The Distribution of *Spartina densiflora* and two rare salt marsh plants in Humboldt Bay 1998-1999

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INTRODUCTION

As in other parts of California, Humboldt Bay's salt marshes have been drastically reduced as a result of human impacts. The single most damaging event was construction of the railroad around the margin of the Bay in the early 1900s. As a result, salt marshes were diked and converted primarily to seasonally flooded pasture. Due to this and later impacts, salt marsh habitat has decreased from approximately 9,000 to less than 900 acres (Fig. 1). The remaining salt marsh has been further degraded by the invasion of introduced dense-flowered cordgrass (*Spartina densiflora*), native to Chile. Although the introduction date for this species is not known, it was probably accidentally introduced in association with the lumber trade that existed between Humboldt Bay and Chile in the late 1800s (Spicher 1984). Despite these drastic losses, populations of two rare salt marsh annual plants, Humboldt bay owl's clover (*Castilleja ambigua* var. *humboldtiensis*) and Point Reyes bird's beak (*Cordylanthus maritimus* ssp. *palustris*) have persisted. These two taxa, listed as rare and endangered by the California Native Plant Society (Skinner and Pavlik 1994), have been studied at the Mad River Slough (Pickart and Miller 1988, Bivin et al. 1991, U.S. Fish and Wildlife Service 2001), but little was known about their distribution bay-wide. For this reason, the U.S. Fish and Wildlife Service undertook a bay-wide survey of these two taxa and *Spartina densiflora* during 1998 and 1999.

SPECIES BIOLOGY

Rare Salt Marsh Plants

The demography and life history of Humboldt Bay owl's clover and salt marsh bird's beak was studied by Bivin et al. (1991) at the high elevation salt marshes now located within U.S. Fish and Wildlife Service's Lanphere Dunes Unit (Mad River Slough). Both taxa are annuals, and they occupy similar habitat—high elevation salt marshes. They commonly occur in association with each other above 7.5 ft MLLW, although bird's beak extends as low as 7.0 ft. MLLW (Eicher 1987). In areas where they co-occur the two taxa may escape direct competition through temporal partitioning. While both taxa germinate around the same time (mid February), owl's clover grows and flowers more quickly, with peak flowering in mid-May through mid-June, while bird's beak peaks in late June-August. Both taxa are hemi-parasitic, and haustoria form within days of emergence (Bergvall 1991). Mortality is highest in the seedling stage, with approximately half the individuals studied surviving to reproduction (Bivin et al. 1991). Bird's beak produced substantially more fruits per pant than owl's clover, so although owl's clover produced slightly more seeds per fruit, an individual of bird's beak can be expected to produce over twice as many seeds as an individual of owl's clover.

Dense-flowered cordgrass

Dense-flowered cordgrass occurs between 5.9 and 7.9 MLLW, but is most abundant between 6.2 and 7.3 MLLW (Eicher 1987). At intermediate tidal elevations cordgrass is so dominant that it constitutes a vegetation type (named the *Spartina* type by Eicher)with a mean cover of 87% cordgrass. Pickleweed (*Salicornia virginica*) is scattered sparsely within the understory of this type, but other species are mostly restricted to occasional openings in the stands. Cordgrass reproduces both vegetatively and by seed, with seedling recruitment probably lower in years of low precipitation (Kittelson and Boyd 1997). Seed germination and seedling growth are limited at higher salinities, but mature plants are not as adversely affected (Kittelson and Boyd 1997). Cordgrass does not undergo a dormancy period during winter months, which gives it a competitive advantage over the native salt marsh plants (Kittelson 1993). Tiller growth occurs throughout the year, although the majority are produced between May and September. Tillers arise along short rhizomes, producing its characteristic tussocky appearance (Kittelson 1993). Tussocks expand in size from November to February, when most native plants are dormant. Flowering occurs from June through August, with seed set from September to October (Kittelson 1993). Seed germination is reportedly rare in established salt marsh areas (Kittelson and Boyd 1997) but seedling recruitment been observed in some years (personal observation).

METHODS

Mapping of the two rare salt marsh plants was conducted during their blooming season to increase ease of detection. Humboldt Bay owl's clover was mapped in May-June 1998, and Point Reyes bird's beak in June 1999. Cordgrass was mapped concurrently with bird's beak in late June 1999. Mapping was done by visiting every salt marsh site on the bay (with access by canoe where necessary) and estimating the abundance of the rare salt marsh plants and the density of the cordgrass visually within polygons drawn onto printouts of 1998 geo-referenced air photos (Terra-Mar Humboldt Bay orthophotos) at scales ranging from 1:4,000 to 1:12,000. Abundance and cover classes were used to facilitate estimation. Rare plant abundance was estimated for each polygon delineated in the field and placed in the following logarithmic abundance classes: 1-10, 11-100, 101-1,000, 1,001-10,000, and 10,001-100,000. Cordgrass density was estimated in two cover classes: sparse to moderate (5-69%) and dense (≥70%). Mapping was conducted by several individuals, and preliminary visits were made to practice and calibrate estimation. Polygons were then heads-up digitized over the same orthophotos and attributed for abundance and density. ArcView 3.2 was used to query the resulting database in order to summarize distribution and abundance/density data by subarea.

RESULTS

The bay was divided into four subareas for the purpose of summarizing data (Fig. 2): Mad River Slough, North Bay, Central Bay, and South Bay. Distribution maps for the rare plants and cordgrass by subarea are shown in Figs. 3(a-d) through 5(a-d) (note that the subareas are not necessarily shown at the same scale). Acreages of salt marsh occupied by each abundance class (of rare plants) and density class (of cordgrass) are summarized by subarea in Table 1, and compared with total salt marsh acreage for each subarea.

The amount of current salt marsh present in each subarea varied greatly and was not proportionate to the total acreage of bay in each subarea. Mad River Slough, the smallest of the subareas, had the largest proportion of bay area occupied by salt marsh (32%). Central Bay and South Bay had the lowest proportion of salt marsh (1% and 2% respectively) (Fig.6). Although the amount of total cordgrass present in a subarea was correlated with the amount of salt marsh (r^2=.998, p=.002) (Fig. 7), there were some differences among subareas. Mad River Slough, with 76% of its salt marshes occupied by cordgrass, was the least invaded and Central Bay (100%), the most. Moreover, the proportion of low vs. high density cordgrass was not equal for the four areas (Fig. 8). The Mad River Slough subarea was distinguished as the only area of the four that had a higher proportion of low density cordgrass (88%) than high density cordgrass (12%).

Differences were also detected among subareas for rare plant populations (Fig. 9). Mad River Slough had the highest proportion of its salt marsh occupied by rare plants (47 and 43% respectively for Humboldt Bay owl's clover and Point Reyes bird's beak). North Bay had a relatively high proportion of salt marsh occupied by owl's clover (31%) but not bird's beak (14%), and all other subareas fell below 16%. The above percentages do not, however, take into account relative abundance classes. When the occupied acreage is multiplied by the midpoint of the abundance class to yield a rough density estimate, the result is slightly different (Figs. 10 and 11). The density of Humboldt Bay owl's clover per salt marsh acre was similar in Mad River Slough and North Bay, both of which had substantially higher densities than Central and South Bay. However, for Point Reyes bird's beak, Mad River Slough had higher densities than all other subareas.

DISCUSSION

Of the four subareas, Mad River Slough was distinguished by having the largest amount of salt marsh as a proportion of total bay acreage, the least severe invasion of cordgrass (based both on percent of salt marsh invaded and the proportion of cordgrass in the lower density class), and the highest densities of rare salt marsh plants per acre. The latter three characteristics are likely the result of tidal elevation differences. Although most of Humboldt Bay's marshes have never been surveyed, tidal elevation can be inferred from vegetation pattern. Eicher (1987) described three salt marsh vegetation types in Humboldt bay that correlated with surveyed tidal elevation. Low and intermediate elevation marshes were dominated by a single species for which the types were named: *Salicornia virginica* and *Spartina densiflora*. The high elevation marshes, termed "mixed marshes", were more diverse and were associated with the two rare salt marsh taxa. Quantitative descriptions of species composition of salt marshes located on the Lanphere Dunes Unit within the Mad River Slough subarea agree with Eicher's definition of mixed marsh (Pickart 1997).

North Bay, the largest subarea, was distinctive in having the largest acreage of salt marsh (609), but also the largest acreage of cordgrass (601). North Bay had several extensive areas of low-moderate density cordgrass, located near the mouth of Jacoby

Creek and on Indian Island. Both of these sites were characterized by high densities of rare salt marsh plants and apparently support areas of high elevation salt marsh.

Central Bay had very limited salt marsh acreage, in keeping with the fact that it is primarily deepwater channel (Barnhart et al. 1992). The only sizeable area of salt marsh was found in the vicinity of the Elk River Spit, which had high densities of cordgrass and low to moderate densities of rare salt marsh plants.

South Bay was the second largest subarea, but had less salt marsh than the much smaller Mad River Slough. The majority of salt marsh in South Bay was covered with high density cordgrass, and of the four subareas, it had the smallest proportion of its salt marsh occupied by rare plants. Salt marshes and rare plants in this subarea were restricted to the base of the South Spit and an undiked remnant of the Salmon Creek slough.

Both rare salt marsh plants are annuals, and occur in high densities and numbers. They are rare as the result of the drastic decline of their habitat. Annual plants are frequently characterized by very high annual fluctuations in numbers. Monitoring at the Lanphere Dunes for more than a decade has documented the high variation that these two taxa are subject to (Fig. 12). Humboldt Bay owl's clover in particular, is subject to more extreme variation. Because of this, it is not appropriate to compare density and abundance data from this study for the two taxa, since they were mapped in two different years.

No previous mapping has been carried out for dense-flowered cordgrass, but there are several studies that indicate it is continuing to expand in Humboldt Bay. Kittelson and Boyd (1997) found that seedling recruitment was responsible for cordgrass establishment in bare and disturbed areas, and that vegetative expansion resulted in incremental expansion in established marshes. Although they did not observe seedling recruitment in established marshes, this phenomenon has been observed at the Mad River Slough (personal observation). In addition, the frequency of cordgrass measured in high marshes at the Mad River Slough (Pickart 1997) showed a 50-fold increase between 1989 and 1997 (Fig. 13), which is far greater than the incremental increases predicted by Kittelson and Boyd (1997). This increase occurred in areas of high elevation salt marsh, which are theoretically poor habitat for the cordgrass as well as being high quality habitat for the rare salt marsh plants. (Eicher 1987). Although the majority of Humboldt Bay salt marshes (94%) are currently occupied by some density of cordgrass, cordgrass threatens to invade into the remaining 6% of salt marshes and to increase its density in the 38% of marshes where it is currently still sparse to moderate. These areas that remain vulnerable have the highest native plant species diversity and the most abundant populations of rare plants.

MANAGEMENT IMPLICATIONS

There are several major implications of this study for conservation and management of Humboldt Bay's salt marshes. The first is that dense-flowered cordgrass continues to be a major threat to biological diversity. There seems to be a prevailing attitude that cordgrass has already invaded all suitable habitat and that it represents an ecological battle not worth fighting. Past studies together with this survey show compellingly that cordgrass is continuing to spread, into the very areas where it will do the greatest damage to biological diversity. Identifying and applying control measures for this invasive plant is of the highest priority, given that an already rare and threatened plant community is at stake.

A second implication is for future salt marsh restoration projects in Humboldt Bay. Based on the only study to date, the frequency of cordgrass is currently increasing in high elevation marshes. However, these marshes are the last to be invaded, and exhibit some resistance to invasion. These observations suggest that restoration projects should be designed to create the conditions suitable for high, rather than low-medium elevation marshes in order to discourage the establishment of cordgrass. This tactic, in combination with the use of revegetation to reduce disturbance and germination sites (Kittelson and Boyd 1997, U.S. Fish and Wildlife Service 2001) may reduce the invasion potential, but further study is needed.

Finally, this study echoes previous recommendations (Pickart and Miller 1988) for permanent protection of the salt marshes of the Mad River Slough. Although portions of the slough are in public ownership including U.S. Fish and Wildlife Service and Humboldt State University, other areas are still privately owned. Both the Mad River Slough and Indian Island, which also has extensive populations of rare plants, would be ideal additions to Humboldt Bay National Wildlife Refuge, but only the latter is in the approved boundary. In addition to protecting these unique areas, restoration should be undertaken. Before this can happen, research on feasible control techniques, including biological control, must be carried out.

ACKNOWLEDGEMENTS

Field mapping was carried out primarily by Kyle Wear, Abe Walston, and Hal David. They deserve to be commended for the arduous task of floating around Humboldt Bay in a canoe for several weeks during two consecutive summers (!). Thanks to Kyle Wear for creating the ArcView maps showing distribution data.

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Table 1: Acreage occupied by rare plants, cordgrass, and salt marsh within each subarea. (for definition of subclasses see Methods)

		Region			
Taxon	Abundance/ density class	Mad River Slough	North Bay	Central Bay	South Bay
Humboldt Bay owl's clover	1	0.4	1.2	0	0
	2	4.6	6.1	0	0
	3	2.8	12.4	1.1	0.5
	4	32.9	101.4	4.3	4.9
	5	12.9	67.4	0	3.5
	Total	53.6	188.5	5.4	8.9
	Total salt marsh in subarea	149	609	37	73
	% of total salt marsh occupied	36%	31%	15%	12%
Point Reyes bird's beak	1	0.2	0.2	0	0
	2	2.4	7.5	0.4	0.5
	3	11.5	26.9	1.1	0.3
	4	13.5	14.4	4.4	0.2
	5	21.2	34.6	0	0.9
	Total	48.8	83.6	5.9	1.9
	Total salt marsh in subarea	149	609	37	73
	% of total salt marsh occupied	33%	14%	16%	3%
Cordgrass	1	100.2	192.8	9.0	31.8
	2	13.4	407.9	28.0	30.2
	Total	113.6	600.7	37	62
	Total salt marsh in subarea	149	609	37	73
	% of total salt marsh occupied	76%	99%	100%	85%

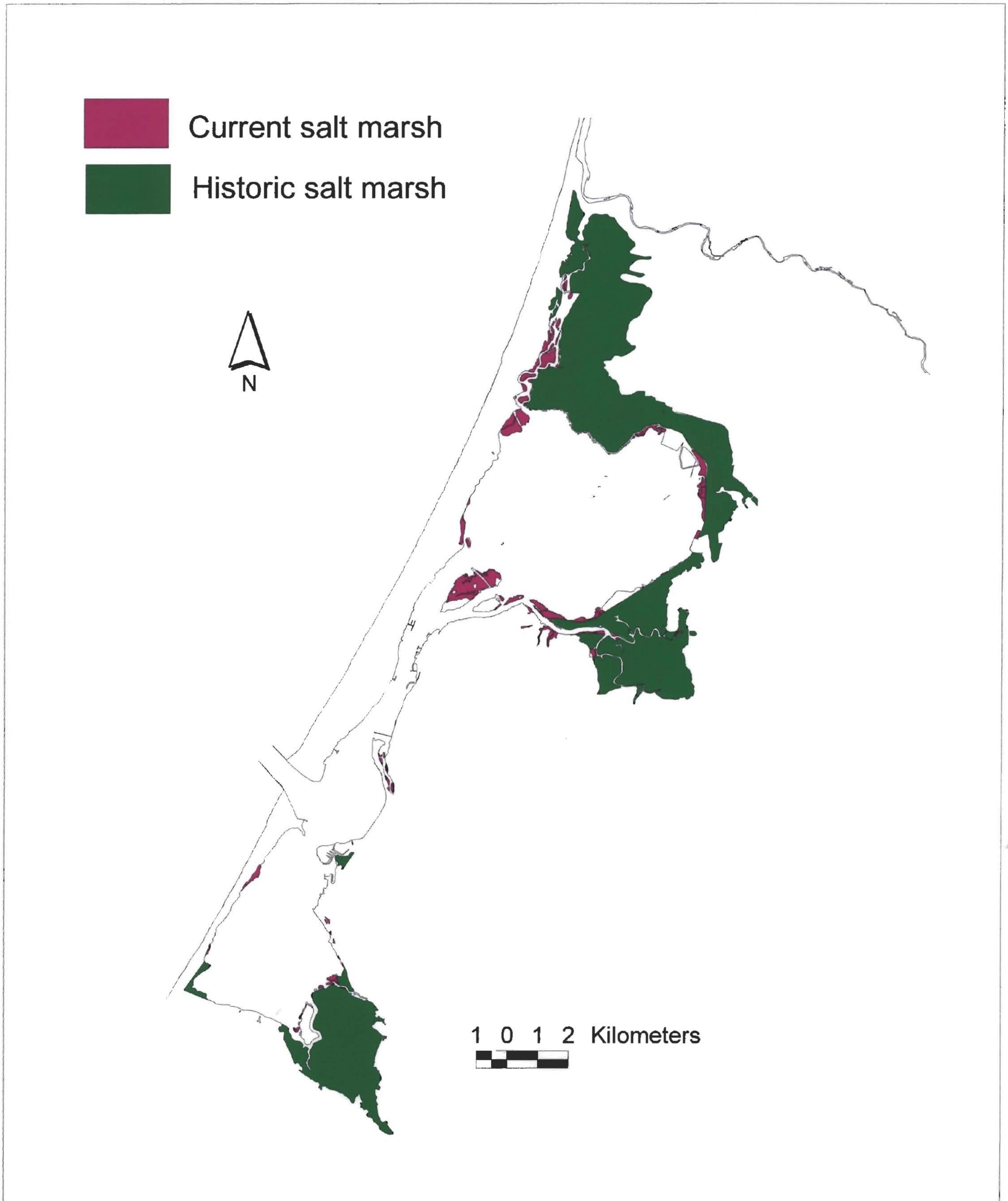

Figure 1. Current and former extent of salt marsh around Humboldt Bay (after National Wetland Inventory mapping, USFWS).

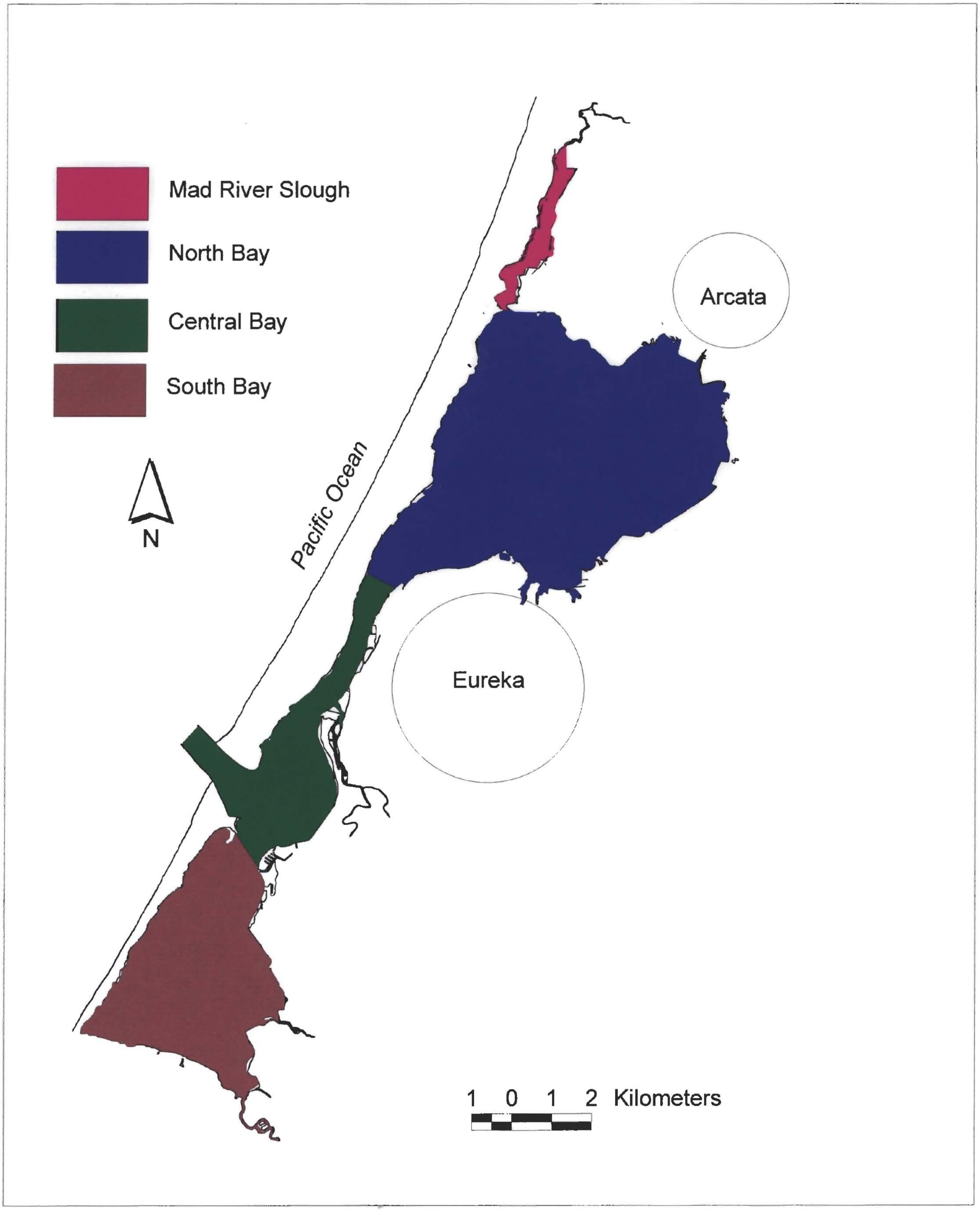

Figure 2: Subareas of Humboldt Bay.

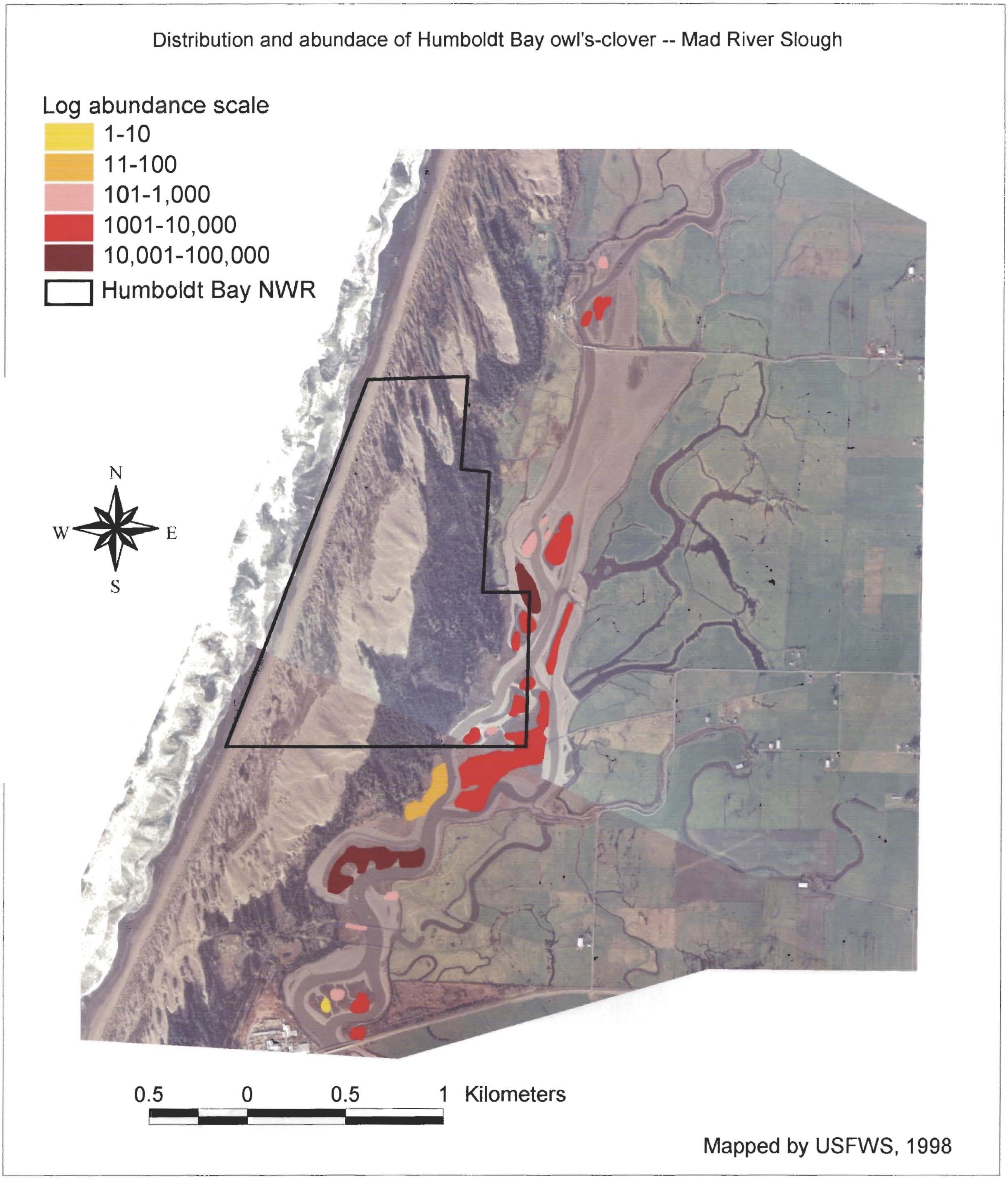

Figure 3a. Abundance and distribution of Humboldt Bay owl's clover, Mad River Slough.

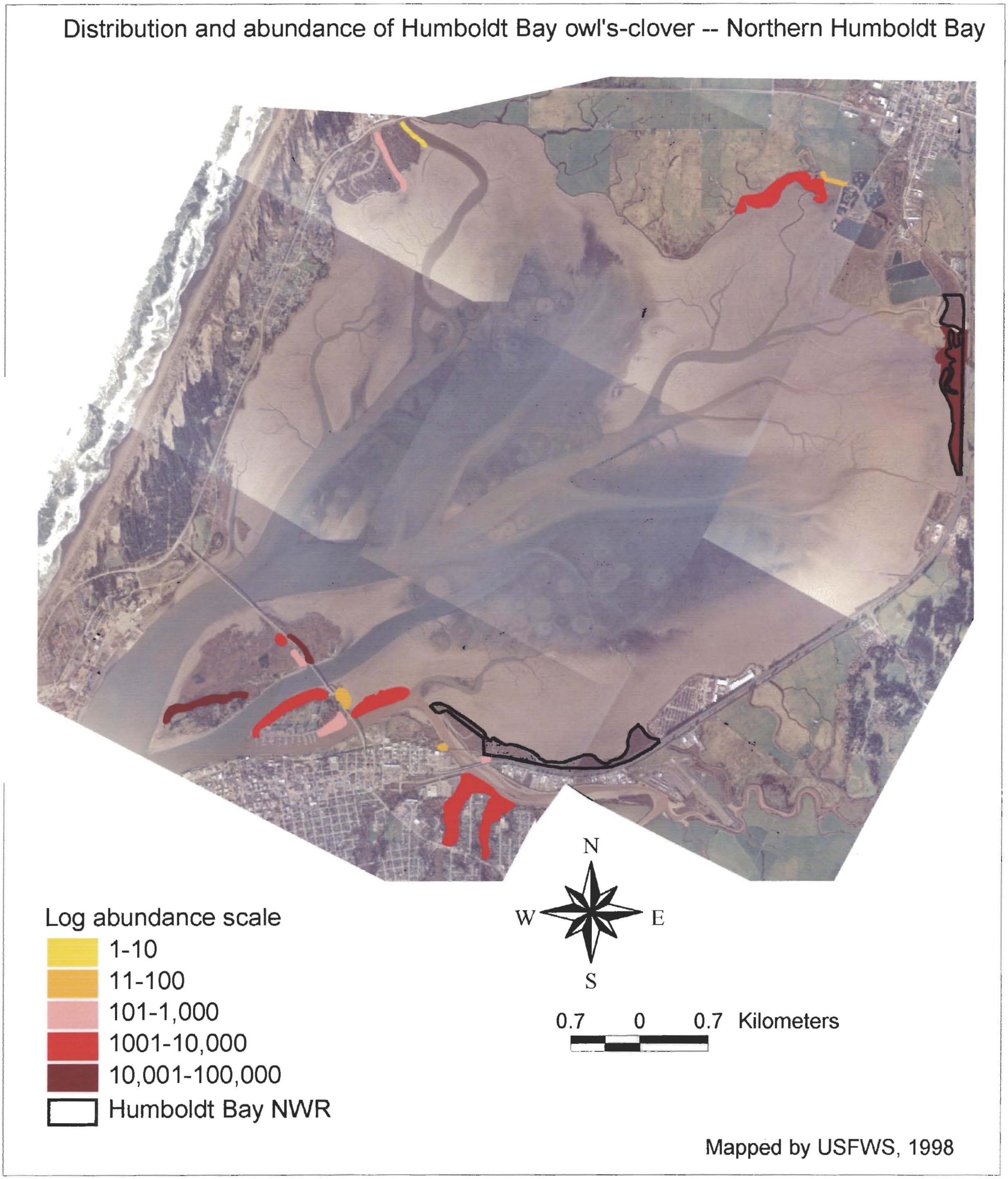

Figure 3b. Abundance and distribution of Humboldt Bay owl's clover, North Humboldt Bay.

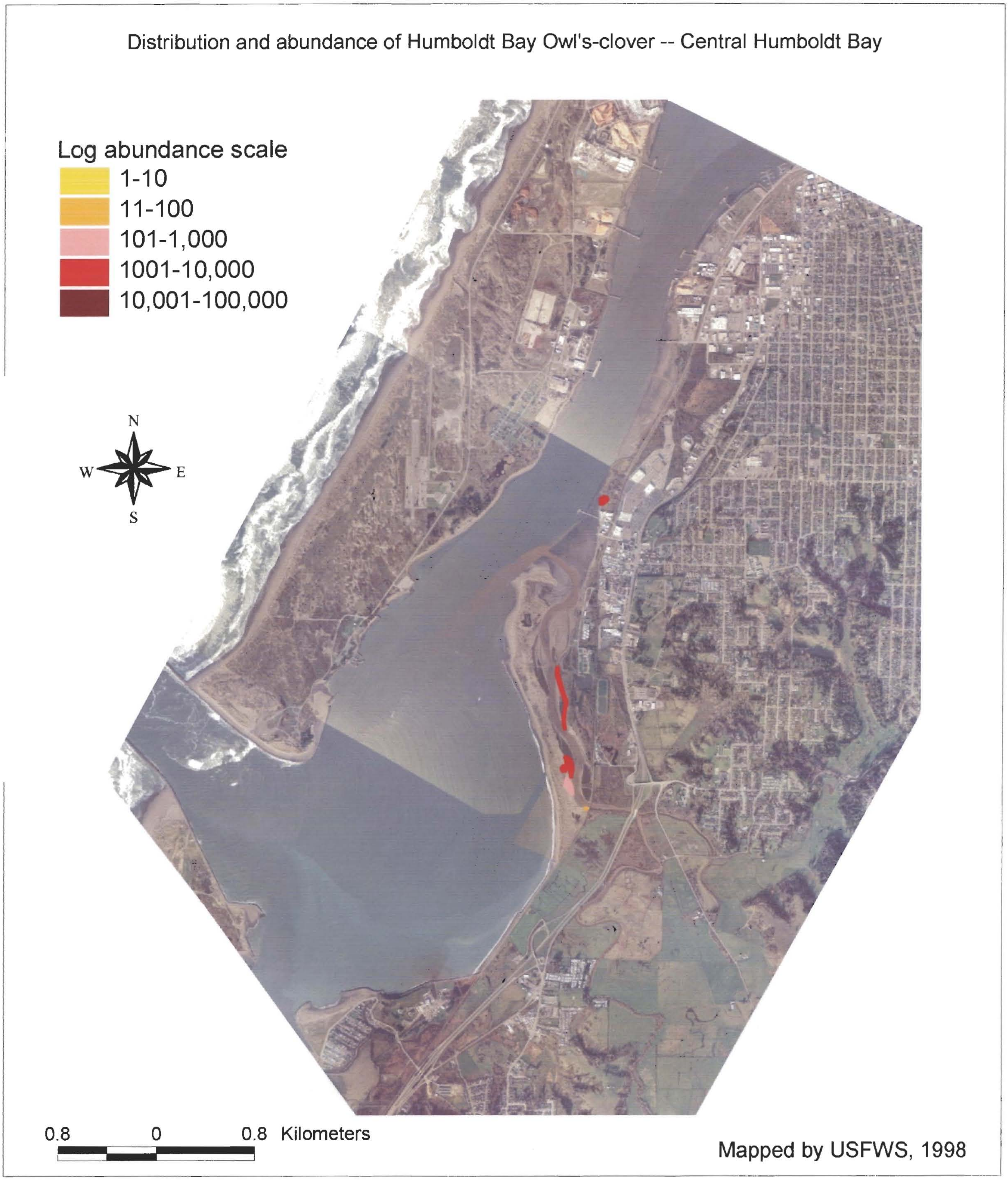

Figure 3c. Abundance and distribution of Humboldt Bay owl's clover, Central Humboldt Bay.

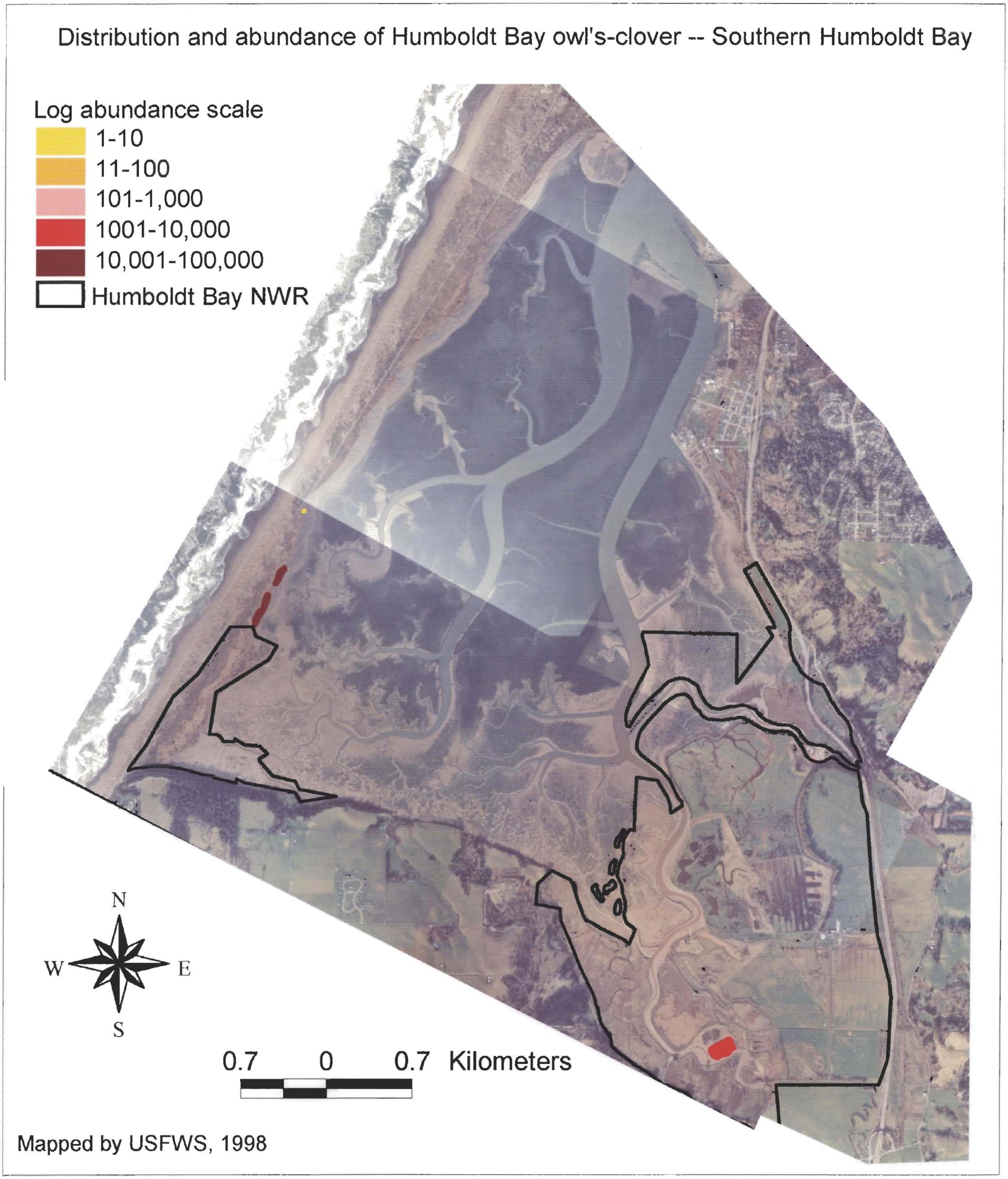

Figure 3d. Abundance and distribution of Humboldt Bay owl's clover, South Humboldt Bay.

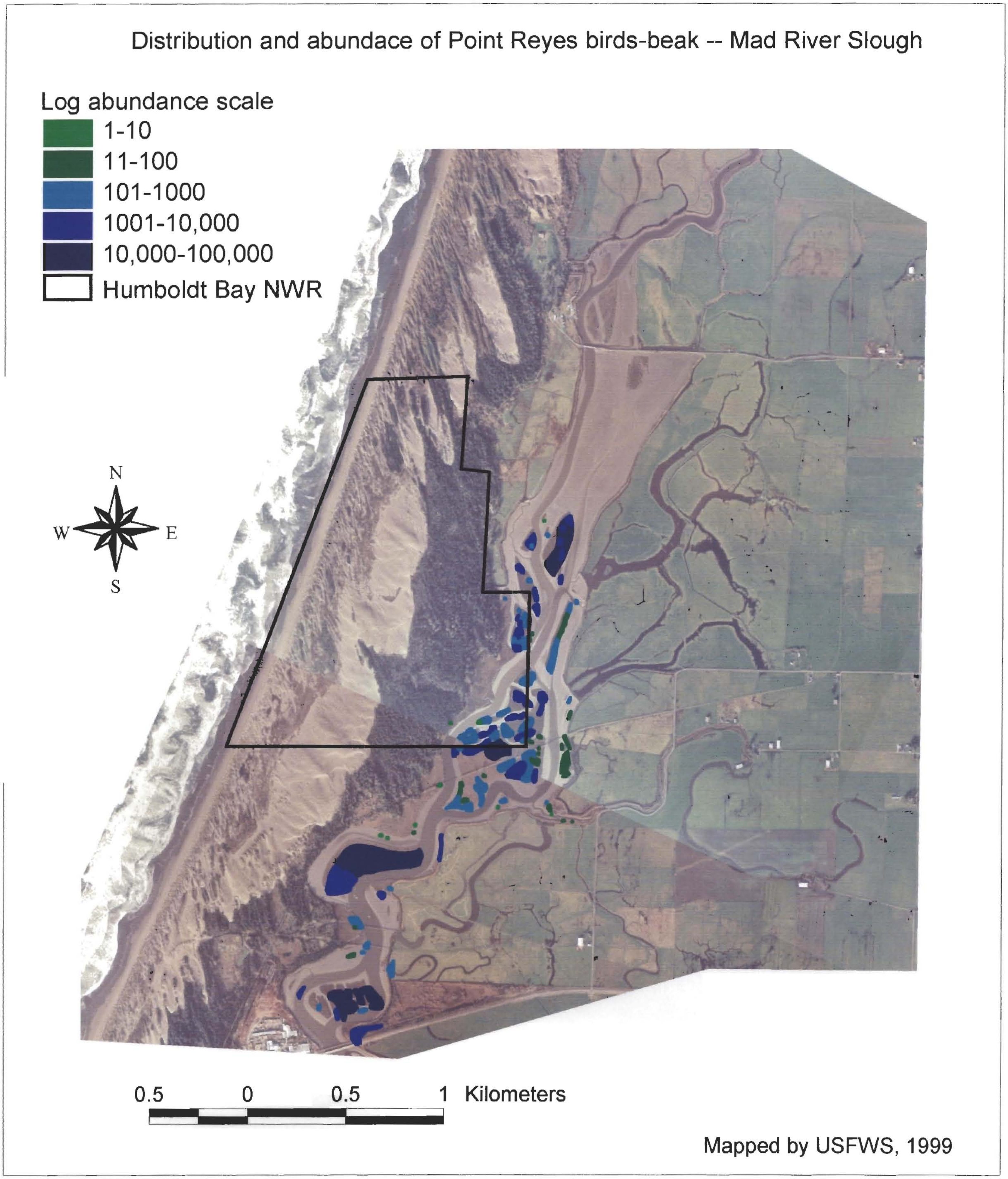

Figure 4a. Abundance and distribution of Point Reyes bird's beak, Mad River Slough.

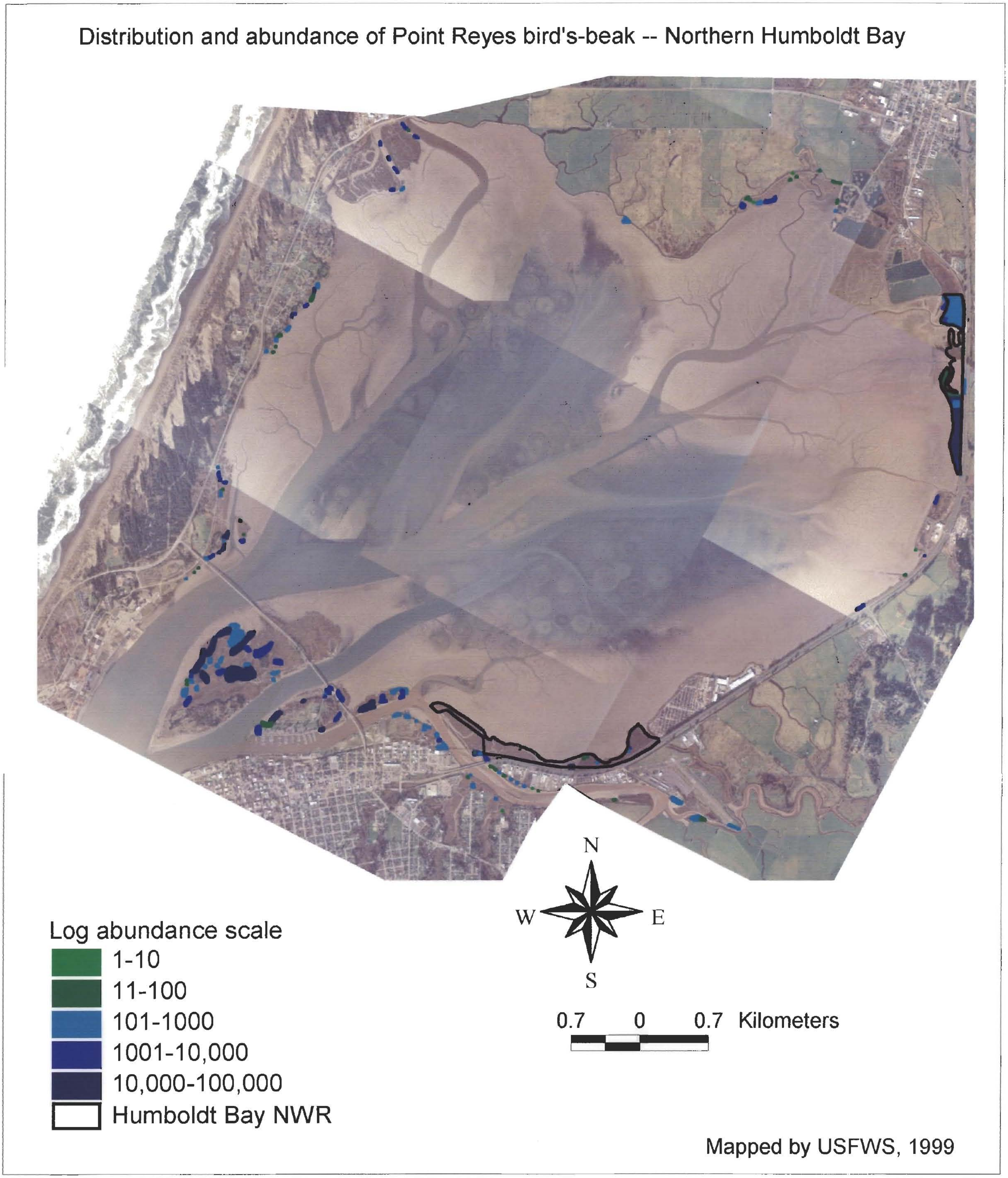

Figure 4b. Abundance and distribution of Point Reyes bird's beak, North Humboldt Bay.

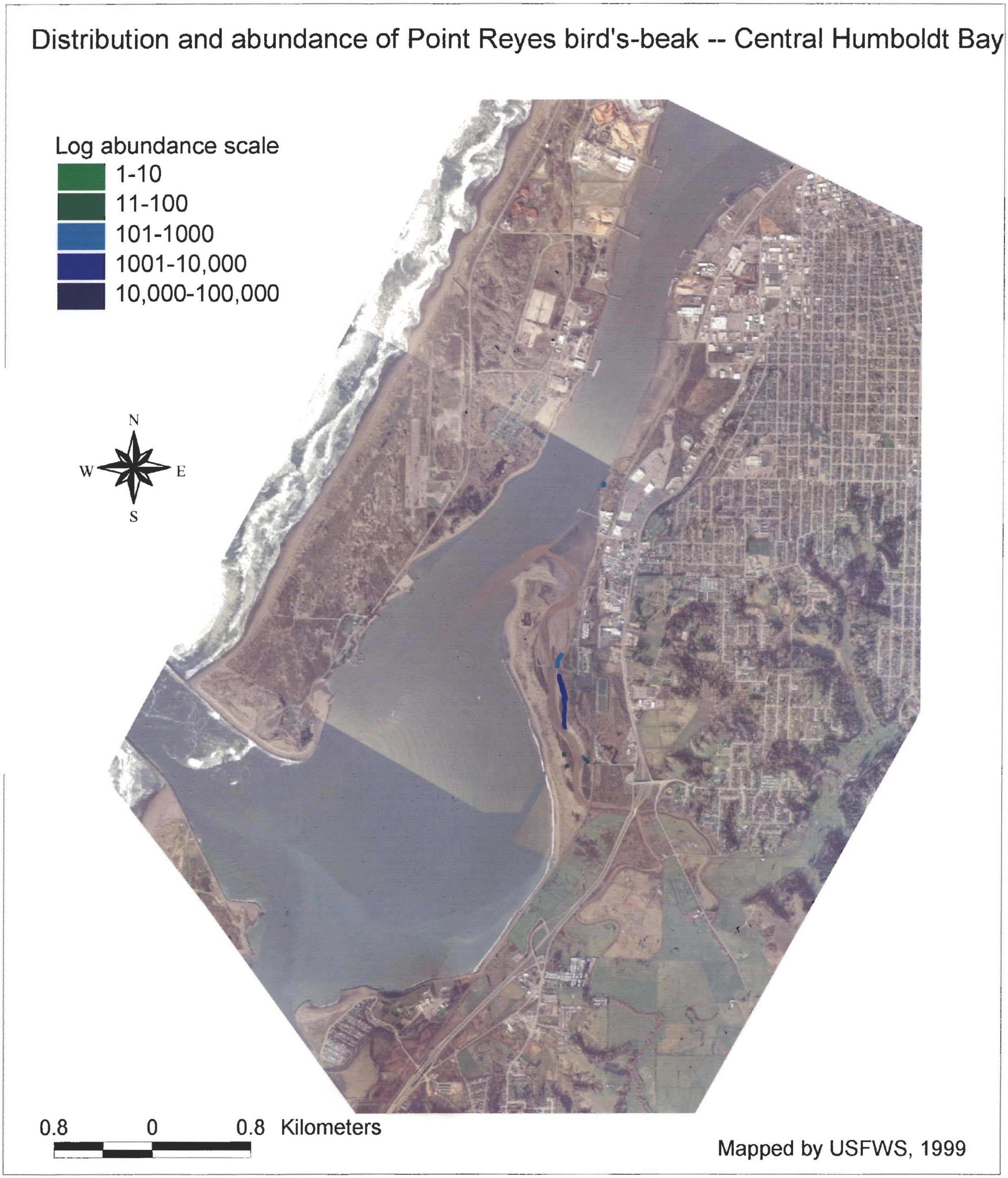

Figure 4c. Abundance and distribution of Point Reyes bird's beak, Central Humboldt Bay.

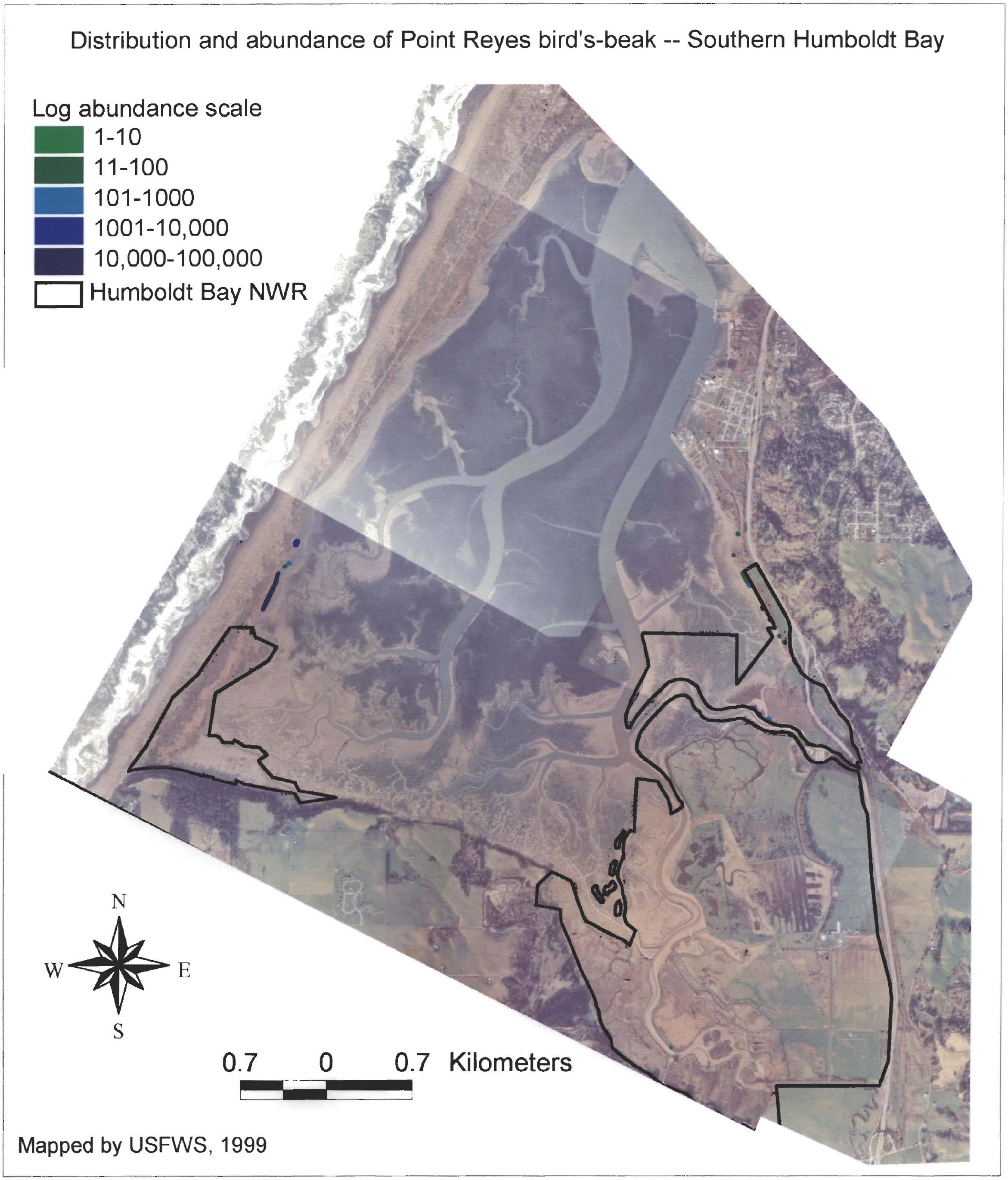

Figure 4d. Abundance and distribution of Point Reyes bird's beak, South Humboldt Bay.

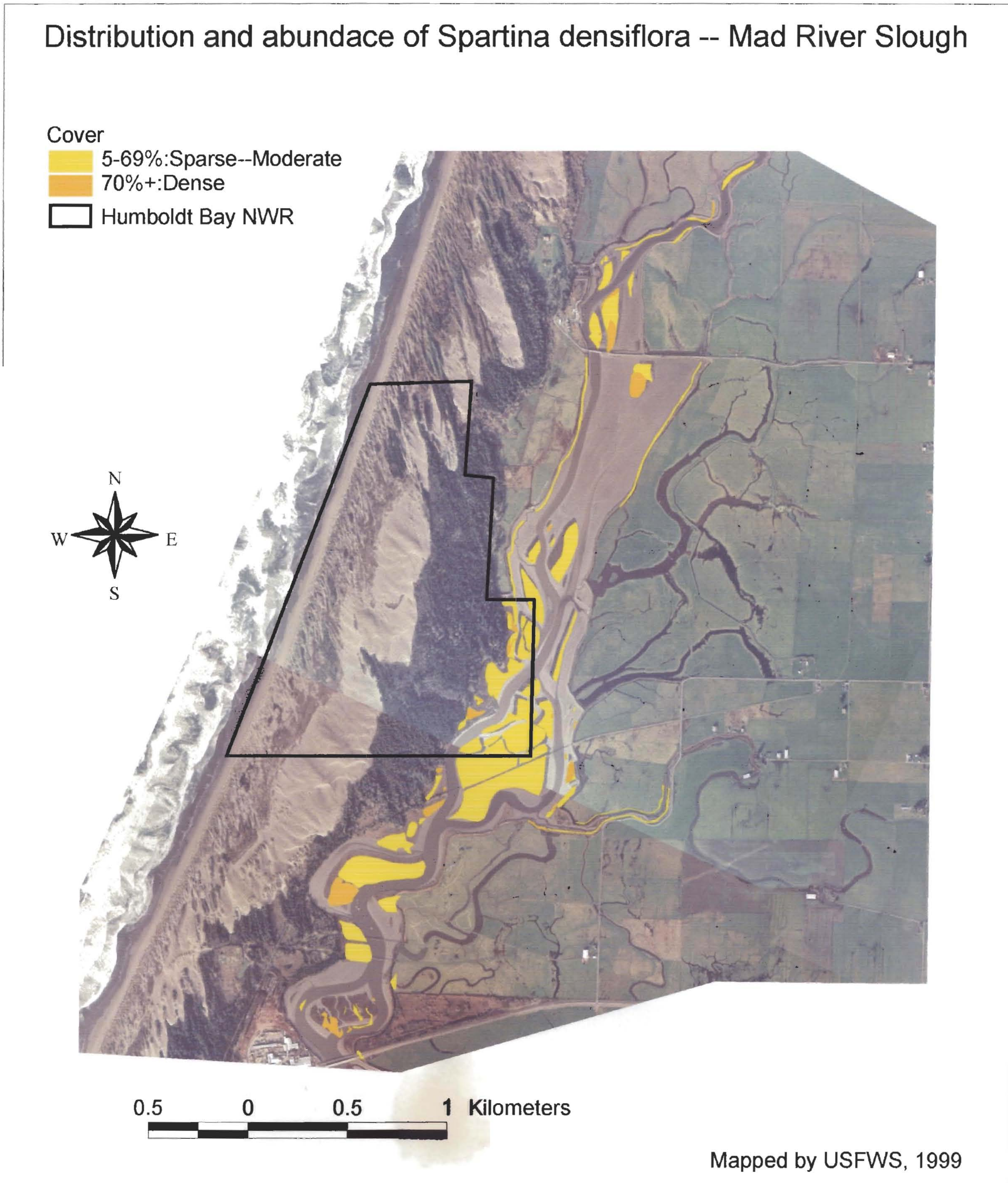

Figure 5a. Abundance and distribution of *Spartina densiflora*, Mad River Slough.

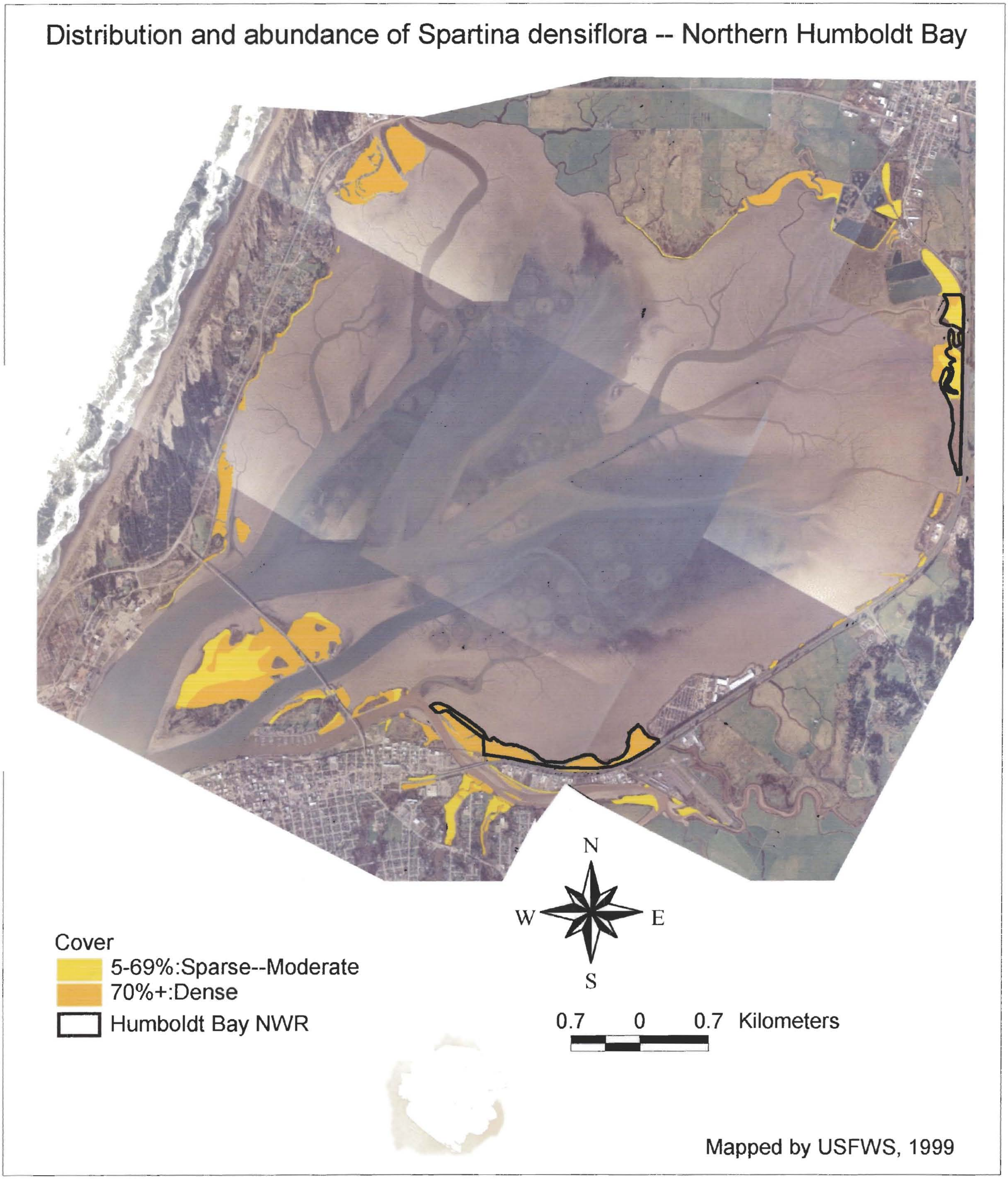

Figure 5b. Abundance and distribution of *Spartina densiflora*, North Humboldt Bay.

Figure 5c. Abundance and distribution of *Spartina densiflora*, Central Humboldt Bay.

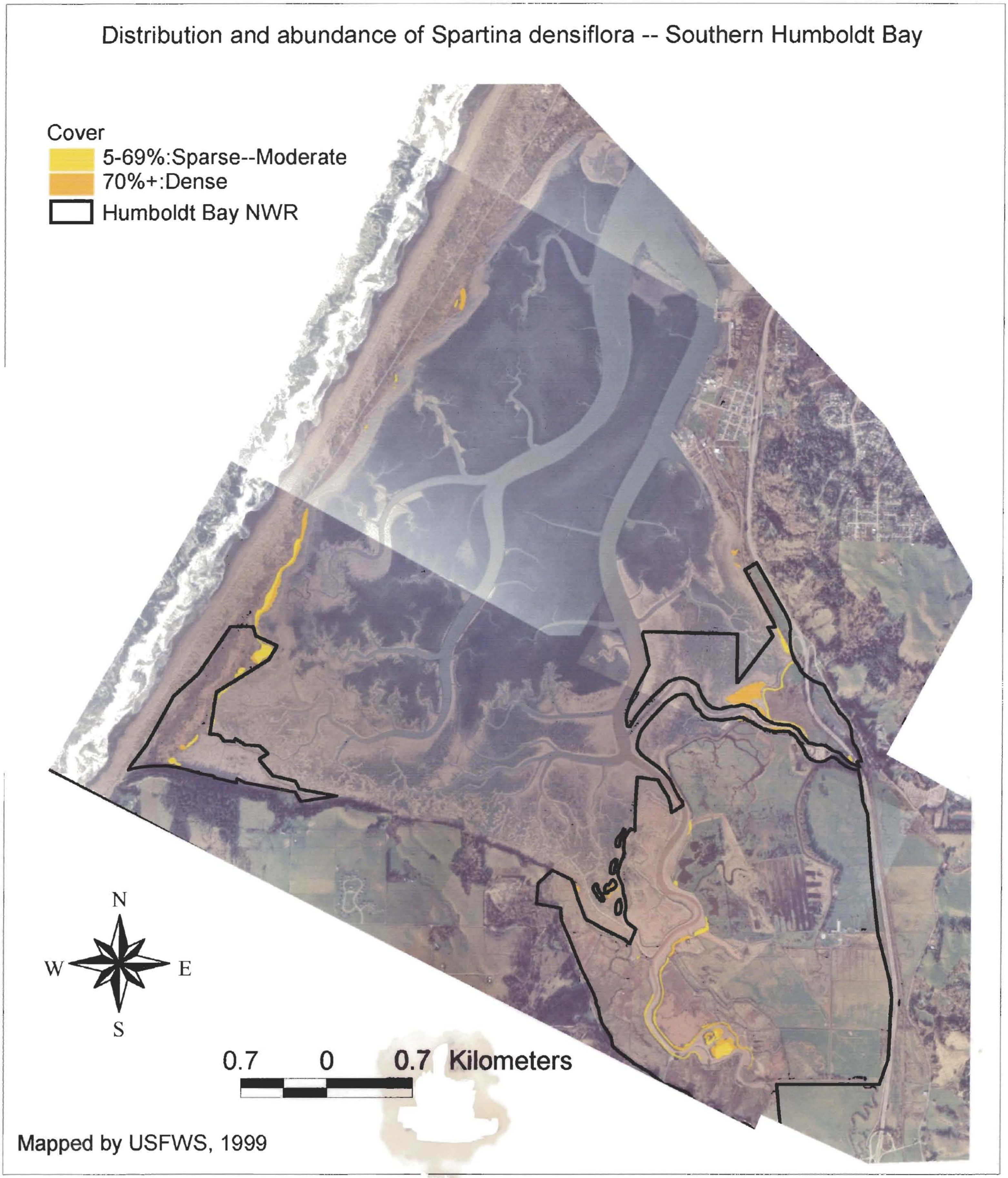

Figure 5d. Abundance and distribution of *Spartina densiflora*, South Humboldt Bay.

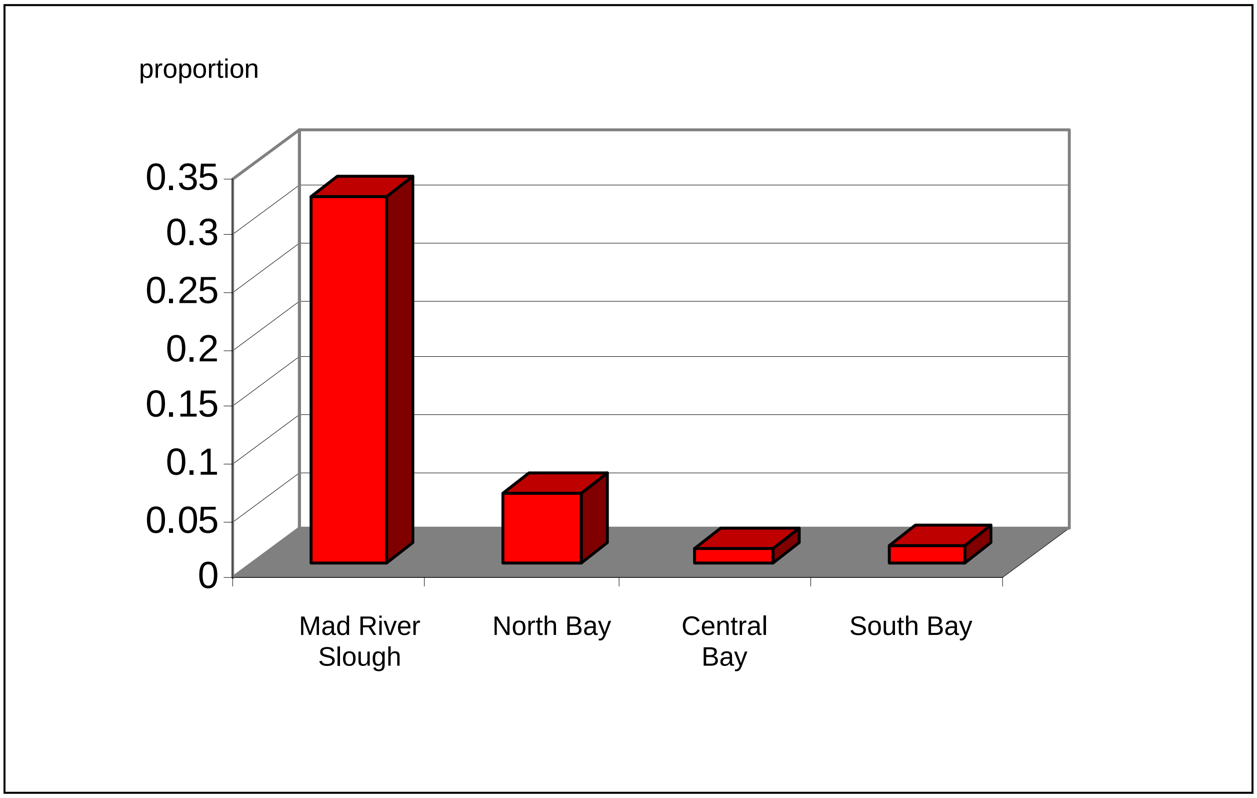

Figure 6. Proportion of each subarea of Humboldt Bay occupied by salt marsh.

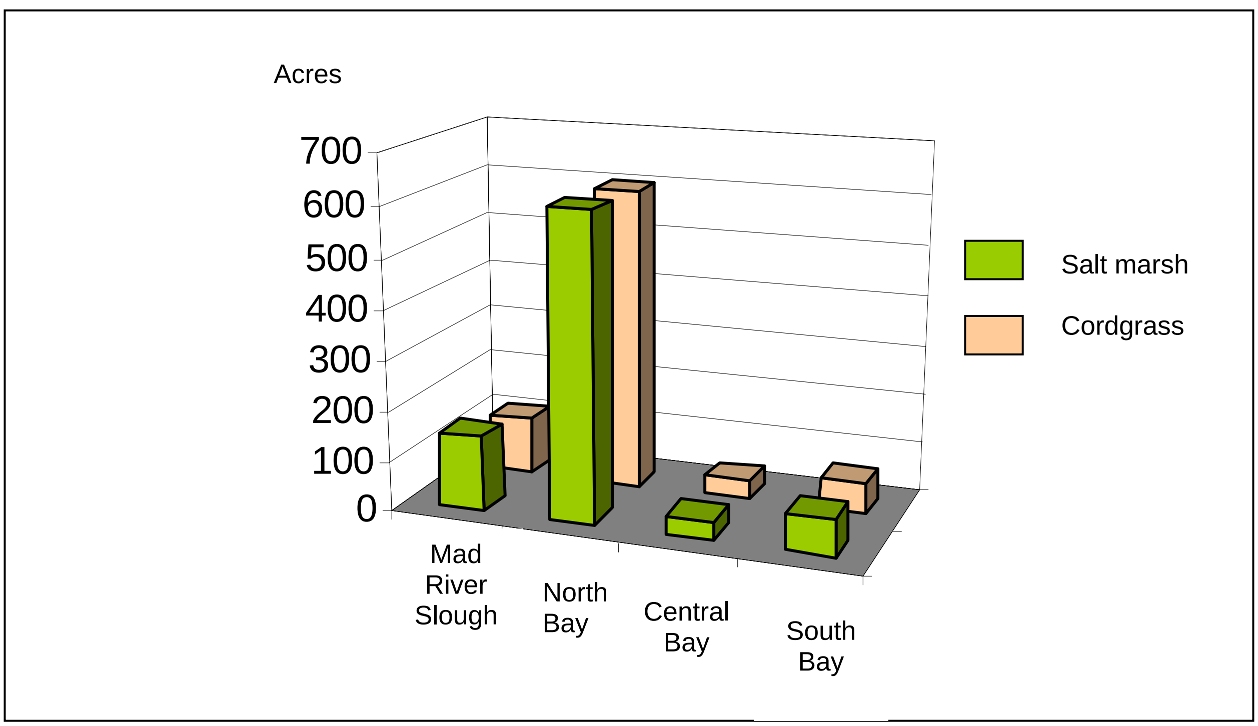

Figure 7. Acres of salt marsh and dense-flowered cordgrass by subarea.

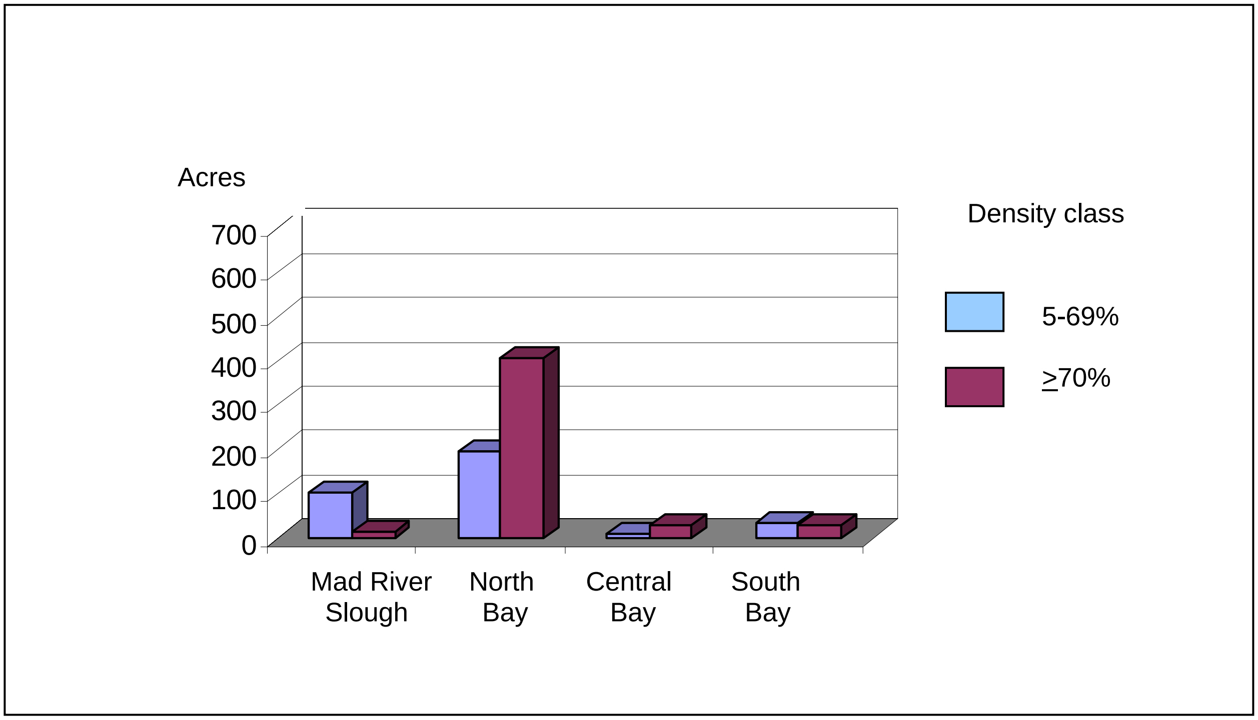

Figure 8. Proportion of total acres of *Spartina densiflora* within each density class by subarea.

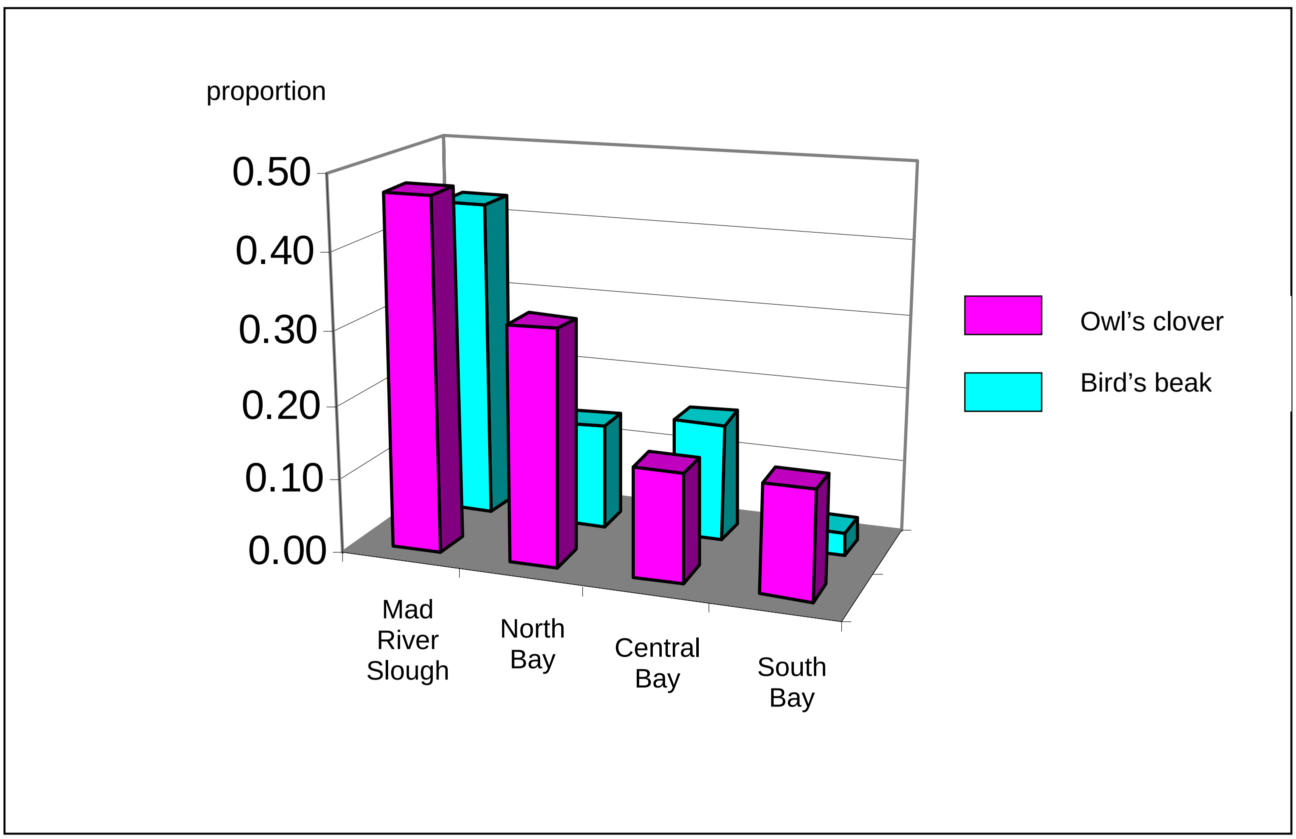

Figure 9. The proportion of total salt marsh occupied by rare salt marsh plants by subarea.

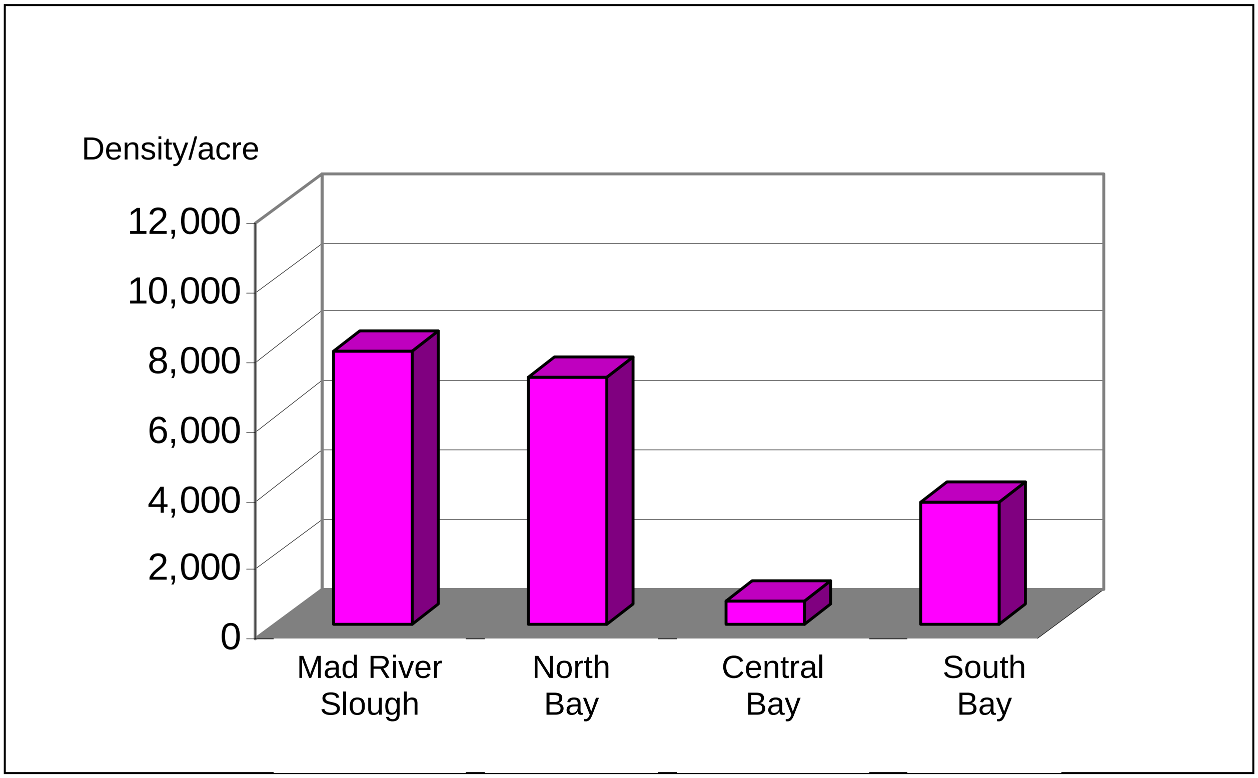

Figure 10. Density per acre of Humboldt Bay owl's clover by subarea. Density is a rough estimate calculated by occupied area x midpoint of logarithmic size class.

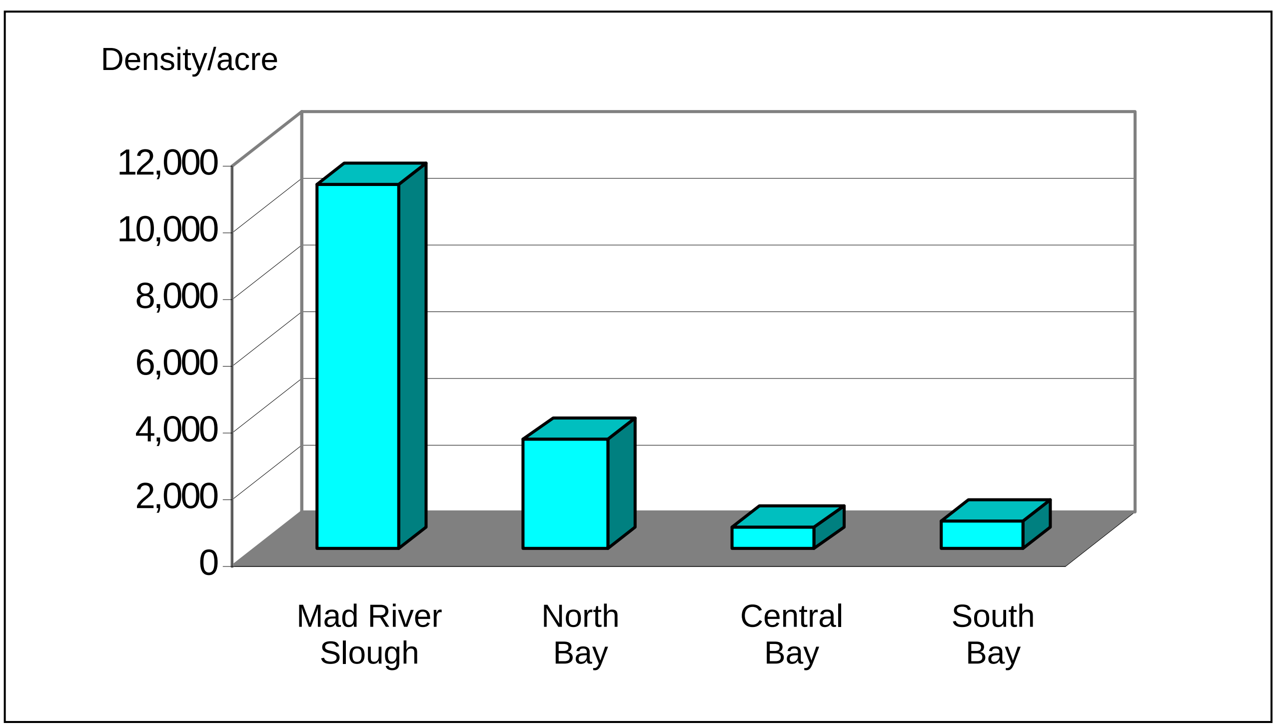

Figure 11. Density per acre of Point Reyes bird's beak by subarea. Density is a rough estimate calculated by occupied area x midpoint of logarithmic size class.

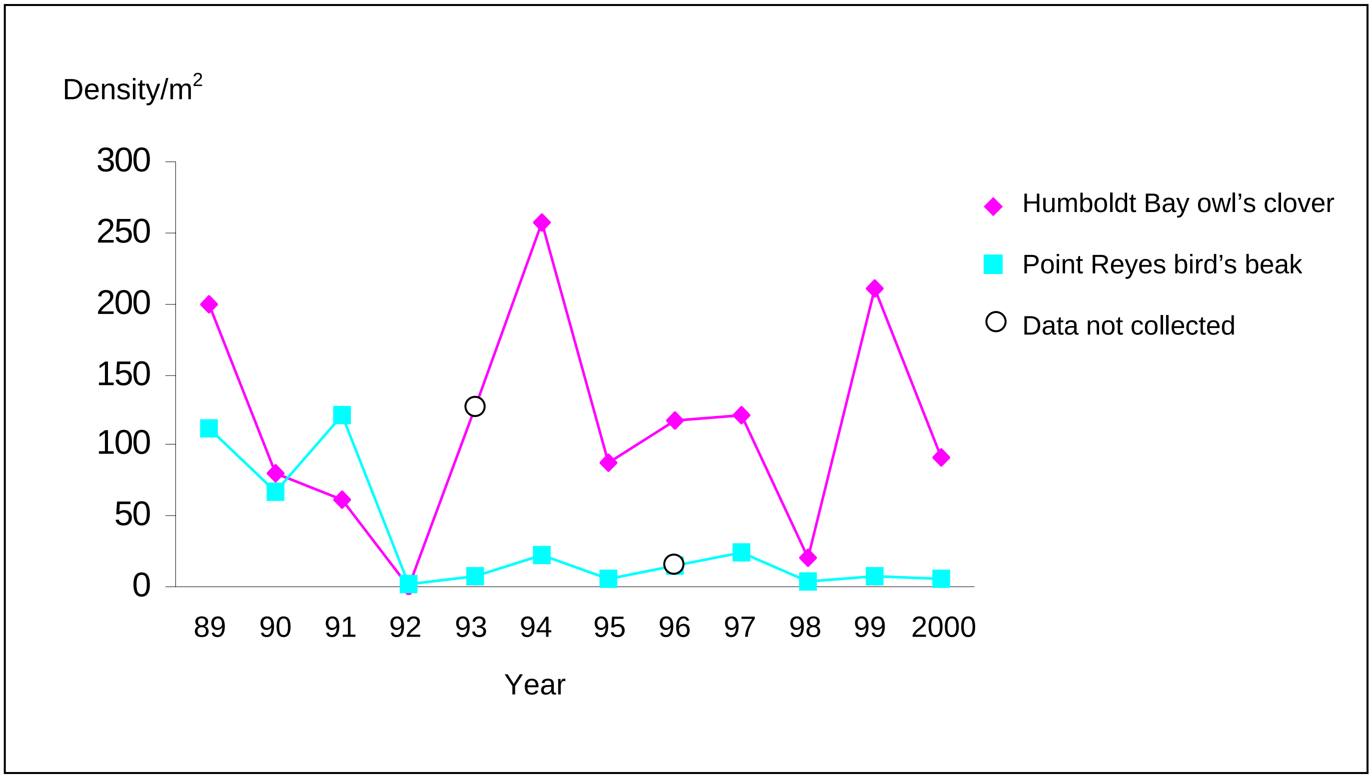

Figure 12: Changes in density per square meter of rare salt marsh plants in monitored macroplots at the Lanphere Dunes Unit, Humboldt Bay National Wildlife Refuge, between 1989 and 2000 (Data from U.S. Fish and Wildlife Service 2001).

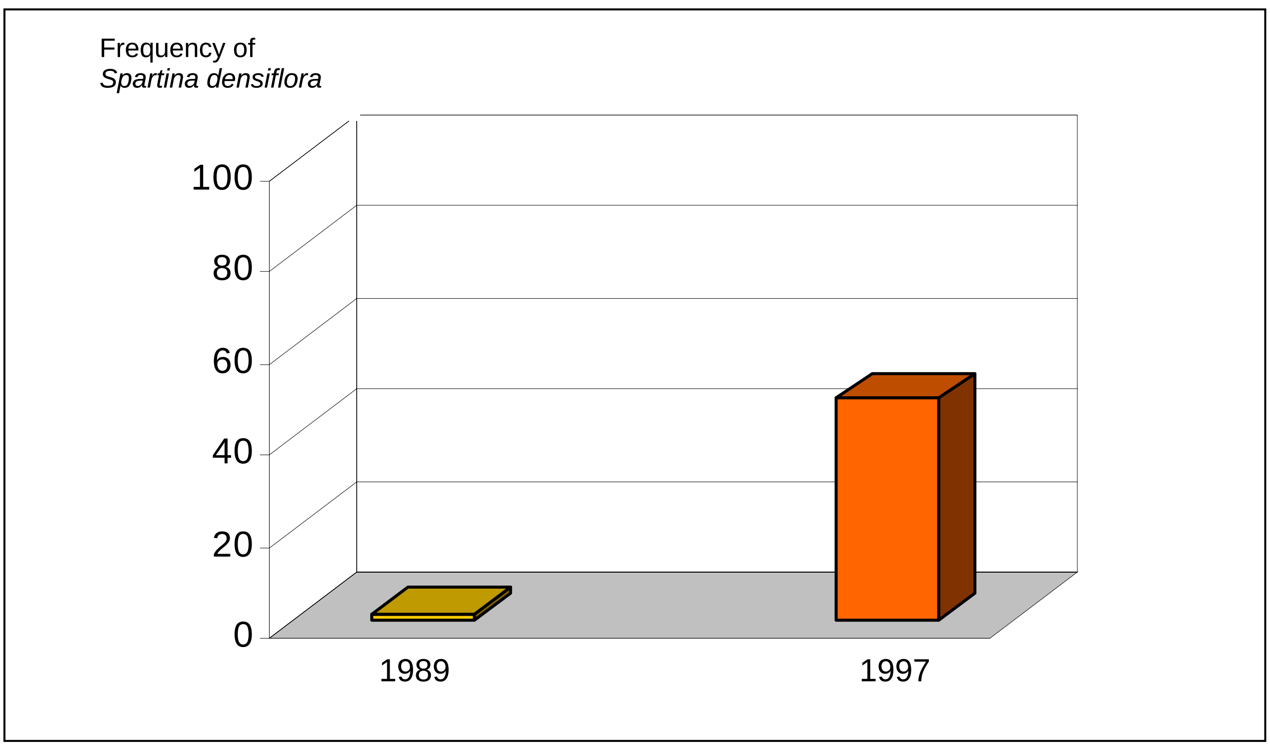

Figure 13: Change in the frequency of dense-flowered cordgrass measured in macroplots at the Lanphere Dunes Unit, Humboldt Bay National Wildlife Refuge, Mad River Slough subarea, between 1989 and 1997 (Data from Pickart 1997).