U.S. Fish and Wildlife Service
Humboldt Bay National Wildlife Refuge
Humboldt County, California

The Distribution of *Spartina densiflora* in Humboldt Bay National Wildlife Refuge: Baseline Mapping, 2010

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INTRODUCTION

Spartina densiflora, an invasive salt marsh cordgrass native to the coasts of Argentina and Brazil (Bortolus 2006), was introduced to Humboldt Bay in the late 1800s and has since invaded over 90% of the bay's salt marshes (Pickart 2001). Restoration of *Spartina*-dominated salt marsh has been the focus of research and management at the Lanphere and Ma-le'l Dunes Units of Humboldt Bay National Wildlife Refuge (HBNWR) since 2004 (Pickart 2005, 2008). Based on the success of early research and experimental trials, the California State Coastal Conservancy and USFWS jointly funded a 35-ac (14-ha) *Spartina* eradication/salt marsh restoration project on the Lanphere and Ma-le'l Dunes Units of the refuge. At the onset of this pilot project in 2006 all *Spartina* within the Lanphere Dunes, Ma-le'l Dunes, Salmon Creek, Hookton Slough and White Slough Units was mapped using a two-cover-class system to serve as a baseline data set (Pickart 2008). As the project progressed successfully, the Conservancy awarded additional funds to the Service to carry out research designed to refine control methods as well as to map the regional infestation of *Spartina* in the Mad River and Eel River estuaries and Humboldt Bay. This regional mapping effort was begun in 2009. In 2010 the Refuge received $1 million in USFWS funding to complete the removal of *Spartina* within the entire Refuge boundary. The decision was made at this time to complete Refuge *Spartina* mapping as a first phase of regional mapping. This report documents the Refuge mapping effort. A subsequent report will document the remainder of the project outside Refuge boundaries.

PROJECT AREA

Humboldt Bay National Wildlife Refuge (Fig. 1) is comprised of 3,379 ac (1,367.4 ha) of freshwater and estuarine wetlands and coastal dunes distributed within 10 units around the bay (USFWS 2009). According to the recently updated National Wetland Inventory Mapping (USFWS 2010), there are 140.5 ac (56.8 ha) of brackish marsh, and 257 ac (104 ha) of salt marsh in the refuge (Fig. 2), for a total of 405.6 ac (164 ha). This is the area of potential invasion by *Spartina*, although those areas of brackish marsh located behind tide gates are less readily colonized. In the past two years, several tidegates along Hookton Slough have been replaced, allowing additional tidal influence into parts of the Hookton Slough and Salmon Creek Units (UFWS 2009).

METHODS

Methods are detailed in Pickart and Goodman (2008) and summarized here. For the refuge portion of the project, field mapping (streaming data or ground-truthing) was used to the highest degree possible, although photo-interpretation (PI) was also utilized. These two methods were employed in a continuous feedback loop, where potential occurrences were identified using PI, visited, and then refined using heads-up digitizing. Over the course of the project the mappers became more skilled at photo-interpretation. This allowed for reliable detection of dense stands of *Spartina,* resulting in a shift away from field mapping to PI and heads-up digitizing. Some areas still required 100% field mapping due to variable color signatures on the imagery, and low abundance or sparse distribution of *Spartina* among native species.

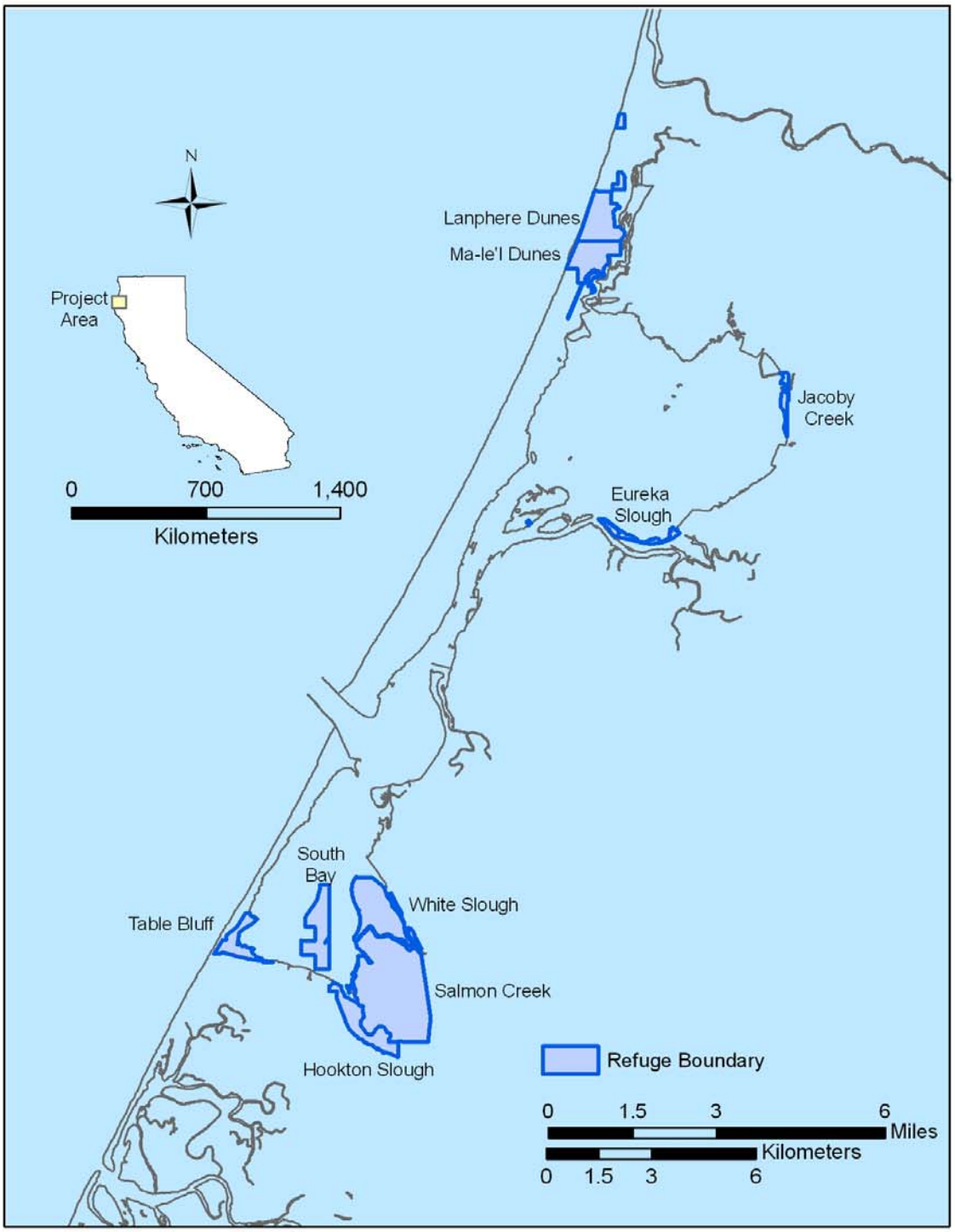

Figure 1. Location of the ten units of Humboldt Bay National Wildlife Refuge (the Indian Island Unit is very small and is unlabeled on the map).

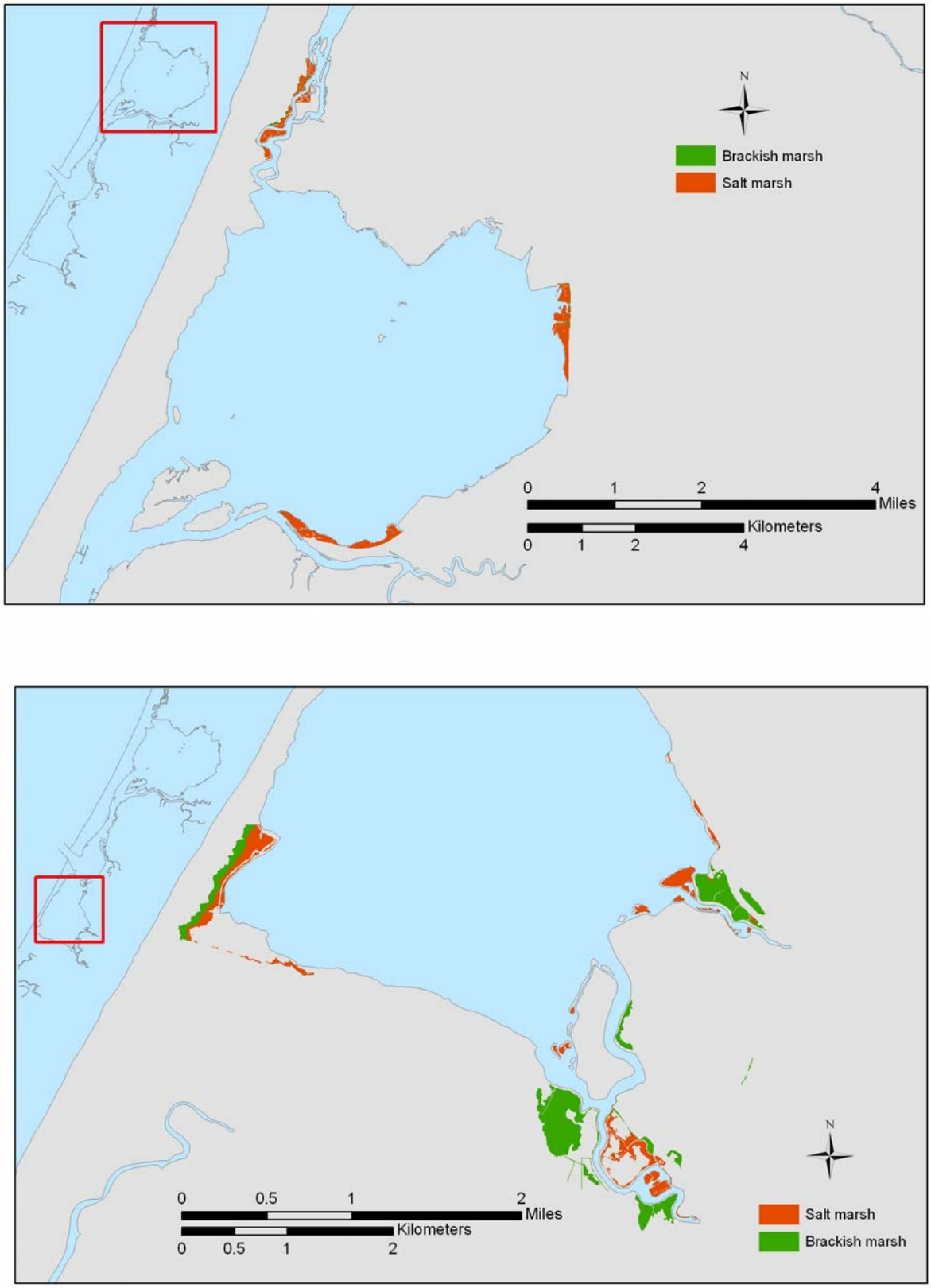

Figure 2. Distribution of estuarine vegetation types (including salt marsh and brackish marsh) on the Lanphere, Ma-le'l, Jacoby Creek, Eureka Slough (top), White Slough, Salmon Creek, Hookton Slough, and Table Bluff Units (bottom) of Humboldt Bay National Wildlife Refuge (NWI 2010).

Mapping Features

Mapping utilized a combination of point, line, and polygon features. Attributes recorded differed for each of these feature classes and were associated with features within a geodatabase (Table 1). Attributes varied among feature classes, and included biological and ecological as well as methodological variables. Information was collected on average plant size (diameter and height), substrate, degree of freshwater influence, tidal inundation, and whether plants were directly colonizing mudflats. To the extent that data were field collected or ground-truthed, ecological relationships can be examined. For the purpose of this report, only the question of colonization of mudflats was addressed.

Points

Points were used to map *Spartina* tussocks when they were isolated and distinct from other surrounding vegetation, and too small to create a useful polygon. This was a judgment made in the field, and specific thresholds varied from site to site depending on the structure and distribution of vegetation there. As a general rule, tussocks were recorded as points when they fell within a 10-meter-diameter circle. Recording the exact number of plants is an attribute unique to the point feature class (Table 1).

Lines

Spartina plants distinct from the surrounding vegetation and found to be growing in linear occurrences (as is common along tidal creeks, roads and levees) were mapped as lines. Lines were attributed with average width to allow for the calculation of an area for the occurrence (Table 1).

Polygons

All other occurrences were mapped as polygons. Polygons differ from point and lines in that percent cover within five cover classes was recorded. The following cover classes were designed based on the ease of estimation as well as the labor needed for mechanical treatment:

$0 <$ Cover Class 1 $<10\%$
$10\% \leq$ Cover Class 2 $< 25\%$
$25\% \leq$ Cover Class 3 $< 60\%$
$60\% \leq$ Cover Class 4 $< 75\%$
$75\% \leq$ Cover Class 5 $\leq 100\%$

In addition to the above cover classes, a sixth category was defined to characterize areas that had been restored in the Lanphere and Ma-le'l Dunes Units prior to the initiation of the 2009 mapping effort. These areas are currently characterized by no more than 1% cover of *Spartina* as the result of new recruitment, and control efforts are ongoing to remove new juvenile plants and seedlings until such time as regional eradication is complete. These restored areas are incorporated into the total acreage of infested area for the baseline mapping, but are included in a separate category of "restored" when results are displayed by cover class, reflecting current conditions. Small areas that had undergone control efforts in the Salmon Creek Unit prior to the 2009 mapping were retained in the base maps, and reflect baseline (pre-control) rather than current conditions.

Table 1. Attributes associated with mapped point, line, and polygon features.

Point Feature		Line Feature		Polygon Feature	
Date		Date		Date	
Personnel		Personnel		Personnel	
Mapping Method	On The Ground	Mapping Method	On The Ground	Mapping Method	On The Ground
	Photo Interpretation		Photo Interpretation		Photo Interpretation
	Other		Other		Other
Mapping Device	GeoXT 2005	Mapping Device	GeoXT 2005	Mapping Device	GeoXT 2005
	Tablet PC		Tablet PC		Tablet PC
	Office PC		Office PC		Office PC
	Other		Other		Other
Number of Individuals		Average Width		Cover Class	Restored
Average Diameter	<15 cm	Average Diameter	<15 cm		1 - 10 %
	>15cm but <50cm		>15cm but <50cm		11 - 25 %
	>50cm		>50cm		26 - 60 %
Average Height	<15 cm	Average Height	<15 cm		61 - 75 %
	>15cm but <50cm		>15cm but <50cm		76 - 100 %
	>50cm		>50cm	Average Diameter	<15 cm
Substrate	Mud	Substrate	Mud		>15cm but <50cm
	Sand		Sand		>50cm
	Gravel		Gravel	Average Height	<15 cm
	Other		Other		>15cm but <50cm
Tidal Influence	Regularly Flooded	Tidal Influence	Regularly Flooded		>50cm
	Intermittently Flooded/Brackish		Intermittently Flooded/Brackish	Substrate	Mud
	Behind Levee/TideGate		Behind Levee/TideGate		Sand
Colonization of Mudflats	Colinizing mud flats	Colonization of Mudflats	Colinizing mud flats		Gravel
	Not colinizing mud flats		Not colinizing mud flats		Other
Freshwater Influence	Riverine	Freshwater Influence	Riverine	Tidal Influence	Regularly Flooded
	Stream or Spring		Stream or Spring		Intermittently Flooded/Brackish
	No freshwater influence		No freshwater influence		Behind Levee/TideGate
Comments		Comments		Colonization of Mudflats	Colinizing mud flats
					Not colinizing mud flats
				Freshwater Influence	Riverine
					Stream or Spring
					No freshwater influence
				Comments	

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Photo-interpretation (PI)

Photo-interpretation was carried out using several sets of imagery, including National Agricultural Imagery Program (NAIP) 2005 and 2009 true-color imagery, and Humboldt Bay 2009 true-color imagery captured at a resolution of .5 m. ArcMap 9.2 was used in conjunction with the previous, 2006 mapping data to allow mappers to familiarize themselves with *Spartina* signatures and appearance in different imagery sets. The 2009 Humboldt Bay imagery proved to be most useful in detecting *Spartina* remotely. Heads-up digitizing was used to carry out preliminary delineations that were subject to either partial or full ground-truthing.

Field Methods

Field mapping consisted of direct streaming of features using ArcPad 7.1 on 2005 Trimble Geo-XT GPS units, or taking photo-interpreted features into the field on paper maps or in ArcPad to ground truth.

Paper maps were also printed out for the field visits at site-specific scales suitable for delineation. Heads up digitizing of the data that were gathered using paper maps as well as the

importing of GPS data was completed using Arc Map 7.1 on an office PC.

Field mapping was limited by tides and weather. Mainland sites were accessed by walking, while estuarine islands, levees, and other remote locations were accessed by kayak.

RESULTS

Extent of Infestation

A total of 288.8 ac (116.9 ha) of salt and brackish marsh on Humboldt Bay National Wildlife Refuge were infested with *Spartina* as represented by polygon or line features (Table 2). In addition, a total of 70 individual point features were mapped. The distribution of *Spartina* by cover class and among Units is shown in Figs. 4-8. *Spartina* was present in 97% of the unrestored salt marsh but only 22% of the brackish marsh (excluding that adjacent to restored areas) on the refuge. The presence of *Spartina* in brackish marsh was confined to areas near open or leaking tide gates. *Spartina* spreads more slowly behind dikes in brackish marshes, both due to impeded dispersal and to the apparent resistance of dense *Distichlis* stands to invasion (Pickart 2006). Although *Distichlis* is a salt marsh species, it is also a common dominant of brackish marshes in areas that have leaking tidegates, residual soil salts, and/or salt spray.

Colonization of Mudflats

Whether *Spartina densiflora* is capable of colonizing bare mud has been an important and unanswered question. Unlike *Spartina alterniflora*, it is primarily a colonizer of existing salt marsh. However, *S. densiflora* had been observed for some time colonizing bare mud flats in some areas of the bay. The addition of this attribute to the mapping was intended to provide additional, indirect evidence of the extent of this phenomenon. Within refuge boundaries, a total of 4.9 ac (2.0 ha) of *Spartina densiflora* was growing directly on mudflat, with no evidence of other salt marsh species (Table 3, Fig. 3). Although this represents only 2% of the total extent of *Spartina* on the refuge, it may have a disproportionate significance if it represents a new trend. A large amount of mudflat at the Salmon Creek "overflow" was recently exposed to increased tidal influence as part of the Salmon Creek Restoration Phase II activities (USFWS 2009). This probably accounts for the relatively large proportion of colonized mudflat on the Salmon Creek Unit compared to other units. This area should be considered at high risk of colonization in the near future. It is also possible that the presence of a freshwater source on Table Bluff, White Slough, Jacoby Creek, Lanphere Dunes, and Ma-le'l Dunes contributes to the conditions that allow for more colonization of mudflats on those units (Table 3).

Accuracy of Data

Because the refuge mapping was needed for an immediate control project, a large degree of accuracy was needed. A total of 64% of the infested area was fully ground-truthed (either directly streamed on the ground, or polygon walked through completely), 29% was partially ground-truthed (the site was visited but not walked through completely) and 7% had no field verification. Due to the large extent of field mapping and ground-truthing, and the fact that control efforts immediately followed mapping in some areas, no accuracy assessment was performed after mapping was completed.

Table 2. Total area (ac) infested by *Spartina densiflora* mapped as linear and polygon features distributed by cover class on units of Humboldt Bay National Wildlife Refuge. The row "Total Baseline Infested Acres" represents all infestations prior to restoration efforts initiated in 2004.

		Occurrences Mapped as Polygons by Cover Class						
Unit	Infested Acres	75-100%	60-75%	26-60%	11-25%	1-10%	Linear Features	Restored Acres
Lanphere Dunes	11.52	0	0	0	0	0	0	11.5
Ma-le'l Dunes	44.99	0	0	0.31	0.23	22.58	0.19	21.7
Jacoby Creek	68.56	16.62	1.19	21.43	17.75	11.46	0.11	0
Eureka Slough	73.02	49.64	2.03	4.19	10.26	6.90	0	0
White Slough	15.59	7.65	0.32	2.83	2.58	1.45	0.76	0
Salmon Creek	27.04	0.98	5.53	4.60	4.93	5.84	5.16	0
Hookton Slough	15.52	1.31	0.34	5.04	0	6.73	2.10	0
Table Bluff	32.54	1.21	4.98	12.01	1.19	12.97	0.18	0
Total Baseline Infested Acres	288. 8	77.4	14.4	50.4	36.9	67.9	8.5	33.2

Table 3. Area (in m^2 and ac) of mudflat habitat being colonized by *Spartina densiflora* in Humboldt Bay National Wildlife Refuge. Point occurrences are shown with the associated number of individual plants distributed by Refuge Unit (area was not calculated for point features).

Unit	Mudflat Point Occurrences, and (Total Number of Individuals)	Area of mudflat colonized by linear occurrences (m^2)	Area of mudflat colonized by polygonal occurrences (m^2)	Total
Lanphere Dunes	0	0	0	0
Ma-le'l Dunes	0	0	0	0
Jacoby Creek	10 (24)	321.5	494.9	816.4
Eureka Slough	0	0	0	0
White Slough	19 (49)	0	6015.5	6015.5
Salmon Creek	3 (9)	797.8	10594.8	11392.6
Hookton Slough	1 (1)	0	0	0
Table Bluff	0	579.2	1085.4	1664.6
Total Acres of Mudflat Colonies	n/a	0.4 ac	4.5 ac	4.9 ac

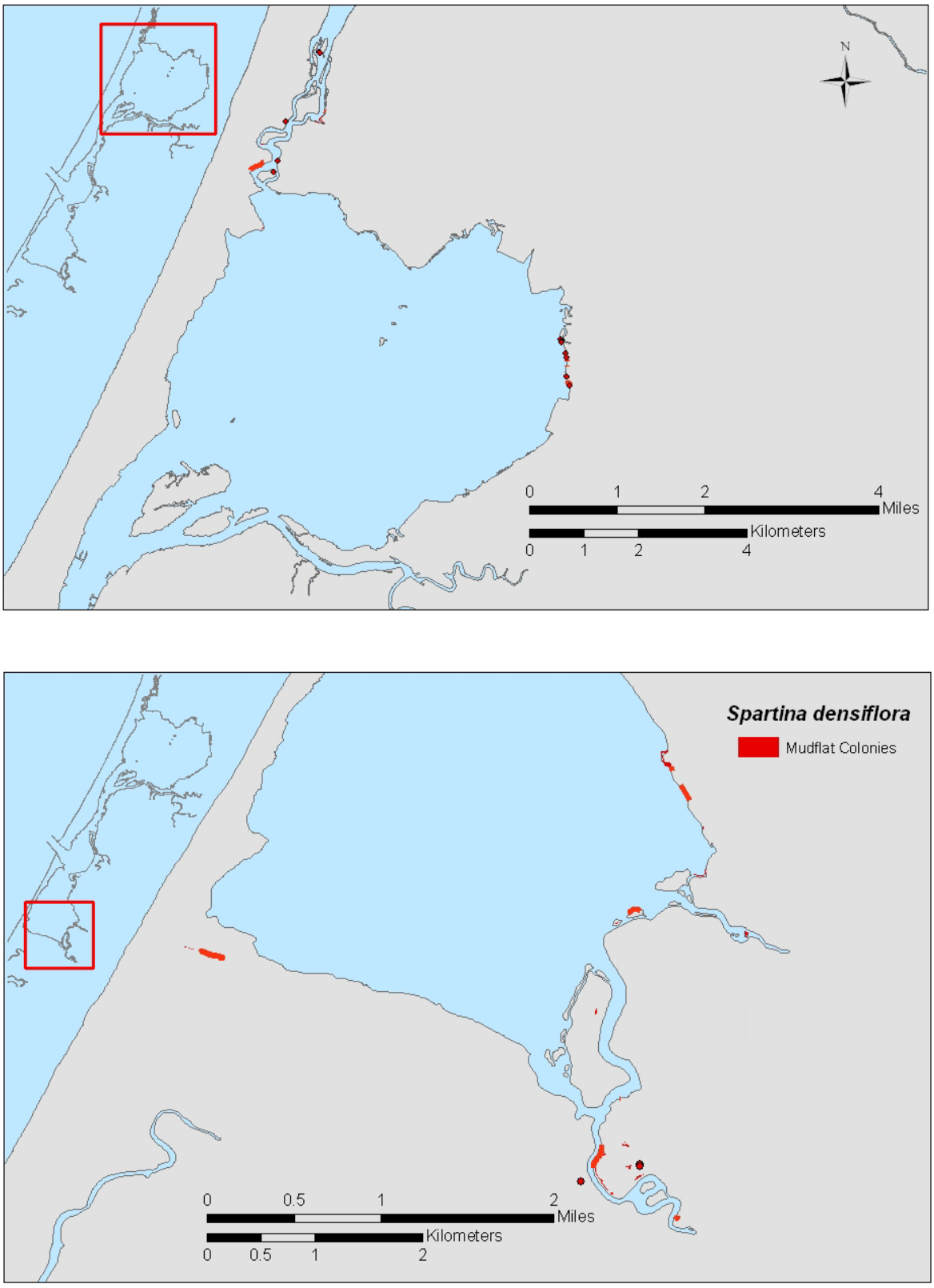

Figure 3. Distribution of *Spartina densiflora* mudflat colonies mapped as point, linear, and polygon features on Humboldt Bay National Wildlife Refuge.

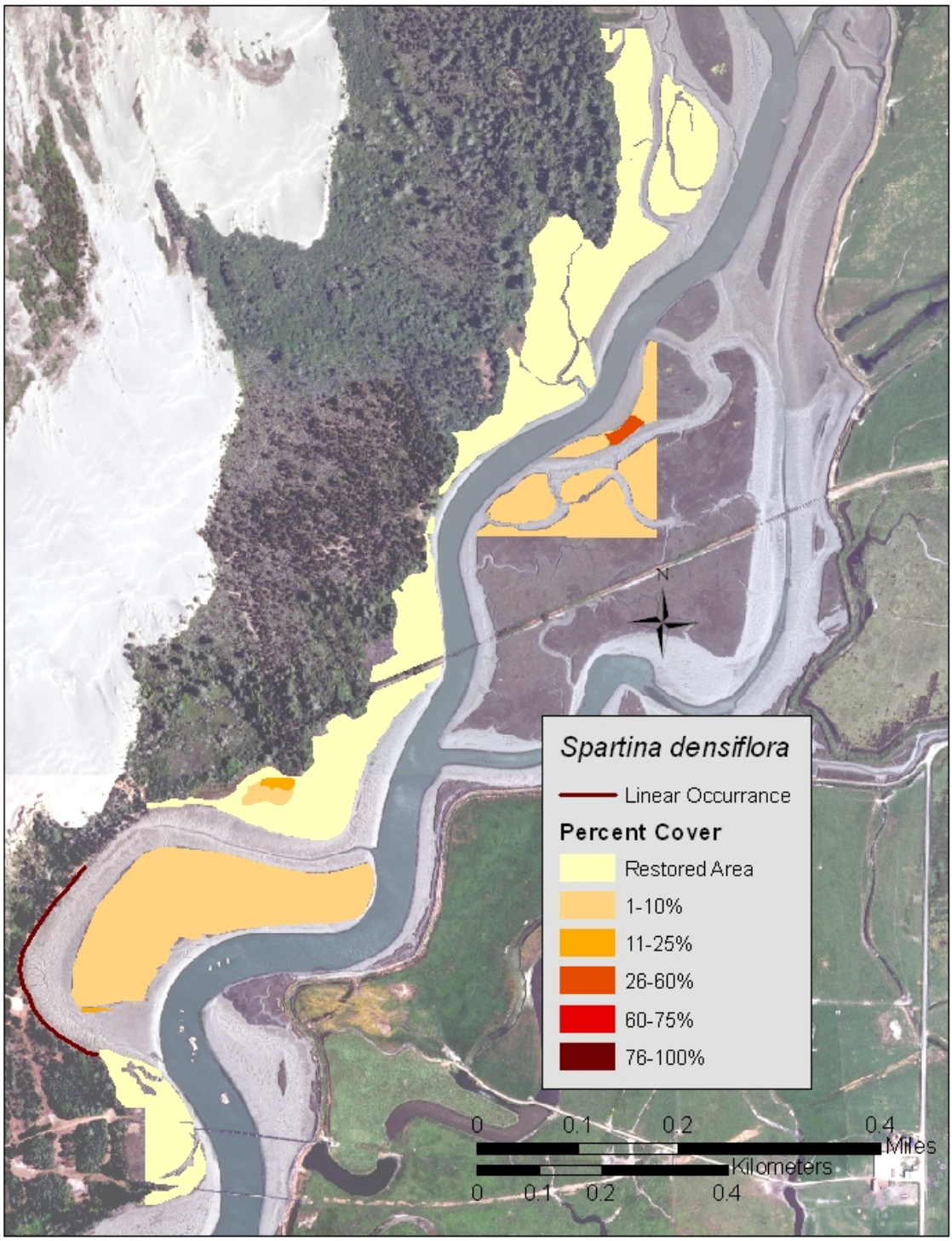

Figure 4. Distribution of *Spartina densiflora* by cover class on the Lanphere and Ma-le'l Dunes Units of the Humboldt Bay National Wildlife Refuge.

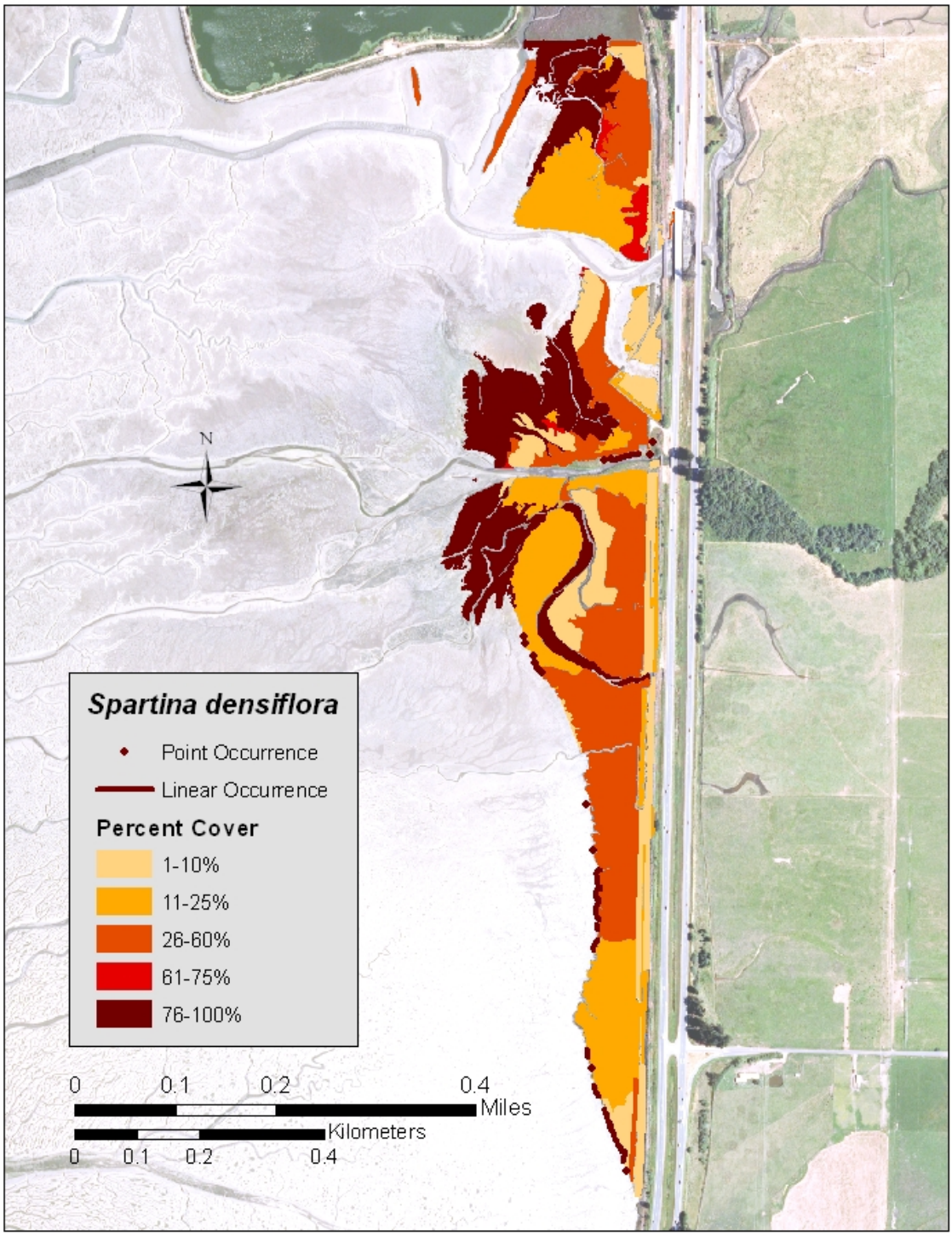

Figure 5. Distribution of *Spartina densiflora* by cover class on the Jacoby Creek Unit of the Humboldt Bay National Wildlife Refuge.

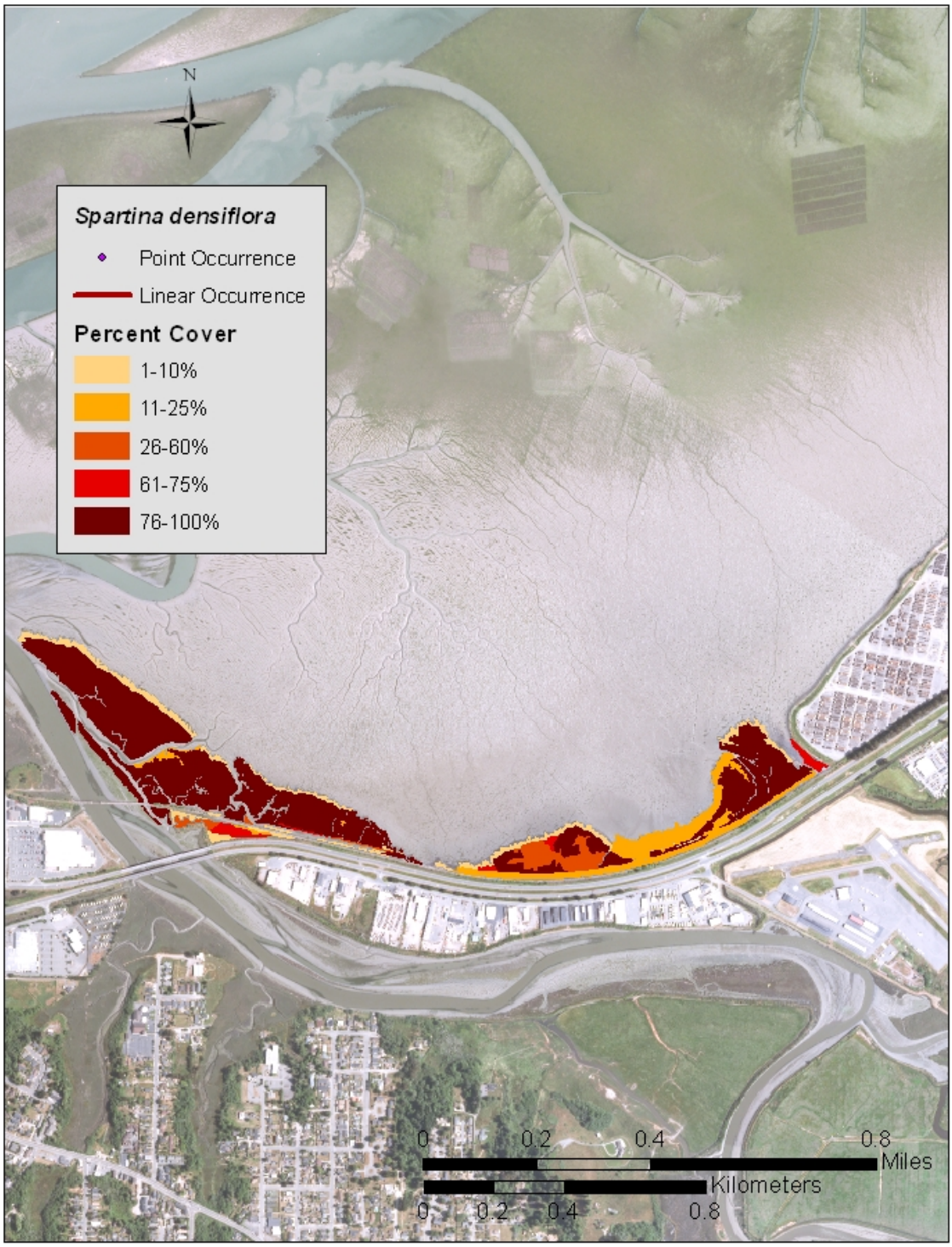

Figure 6. Distribution of *Spartina densiflora* by cover class on the Eureka Slough Unit of the Humboldt Bay National Wildlife Refuge.

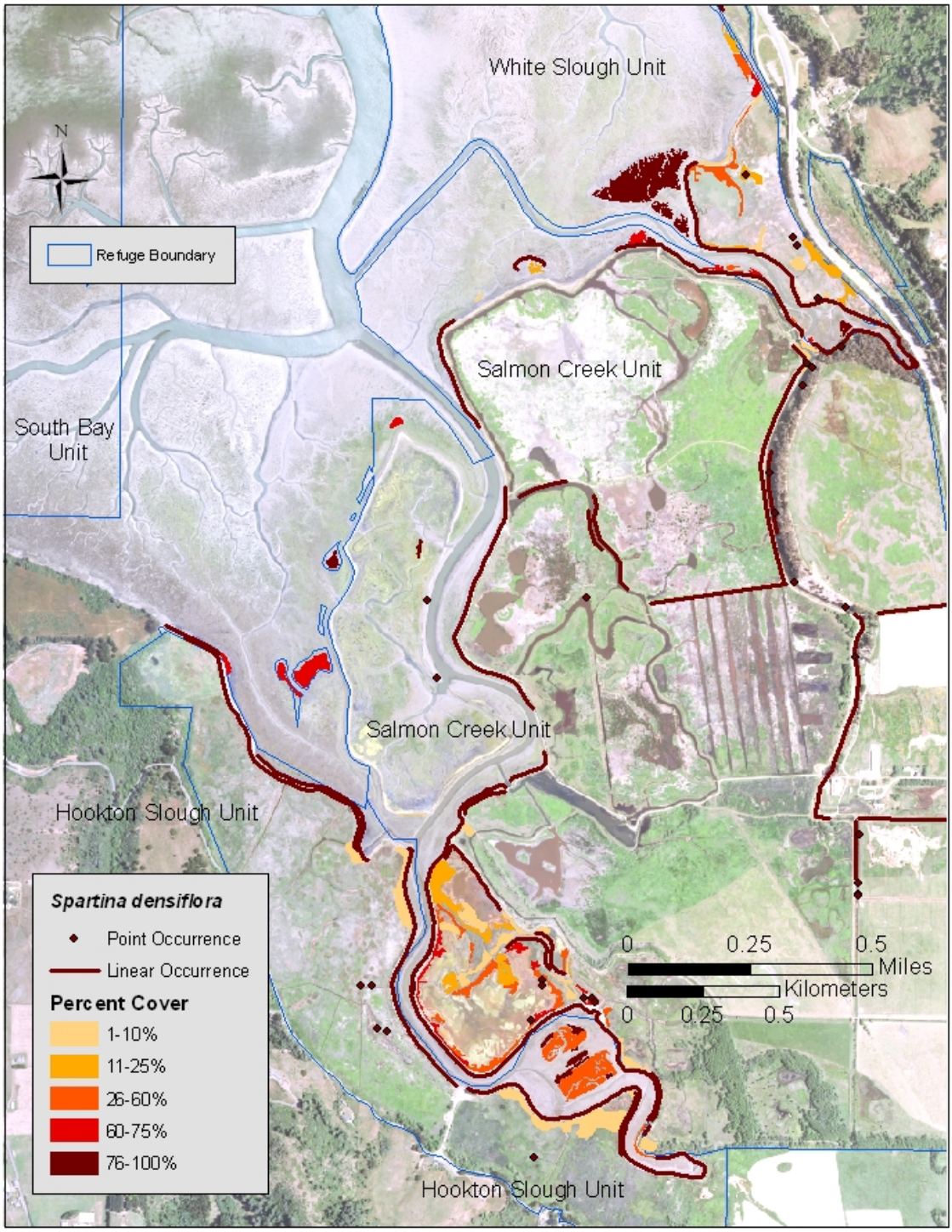

Figure 7. Distribution of *Spartina densiflora* by cover class on the White Slough, Salmon Creek, and Hookton Slough Units of the Humboldt Bay National Wildlife Refuge. There are no occurrences of *Spartina densiflora* on the South Bay Unit.

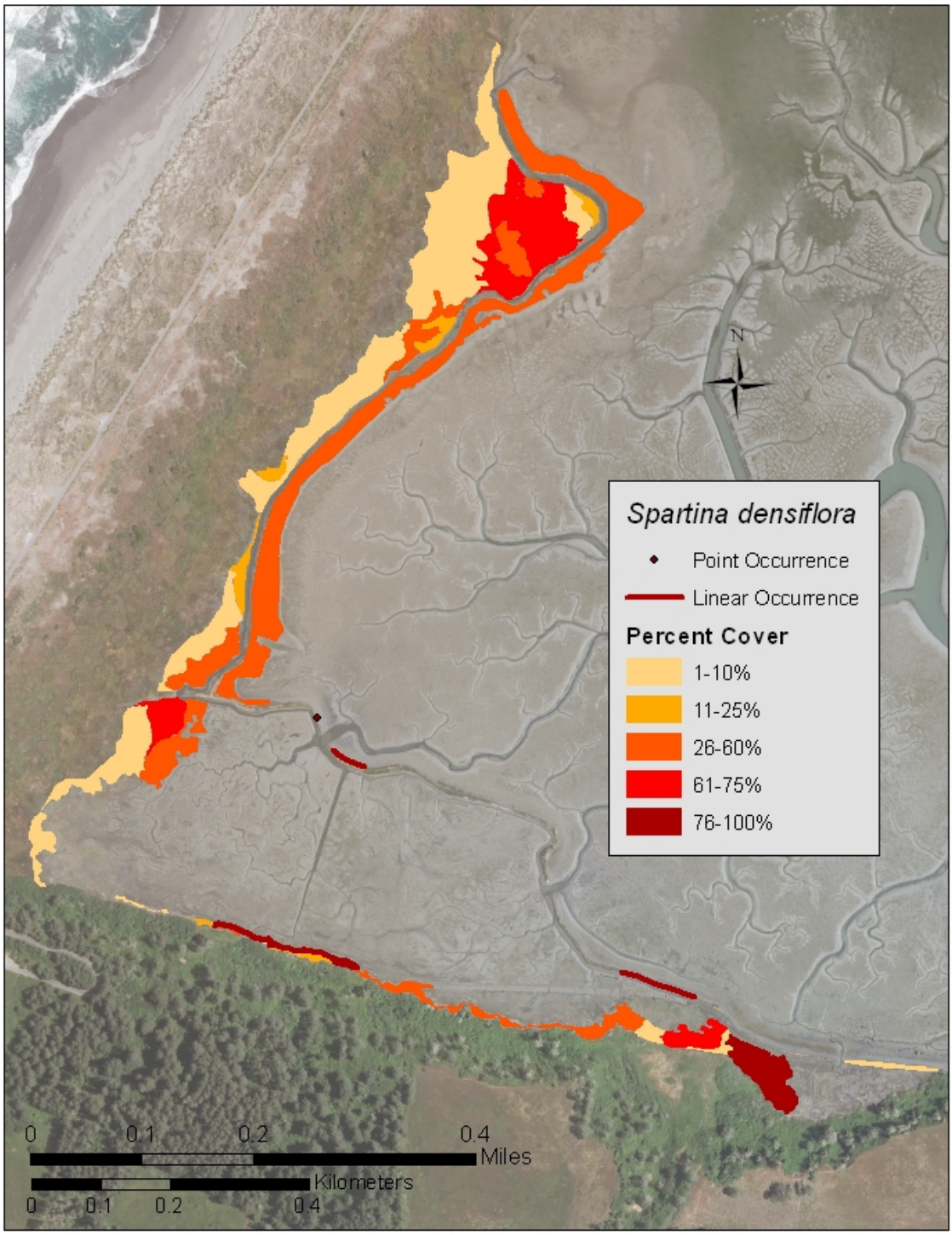

Figure 8. Distribution of *Spartina densiflora* by cover class on the Table Bluff Unit of the Humboldt Bay National Wildlife Refuge.

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