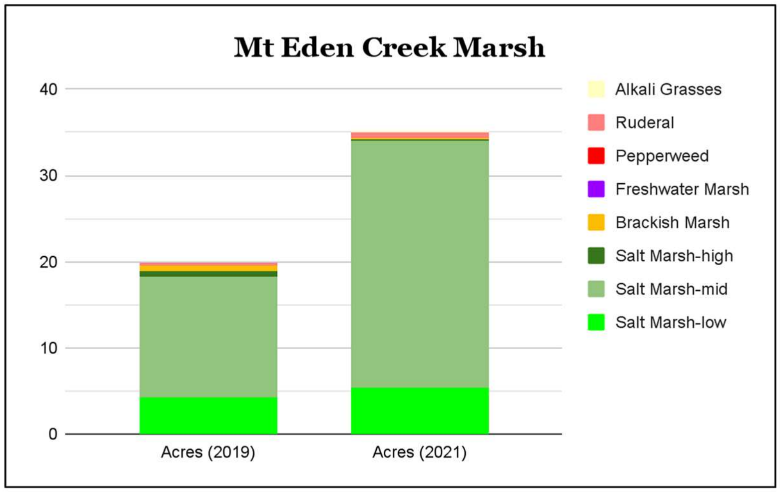
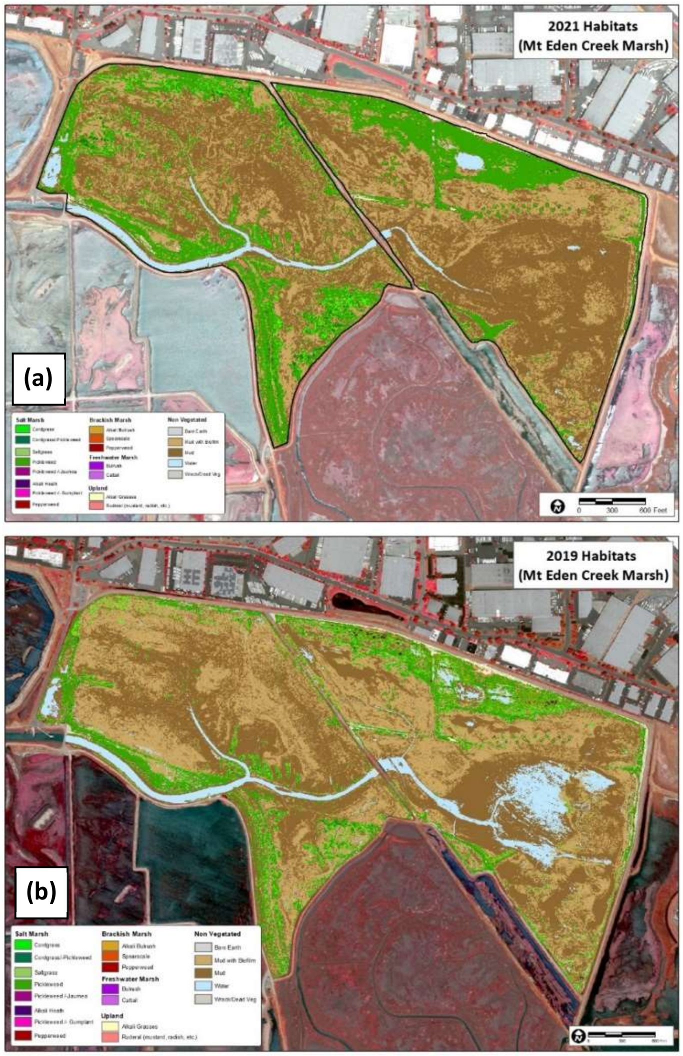


Figure 10: Acreage by Habitat Type for Mt Eden Creek Marsh (2019 & 2021)

Table 12: Acreage by Habitat Type for Mt Eden Creek Marsh (2019 & 2021)

Mt Eden Creek Marsh			
Habitat Type		**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	4.29	5.49
	Salt Marsh-mid	13.94	28.53
	Salt Marsh-high	0.72	0.16
	Brackish Marsh	0.61	0.13
	Freshwater Marsh	0.00	0.00
	Pepperweed	0.03	0.07
	Ruderal	0.23	0.54
	Alkali Grasses	0.11	0.21
	Biotic total	**19.92**	**35.14**
abiotic habitats	Mudflat	92.26	78.80
	Wrack (or dead veg)	0.14	0.00
	Bare Earth	0.33	0.46
	Water	6.77	5.02
	Abiotic total	**99.49**	**84.28**
	Grand Total	**119.42**	**119.42**



Map 6a-b: Mapped habitats for Mt Eden Creek Marsh (2019 & 2021)

Figure 11: Mapped mudflat floral colonization for Mt Eden Creek Marsh

2.4 Alviso

Salt Marsh

There was a 5% net increase (28 acres) in Pickleweed within the Alviso unit between 2019 and 2021. At the same time, there were approximately 72 acres of mudflat that were colonized by Pickleweed between 2019 and 2021. This includes 60 acres of Pickleweed that mapped as mudflat in 2019 and an additional 12 acres of Pickleweed in 2021 which mapped as water in 2019 (these 12 acres were either mudflats that were under very shallow water in 2019 or continued to accrete between years enough to be colonized by pickleweed).

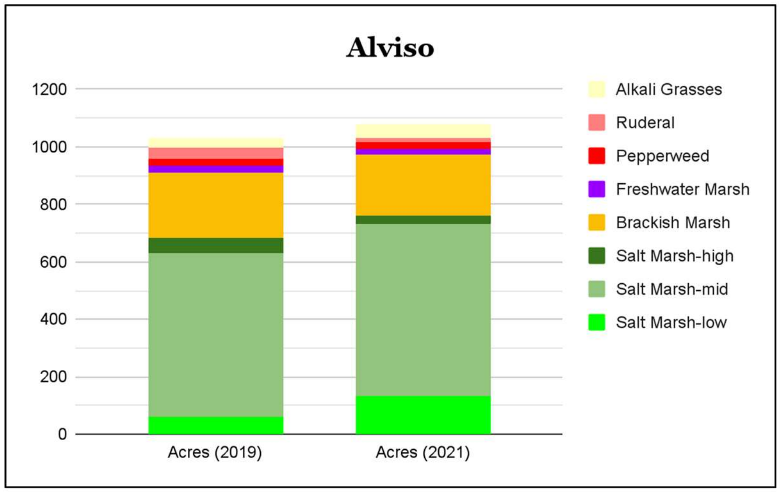


Figure 12: Acreage by Habitat Type for Alviso (2019 & 2021)

Table 13: Acreage by Habitat Type for Alviso (2019 & 2021)

Alviso			
Habitat Type		**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	63.5	134.8
	Salt Marsh-mid	568.8	597.2
	Salt Marsh-high	51.0	26.2
	Brackish Marsh	226.7	214.1
	Freshwater Marsh	24.9	21.0
	Pepperweed	25.0	21.2
	Ruderal	36.4	15.1
	Alkali Grasses	34.2	49.8
	Biotic total	**1,030.5**	**1,079.5**
abiotic habitats	Mudflat	795.3	820.8
	Wrack (or dead veg)	82.0	3.6
	Bare Earth	107.7	183.9
	Water	526.9	454.6
	Abiotic total	**1,511.9**	**1,462.9**
	Grand Total	**2,542.4**	**2,542.4**

Within the Alviso restoration unit, the acreage of low salt marsh (both Cordgrass and Cordgrass /- Pickleweed) also more than doubled between 2019 and 2021, increasing by approximately 70 acres. Around 36% (25 acres) of this growth in low marsh classes (15 acres of Cordgrass and 10 acres of Cordgrass /- Pickleweed) was direct floral colonization of locations that were mudflats in 2019. The majority (70%) of these 25 acres was Cordgrass (10 acres) or Cordgrass /- Pickleweed (7.5 acres) colonizing mudflats within the Island ponds (A21, A20, A19). When comparing the difference between Island ponds, Pond A19 had the largest absolute increase in Cordgrass colonizing mudflat (~7 acres), versus A20 (~2.1 acres) and A21 (~1.3 acre).

Cordgrass appears to be increasing in Alviso not only within the Island ponds (A21, A20, A19) but also some fringe marshes such as Calaveras marsh and the marshes that surround pond A6 (see Figure 36 or Figure 42 below). As outlined above, the majority of this appears to be ongoing floral colonization of

Table 14: Acreage by Mapped Habitat for Alviso (2019 & 2021)

Mapped Habitat	Alviso	
	Acres (2019)	**Acres (2021)**
Alkali Bulrush	197.0	171.8
Alkali Grasses	34.2	49.8
Alkali Heath	3.3	8.7
Bare Earth	107.7	183.9
Freshwater Bulrush	15.0	0.5
Cattails	9.9	20.5
Cordgrass	49.8	87.4
Cordgrass/-Pickleweed	13.7	47.4
Mudflat without Biofilm	365.7	274.9
Mudflat with Biofilm	429.6	545.9
Pepperweed	25.0	21.2
Pickleweed	558.2	586.4
Pickleweed /- Gumplant	47.7	17.4
Pickleweed /- Jaumea	7.9	4.3
Ruderal	36.4	15.1
Saltgrass	2.7	6.5
Spearscale	29.7	42.4
Water	526.9	454.6
Wrack	82.0	3.6
Total	**2,542.4**	**2,542.4**

mudflats within restored ponds and bay fronting mudflats. However, we cannot rule out that at least some of this increase might also be related to differences in relative fluorescence (between Cordgrass and Alkali Bulrush or Pickleweed) at time of image acquisition. Approximately 60 acres of low marsh in 2021 (39 acres of Cordgrass and 21 acres of Cordgrass /- Pickleweed) had been mapped as Pickleweed in 2019. Forty percent (24 acres) of this 'shift' to Cordgrass or Cordgrass /- Pickleweed from Pickleweed was also within the 'Island' ponds (A21, A20, or A19). We believe this shift, which largely accounts for the remaining growth of low marsh in 2021, is a combination of both undermapped Cordgrass classes in 2019 as well as an increase in both the distribution and fluorescence of Cordgrass classes in 2021.

Unfortunately, there was also a large decrease in mapped Gumplant (63%) between 2019 and 2021. At the same time, there was a coincident tripling of acreage in Alkali Heath (from 3 to 9 acres), resulting in a 49% net decrease in high salt marsh. Although this can be seen as a significant reduction, there is also evidence (from both the accuracy assessment and extensive QA) that the distribution and extent of Gumplant in 2021 is more accurate and the decrease could at least be partially overmapping of Gumplant in 2019 or relative changes in fluorescence across years (see Change Analysis section below).

Brackish Marsh

There was about a 13% (~25 acres) drop in Alkali Bulrush between 2019 and 2021. Brackish Marsh also decreased, but less so (12 acres or 5%) due to a 40% increase in Spearscale (from 30 to 42 acres) during the same time period. This drop in acreage in Alkali Bulrush is a result of both the growth of Spearscale as well as phenological differences between years, which are likely both correlated with a drop in precipitation during this same time period (from 16.43 in 2019 to 5.32 inches in 2021). The reduction in acreage appears to be pretty evenly distributed throughout the restoration area, although there are areas where the phenological differences are greater, especially where there is *Scirpus Maritimus.* At certain scales, it is apparent that the density of Bulrush is lower in 2021 but still appears to show the same overall distribution. In many locations, these phenological differences between 2021 and 2019 seem to expose mostly pickleweed in the 'understory' or senescing bulrush mixed with fluorescing pickleweed and that are consequently mapped as pickleweed, especially in marshes within Guadalupe and Alviso sloughs and Coyote Creek. Notably, around 58 acres of Alkali Bulrush in 2021, were mapped as Pickleweed in 2019. However, almost the same amount, around 52 acres, which mapped as Pickleweed in 2021, mapped as Alkali Bulrush in 2019. These Pickleweed-Alkali Bulrush shifts between 2019 and 2021 are likely not coincidental or simply an artifact of the mapping methodology. It is possible that within these marshes, especially in locations where this is mix of salinities, there is a cyclical shifting relative distribution of Alkali Bulrush and Pickleweed, correlated with phenological difference between years (and seasons) and other related environmental factors (e.g., precipitation). In at least some of these locations, the pickleweed might also be partially Spearscale (since we have concluded that we are undermapping Spearscale as Pickleweed). In the end, what appears to be a habitat shift from Alkali Bulrush (2019) to Pickleweed (2021) is at least partially a result of senescing (i.e., decomposed) Alkali Bulrush on the day of satellite overpass in 2021 and undermapping of Spearscale (as Pickleweed) in these same locations.

Although there was an overall drop in Alkali Bulrush, there were also about 11 acres of Alkali Bulrush in 2021 that had colonized what were mudflats in 2019. At least 6 acres of Alkali Bulrush in 2021 were mapped as Freshwater Bulrush in 2019, mostly in the vicinity of Artesian slough (and below A17) and around Coyote Creek lagoon. Based on our accuracy assessment and our qualitative review of our results, it appears Freshwater Bulrush undermapped in 2021 (as Alkali Bulrush or Cattail). We assume the majority of this is mis mapping (should map as freshwater bulrush), but it is also possible that there are some actual salinity changes in these locations that are causing these shifts.

Abiotic Habitats

There was a 41% increase in bare earth between 2019 and 2021 within Alviso. The increase could indicate the potential of more upland within the study area. However, half (40 acres) of the ~80 acres increase in Bare Earth between 2019 and 2021 within Alviso was locations mapped as Wrack/Dead Vegetation in 2019. A large proportion of this are along levees (or paths). This is likely senescing vegetation that is now bare earth along levees due to control efforts, phenology, and (lack of) precipitation. An additional 20% (16 acres) mapped as water in 2019 - which is also due to a combination of mis mapping in 2019 (e.g., part of the Amtrak corridor is mapped as water in 2019) and actual conversion of certain locations, at least partially due to low precipitation in 2021 relative to 2019. The remaining increase is mostly locations that were mapped as ruderal, alkali grasses, or mudflat in 2019, and are distributed throughout Alviso, mostly along levees and levee flanks.

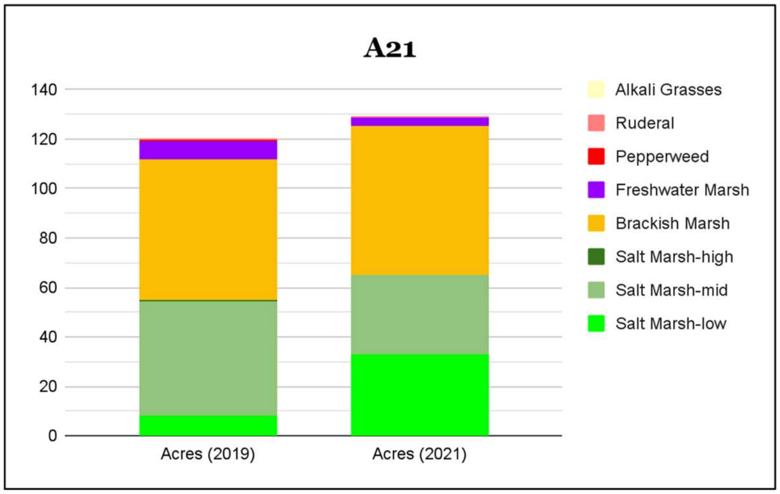


Figure 13: Acreage by Habitat Type for A21 (2019 & 2021)

Table 15: Acreage by Habitat Type for A21 (2019 & 2021)

A21			
Habitat Type		Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	8.21	33.16
	Salt Marsh-mid	46.31	31.93
	Salt Marsh-high	0.36	0.01
	Brackish Marsh	57.13	60.11
	Freshwater Marsh	7.26	3.50
	Pepperweed	0.57	0.05
	Ruderal	0.12	0.29
	Biotic total	**119.96**	**129.05**
abiotic habitats	Mudflat	23.62	17.23
	Wrack (or dead veg)	0.58	0.02
	Bare Earth	0.03	0.17
	Water	2.32	0.05
	Abiotic total	**26.55**	**17.47**
	Grand Total	**146.51**	**146.51**

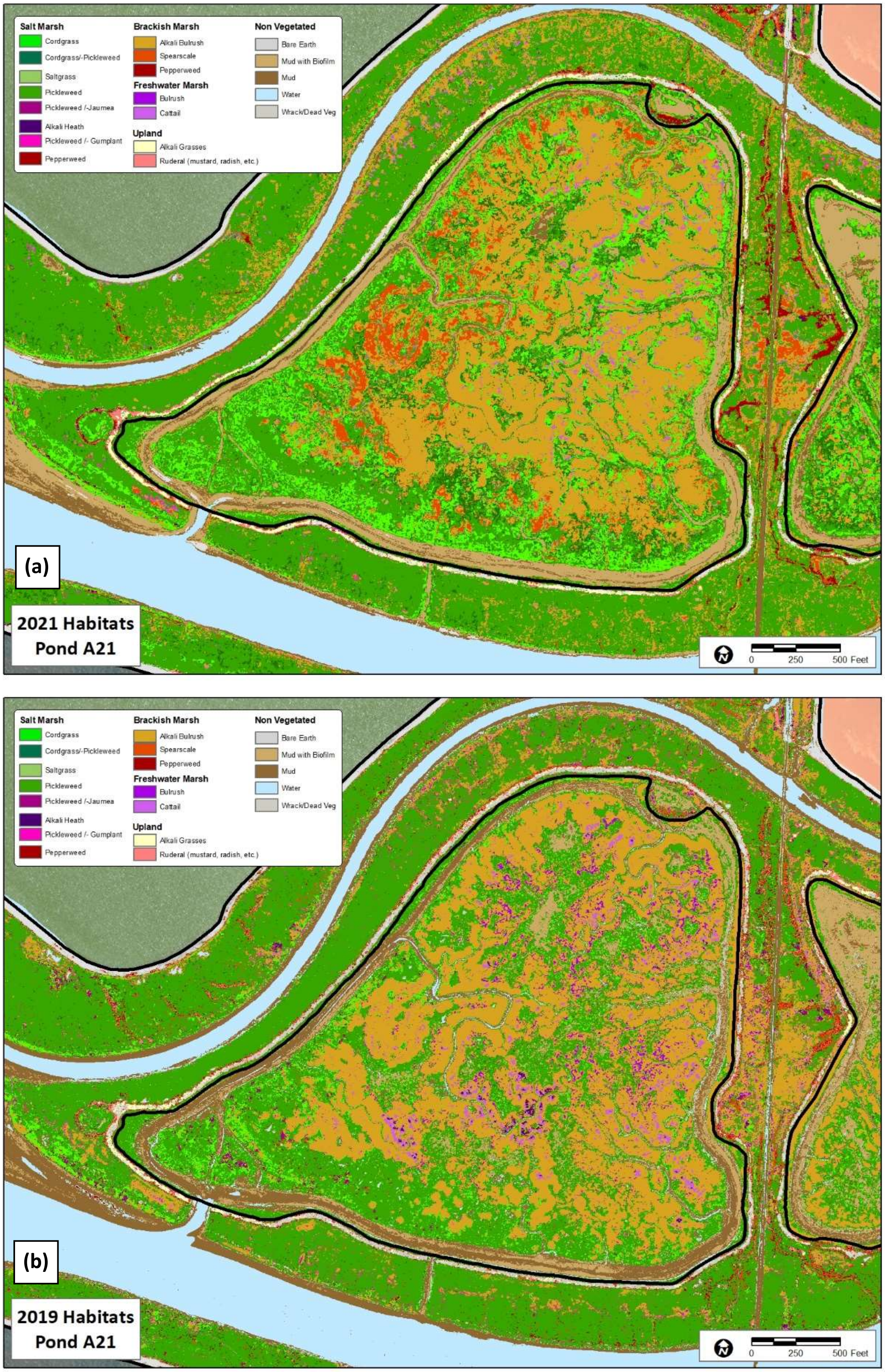
Pond A21

Salt Marsh

There was a 25% increase in low salt marsh within A21 between 2019 and 2021 (see Figure 13 and Table 15). The acreage of Cordgrass tripled between 2019 and 2021 (from 7 to 21 acres) when compared to 2019. There was also ~10 acres increase in Cordgrass /- Pickleweed, which could indicate a shift to low marsh or simply variable phenology between years at the time of satellite flyover. A large part of A21 is low marsh, with some signs of increasing salinity (i.e., the increase in Spartina relative to Alkali Bulrush) within the pond (see Map 7a-b). However, at the same time, there was a 29% reduction of Pickleweed (~13 acres). This is likely a combination of actual change, tidal differences between years at time of image acquisition, and overmapping of Spearscale and consequent undermapping of Pickleweed (which we have seen in other locations in Alviso). Despite that decrease, there were also approximately 4 acres of Pickleweed that colonized mudflat between 2019 and 2021. We believe the reduction in Pickleweed is in locations where Cordgrass (or Cordgrass /- Pickleweed) has now become dominant. The increase overall in low marsh species could also indicate some threshold of sediment accretion has been achieved in the pond.

Brackish Marsh

There was a 5% increase in brackish marsh between 2019 and 202 within A21. However, this is entirely an artifact of our inclusion of Spearscale within the brackish marsh category. In fact, there was a reduction of around ~4 acres of Alkali Bulrush and an increase of ~7 acres in Spearscale, between 2019 and 2021.



Map 7a-b: Mapped habitats for A21 (2019 & 2021)

Pond A20

Salt Marsh

The trend in A20 is very similar to A21 but even greater, with a 7x increase in low salt marsh species (see Figure 14 and Table 16). Cordgrass increased from ~3 to ~12 acres and Cordgrass /-Pickleweed from ~0.5 to ~8 acres between 2019 and 2021 (see Map 8a-b). At the same time, there was a 25% decrease in Pickleweed (from 20 to 15 acres). Despite that decrease, there were also approximately 5 acres of Pickleweed that colonized mudflat between 2019 and 2021 (and a total of ~9.5 acre decrease of mudflat total within the pond). We believe the reduction in Pickleweed is in locations where Cordgrass (or Cordgrass /-Pickleweed) has now become dominant.

Brackish Marsh

There was a 26% decrease (~3.5 acres) in Alkali Bulrush between 2019 and 2021 within A20 and only 1 acre increase of Spearscale during that same period (see Table 16).

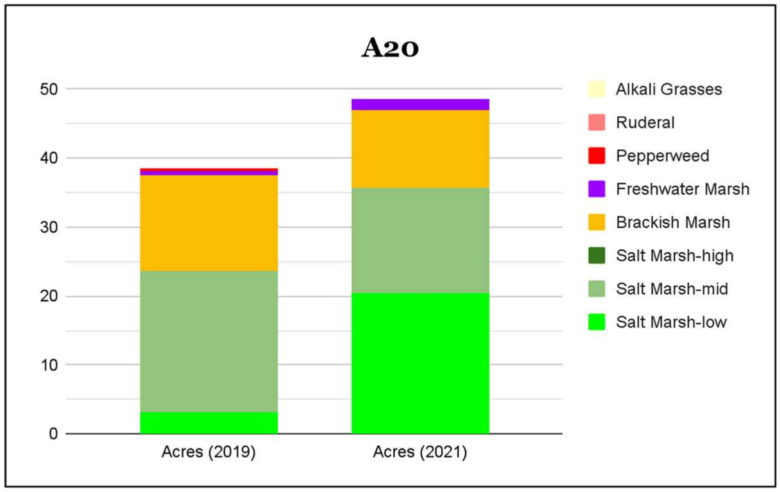
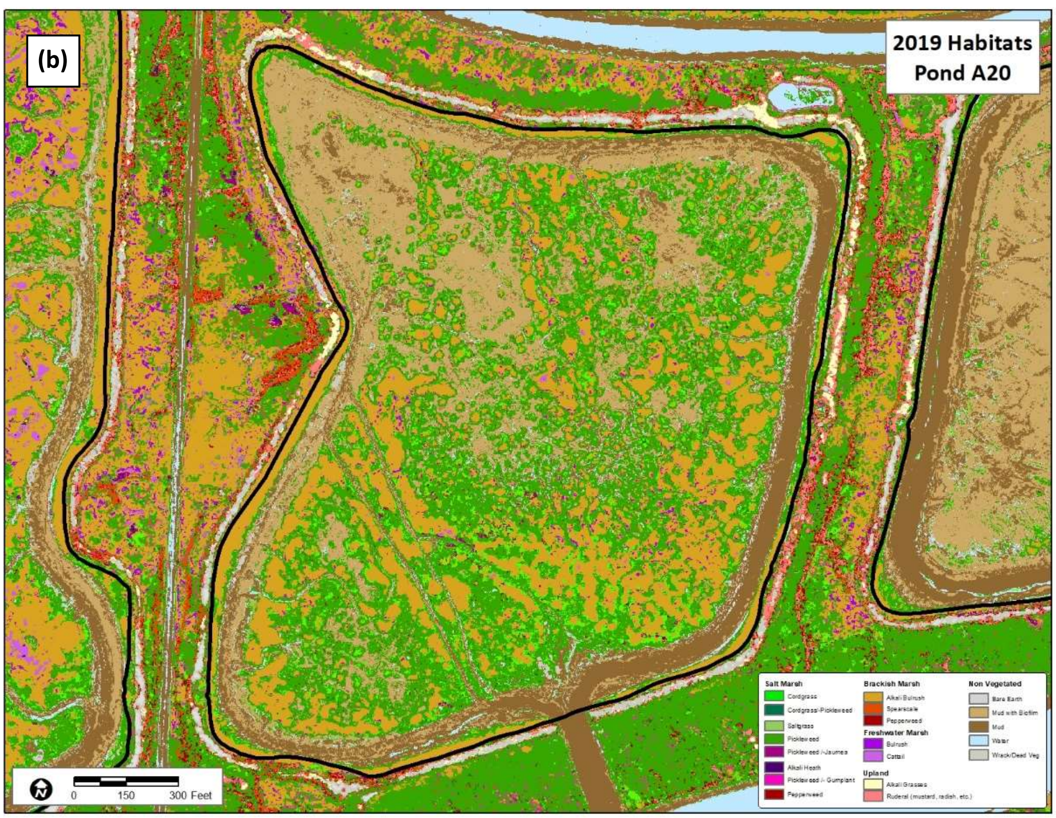


Figure 14: Acreage by Habitat Type for A20 (2019 & 2021)

Table 16: Acreage by Habitat Type for A20 (2019 & 2021)

A20			
Habitat Type		**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	3.16	20.46
	Salt Marsh-mid	20.41	15.20
	Salt Marsh-high	0.01	0.00
	Brackish Marsh	13.83	11.31
	Freshwater Marsh	0.72	1.54
	Pepperweed	0.37	0.03
	Ruderal	0.01	0.06
	Alkali Grasses		0.00
	Biotic total	**38.51**	**48.60**
abiotic habitats	Mudflat	22.54	14.00
	Wrack (or dead veg)	0.39	0.01
	Bare Earth	0.05	0.01
	Water	1.13	0.00
	Abiotic total	**24.11**	**14.02**
	Grand Total	**62.61**	**62.61**



Map 8a-b: Mapped habitats for A20 (2019 & 2021)

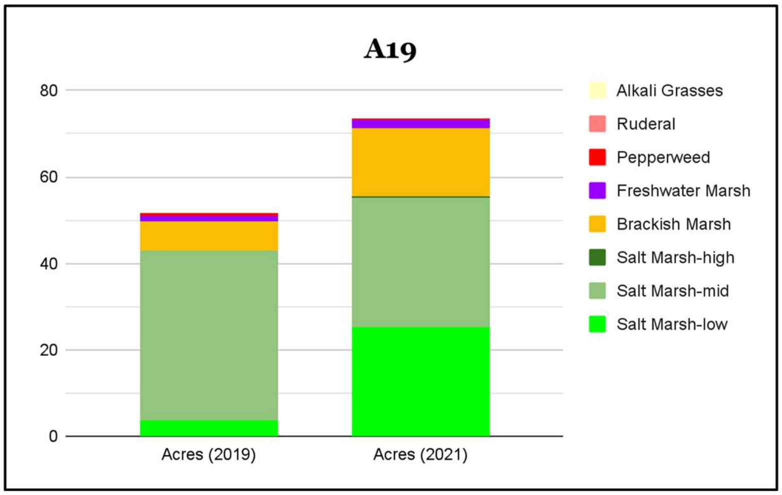


Figure 15: Acreage by Habitat Type for A19 (2019 & 2021)

Table 17: Acreage by Habitat Type for A19 (2019 & 2021)

A19			
Habitat Type		**Acres (2019)**	**Acres (2021)**
Biotic habitats	Salt Marsh-low	3.70	25.35
	Salt Marsh-mid	39.38	29.95
	Salt Marsh-high	0.02	0.06
	Brackish Marsh	6.49	15.81
	Freshwater Marsh	1.51	2.13
	Pepperweed	0.48	0.10
	Ruderal	0.02	0.22
	Alkali Grasses	0.00	0.02
	Biotic total	**51.60**	**73.65**
Abiotic habitats	Mudflat	199.12	187.56
	Wrack (or dead veg)	0.92	0.02
	Bare Earth	0.02	0.16
	Water	13.33	3.60
	Abiotic total	**213.38**	**191.34**
	Grand Total	**264.98**	**264.98**

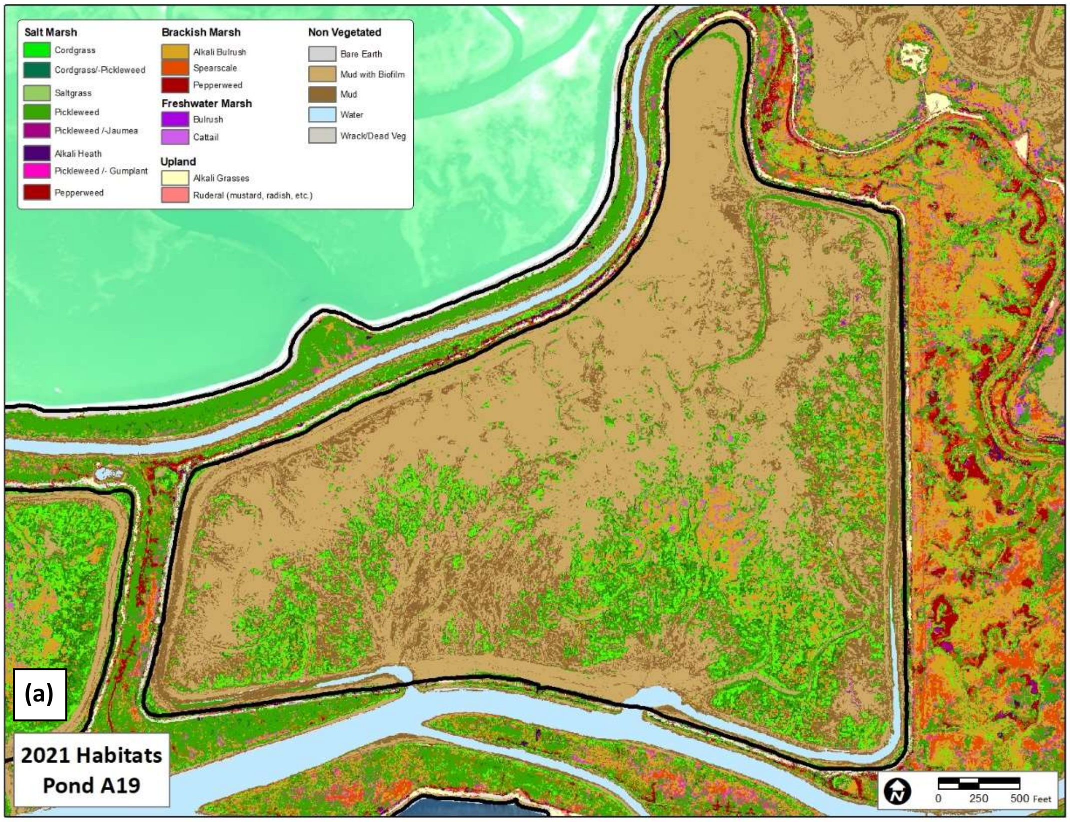
Pond A19

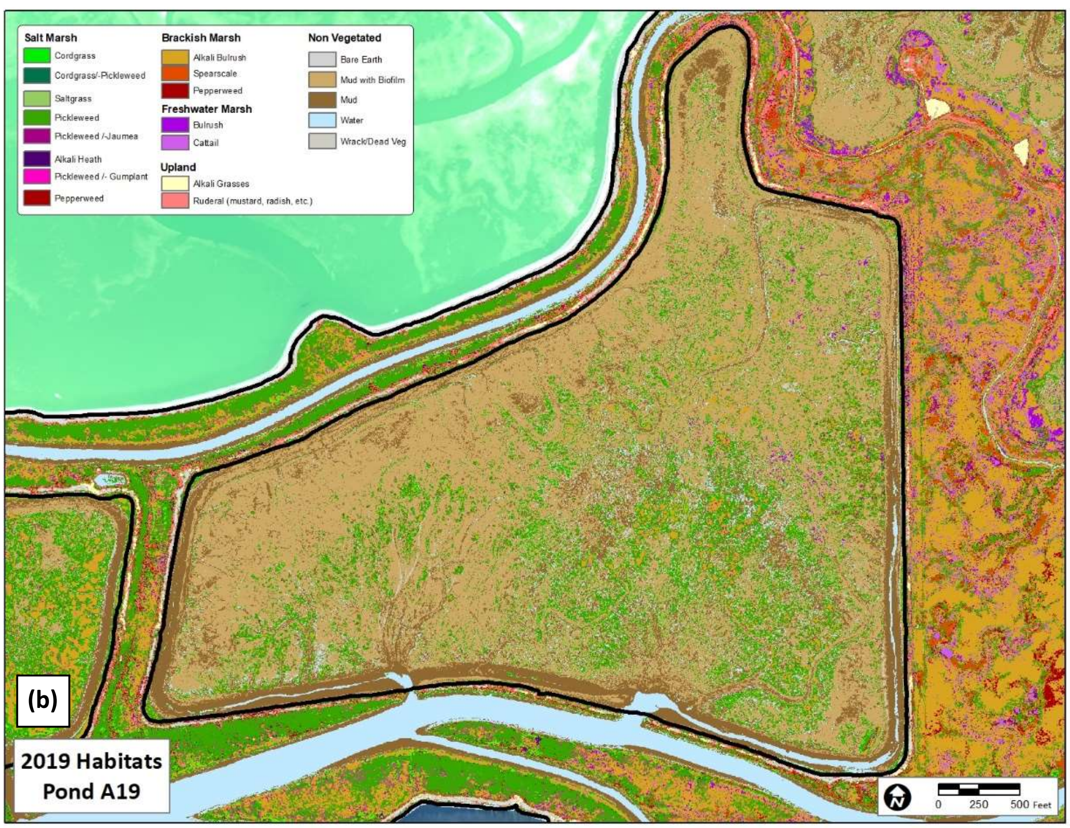
Salt Marsh

Habitat classes associated with low salt marsh (Cordgrass and Cordgrass /-Pickleweed) increased by more than 6x (~4 acres to ~25 acres) between 2019 and 2021 (see Figure 15 and Table 17). A little more than half of this growth (12 acres) was direct floral colonization of mudflats (see Map 9a-b). Approximately 7 acres of Cordgrass mapped in 2021 and an additional 5 acres of Cordgrass /- Pickleweed (also mapped in 2021) were in locations mapped as mudflat in 2019. In addition, slightly more than 6 acres of Cordgrass mapped in 2021 mapped as Pickleweed in 2019. At the same time there was a significant increase in low marsh, there was a 23% net reduction in Pickleweed in A19 (from ~39 to ~30 acres. Despite this overall reduction, Pickleweed colonized approximately 19 acres of mudflat. Some of the increases in Alkali Bulrush or Cordgrass were in locations that mapped as Pickleweed in 2019. Approximately 26 acres mapped as Pickleweed in 2019, mapped as either Mudflat or Cordgrass /- Pickleweed in 2021. This is likely a combination of a small fraction of the Pickleweed overmapping in 2019 and/or Pickleweed that did not fully establish within the pond.

Brackish Marsh

Between 2019 and 2021, Alkali Bulrush more than doubled (~6 acres to ~15 acres) within pond A19 (see Table 17).





Map 9a-b: Mapped habitats for A19 (2019 & 2021)

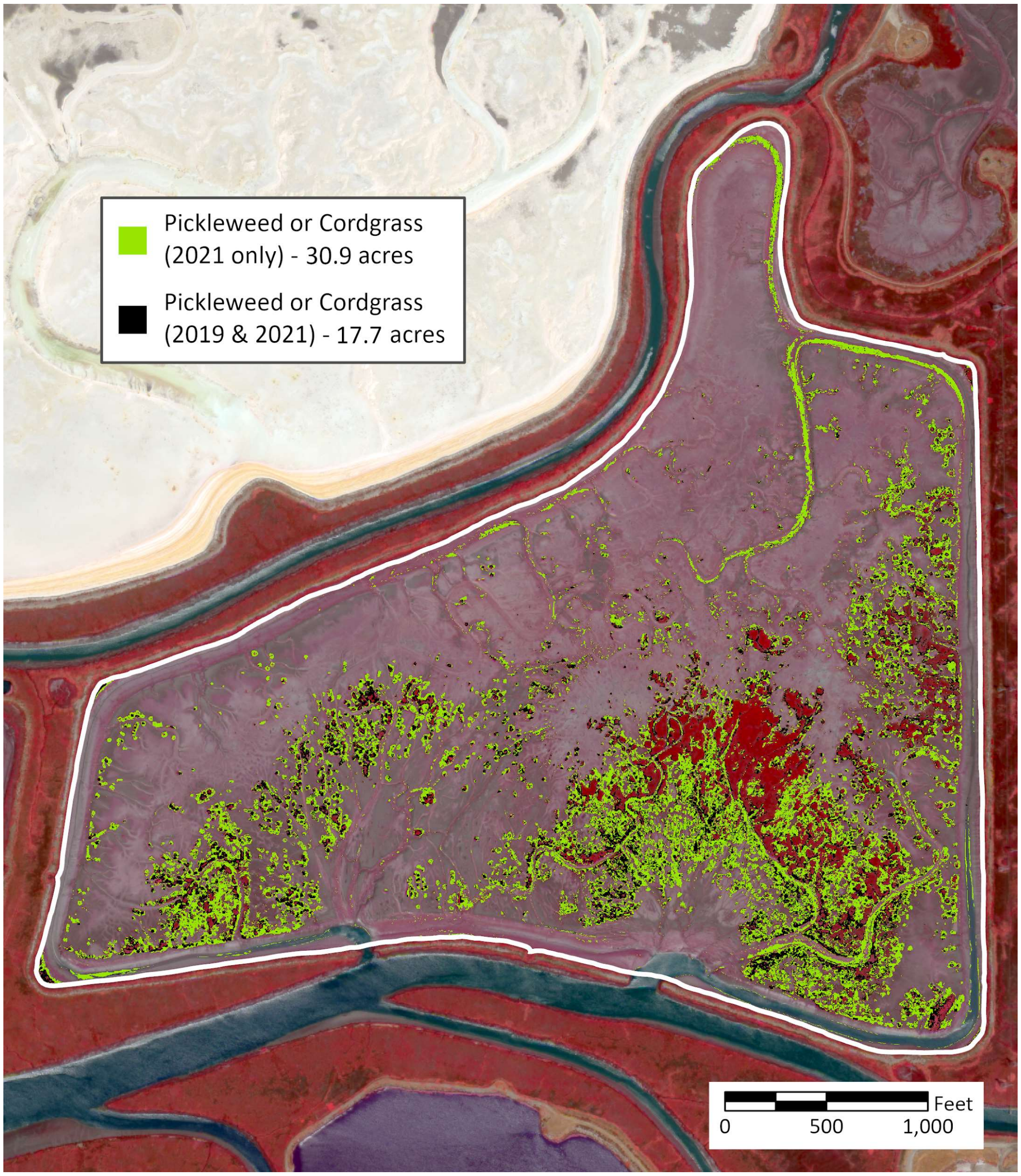


Figure 16: Mapped mudflat floral colonization for A19

Pond A17

Compared to the other restored ponds in Alviso, the rate and amount of floral colonization and growth of vegetative habitats in A17 were significantly lower. Between 2019 and 2021, there was about 1 acre of net growth of Pickleweed within A17. There were also about 3 acres of mudflat colonized by Pickleweed during this same time period. The difference can be accounted for by the slightly under 2 acres mapped as Pickleweed in 2019 that mapped as mudflat in 2021. Although a tide gauge was installed in 2005, pond A17 was not breached until 2012, after the end of HEMP1 (2011). Unfortunately, there has not been a significant amount of floral colonization within A17 since 2012.

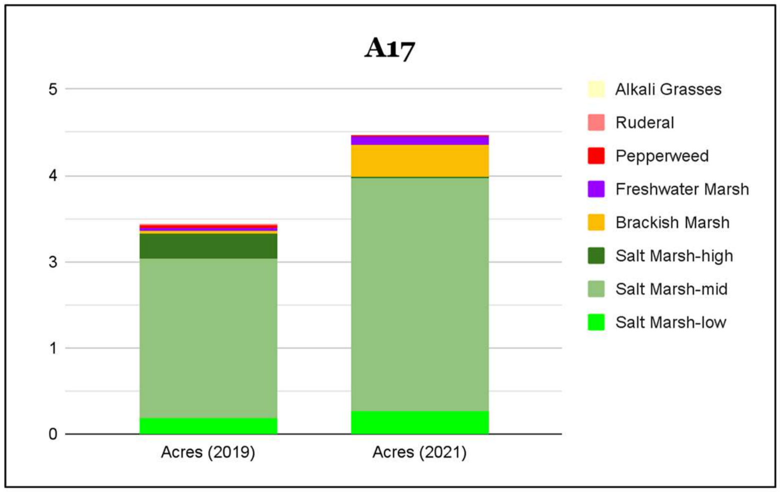
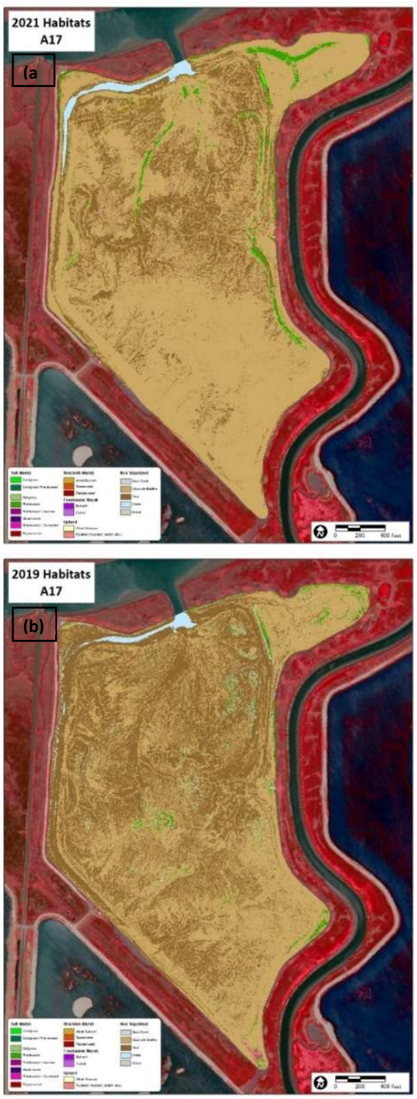


Figure 17: Acreage by Habitat Type for A17 (2019 & 2021)



Map 10a-b: Mapped habitats for A17 (2019 & 2021).

Table 18: Acreage by Habitat Type for A17 (2019 & 2021)

A17			
	Habitat Type	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	0.24	0.33
	Salt Marsh-mid	2.30	3.38
	Salt Marsh-high	0.37	0.03
	Brackish Marsh	0.04	0.46
	Freshwater Marsh	0.04	0.12
	Pepperweed	0.04	0.01
	Ruderal	0.02	0.01
	Alkali Grasses	0.00	0.00
	Biotic total	3.05	4.34
abiotic habitats	Mudflat	125.57	125.62
	Wrack (or dead veg)	0.47	0.00
	Bare Earth	0.13	0.01
	Water	2.33	1.60
	Abiotic total	128.50	127.23
	Grand Total	131.55	131.57

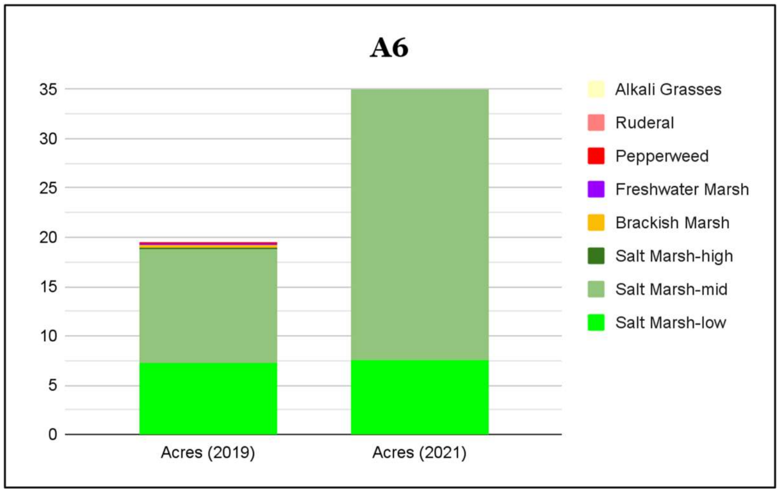


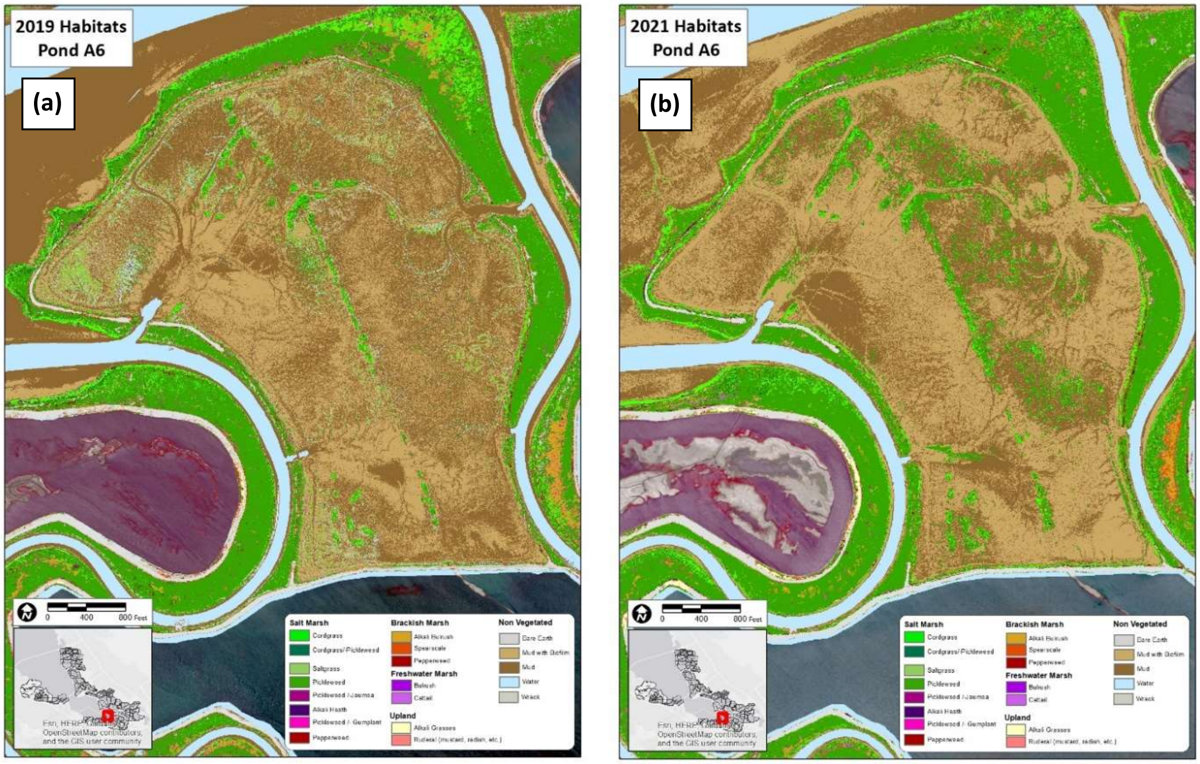
Figure 18: Acreage by Habitat Type for A6 (2019 & 2021)

Table 19: Acreage by Habitat Type for A6 (2019 & 2021)

A6			
Habitat Type		**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	7.29	7.61
	Salt Marsh-mid	11.50	29.18
	Salt Marsh-high	0.18	0.08
	Brackish Marsh	0.23	0.53
	Freshwater Marsh	0.23	0.30
	Pepperweed	0.02	0.12
	Ruderal	0.00	0.08
	Alkali Grasses		0.00
	Biotic total	**19.45**	**37.90**
abiotic habitats	Mudflat	324.88	319.07
	Wrack (or dead veg)	0.19	0.09
	Bare Earth	0.04	0.02
	Water	12.96	0.44
	Abiotic total	**338.07**	**319.63**
	Grand Total	**357.53**	**357.53**

Pond A6

Within A6, Pickleweed almost tripled (from 9 to 25 acres) between 2019 and 2021, with a net increase of 16 acres (see Table 19 and Figure 20). During this same time period, about 20 acres of mudflat within A6 were colonized by Pickleweed between 2019 and 2021 (see Map 11a-b). This indicates that about 4 acres of pickleweed in other locations did not retain density between years and/or Cordgrass was more prominent. There was no net increase of Cordgrass classes between years since the small decrease in Cordgrass is almost exactly accounted for by the increase of Cordgrass / Pickleweed. The significant amount of Pickleweed (and to a lesser degree Cordgrass) colonizing mudflats between years (20 acres) is shown in Figure 21 (green is the new area in 2021 while black is the area of Pickleweed mapped in both 2019 and 2021).



Map 11a-b: Mapped habitats for A6 (2019 & 2021)

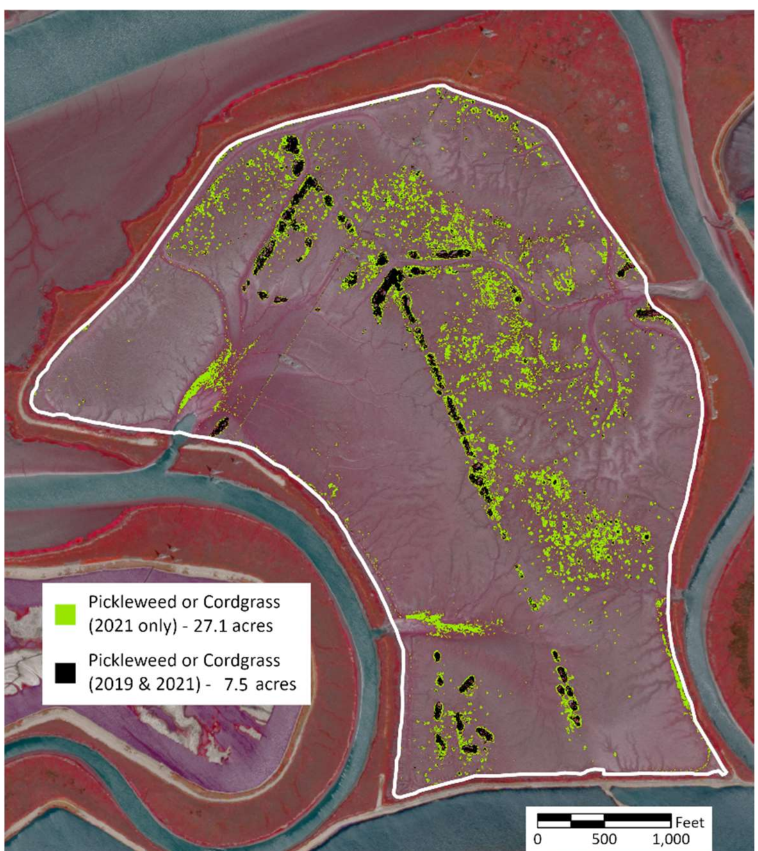


Figure 19: Mapped mudflat floral colonization for A6

2.5 Ravenswood

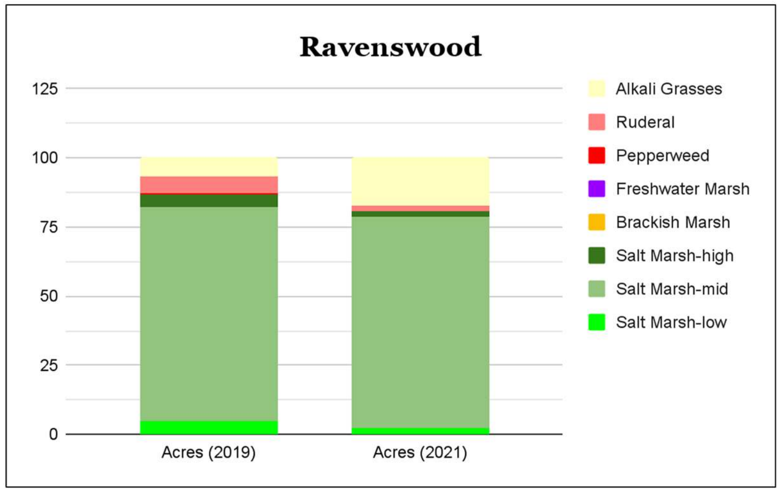


Figure 20: Acreage by Habitat Type for Ravenswood (2019 & 2021)

Within the Ravenswood restoration unit, the marsh habitats and mudflats are almost entirely outside of ponds already or undergoing enhancement or restoration. Pond SF2 was enhanced in 2010 for bird habitat. Pond R4 began restoration during the first year of HEMP2 (2019) and was still underway in 2021. Pond R5 and S5 are also currently undergoing enhancement to complement the restoration at R4. The remaining ponds are currently being managed by SBSP and its partners for potential restoration or enhancement in the future. We have excluded the area within these ponds undergoing restoration or enhancement (or being managed) from our final datasets and the figures and tables below. Based on the boundary we are using for the Ravenswood unit, the marsh within Ravenswood slough is the only marsh and mudflats being mapped (in addition to the enhanced area within SF2).

Table 20: Acreage by Habitat Type for Ravenswood (2019 & 2021)

Ravenswood			
	Habitat Type	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	4.7	2.4
	Salt Marsh-mid	77.3	76.5
	Salt Marsh-high	4.5	1.9
	Brackish Marsh	0.1	0.0
	Freshwater Marsh	0.0	0.0
	Pepperweed	0.6	0.0
	Ruderal	6.0	2.0
	Alkali Grasses	6.9	17.5
	Biotic total	**100.2**	**100.4**
abiotic habitats	Mudflat	46.0	90.0
	Wrack (or dead veg)	13.9	0.3
	Bare Earth	100.3	109.4
	Water	152.7	113.0
	Abiotic total	**313.0**	**312.8**
	Grand Total	**413.2**	**413.2**

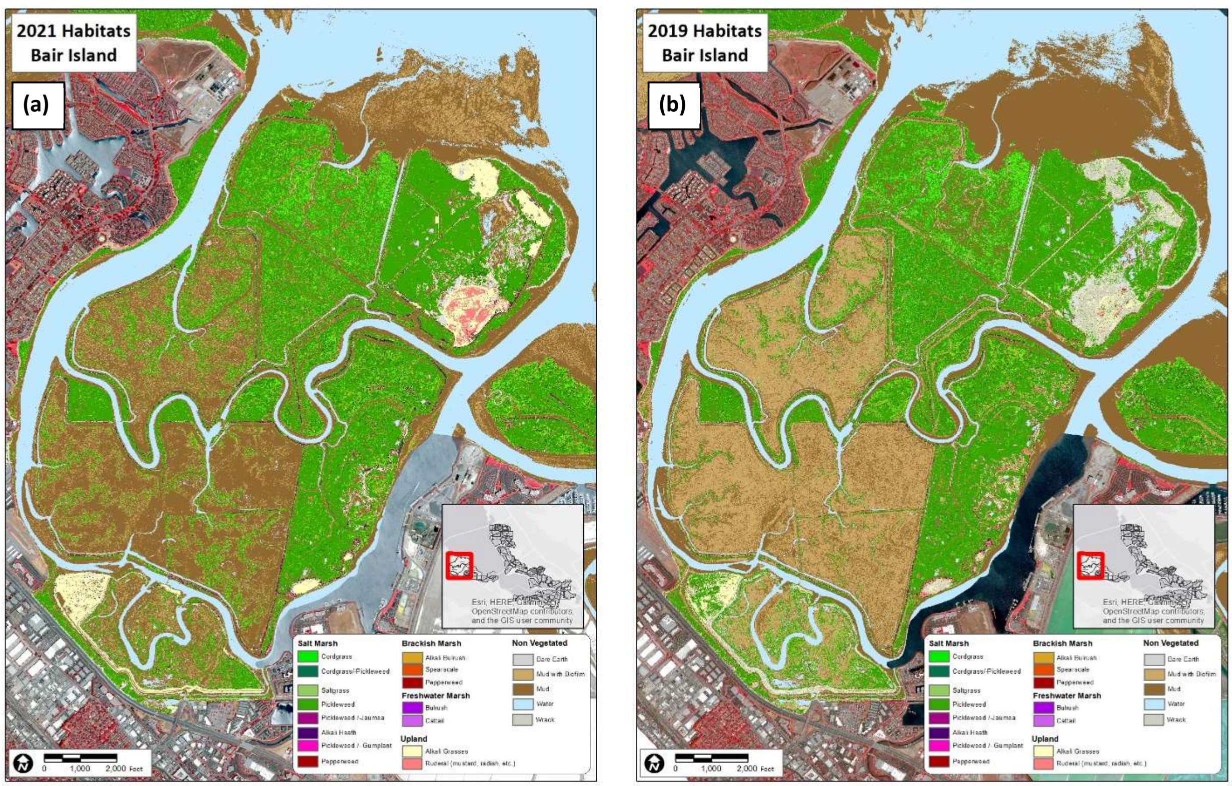
Higher tide is at least partially to blame for the reduction in low marsh (~2.3 acres) in between 2019 and 2021. There is a very small reduction (1 %) in mid marsh (i.e., Pickleweed, Jaumea, and Saltgrass) that is likely simply a result of tidal, phenological, and/or radiometric differences.

However, high marsh within Ravenswood slough appears to have been reduced by half (4.5 to 2 acres) between 2019 and 2021, despite the presence of robust Gumplant channels along Ravenswood slough (see Maps 23a and 23b). Alkali heath dropped from 0.9 to 0.4 acres within the same time period. Gumplant dropped by 2 acres (from 3.6 to 1.5 acres). This “reduction” in both high marsh habitats could at least partially be due to the variability in phenology between years. As detailed in the change analysis section below, the acreage of Gumplant within Ravenswood slough has fluctuated over the time period of the two projects and 2021 acres are still higher than both 2009 and 2010.

2.6 Select Marshes

Bair Island

The majority of changes at Bair Island occurred within the restored ponds in both Outer and Middle Bair as well at Inner Bair Island. The rate of floral colonization at these two restored ponds appears to have increased between 2019 and 2021 when compared to the time period between the two studies (2011-2019). In addition to the extensive (mostly low or mid) salt marsh that comprise remaining parts of both Middle and Outer Bair (including the south side of corkscrew slough), there are large areas of Upland, especially in the northeastern portion of Outer Bair (see Maps 12a and 12b). Within the salt marsh on the eastern side of Middle Bair, the field surveys (mostly 2019) also indicated the presence of relatively large patches of *Limonium ramosissimum*, which were mapped as part of the Ruderal classification. Similar large patches of Algerian Sea Lavender were identified in the southwestern part of Greco Island.



Map 12a-b: Mapped habitats for Bair Island (2019 & 2021)

At Inner Bair, which was opened to tidal action between 2011 and 2019, the interior of the island has developed into either mudflat or salt marsh. This area is dominated by Pickleweed with some Cordgrass (see Map 13a-b) and even small patches of Gumplant or Alkali Heath, with high marsh doubling between 2019 and 2021 (see Figure 21 and Table 21). On the western side of the island, there is also a large upland area, dominated by Alkali Grasses in 2021. Although it appears there has been a 23% (18 acres) drop in mid marsh (i.e., Pickleweed) between 2019 and 2021 (and a consequent doubling of Alkali Grasses), all of this change occurs within this upland area, as the restoration was ongoing.

Inner Bair

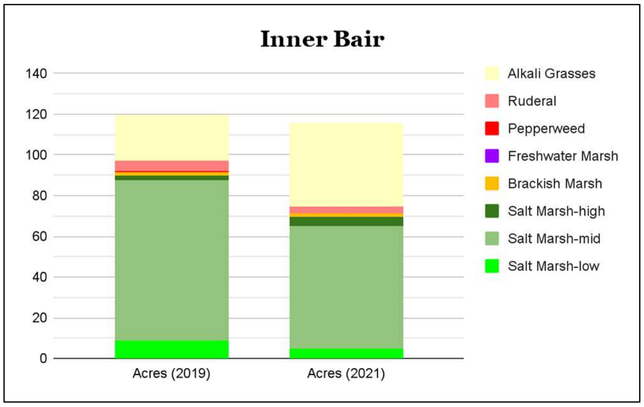
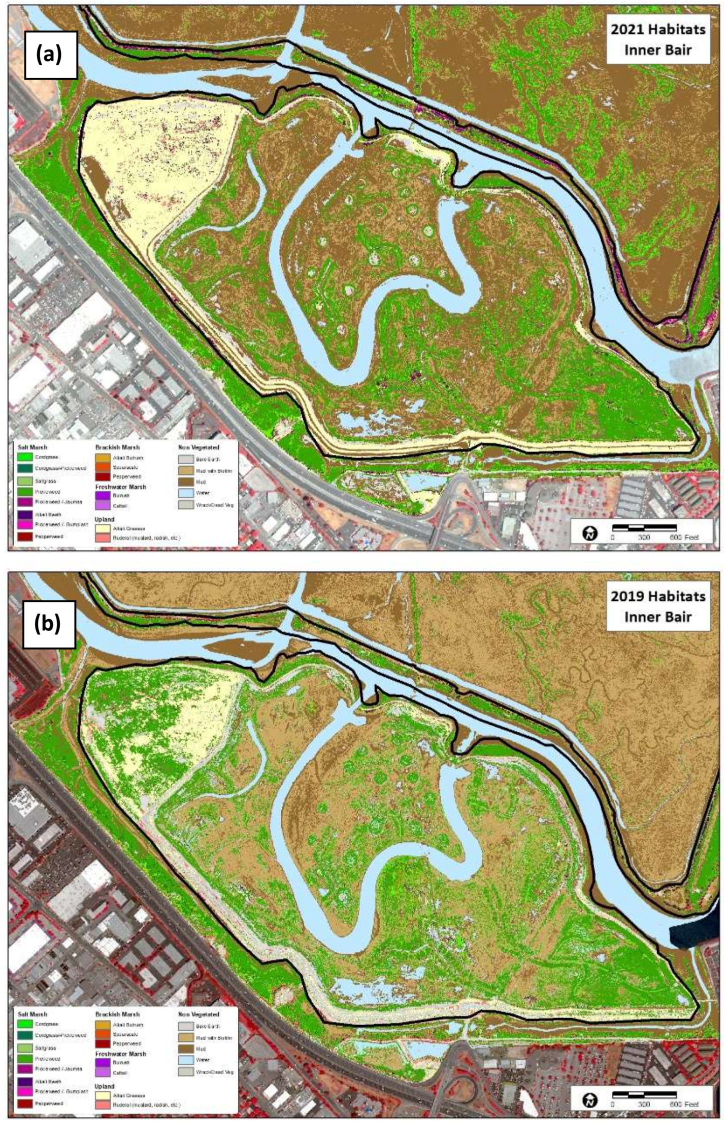


Figure 21: Acreage by Habitat Type for Inner Bair (2019 & 2021)

Table 21: Acreage by Habitat Type for Inner Bair (2019 & 2021)

Inner Bair			
	Habitat Type	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	8.63	5.10
	Salt Marsh-mid	78.82	59.86
	Salt Marsh-high	2.27	4.51
	Brackish Marsh	1.78	1.68
	Freshwater Marsh	0.04	0.00
	Pepperweed	0.43	0.12
	Ruderal	5.27	3.34
	Alkali Grasses	22.51	40.91
	Biotic total	**119.75**	**115.52**
abiotic habitats	Mudflat	113.81	139.74
	Wrack (or dead veg)	13.39	0.70
	Bare Earth	6.45	10.85
	Water	37.42	24.02
	Abiotic total	**171.07**	**175.31**
	Grand Total	**290.82**	**290.83**



Map 13a-b: Mapped habitats for Inner Bair (2019 & 2021)

Middle Bair (restored pond only)

Between 2019 and 2021, the acreage of low salt marsh (i.e., Cordgrass and Cordgrass /- Pickleweed) increased by more than 4X and mid salt marsh (i.e., Pickleweed, Jaumea, and Saltgrass) more than doubled (see Figure 22 and Table 22). The degree of floral colonization during the time period of the study was significant (see Map 14a-b). The area of change between years is highlighted in Figure 23 (see below), with the new vegetation show in green (~48 acres) and the vegetation consistent between years (~14 acres) shown in black. The floral colonization of continued mostly to expand outward from channels, as denser and larger mats of Pickleweed (and Cordgrass) appear to be forming.

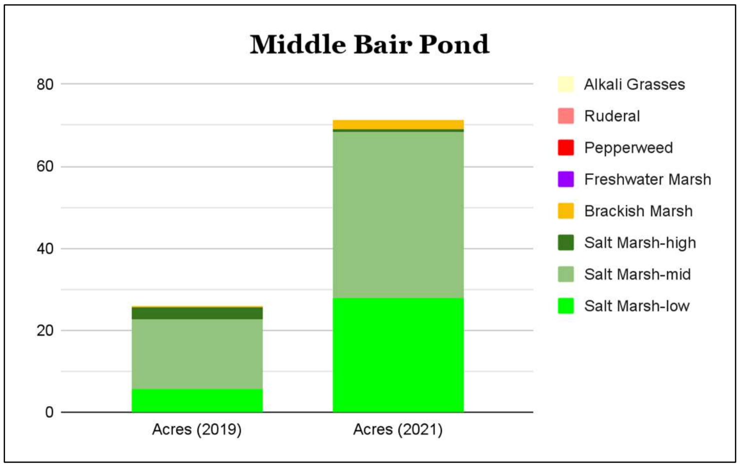
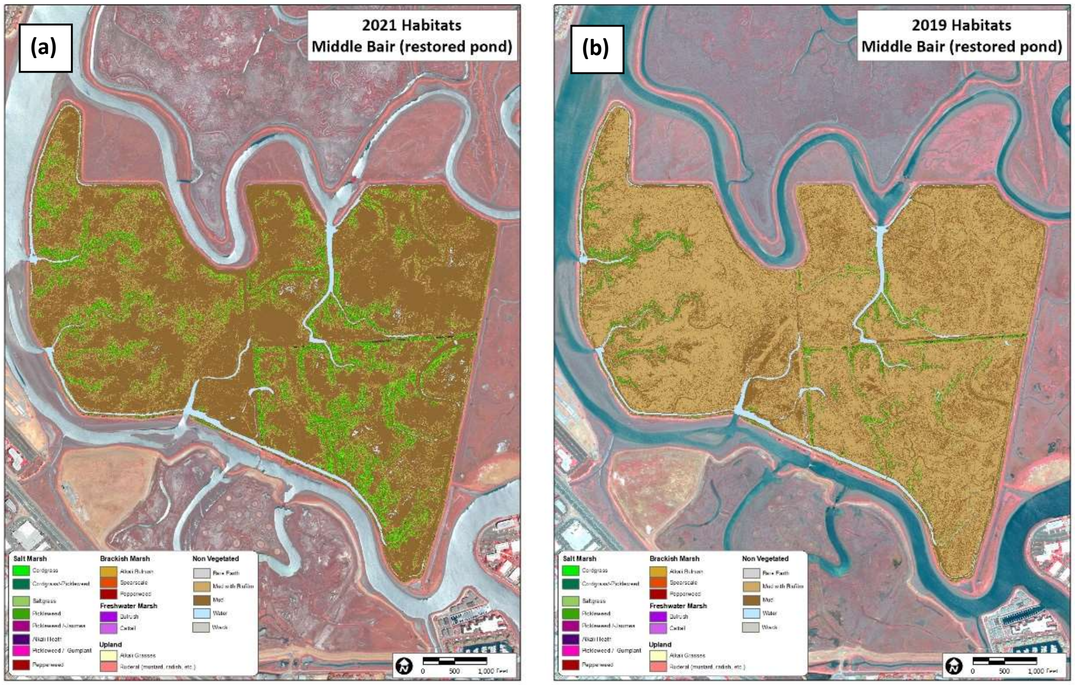


Figure 22: Acreage by Habitat Type for Middle Bair Pond (2019 & 2021)

Table 22: Acreage by Habitat Type for Middle Bair Pond (2019 & 2021)

Middle Bair Pond			
	Habitat Type	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	5.78	27.94
	Salt Marsh-mid	17.07	40.41
	Salt Marsh-high	2.86	0.69
	Brackish Marsh	0.16	2.27
	Freshwater Marsh	0.00	0.00
	Pepperweed	0.08	0.04
	Ruderal	0.03	0.04
	Alkali Grasses	0.00	0.02
	Biotic total	**25.97**	**71.41**
abiotic habitats	Mudflat	611.92	568.86
	Wrack (or dead veg)	0.01	0.00
	Bare Earth	1.65	1.80
	Water	21.69	19.16
	Abiotic total	**635.27**	**589.83**
	Grand Total	**661.24**	**661.24**



Map 14a-b: Mapped habitats for Middle Bair Pond (2019 & 2021)

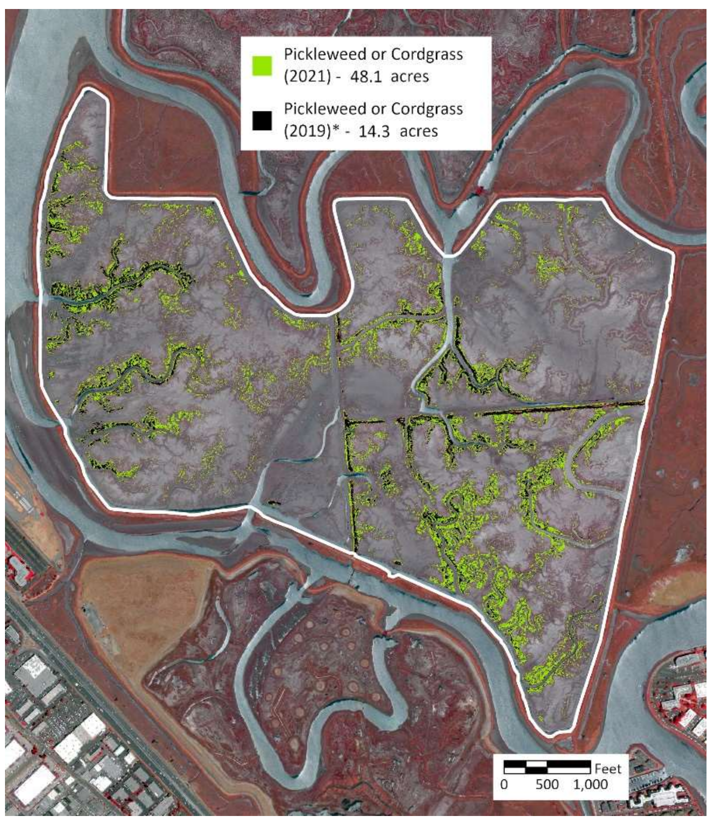


*Figure 23: Mapped mudflat floral colonization for Middle Bair Pond. *For visualization purposes, we included all mapped pickleweed and cordgrass for 2019. A very small area of pickleweed or cordgrass in 2019 mapped as other habitat classes in 2021.*

Outer Bair (restored pond only)

The changes at the restored pond in Outer Bair are similar to Middle Bair (see Figure 24 and Table 23), with acreages of Pickleweed (along with other mid salt marsh species) more than doubling (from 32 to 76 acres). The floral colonization apparent along mudflat channels in 2019 had expanded significantly by 2021, creating larger mats of Pickleweed and Cordgrass (see Map 15a-b). The area of change between years is highlighted in Figure 25 (see below), with the new vegetation show in green (~48 acres) and the vegetation consistent between years (~37 acres) shown in black.

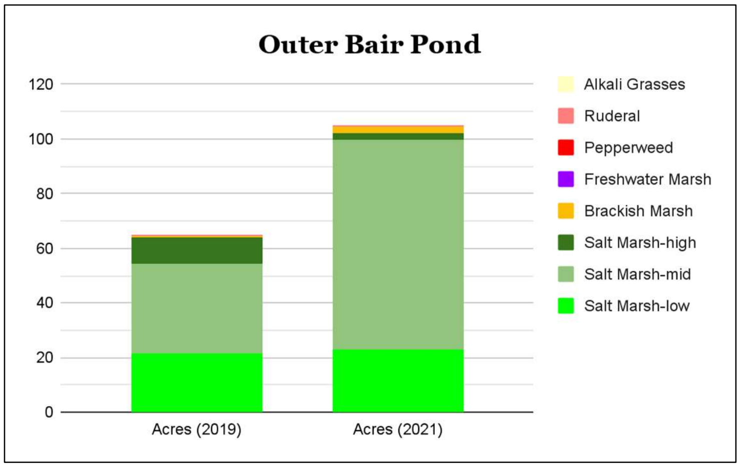
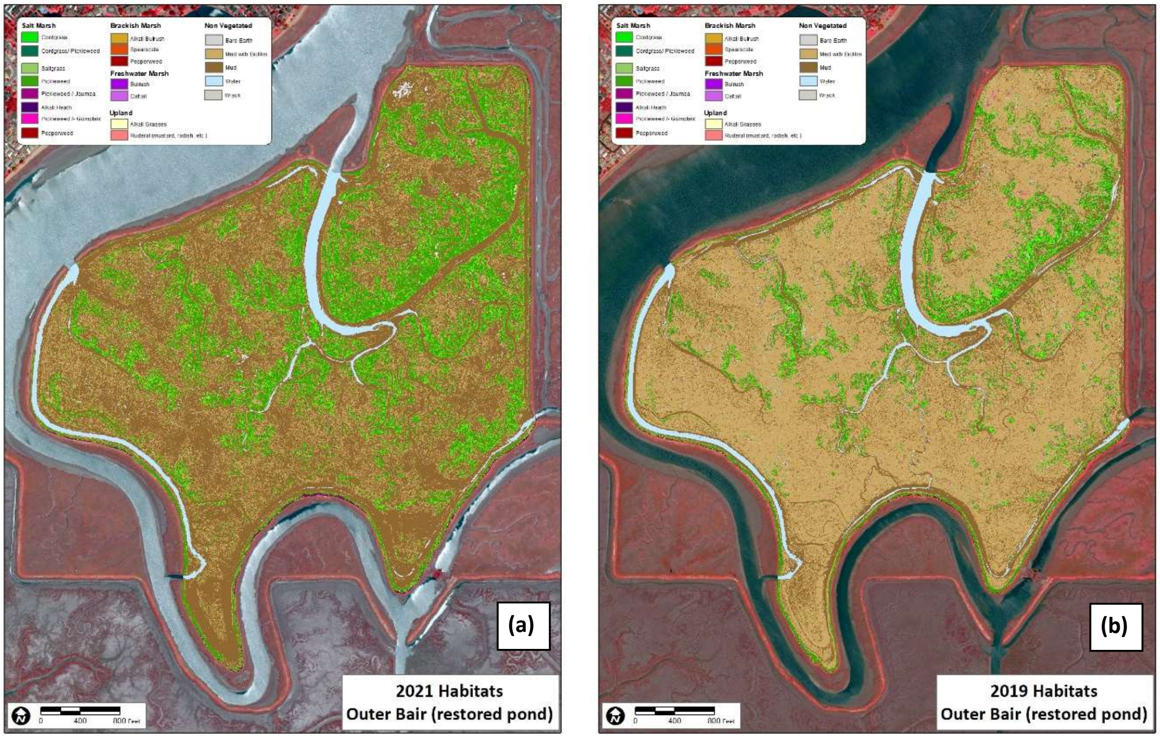


Figure 24: Acreage by Habitat Type for Outer Bair Pond (2019 & 2021)

Table 23: Acreage by Habitat Type for Outer Bair Pond (2019 & 2021)

Outer Bair Pond			
Habitat Type		Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	21.62	23.23
	Salt Marsh-mid	32.81	76.67
	Salt Marsh-high	9.67	2.00
	Brackish Marsh	0.24	2.80
	Freshwater Marsh	0.00	0.00
	Pepperweed	0.21	0.03
	Ruderal	0.26	0.26
	Alkali Grasses	0.01	0.20
	Biotic total	**64.82**	**105.19**
abiotic habitats	Mudflat	320.03	287.03
	Wrack (or dead veg)	0.03	0.01
	Bare Earth	1.14	2.99
	Water	22.57	13.37
	Abiotic total	**343.77**	**303.40**
	Grand Total	**408.59**	**408.59**



Map 15a-b: Mapped habitats for Outer Bair Pond (2019 & 2021)

Figure 25: Mapped mudflat floral colonization for Outer Bair Pond

2.7 Mud Flats

Within the study area, there were a total of **17,542 acres of mudflats in 2019** and 16,014 acres in 2021 (see Table 24). The 2019 results, which have been revised since the preliminary report, provide an excellent baseline for monitoring mudflats in the south bay. However, since the 2021 satellite image was taken at +0.41 MLLW, it should not be used for comparison. We obtained another satellite image in 2016 (Fulfrost, B., 2017) that was captured at a nearly identical tide to 2019 (see Table 25). As a result, both 2016 and 2019 can be used for comparing mudflat acreages since they both encompass the full extent and distribution of mudflats within the study area.

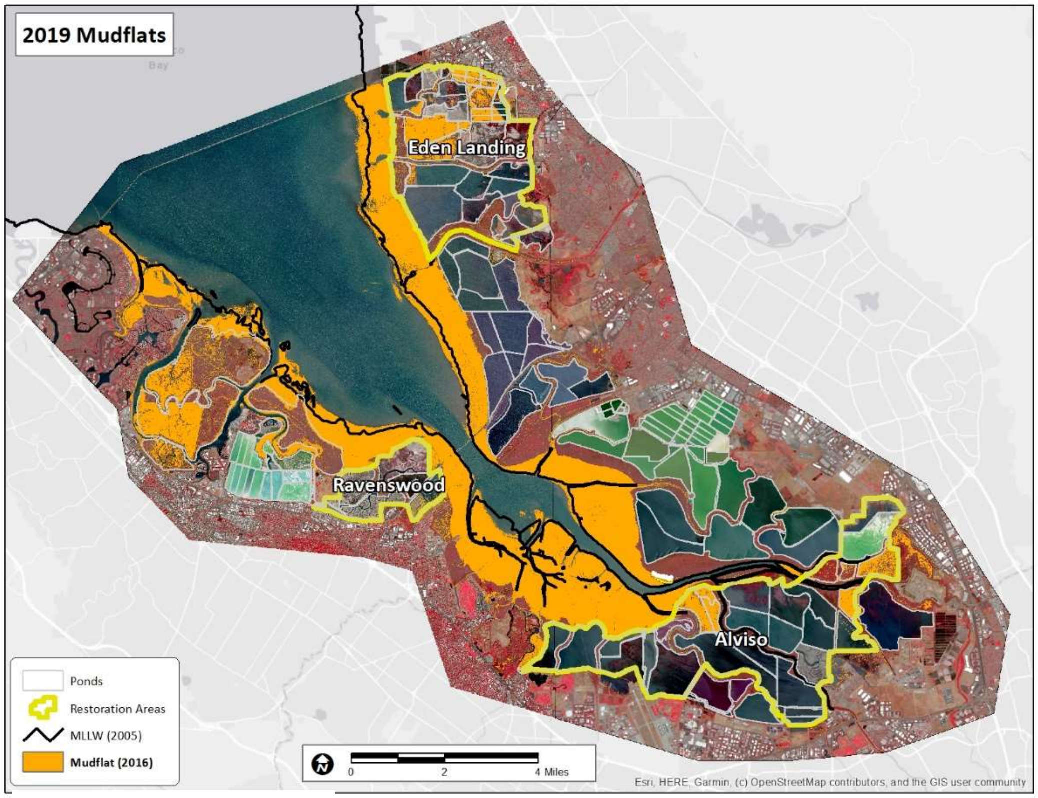
Table 24: Mudflat Acreage (2016, 2019, 2021)

	2016 (acres)*	2019 (acres)	2021 (acres)**
bay/slough	14,413	13,773	11,989
pond/wetland	4,022	3,769	4,024
Total	**18,435**	**17,542**	**16,014**

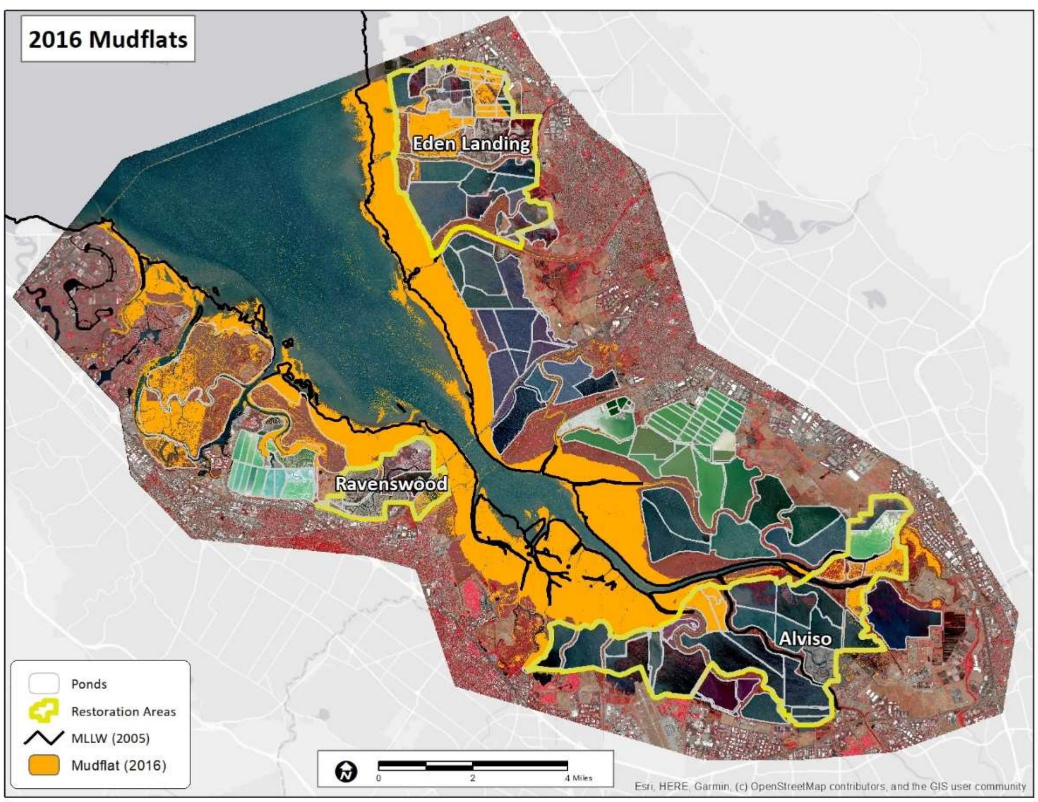
* The 2016 mudflats have not been 'cleaned' based on improvements form HEMP2, which would reduce the acreage of mudflats within the bay/slough but these changes are likely too small to make any significant impact on acreage trends.
** The 2021 imagery was not taken at MLLW (+0.41 ft) and therefore is an undercount.

Despite a 4% decrease (640 acres) between 2016 and 2019 in acres of mudflats exposed to the bay or within sloughs (i.e., bay/slough), the extent and distribution of these tidal mudflats appear to be relatively unchanged from 2016 (see Map 16 and Map 17). Without data for other years, it is impossible to determine if this is a longer-term trend or simply represent some type of interannual variability. The differences in acreages between 2016 and 2019 could be a result of a number of factors, including: (a) slight differences in how we extracted mudflats from our unsupervised classification and NDWI (see Methods – Mudflat Model), which resulted in a slightly larger mudflat edge in 2016; (b) interannual tidal variability; or (c) floral colonization of bay exposed mudflats (e.g., Coyote Creek (above A6), on the south side of Ogilvie Island, and in Calavares marsh). Since there is now a good baseline, mapping mudflat extent at regular intervals (e.g., every 5-10 years) can give a better understanding of long-term trends.

There was also a corresponding 6% decrease (253 acres) in mudflats within ponds and wetlands between 2016 and 2019. This reduction of mudflats within the ponds and wetlands is to be expected since it is the corollary of floral colonization within restored ponds (notably in the Island Ponds, E9/E8A, and old Baumberg tract). There was also a significant decrease in mudflats at pond SF2 between 2016 and 2019. This difference is likely due to the managed tide gate at that pond. Decrease in mudflats in restored ponds is also to be expected where floral colonization is targeted. The increase in the acreage



Map 16: 2019 Mudflats



Map 17: 2016 Mudflats

of mudflats within ponds and wetlands from to 2019 to 2021 were almost entirely where water in one year (2019) was mapped as mudflat (2021) in the other.

The extent and distribution of mudflats from both 2019 and 2016 also show a general spatial correspondence with MLLW line from 2005 provided by the USGS (Jaffee, B. & Foxgrover, A., 2006). In some locations, such as along the eastern shore of the bay above the Dumbarton bridge, mudflats that are directly facing the bay appear to have grown when compared to the 2005 MLLW line (see Map 16 and Map 17). There is also a possible sign of erosion, in the central part of the bay, south of the Dumbarton bridge.

Although tidal mudflats directly exposed to the bay remain relatively unchanged since 2016, there are some localized areas with evidence of accretion and/or erosion. On the western side of Alviso slough, the pickleweed marsh has grown approximately 6 meters since 2011 in some locations, with a subsequent decrease in the narrow mudflat that is contiguous to the fringe marsh. That trend toward the marsh expanding on to the narrow mudflat appears to be continuing in 2021. There was also up to 60 meters of erosion between 2016 and 2019 in the mudflat at the mouth of Mowry slough. However, this erosion is very linear and localized (i.e., *not* a large area). When compared to 2005, there are also possible locations of both erosion and accretion in the mudflats at the “center” of the bay, south of Dumbarton bridge. On the southern side of A6, just west of the breach, there appears to be a small portion of mudflat eroding compared to 2016, creating a ‘broad’ notch. On the west side of Ogilvie Island, there is a very small “notch” of erosion has appeared since 2011, despite mudflats accreting between the island and the marsh on it is the south side. At least some of the change at these locations could be “normal” interannual or even seasonal variability.

Table 25: Tide Values for April 13th, 2016; June 8th, 2019; June 15th, 2021

	2016 (April 13th)	**2019 (June 8th)**	**2021 (June 15th)**
Tide (MLLW) @ Redwood City Tide Gauge (9414523)	**- 0.16 ft**	**- 0.18 ft**	**+ 0.41 ft**

In the first HEMP study (2009-2011), we did not obtain satellite imagery at MLLW. As a result, we cannot use the acreages and maps of mudflat extent to analyze change to mudflats in 2019. However, in 2016 we obtained an image close to MLLW with the Worldview-3 satellite sensor (nearly identical spectrally to the 8 bands in Worldview-2 used for HEMP2). The timing of the image with MLLW, in combination with the increased spectral resolution of these sensors, allowed us to develop techniques to map mudflats, even under shallow water. We used these same techniques to successfully map mudflats in both 2021 and 2019. These techniques (Fulfrost, B., 2017) are focused on mapping the extent and distribution of mudflats and not in identifying biofilm on the mudflats. We continue to map biofilm using pixel based supervised classification as part of our habitat classification.

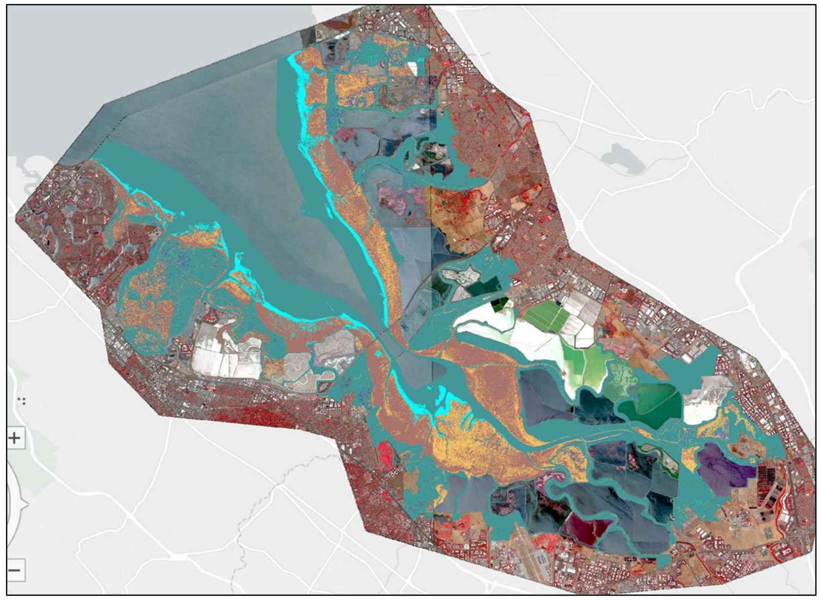


Figure 26: Difference (reduction) in Mudflat from 2019 to 2021 (highlighted in blue).

In 2021, the majority of the days that we could acquire imagery were in the Spring, with very few or no days between July and August. Based on feedback from stakeholders, and in conjunction with the Project Management Team (PMT), we decided to prioritize the latest date possible in the hopes to gain vegetation closer to peak fluorescence (e.g., Cordgrass), even if it was not at optimal tide level. The justification was that the project had already obtained an excellent tide level for mapped mudflats at their full extent in 2019. As a result, the 2021 imagery is not a good measure of the full extent of mudflat in the bay. Any changes to mudflats between 2021 and 2019, especially in the bay/slough category, are largely due to these tidal differences and not a measure of real change in mudflat extent. Not surprisingly, close to two thousand acres mapped as mudflat in 2019 in the bay or sloughs mapped as water in 2021 (see Figure 26). The area highlighted in blue is a measure of the mudflat inundated with water as a result of the 0.59 foot difference between the tides on these two dates.

Mudflat with Biofilm

The results from both 2019 and 2021 indicate that biofilm is predominate within restored ponds, as well as on large mudflats found within sloughs. This is true in A20, A19, A6, Bair Island, Palo Alto lagoon, E9, E8A, North Creek, and Mt Eden Creek Marsh. Interestingly, although we captured the study area at MLLW in 2019, the extent of biofilm mapped on bay exposed mudflats was significantly less than in 2021, when the tide was higher. It is possible that the mudflats in 2021 had longer exposure time to the sun and therefore diatoms and other microphytobenthos are more apparent. In previous years we suggested that biofilm was more apparent on mudflats closer to the edge of the marsh because they had more time for the tide to recede and therefore for microphytobenthos and diatoms to emerge. Even at those locations where mudflat was classified as not having biofilm, it is possible that there were lower densities or different species of biofilm that are harder to distinguish in our classifications. Unfortunately, differences in tidal exposure between our ground truthing and time and day of image acquisition made it difficult to accurately validate the presence (or absence) of biofilm. Since we did not focus on ground truthing mudflats (and biofilm) on day of satellite flyover, our field team’s ability to assess mudflat with biofilm in situ, especially at offset distances, was not always as great as the ability to identify biofilm directly in the false color imagery itself.

2.8 Accuracy Assessment (2021 and 2019)

We built error matrices to evaluate how well our mapped classification matched our validation sample. Results (see Tables 26 – 29) indicate that the overall accuracy of the final habitat datasets in both 2019 and 2021 more than met our accuracy goal (of at least 70%) both at the dominant habitat alliance (2021: 84%; 2019: 85%) and habitat association level (2021: 78%; 2019: 80%). Since we have significantly reduced the mapped vegetation associations, mostly sub-dominant associations of alkali bulrush, it is not surprising to see this increase in overall accuracy especially at the *association* level (accuracy for tidal marshes at this level was 61% in 2011, 66.8% in 2010; and 56% in 2009).

The goal of the accuracy assessment was to provide a metric to evaluate how close the mapped classifications were to the habitats on the ground. Our target sample sizes for statistical validation were based on the relative proportion of broad marsh habitat types (salt, brackish, and fresh) that comprised the entire study area. Most habitats at the Alliance level exceeded the accuracy of the overall model for both years, including Cordgrass, Pickleweed, Gumplant, and Alkali Bulrush.

We have included below (see Tables 26 – 29) the error matrices used for quantifying the statistical accuracies of our habitat classifications for both 2019 and 2021. The tables include accuracy assessments for habitats at both the habitat alliance and habitat association level. The association error matrix includes all the habitat classification used in our model, shown in all the maps, and in the final datasets. As in the first mapping report (09-11), we found the best accuracy for our habitat classifications for both 2019 and 2021 at the Alliance level. Our improved overall accuracy is partially due to not mapping many of the inaccurate vegetation associations (e.g., Alkali Bulrush /- Pickleweed) used during the first HEMP study. As a result, there is a lot less difference between our Alliance (15 classes) and Association (19 classes) level error matrices. Significantly, we did not map any vegetation associations with Alkali Bulrush, since previous work indicated the low level of accuracy associated with mapping these associations. Although we mapped Spearscale (*Atriplex spp.*) only as an association with Alkali Bulrush in previous years, it appeared to have significantly wider distribution in both 2019 and 2021 when compared to previous years. As a result, it has been given its own habitat category. However, for some vegetation communities, including Pickleweed /- Gumplant, Pickleweed /- Jaumea, and Cordgrass /- Pickleweed, we continued to map these habitats at the association level because these were essential for differentiating low, “mid” high, and high salt marsh (see Table 1).

We created standard error matrices for habitats at both the Alliance and Association level. These matrices (see Tables 26 – 29) allow us to evaluate the statistical accuracy of the classified results by comparing habitats obtained from our ground truthing with habitats classified by our model. Matrices calculate a number of values that can be used to assess the accuracy of the model (see Appendix 2), including the *Kappa* statistic. In evaluating our model results, we focus on 1) overall accuracy, which tells us how well the classified results matched our ground truthing for all habitats; 2) “producer’s” accuracy for each habitat, which tells us how well our classified results matched our ground truthing for a particular habitat; 3) “user's” accuracy, which essentially tells us how often the class on the map will actually be present on the ground; and 4) the *Kappa* statistic. Kappa evaluates how well the classification performed as compared to just randomly assigning values (i.e., did the classification do better than random). Values close to 1 indicate that the classification is significantly better than random.

Table 26: Error Matrix (2021) - Alliance Level

		Classified Data																
		Alkali Bulrush	**Alkali Grasse**	**Alkali Heath**	**Bare Earth**	**Cattails**	**Cordgrass**	**Freshwater Bulrush**	**Gumplant**	**Mudflat**	**Pepperweed**	**Pickleweed**	**Ruderal**	**Saltgrass**	**Spearscale**	**Water**	Producer's Accuracy	
Reference Data	**Alkali Bulrush**	18										1					*19*	**95%**
	Alkali Grasses	1	8														*9*	**89%**
	Alkali Heath			12								6	1				*19*	**63%**
	Bare Earth				1												*1*	**100%**
	Cattails	1				2											*3*	**67%**
	Cordgrass						21					4					*25*	**84%**
	Freshwater	2				4		1				1					*8*	**13%**
	Gumplant	1							8			1					*10*	**80%**
	Mudflat									16							*16*	**100%**
	Pepperweed	1		1							13				1		*16*	**81%**
	Pickleweed	2		1			1					102			1		*107*	**95%**
	Ruderal											1	7				*8*	**88%**
	Saltgrass											2	1	6			*9*	**67%**
	Spearscale	1					1					6			6		*14*	**43%**
	Water															2	*2*	**100%**
		27	*8*	*14*	*1*	*6*	*23*	*1*	*8*	*6*	*13*	*124*	*9*	*6*	*8*	*2*	Overall Accuracy	
	User's Accuracy	**67%**	**100%**	**86%**	**100%**	**33%**	**91%**	**100%**	**100%**	**100%**	**100%**	**82%**	**78%**	**100%**	**75%**	**100%**	***84%* (266)**	

Overall Accuracy: 0.84
Expected Accuracy: 0.22
Kappa: 0.79

Table 27: Error Matrix (2021) - Association Level

		Classified Data																			
		Alkali Bulrush	**Alkali Grasses**	**Alkali Heath**	**Bare Earth**	**Cattails**	**Cordgrass**	**Cordgrass /- Pickleweed**	**Freshwater Bulrush**	**Gumplant**	**Jaumea**	**Mudflat**	**Mudflat w/ Biofilm**	**Pepperweed**	**Pickleweed**	**Ruderal**	**Saltgrass**	**Spearscale**	**Water**	Producer's Accuracy	
Reference Data	**Alkali Bulrush**	18													1					*19*	**95%**
	Alkali Grasses	1	8																	*9*	**89%**
	Alkali Heath			12							2				4	1				*19*	**63%**
	Bare Earth				1															*1*	**100%**
	Cattails	1				2														*3*	**67%**
	Cordgrass						12	6							3					*21*	**57%**
	Cordgrass /- Pickleweed						1	2							1					*4*	**50%**
	Freshwater Bulrush	2				4			1						1					*8*	**13%**
	Gumplant	1								8					1					*10*	**80%**
	Jaumea	2		1			1				8				5					*17*	**47%**
	Mudflat											6	3							*9*	**67%**
	Mudflat w/ Biofilm												7							*7*	**100%**
	Pepperweed	1		1										13				1		*16*	**81%**
	Pickleweed														89			1		*90*	**99%**
	Ruderal														1	7				*8*	**88%**
	Saltgrass														2	1	6			*9*	**67%**
	Spearscale	1					1				1				5			6		*14*	**43%**
	Water																		2	*2*	**100%**
		27	*8*	*14*	*1*	*6*	*15*	*8*	*1*	*8*	*11*	*6*	*10*	*13*	*113*	*9*	*6*	*8*	*2*	Overall Accuracy ***78%*** *(266)*	
	User's Accuracy	**67%**	**100%**	**86%**	**100%**	**33%**	**80%**	**25%**	**100%**	**100%**	**73%**	**100%**	**70%**	**100%**	**79%**	**78%**	**100%**	**75%**	**100%**		

Overall Accuracy: 0.78

Expected Accuracy: 0.17

Kappa: 0.73

Table 28: Error Matrix (2019) - Alliance Level

		Classified Data																
		Alkali Bulrush	**Alkali Grasse**	**Alkali Heath**	**Bare Earth**	**Cattails**	**Cordgrass**	**Freshwater Bulrush**	**Gumplant**	**Mudflat**	**Pepperweed**	**Pickleweed**	**Ruderal**	**Saltgrass**	**Spearscale**	**Water**	Producer's Accuracy	
Reference Data	**Alkali Bulrush**	39					2					2					*43*	**91%**
	Alkali Grasses		2														*2*	**100%**
	Alkali Heath			4		1					3			1			*9*	**44%**
	Bare Earth		1		4												*5*	**80%**
	Cattails	1				8		3				1					*13*	**62%**
	Cordgrass						19		1			4					*24*	**79%**
	Freshwater	1				1		10									*12*	**83%**
	Gumplant	1							9			1					*11*	**82%**
	Mudflat									9							*9*	**100%**
	Pepperweed	2						1			10	2			2		*17*	**59%**
	Pickleweed						1					80		1			*82*	**98%**
	Ruderal												5				*5*	**100%**
	Saltgrass											1		4			*5*	**80%**
	Spearscale											4			7		*11*	**64%**
	Water															2	*2*	**100%**
		44	*3*	*4*	*4*	*10*	*22*	*14*	*10*	*9*	*13*	*95*	*5*	*6*	*9*	*2*	Overall Accuracy	
	User's Accuracy	**89%**	**67%**	**100%**	**100%**	**80%**	**82%**	**71%**	**90%**	**100%**	**77%**	**84%**	**100%**	**67%**	**78%**	**100%**	***85%** (250)*	

Overall Accuracy: 0.85

Expected Accuracy: 0.18

Kappa: 0.82

Table 29: Error Matrix (2019) - Association Level

		Classified Data																			
		Alkali Bulrush	**Alkali Grasses**	**Alkali Heath**	**Bare Earth**	**Cattails**	**Cordgrass**	**Cordgrass /- Pickleweed**	**Freshwater Bulrush**	**Gumplant**	**Jaumea**	**Mudflat**	**Mudflat w/ Biofilm**	**Pepperweed**	**Pickleweed**	**Ruderal**	**Saltgrass**	**Spearscale**	**Water**	Producer's Accuracy	
Reference Data	**Alkali Bulrush**	39					1	1							2					*43*	**91%**
	Alkali Grasses		2																	*2*	**100%**
	Alkali Heath			4		1								3			1			*9*	**44%**
	Bare Earth		1		4															*5*	**80%**
	Cattails	1				8			3						1					*13*	**62%**
	Cordgrass						9	6		1										*16*	**56%**
	Cordgrass /- Pickleweed						1	3							4					*8*	**38%**
	Freshwater Bulrush	1				1			10											*12*	**83%**
	Gumplant	1								9					1					*11*	**82%**
	Jaumea							1			6						1			*8*	**75%**
	Mudflat											1	6							*7*	**14%**
	Mudflat w/ Biofilm												2							*2*	**100%**
	Pepperweed	2							1					10	2			2		*17*	**59%**
	Pickleweed														74					*74*	**100%**
	Ruderal															5				*5*	**100%**
	Saltgrass														1		4			*5*	**80%**
	Spearscale														4			7		*11*	**64%**
	Water																		2	*2*	**100%**
		44	*3*	*4*	*4*	*10*	*11*	*11*	*14*	*10*	*6*	*1*	*8*	*13*	*89*	*5*	*6*	*9*	*2*	Overall Accuracy *80% (250)*	
	User's Accuracy	**89%**	**67%**	**100%**	**100%**	**80%**	**82%**	**27%**	**71%**	**90%**	**100%**	**100%**	**25%**	**77%**	**83%**	**100%**	**67%**	**78%**			

Overall Accuracy: 0.80

Expected Accuracy: 0.15

Kappa: 0.76

Notes on Select Habitats

The reader should be aware that accuracy results do not necessarily mean the accuracy is the same everywhere for a given mapped habitat class. As an example, the wider range of salinity and mix of (often ruderal) vegetation in the muted or managed marshes potentially produce larger inaccuracies since our habitat model focused on vegetation at locations fully exposed to tidal action. This section includes a discussion of the habitat classes that did *not* meet our accuracy goals. These habitats either did not meet the accuracy assessment goal (e.g., Freshwater Bulrush) and/or contained acreage values that seemed anomalous at one or more locations. The discussion outlines possible reasons for inaccuracy to provide guidance for interpretation.

Freshwater Bulrush and Cattail

Although our sample size for Freshwater Bulrush was smaller than desired for both years (8 in 2021, 12 in 2019), the results for Freshwater Bulrush indicate we are significantly undermapping Freshwater Bulrush in 2021 (13% user's accuracy) but not in 2019 (82%). Unfortunately, the model did not consistently differentiate our two freshwater marsh classes (Freshwater Bulrush and Cattails) in 2021. Most of what should be Freshwater Bulrush is being mapped as Cattail or Alkali Bulrush in 2021. This is further bolstered by the producer's accuracy for Cattail in 2021 (33%), which indicates the model is overmapping Cattail (which should be Freshwater Bulrush) in that year. As a result, when these two classes (Freshwater bulrush and Cattail) are combined into "Freshwater Marsh" (in 2021), the extent and distribution is a good representation of the actual acreages.

Spearscale

Unfortunately, the producer's accuracy in both 2019 (64%) and 2021 (43%) indicate we are undermapping Spearscale in both years as Pickleweed. When we reviewed the many field photos of these locations (e.g., at Alviso marina or the easternmost part of Coyote Creek), the areas of 'matted' Spearscale appear surprisingly similar to Pickleweed. As a result, the two habitats are spectrally similar. In some locations, the Spearscale also appears heavily inundated by tidal water (e.g., Alviso slough), making it even more spectrally similar to pickleweed, where there is often presence of some water.

Pepperweed

The producer's accuracy for Pepperweed in 2021 (81%) meets our accuracy standards (of 70% or better) but it is lower than our standard in 2019 (59%). This indicates that Pepperweed *might* be undermapping slightly in 2019. Although we do believe that Pepperweed has significantly reduced in density since 2009 (as well as in extent and distribution to a lesser degree), it is likely we are also undermapping Pepperweed to some degree in both years. We based this conclusion on the accuracy assessment, model/imagery QA, review of ground truthing surveys, and field photos.

Alkali Heath

The accuracy assessment indicates that we are undermapping Alkali Heath in both years (63% in 2021; 44% in 2019), although significantly less in 2021. In 2019, the unmatched surveys were mapping as Pepperweed. When fluorescent, Pepperweed and Alkali Heath are spectrally similar, providing some explanation for undermapping in 2019. However, in 2021, most of the ground surveys that did not match were mapped as Pickleweed. We believe that the relative fluorescence and density of Pickleweed, rather than spectral similarity, provides an explanation for the undermapping in 2021.

Gumplant

The error matrices indicate that Gumplant is accurately mapping in both years (80% or better). However, Gumplant did not map consistently between 2019 and 2021. After review, the 2021 results qualitatively appear to be a better estimation of the acreage, extent, and distribution of Gumplant. Even upon visual review (especially in 'false color'), the Gumplant is much more apparent (and spectrally distinct) in the 2021 image. On the other hand, Gumplant is likely overmapping in some locations in 2019. This is especially the case along slough edges and in the mid marsh plain, where it should be Pickleweed. Part of the reason we mapped two years was in case we encountered issues mapping any particular habitats. At the same time, the acreages of Gumplant in 2019 could be overestimated. We came to our conclusion about Gumplant in 2019 and 2021, at least partially by quantifying, mapping, and exploring the geographic distribution of differences between 2019 and 2021. Although there was a 156 acre drop in acreage of Gumplant between 2019 and 2021, there were 187 acres mapped as Gumplant in 2019 that mapped as Pickleweed in 2021. The vast majority (78% - 145 acres) of these 2019 Gumplant locations mapping as Pickleweed in 2021 are *outside* of the three restoration units. This indicates that Gumplant is overmapping less in 2019 within the restoration areas. Rather than Gumplant being clustered in specific locations, it is distributed in very small patches throughout the study area. Although Gumplant is mapping 156 acres more in 2019 than 2021, our review revealed that the 2019 Gumplant distributions are still missing a lot of the Gumplant mapping along channels that is accurately mapping in 2021 (e.g., at Calavares Marsh or Whale's Tail).

Saltgrass

Saltgrass is almost always sub or co dominant with other species, mostly pickleweed. A certain density of Saltgrass must be achieved (usually 25% cover or more) for it to be mapped as a unique habitat class. Despite indications that Saltgrass was undermapping in 2021 (67% producer's accuracy), there was a significant increase (152%) of Saltgrass in 2021. Fifty-seven percent (162 acres) of saltgrass mapping in 2021 mapped as Pickleweed in 2019. As noted above, the model most effectively maps saltgrass when density is high enough and is fluorescing (phenology). However, Saltgrass is often interspersed with pickleweed or other mapped habitats. As the relative phenology of different habitats shifts, it is not surprising to see similar 'shifts' between habitats between years.

Abiotic Habitats

Validation for any abiotic class heavily influenced by tides, such as mudflat, mudflat with biofilm, and water, are not very reliable due to variations in tide during the large range of days and months we obtained field surveys. We visually assessed the presence of biofilm on top of mudflats at the time of field surveys. The presence, or certainly the visual appearance, of biofilm (and mudflat itself) is influenced by the amount of water present due to tide, precipitation, and hydrologic control structures, as well as the differences between the day of a given survey and the day of image acquisition.

Section 3. Change Analysis - HEMP1 (2009-11) with HEMP2 (2019/2021)

3.1 Study Area

Despite acreage fluctuations between years and among some mapped habitat classifications, the relative acreage of most marsh habitats has remained similar between 2009 and 2021, with some notable exceptions (see Figure 27 and Table 30). There was a relatively small 3% increase in the acreage of Salt Marsh (low, mid, and high combined) between 2009 and 2021. In contrast, for some mapped classes and in certain locations like the restored ponds, there have been much larger increases. This is especially true between 2019 and 2021. Between 2009 and 2021, the acreage of low salt marsh (Cordgrass and Cordgrass /- Pickleweed) more than doubled (from 444 to 904 acres) and has trended up, despite the study area wide acreages for 2011 being skewed and a small relative decrease in 2021. There was also a 20% increase in the acreage of Alkali Bulrush (see Table 31) between 2009 and 2021. The acres of Gumplant are identical for both 2009 and 2021 (179) and at the same time the acres of Alkali Heath dropped 18% (from 238 to 193 acres). This resulted in a 10% overall decrease in the acreage of high marsh species (from 435 to 390 acres) between 2009 and 2021. However, in 2019 there were 479 acres of high marsh species, indicating a 10% increase between 2009 and 2019. At the same time, the acreages of high marsh species have fluctuated, increasing by as much as 46% between 2009 and 2010 (435 to 638 acres), and then decreasing by 25% in 2019 (to 479 acres). Our review and the original accuracy assessment indicate that the acres of high marsh species in 2010 (638) are an overcount, but not large enough of one to be ignored. The acreages of 2011 are much more highly skewed due to mapping/image issues, and we have excluded them from our review.

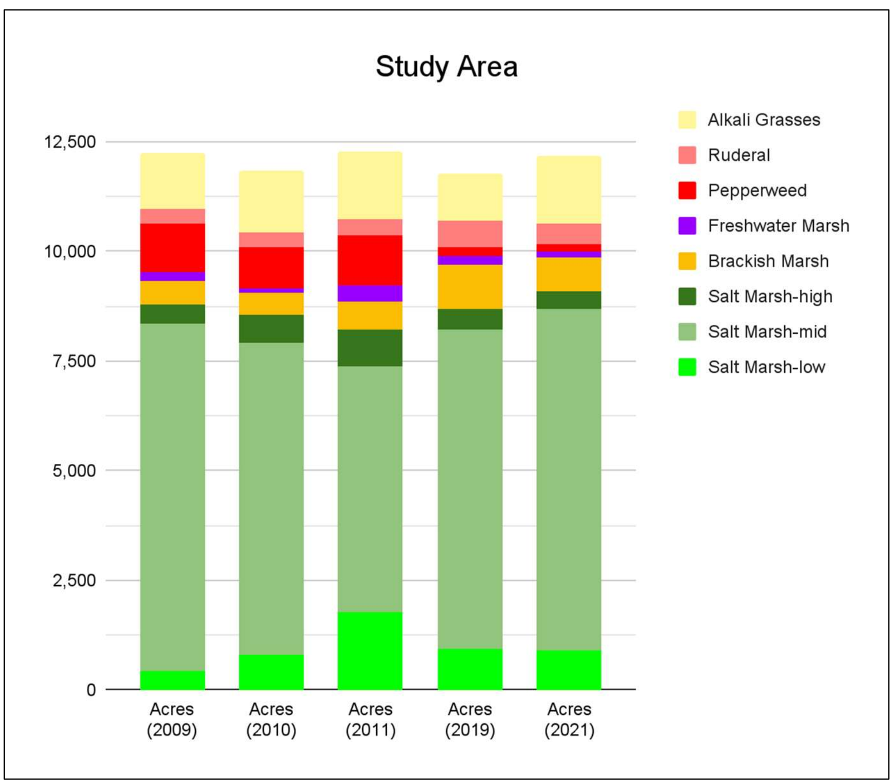


Figure 27: Acreage by Habitat Type for Study Area (2009 - 2011, 2019 & 2021)

Within several restored ponds, there has been a significant increase in floral colonization (e.g., E8A, A21, A20, North Creek marsh), but not as much in others (E9, A6, A17, A19, Mt Eden Creek Marsh). The ponds with less floral colonization have changed into large mudflats, where biofilm also predominates. Although the largest increases in marsh vegetation were between the two time periods (2011 to 2019), the rate of floral colonization of mudflats greatly increased between 2019 and 2021. The changes to habitats over the lifetime of the two studies (12 years in total) are detailed below by SBSP restoration unit, restored pond, and for select marshes. Freshwater marsh classes (Cattails and Freshwater Bulrush) have fluctuated more than other habitat types. Interestingly, the acreages for 2019 (206) are nearly identical to 2009 (204), which might indicate stability between the two time periods, despite the reduction from 2019 to 2021. Although there has been a general trend towards decreasing acreages of Freshwater Bulrush over the five years of the two mapping projects (excluding 2010), we have concluded (based on the accuracy assessment and our review of ground truthing photos and surveys) that Freshwater Bulrush is significantly undermapping in 2021 as either Cattails or Alkali Bulrush. At the same time, there was 26% increase in Cattails between 2019 and 2021. This reflects a longer-term trend since 2009 of increasing acreages of Cattails (see Table 31).

Pepperweed

One of the most notable changes is the 86% reduction (~900 acres) in Pepperweed acreage across the study area between 2009 and 2021 (see Table 30 or 31). Although the accuracy assessment indicates we might be undermapping Pepperweed, this alone cannot explain the degree of decrease in Pepperweed. Some of this decrease in Pepperweed is probably incorrect mapping as Alkali Bulrush, where it is co-dominant or sub dominant, or within the Ruderal habitat classification. Part of the decrease could also be a result of phenological differences (e.g., senescing Pepperweed) at the time of satellite flyover. It is also possible that a proportion of the increase in the Alkali Bulrush, Ruderal, and even Spearscale habitat acreages include some Pepperweed. The increase in Spearscale and Alkali Bulrush could also indicate that these vegetation alliances are competing with Pepperweed at these locations and not allowing it to completely dominate. Some locations, like the levee and adjacent on the east side of A17, that show a significant reduction in Pepperweed from the previous study, could also be partially a result of restoration efforts. In the end, Pepperweed continues to be persistent in extent and distribution but has greatly decreased in density and volume. As a result, it appears that the Pepperweed footprint within the study area poses less of a problem than it did in 2009.

Spearscale

Between 2009 and 2021, the acreage of Spearscale increased by more than 4X (from 57 to 221 acres). This increase accounts for some of the increase in 'brackish marsh' and possibly the decrease in Pepperweed. In 2019 and 2021, we noticed a higher prevalence of Spearscale in our field surveys, especially in Aviso and surrounding marshes. Although there has been a trend toward increasing acreages of Spearscale over time, large interannual differences in Spearscale within the study area have also been noted elsewhere (John Bourgeoise, personal communication).

Mudflats

The mudflat acreages for 2009-2011 were captured at much higher tides and should not be used for comparison with 2019 or 2021. We obtained imagery in 2016 at Mean Lower Low Water with the help of the USGS (Fulfrost et al 2017) and that year should be used as a baseline. The image from 2019 was also captured at Mean Lower Low Water (MLLW) and can be used for comparison. The satellite image from 2021 was captured at slightly above MLLW (see Mudflats section) so 2021 mudflats should not be used for comparison (although we have quantified the difference in acreages between 2019 and 2021).

Table 30: Acreage by Habitat Type for Study Area (2009 - 2011, 2019 & 2021)

Study Area						
	Habitat Type	**Acres (2009)**	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	444	811	1,789	926	903
	Salt Marsh-mid	7,917	7,096	5,606	7,277	7,785
	Salt Marsh-high	435	638	829	479	390
	Brackish Marsh	530	521	644	1,009	789
	Freshwater Marsh	204	85	366	206	146
	Pepperweed	1,100	949	1,141	194	153
	Ruderal	357	329	345	608	468
	Alkali Grasses	1,243	1,408	1,574	1,092	1,540
	Biotic total	**12,229**	**11,839**	**12,295**	**11,792**	**12,174**
abiotic habitats	Mudflat*	3,628	4,056	7,487	17,542	16,014**
	Wrack (or dead veg)	1,119	984	963	775	37
	Bare Earth	2,209	2,228	1,403	1,032	1,863
	Water	13,858	13,289	10,087	11,417	12,478
	Abiotic total	**20,813**	**20,557**	**19,940**	**30,766**	**30,393**
	Grand Total	**33,042**	**32,396**	**32,235**	**42,557**	**42,567**

* Mudflats in 2009-11 were mapped at tides closer to or at MTL and should not be used for comparison with other years.
** The image used in 2021 was obtained at +0.41 MLLW (see Mudflats section)

Updates to HEMP1 (2009-2011)

In addition to the 2019 and 2021 acreage values for habitats, we have also provided updated acreage values from 2009-2011 for comparison (see Figure 27 and Tables 30 - 31). When we compiled the values from the baseline study (09-11), we identified some issues with these datasets, largely in 2011. First, all the images used in the original HEMP1 datasets were taken closer to mean tide (rather than MLLW). As result, we cannot use the HEMP1 habitat data to track changes to the acreage of mudflats for the entire study area. These higher tides also resulted in a varying amount of water within some of the tidally exposed ponds and marshes, most significantly in 2011. This could impact the mapped extent and distribution of biotic or abiotic habitats.

In an effort to normalize the data between years as much as possible, we spent some time identifying locations and habitats where these issues were predominant. We focused our review and edits on ‘change areas’ like restored (or enhanced) ponds (e.g., Pond A6) or habitats that were obviously mis-mapping (e.g., Alkali Heath). We have used these edited/updated habitat datasets for 2009-11 in all the relevant figures and tables included in this report.

Table 31: Acreage by Mapped Habitat for Study Area (2009 - 2011, 2019 & 2021)

Study Area					
Mapped Habitat	**Acres (2009)**	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
Alkali Bulrush	473	425	545	792	568
Alkali Grasses	1,243	1,408	1,574	1,092	1,540
Alkali Heath	238	259	327	130	193
Bare Earth	2,209	2,228	1,403	1,032	1,863
Freshwater Bulrush	163	73	135	102	15
Cattails	41	13	232	104	131
Cordgrass	92	255	730	595	534
Cordgrass/-Pickleweed	352	557	1,059	331	369
Mudflat without Biofilm	2,283	1,895	5,835	14,656	11,187
Mudflat with Biofilm	1,344	2,161	1,652	2,886	4,828
Pepperweed	1,100	949	1,141	194	153
Pickleweed	7,355	6,292	5,312	6,963	7,315
Pickleweed /- Gumplant	197	379	502	349	`197
Pickleweed /- Jaumea	152	304	204	201	185
Ruderal	357	329	345	608	468
Saltgrass	410	500	90	113	285
Spearscale	57	96	100	216	221
Water	13,858	13,289	10,087	11,417	12,478
Wrack	1,119	984	963	775	37
Upland	-	-	-	29	20
Total	**33,042**	**32,396**	**32,235**	**42,587**	**42,587**

In 2011, both the amount of water within restored ponds and potentially anomalous acreages of certain habitats were more pronounced than in 2009 or 2010. The amount of water within restored ponds and marshes in North Creek marsh, Mt Eden Creek marsh, and Bair Island were much greater in 2011 when compared with other years. There is also evidence that water within at least part of these ponds was also mis-mapping as Pickleweed, so we edited these locations where possible. Although these issues were most prevalent in 2011, we also identified similar issues and conducted similar edits in other years and other locations (e.g., Island ponds). The review also highlighted anomalous acreages values which indicate potential overmapping of a number of habitats, including Alkali Heath (*Frankenia salina*), Gumplant (*Grindelia stricta*), Cordgrass, and Cordgrass /- Pickleweed. Although some of these issues have been accounted for in our edits, mostly within restored or enhanced ponds, we *suggest that the acreages for 2011 should be evaluated by comparing acreages values as one value within the available time series, especially for problematic habitats and at the study area wide scale*. In 2010, there are a number of locations throughout the study area where Gumplant appears to be overmapping. Most of these locations should probably be classified as Pickleweed. In specific locations, such as Dumbarton and Faber/Laumeister marshes, Gumplant is likely mapping what should be Jaumea (or Alkali Heath). Unfortunately, we did not have the time to systematically address this issue in the update to the 2010 habitat dataset, since we focused on edits on restored, enhanced, or managed ponds.

3.2 Eden Landing

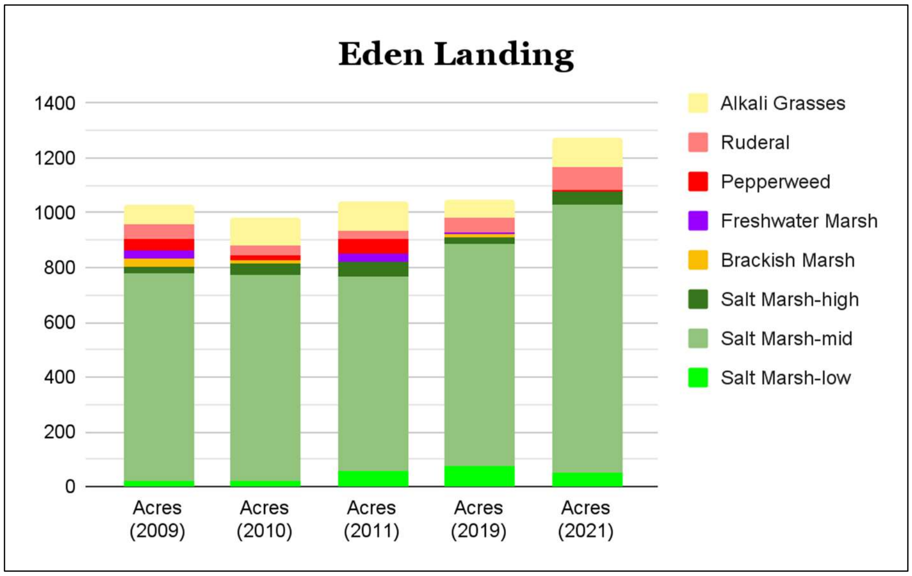


Figure 28: Acreage by Habitat Type for Eden Landing (2009 - 2011, 2019 & 2021)

Between 2009 and 2021 there was a 23% increase in biotic habitats at Eden Landing (see Figure 28 and Tables 32-33). This includes a more than doubling of low salt marsh (from 23 to 54 acres), a 29% increase in mid salt marsh (from 755 to 976 acres), and a doubling of high salt marsh (from 23 to 45 acres). The acreage of Pepperweed also plummeted (mostly in the east side of Alameda Creek and Old Alameda Flood Control Channel), from a high of 39 acres in 2009 to about 3 acres in 2021. However, there was a corresponding 63% increase in Ruderal vegetation (from 52 to 85 acres) that could account for some of the reduction in Pepperweed. Although the acreages for Alkali Bulrush have gone up and down (see Table 33), there was also a significant reduction in Brackish marsh during the same time period (from 32 to 4 acres).

Table 32: Acreage by Habitat Type for Eden Landing (2009 - 2011, 2019 & 2021)

Eden Landing						
	Habitat Type	**Acres (2009)**	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	24.5	19.5	58.9	75.1	53.4
	Salt Marsh-mid	755.6	752.7	709.1	809.8	976.6
	Salt Marsh-high	23.6	41.0	52.3	25.8	45.3
	Brackish Marsh	31.4	10.7	2.2	14.2	4.2
	Freshwater Marsh	29.8	0.0	27.2	0.2	0.5
	Pepperweed	39.4	18.2	56.1	5.6	2.6
	Ruderal	52.6	39.2	29.2	51.6	85.7
	Alkali Grasses	74.5	101.5	104.6	64.2	104.3
	Biotic total	**1,031.4**	**982.9**	**1,039.6**	**1,046.5**	**1,272.6**
abiotic habitats	Mudflat	315.5	519.7	373.5	1,126.9	1,010.8
	Wrack (or dead veg)	166.5	153.0	68.9	94.2	0.7
	Bare Earth	443.5	298.1	334.6	172.0	258.4
	Water	853.5	759.5	906.1	388.8	285.7
	Abiotic total	**1,778.9**	**1,730.3**	**1,683.1**	**1,781.8**	**1,555.6**
	Grand Total	**2,810.3**	**2,713.1**	**2,722.7**	**2,828.3**	**2,828.2**

* There is a 72 acre mask difference between hemp1 and hemp2. The additional area (2019/2021 only) is almost entirely upland classes.

Table 33: Acreage by Mapped Habitat for Eden Landing (2009 - 2011, 2019 & 2021)

Mapped Habitat	Eden Landing				
	Acres (2009)	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
Alkali Bulrush	31.4	10.7	2.2	14.0	3.8
Alkali Grasses	74.5	101.5	104.6	64.2	104.3
Alkali Heath	12.3	14.7	16.9	6.7	19.0
Bare Earth	443.5	298.1	334.6	172.0	258.4
Freshwater Bulrush	27.9	0.0	10.9		0.1
Cattails	1.9	0.0	16.3	0.2	0.5
Cordgrass	2.9	1.6	17.2	41.8	20.4
Cordgrass/-Pickleweed	21.6	17.9	41.7	33.3	33.0
Mudflat without Biofilm	99.2	100.8	111.9	732.0	557.8
Mudflat with Biofilm	216.2	418.9	261.6	394.9	453.1
Pepperweed	39.4	18.2	56.1	5.6	2.6
Pickleweed	723.7	702.1	683.8	790.2	956.2
Pickleweed /- Gumplant	11.2	26.3	35.5	19.1	26.3
Pickleweed /- Jaumea	5.3	9.8	20.8	9.6	3.9
Ruderal	52.6	39.2	29.2	51.6	85.7
Saltgrass	26.6	40.8	4.4	10.1	16.4
Spearscale	-	-	0.0	0.2	0.4
Water	853.5	759.5	906.1	388.8	285.7
Wrack	166.5	153.0	68.9	94.2	0.7
Total	**2,810.3**	**2,713.1**	**2,722.7**	**2,828.3**	**2,828.2**

Ponds E8A/E8X/E9

In Eden Landing, ponds E9, E8A, and E8X were opened to tidal action after the satellite image was captured in 2011 for HEMP1. Within pond E8A, there was a 12x (from ~5 to ~62 acres) increase in vegetation between 2011 and 2019 (see Tables 34 and 35). This vegetation almost entirely comprised Pickleweed. However, between 2019 and 2021, the rate of floral colonization appears to have greatly increased compared to the increase between 2011 and 2019, when an additional 40 acres of Pickleweed colonized mudflats within E8A, filling in channels into more dense mats. By 2019, about 11 acres of Pickleweed (and some Spartina) had also colonized the mudflats in E9 (see Tables 34 and 35), although the Pickleweed was significantly less dense when compared to E8A. Between 2019 and 2021, the acreage of Pickleweed (and Cordgrass) in E9 had more than doubled to about 25 acres.

Table 34: Acreage by Habitat Type for E8A (2009 - 2011, 2019 & 2021)

	E8A (acres)					
	Habitat Type	Acres (2009)*	Acres (2010)*	Acres (2011)*	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	0.11	0.02	0.52	3.77	5.94
	Salt Marsh-mid	2.86	2.86	2.97	56.52	93.29
	Salt Marsh-high	0.29	0.49	0.31	0.60	0.57
	Brackish Marsh	0.00	0.02	0.00	1.53	0.26
	Freshwater Marsh	0.00	0.00	0.02	0.00	0.00
	Pepperweed	0.05	0.05	0.27	0.11	0.04
	Ruderal	0.13	0.19	0.20	0.18	1.10
	Alkali Grasses	2.68	0.73	0.73	0.09	1.00
	Biotic total	**6.14**	**4.37**	**5.03**	**62.79**	**102.21**
abiotic habitats	Mudflat	23.23	80.33	14.52	183.50	148.12
	Wrack (or dead veg)	24.94	-	-	1.22	0.00
	Bare Earth	126.62	47.35	104.33	4.65	3.93
	Water	84.27	133.16	141.32	13.04	10.94
	Abiotic total	**259.06**	**260.84**	**260.17**	**202.41**	**162.99**
	Grand Total	**265.20**	**265.20**	**265.20**	**265.20**	**265.20**

* Acreages for 2009, 2010, and 2011 in E9, E8A, and E8X are pre-breach

Table 35: Acreage by Habitat Type for E9 (2009 - 2011, 2019 & 2021)

	E9					
	Habitat Type	Acres (2009)*	Acres (2010)*	Acres (2011)*	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	-	-	-	1.50	3.56
	Salt Marsh-mid	-	-	-	8.87	20.81
	Salt Marsh-high	-	-	-	0.29	0.15
	Brackish Marsh	-	-	-	0.20	0.53
	Freshwater Marsh	-	-	-	0.00	0.00
	Pepperweed	-	-	-	0.01	0.02
	Ruderal	-	-	-	0.01	0.14
	Alkali Grasses	-	-	-	0.00	0.07
	Biotic total	**0.00**	**0.00**	**0.00**	**10.89**	**25.29**
abiotic habitats	Mudflat	0.00	46.49	73.35	347.15	333.60
	Wrack (or dead veg)	-	-	-	0.06	0.00
	Bare Earth	-	0.69	6.67	0.41	0.53
	Water	365.30	318.12	284.61	6.79	5.88
	Abiotic total	**365.30**	**365.30**	**364.64**	**354.42**	**340.02**
	Grand Total	**365.30**	**365.30**	**364.64**	**365.30**	**365.30**

* Acreages for 2009, 2010, and 2011 in E9, E8A, and E8X are pre-breach

North Creek Marsh

There has been significant floral colonization of mudflats within North Creek Marsh between 2009 and 2021, but the majority of that change has occurred between 2019 and 2021 (see Figure 29 and Table 36). There were the beginnings of this floral colonization along channels as far back as 2009 (see Map 16a). The vast majority of this vegetative growth is in the northern section of the marsh. In the southern section of the marsh, there was very little floral colonization between 2011 and 2019. However, in 2021 (see Map 16d), there appear to be the very beginnings of Pickleweed forming in this part of the marsh.

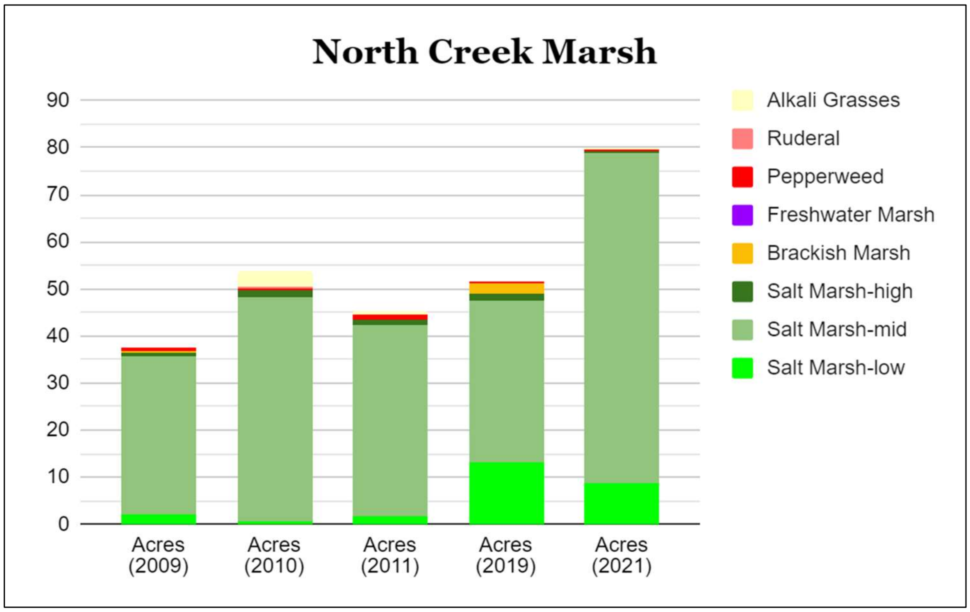
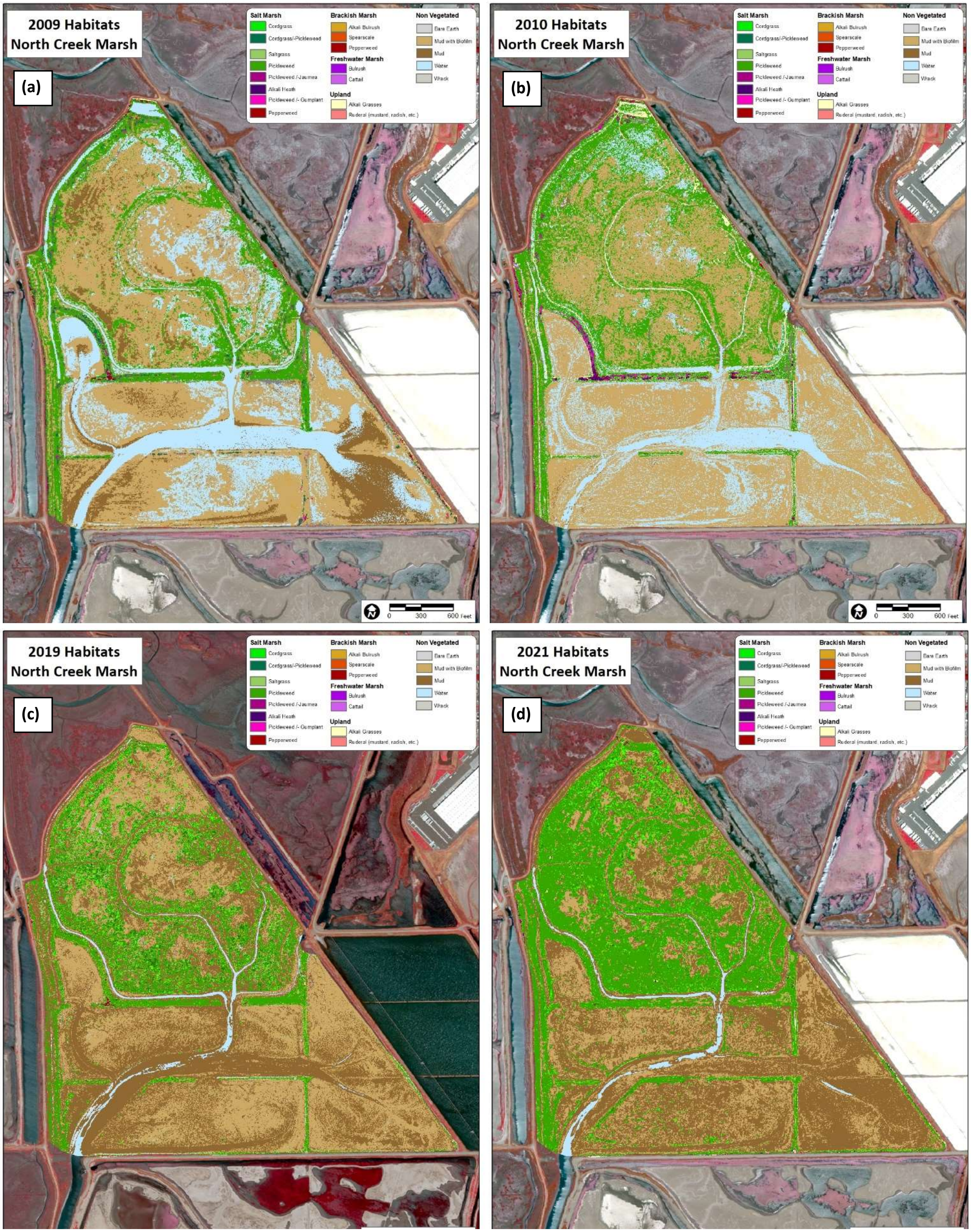


Figure 29: Acreage by Habitat Type for North Creek Marsh (2009 - 2011, 2019 & 2021)

By 2021, Pickleweed has begun to form into denser mats within the northern section of North Creek Marsh (see Maps 18a – 18d). There are also significant patches of Cordgrass, both dispersed and in denser stands, often adjacent to pickleweed. However, the southern area of North Creek Marsh, as well as most of Mt Eden Creek Marsh, are still dominantly mudflats, with some significant dispersed patches of pickleweed, mostly found forming channels within the mudflat.



Map 18a-d: Mapped habitats for North Creek Marsh a) 2009, b) 2010, c) 2019, d) 2021

Our review of the datasets from 2009-2011 resulted in some edits to North Creek marsh for 2009-2011. The edits mostly involved the reclassification of Pickleweed to water or mudflat w/ biofilm. Although we reclassified these to abiotic or non macrophytic biotic classes, the source of the issue was the mis classification of Algae (or Biofilm) mapping as Pickleweed. Algae mapping as Pickleweed is also potentially the reason for overmapping Pickleweed in other restored ponds (e.g., A19 and to a lesser degree A20) in the original (i.e., unedited) 2009-2011 habitats data.

Table 36: Acreage by Habitat Type for North Creek Marsh (2009 - 2011, 2019 & 2021)

Habitat Type		North Creek Marsh				
		Acres (2009)	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	2.00	0.50	1.60	13.11	8.86
	Salt Marsh-mid	33.66	47.65	40.66	34.51	70.09
	Salt Marsh-high	0.91	1.56	1.06	1.20	0.25
	Brackish Marsh	0.32	0.12	0.01	2.55	0.16
	Freshwater Marsh	0.05	0.00	0.03	0.00	0.00
	Pepperweed	0.45	0.38	1.16	0.07	0.09
	Ruderal	0.10	0.07	0.12	0.12	0.26
	Alkali Grasses	0.16	3.64	0.73	0.02	0.22
	Biotic total	**37.66**	**53.92**	**45.36**	**51.57**	**79.94**
abiotic habitats	Mudflat	123.32	120.42	82.93	162.08	136.85
	Wrack (or dead veg)	4.12	1.82	2.52	0.30	0.01
	Bare Earth	0.01	0.21	0.79	0.72	0.48
	Water	55.96	44.60	89.45	6.41	3.79
	Abiotic total	**183.40**	**167.05**	**175.70**	**169.50**	**141.13**
	Grand Total	**221.06**	**220.98**	**221.06**	**221.07**	**221.07**

Mt Eden Creek Marsh

Between 2009 and 2019 there was a 50% increase in Pickleweed (from 8 to 14 acres) and a 4X increase in Cordgrass (~1 to 4 acres) within Mt Eden Creek marsh (see Figure 30 and Table 37). However, following the trend found within other ponds, floral colonization accelerated significantly between 2019 and 2021, with Pickleweed doubling to a total of 28 acres. We did not differentiate between the tidal and muted portions of the marsh in our acreage calculations.

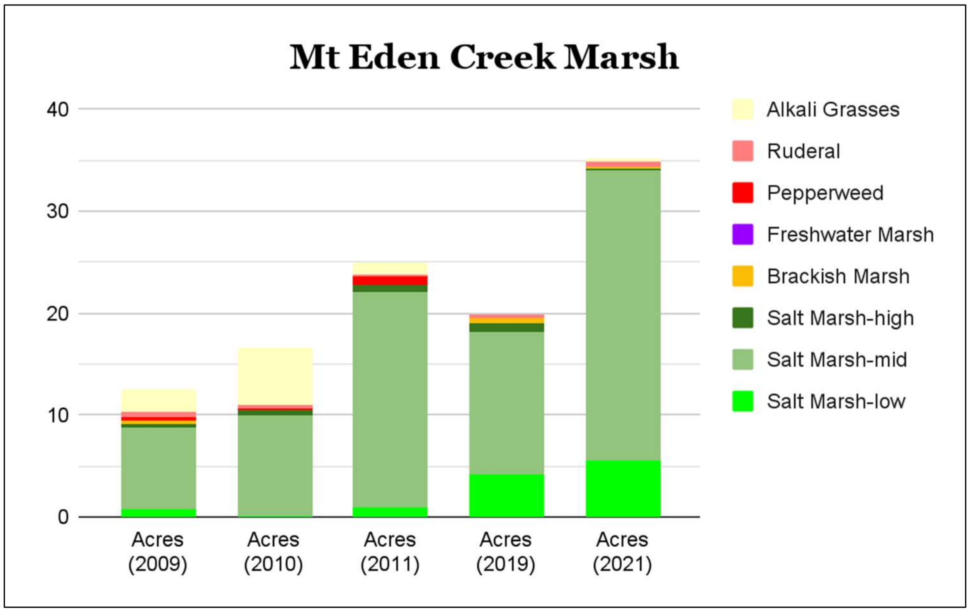


Figure 30: Acreage by Habitat Type for Mt Eden Creek Marsh (2009 - 2011, 2019 & 2021)

Table 37: Acreage by Habitat Type for Mt Eden Creek Marsh (2009 - 2011, 2019 & 2021)

	Habitat Type	Mt Eden Creek Marsh				
		Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	0.84	0.15	0.99	4.29	5.49
	Salt Marsh-mid	8.00	9.85	21.14	13.94	28.53
	Salt Marsh-high	0.35	0.44	0.65	0.72	0.16
	Brackish Marsh	0.25	0.12	0.01	0.61	0.13
	Freshwater Marsh	0.05	0.00	0.03	0.00	0.00
	Pepperweed	0.39	0.13	0.73	0.03	0.07
	Ruderal	0.47	0.38	0.17	0.23	0.54
	Alkali Grasses	2.17	5.54	1.26	0.11	0.21
	Biotic total	**12.54**	**16.61**	**24.98**	**19.92**	**35.14**
abiotic habitats	Mudflat	23.78	76.15	50.25	92.26	78.80
	Wrack (or dead veg)	2.44	2.98	1.74	0.14	0.00
	Bare Earth	0.41	0.63	1.34	0.33	0.46
	Water	80.26	23.04	40.35	6.77	5.02
	Abiotic total	**106.88**	**102.81**	**93.69**	**99.49**	**84.28**
	Grand Total	**119.42**	**119.42**	**118.67**	**119.42**	**119.42**

3.3 Alviso

Over the last decade, there have been considerable increases in a number of habitat types within the Alviso Restoration unit (see Figure 31 and Table 38). Between 2009 and 2021, low salt marsh (Cordgrass and Cordgrass /-Pickleweed) almost tripled in size, from 54 to 135 acres. Although the acreages have fluctuated, there was also a 22% increase in mid salt marsh between 2009 and 2021 (see Figure 31). Of the three habitat classes included in mid marsh (see Table 39), Pickleweed increased by 35% (from 435 to 586 acres) while Saltgrass decreased by 83% (from 42 to 7 acres), and Jaumea decreased by 60% (from 10 to 4 acres). Although it is likely that we are undermapping Saltgrass in 2021, and the ability for the model to accurately map its presence is reliant on its density and relative fluorescence, it appears the density and extent of Saltgrass has also significantly reduced since 2009 within Alviso. However, the degree of change might not be as much as indicated since there is the possibility that some of the increase in Pickleweed (or even Cordgrass) is actually Saltgrass.

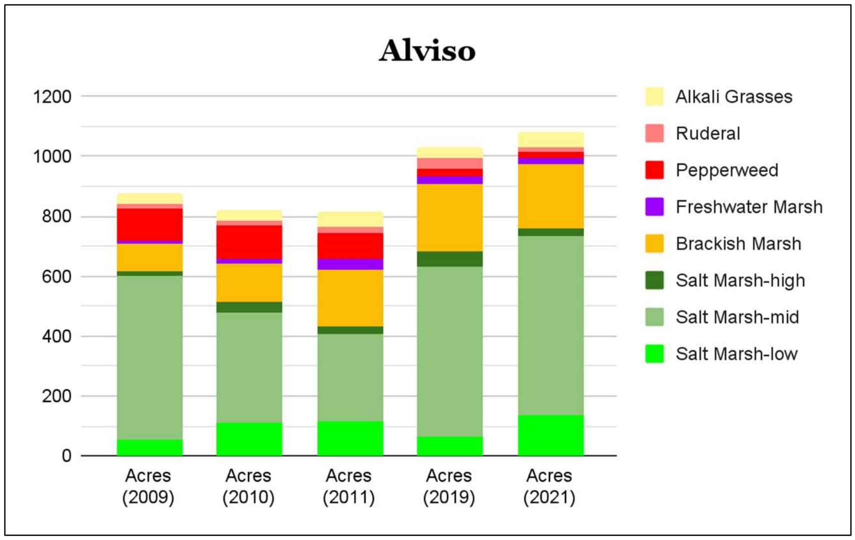


Figure 31: Acreage by Habitat Type for Alviso (2009 - 2011, 2019 & 2021)

Table 38: Acreage by Habitat Type for Alviso (2009 - 2011, 2019 & 2021)

	Habitat Type	Alviso Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	53.9	112.0	115.1	63.5	134.8
	Salt Marsh-mid	488*	369.2	293.1	568.8	597.2
	Salt Marsh-high	16.1	33.8	26.4	51.0	26.2
	Brackish Marsh	90.8	128.9	186.7	226.7	214.1
	Freshwater	11.9	11.2	36.1	24.9	21.0
	Pepperweed	102.8	115.4	89.5	25.0	21.2
	Ruderal	19.6	16.3	17.2	36.4	15.1
	Alkali Grasses	35.7	34.6	51.7	34.2	49.8
	Biotic total	**879.1**	**821.4**	**815.8**	**1.030.5**	**1.079.5**
abiotic habitats	Mudflat	321.8	426.8	648.7	795.3	820.8
	Wrack (or dead	75.1	35.8	72.5	82.0	3.6
	Bare Earth	438.2	423.6	128.2	107.7	183.9
	Water	814.4	704.0	698.1	526.9	454.6
	Abiotic total	**1.649.5**	**1.590.3**	**1.547.5**	**1.511.9**	**1.462.9**
	Grand Total	**2,528.6**	**2,411.7**	**2,363.3**	**2,542.4**	**2,542.4**

Table 39: Acreage by Mapped Habitat for Alviso (2009 - 2011, 2019 & 2021)

Mapped Habitat	Alviso				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	72.3	98.0	165.2	197.0	171.8
Alkali Grasses	35.7	34.6	51.7	34.2	49.8
Alkali Heath	6.4	7.2	11.1	3.3	8.7
Bare Earth	438.2	423.6	128.2	107.7	183.9
Freshwater Bulrush	11.5	10.6	18.7	15.0	0.5
Cattails	0.4	0.6	17.4	9.9	20.5
Cordgrass	10.3	39.9	50.0	49.8	87.4
Cordgrass/-Pickleweed	43.6	72.2	65.1	13.7	47.4
Mudflat without Biofilm	101.8	162.8	321.1	365.7	274.9
Mudflat with Biofilm	220.0	264.0	327.6	429.6	545.9
Pepperweed	102.8	115.4	89.5	25.0	21.2
Pickleweed	435.8*	329.8	276.4	558.2	586.4
Pickleweed /- Gumplant	9.7	26.7	15.3	47.7	17.4
Pickleweed /- Jaumea	10.2	16.6	11.6	7.9	4.3
Ruderal	19.6	16.3	17.2	36.4	15.1
Saltgrass	42.4	22.8	5.1	2.7	6.5
Spearscale	18.5	30.9	21.5	29.7	42.4
Water	814.4	704.0	698.1	526.9	454.6
Wrack	75.1	35.8	72.5	82.0	3.6
Total	**2,528.6**	**2,411.7**	**2,363.3**	**2,542.4**	**2,542.4**

*Around 60 total acres of Pickleweed found in A19 and A20 in 2009 were determined to be Algae as part of our QA process.) As a result, we have reduced the 2009 acreage total for Pickleweed to 435 from 495 and for "Salt Marsh – mid" from to 488 acres (from 548)

Pond A21

Within Alviso, the most significant change in restored ponds since 2011 appears to be in A21. This pond was opened to tidal action before even the beginning of the first HEMP study in 2009. In 2011, pickleweed and cordgrass had begun to colonize channels within the mudflats found within the pond and Alkali Bulrush began to

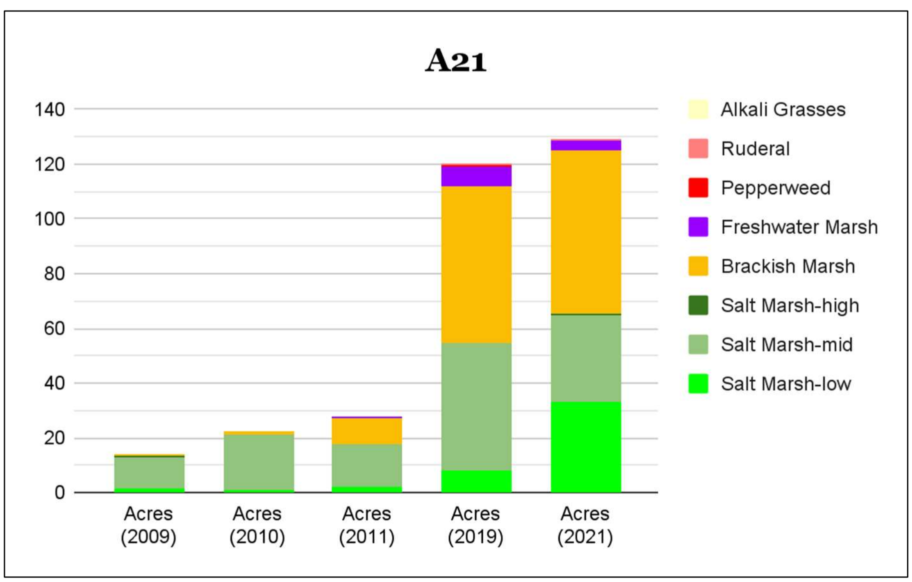
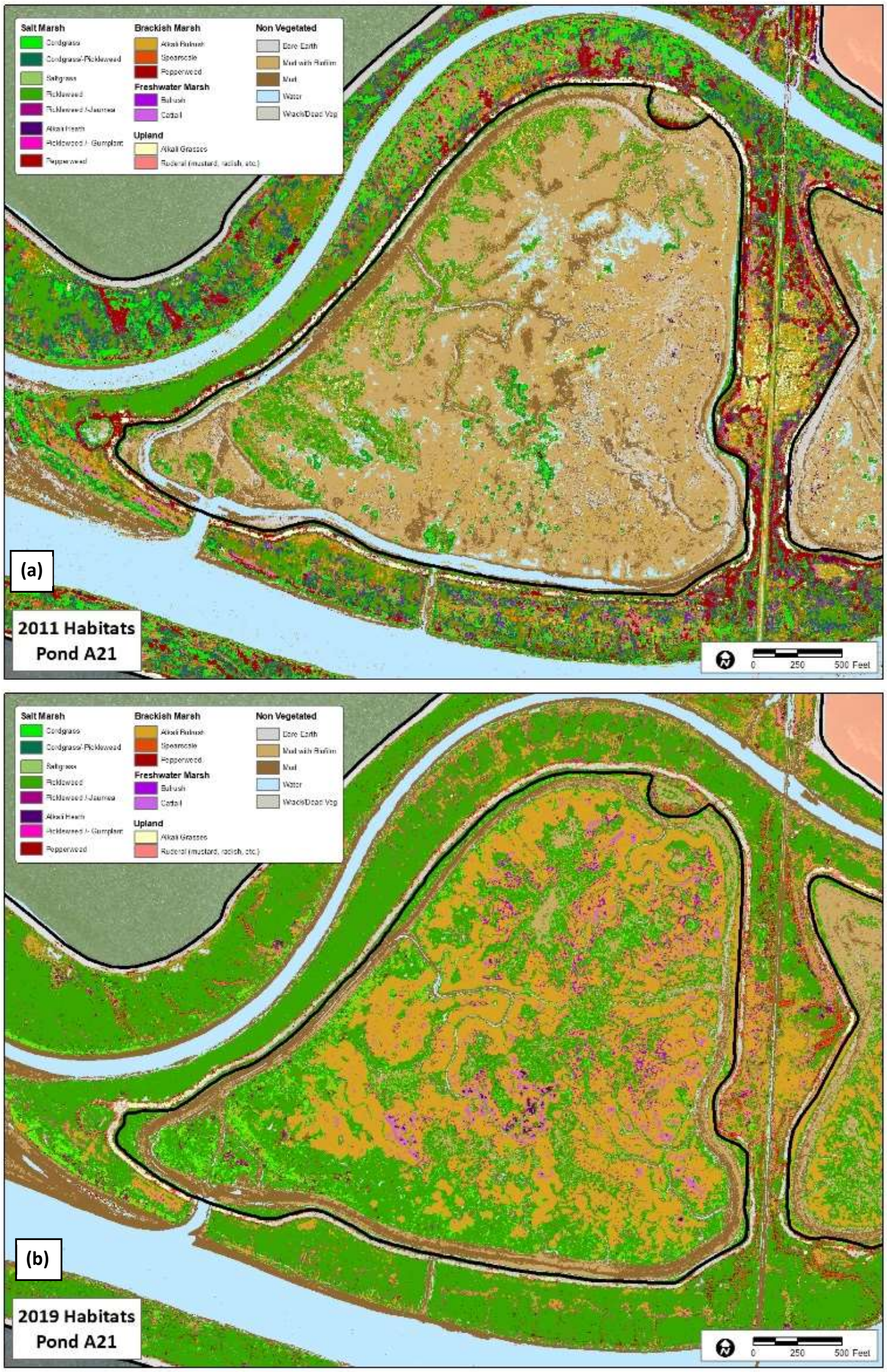


Figure 32: Acreage by Habitat Type for A21 (2009 - 2011, 2019 & 2021)

establish itself (see Map 19a). Between 2011 and 2021, there was more than a 4X increase in vegetation (from 28 to 129 acres) within A21 (see Figure 32 and Table 40). Sixty percent of this floral colonization was Alkali Bulrush, which increased by 6X during this ten-year period (from 10 to 60 acres). The other forty percent of floral colonization was salt marsh vegetation, with Pickleweed doubling (from 15 to 32 acres) and Cordgrass increasing by more than 15X (from 2 to 33 acres) during this same time period. The brackish marsh appears to have mostly colonized in the center, with Pickleweed and Cordgrass found along channels within the Alkali Bulrush, and around the southern (and southwestern) edge of the old "borrow" ditch, where mudflats also seem persistent (see Map 19b). Moving east along Coyote Creek, although there has been significant floral colonization, the degree of colonization decreases relative to A21.

Table 40: Acreage by Habitat Type for A21 (2009 - 2011, 2019 & 2021)

	Habitat Type	A21				
		Acres (2009)	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	1.73	1.20	2.15	8.21	33.16
	Salt Marsh-mid	11.47	19.86	15.27	46.31	31.93
	Salt Marsh-high	0.09	0.15	0.45	0.36	0.01
	Brackish Marsh	0.57	0.98	9.65	57.13	60.11
	Freshwater Marsh	0.00	0.01	0.02	7.26	3.50
	Pepperweed	0.04	0.09	0.28	0.57	0.05
	Ruderal	-	0.00	0.01	0.12	0.29
	Alkali Grasses	-	0.00	0.05	-	0.00
	Biotic total	**13.91**	**22.29**	**27.88**	**119.96**	**129.05**
abiotic habitats	Mudflat	87.30	108.81	94.67	23.62	17.23
	Wrack (or dead veg)	2.34	0.08	1.40	0.58	0.02
	Bare Earth	0.47	0.61	9.20	0.03	0.17
	Water	42.50	14.72	13.36	2.32	0.05
	Abiotic total	**132.61**	**124.22**	**118.64**	**26.55**	**17.47**
	Grand Total	**146.51**	**146.51**	**146.52**	**146.51**	**146.51**



Map 19a-b: Mapped habitats for A21 (2011 & 2019)

Pond A20

In A20, there was a 7X increase (from ~7 to ~49 acres) in vegetation between 2011 and 2021 (see Figure 33). When compared to A21, Alkali Bulrush (~11 acres) is not as widely distributed throughout the pond or as dense, and Pickleweed and Cordgrass (~35 acres) dominate (see Maps 20a – 20d). Between 2011 and 2019, Pickleweed increased by 6X (from ~4 to 24 acres) and Cordgrass had begun to establish (from 0.5 to 3.5 acres). However, as detailed above (see "A20" within 2019-2021 Results section), between 2019 and 2021, Cordgrass (and Cordgrass /-Pickleweed) increased by 5X (from 3.5 to 20 acres).

When we reviewed the mapped habitats and trends from 2009-2011, in conjunction with the Ikonos imagery used for those years, it appears that Pickleweed is overmapping within A19, and to a lesser degree A20. Although we included algae as a

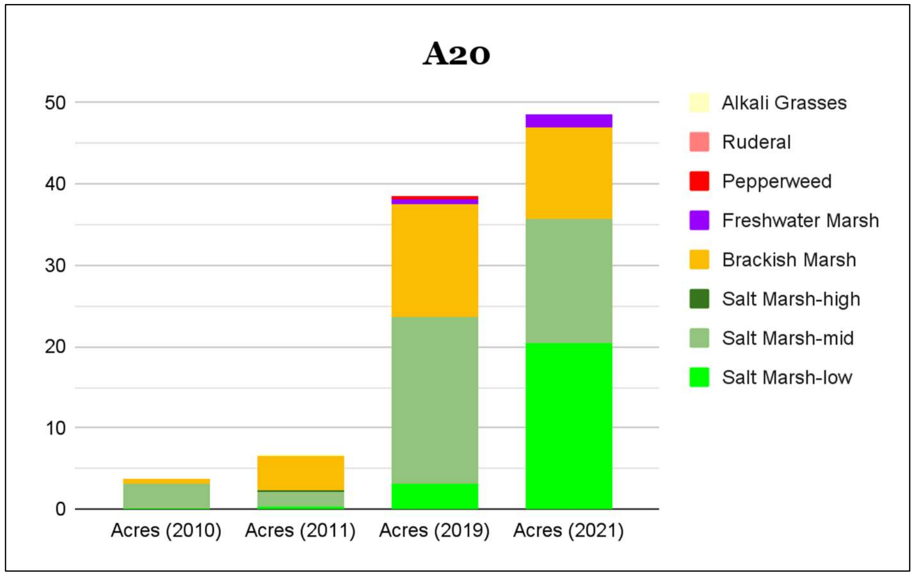
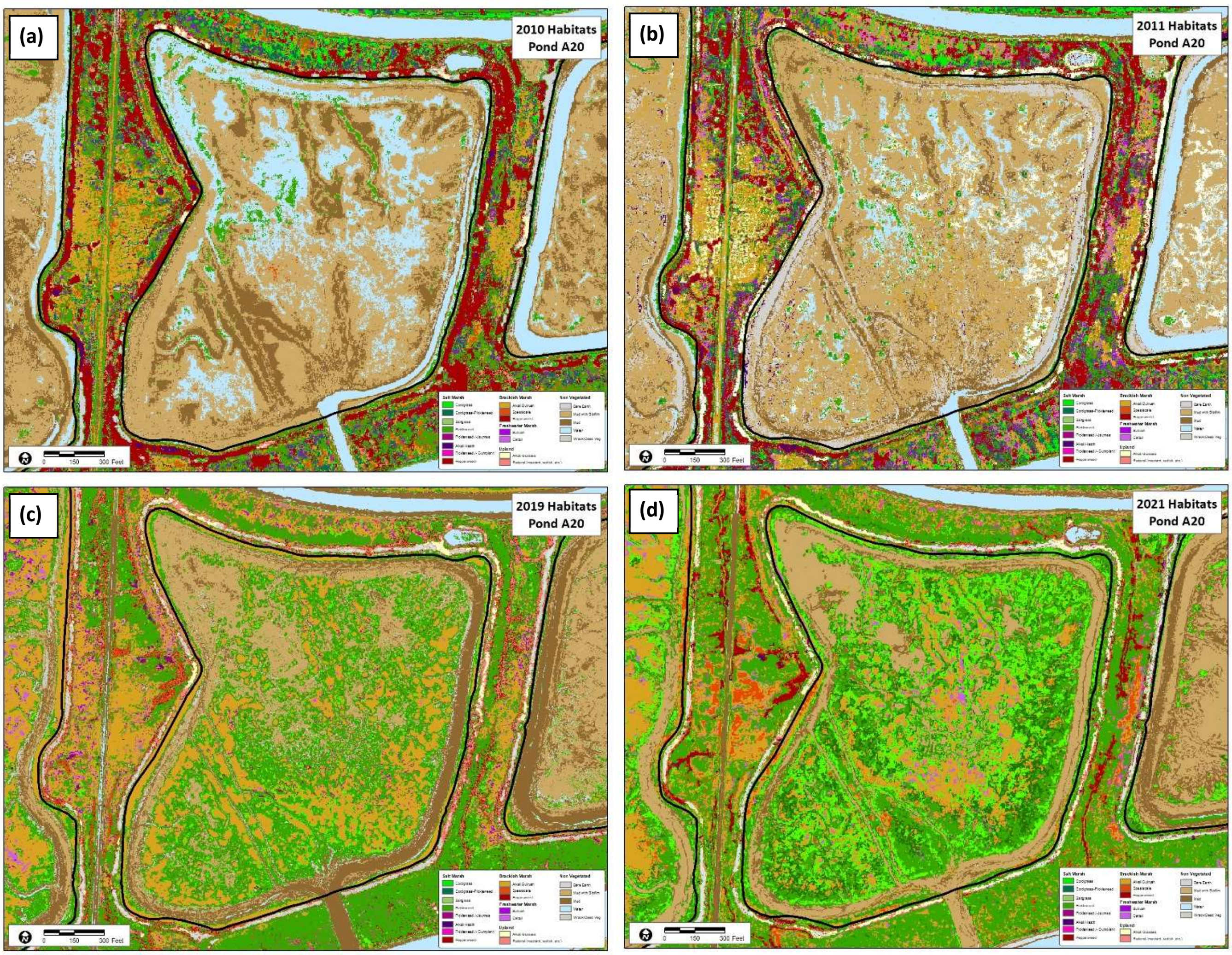


Figure 33: Acreage by Habitat Type for A20 (2010 - 2011, 2019 & 2021)

Table 41: Acreage by Habitat Type for A20 (2009 - 2010, 2019 & 2021)

	Habitat Type	A20				
		Acres (2009)	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	0.71	0.12	0.26	3.16	20.46
	Salt Marsh-mid	13.18	3.08	1.87	20.41	15.20
	Salt Marsh-high	0.08	0.01	0.31	0.01	0.00
	Brackish Marsh	0.50	0.49	4.14	13.83	11.31
	Freshwater Marsh	0.01	0.00	0.00	0.72	1.54
	Pepperweed	0.03	0.08	0.05	0.37	0.03
	Ruderal	-	0.01	0.01	0.01	0.06
	Alkali Grasses	0.00	0.00	0.05	-	0.00
	Biotic total	**14.51**	**3.80**	**6.69**	**38.51**	**48.60**
abiotic habitats	Mudflat	25.27	43.56	39.66	22.54	14.00
	Wrack (or dead veg)	1.50	0.06	2.47	0.39	0.01
	Bare Earth	0.05	0.28	6.94	0.05	0.01
	Water	21.28	14.92	6.85	1.13	0.00
	Abiotic total	**48.10**	**58.81**	**55.92**	**24.11**	**14.02**
	Grand Total	**62.61**	**62.61**	**62.61**	**62.61**	**62.61**

mapped class between 2009-2011 (and did *not* include it in 2019 and 2021), there is a possibility that some of this over mapped Pickleweed is simply Algae (or Biofilm). As a result, the habitat results in 2009 for both Pond A19 and A20 should be ignored (and have been omitted from the relevant tables and figures below). The habitats acreages in 2010 and 2011 are a much better representation of the extent of biotic (and abiotic) classes for A19 and A20. In A20, there were around 15 acres of biotic habitats (mostly pickleweed) that were overmapping in the original 2009 habitat dataset and were reclassified as either water or mudflat with biofilm.



Map 20a-d: Mapped habitats for A20 a) 2010, b) 2011, c) 2019, d) 2021

Pond A19

In A19, although salt and brackish marsh classes increased more than 8X (from ~9 to ~73 acres) over the 10 years between 2011 and 2021 (see Figure 34 and Table 42), the pond is still predominantly mudflat (187 acres). By 2019, there were patches of Pickleweed and Cordgrass forming along channels emanating from the borrow ditch, as well as some adjacent patches of Alkali Bulrush. Between 2019 and 2021, there was an increase of 20 acres (both Cordgrass and Alkali Bulrush), "filling in" the channels (see Map 21a-b).

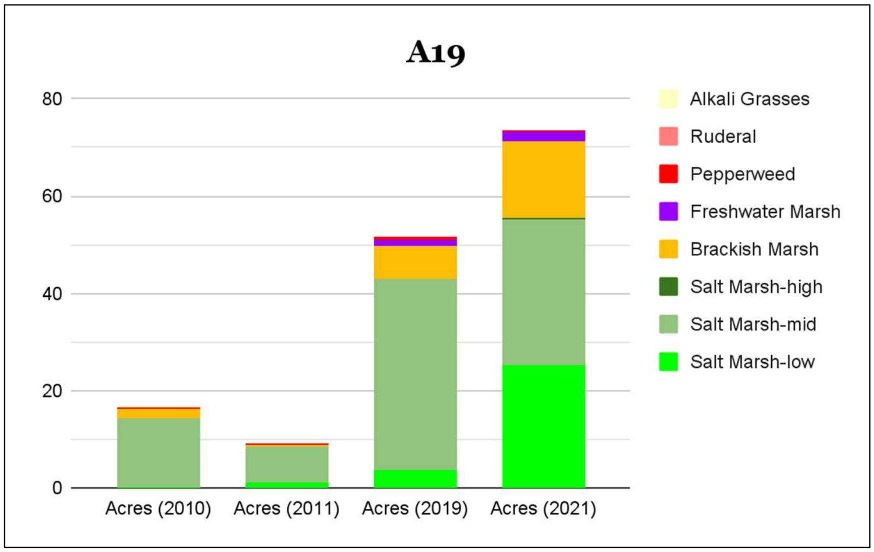
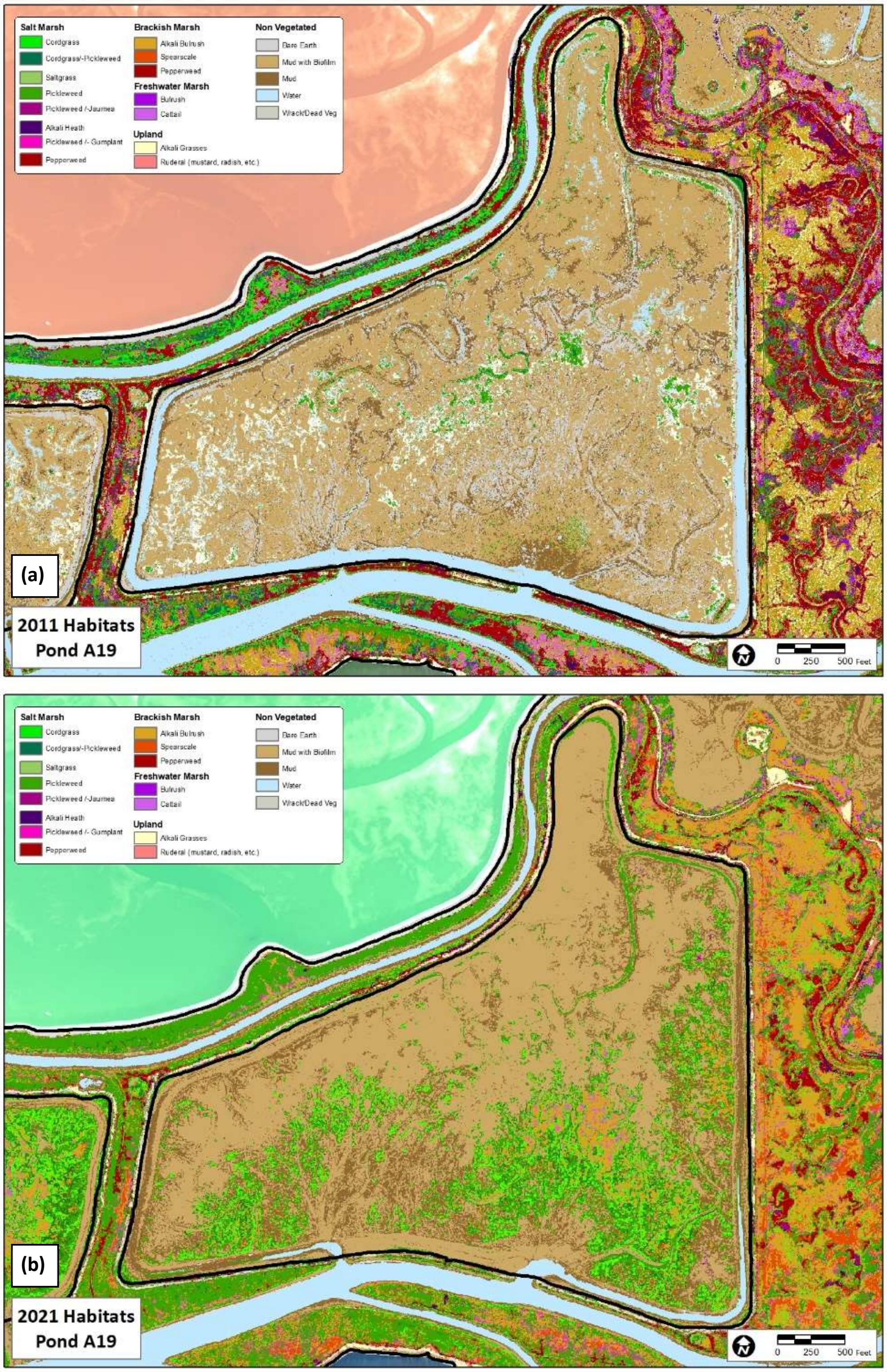


Figure 34: Acreage by Habitat Type for A19 (2010 - 2011, 2019 & 2021)

Table 42: Acreage by Habitat Type for A19 (2010 - 2011, 2019 & 2021)

	Habitat Type	A19			
		Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	0.37	1.03	3.70	25.35
	Salt Marsh-mid	14.01	7.68	39.38	29.95
	Salt Marsh-high	0.06	0.01	0.02	0.06
	Brackish Marsh	1.85	0.07	6.49	15.81
	Freshwater Marsh	0.01	0.01	1.51	2.13
	Pepperweed	0.43	0.33	0.48	0.10
	Ruderal	0.04	0.04	0.02	0.22
	Alkali Grasses	0.04	0.17	0.00	0.02
	Biotic total	**16.81**	**9.35**	**51.60**	**73.65**
abiotic habitats	Mudflat	210.64	179.04	199.12	187.56
	Wrack (or dead veg)	0.57	12.46	0.92	0.02
	Bare Earth	2.06	31.97	0.02	0.16
	Water	34.91	32.15	13.33	3.60
	Abiotic total	**248.19**	**255.61**	**213.38**	**191.34**
	Grand Total	**265.00**	**264.96**	**264.98**	**264.98**

There were around 45 acres of biotic habitat (mostly pickleweed) overmapping in 2009 within A19 (likely Algae or Biofilm). After reviewing the satellite imagery from 2009, we identified very small patches of pickleweed around the borrow ditch. However, it was unfeasible to edit logically and the assumed actual pickleweed area was insubstantial. Although we removed some Pickleweed within A19 in 2010 that appeared to be Algae, it is likely that the final acreage shown here, although closer to the actual acreage, is also overmapping. However, this overmapping in 2010 is certainly not to the same degree as 2009. Regardless, the scale of change between HEMP1 and HEMP2 is accurate and substantial.



Map 21a-b: Mapped habitats for A19 (2011 & 2019)

Pond A6

The levees around A6 were breached in 2011, before the satellite flyover, so the habitats map for that year shows the pond soon after the breach (see Map 22a). At that time, mudflats were already starting to form within the pond, though it was too soon to see any significant floral colonization apart from the remnant levee in the center of the pond.

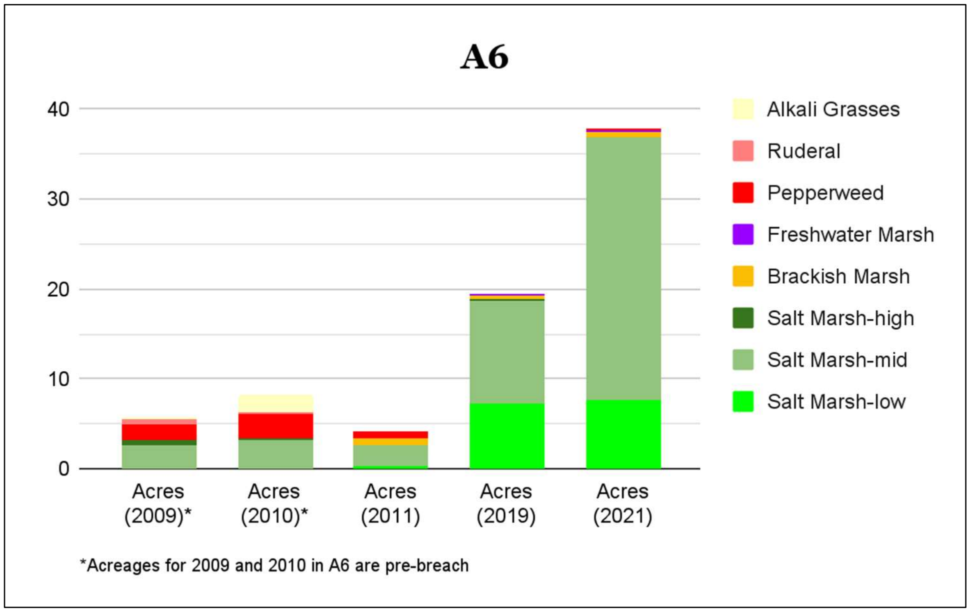
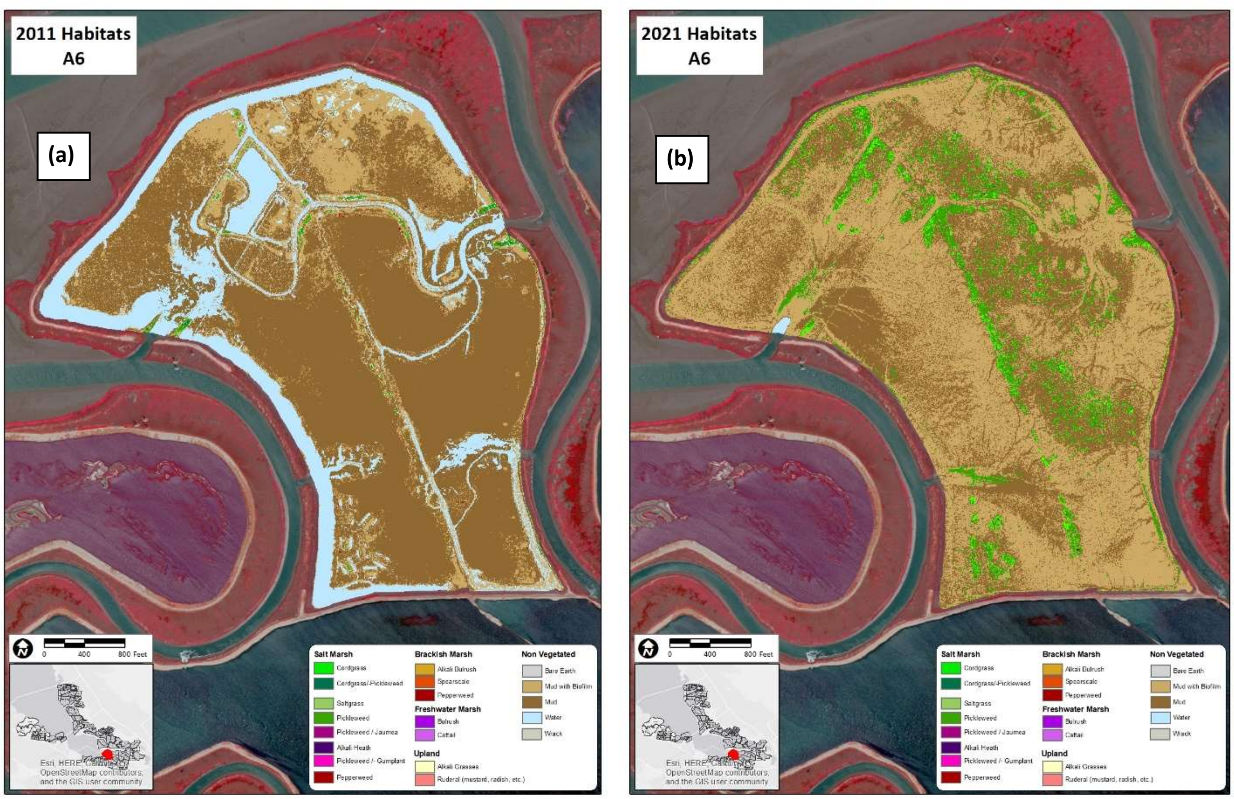


Figure 35: Acreage by Habitat Type for A6 (2009 - 2011, 2019 & 2021)



Map 22a-b: Mapped habitats for A6 (2011 & 2019)

Between 2011 and 2019, there was an almost 5X increase in vegetation (from ~4 to 19 acres). This increase included floral colonization of pickleweed along channels that formed on the mudflats within the pond (see Figure 35 and Table 43). There are also some large patches and small clumps of Cordgrass. However, in 2019, A6 was still dominantly mudflat (with biofilm). Between 2011 and 2019, the degree of floral colonization seen within A6 was most similar to E9, E8A, or even A19 (without Alkali Bulrush). Between 2019 and 2021, an additional 19 acres of mudflat were colonized by Pickleweed (see Map 22b), doubling the total acreage of biotic habitats to 38 acres (see Map Figure 35 and Table 43).

Table 43: Acreage by Habitat Type for A6 (2009 - 2011, 2019 & 2021)

Habitat Type		A6				
		Acres (2009)*	Acres (2010)*	Acres (2011)	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	0.00	0.00	0.31	7.29	7.61
	Salt Marsh-mid	2.68	3.30	2.39	11.50	29.18
	Salt Marsh-high	0.60	0.03	0.00	0.18	0.08
	Brackish Marsh	0.02	0.12	0.77	0.23	0.53
	Freshwater Marsh	0.00	0.00	0.00	0.23	0.30
	Pepperweed	1.66	2.58	0.64	0.02	0.12
	Ruderal	0.54	0.25	-	0.00	0.08
	Alkali Grasses	0.16	1.87	0.06	-	0.00
	Biotic total	**5.66**	**8.16**	**4.18**	**19.45**	**37.90**
abiotic habitats	Mudflat	15.98	3.97	277.80	324.88	319.07
	Wrack (or dead veg)	7.32	3.89	0.61	0.19	0.09
	Bare Earth	281.90	286.67	6.89	0.04	0.02
	Water	46.68	54.83	68.05	12.96	0.44
	Abiotic total	**351.88**	**349.36**	**353.35**	**338.07**	**319.63**
	Grand Total	**357.54**	**357.52**	**357.53**	**357.53**	**357.53**

* Acreages for 2009 and 2010 in A6 are pre-breach

Between 2011 and 2021, the fringe marsh on the north side of A6 expanded northward from approximately 13 meters on the west side of the top of the duck's head (but before the "bill"), to 40 meters or more on the east side of the top closer to the mouth of Alviso slough (see Figure 36). At these same two locations, the marsh expanded northward approximately 2 and 14 meters just between 2019 and 2021. The colonized mudflat is now mostly low marsh with Cordgrass, a small amount of Pickleweed (likely annual), and some Alkali Bulrush. The Pickleweed marsh on the west side of Alviso slough has also grown approximately 6 meters, at least in some locations. It is also possible that the mudflat above A6 has accreted; however, our 2011 image was not taken at MLLW so we cannot say definitively. The mudflat at this location has remained nearly identical to that from 2016.

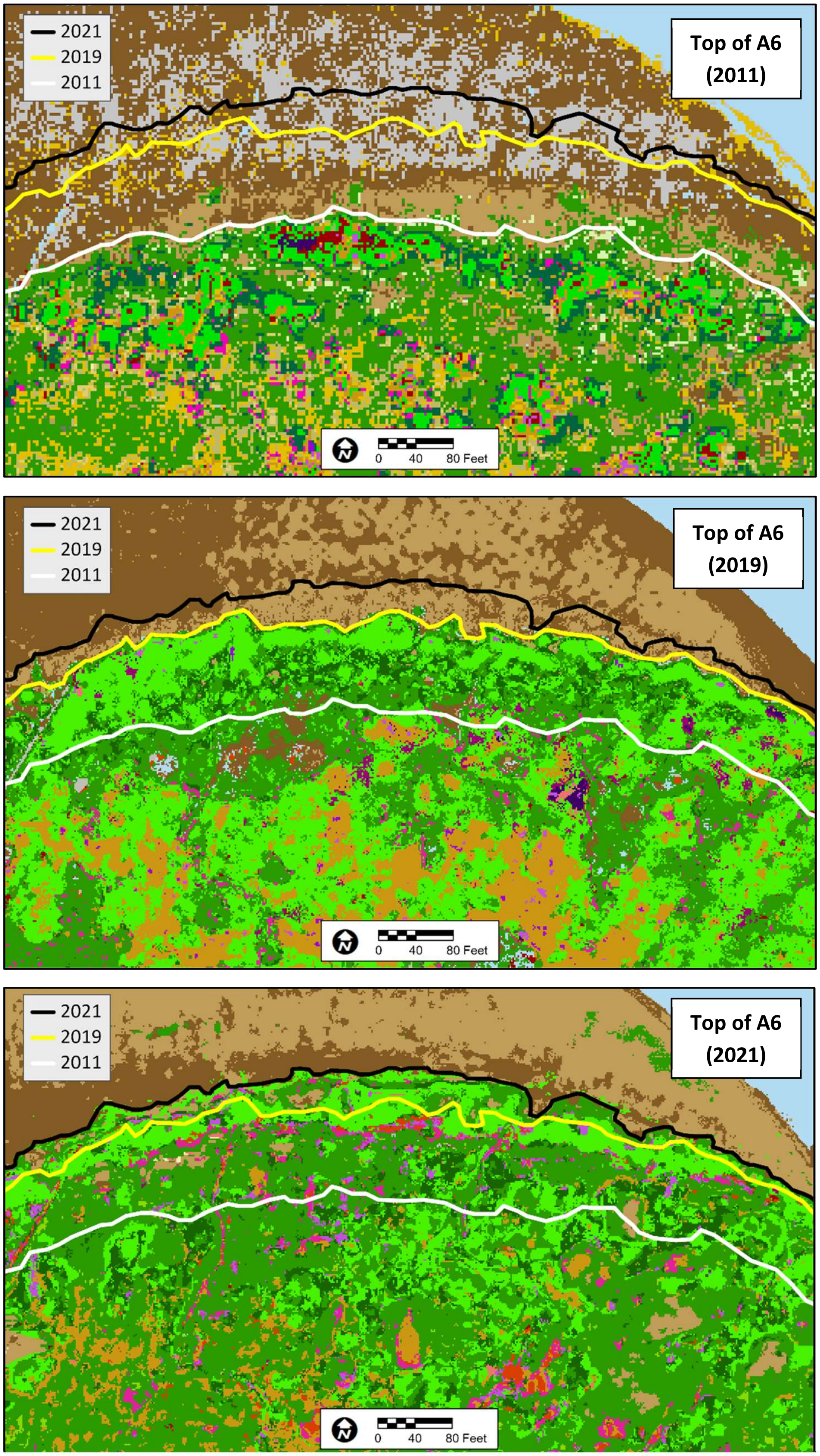


Figure 36: Marsh growth for top of A6 (2011, 2019, 2021)

3.4 Ravenswood

Within the Ravenswood restoration unit, the marsh habitats and mudflats are almost entirely outside of ponds already or undergoing enhancement or restoration. Pond SF2 was enhanced in 2010 for bird habitat. Pond R4 began restoration during the first year of HEMP2 (2019) and was still underway in 2021. Pond R5 and S5 are also currently undergoing enhancement to complement the restoration at R4. The remaining ponds are currently being managed by SBSP and its partners for potential restoration or enhancement in the future. We have excluded the area within these ponds undergoing restoration or enhancement (or being managed) from our final datasets and the figures and tables below. Based on the boundary we are using for the Ravenswood unit, the marsh within Ravenswood slough is the only marsh and mudflats being mapped (in addition to the enhanced area within SF2).

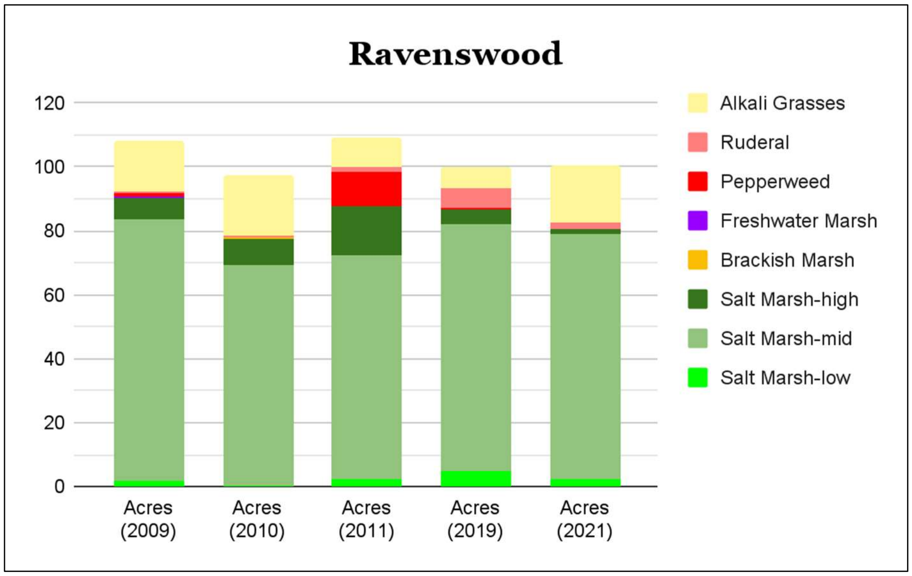


Figure 37: Acreage by Habitat Type for Ravenswood (2009 - 2011, 2019 & 2021)

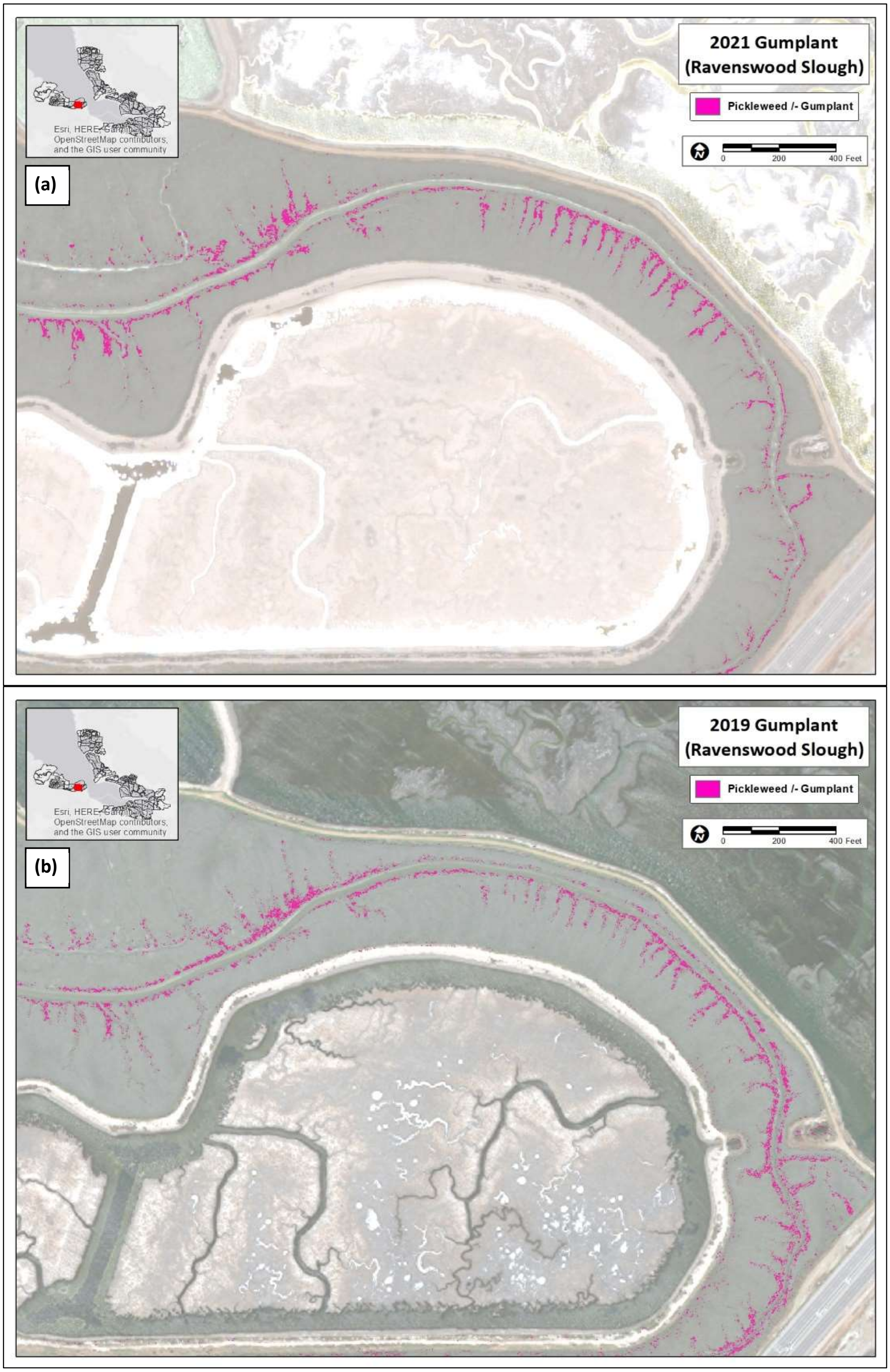
Table 44: Acreage by Habitat Type for Ravenswood (2009 - 2011, 2019 & 2021)

Habitat Type		Ravenswood				
		Acres (2009)	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	2.0	0.5	2.4	4.7	2.4
	Salt Marsh-mid	81.5	69.0	69.8	77.3	76.5
	Salt Marsh-high	6.9	8.3	15.5	4.5	1.9
	Brackish Marsh	0.1	0.1	0.0	0.1	0.0
	Freshwater	0.1	0.0	0.1	0.0	0.0
	Pepperweed	1.1	0.5	10.6	0.6	0.0
	Ruderal	0.9	0.3	1.7	6.0	2.0
	Alkali Grasses	15.8	19.0	9.1	6.9	17.5
	Biotic total	**108.4**	**97.6**	**109.1**	**100.2**	**100.4**
abiotic habitats	Mudflat	35.6	39.4	17.5	46.0	90.0
	Wrack (or dead	35.1	29.0	16.0	13.9	0.3
	Bare Earth	220.2	197.2	81.0	100.3	109.4
	Water	11.9	31.7	153.2	152.7	113.0
	Abiotic total	**302.8**	**297.3**	**267.7**	**313.0**	**312.8**
Grand Total		**411.2**	**394.9**	**376.8**	**413.2**	**413.2**

Table 45: Acreage by Mapped Habitat for Ravenswood (2009 - 2011, 2019 & 2021)

Mapped Habitat	Ravenswood				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.1	0.1	0.0	0.1	0.0
Alkali Grasses	15.8	19.0	9.1	6.9	17.5
Alkali Heath	6.0	7.0	12.7	0.9	0.4
Bare Earth	220.2	197.2	81.0	100.3	109.4
Freshwater Bulrush	0.1	0.0	0.0	0.0	0.0
Cattails	0.0	-	0.1	0.0	0.0
Cordgrass	0.9	0.1	0.6	3.0	1.1
Cordgrass/-Pickleweed	1.1	0.4	1.8	1.7	1.3
Mudflat without Biofilm	23.8	29.7	6.1	37.0	81.2
Mudflat with Biofilm	11.8	9.7	11.5	9.0	8.8
Pepperweed	1.1	0.5	10.6	0.6	0.0
Pickleweed	79.9	67.1	68.9	75.4	71.6
Pickleweed /- Gumplant	1.0	1.3	2.8	3.6	1.5
Pickleweed /- Jaumea	0.2	0.2	0.7	1.0	2.9
Ruderal	0.9	0.3	1.7	6.0	2.0
Saltgrass	1.5	1.6	0.2	0.8	2.0
Spearscale	-	0.0	0.0	0.0	0.0
Water	11.9	31.7	153.2	152.7	113.0
Wrack	35.1	29.0	16.0	13.9	0.3
Total	**411.2**	**394.9**	**376.8**	**413.2**	**413.2**

Our review of the fluctuations in acreages of low, mid and high salt marsh within Ravenswood (see Figure 37 and Table 44) between 2009 and 2021 indicate potentially normal variability due to tidal, phenological, and/or radiometric differences over time. Therefore, the fluctuations may not necessarily represent any long-term changes. Although there was a decrease in low salt marsh (Cordgrass and Cordgrass /- Pickleweed) between 2019 and 2021, the acreages in 2021 are 20% higher (0.4 acre) than those in 2009. Between 2009 and 2021, there was a 6% decrease (5 acres) in mid salt marsh. At the same time, the acreage in 2021 for mid salt marsh (76.5 acres) is slightly above the average for the five years mapped (~75 acres). The "reduction" for mid salt marsh was entirely Pickleweed, while the acreages of Saltgrass (from 1.5 to 2 acres) and Jaumea (from 0.2 to 2.9 acres) both increased during this same time period. On the surface, the reduction in high salt marsh between 2009 and 2021 (72% - from 6.9 to 1.9 acres) appears to be significant and not explainable by normal variability. Interestingly, our ability to map Gumplant within channels along Ravenswood slough was greatly improved in 2019 and 2021. Over the ten years between 2009 and 2019, the acreage of Gumplant increased steadily from 1 to 3.6 acres, before dropping back to 1.5 acres in 2021 (see Table 45). The acreages for mapped Alkali Heath dropped 85% (from 6 to 0.9 acres) between this same time period. The vast majority of this Alkali Heath in 2009-2011 was mapped within the bare earth parts of SF2 (including the bird islands). Despite the decline in Alkali Heath, the ground truthing and final maps for 2019 and 2021 indicate the ongoing presence of large and healthy "Gumplant channels" within Ravenswood slough (see Map 23a-b).



Map 23a-b: Gumplant channels in Ravenswood Slough (2019 & 2021)

3.5 Select Marshes

Inner Bar

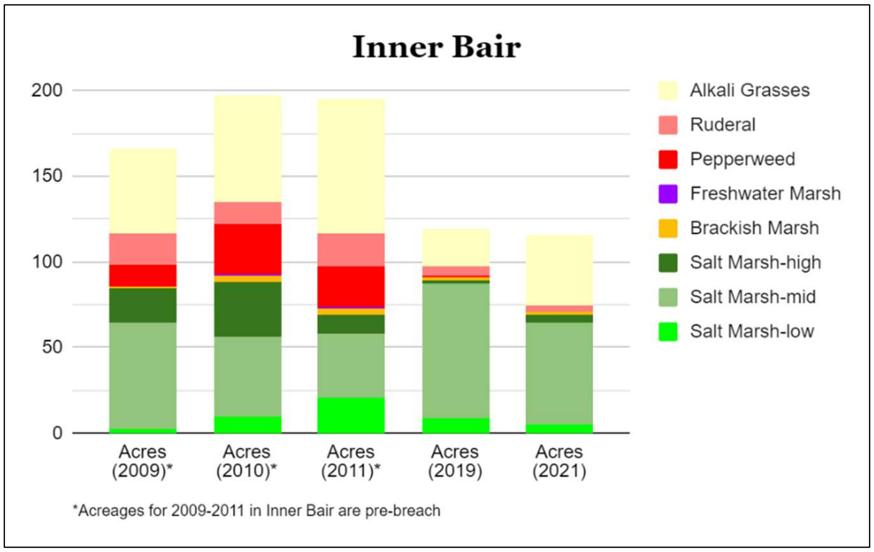


Figure 38: Acreage by Habitat Type for Inner Bair (2009 - 2011, 2019 & 2021)

Inner Bair had begun to be breached in 2011. By 2019, most of the island was a mudflat, once again dominated by biofilm, with Pickleweed in some locations including the mounds in the central part of the island (see Figure 38 and Table 46). The acreages of vegetation between 2009-11 therefore represent the island before it was fully exposed to tidal action. Since 2019, Pickleweed can also be found in denser mats and colonizing along with Cordgrass in channels on the easternmost side of Inner Bair. See the Results section above for the 2019 and 2021 maps of Inner Bair.

Table 46: Acreage by Habitat Type for Inner Bair (2009 - 2011, 2019 & 2021)

	Habitat Type	Inner Bair				
		Acres (2009)*	Acres (2010)*	Acres (2011)*	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	2.53	9.80	20.78	8.63	5.10
	Salt Marsh-mid	61.95	46.19	37.76	78.82	59.86
	Salt Marsh-high	20.65	31.99	10.27	2.27	4.51
	Brackish Marsh	0.63	4.05	4.38	1.78	1.68
	Freshwater Marsh	0.09	0.51	0.17	0.04	0.00
	Pepperweed	12.53	29.47	23.86	0.43	0.12
	Ruderal	18.64	13.15	19.08	5.27	3.34
	Alkali Grasses	48.98	61.60	79.19	22.51	40.91
	Biotic total	**166.00**	**196.77**	**195.50**	**119.75**	**115.52**
abiotic habitats	Mudflat	10.58	12.98	9.38	113.81	139.74
	Wrack (or dead veg)	52.11	21.29	11.44	13.39	0.70
	Bare Earth	20.50	14.17	28.61	6.45	10.85
	Water	41.65	45.63	45.90	37.42	24.02
	Abiotic total	**124.84**	**94.06**	**95.34**	**171.07**	**175.31**
	Grand Total	**290.84**	**290.83**	**290.84**	**290.82**	**290.83**

**Inner Bair was breached after 2011, so the acreages from HEMP1 (2009-11) are all pre-breach.*

Middle Bair (restored pond only)

In Middle Bair, the levees around the restored pond were not breached until after the end of HEMP1. Therefore, the acreages from this time period (09-11) represent any vegetation within the pond when it was not fully exposed to tidal action (see Figure 39 and Table 47). By 2019, the acreage of salt marsh vegetation within the restored pond at Middle Bair was around 26 acres. However, between 2019 and 2021, the acreage of Pickleweed (and Cordgrass) almost tripled (from 26 to 71 acres). See the Results section above for the 2019 and 2021 maps of Middle Bair.

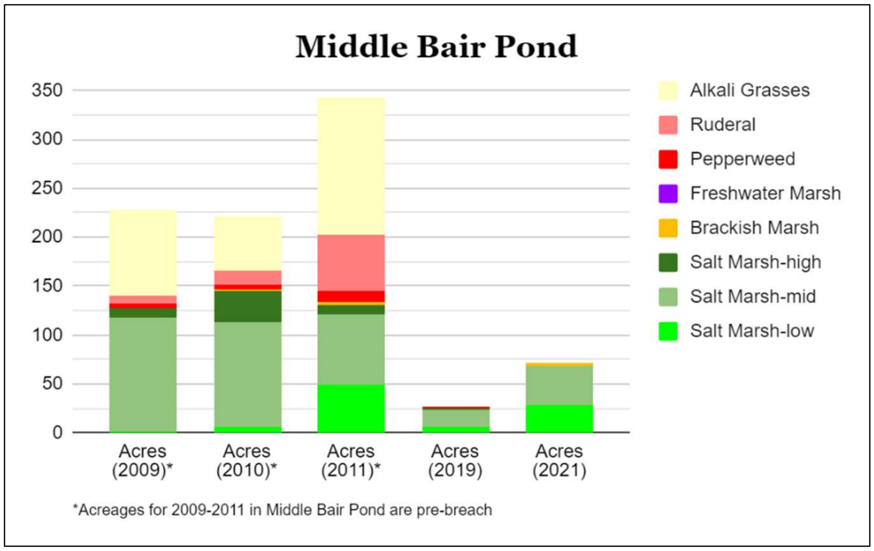


Figure 39: Acreage by Habitat Type for Middle Bair Pond (2009 - 2011, 2019 & 2021)

Table 47: Acreage by Habitat Type for Middle Bair Pond (2009 - 2011, 2019 & 2021)

	Habitat Type	Middle Bair Pond				
		Acres (2009)*	Acres (2010)*	Acres (2011)*	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	0.81	6.03	48.62	5.78	27.94
	Salt Marsh-mid	116.90	107.11	72.24	17.07	40.41
	Salt Marsh-high	9.55	31.22	10.31	2.86	0.69
	Brackish Marsh	0.01	1.52	2.91	0.16	2.27
	Freshwater Marsh	0.01	0.13	0.01	0.00	0.00
	Pepperweed	5.22	5.92	11.34	0.08	0.04
	Ruderal	7.61	13.55	57.82	0.03	0.04
	Alkali Grasses	88.41	56.67	139.73	0.00	0.02
	Biotic total	**228.51**	**222.14**	**342.99**	**25.97**	**71.41**
abiotic habitats	Mudflat	3.56	9.41	23.32	611.92	568.86
	Wrack (or dead veg)	128.85	149.01	121.66	0.01	0.00
	Bare Earth	274.94	225.96	113.41	1.65	1.80
	Water	25.38	54.73	59.88	21.69	19.16
	Abiotic total	**432.73**	**439.11**	**318.26**	**635.27**	**589.83**
	Grand Total	**661.24**	**661.25**	**661.25**	**661.24**	**661.24**

**This part of Middle Bair was breached after 2011, so the acreages from HEMP1 (2009-11) are all pre-breach.*

Outer Bair (restored pond only)

Between 2010 and 2019, in the restored pond within Outer Bair (at the southwestern part of the Island), the amount of low (Cordgrass and Cordgrass /-Pickleweed) and mid (Pickleweed, Saltgrass, and Jaumea) salt marsh had increased by 25% (from 52 to 65 acres). These habitats colonized along the channels formed and emanating out of the levee breach (see Figure 40 and Table 48). Despite this amount of floral colonization over the 8 years between the two studies, by 2019 the pond was still dominantly mudflat (see Maps 24a and 24b). However, between 2019 and 2021, the amount of Pickleweed (and Cordgrass) colonizing the mudflats had increased by 62% (from 65 to 105 acres), providing further evidence of the increased rate of floral colonization between 2019 and 2021 seen in other restored ponds within the study area.

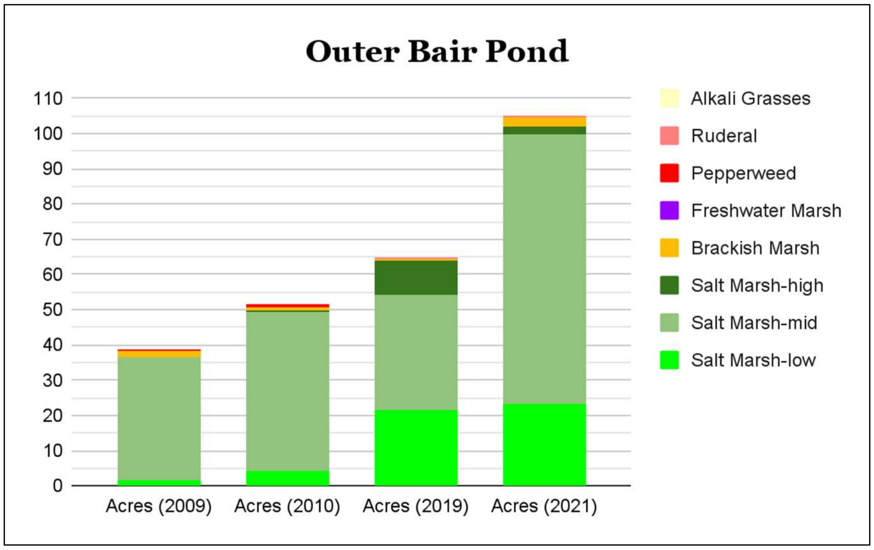
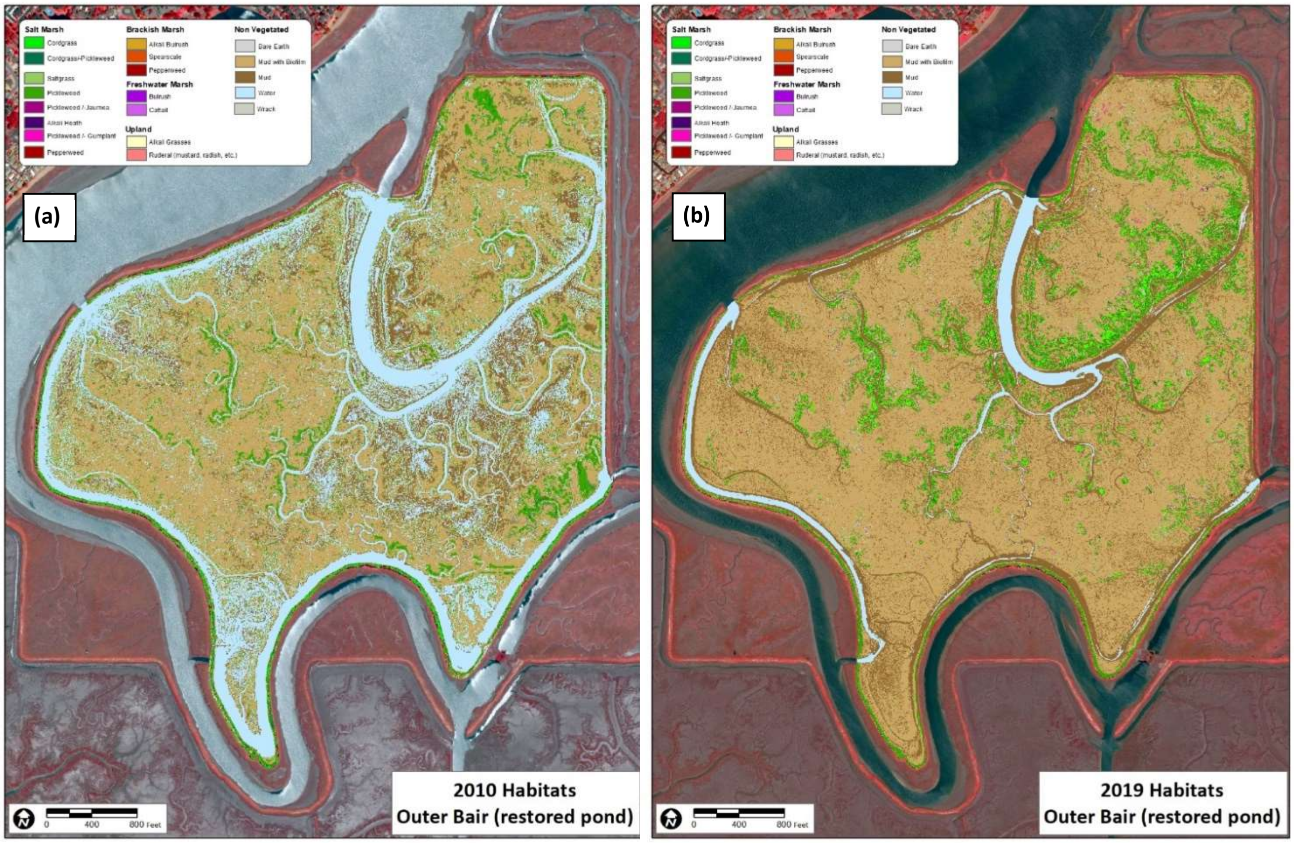


Figure 40: Acreage by Habitat Type for Outer Bair (2009 - 2011, 2019 & 2021)

Table 48: Acreage by Habitat Type for Outer Bair Pond (2009 - 2010, 2019 & 2021)

Habitat Type		Outer Bair Pond			
		Acres (2009)	Acres (2010)	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	1.58	4.23	21.62	23.23
	Salt Marsh-mid	34.85	45.29	32.81	76.67
	Salt Marsh-high	0.27	0.49	9.67	2.00
	Brackish Marsh	1.44	0.66	0.24	2.80
	Freshwater Marsh	0.00	0.02	0.00	0.00
	Pepperweed	0.41	0.86	0.21	0.03
	Ruderal	0.05	-	0.26	0.26
	Alkali Grasses	0.10	0.14	0.01	0.20
	Biotic total	**38.69**	**51.68**	**64.82**	**105.19**
abiotic habitats	Mudflat	273.88	227.77	320.03	287.03
	Wrack (or dead veg)	13.15	6.82	0.03	0.01
	Bare Earth	0.03	0.23	1.14	2.99
	Water	82.83	122.09	22.57	13.37
	Abiotic total	**369.89**	**356.91**	**343.77**	**303.40**
	Grand Total	**408.58**	**408.59**	**408.59**	**408.59**



Map 24a-b: Mapped habitats for Outer Bair Pond (2011 & 2019)

There was considerable overmapping of biotic habitats in 2011 (105.24 acres) compared to 2010 (51.68 acres) within Outer Bair. We did not edit (the restored pond in) Outer Bair for 2011 because there was no clear way to accurately edit biotic habitats for that year. As a result, we have excluded 2011 from the tables and figures for the resorted pond in Outer Bair.

Faber/Laumeister Marsh

Although the Faber-Laumeister marsh continues to contain significant patches of high marsh (~ 4 acres) dominated by Gumplant (and Alkali Heath) throughout the marsh plain and along channels (see Figure 41), it is less than half of what was mapped in 2019 (9 acres) and one fifth of what was mapped in 2011 (~20 acres). This could indicate a significant reduction in high marsh between 2011 and 2021. Part of this reduction could be phenological, potentially related to the significant reduction in precipitation from 16 in 2019 to 5 inches in 2021, as we have seen in other habitats for 2021 (e.g., Alkali Bulrush). However, even if we take the average acreages over the 3 years of HEMP1 (18 acres) and compare it to the average over the 2 years of HEMP2 (7 acres) to account for mapping variability for each project, this would still indicate a significant reduction in high marsh at Faber/Laumeister between 2011 and 2021.

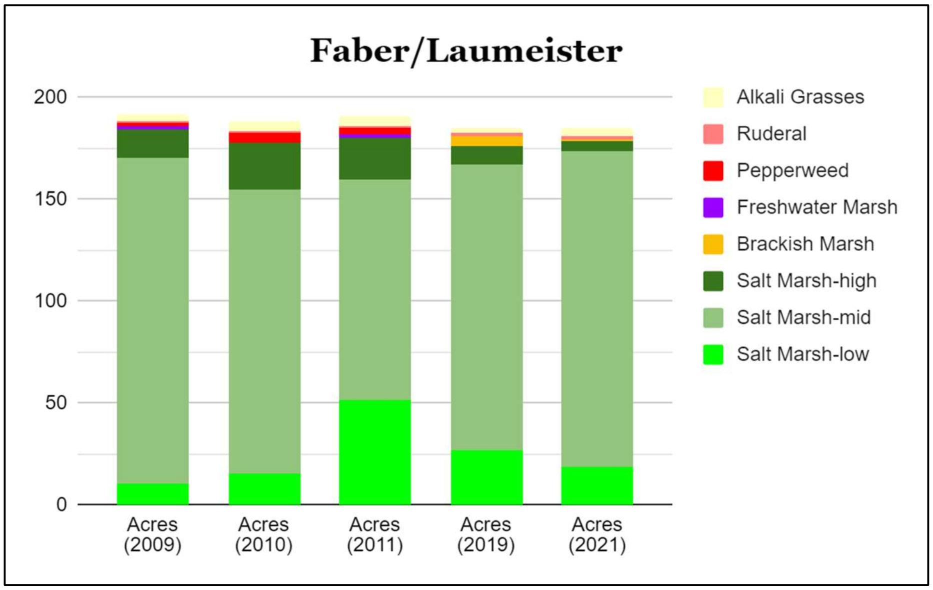
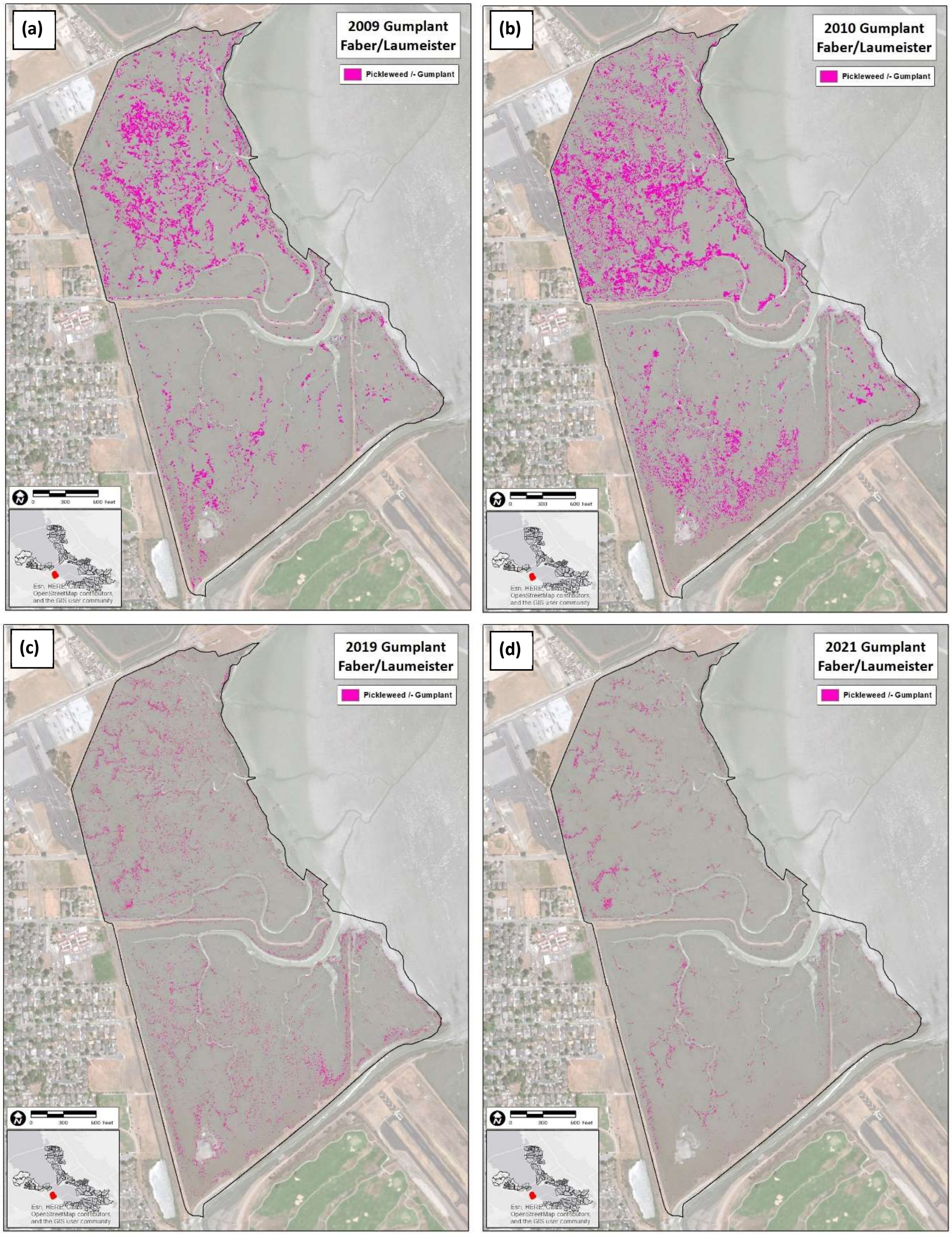


Figure 41: Acreage by Habitat Type for Faber/Laumeister (2009 - 2011, 2019 & 2021)

That stated, the imagery (for all years) seem to contradict the mapped acreages to some degree. In both 2009 and 2010 (see Maps 25a and 25b), the distribution of Gumplant along channels and within elevated locations in the 'mid' marsh appears to comply with visual trends see in the satellite imagery and from ground truthing. At the same time, Gumplant also appears to be overmapping (what should likely be Jaumea or Alkali Heath) in the northern section of the marsh in 2010. In 2011, Gumplant appears to be accurately mapping along channels (and within elevated areas) in the northern section of the marsh. However, in the southern section, the distribution does not seem to comply with the expected patterns, resulting in more uncertainty in that area (for 2011). In both 2019 and 2021, the extent and distribution of Gumplant appears to be mapping well along channels and in elevated areas within the marsh (see Maps 25c and 25d). However, the density of Gumplant is significantly reduced from 2009-2011. One factor possibly contributing to the acreage reduction is the difference in spatial resolution between the imagery used to create the habitat datasets. The Ikonos imagery from 2009-11 was pansharpened to 0.9 meter spatial resolution. As a result, the boundaries between Gumplant and adjacent habitats are mapped more coarsely (almost 2X less coarse than 2019 and 2021). The possible acreage inflation of Gumplant and the finer spatial resolution from 2021/2019 (0.5 meter) exacerbates the differences by more precisely mapping Gumplant.

In the southern tract, there was a significant amount of brackish marsh (i.e., Alkali Bulrush) in 2019, which did not appear in any significant stands between 2009-11. However, in 2021, although the acreage of Alkali Bulrush (0.67 acres) was more than twice what it had been in 2009 (0.3 acres), it was still only 15% as much as 2019 (~4 acres). Interestingly, the acreage of Freshwater Marsh increased from 1-2 acres between 2009-2011 to 5-10 acres between 2019 and 2021. The growth of either brackish or freshwater marsh habitats opens the possibility of salinity changes within the time period of the two studies. In the end, it is still unclear whether the amount of Alkali Bulrush (and Freshwater Bulrush) in 2019 was evidence of a shift in salinity in certain locations or 'normal' interannual variability.



Map 25a-d: Gumplant mapping in Faber/Laumeister (2009, 2010, 2019 & 2021). Note: gumplant in 2010 is overmapping, but the distribution is more accurate than 2021.

Table 49: Acreage by Habitat Type for Faber/Laumeister (2009 - 2011, 2019 & 2021)

Habitat Type		Faber/Laumeister				
		Acres (2009)	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	10.60	15.19	51.79	27.08	18.38
	Salt Marsh-mid	159.81	139.74	107.97	140.32	155.60
	Salt Marsh-high	13.67	22.91	20.45	9.03	4.37
	Brackish Marsh	0.30	0.26	0.06	4.38	0.67
	Freshwater Marsh	1.19	0.00	1.70	0.06	0.00
	Pepperweed	2.00	4.58	2.98	0.20	0.02
	Ruderal	1.17	1.07	0.80	1.58	1.63
	Alkali Grasses	2.69	4.96	4.93	2.13	4.44
	Biotic total	**191.44**	**188.71**	**190.68**	**184.77**	**185.12**
abiotic habitats	Mudflat	7.76	5.59	3.58	9.57	13.19
	Wrack (or dead veg)	1.75	2.61	2.09	3.49	0.20
	Bare Earth	0.05	0.74	1.66	2.11	2.85
	Water	0.51	3.97	3.55	1.81	0.38
	Abiotic total	**10.06**	**12.91**	**10.87**	**16.97**	**16.62**
	Grand Total	**201.50**	**201.62**	**201.55**	**201.74**	**201.75**

Calavares Marsh

Since 2011, the mudflat on the southside of *Calavares* marsh continues to be colonized by Cordgrass and, to a lesser extent, Pickleweed (probably *Salicornia europaea*). The marsh at Calaveras has expanded up to 60 meters south or more from the edge of low marsh in 2011 (see Figure 42). In the center of the marsh, there are significant patches of *Alkali Bulrush (*and Gumplant), indicating a range of salinities. Interestingly, although patches of Alkali Bulrush were identified during our field surveys in 2019, it was almost entirely absent during our 2021 field surveys. Since we know there is Alkali Bulrush within the marsh, it is most likely that the brackish bulrush was largely decomposed during our 2021 field surveys (and therefore likely *Scirpus Maritimus*). This decomposition could have been due to a range of factors, perhaps including the lack of precipitation in 2021.

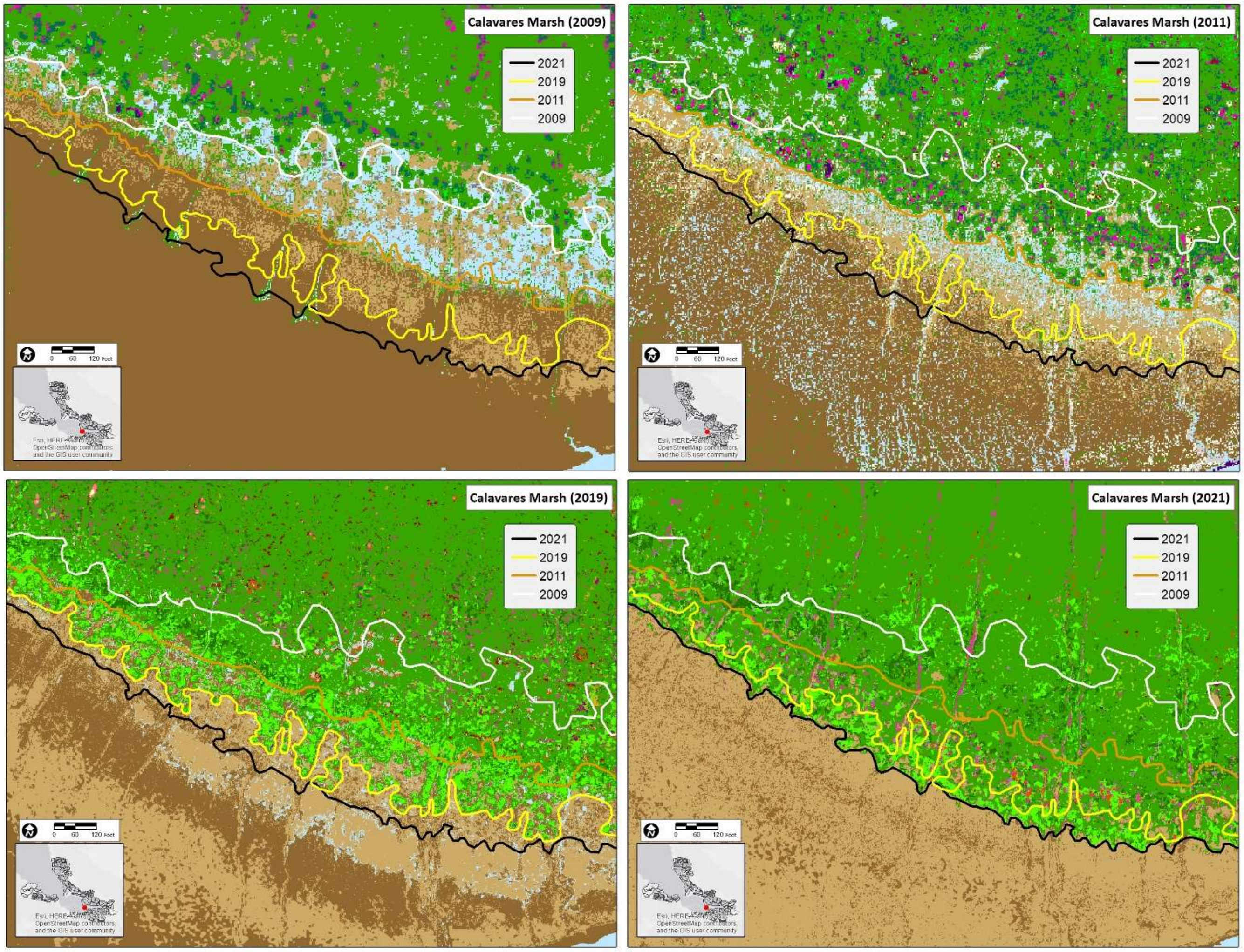


Figure 42: Marsh growth at Calavares Marsh (2009, 2011, 2019, 2021)

Ogilvie Island

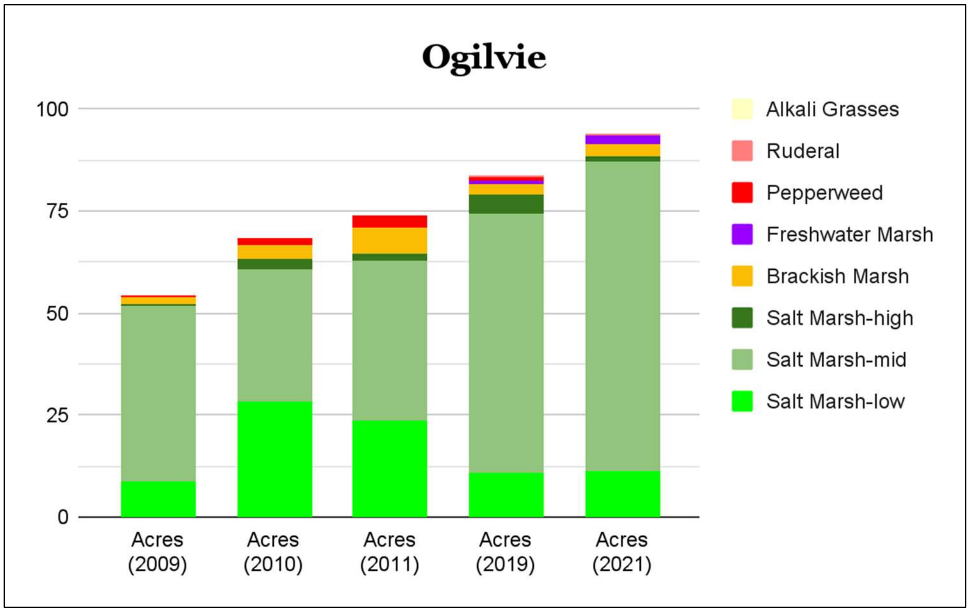


Figure 43: Acreage by Habitat Type for Ogilvie (2009 - 2011, 2019 & 2021)

Pickleweed and Cordgrass have completely colonized both the western and eastern portion of Ogilvie Island since 2009 (see Figure 43). In addition, the channel that existed in 2009 has been almost completely filled with accreted mudflat and vegetation is already colonizing the area. There was a 77% increase (from 43 to 76 acres) in mid salt marsh and a 31% increase (from 8.6 to 11.3 acres) in low salt marsh (see Figure 43 and Table 50). Alkali Bulrush has also grown, along with Spearscale, and has begun to compete with the salt marsh on the southeastern part of the island (not shown).

Table 50: Acreage by Habitat Type for Ogilvie (2009 - 2011, 2019 & 2021)

	Habitat Type	Ogilvie				
		Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
biotic habitats	Salt Marsh-low	8.62	28.23	23.73	10.85	11.30
	Salt Marsh-mid	43.13	32.46	39.15	63.38	75.93
	Salt Marsh-high	0.48	2.57	1.83	4.70	1.12
	Brackish Marsh	1.91	3.67	6.12	2.85	3.18
	Freshwater Marsh	0.00	0.00	0.06	0.89	2.11
	Pepperweed	0.11	1.52	2.88	0.77	0.09
	Ruderal	-	0.00	0.01	0.11	0.09
	Alkali Grasses	-	0.00	0.05	-	0.01
	Biotic total	**54.25**	**68.46**	**73.82**	**83.56**	**93.84**
abiotic habitats	Mudflat	46.10	46.40	40.70	42.31	34.09
	Wrack (or dead veg)	0.48	0.24	1.11	1.96	1.95
	Bare Earth	0.00	0.21	6.73	0.02	0.04
	Water	31.03	16.55	9.49	4.00	1.94
	Abiotic total	**77.61**	**63.40**	**58.04**	**48.30**	**38.02**
	Grand Total	**131.86**	**131.85**	**131.86**	**131.85**	**131.86**

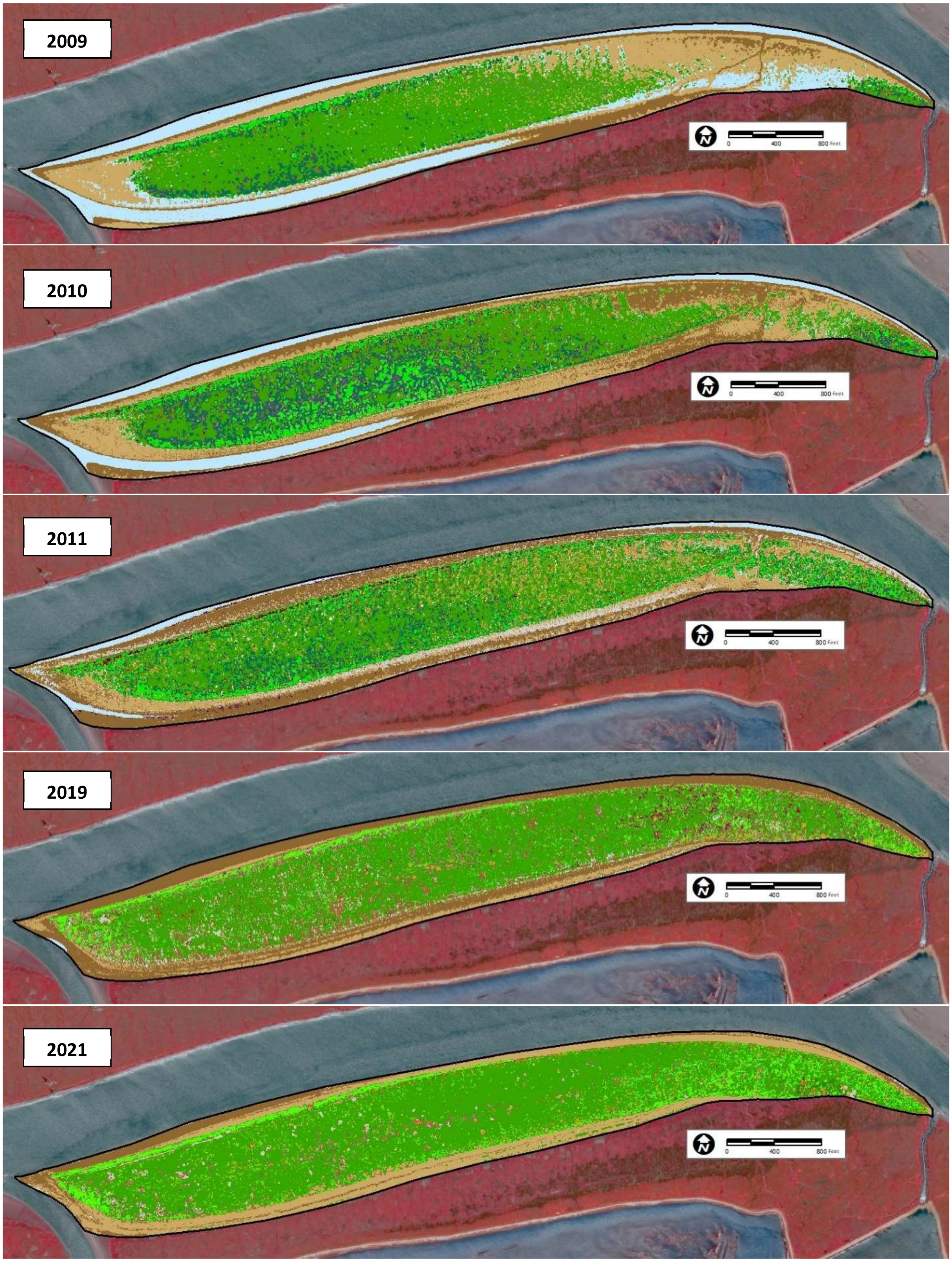


Figure 44: Marsh growth for Ogilvie (2009, 2010, 2011, 2019, 2021)

LaRiviere Marsh

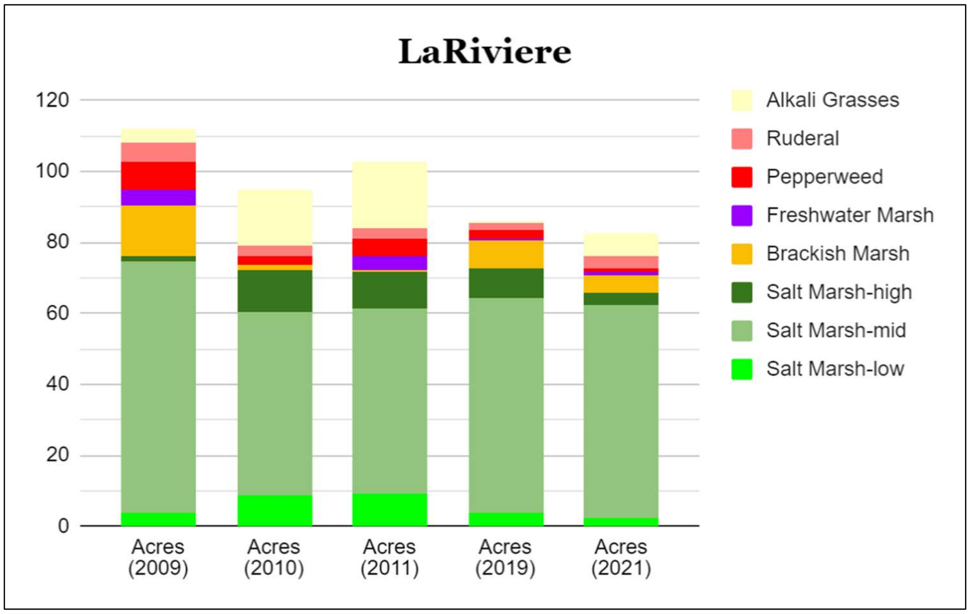


Figure 45: Acreage by Habitat Type for LaRiviere (2009 - 2011, 2019 & 2021)

Table 51: Acreage by Habitat Type for LaRiviere (2009 - 2011, 2019 & 2021)

	Habitat Type	LaRiviere				
		Acres (2009)	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
biotic habitats	Salt Marsh-low	3.71	8.58	9.35	3.73	2.28
	Salt Marsh-mid	70.93	51.70	51.98	60.81	60.16
	Salt Marsh-high	1.64	11.92	10.25	8.12	3.42
	Brackish Marsh	14.04	1.31	0.38	7.87	4.89
	Freshwater Marsh	4.47	0.02	4.19	0.32	1.14
	Pepperweed	8.09	2.81	4.85	2.51	1.03
	Ruderal	5.22	2.89	3.16	2.18	3.19
	Alkali Grasses	3.80	15.55	18.74	0.51	6.37
	Biotic total	**111.90**	**94.80**	**102.91**	**86.04**	**82.48**
abiotic habitats	Mudflat	1.86	5.38	2.31	11.69	25.21
	Wrack (or dead veg)	9.11	13.06	8.42	7.47	0.34
	Bare Earth	1.60	9.90	3.55	8.71	18.67
	Water	3.60	4.41	8.52	14.25	1.46
	Abiotic total	**16.17**	**32.75**	**22.80**	**42.12**	**45.69**
	Grand Total	**128.08**	**127.55**	**125.71**	**128.16**	**128.16**

Section 4. Methods

All habitats and mudflats were derived using semi-automated classification of high-resolution satellite imagery. For mapping habitats, we repeated the methods used between 2009 and 2011 because they achieved accurate results, are easily replicable, and widely used. The training sites for our classification (both 2019 and 2021) were based on the same set of ecologically relevant habitat classes (see Table 1 and Appendix 1), that we developed between 2009-2011 (Fulfrost, B., and Thomson., D., 2012). For mudflats, we used methods developed in our 2016 pilot study (Fulfrost, B., 2017) using imagery from the Worldview-3 sensor. Both our methods for mapping vegetative (and non-vegetative) habitats and our separate process for mudflats, which rely on identifying and distinguishing habitats based on their unique spectral responses, are optimized when using multispectral imagery like that found in the Worldview-2 (or Worldview-3) sensor.

HEMP2 was a two-year project. We used the first year (2019) to re-apply the methods from HEMP1 (and our 2016 mudflat study) to newer and higher resolution satellite imagery (Worldview-2). In this process, we refined our habitat classifications, enhanced some of our methods (e.g., mudflats), and brought into clearer focus some of the issues with the original HEMP datasets. After we had completed the 2021 mapping, we then reran our automated classification for 2019 based on our improved understanding of habitat distributions obtained from both years (2019 *and* 2021).

Our methodology for mapping these biotic (and abiotic) habitat types consisted largely of six steps. First, we focused on acquiring satellite imagery by identifying days between May and August where one of the selected satellites (WV2 or WV3) passed over the study area close to Mean Lower Low Water (MLLW). Once we obtained the 'raw' (level 2A) satellite imagery we conducted a QA to check for radiometric, geometric, or other issues, and to evaluate the need for imager preprocessing. Second, we conducted GPS based ground truthing for statistical validation and for building our initial training sites. Third, we compiled a set of spectral training sites for each habitat type and ran a supervised classification on each image. Fourth, we would review model output both in GIS and in the field in order to calibrate model results. The model review would lead to improvements to the spectral model and changes to our training sites, rerunning of the supervised classifications, resulting in new and improved model output. Fifth, we would repeat steps four and five until the model output was well calibrated, resulting in our final habitat model. The final step was to conduct an accuracy assessment using the field-based validation surveys (acquired in step #3). Additional details and discussion for steps one through six, as well as the methods used to map mudflats, are included below. A discussion of step six (the accuracy assessment) can be found in both the section on ground truthing (see below) or accuracy assessment (see above).

4.1 Step #1: Satellite Acquisition and Pre-Processing

Satellite Acquisition

In order to capture both the full extent of vegetation with tidal marsh as well as the full extent of tidal mudflats, our first requirements is to obtain imagery closest to Mean Lower Low Water (MLLW). The only satellite imagery that meets both our spatial (~ 1 meter) and spectral requirements (4 band or better) are those satellite available from MAXAR (formerly Digital Globe). These satellites pass over approximately at noon to minimize sun going while closest to 'nadir' (i.e., directly above the area of interest). As in previous years, we used the National Oceanographic and Atmospheric Associations (NOAA) tide prediction from their Redwood City tide gauge (ID 9414523) obtained online (see https://tidesandcurrents.noaa.gov/tide_predictions.html) to identify days between May and August where MLLW was closest to noon. This time period (May – August) is the best for mapping overall maximum vegetation growth. In 2019, we identified six days within this period that met our tidal requirements and obtained imagery captured on June 8th just below MLLW by Worldview-2 (WV2). These images provided full exposure of tidal mudflats, and contained limited water within marshes, and consequently provided an excellent baseline for both tracking changes to mudflats and mapping habitats. In 2021, the number of days were more limited (4), and in consultation with the PMT, we chose the day with the highest likelihood for overall peak fluorescence of vegetation. The 2021 imagery was captured by the WV2 satellite on June 15th about half a foot above MLLW.

Worldview-2 is an 8-band multispectral sensor that includes a 'coastal' blue band that is very useful for mapping shallow water mudflats. It also provides additional bands (yellow, red edge, 2 near infrared) that aid in vegetation discrimination. The combination of these additional bands, as well as mapping at MLLW between May and August, allow us to best discriminate the different species of concern and to map tidal mudflats at their maximum extent.

In both 2019 and 2021, we performed a thorough QA on the imagery, which came in three 'snapshots' in 2019 and two 'snapshots' in 2021. The Worldview-2 is bi-directional satellite that can rotate during acquisition to cover an area larger than its normal swath width. During this review process, we evaluated the images (all 8 bands) for any erroneous values (like negative values), image distortion, or significant geometric issues. While conducting the pan sharpening process for the 2019 imagery, we noticed an issue regarding the alignment of the panchromatic and multispectral image for one of the snapshots. Although it took us some time to diagnose, the georeferencing file for one of the images contained the incorrect registration coordinates.

Atmospheric Correction

In order to remove impacts of the atmosphere on the reflected values of the features of concern (i.e., the marshes and mudflats) that are recorded at the satellite, the satellite provider (MAXAR) performed an atmospheric correction and delivered the final imagery for both years as 11-bit ground reflectance values. We also received uncorrected imagery from MAXAR in case there was an issue with the correction or we wanted to compare other atmospheric correction methods. However, after comparing the two sets of images, the atmospheric correction performed by MAXAR met all our expectations, reducing sun glint, haze, and other atmospheric effects.

Pansharpening and Orthorectification

The imagery is delivered by the satellite provider as two separate sets of files: one panchromatic at half meter resolution; and one multispectral image (with 8 bands) at 1.8-meter resolution. We fused these images together in Erdas Imagine 2020, using the HCS method designed specifically for Worldview-2, to produce a multispectral image of the study area at half meter resolution (which we used to build our habitat model in both 2019 and 2021).

Although we received geocorrected imagery (which gave the delivered imagery a >= 10 meter spatial accuracy), we improved upon this and reduced any underlying terrain distortion by orthorectifying all of the images for each year. We used local ground control points obtained from high resolution aerial photography available as streaming web services from Alameda (2017), Santa Clara (2018), and San Mateo (2018) counties. In order to prioritize the spatial accuracy of the marshes and mudflats, we chose the ground control points (GCPs) within and around the baylands and not the adjacent urban areas. For terrain correction, we used a 2-meter Digital Elevation Model (DEM) downloaded from the USGS (Buffington, K.J., and Thorne, K.M., 2019). For 2019, we performed a qualitative QA on the results comparing it to our source of higher accuracy (the high-resolution aerial imagery). Using a series of spot tests throughout the baylands for each image 'snapshot', we approximate the spatial accuracy of the final 2019 images (and model results) to be 1-2 meters (or less). In 2021, we created and used 30 GCPs focusing on the baylands, derived from the aerial orthoimagery, to quantify the spatial accuracy of the 2021 satellite imagery. We created points corresponding to each GCP location in the satellite imagery and measured the distance between each GCP and corresponding point in the imagery. The mean and median distances from GCPs in 2019 were 0.80m and 0.76m, respectively.

4.2 Step #2: Ground Truthing

Between 2019 and 2022, we conducted a total of 599 in situ surveys of vegetative and non-vegetated habitats within the study area (see Figure 46 and 47). The majority of surveys (406) were acquired for use in our statistical validation. The remainder of surveys (193) were used for model calibration. This ground truthing served several functions, including calibrating the edge (and presence of biofilm) of mudflat during satellite flyover (or similar tidal days); generating training sites for our habitat types;

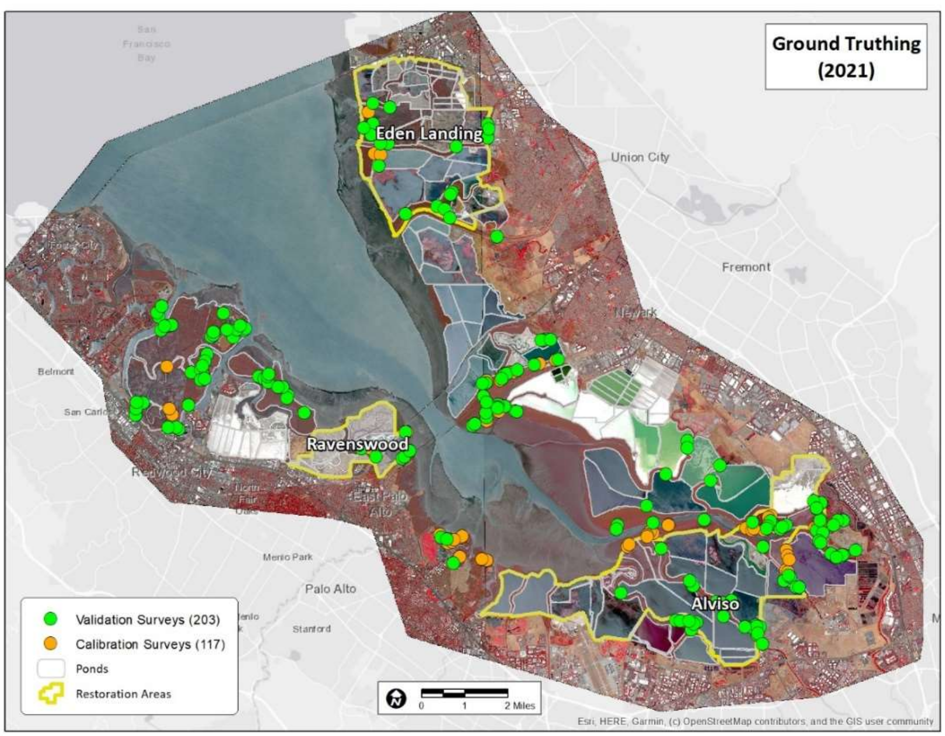


Figure 46: Ground Truthing (2021)

assisting with the evaluation and improvement of model results (calibration); and assessing the accuracy of final model results (validation).

We conducted ocular surveys of vegetation and abiotic habitats using the Rapid Assessment/Releve methods promulgated by the California Native Plant Society (CNPS, 2019) and used in the Manual of California Vegetation (Sawyer, J.O., T. Keeler-Wolf, and J. M. Evens., 2009). The 'standard' survey we use for validation is to navigate to a survey point with a sub meter mapping grade GPS (Trimble ProXT or GeoXT) and record the dominant, co-dominant and subdominant vegetation species (or abiotic habitat) within a 20-meter radius. In addition to species, our survey forms include a significant amount of other information (e.g., percent cover, pattern, and shape) to aid in interpretation, including assigning each survey points a habitat category (e.g., "Pickleweed /- Gumplant"). At most validation points we also took photos in each cardinal direction. This photo archive was essential in our iterative review of habitat classifications used to calibrate mapped classes with actual vegetation distributions. For 2021, these photos are linked to each survey point and stored directly within the ESRI geodatabase.

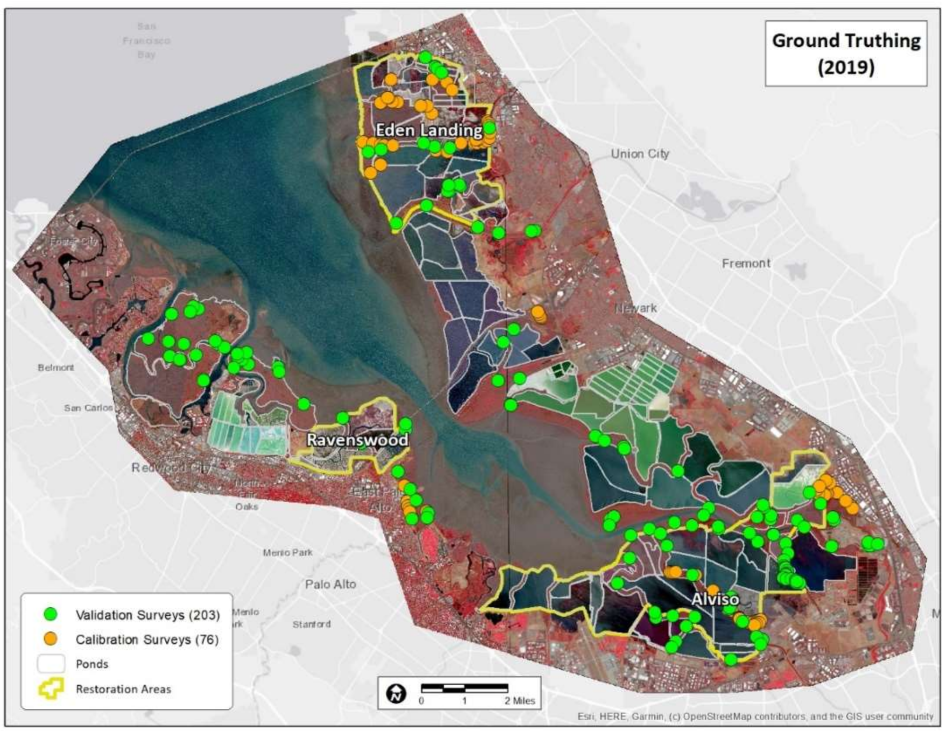


Figure 47: Ground Truthing (2019)

Validation

We created a stratified random sample of 200 survey points to be used for our statistic validation of our final model classification. Points were stratified by the relative area of salt, brackish and freshwater marshes (see Table 53). We used a modified version of SFEI's Eco Atlas, developed for the previous habitat mapping project (09-11), for our habitat stratification. The focus of our validation was on biotic habitats and as a result certain abiotic habitats (bare earth, wrack, and water) were not directly included in the sample. We met our desired sample size for brackish and freshwater marshes in 2019 but not in

2021. For salt marsh, we visited 86% (128) of our target locations in 2021 and 75% (111) in 2019 (see Table 53). The surveys for salt marsh were still more than enough to run our accuracy assessment for both years. For specific habitats with low survey numbers (e.g., Alkali Heath in 2019), we supplemented our validation sample with calibration data containing completed surveys and/or co-dominant or sub-dominant habitats at existing validation locations. Since we were only allowed into the marsh starting in September, a proportion of our validation points are from levees, boardwalks, or boat.

Table 52: Proportion of Validation Points by Habitat Type

Habitat Type	**2019 (surveys completed)**	**2021 (surveys completed)**	**# of surveys in sample**
Salt Marsh	111	128	*149*
Brackish Marsh	48	25	*34*
Freshwater Marsh	18	7	*17*
Upland	9	22	-
Non-Vegetated	17	21	-
Total	**203**	**203**	*200*

Our habitat model focuses on tidal marshes to ensure highest accuracy, and subsequently our validation surveys also focused on these locations, including fringe marshes and restored ponds. We continue to see that in muted marshes, which often have a more complex mix of vegetation and salinity, as well as more ruderal intrusion, the model results are not as consistent or as accurate. To optimize the performance of the habitat classifier our classifications focus on ground truthing and training sites found within tidal marsh and restored ponds open to tidal action.

All of ground truthing surveys used for validation went through a Quality Assurance (QA) process. First, we reviewed each survey for any errors in data entry. This QA identified a handful of cases that were either (a) mis entered habitat classes (e.g., Alkali Bulrush vs. Freshwater Bulrush) or (b) mis identified vegetation species. Second, we assigned a “final alliance” based on dominance of the different habitat classes reported in the survey, surveyor comments and notes, and a review of field photos. For the vast majority of surveys, the final alliance was identical to the field assessed alliance. We also used this process to identify surveys that had co or sub dominant habitats classes which we could potentially use to supplement habitat classes with low sample sizes (e.g., Alkali Heath). We generated up to four more entries based on the final assessed habitat alliances. These included: dominant habitat, co-dominant habitat, subdominant habitat1, and subdominant habitat2. Although the primary validation points were assessed using the dominant habitat(s) at the survey point, these additional fields were used to identify surveys where co or sub dominant habitats could be used to supplement the set of validation points where counts were low for particular habitats (e.g., Alkali Heath). For those habitats where we had less than 10 field surveys, we identified field surveys where these habitat classes were identified as sub dominant in the field (minimum of 15% cover) and used these to supplement our validation datasets. We also used calibration surveys (mostly polygons) where the survey forms were completely filled out, to supplement our validation set for these habitats. For example, in 2019, we did not have any ground truthing locations where Alkali Heath was the dominant vegetative cover and only a single survey location for Spearscale. However, there were many validation surveys where these habitats were sub-dominant (and for Spearscale a few were co-dominant). For Alkali Heath, this usually meant less than or equal to 25% cover (and often less than 15%). At a vast majority of these locations, where either Spearscale or Alkali Heath were noted in our field surveys (but not dominant), they were also present in the classified result, indicating good model performance although not reaching a threshold for being included in our statistical validation.

During the QA process, we identified a number of field surveys where the habitats (or percentage cover of those habitats) identified in the field did not match the mapped habitats because of differences in time of year between the two. Due to the restrictions on access to marshes during breeding season of obligate fauna (Ridgeways Rail and Salt Marsh Harvest Mouse), we could not conduct in marsh surveys until September for all years. Unfortunately, that sometimes-caused large differences in phenology of vegetation between the day of satellite flyover and the day of our ocular field surveys. This difference could have impacted our use of field surveys for validation since it could have led to false negatives (and to a lesser degree false positives). In addition, some surveys were conducted at offset locations (e.g., from levees) and/or the actual surveyed area did not fall "crisply" into the buffered area we use to connect our reference data (i.e., ground truthing) with our mapped imagery classifications. For both of these potential issues, we adjusted or removed surveys from our sample so that the reference data most accurately represented the surveyed locations.

Calibration

In addition to our field surveys used for model validation, we visited approximately 199 additional locations throughout the study area between 2019 and 2022 to 'calibrate' how well out model was doing as part of an iterative process of improving the model. These locations were also surveyed using a mapping grade sub meter GPS (Trimble GeoXT or Trimble Yuma) but not all locations included surveys of a 20-meter radius. At some locations, only basic species and habitats information was acquired, by walking the length of features as lines or locating small patches of specific vegetation as points or polygons. Some of these locations were also used as training sites for our supervised classification. Since most of our ground truthing was curtailed in 2020, we obtained most of these surveys in 2021. A large proportion of our calibration occurred before we were allowed to survey within marsh based on our Special Use Permit (SUP) from the USWFS. In these cases, the calibration surveys were taken from a levee, boardwalk or by boat.

4.3 Step #3 - Step #5: Habitat Model

Step #3: Training Sites

Our preliminary ground truthing was used to generate a series of "training sites" which formed the basis of our spectral habitat model used to classify the satellite imagery. For each "habitat" type, we identified ground truthing points with the highest percent cover (or mix of high percent of covers) and with the most recognizable spectral and spatial signature. Each habitat type was assigned one or more training sites, based on our review of the phenological variability of a given habitat both in the field and on the satellite image, the geographic distribution across the study area, and the variability of observed plant associations identified for a given habitat. These sites, which are examples of areas and their related spectral signatures for each type of vegetation or vegetation association, are used to "supervise" the classification of the satellite imagery into habitat types or other abiotic features like sediment and water. The size of each training sites also varied, depending on the relative spatial footprint of a given habitat, spectral separability, and phenological variability of a given habitat across the study area. Once a set of training sites was finalized, they were converted to "Areas of Interest" in Erdas Imagine (Erdas Imagine 2020, Ver 16) which were subsequently used to generate the spectral signature files (.sig) used in the supervised classification of the imagery (see Step 2). These "spectral signature files" are the foundation for the habitat model discussed throughout this report. To optimize the performance of the habitat classifier our classifications focus on training sites found within tidal marsh and restored ponds open to tidal action.

Step #4: Supervised Classification

We utilized the resulting spectral habitat model (.sig files) to run a supervised classification of the imagery in Erdas Imagine. The supervised classification(s) were comprised of three components (in addition to the spectral signature file itself): (a) a parametric rule (maximum likelihood); (b) non-parametric rule (parallelpiped); and (c) a priori probabilities. This combination produced the results that were the most sensitive to habitats with lower densities or that were distributed according to ecological or biophysical phenomena like marsh channels.

Although we ultimately used maximum likelihood, we compared the results to other supervised classification algorithms (e.g., spectral angle mapper) to identify the one most accurately and completely mapped the habitat classes across the study area. Maximum likelihood (a class probability density function extracted from the signature files for each class) calculates the probability that a given pixel belongs to a specific class. Each pixel is assigned to the class that has the highest probability (i.e. the maximum likelihood). These spectral signatures are used to "train" the parametric classifier (in this case maximum likelihood). The parallelepiped classifier, also called a "box classifier", assigns pixels based on how they fit into a rectangular area defined by the highest and lowest image values in each band. Nonparametric rules do not use statistics in classifying the pixels and are used only after the parametric rule has been applied (in a multilevel approach) and there is no one signature more likely to be correct.

Step #5: Review of Model Output and Ground Truthing (calibration)

A significant amount of project time was spent in the process of model review and model refinement. Since the habitat model consists of a series of training site(s) for each habitat class (that are used to represent the "spectral signature" for each habitat being mapped), the primary mechanism for implementing these changes was either to alter existing training sites or to introduce new and/or multiple training sites for each habitat. Once an initial set of training sites was created (in 2021 this was based on our 2019 training sites), we would review the results to identify possible edits, deletions or additions to our training sites that would lead to another classification, in a process of iterative improvement. During this iterative process, we used spectral mean plots and feature space images to evaluate the spectral separability of training sites. A secondary mechanism used to refine the spectral model was by using probabilities as a priori probabilities on training to help balance the relative distribution of habitats. In addition to these quantitative measures, we performed extensive qualitative reviews of imagery and ground truthing surveys (including field photos) to 'calibrate' how well our training sites were mapped the biotic (and abiotic) habitats. This iterative process of model improvement produced dozens (if not hundreds) of mapped classifications for each year.

The timing of the satellite as well as 'normal' interannual variability among some habitat classes as they both relate to the relative level of fluorescence of the different vegetation captured, can have a big impact on the extent and distribution of biotic classes mapped. In other words, the phenology can have a big impact on the acreages of vegetation mapped. Although we do our best to acquire imagery during overall peak fluorescence, it is impossible to acquire imagery at peak fluorescence for all vegetation throughout the study area at the same time. This is not only true for different biotic classes but even within a single biotic class (e.g., Pickleweed).

For both 2019 and 2021 we performed one final QA on our final results. The final QA led to a series of manual edits which focused on specific locations and habitats of concern with the highest likelihood of error and therefore improved our confidence in the distribution and acreages of mapped habitats. We also conducted a less extensive but focused series of edits on the habitat datasets (09-11) from HEMP1. The majority of the final edits revolved around misclassifications, mostly due to 'spectral confusion' between habitats or bottom reflectance of water in ponds showing up as vegetation

4.4 Mudflat Model

In 2016 (Fulfrost, B., 2017), we developed techniques designed to map the extent and distribution of tidal mudflats under various tidal conditions. We applied these same methods to the 2019 imagery, which, like the 2016 imagery, was captured close to MLLW (see Table 25). Although we also applied these same methods to the images from 2021, these images were captured at a higher tide and could not be used to compare the full extent of mudflats.

Step #1: Ground Truthing

To provide in situ measures of mudflat edge to calibrate with the edge of mudflat from our model, we visited 5 locations (including the mouth of Coyote Creek, the mudflat at the mouth of Newark slough, and the mudflats within A19) with a sub meter mapping grade GPS (Trimble ProXT or GeoXT) and walked the 'water line' at the approximate time of satellite overpass (on June 8th, 2019) as well as on similar tidal days. The ground truthing was primarily used to qualitatively assess (i.e., calibrate) the model's ability to capture the presence of mudflat, the presence of biofilm on mudflat (used in the habitat model) and verifying the "edge" (or full extent) of mudflat. The ground truthing surveys also allowed us to better evaluate how good different image processing techniques were at identifying and/or differentiating various "types" of mudflats based on the presence of biofilm, % water coverage, water depth, % exposure, and water "sheen" (as a proxy for soil moisture).

A variety of factors at time of image acquisition can influence the precision of our image analysis techniques to map the full extent of mudflat and specifically map the "edge" of mudflat, defined for this study as MLLW. These factors include (but are not limited to): tide level, wind waves, water turbidity, barometric pressure, mud flat slope, and water depth. We used a combination of spectral image processing techniques to derive and calibrate our final mudflat extent and distribution (Steps #2-4).

Step #2: Unsupervised Classification

We ran our unsupervised classification with 30 (and 50 for comparison) classes using a variety of band combinations (including all bands) of the 8 bands available on Worldview-2. In the end we used the 3 band "mud flat composite" (near infrared, yellow and coastal blue bands). The unsupervised classification (ISO cluster) delineated mud flats cleanly from adjacent marshes and other land cover features. Although the focus of our work was on mudflat extent, the unsupervised classification also appears to do a good job at differentiating a variety of mudflat "types" that likely relate to geomorphology, moisture or ponding water, and the presence of biofilm. We selected the classes most associated with mudflats by comparing the results to imagery itself, the NDWI (see Step #3), and the zero-contour derived from the MSAVI2 band index (used as a proxy for the MLLW).

Step #3: Normalized Difference Water Index (NDWI)

The Normalized Difference Water Index (NDWI), which is a ratio of the Green to Near Infrared bands, has shown to be very good at differentiating the land/water interface (Baiocchi, V., et al, 2012; Ji, L., Zhang, L., & Wylie, B., 2009; Ho, L. T. K., Umitsu, M., & Yamaguchi, Y., 2010; McFeeters, S. K., 1996).

$$\mathrm{NDWI} = \frac{(Xgreen - Xnir)}{(Xgreen + Xnir)}$$

Index values between -1 to 0 depict land while values between 0 and 1 depict water. The NDWI demonstrated the best ability to identify the possible presence of "shallow water" mudflat from exposed mudflat, especially in areas with very shallow slopes (e.g., Eden Landing). We utilized thresholds based on previous research that explored the use of NDWI (and MNDWI) to delineate open water and coastal water features (Ji, L., et al, 2009). We used the index (index values are in parenthesis) to differentiate four types of features:

- "land" (< -0.3) - which directly adjacent to mudflats was marsh.
- "mudflat"(-0.3 to 0) - which seemed to delineate exposed mudflat.
- "shallow water" (0 to 0.3) - which might indicate possible shallow water mudflat.
- "water" (> 0.3) - which indicates deeper water

Step #4: Modified Soil Adjust Vegetation Index (MSAVI2)

The Modified Soil and Vegetation Index (we used the second revision or "MSAVI2") adds an additional measure for us to calibrate the edge of mudflat under shallow water. In our pilot study (Fulfrost 2017), we found that the MSAVI2 zero contour corresponded very well with the MLLW line (as long as the image was captured close to MLLW). We used the results of MSAVI2, and specifically the zero contour, to assist in determining what classes from the unsupervised classification best represented the edge of the mudflat. MSAVI2 is well suited to mapping mudflat since it can be applied to areas of high soil surface exposure like mudflats to identify a change from "soil" (or mudflat) to "no soil" (or water) even in shallow environments.

$$MSAVI2 = \frac{\left(2 * NIR + 1 - \sqrt{(2 * NIR + 1)^2 - 8 * (NIR - RED)}\right)}{2}$$

Step #5: Final Mudflats

We calculated the final mudflat extent and distribution using a combination of our unsupervised classification and NDWI. After the results of both of these techniques had both been evaluated and calibrated to the MSAVI2 (or MLLW) line, they were combined so to maximize the usefulness of each approach. Locations were considered to be "mudflat" if they met either one of the following two criteria:

1. identified as "mudflat" in *both* the (a) unsupervised classification *and* (b) the NDWI; or
2. identified as both (a) "shallow water" in the NDWI *and* identified as (b) "mudflats" in the unsupervised classification.

After reviewing locations that were identified from the NDWI as "shallow water", it was not clear that all of these areas were actually shallow water *mudflats*. As a result, we only included areas of "shallow water" that were *also* identified as mudflats by the unsupervised classification. We used a mask that was derived from SFEI's Bay Area Aquatic Resource Inventory (BAARI) to calculate acreages of mudflats that were directly exposed to the bay ("bay/sloughs") and those within wetlands or restored ponds ("pond/wetland").

Limitations and Uncertainty

The methods serve as a cost-effective means for mapping and tracking to changes to mudflats, with some limitations. Although we have developed a relatively robust mechanism to map mudflat extent and distribution, we have not yet quantified the degree of spatial or temporal variability corresponding to the mapped presence of mud flats at a given location or quantified the degree of uncertainty in our modeling approach. Quantifying the range of "normal" variability of seasonal and interannual variability of mudflat extent (and "type") would improve our understanding of changes to those mudflats. Mean Lower Low Water (MLLW) serves as a convenient and documented method for delineating the edge of mudflats (Jaffee, B. & Foxgrover, A., 2006). However, using MLLW can introduce mitigating factors when calculating changes to mudflats due to possible spatial and temporal variability that are inherent in tidal datums and uncertainties in various method used to map the MLLW line (Jaffee, B. & Foxgrover, A., 2006). The largest uncertainties appear to occur in areas of very gradual slopes with very shallow water, where there is not as distinct boundary (e.g., Eden Landing). Consensus should be obtained whether extremely shallow water mudflats are intertidal or subtidal (or perhaps somewhere shifting between the two).

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APPENDIX 1: Habitat Type Descriptions

Cordgrass (*Spartina sp.*) Herbaceous Alliance

California Cordgrass marsh (low marsh / MTL - MHW)

Spartina foliosa is dominant in the herbaceous layer with *Salicornia europaea, Bolboschoenus maritimus, Schoenoplectus californicus, Schoenoplectus americanus*, and algae. Herbs <1.5m; canopy is intermittent to continuous.

Habitats: Coastal salt marshes on mudflats, banks, berms, and margins of bays and deltas. The USFWS Wetland Inventory (1996 national list) recognizes Spartina foliosa as an OBL plant.

Elevation: 0.5-1m.

Membership Rules

Spartina foliosa >50% relative cover in the herbaceous layer (Keeler-Wolf and Vaghti 2000).

Remarks

Pacific cordgrass (*Spartina foliosa*) was mapped as "Cordgrass" due to hybridization with Atlantic cordgrass (*S. alterniflora*), creating cryptic hybrids that require genetic analysis to differentiate. CORD distributions are currently anthropogenically modified due to the estuary-wide Invasive Spartina Project control program. Therefore their current distribution should not be considered ecologically relevant or indicative of their potential spatial extent.

Cordgrass /-Pickleweed Herbaceous association

(low -"mid" marsh transitional area)

Sarcocornia Pacifica quickly begins to co-dominate with Spartina foliosa (but not Spartina alterniflora x foliosa hybrids) as elevation rises above MTL towards MHW. Depending on your perceptions of plant communities this could be considered a distinct alliance, an *ecotone* between the Spartina foliosa Alliance and the Sacrocornia pacifica Alliance, or as part of one great *ecocline* continuum between open water-mudflats and adjacent uplands.

Habitats: Coastal salt marshes. The USFWS Wetland Inventory (1996 national list) recognizes Salicornia virginica and Spartina foliosa as OBL plants.

Elevation: 0.15-2.5m.

Membership Rules

unknown

Remarks

The co-occurrence of S. foliosa and S. pacifica could be considered indicative of a transition zone between low and high-marsh. It could also be found surrounding depressional pannes throughout the high marsh plane. As the actual extent of this transition zone is unclear, requiring further study to clarify, the relative dominance and sub-dominance of Cordgrass and Pickleweed can vary.

Pickleweed (Sarcocornia pacifica *or* Salicornia europaea) Herbaceous alliance

Pickleweed mats (below MHW to above MHHW)
Annual pickleweed marsh (low marsh habitat/ MTL - MHW)

Sarcocornia pacifica (or Salicornia depressa) is dominant or co-dominant in the subshrub and herbaceous layers with Atriplex patula, A. prostrata, Bolboschoenus maritimus, Cotula coronopifolia, Cuscuta salina, Distichlis spicata, Frankenia salina, Grindelia stricta, Jaumea carnosa, Lepidium latifolium, Limonium californicum, Spartina foliosa, Triglochin maritima, and algae. Plants up to 1.5m; canopy is intermittent to continuous. Salicornia europaea is the dominant in the herbaceous layer with Spartina foliosa, S. alterniflora, and their hybrids, as well as Sarcocornia pacifica in some cases. Herbs 0.1-2m. Canopy is intermittent to continuous.

Habitats: Coastal salt marshes, alkaline flats. The USFWS Wetland Inventory (1996 national list) recognizes Salicornia virginica and Salicornia europaea as OBL plants.

Elevation: 0.15-2.5m (perennial); 0.5 -1m (annual)

Membership Rules

Sarcocornia pacifica >10% absolute cover and sometimes over a higher cover of short annual or perennial grasses; if Distichlis spicata >=50% relative cover, stands are in the DISP alliance (Keeler-Wolf and Vaghti 2000).

Remarks

Sarcocornia pacifica (perennial pickleweed) was generally mapped as "Pickleweed", which could include the high marsh species Arthrocnemum subterminale (Parish's pickleweed) and the low marsh species Salicornia europaea (annual pickleweed). Due to S. pacifica's broad hydrologic tolerances (both duration of flooding and drying somewhat) it is found from the upper edge of the low marsh, dominating high-marsh elevations, and through the high marsh up into the upland transition zone. In the "mid" high marsh it grows with Distichlis spicata, Frankenia Salina, Jaumea carnosa, Lepidium latifolium, Triglochin concinna, Atriplex triangularis, and Bolboschoenus maritimus. In the high marsh it grows with Limonium californicum, Grindelia stricta, Frankenia salina, Distichlis spicata, Triglochin maritima, and Arthrocnemum subterminale. Salicornia europaea is the most flood tolerant of native tidal salt marsh plants. Spartina alterniflora is more tolerant and would be found lower in the tidal profile if present. S. europaea is found adjacent to mudflats, between it and Spartina foliosa. S. europaea is often one of the first species to colonize areas that have reached appropriate elevations (i.e. near MSL), along with the spartinas.

Pickleweed/-Jaumea Herbaceous Association (Sarcocornia pacifica /- Jaumea carnosa)

Jaumea carnosa is usual subdominant to Sarcocornia pacifica in the herbaceous layer with Distichlis spicata, Frankenia salina, Grindelia stricta, Triglochin concinna, and T. maritima. Plants 0.1-0.66m. Canopy is intermittent to continuous.

Habitats: coastal salt marsh. The USFWS Wetland Inventory (1996 national list) recognizes Jaumea carnosa as an OBL plant.

Elevation: 0.15-2.5m.

Membership Rules
Unknown

Remarks
A common species association in the mid-aged and older marshes is perennial pickleweed and salty susan (Jaumea carnosa). Salty susan is often a subdominant, with a patchy distribution amongst the pickleweed, but in a few cases it is more dispersed (older mashes up Newark Slough just south of the Refuge Headquarters hill) or dominant (older marshes on the northern end of Greco Island). Salt susan is the only species known to not provide cover for CCRA (unsure of its utility to SMHM) so its ecological significance remains unknown. Some evidence that this association occupies lower high marsh elevations.

Pickleweed /- Gumplant (Sarcocornia pacifica /- Grindelia stricta) Herbaceous Association
Gumplant patches (high marsh / MHHW)

Grindelia stricta or another Grindelia species is co-dominant in the herbaceous layer with Sarcocornia pacifica and dominant with Distichlis spicata, Frankenia salina, Jaumea carnosa, Limonium californicum, Arthrocnenum subterminalis, Triglochin maritime, and T. concinna. Herbs 0.1-1.5m; canopy is intermittent to continuous.

Habitats: Slightly elevated or drier ground that is adjacent to coastal dunes, within salt marshes, or alkaline marshes, including bluffs, levees, and road margins. The USFWS Wetland Inventory (1996 national list) recognizes Grindelia stricta var. angustifolia as an OBL plant. Elevation: 0-200m.

Remarks
Grindelia stricta was mapped as "Pickleweed/-Gumplant" and is generally limited to a narrow elevation band in marshes it is one of the best indicators of high marsh elevations. It is also considered to be one of the most important plant species in high tide refugia for certain marsh obligate fauna, because it is a relatively tall sub-shrub and can provide habitat when the high marsh ground surface is flooded. Its distribution seems to be limited, perhaps by marsh age as many current marshes are young to high-aged (as they have developed outside of our levees in the last 50-100yrs). Usually associated with GRST are FRSA, DISP, SAPA, LICA, TRMA, and ARSU (if present).

Alkali Heath (Frankenia salina) Herbaceous Alliance

Alkali heath marsh (high marsh/upland transitions / MHHW and up)

Frankenia salina is dominant or co-dominant in the herbaceous and subshrub layers with Arthrocnemum subterminale, Atriplex spp., Agrostis avenacea, Cressa truxillensis, Distichlis spicata, Hordeum murinum, Lasthenia spp., Lepidium spp., Limonium californicum, Monathochloe littoralis, Sarcocornia pacifica, and Suaeda taxifolia. Herbs and subshrubs <60cm; cover is open to continuous.

Habitats: Coastal salt marshes, brackish marshes, alkali meadows, alkali playas. Soils are saline, sandy to clayey alluvium. The USFWS Wetland Inventory (1996 national list) recognizes Frankenia salina as a FACW+ plant. Elevation: <300m.

Membership Rules
Frankenia salina >30% relative cover in the herbaceous layer, sometimes co-dominant with Distichlis spicata or other herbs and subshrubs (Keeler-Wolf and Vaghti 2000, Keeler-Wolf and Evens 2006).

Remarks
Frankenia salina was mapped as "Alkali Heath", and though it does appear to be a good indicator of high marsh elevations it does seem to occupy slightly lower elevations than Gumplant and range well into the upland transitions. While alkali heath does form small mono-typic stands, because each clone appears able to outcompete other species, they are never broad-ranging stands like other marsh dominants. Although it is possible this is due to anthropogenic disturbances that have also reduced the once broad and dominant distribution of saltgrass in the upland transitions where alkali heath may also have been sub-dominant. Usually associated with DISP, GRST, SAPA, ARSU, LICA, TRMA, and upland transition species.

Saltgrass (Distichlis Spicata) Herbaceous Alliance

Saltgrass flats (high marsh/upland transitions)

Distichlis spicata is dominant or co-dominant in the herbaceous layer with Agrostis viridis, Ambrosia chamissonis, Anemopsis californica, Atriplex prostrata, Batis maritima, Bromus diandrus, Cotula coronpifolia, Eleocharis palustris, Frankenia salina, Hordeum brachyantherum, H. murinum, Jaumea carnosa, Juncus arcticus, J. cooperi, Leipdium latifolium, Leymus triticoides, Limonium californicum, Muhlenbergia asperifolia, Parapholis strigosa, Pascopyrum smithii, Poa secunda, Puccinellia nuttalliana, Sarcocornia pacifica, Sporobolus airoides, and Triglochin maritima. Emergent shrubs, such as Allenrolfea occidentalis, Atriplex spp., Ericameria albida, Ericameria nauseosa, Sarcobatus vermiculatus, and Suaeda Moquinii may be present at low cover. Herbs <1m; canopy is open to continuous.

Habitats: Coastal salt marshes, inland habitats include playas, swales, and terraces along washes that are typically intermittently flooded. Soils are often deep, alkaline, or saline, and often have an impermeable layer making them poorly drained. When the soil is dry, the surface usually has salt accumulations. The USFWS Wetland Inventory (1996 national list) recognizes Distichlis spicata as a FACW plant. Elevation: 0-1500m.

Membership Rules

Distichlis spicata >50% relative cover in the herbaceous layer, D. spicata has higher cover than any other single grass species (or) >30% relative cover in the herbaceous layer, Sarcocornia or Salicornia spp. If present <30% relative cover.

Remarks

Distichlis spicata was mapped as "Saltgrass", and while it is usually found in the high marsh its range appears to extend lower than GRST or FRSA, and historically it dominated the upland transition. Currently its distribution in most upland transitions is rarer, except for a few locations such as Moffett Field, Warm Springs, and the SJ/SC WPCP region. Usually associated with FRSA, GRST, SAPA, LICA, TRMA, and upland ecotone species.

Alkali Bulrush (Bolboschoenus maritimus) Herbaceous Alliance

Brackish bulrush marshes (high-low marsh to high marsh)

Bolboschoenus maritimus is dominant or codominant in the herbaceous layer with Lepidium latifolium, Atriplex triangluaris, B. robustus, Cotula coronipfolia, Distichlis spicata, Eleocharis parvula, Sarcocornia pacifica, and Typha latifolia. Herbs <1.5m tall; canopy is intermittent to continuous.

Habitat: Seasonally flooded mudflats; tidal brackish marshes. The USFWS Wetland Inventory (1996 national list) lists Bolboschoenus maritimus as an OBL plant. Elevation: 0-2500m.

Membership Rules

Bolboschoenus maritimus >50% relative cover in the herbaceous layer (Keeler-Wolf and Vaghti 2000).

Remarks

Bolboschoenus maritimus was mapped as "Alkali Bulrush", to avoid differentiating between it and B. robustus. Usually mapped with ATTR, LELA, SAPA, FRSA, CORD, and TULE.

Freshwater Bulrush Herbaceous Alliance (Schoenoplectus californicus / acutus)

Tidal Fresh Marsh Tules

The taller "tules" of Schoenoplectus spp. co-occur in the limited tidal fresh marshes of South San Francisco Bay with Typha angustifolia, T. latifolia, (T. x glauca likely), Euthamia occidentalis, as well as S. americanus and Bolboschoenus maritimus/robustus in the fresh-brackish marsh transitions, and a variety of species in the tidal marsh-upland transition. Herbs <4m; cover is intermittent to continuous.

Habitats: along streams; around ponds and lakes; and in sloughs, swamps, freshwater and brackish marshes, and roadside ditches. Soils have a high organic content and are poorly aerated. The USFWS Wetland Inventory (1996 national list) recognizes Schoenoplectus spp. as OBL plants. Elevation: 0-2500m.

Membership Rules
Schoenoplectus acutus/californicus > = 50% absolute cover in the herbaceous layer; Typha spp., if present, can be >30-60% relative cover

Remarks
S. acutus/californicus were mapped as “Freshwater Bulrush” as they can be difficult to distinguish in the field and do not play a significantly different habitat role.

Cattail (Tyhpus angustifolia | latifolia) Herbaceous Alliance

Tidal Fresh Marsh Cattails

Typha angustifolia is found with Schoenoplectus acutus and S. californicus. It potentially could be found with Typha latifolia, with which it hybridizes to form Typha x glauca, but this may indicate the transitional type between fresh and brackish marshes. Herbs 3-4m. Cover is continuous.

Habitats: tidal fresh marsh. TYAN and TYLA are OBL species. (3-5m)

Membership Rules
unknown

Remarks
Typha angustifolia seldom dominates the herbaceous layer in tidal fresh marshes of the study area, although it can be found further upstream on several creeks feeding the study area. Typha latifolia is not a common component of the brackish marshes in the study area and may be an indication of a transition zone between tidal fresh and brackish marsh vegetation types. The only known locations are on Alviso Slough (now the outlet for the Guadalupe River) and along Artesian Slough, which is the outfall for the region's wastewater, although there was a small amount of TYLA at the head of Newark Slough.

Spearscale (Atriplex triangluaris) Herbaceous Alliance

Atriplex triangluaris (now considered non-native) can form large stands where it can dominate especially the high marsh-upland transition. However, Atriplex triangular is often associated with Bolboschoenus maritimus and/or Lepidium Latifolium where it can be co dominant or sub dominant.

Habitats: Tidal brackish marshes. The USFWS Wetland Inventory (1996 national list) recognizes Atriplex triangluaris as an OBL plant.

Elevation: 2.5-3.5 m.

Membership Rules
Unknown

Remarks
ATTR is often found amongst BOMA, able to colonize the open “interstitial” spaces amongst the bulrushes like SASO (Salsola soda – Russian thistle, in Triangle Marsh along Coyote Creek by the RR trestle). It is unknown what impact these species have on the habitat functions and values, nor does it appear that they out compete BOMA – coexistence seems the best description.

Pepperweed (Lepidium latifolium) Herbaceous Alliance

Perennial Pepperweed

Predominantly found in the Brackish Marsh habitats where it appears to compete well with alkali bulrushes, it also has limited success invading salt marsh, although it does have success in the tidal salt marsh-upland transition zone, but no success invading fresh marsh and does not appears as competitive against other weeds that currently dominate the tidal fresh marsh-upland transitions. It appears to invade via water-borne materials, as it establishes along tidal sloughs, although this may be a function of their slightly higher elevations. As a perennial clonal spreading species, forming large stands via an incredible rooting system, any tiny fraction of which can create a new individual if broken off or unearthed even from depths of many feet or more. It associates with everything found in this study except for the tidal fresh marsh species and perhaps their upland transition weeds. Herbs 0.5-2m; cover is intermittent to continuous (and seasonal).

Habitats: all, except for tidal fresh marsh, tidal mudflat, and open water.

Membership Rules
Lepidium latifolium >15% relative cover; more likely mapped as Pepperweed where >25% relative cover.

Remarks
Lepidium latifolium was mapped as "Pepperweed" and we found they varied substantially both locally and regionally in their phenology. It is assumed their invasion reduces habitat values due to their seasonality. Some locations mapping as Pepperweed might also represent other invasive species (see "Ruderal" below for list).and locations mapped as Ruderal might also include Pepperweed.

Alkali Grasses (Leymus triticoides /- Lolium multiflorum) Herbaceous Alliance

Historic Tidal Marsh / Upland Transitional Habitat

In some areas the upland transition was wetter, either due to river flooding, artesian groundwater, or high-water tables, and those areas were dominated by grasses such as Leymus triticoides or L. x multiflorus (the hybrid with L. condensatus said to once dominate the bay's margin). Interspersed in these alkali grasslands were alkali vernal pools, seasonal wetlands that once were common.

While this area still contains a significant amount of Leymus triticoides, it has been losing acreage to non-native grasses primarily Lolium multiflorum or Bromus Diandrus. The broadleaf (forb) component of these grasslands has likely been significantly diminished by the prescribed grazing regime used by the refuge to protect the vernal pools from invasion by weeds. The cows do a very good job of keeping the vernal pools from becoming choked by weeds, but the trade-off is they are very hard on parts of the alkali grassland community. And there are broadleaf weeds competing with the natives for space in the grassland.

Common species are similar to halophytic disturbance community: Conium maculatum, Lepidium latifolium, mustards (several species), and thistles (several genera). Natives include many that should be common in the peripherial halophytic community but due to the extent of impacts to them (>90% disturbed) they are not able to self-propagate and are restricted to some historic locations; these are: Malvella leprosa, Lasthenia glabrata, Heliotropium currasavicum, Centromadia pungens, Amsinckia menzieseii, and Suaeda nigra.

Elevation: 0.5-2m; cover is intermittent to continuous (and seasonal)

Membership Rules
Leymus triticoides >30% or Lolium multiflorum >30% or Bromus diandrus >30% cover, with regular interspersion of alkali vernal pools (percentages based on qualitative review of 3 years of ground truthing data from 09-11).

Ruderal (*various*) Herbaceous Alliance

Peripheral halophytic disturbance community

This is a mostly invasive herbaceous habitats class that is essentially disturbance communities dominated by exotic species. We combined the following mapping classifications into a single 'Ruderal' category: Mustard (Brassica negra), Radish (Raphanus raphanistrum), Common Reed (Phragmites australis), Iceplant (Carpobrotus edulis), and Sea Lavender (Limonium ramosissimum). Abundant annual on levees, paths, disturbed soils above tide line. Although not directly mapped, this herbaceous allaince can also include Foeniculum vulgare, Conium maculatum, Lepidium latifolium, thistles (several genera), Mesembranthemum nodiflorum, Tetragonia tetragonioides, spearscales (Atriplex spp.), and Chenopodium chenopodioides. Herbs 0.5-4m; cover is intermittent to and continuous (and seasonal)

Habitats: all, but the community varies depending on the adjacent habitats.

Membership Rules

None (too chaotic)

Remarks

We mapped a series of ruderal, mostly invasive halophytic tolerant upland species, common to levee flanks, tops, and uplands, and combined these into one classification (ie. Ruderal). These plant communities are often referred to as "peripherial halophytes". In the first phase of the HEMP project, this habitats class was *mostly* mapping Mustard (Brassica spp) and therefore was called *Mustard*, although it likely included other peripheral halophytes.

Abiotic Habitat Types

Mudflats were mapped as "*Mud*" and vary substantially in appearance, from different types of mud, its slope, degree of wetting (as opposed to dry upland dirt, which also varies), presence of wrack or any algae and biofilms (diatoms).

Mudflats with Biofilm have been noted as an important characteristic of some mudflat, comprised of microphytic communities on the surface of mudflats, and have been shown as an important food resource for foraging birds (Kuwae, T., Beninger, P. G., 2008). For these reasons, it was included as a distinct habitat type in the model.

Wrack is floating debris deposited by the tides, and often forms a line perpendicular to the shore. Often composed of wood it disturbs the plant communities and may play a role in successional dynamics (temporal variability). But it is most importantly known as habitat for the potentially extirpated (extinct?) salt marsh wandering shrew (vagrant). Dead or dried out vegetation can also map as wrack.

Bare Earth is non-wetland soil types, taken from levee tops, or wetland soils that have been piled above the tides (levees). Wrack and bare earth often map as each other.

Water within the study area was mapped with a range of training sites throughout the study area. Surface water varies substantially in its appearance and therefore necessarily in its reflected spectral values. From the deeper parts of the open bay, in sloughs, to the shallowest pannes within the marshes or restored ponds, this requires a substantial number of training sites to characterize this variability.

APPENDIX 2: Accuracy Statistics included in Error Matrices

STATISTIC	DESCRIPTION	COMPUTATION
User's Accuracy	Percentage of model-derived samples that are correctly mapped	Major diagonal value divided by the column total
Producer's Accuracy	Percentage of field-derived samples that are correct mapped	Major diagonal value divided by the row total
Overall Accuracy (Observed Agreement)	Percentage of correctly mapped samples	The sum of the major diagonal elements of the error matrix divided by the total number of samples
Chance Agreement	Percentage of chance agreements between model-derived and field-derived classifications	Sum of the products of corresponding User's Accuracy Producer's Accuracy values
Kappa	Measure of difference between observed agreement and chance agreement	(Observed Agreement - Chance Agreement) / (1 - Chance Agreement)

(Adapted from Garfield et al 2009)

APPENDIX 3: Additional Mapped Habitat Classification Tables

Table A1: Acreage by Mapped Habitat for E8A (2009 - 2011, 2019 & 2021)

Mapped Habitat	E8A				
	Acres (2009)*	Acres (2010)*	Acres (2011)*	Acres (2019)	Acres (2021)
Alkali Bulrush	0.00	0.02	0.00	1.53	0.26
Alkali Grasses	2.68	0.73	0.73	0.09	1.00
Alkali Heath	0.25	0.49	-	0.03	0.57
Bare Earth	126.62	47.35	104.33	4.65	3.93
Freshwater Bulrush	0.00	0.00	0.00	-	-
Cattails	-	-	0.02	0.00	-
Cordgrass	0.01	0.00	0.12	1.83	0.72
Cordgrass/-Pickleweed	0.10	0.02	0.41	1.94	5.22
Mudflat without Biofilm	20.85	39.18	7.77	141.50	75.98
Mudflat with Biofilm	2.38	41.15	6.75	42.00	72.14
Pepperweed	0.05	0.05	0.27	0.11	0.04
Pickleweed	2.59	2.74	2.68	56.03	91.78
Pickleweed /- Gumplant	0.04	-	0.31	0.57	0.00
Pickleweed /- Jaumea	0.00	0.00	0.22	0.12	0.05
Ruderal	0.13	0.19	0.20	0.18	1.10
Saltgrass	0.26	0.12	0.07	0.38	1.47
Spearscale	-	-	-	0.00	0.00
Water	84.27	133.16	141.32	13.04	10.94
Wrack	24.94	-	-	1.22	0.00
Grand Total	**265.20**	**265.20**	**265.20**	**265.20**	**265.20**

* Acreages for 2009, 2010, and 2011 in E9, E8A, and E8X are pre-breach

Table A2: Acreage by Mapped Habitat for E9 (2019 & 2021)

Mapped Habitat	E9	
	Acres (2019)	Acres (2021)
Alkali Bulrush	0.20	0.51
Alkali Grasses	0.00	0.07
Alkali Heath	0.00	0.14
Bare Earth	0.41	0.53
Cordgrass	1.17	0.90
Cordgrass/-Pickleweed	0.33	2.66
Mudflat without Biofilm	209.39	174.15
Mudflat with Biofilm	137.76	159.45
Pepperweed	0.01	0.02
Pickleweed	8.84	20.50
Pickleweed /- Gumplant	0.29	0.00
Pickleweed /- Jaumea	0.01	0.02
Ruderal	0.01	0.14
Saltgrass	0.02	0.29
Spearscale	-	0.01
Water	6.79	5.88
Wrack	0.06	0.00
Grand Total	**365.30**	**365.30**

Table A3: Acreage by Mapped Habitat for North Creek Marsh (2009 - 2011, 2019 & 2021)

Mapped Habitat	North Creek Marsh				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.32	0.12	0.01	2.55	0.11
Alkali Grasses	0.16	3.64	0.73	0.02	0.22
Alkali Heath	0.05	0.48	0.16	0.03	0.25
Bare Earth	0.01	0.21	0.79	0.72	0.48
Freshwater Bulrush	0.03	0.00	0.01	-	-
Cattails	0.02	0.00	0.03	-	-
Cordgrass	0.29	0.12	0.29	7.45	6.20
Cordgrass/-Pickleweed	1.71	0.38	1.31	5.66	2.67
Mudflat without Biofilm	23.47	0.95	15.50	85.50	84.81
Mudflat with Biofilm	99.84	119.48	67.44	76.58	52.03
Pepperweed	0.45	0.38	1.16	0.07	0.09
Pickleweed	32.79	46.20	40.10	33.98	68.65
Pickleweed /- Gumplant	0.86	1.08	0.90	1.17	0.00
Pickleweed /- Jaumea	0.34	0.40	0.43	0.23	0.11
Ruderal	0.10	0.07	0.12	0.12	0.26
Saltgrass	0.53	1.05	0.12	0.29	1.33
Spearscale	-	-	-	0.00	0.06
Water	55.96	44.60	89.45	6.41	3.79
Wrack	4.12	1.82	2.52	0.30	0.01
Grand Total	**221.06**	**220.98**	**221.06**	**221.07**	**221.07**

Table A4: Acreage by Mapped Habitat for Mt Eden Creek Marsh (2009 - 2011, 2019 & 2021)

Mapped Habitat	Mt Eden Creek Marsh				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.25	0.12	0.01	0.61	0.07
Alkali Grasses	2.17	5.54	1.26	0.11	0.21
Alkali Heath	0.09	0.08	0.14	0.03	0.16
Bare Earth	0.41	0.63	1.34	0.33	0.46
Freshwater Bulrush	0.04	0.00	0.01	-	-
Cattails	0.01	-	0.01	0.00	-
Cordgrass	0.14	0.03	0.13	3.28	3.38
Cordgrass/-Pickleweed	0.70	0.12	0.87	1.01	2.11
Mudflat without Biofilm	3.21	2.63	11.77	49.65	45.79
Mudflat with Biofilm	20.58	73.52	38.48	42.60	33.01
Pepperweed	0.39	0.13	0.73	0.03	0.07
Pickleweed	7.63	9.18	20.79	13.78	27.91
Pickleweed /- Gumplant	0.26	0.36	0.51	0.69	0.00
Pickleweed /- Jaumea	0.16	0.20	0.25	0.07	0.08
Ruderal	0.47	0.38	0.17	0.23	0.54
Saltgrass	0.22	0.47	0.10	0.09	0.54
Spearscale	-	-	-	0.00	0.06
Water	80.26	23.04	40.35	6.77	5.02
Wrack	2.44	2.98	1.74	0.14	0.00
Grand Total	**119.42**	**119.42**	**118.67**	**119.42**	**119.42**

Table A5: Acreage by Mapped Habitat for A21 (2009 - 2011, 2019 & 2021)

Mapped Habitat	A21				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.48	0.55	9.11	56.81	52.29
Alkali Grasses	-	0.00	0.05	-	0.00
Alkali Heath	0.00	0.00	0.36	0.36	0.01
Bare Earth	0.47	0.61	9.20	0.03	0.17
Freshwater Bulrush	0.00	0.01	0.01	4.08	0.03
Cattails	-	0.00	0.01	3.19	3.47
Cordgrass	0.40	0.26	0.65	7.08	21.97
Cordgrass/-Pickleweed	1.33	0.95	1.50	1.13	11.19
Mudflat without Biofilm	8.43	31.29	22.30	12.53	3.79
Mudflat with Biofilm	78.87	77.52	72.37	11.09	13.44
Pepperweed	0.04	0.09	0.28	0.57	0.05
Pickleweed	11.39	19.74	14.99	45.37	31.76
Pickleweed /- Gumplant	0.09	0.15	0.09	-	-
Pickleweed /- Jaumea	0.02	0.03	0.00	0.79	0.01
Ruderal	-	0.00	0.01	0.12	0.29
Saltgrass	0.06	0.09	0.27	0.15	0.16
Spearscale	0.09	0.42	0.54	0.33	7.81
Water	42.50	14.72	13.36	2.32	0.05
Wrack	2.34	0.08	1.40	0.58	0.02
Grand Total	**146.51**	**146.51**	**146.52**	**146.51**	**146.51**

Table A6: Acreage by Mapped Habitat for A20 (2009 - 2011, 2019 & 2021)

Mapped Habitat	A20				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.4533	0.23	4.08	13.74	10.14
Alkali Grasses	0.0006	0.00	0.05		0.00
Alkali Heath	0.0048	0.00	0.30	0.01	0.00
Bare Earth	0.0523	0.28	6.94	0.05	0.01
Freshwater Bulrush	0.0056	0.00	0.00	0.61	0.01
Cattails		0.00		0.11	1.53
Cordgrass	0.0979	0.03	0.03	2.75	12.36
Cordgrass/-Pickleweed	0.6136	0.09	0.23	0.41	8.09
Mudflat without Biofilm	3.6228	11.00	7.93	7.35	2.55
Mudflat with Biofilm	21.6520	32.56	31.74	15.18	11.45
Pepperweed	0.0346	0.08	0.05	0.37	0.03
Pickleweed	13.1145	3.05	1.83	20.22	15.14
Pickleweed /- Gumplant	0.0745	0.01	0.00		
Pickleweed /- Jaumea	0.0120	0.02	0.00	0.12	0.00
Ruderal		0.01	0.01	0.01	0.06
Saltgrass	0.0505	0.01	0.04	0.07	0.05
Spearscale	0.0489	0.26	0.06	0.09	1.17
Water	21.2768	14.92	6.85	1.13	0.00
Wrack	1.4972	0.06	2.47	0.39	0.01
Grand Total	**62.61**	**62.61**	**62.61**	**62.61**	**62.61**

Table A7: Acreage by Mapped Habitat for A19 (2009 - 2011, 2019 & 2021)

Mapped Habitat	A19				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.39	1.54	0.03	6.33	14.86
Alkali Grasses	0.02	0.04	0.17	0.00	0.02
Alkali Heath	0.02	0.04	0.01	0.02	0.06
Bare Earth	0.35	2.06	31.97	0.02	0.16
Freshwater Bulrush	0.00	0.01	0.00	1.37	0.19
Cattails	0.00	0.00	0.00	0.14	1.94
Cordgrass	0.18	0.13	0.18	3.26	16.48
Cordgrass/-Pickleweed	1.16	0.24	0.85	0.44	8.87
Mudflat without Biofilm	15.71	82.36	32.76	46.44	43.57
Mudflat with Biofilm	90.63	128.28	146.27	152.68	143.99
Pepperweed	0.23	0.43	0.33	0.48	0.10
Pickleweed	42.40	13.88	7.55	39.27	29.77
Pickleweed /- Gumplant	0.03	0.02	0.00	-	-
Pickleweed /- Jaumea	0.02	0.03	0.03	0.09	0.03
Ruderal	0.01	0.04	0.04	0.02	0.22
Saltgrass	0.26	0.10	0.10	0.02	0.16
Spearscale	0.05	0.30	0.04	0.16	0.95
Water	106.37	34.91	32.15	13.33	3.60
Wrack	7.15	0.57	12.46	0.92	0.02
Grand Total	**265.00**	**265.00**	**264.96**	**264.98**	**264.98**

Table A8: Acreage by Mapped Habitat for A17 (2009 - 2011, 2019 & 2021)

Mapped Habitat	A17				
	Acres (2009)	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
Alkali Bulrush	0.09	0.13	0.55	0.03	0.43
Alkali Grasses	-	0.27	1.01	0.00	0.00
Alkali Heath	0.01	0.04	0.04	0.00	0.01
Bare Earth	0.70	1.05	0.31	0.13	0.01
Freshwater Bulrush	0.01	0.01	0.02	0.04	0.11
Cattails	0.00	0.00	0.01	0.00	0.01
Cordgrass	0.06	0.05	0.11	0.22	0.19
Cordgrass/-Pickleweed	0.20	0.09	0.19	0.02	0.14
Mudflat without Biofilm	0.03	0.14	0.09	57.59	29.46
Mudflat with Biofilm	0.05	0.05	0.12	67.98	96.16
Pepperweed	0.18	0.46	0.71	0.04	0.01
Pickleweed	1.46	0.70	1.03	2.27	3.37
Pickleweed /- Gumplant	0.01	0.01	0.01	0.37	0.02
Pickleweed /- Jaumea	0.07	0.03	0.03	0.02	0.01
Ruderal	-	0.01	0.04	0.02	0.01
Saltgrass	0.31	0.12	0.04	0.01	0.00
Spearscale	0.21	0.05	0.09	0.01	0.03
Water	127.24	127.72	126.50	2.33	1.60
Wrack	0.94	0.63	0.67	0.47	0.00
Grand Total	**131.56**	**131.56**	**131.57**	**131.55**	**131.57**

Table A9: Acreage by Mapped Habitat for A6 (2009 - 2011, 2019 & 2021)

Mapped Habitat	A6				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.00	0.00	0.74	0.19	0.15
Alkali Grasses	0.16	1.87	0.06	-	0.00
Alkali Heath	0.60	0.03	-	0.00	0.05
Bare Earth	281.90	286.67	6.89	0.04	0.02
Freshwater Bulrush	0.00	0.00	0.00	0.23	0.00
Cattails	-	-	0.00	0.00	0.30
Cordgrass	0.00	0.00	0.11	6.87	5.23
Cordgrass/-Pickleweed	0.00	0.00	0.20	0.43	2.38
Mudflat without Biofilm	15.96	3.97	216.98	164.83	129.15
Mudflat with Biofilm	0.02	0.00	60.82	160.05	189.93
Pepperweed	1.66	2.58	0.64	0.02	0.12
Pickleweed	2.39	3.29	2.36	11.41	28.79
Pickleweed /- Gumplant	-	-	0.00	0.18	0.03
Pickleweed /- Jaumea	0.00	0.00	0.00	0.07	0.12
Ruderal	0.54	0.25	-	0.00	0.08
Saltgrass	0.29	0.01	0.04	0.02	0.27
Spearscale	0.02	0.12	0.03	0.03	0.38
Water	46.68	54.83	68.05	12.96	0.44
Wrack	7.32	3.89	0.61	0.19	0.09
Grand Total	**357.54**	**357.52**	**357.53**	**357.53**	**357.38**

Table A10: Acreage by Mapped Habitat for Inner Bair (2009 - 2011, 2019 & 2021)

Mapped Habitat	Inner Bair				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.36	1.39	0.35	1.75	1.57
Alkali Grasses	48.98	61.60	79.19	22.51	40.91
Alkali Heath	18.99	29.34	7.94	1.42	2.40
Bare Earth	20.50	14.17	28.61	6.45	10.85
Freshwater Bulrush	0.04	0.05	0.05	-	-
Cattails	0.05	0.46	0.12	0.04	-
Cordgrass	1.52	8.09	16.12	8.07	3.50
Cordgrass/-Pickleweed	1.01	1.71	4.66	0.56	1.60
Mudflat without Biofilm	1.47	8.90	4.96	30.47	92.87
Mudflat with Biofilm	9.11	4.07	4.42	83.34	46.87
Pepperweed	12.53	29.47	23.86	0.43	0.12
Pickleweed	44.39	37.94	32.24	75.87	54.83
Pickleweed /- Gumplant	1.66	2.64	2.32	0.85	2.12
Pickleweed /- Jaumea	3.71	3.07	1.79	0.66	2.00
Ruderal	18.64	13.15	19.08	5.27	3.34
Saltgrass	13.86	5.18	3.73	2.29	3.03
Spearscale	0.27	2.66	4.03	0.03	0.11
Upland	-	-	-	0.01	-
Water	41.65	45.63	45.90	37.42	24.02
Wrack	52.11	21.29	11.44	13.39	0.70
Grand Total	**290.84**	**290.83**	**290.84**	**290.83**	**290.83**

Table A11: Acreage by Mapped Habitat for Middle Bair Pond (2009 - 2011, 2019 & 2021)

Mapped Habitat	Middle Bair Pond				
	Acres (2009)*	Acres (2010)*	Acres (2011)*	**Acres (2019)**	**Acres (2021)**
Alkali Bulrush	0.01	0.26	0.07	0.16	1.84
Alkali Grasses	88.41	56.67	139.73	0.00	0.02
Alkali Heath	8.96	28.63	3.88	0.12	0.14
Bare Earth	274.94	225.96	113.41	1.65	1.80
Freshwater Bulrush	0.00	0.08	0.01	-	-
Cattails	0.00	0.06	0.01	-	-
Cordgrass	0.21	2.16	28.61	4.30	26.81
Cordgrass/-Pickleweed	0.60	3.86	20.02	1.48	1.14
Mudflat without Biofilm	3.20	8.78	22.75	196.91	473.75
Mudflat with Biofilm	0.36	0.63	0.56	415.01	95.11
Pepperweed	5.22	5.92	11.34	0.08	0.04
Pickleweed	99.61	97.49	66.18	16.74	37.05
Pickleweed /- Gumplant	0.58	2.59	6.43	2.74	0.56
Pickleweed /- Jaumea	1.30	0.99	0.66	0.19	2.48
Ruderal	7.61	13.55	57.82	0.03	0.04
Saltgrass	15.98	8.63	5.40	0.14	0.89
Spearscale	0.00	1.27	2.84	0.00	0.43
Water	25.38	54.73	59.88	21.69	19.16
Wrack	128.85	149.01	121.66	0.01	0.00
Grand Total	**661.24**	**661.25**	**661.25**	**661.24**	**661.24**

This part of Middle Bair was breached after 2011, and so the acreages from HEMP1 (2009-11) are all pre-breach.

Table A12: Acreage by Mapped Habitat for Outer Bair Pond (2009 - 2010, 2019 & 2021)

Mapped Habitat	Outer Bair Pond			
	Acres (2009)	Acres (2010)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.82	0.02	0.24	2.46
Alkali Grasses	0.10	0.14	0.01	0.20
Alkali Heath	0.18	0.42	0.20	0.35
Bare Earth	0.03	0.23	1.14	2.99
Freshwater Bulrush	0.00	0.00	-	-
Cattails	0.00	0.02	0.00	-
Cordgrass	0.32	2.93	17.22	21.53
Cordgrass/-Pickleweed	1.26	1.30	4.40	1.70
Mudflat without Biofilm	11.07	51.71	81.27	205.85
Mudflat with Biofilm	262.81	176.07	238.76	81.19
Pepperweed	0.41	0.86	0.21	0.03
Pickleweed	33.74	44.20	31.69	70.85
Pickleweed /- Gumplant	0.09	0.07	9.47	1.65
Pickleweed /- Jaumea	0.20	0.49	0.65	2.31
Ruderal	0.05		0.26	0.26
Saltgrass	0.91	0.60	0.48	3.51
Spearscale	0.62	0.64	0.00	0.34
Water	82.83	122.09	22.57	13.37
Wrack	13.15	6.82	0.03	0.01
Grand Total	**408.58**	**408.59**	**408.59**	**408.59**

Table A13: Acreage by Mapped Habitat for Faber/Laumeister (2009 - 2011, 2019 & 2021)

Mapped Habitat	Faber/Laumeister				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.30	0.26	0.06	4.35	0.66
Alkali Grasses	2.69	4.96	4.93	2.13	4.44
Alkali Heath	0.48	1.70	1.05	1.07	1.08
Bare Earth	0.05	0.74	1.66	2.11	2.85
Freshwater Bulrush	1.10	0.00	0.47	-	-
Cattails	0.09	0.00	1.23	0.06	-
Cordgrass	0.69	3.52	15.86	10.53	5.25
Cordgrass/-Pickleweed	9.91	11.67	35.93	16.55	13.13
Mudflat without Biofilm	6.19	1.04	1.21	4.70	9.81
Mudflat with Biofilm	1.57	4.55	2.37	4.87	3.38
Pepperweed	2.00	4.58	2.98	0.20	0.02
Pickleweed	157.86	117.62	101.60	134.44	143.90
Pickleweed /- Gumplant	13.19	21.20	19.40	7.96	3.29
Pickleweed /- Jaumea	0.64	7.74	6.08	2.99	2.27
Ruderal	1.17	1.07	0.80	1.58	1.63
Saltgrass	1.32	14.38	0.30	2.89	9.43
Spearscale	-	-	-	0.03	0.01
Water	0.51	3.97	3.55	1.81	0.38
Wrack	1.75	2.61	2.09	3.49	0.20
Grand Total	**201.50**	**201.62**	**201.55**	**201.74**	**201.75**

Table A14: Acreage by Mapped Habitat for Ogilvie (2009 - 2011, 2019 & 2021)

Mapped Habitat	Ogilvie				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	1.01	1.19	4.73	1.66	2.07
Alkali Grasses	-	0.00	0.05	-	0.01
Alkali Heath	-	0.06	0.93	0.05	0.03
Bare Earth	0.00	0.21	6.73	0.02	0.04
Freshwater Bulrush	0.00	0.00	0.00	0.83	2.11
Cattails	-	-	0.05	0.06	0.00
Cordgrass	2.09	10.07	10.27	0.12	0.81
Cordgrass/-Pickleweed	6.53	18.16	13.46	10.73	10.49
Mudflat without Biofilm	14.47	20.60	24.85	31.92	10.15
Mudflat with Biofilm	31.63	25.79	15.85	10.39	23.94
Pepperweed	0.11	1.52	2.88	0.77	0.09
Pickleweed	43.01	29.62	37.46	61.21	74.06
Pickleweed /- Gumplant	0.48	2.51	0.90	4.65	1.10
Pickleweed /- Jaumea	0.00	0.12	0.02	1.94	0.03
Ruderal	-	0.00	0.01	0.11	0.09
Saltgrass	0.11	2.72	1.67	0.23	1.85
Spearscale	0.89	2.47	1.39	1.20	1.12
Water	31.03	16.55	9.49	4.00	1.94
Wrack	0.48	0.24	1.11	1.96	1.95
Grand Total	**131.86**	**131.85**	**131.86**	**131.85**	**131.86**

Table A15: Acreage by Mapped Habitat for La Riviera (2009 - 2011, 2019 & 2021)

Mapped Habitat	**La Riviera**				
	Acres (2009)	**Acres (2010)**	**Acres (2011)**	**Acres (2019)**	**Acres (2021)**
Alkali Bulrush	14.04	1.31	0.38	4.95	3.26
Alkali Grasses	3.80	15.55	18.74	0.51	6.37
Alkali Heath	0.40	2.21	1.63	0.37	0.36
Bare Earth	1.60	9.90	3.55	8.71	18.67
Freshwater Bulrush	3.74	0.00	1.14	0.14	0.13
Cattails	0.72	0.02	3.05	0.18	1.02
Cordgrass	0.82	3.23	5.59	2.92	1.52
Cordgrass/-Pickleweed	2.89	5.35	3.77	0.81	0.76
Mudflat without Biofilm	1.24	3.37	1.66	8.55	7.53
Mudflat with Biofilm	0.63	2.02	0.65	3.14	17.68
Pepperweed	8.09	2.81	4.85	2.51	1.03
Pickleweed	66.57	42.56	48.76	56.90	57.48
Pickleweed /- Gumplant	1.24	9.71	8.62	7.75	3.06
Pickleweed /- Jaumea	2.75	4.80	2.89	3.28	2.05
Ruderal	5.22	2.89	3.16	2.18	3.19
Saltgrass	1.62	4.34	0.32	0.63	0.63
Spearscale	-	-	-	2.91	1.63
Water	3.60	4.41	8.52	14.25	1.46
Wrack	9.11	13.06	8.42	7.47	0.34
Grand Total	**128.08**	**127.55**	**125.71**	**128.16**	**128.16**

Table A16: Acreage by Mapped Habitat for Greco (2009 - 2011, 2019 & 2021)

Mapped Habitat	Greco				
	Acres (2009)	Acres (2010)	Acres (2011)	Acres (2019)	Acres (2021)
Alkali Bulrush	0.06	0.41	0.10	8.85	1.10
Alkali Grasses	2.08	3.95	2.99	1.92	0.91
Alkali Heath	1.89	3.02	3.83	2.01	7.45
Bare Earth	0.47	0.85	3.91	2.24	2.37
Freshwater Bulrush	0.03	0.00	0.00	-	-
Cattails	0.01	0.05	0.02	0.27	-
Cordgrass	0.70	5.28	43.66	30.32	47.71
Cordgrass/-Pickleweed	3.74	15.72	177.48	73.79	48.50
Mudflat without Biofilm	35.51	31.22	50.39	128.02	164.38
Mudflat with Biofilm	27.83	32.56	44.38	45.20	24.01
Pepperweed	6.10	8.29	22.71	2.61	0.38
Pickleweed	558.53	518.24	311.11	440.01	398.28
Pickleweed /- Gumplant	2.08	5.41	8.00	5.34	2.04
Pickleweed /- Jaumea	2.41	3.20	3.41	4.50	13.92
Ruderal	0.07	0.17	1.36	6.38	5.71
Saltgrass	18.51	27.70	13.59	14.61	55.63
Spearscale	0.14	2.47	5.07	0.01	0.01
Water	110.57	111.16	74.46	11.85	12.26
Wrack	14.06	15.11	18.36	6.87	0.16
Grand Total	**784.80**	**784.81**	**784.81**	**784.80**	**784.80**