Mapping Marshes and Mudflats from Space:

2019 Preliminary Results

Habitat Evolution Mapping Project 2.0

South Bay Salt Pond Restoration Project

State of California Coastal Conservancy

U.S. Fish & Wildlife Service

California Department of Fish & Wildlife

California Wildlife Foundation

CAL-IPC

San Francisco Bay Joint Venture

Image courtesy of C Benton

Brian Fulfrost, Lead Geospatial Scientist (co-PI)
David Thomson, Lead Biologist (co-PI)

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Habitat Evolution Mapping Project - Project Goals

Track evolution of tidal marsh habitats (vegetation and mudflats)

Tidal Marsh

- Salt, Brackish and Freshwater Marsh Habitats
- Habitats mapped as vegetation Alliance/Association
- Map floral colonization of restored ponds

Mudflats

- Map extent and distribution of mudflats
- Map presence of and distribution of biofilm

Other

- Map abiotic and upland habitats (including Pepperweed)
- Use ISP data to distinguish invasive and native Cordgrass
- Map channels (time permitting)

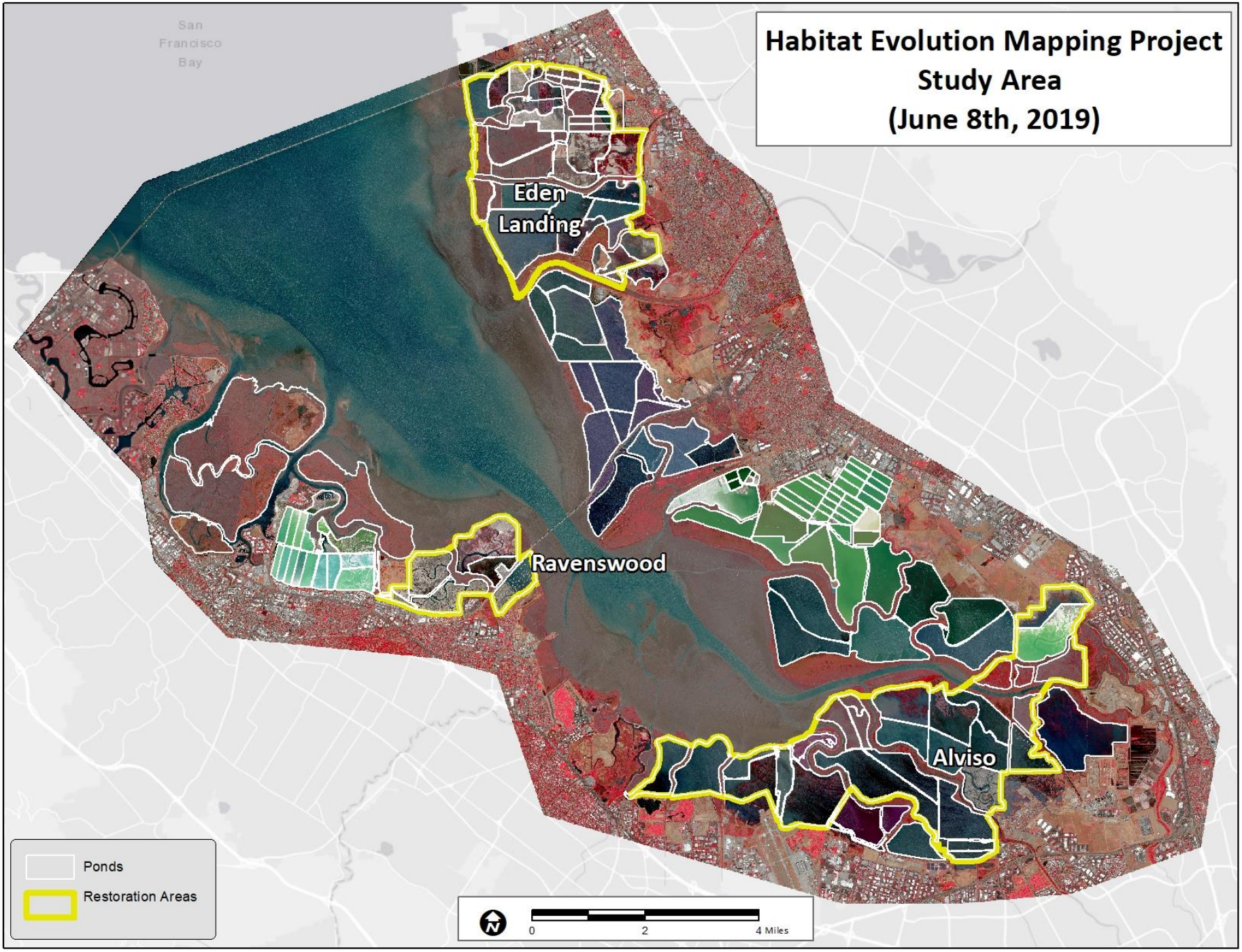
Habitat Evolution Mapping Project (HEMP) 2.0

- Two Year Project (2019 and 2021)
- Decadal Update to HEMP 1.0 (2009-2011)

2019-2021 Accomplishments

- Obtained **Worldview-2 satellite image on June 8th, 2019** during MLLW
- **Orthorectified and geocorrection** of Worldview2 imagery (<2 meters)
- **Pansharpened** to 0.5 meter multispectral
- **Ground Truthing** (~295 surveys)

- **2019 *preliminary* Habitats and Mudflats completed**
- **2019 & 2009-11 *preliminary* Habitat change analysis completed**
- **2019 & 2016 *preliminary* Mudflat change analysis completed**


Habitat Evolution Mapping Project
Study Area
(June 8th, 2019)
San
Francisco
Bay
Eden
Landing
Ravenswood
Alviso
Ponds
Restoration Areas
0
2
4 Miles

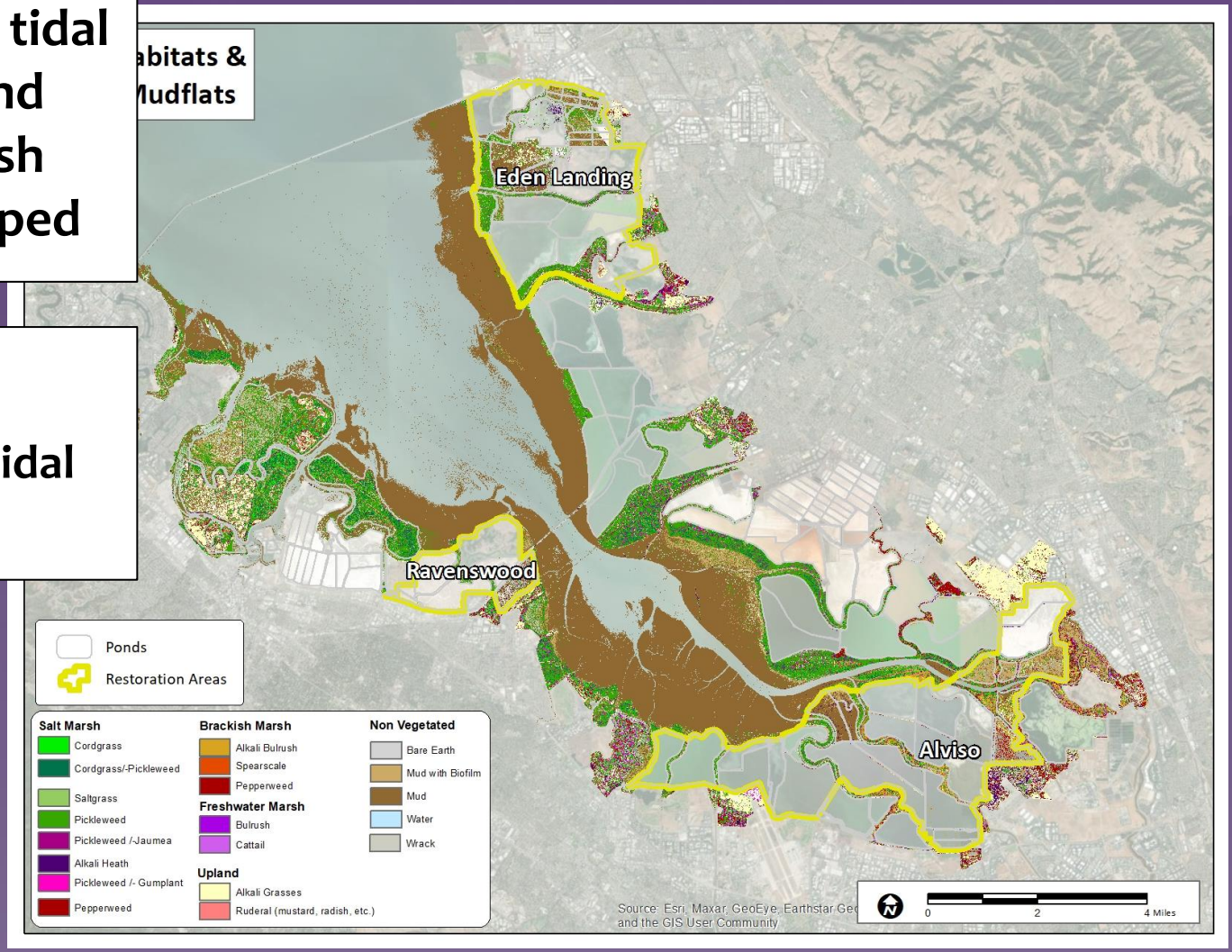
Habitat Evolution Mapping Project 1.0 (2009-2011)

2009-2011

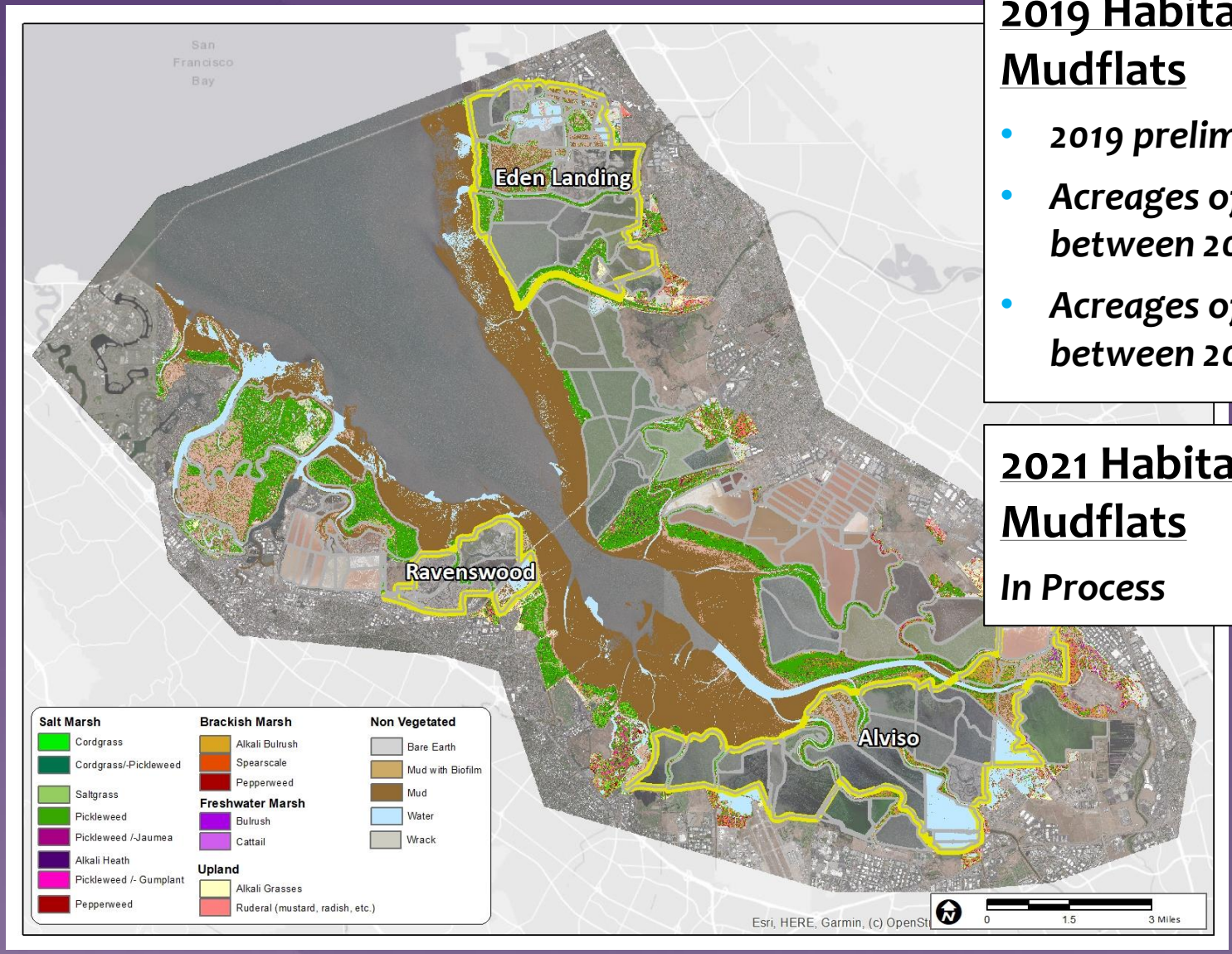
~15,000 *acres* of tidal salt, brackish, and freshwater marsh vegetation mapped

2016

~18,000 *acres* of tidal mudflats mapped



Habitat Evolution Mapping Project 2.0 (2019-2021)



2019 Habitats & Mudflats

- *2019 preliminary results*
- *Acreages of tidal marsh between 2009-11 & 2019*
- *Acreages of mudflat between 2019 and 2016*

2021 Habitats and Mudflats

In Process

Methods - Overview

- Based on analysis of **high resolution multispectral satellite imagery**
- Extensive **ground truthing** of **habitat classifications**

Step 1. Develop Vegetation Classification (Habitat Types)

Step 2. Satellite Imagery acquisition

- time satellite flyover (~12pm) with Mean Lower Low Water (MLLW)
- Worldview-2 (2019 & 2021) - 8 band, ~0.5 meter
- Ikonos (2009-2011) - 4 band, ~1 meter

Step 3. Habitat Model (w/ ground truthing)

- supervised classification of image into habitat classes

Step 4: Mudflat Model (w/ ground truhing)

- mix of methods designed to optimize tidal variability

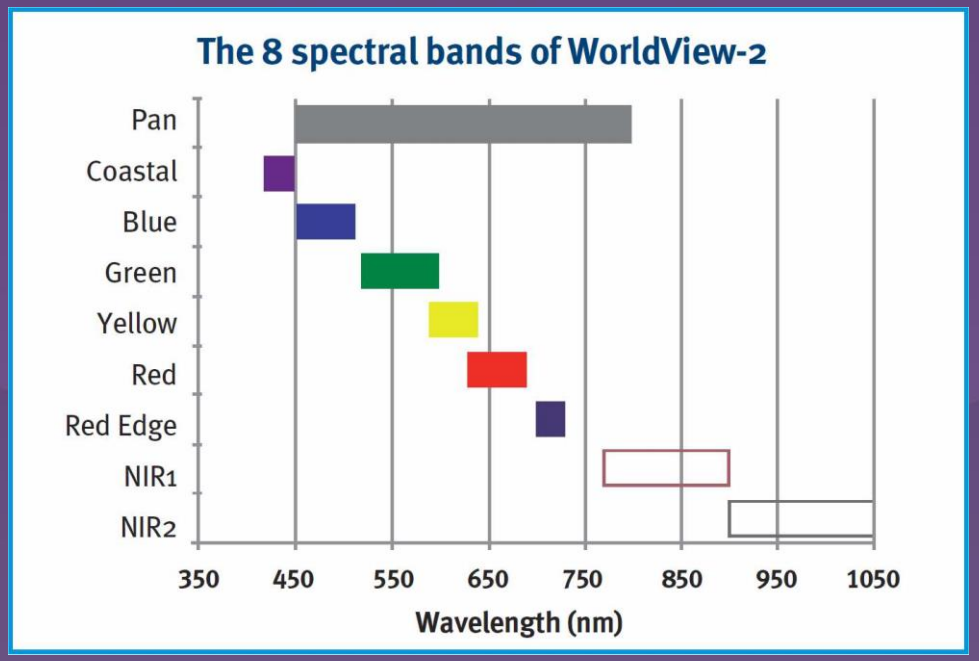
Step 5. Final Model Validation

Methods – Habitat Classifications (19)

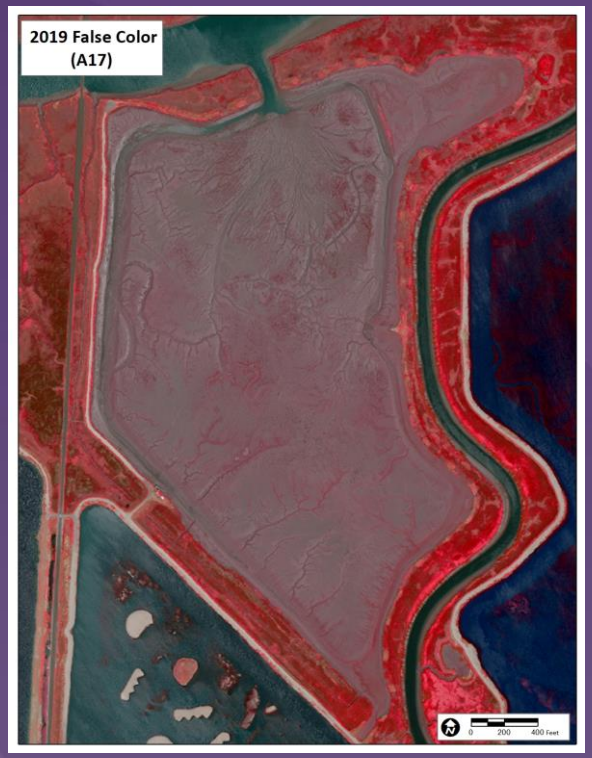
Habitat Type		Mapped Habitats (19) (Alliances and Associations)
Salt Marsh (7)	Salt Marsh – low (MTL-MHW)	Cordgrass
		Cordgrass /- Pickleweed
	Salt Marsh – "mid" (MHW-MHHW)	Pickleweed
		Saltgrass
		Pickleweed /- Jaumea
	Salt Marsh – high (MHHW)	Alkali Heath
		Pickleweed /- Gumplant
Brackish Marsh (2)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

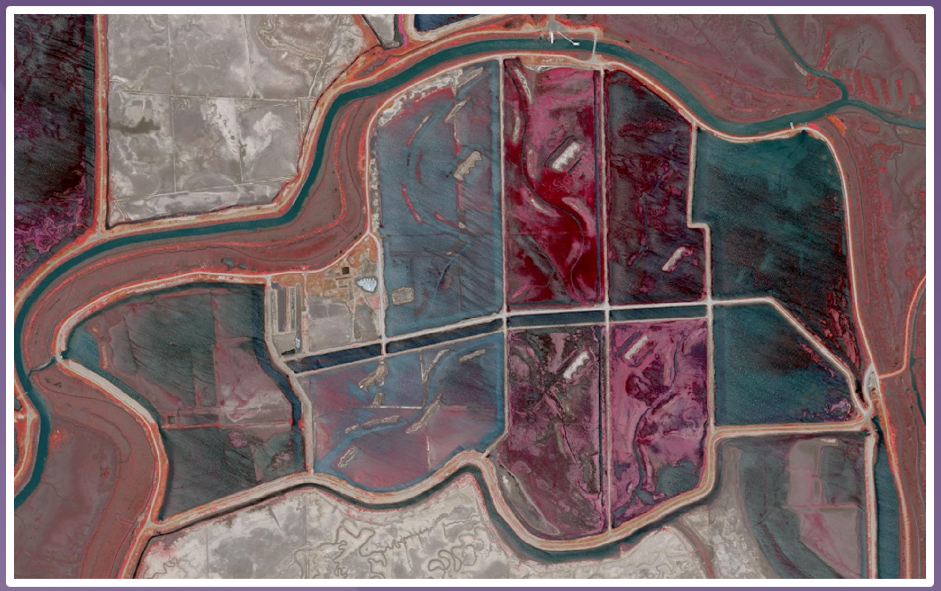
*Pepperweed was not included in the 'Brackish Marsh' habitat category when acreages were calculated.

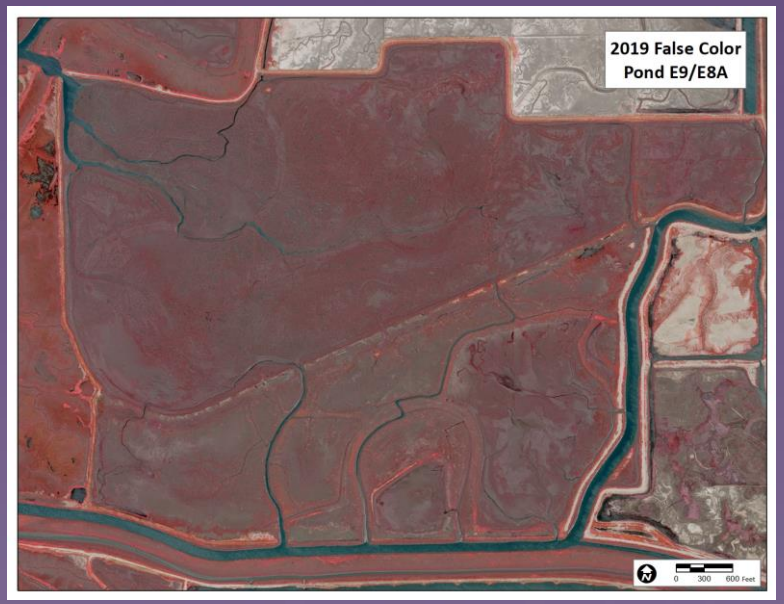
Methods – Satellite Imagery (Worldview-2)



Spectral:	**8 band multispectral, 1 band panchromatic**
Radiometric:	**11 bit radiometric**
Spatial:	**1.8 meters multispectral (at nadir), 0.46 meters panchromatic (at nadir)**
Temporal:	**1.1 days at 1 meter GSD or less 3.7 days at 20° off-nadir or less (0.52 meter GSD)**
Swath Width:	**16.4 kilometers at nadir, bi-directional**







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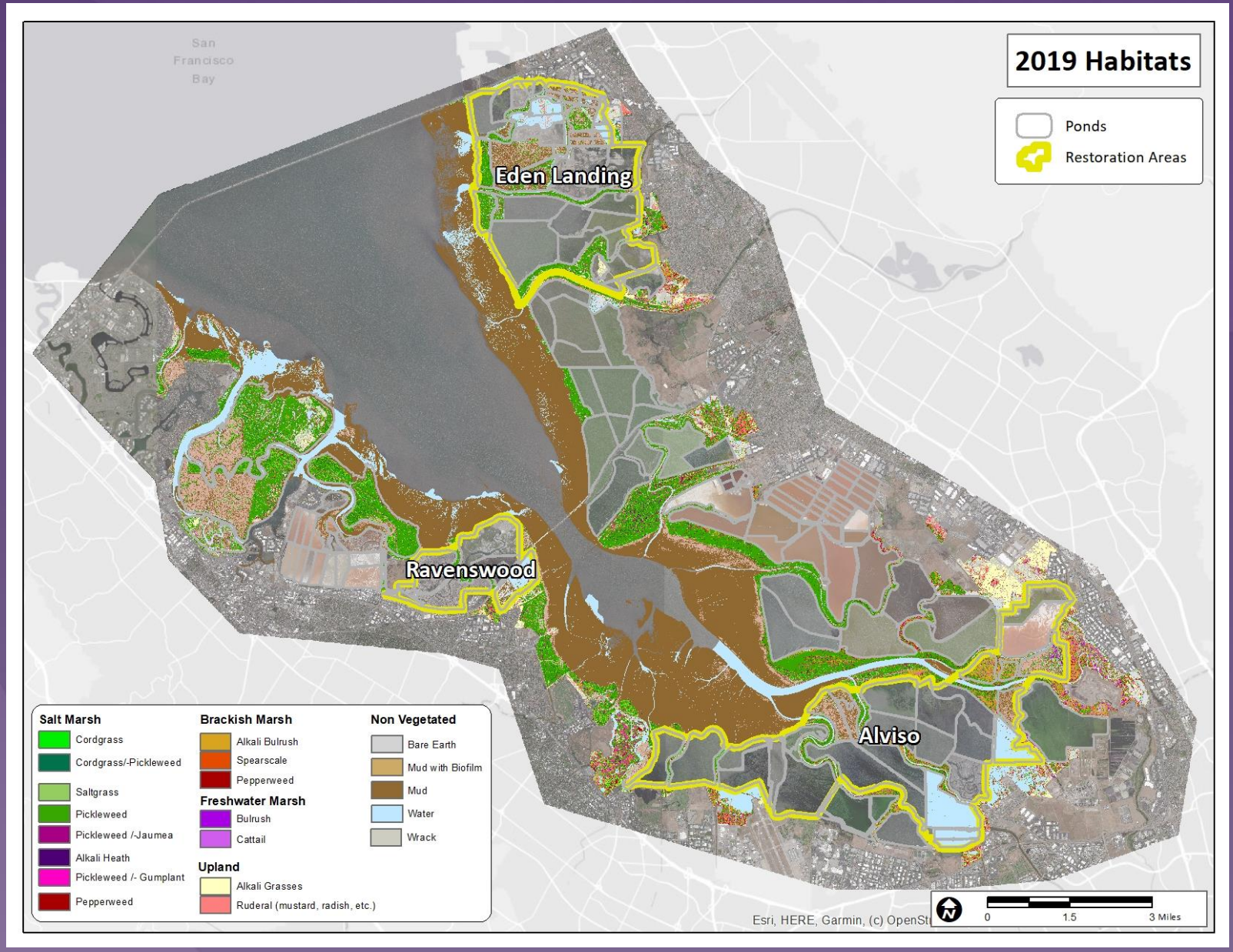
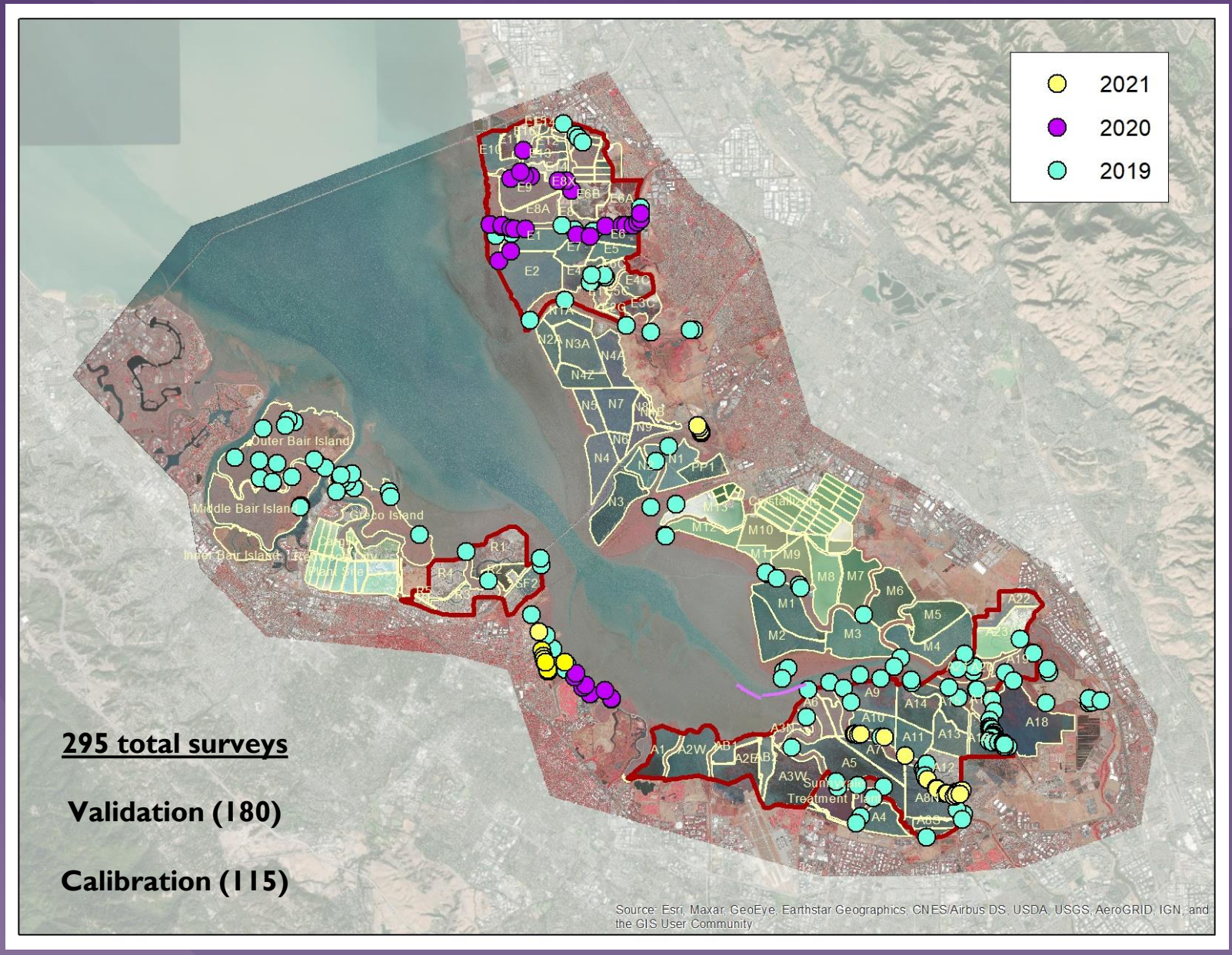
Habitat Evolution Mapping Project 2.0 – Preliminary Results (2019)



Habitat Evolution Mapping Project 2.0 – Ground Truthing (2019-2021)



Preliminary Results (2019) – Accuracy Assesment (Error Matrix)

	Mapped (Classified) Data																
	Alkali Bulrush	Alkali Grasses	Alkali Heath	Bare Earth/Wrack	Cattail	Cordgrass	Freshwater Bulrush	Mud	Pepperweed	Pickleweed	Pickleweed /- Gumplant	Ruderal	Saltgrass	Spearscale	Water	TOTAL VISITED	PRODUCER' S ACCURACY (%)
Alkali Bulrush	28									2	2					*32*	88%
Alkali Grasses		1														*1*	100 %
Alkali Heath																-	*NA*
Bare Earth/Wrack				4											1	*5*	80%
Cattail	3				10											*13*	77%
Cordgrass						14				8						*22*	64%
Freshwater Bulrush	2				1		5									*8*	63%
Mud								9								**9**	100 %
Pepperweed	2								11	1	1			1		**16**	69%
Pickleweed	1									54	1					**56**	96%
Pickleweed /- Gumplant										3	6					**9**	67%
Ruderal										1		1				**2**	50%
Saltgrass										1			3			**4**	75%
Spearscale	1															*1*	0%
Water	1														1	*2*	50%
TOTAL MAPPED	*38*	*1*	-	*4*	*11*	*14*	*5*	*9*	*11*	*70*	*10*	*1*	*3*	*1*	*2*	**OVERALL ACCURACY**	
USER"S ACCURACY (%)	74%	100%	*NA*	100%	91%	100%	100%	100%	100%	77%	60%	100%	100%	0%	50%	**82%**	

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Results (HEMP 1.0 & 2.0) – Accuracy Assessment

Overall Accuracy (dominant habitat alliance)

2019 (preliminary): 82% (*Kappa 0.78*)

2011: 76%

2010: 70%

2009: 70%

Overall Accuracy (sub-dominance habitat association)

2019 (preliminary): 73% (*Kappa 0.68*)

2011: 61 %

2010: 67 %

2009: 56 %

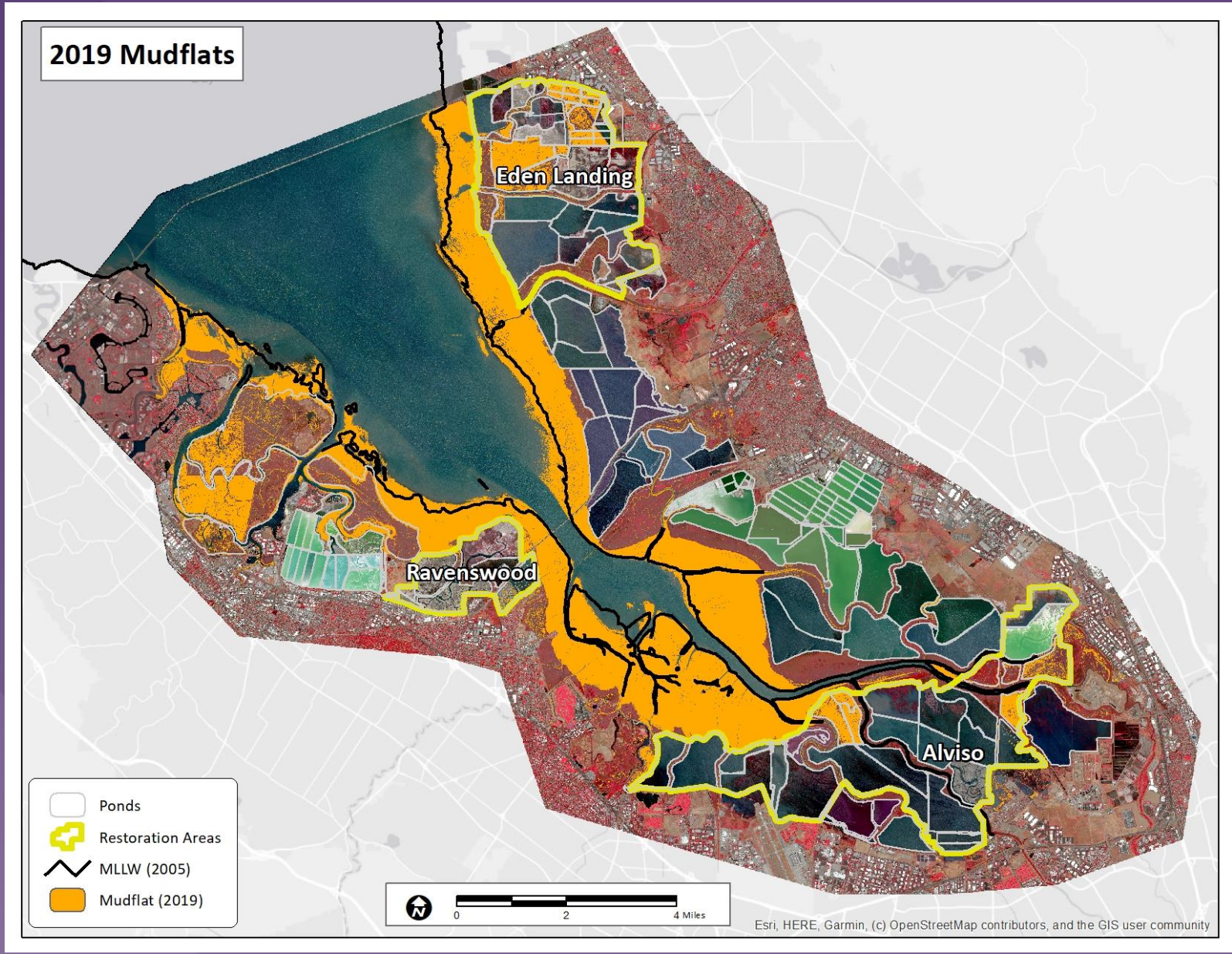
Preliminary Results (2019) – Mudflats Overview

Mudflats

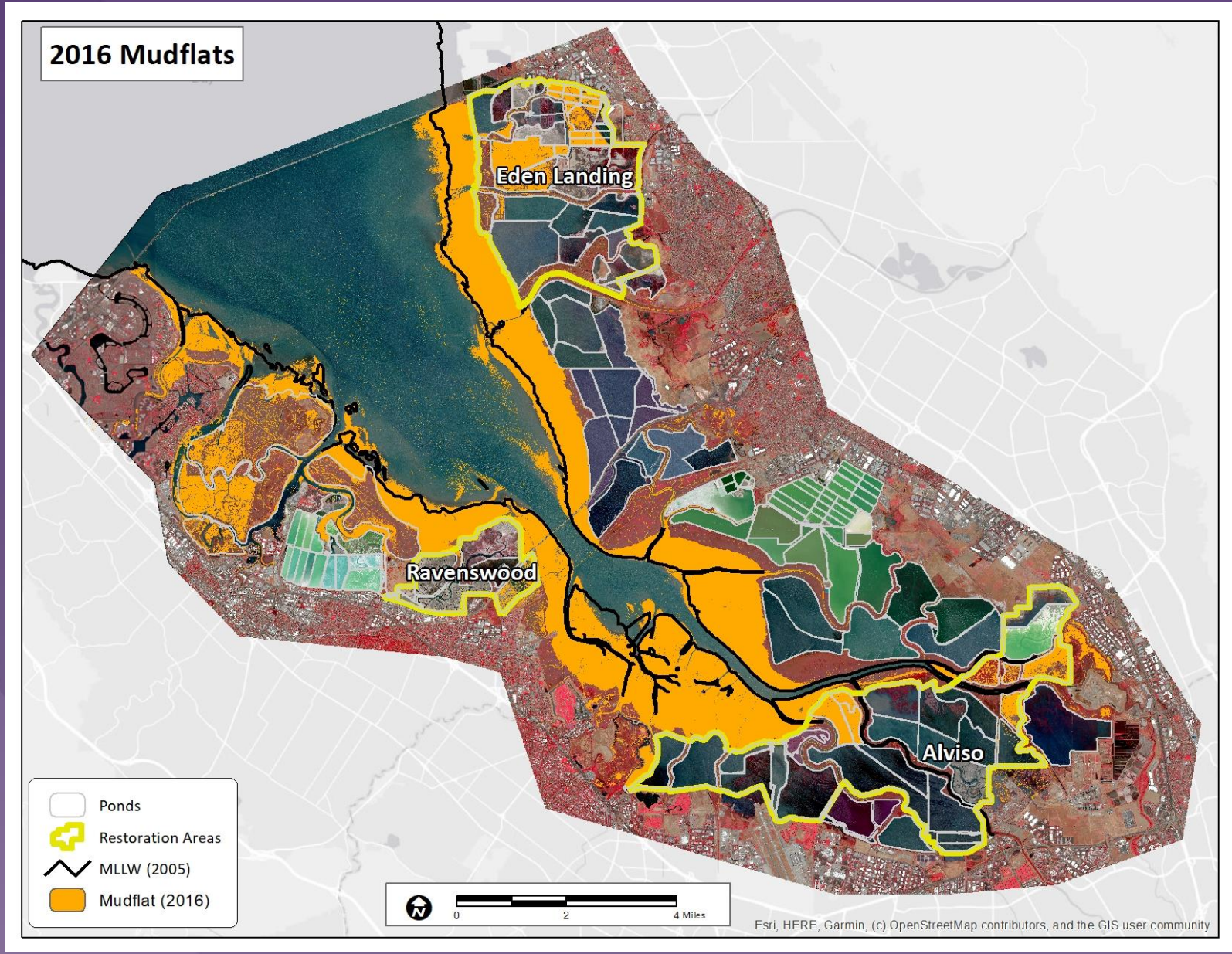
- **Overall extent and distribution relatively unchanged (between 2016 and 2019)**
- **Multiple locations of localized accretion and erosion (possible interannual variability)**
- **Mudflats within restored ponds with floral colonization significantly reduced from 2016**
- **Biofilm dominant within restored ponds**

Mud Flat Type	Acres of Mudflats (June 8, 2019)	Acres of Mudflats (April 13, 2016)
Bay/ Slough	13,800	14,413
Pond/ Wetland	3,342	4,022
Total	17,142	18,435

Preliminary Results (2019) - Mudflats



2016 Mudflats



Preliminary Results (2019) – Habitats Overview

Habitats

- vegetation composition and distribution persistent
- growth of Brackish marsh in and around Alviso

Restored Ponds

- Significant floral colonization in many ponds
  - A21, A20, E9/E8A, North Creek Marsh
- Mudflats formed with less floral colonization in other ponds
  - A6, A19, Mt Eden Creek Marsh, Inner Bair, Middle Bair

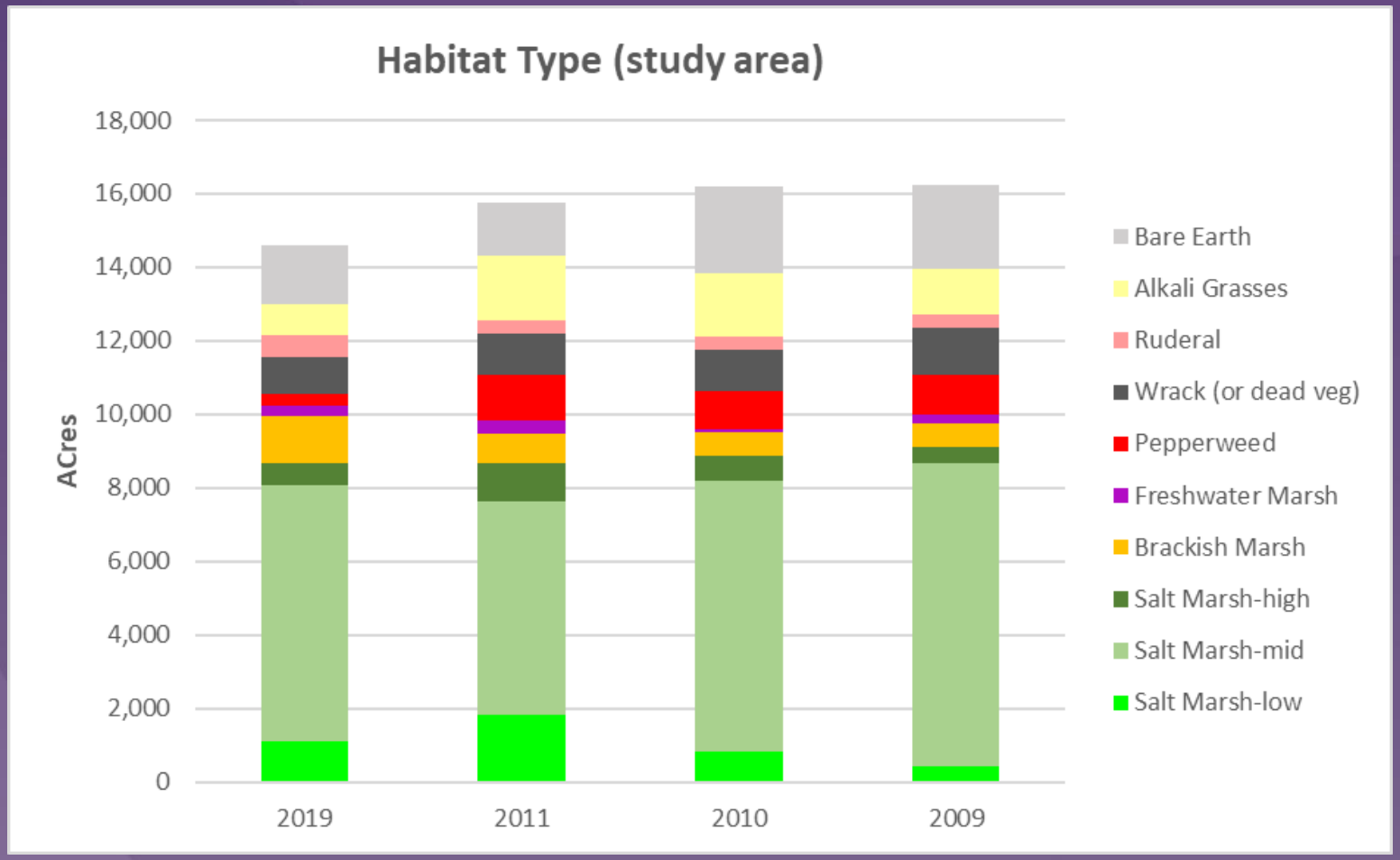
Select Marshes

- Growth of low /mid marshes in some locations
  - above A6, Ogilvie Island, Calavares Marsh, Alviso slough

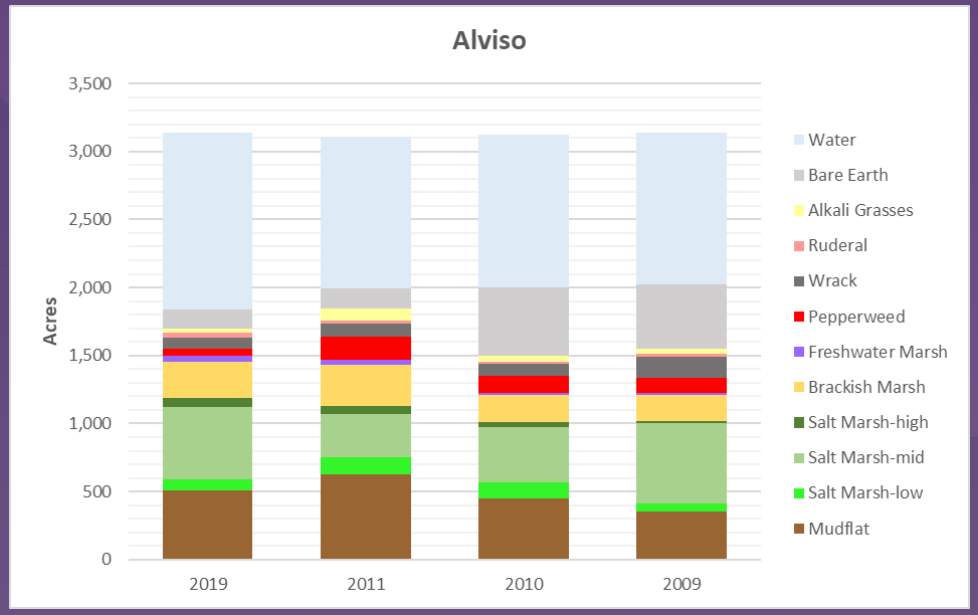
Invasives

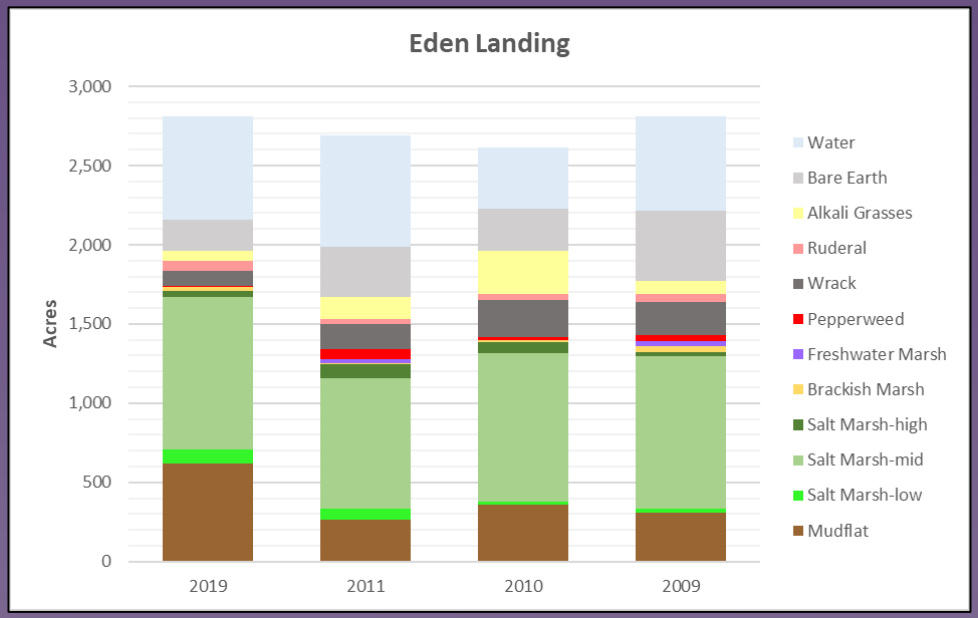
- Spearscale appears more dense and distributed in brackish marsh
- Pepperweed significantly reduced, persists in extent and distribution

Preliminary Results (2019) – Habitat Acreages (Study Area)

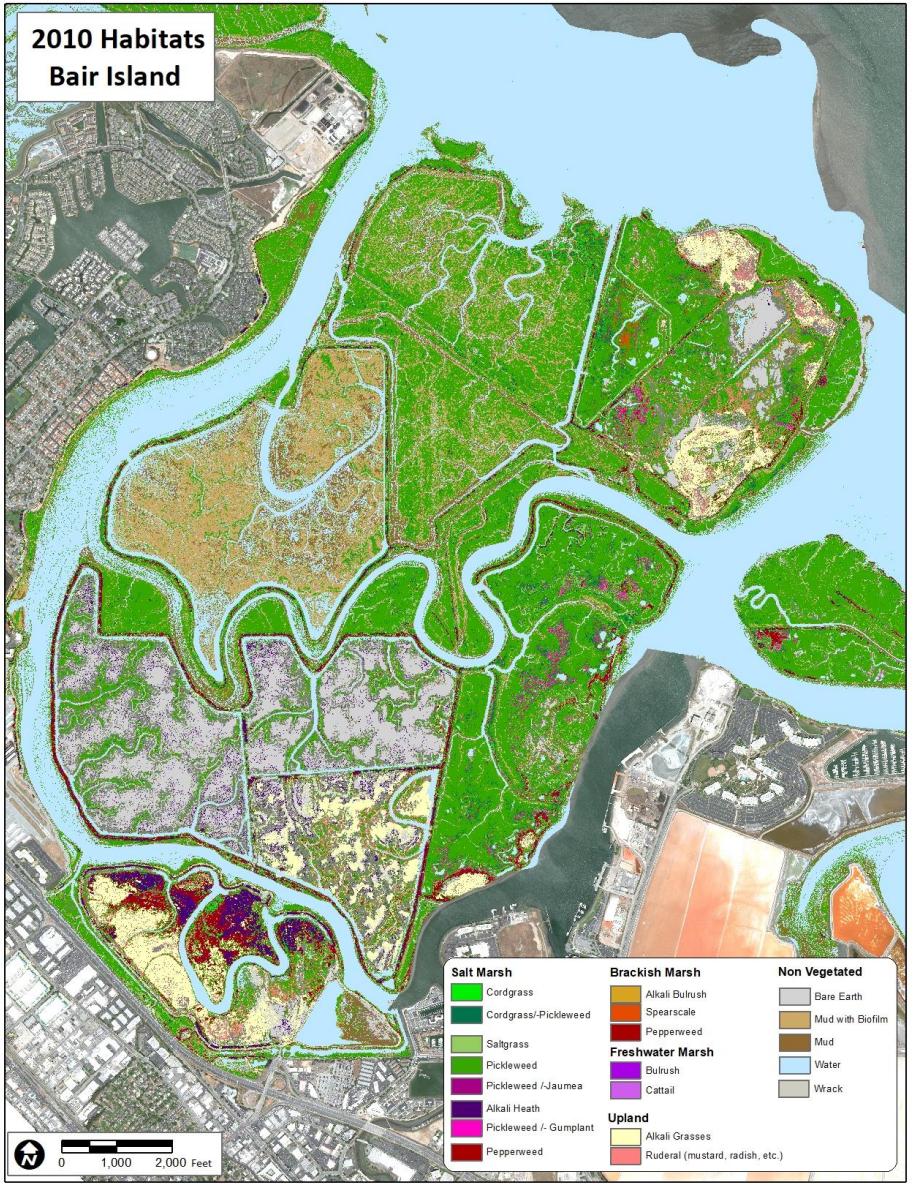


Preliminary Results (2019) – Habitat Acreages (Alviso and Eden Landing)

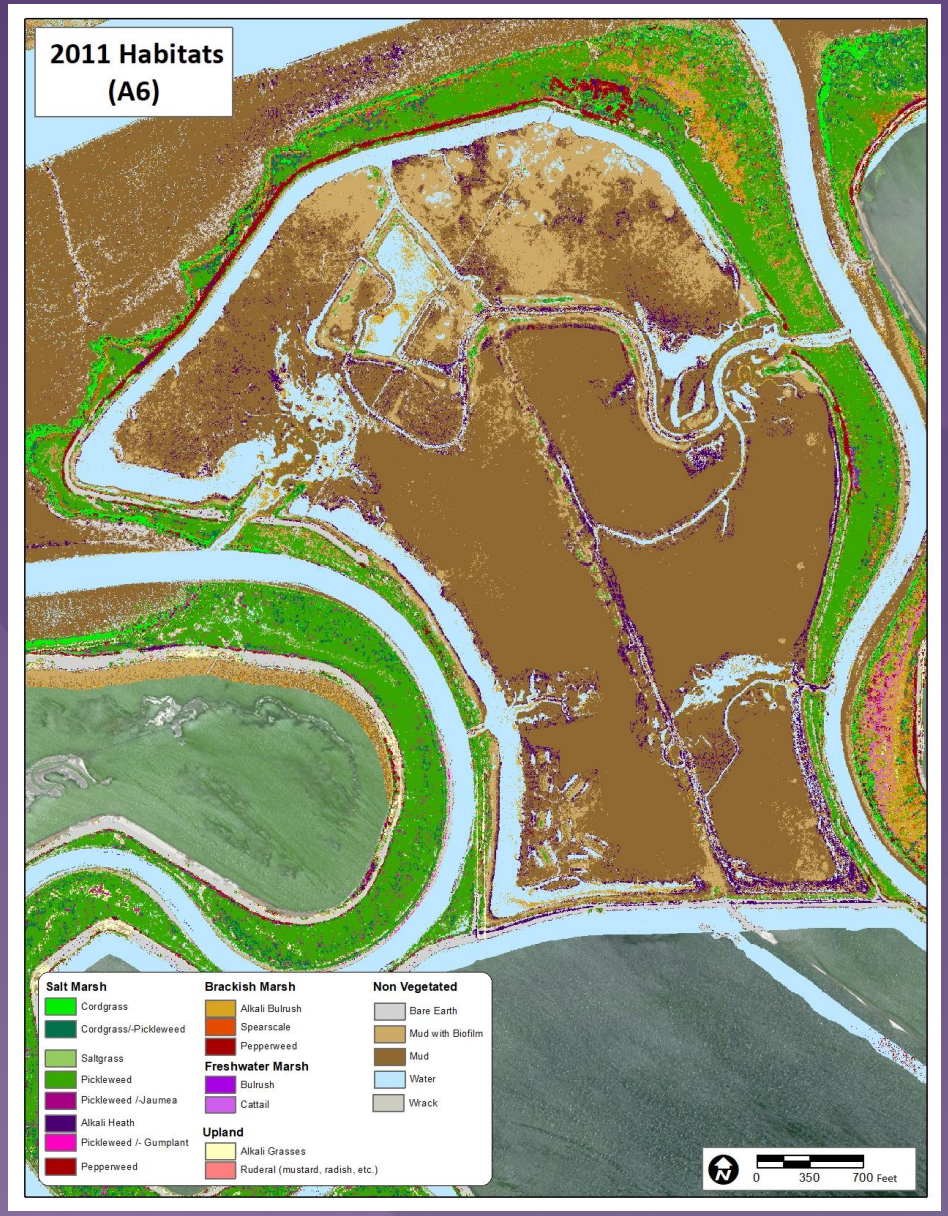




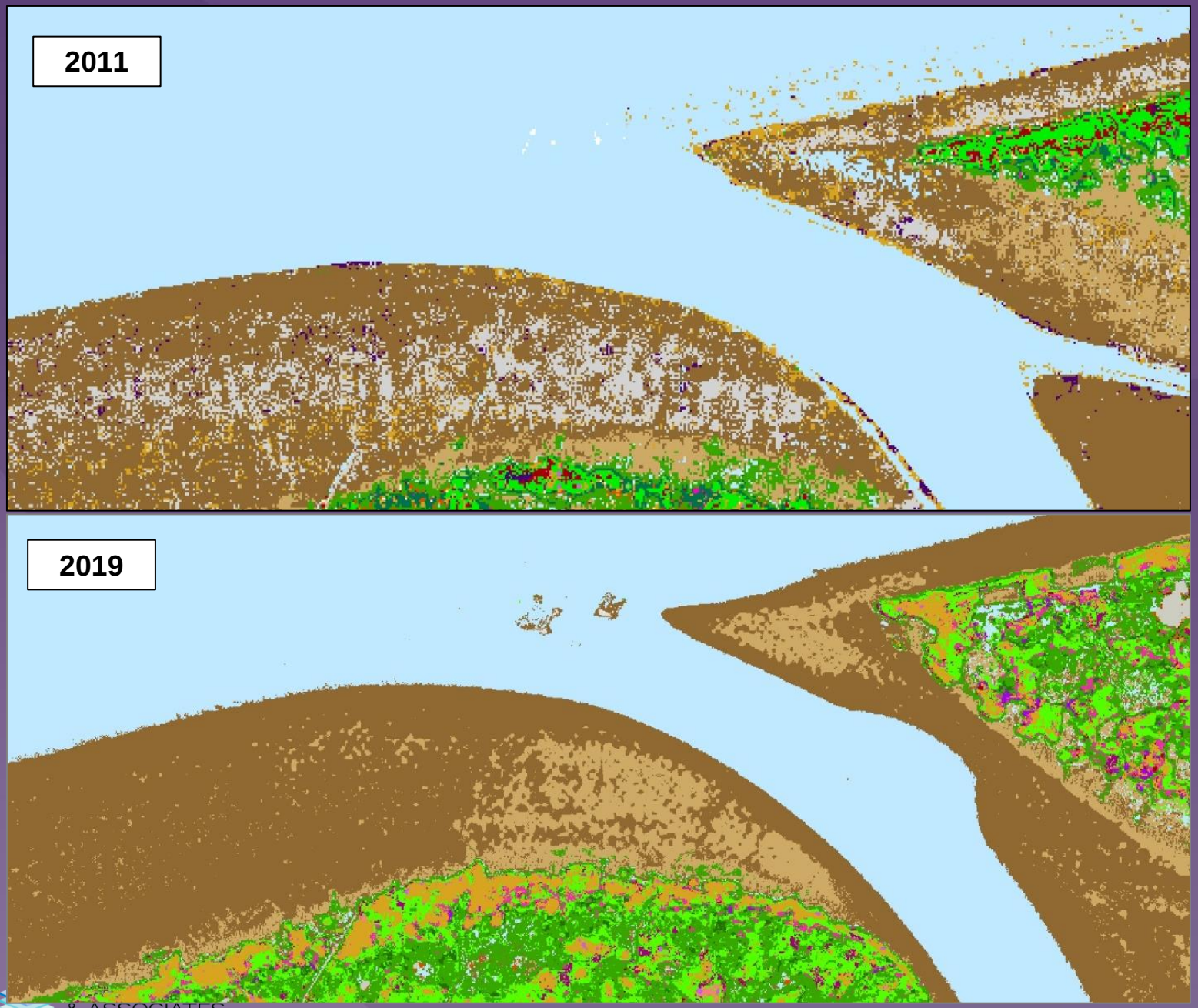
Habitat Evolution Mapping Project 2.0 – 2019 Preliminary Results (Bair Island)



Habitat Evolution Mapping Project 2.0 – 2019 Preliminary Results (A6)

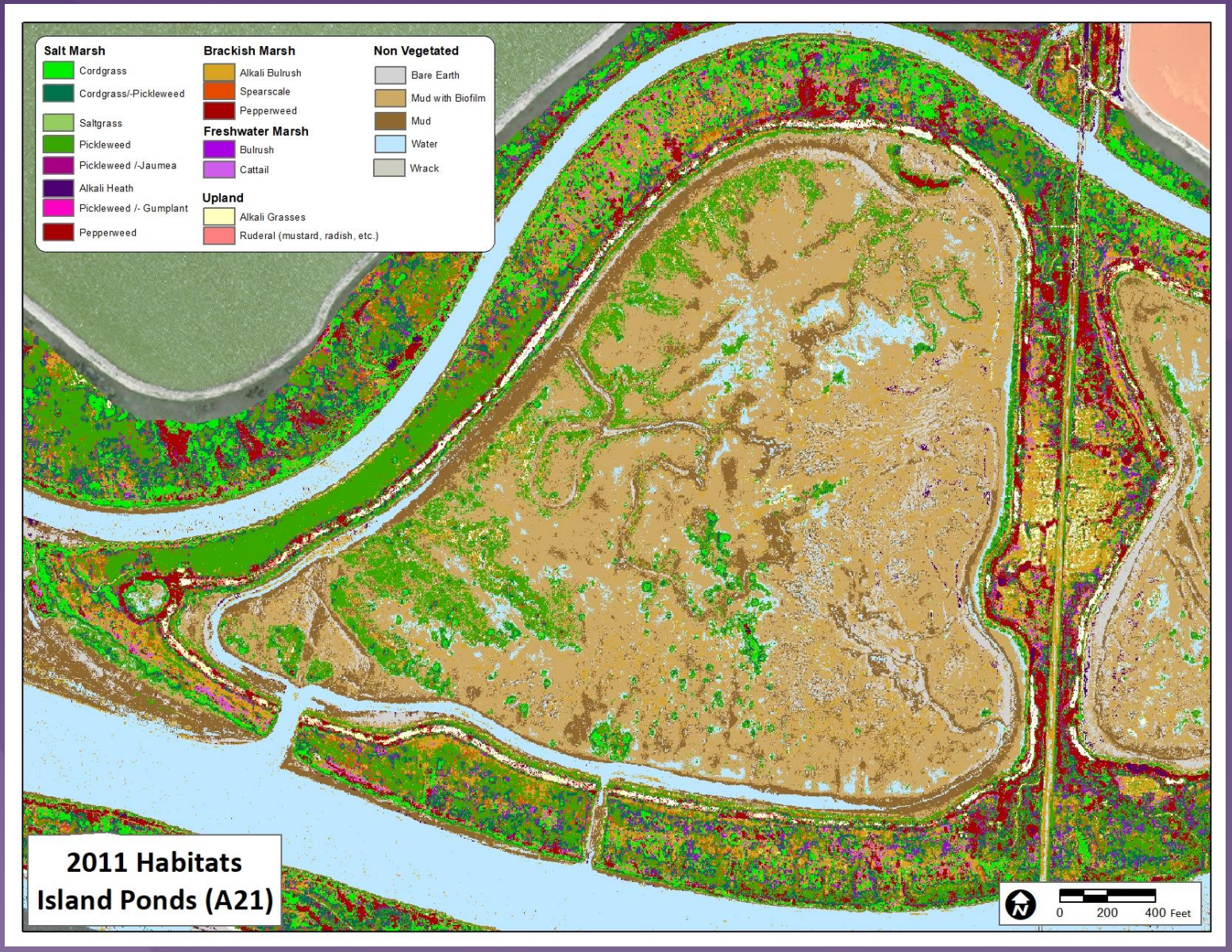


Habitat Evolution Mapping Project 2.0 – 2019 Preliminary Results (above A6)

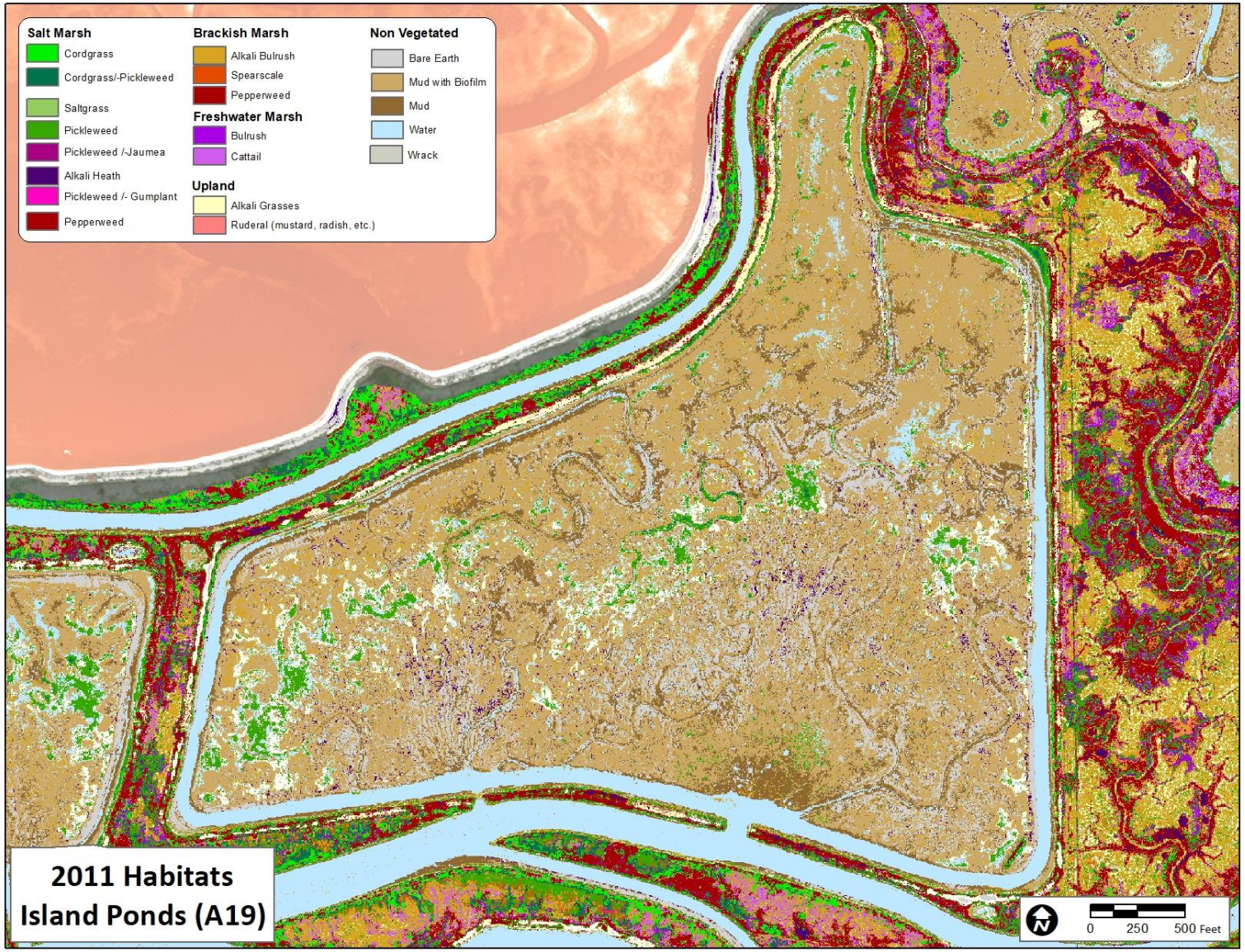


~ 30 meters growth of low marsh

Habitat Evolution Mapping Project 2 – 2019 Preliminary Results (A21)

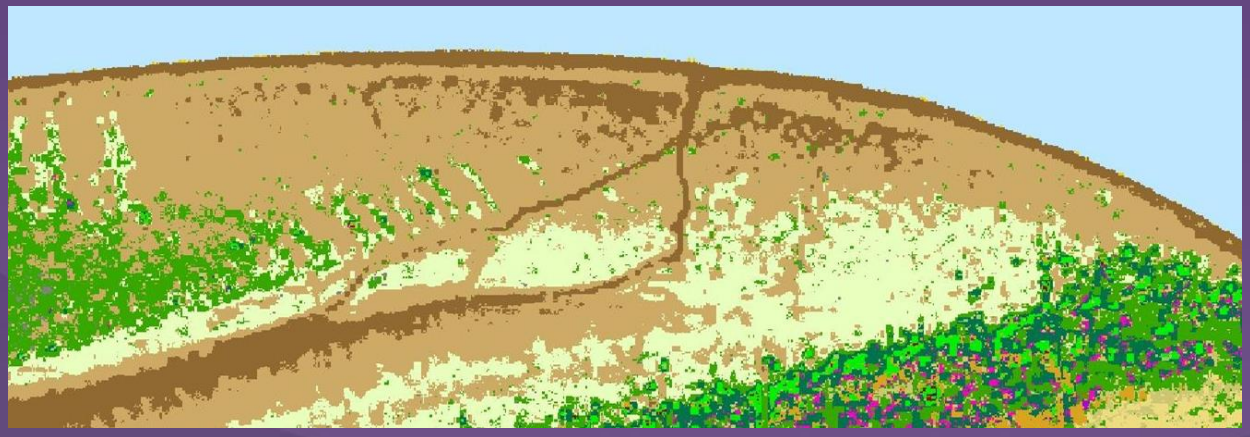


Habitat Evolution Mapping Project 2 – 2019 Preliminary Results (A19)

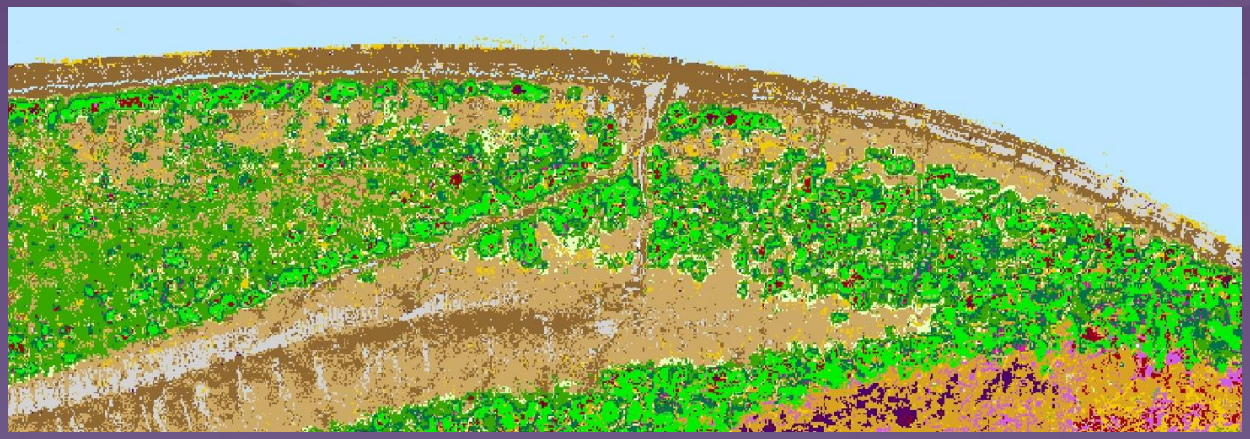


Habitat Evolution Mapping Project 2 – 2019 Preliminary Results (Ogilvie Island)

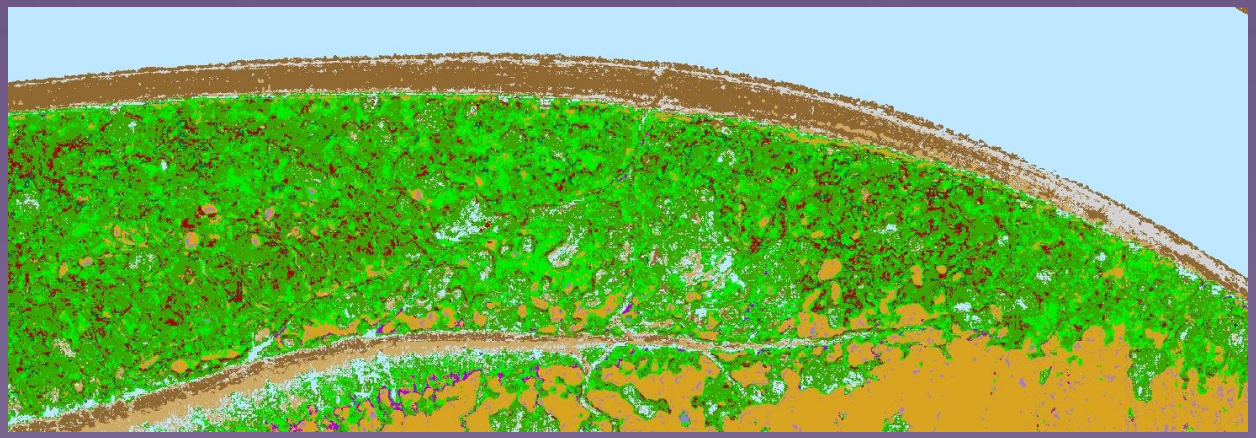
2009



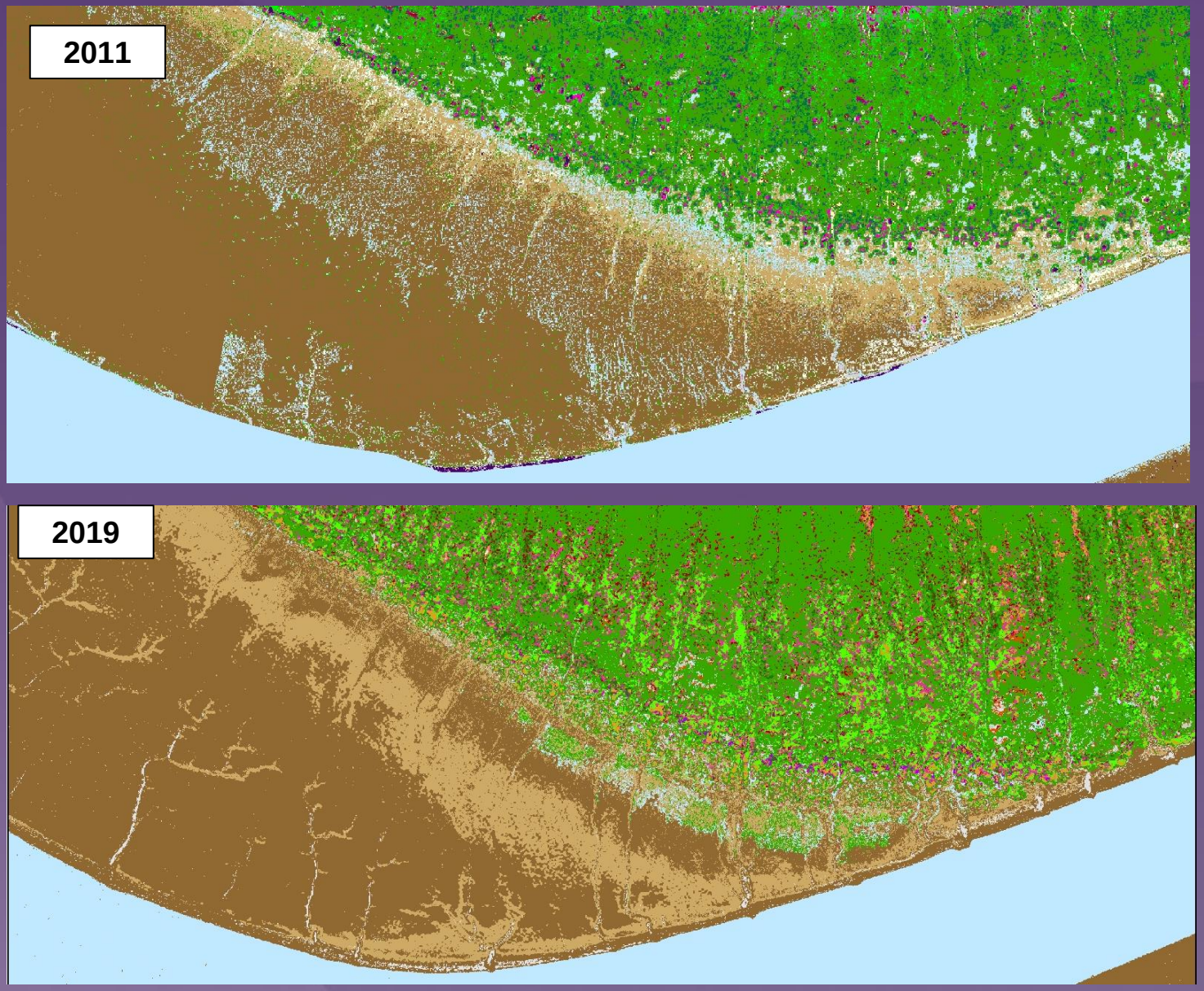
2011



2019



Habitat Evolution Mapping Project 2 – 2019 Preliminary Results (Calavares)



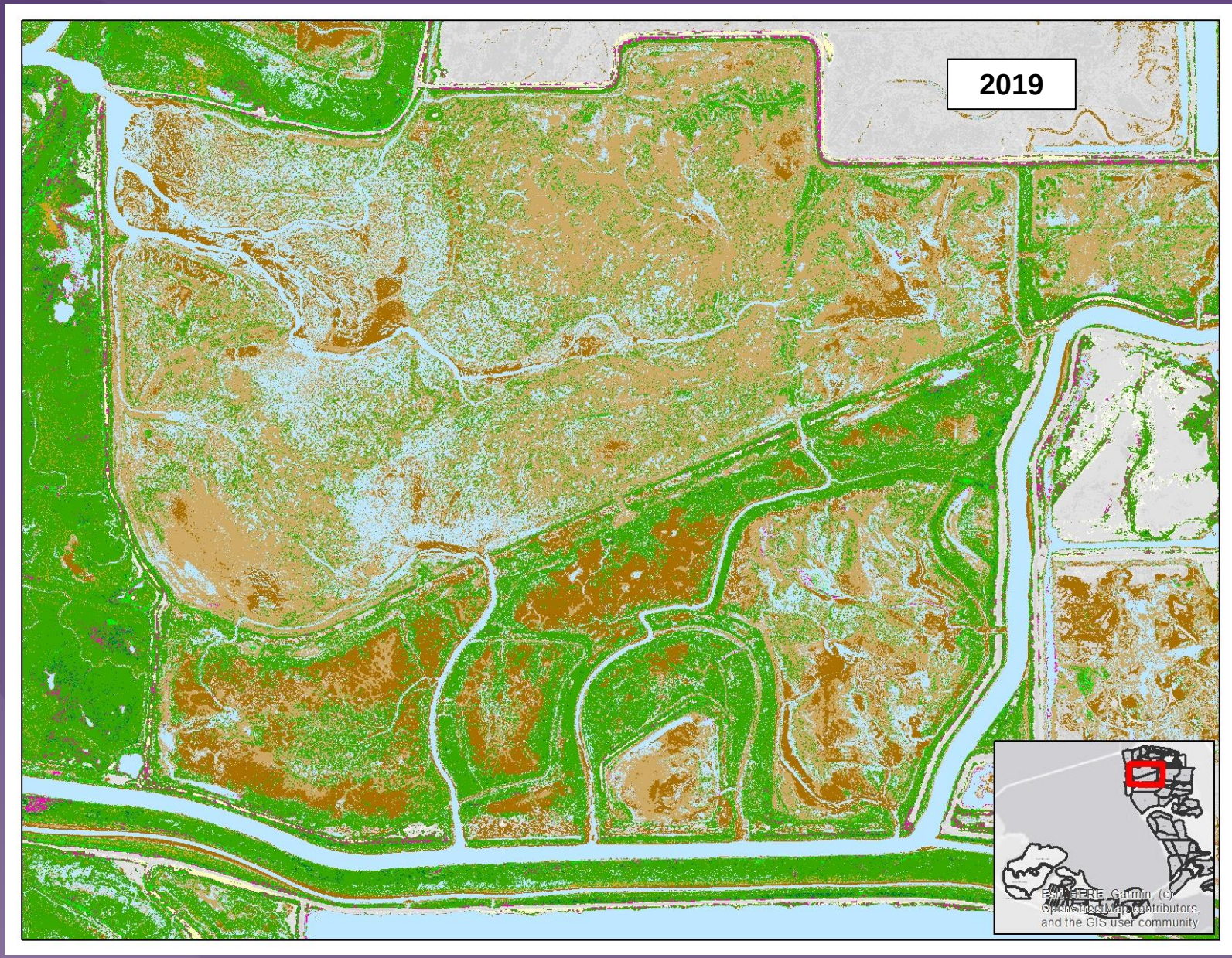
~ 40 meters growth of low marsh

Habitat Evolution Mapping Project 2 – 2019 Preliminary Results (Faber/Laumesiter)

2011

2019

Habitat Evolution Mapping Project 2 – 2019 Preliminary Results (E9/E8A)



Habitat Evolution Mapping Project 2 – 2019 Preliminary Results (E9/E8A)

Habitat Evolution Mapping Project 2.0 – Next Steps (Year Two & Final Results)

May – December, 2021

- 2021 satellite acquisition – *in process*
- Ground Truthing for 2021 (calibration and validation) – *in process*
- Map 2021 Habitat and Mudflats
- Clean up "noise" in all datasets to control differences for change analysis
- Distinguish Invasive and Native Cordgrass (if possible) using ISP w/ HEMP

January – August, 2022

- Final 2019 and 2021 Habitat and Mudflat results
- Final Habitat and Mudflat Change Analysis (2021/2019 to 2009-11)
- Final Invasive vs Native Spartina Results
- Pannes and Channels (time and budget permitting)

Habitat Evolution Mapping Project 2.0 – Deliverables

Year One Deliverables

(1) 2019 Preliminary Results Report

(2) 2019 Preliminary Results Presentation and Webinar

Members of the PMT, and SBSPRP partners, can request access to:

- 2019 Pansharpened Orthorectified Imagery (0.5 meter)
- 2019 Preliminary Habitats and Mudflats (graphics and/or tables)

Final Deliverables

(3) HEMP 2.0 Final Report (with change analysis)

- Final GIS habitat and mudflat datasets (2019 & 2021)
- 0.5 meter multispectral imagery of study area (2019 & 2021)
- Ground Truthing (2019-2021) geodatabase
- Interactive Map of GIS datasets (Data Basin & BIOS)
- Native/Invasive Cordgrass & Channels/Pannes (both if possible)

(4) Presentation and Webinar on Final Results


Questions?
bfaconsult@gmail.com

Habitat Evolution Mapping Project 2 (2019-2021) - Project Synergies

1. **Invasive Spartina Project**
   - overlay HEMP and ISP data to map *native* vs *invasive* Spartina (*in process*)

2. **Coordinate Ground Truthing**
   - Maximize field time across project (coordinated with Point Blue in 2020 and planned in 2021)

Habitat Evolution Mapping Project 2 (2019-2021) - Project Synergies (possible)

1. **Multi-Scalar & Multi-Temporal Analysis**
   - *coordinate w/ UAV veg mapping w/ Point Blue*

2. **Mine Multispectral Imagery**
   - map pannes, channels
   - habitat composition, form, connectivity

4. **Sediment Studies**
   - correlate sediment studies with mudflat maps
   - better understand erosion/accretion

3. **Habitat Association(s) & Habitat Change Analyses**
   - Foraging birds (p/a) correlate with biofilm
   - with other Avian population counts / nesting
   - overlay with SMHM surveys