U.S. Fish and Wildlife Service

Humboldt Bay National Wildlife Refuge

Humboldt County, California

Vegetation of Diked Herbaceous Wetlands of Humboldt Bay National Wildlife Refuge: Classification, Description, and Ecology

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INTRODUCTION AND PURPOSE

Humboldt Bay underwent an abrupt and drastic change in the early 1900s when much of the present-day perimeter of the bay was diked for the completion of the Northwest Pacific Railroad. Historically encompassing 10,930 ha (27,008 ac, the estuary today encompasses about 7,290 ha (18,013 ac) at mean high tide (Barnhart et al. 1992). Tide gates installed at the entrance of sloughs resulted in the conversion of 3,280 ha (8,100 ac) of wetlands from estuarine salt and brackish marsh to palustrine freshwater marsh (Fig. 1). These seasonally saturated diked wetlands were initially used for grazing; and a large percentage of these "agricultural wetlands" are still used to graze beef and dairy cattle. However, large areas (particularly in Humboldt Bay National Wildlife Refuge) are now being managed for their wetland values. In these areas, topography has been lowered in some places ("scraped" with heavy equipment) and water levels manipulated to encourage wetland vegetation and to create habitat for waterfowl. In some areas, faulty tide gates or damaged dikes have allowed restricted tidal influence, resulting in brackish marshes that are technically classified as intermittently flooded estuarine marshes by the National Wetland Inventory (Cowardin et al. 1979).

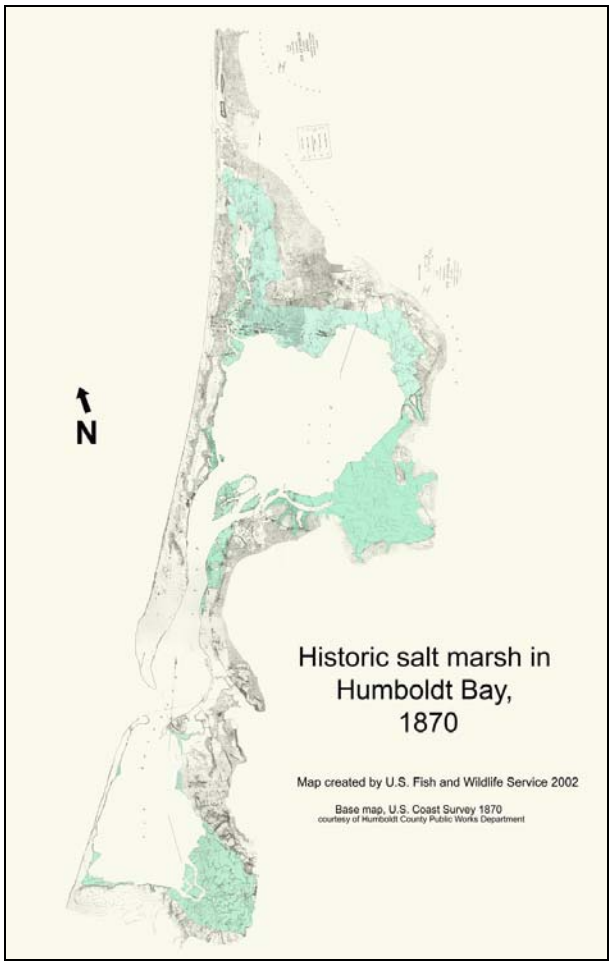


Figure 1. Historic tidal wetlands surrounding Humboldt bay in 1870.

The re-establishment of tidal conditions to small areas of these agricultural wetlands has been carried out dating back to the 1980s, usually as a means of mitigating salt marsh losses resulting from development. Only a handful of projects have been carried out. Most have consisted of the breaching of dikes (Stopher et al. 1981, Claycomb 1983, Pickart 2005), and have had various results including conversion of some or all of the sites to mudflat or the colonization of the site by invasive *Spartina densiflora* (both at least partially a result of lowered elevation due to the compaction of soils). Recently, larger-scale estuary restoration projects have been proposed at McDaniel Slough in North Bay (André 2003), and the Salmon Creek estuary at Humboldt Bay National Wildlife Refuge (HBNWR) in South Bay (Love and Farro 2003). Interest in estuarine restoration has given rise to the formation of the Scientific Advisory Committee for Estuary Restoration (SACER), a local collaborative of scientists with the mission "to contribute to an interdisciplinary science-driven approach to guiding restoration efforts in the Humboldt Bay area." SACER has recently undertaken to prioritize estuary restoration sites around Humboldt Bay.

With the increasing interest in restoration of former tidal wetlands around the Bay comes the obligation to document existing, pre-restoration conditions. Particularly in areas that have been managed for wetland values, such as HBNWR, it is important to evaluate the current wetland values in order to assess the net impact of restoration. The refuge encompasses a variety of herbaceous diked wetlands that are managed for different ecological values, including grazed agricultural wetlands. For this reason it serves as a representative sample of wetland types around the bay. The goal of this study was to survey, classify, and describe wetland vegetation types in the study area and to elucidate their relationship with underlying environmental variables such as salinity, moisture, and elevation. The resulting alliance-based classification should be broadly applicable to diked wetlands around the bay, and will assist in setting restoration priorities by allowing managers to characterize and evaluate existing wetland values. In a related project, the diked wetlands of HBNWR will be mapped to alliance level (using this classification) with GIS-driven mapping software and supporting field work. The classification, together with the mapping project, will provide the tools to begin inventorying diked wetlands around the bay. Such an inventory is an important constituent of the restoration priority-setting envisioned by SACER. A secondary goal of this project is to characterize invasive plant-dominated vegetation of the refuge, contributing to the completion of a refuge-wide invasive plant strategy. Understanding the abiotic relationships underlying invasive plant distribution will assist in developing control strategies.

STUDY SITE

The study was conducted at the southern management units of Humboldt Bay National Wildlife Refuge in Humboldt County, California (Fig. 2). The study area consists of 513 ha (1,267 ac) of diked, herbaceous wetlands within the Salmon Creek, Hookton Slough, and White Slough Units (Fig. 3). All three units were used for cattle ranching in the past. Salmon Creek Unit is the largest unit of the refuge and contains 406 ha (1,003 ac) of diked wetlands including agricultural wetland, brackish marsh, and open water with submergent vegetation. Additionally, the unit contains wooded wetlands (riparian and swamp) that were not included in this study. A portion of the unit is grazed and/or mowed to maintain shortgrass habitat for Aleutian Cackling Geese and other migratory birds (Bachman et al. 2003). The Hookton Slough Unit, containing 92 ha (227 ac) of diked wetlands, lines the base of Table Bluff. Several freshwater springs originating on the bluff provide persistent standing water in some areas. Wetlands present are predominantly brackish marsh. White Slough Unit has only 27 ha (68 ac) of herbaceous wetlands, a small portion of which were still grazed in 2005. A faulty tidegate and deteriorating dikes have resulted in the predominance of typical salt marsh plants on the site.

Soils of the study area are in the process of being remapped by the Natural Resources Conservation Service. According to the draft maps available at the time of this study, soils of the study area fall into two mapping units: Weott and Arlynda. All of the Salmon Creek Unit except for a small portion of Salmon Creek Overflow (SCO) is classified as Weott, characterized by very poorly drained silt loam in the top 31 cm (12 in), with frequent ponding, and very high surface runoff. The Hookton Slough Unit is classified as Arlynda, composed of peat in the top 8cm (3 in) and underlain by silty clay loam to 36 cm (14 in). Hydrologic characteristics are similar to Weott soils: very poorly drained, subject to frequent ponding and very high surface runoff. Weott soils are described as having a salinity of 0-2.0 dS/m and pH of 6.1-7.3 in the top 0-30 cm (0-12 in). Arlynda soils have a reported salinity of 0 dS/m and pH of 5.1-6.0 to a depth of 8 cm (3 in), with higher salinity (0-2,0 S/m) and more acid pH (6.1-7.3 from 8 cm to 36 cm (3-14 in).

Humboldt Bay has been classified as a tide-driven coastal lagoon due to its limited freshwater input (Barnhart et al. 1992). Estuarine conditions result from major winter storm events. The region is characterized by distinct wet and dry seasons, with 90% of rainfall occurring between October and April. Average annual precipitation is 96.8 cm (38.1 in). The dry season is characterized by persistent low clouds and fog (National Weather Service 2006).

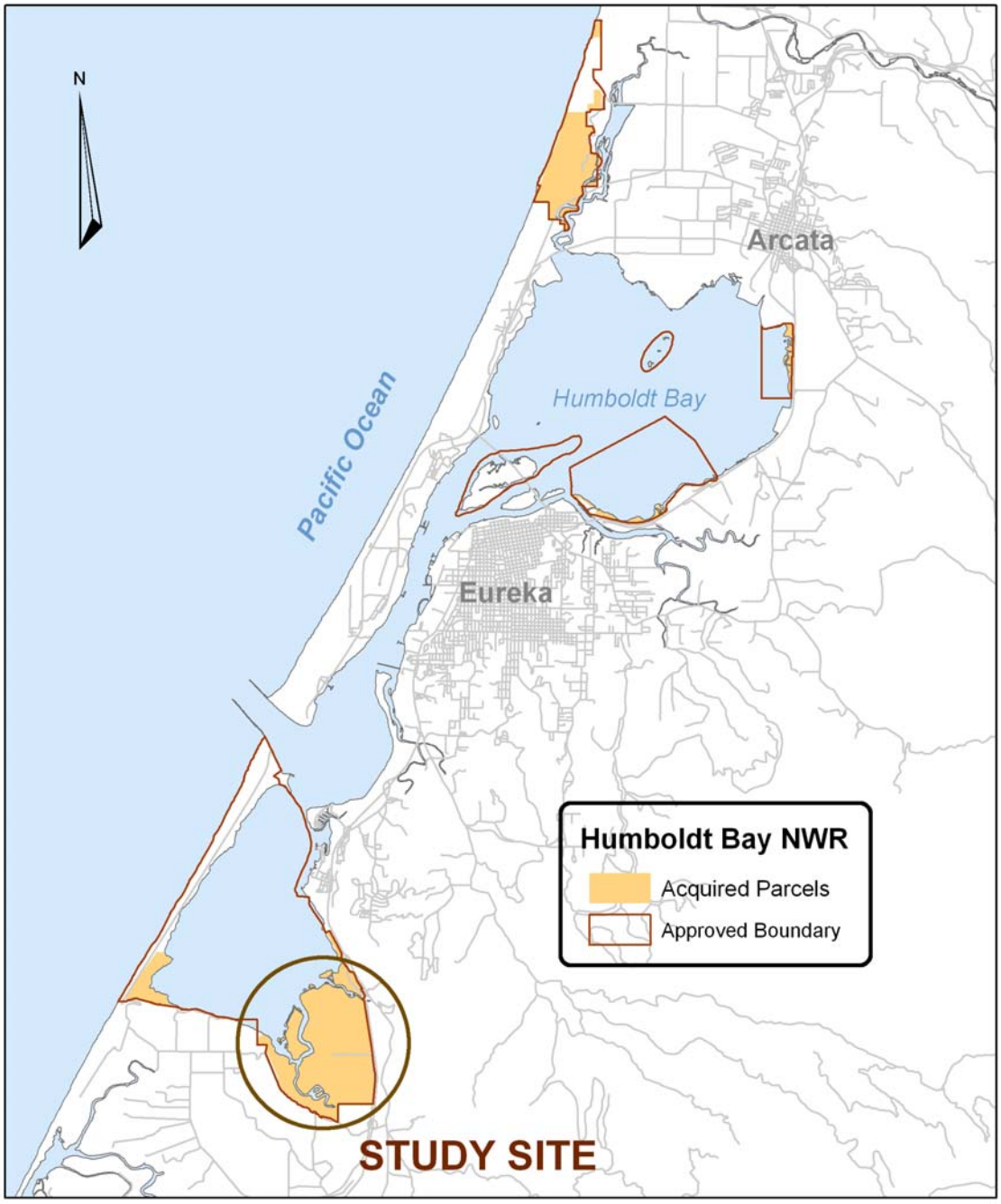


Figure 2. Location of study area.

METHODS

1. Background and Literature Review

The Department of the Interior follows the National Vegetation Classification (NVCS) and its methodology when classifying, naming, and mapping vegetation types (Grossman et al. 1998). The NVCS methodology for vegetation sampling was used as guidance in developing sampling methods for this study (The Nature Conservancy 1994). Prior to and during reconnaissance of the study site, a comprehensive search of the NVCS database (NatureServe 2005) was conducted to determine whether previously described alliances would apply to this area. The resulting descriptions were consulted throughout the study, and assisted in initial sample apportionment. Only a few past studies in the Humboldt Bay region have utilized plot-based descriptions of palustrine wetland vegetation (Stopher et al. 1981, Newton 1989) or of estuarine vegetation that may be present on diked wetlands (Eicher 1987). Two of the three studies located had been completed as a constituent of mitigation projects. Both of the palustrine wetland studies focused on a localized area near the mouth of the Elk River. The 1981 study provided raw, plot-based data for pre- and post-restoration of an agricultural wetland, but did not classify data into vegetation types. Newton (1989) described eight herbaceous freshwater and brackish wetland types occurring pre- and post- restoration at the 49-ha (121-acre) Elk River Wildlife Area.

2. Reconnaissance

A reconnaissance of the site was carried out from 15 May through 3 June 2005. The site was divided into subareas (Fig. 3), each of which was walked through in order to observe and photograph distinct vegetation types. This time was also used to become thoroughly familiar with the flora, keying any unknown species. There were a number of grass species not yet in flower, for which vegetative traits were documented so that later identification to species was possible.

3. Plot locations

Three sets of digital images of the Humboldt Bay vicinity were used in this study. Composites of orthorectified true color photographs flown at 1:16,000 in January 1998 and a digital, georeferenced set flown in July 2004 for California Department of Fish and Game were used to initially delineate homogeneous vegetation types for sample apportionment. A third composite of color-infrared, orthorectified photographs, flown at a combination of 1:12,000 and 1:24,000 in May 2005 by Humboldt State University, became available in July and was used for refinements. The 1998 imagery had good resolution but did not show recent vegetation changes (some major due to management), and timing of the flight was immediately after mowing in pasture areas. The 2004 color photography taken by CDFG was more recent, showed some pasture areas prior to mowing, but had poorer resolution with some areas obscured by clouds.

A random grid was superimposed on photography in ArcMap 9 to identify potential plot locations. Plots were moved when they fell on the boundaries of types, and additional sites were added subjectively to encompass apparent variation of vegetation types. After locating plots in the field, some still needed to be moved because they occurred on boundaries of microvariation, or because the grid failed to encompass variation not evident on photography. Using *a priori* vegetation types based on reconnaissance and the NVCS, a goal of approximately 30 samples per type was

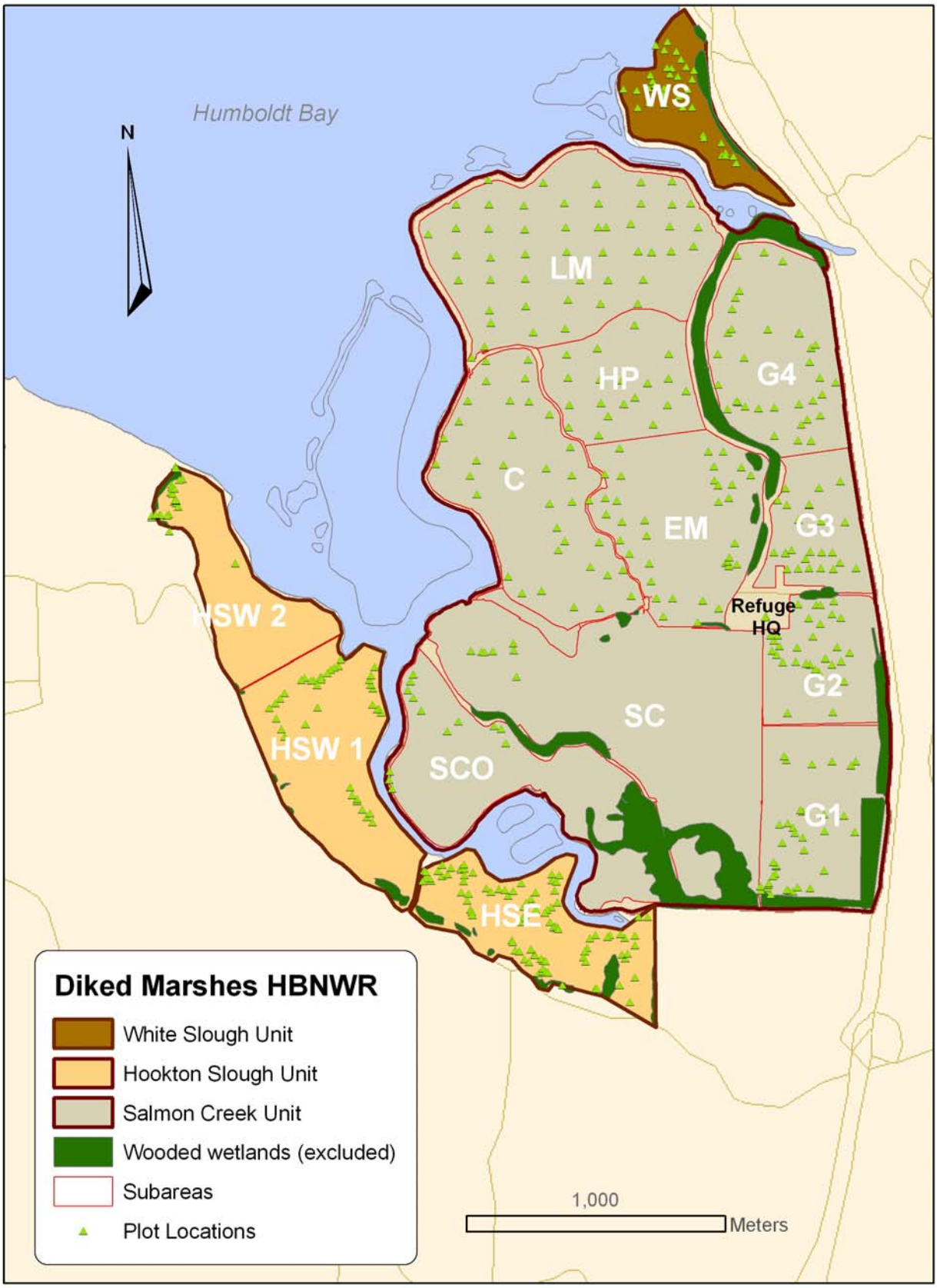


Figure 3. Map showing Refuge Units and subareas sampled.

targeted. Sampling was stopped if the sample size exceeded 30, unless additional variation in species composition was encountered. This balance between preselection of plots and refinement in the field worked for all areas except Hookton Slough Unit. There was so much microvariation in the vegetation at Hookton Slough Unit that a different method was needed. The area was divided into three broad regions, and the first was sampled intensively to capture the extent of variation. Then, in the second and third areas, only areas with uncaptured variation or types with insufficient sample size were visited. This was accomplished by meandering through these areas, sampling as needed. After the Hookton Unit was sampled in this way, additional subjective plot location was required to further increase sample size in a few under-represented types which were uncommon or inaccessible (e.g. *POTAMOGETON* and *HYDROCOTYLE* Alliances). These types could be located with the help of the new CIR photography completed in July. One alliance (*DESCHAMPSIA*) was not discernable on the imagery, and plots were located as a result of familiarity gained by the intensive field sampling.

4. Plot establishment

Between 21 June and 31 October, 2005, 461 plots were established and visited. A Trimble Geo XT or Dell Axim PDA with flashcard GPS and ArcPad 6.03 was used to navigate to plots. The preselected plots were visible as points on a shapefile overlaying the 2000 photography. At each sample location, the GPS coordinates of the pre-selected plots were used as the plot center. When deviating from preselected plots, the center point was subjectively established within homogeneous vegetation. A quadrat was constructed from two intersecting PVC pipes. The center of the PVC "X" was placed at the plot center, and the square described by using each PVC as a diagonal measured 10 m^2 (Fig. 4). This relatively small plot size was chosen to avoid encompassing ecotones in the highly variable observed vegetation, and followed generalized recommendations for sampling herbaceous vegetation (Kent and Coker 1992). A digital photograph was taken of each plot (Canon EOS 10D with 25 mm lens), and a bamboo stake with flagging or a pinflag was placed at the center point with the plot number labeled. The photos were later used to confirm recorded data accuracy, and to relocate plots for soil sampling (done later in the year, when some flags had disappeared). Once a plot was established, the GPS location was recorded on a new shapefile in ArcPad. Data recorded for each point included plot number, observer, date, and flag location (usually center, but occasionally due to high water, offset). Flags could not be placed in pasture areas (G1-G4) because haying was scheduled immediately after vegetation data collection.

5. Vegetation Sampling

After a GPS point was taken for the plot, vegetation data were recorded in an Excel spreadsheet loaded on the PDA or Trimble. The spreadsheet included all of the species encountered in wetlands of Humboldt Bay during the Humboldt Bay Flora collection project (Leppig and Pickart 2005). Any additional species encountered were collected and

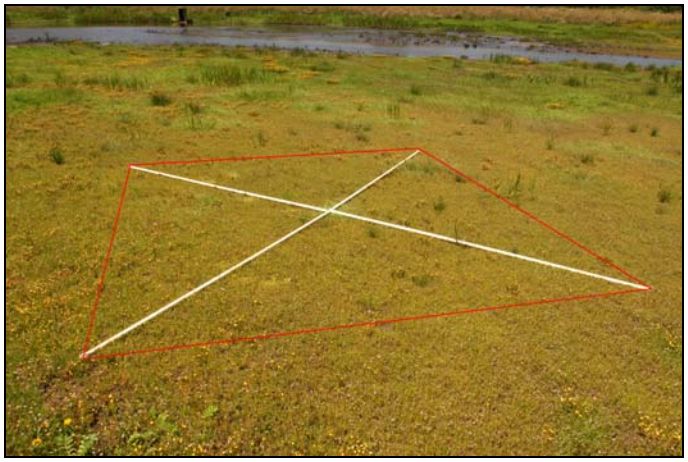


Figure 4. Red outline bounds the 10-m^2 plot.

added to the spreadsheet (See Appendix A for final species list). First, the total vegetation cover of the plot was recorded as a continuous variable. Then, a modified Braun-Blanquet cover scale was used to record abundance of each species encountered (Table 1). The classes were defined with the intent of maximizing accuracy of estimation while still allowing for effective discernment of vegetation types in the analysis. A comment field allowed observations such as high water levels, indicating the need to return to the plot later (an unusually extended rainy season caused late standing water).

Preliminary data were collected from June-August by a total of five people, all of whom were trained and their cover estimates calibrated with the Principal Investigator's. At the end of each field day data were downloaded, PDAs and Trimbles recharged, and photographs labeled. At this time photographs were checked against the spreadsheet for errors. This time was also used to key any uncertain plant specimens.

Following this period of data collection, a preliminary classification was carried out using using PcOrd Version 4, in order to refine *a priori* vegetation types and determine sample size sufficiency. Based on this preliminary classification, data collection was resumed in October in order to achieve adequate sample sizes. Location of new plots in under-represented types was aided by the 2005 photography. Previously sampled plots were revisited periodically to determine whether vegetation had undergone seasonal changes in cover, and new plots were added only when the species composition of preliminary alliance type had not changed significantly since sampling began in June. One entire alliance (*ATRIPLEX*) emerged late enough in the season so as not to be present in the preliminary classification. Occurring in areas that had been flooded in the first sampling period, it was targeted for sampling in this later period. Overall, each vegetation type was sampled during a period of consistent vegetation.

Table 1. Cover classes

R = present in <1% of plot.
1 = 1-4%
2 = 5-9 %
3 = 10-24%
4 = 25-49%
5 = 50-74%
6 = 75 -89%
7 = 90-100%

6. Soil sampling

A random subsample of plots were revisited from 13 September - 28 October 2005 to measure soil moisture and collect soil samples for laboratory testing of salinity, pH, and other variables. At the time sampling began, only the preliminary classification of vegetation types had been completed, and was used to apportion the sample among types. Later refinements resulted in unequal sample sizes, and no soil samples were collected in a few vegetation types. While the initial goal was to sample 7 plots per type, the final sample sizes were 4-9 plots in sampled types (Table 2).

Plots were located by navigating to the GPS point with a Trimble XT, and then looking for flags. Some flags had disappeared, and all pasture areas (G1-G4) had not received flags. In these cases, we navigated to the point, and then checked the plot data. If the data at the point did not match, we moved to the nearest area where vegetation was consistent with the plot data. All of the drier types were sampled in the initial two-week period, during which weather was stable. A total of 1.2 cm (0.5 in) of rain fell over a four-day period between the first and second collection groups. However, only the wettest types (*Hydrocotyle* and *Oenanthe*), which were still covered with standing water, remained to be sampled. We waited a minimum of two weeks after the rain had ceased to collect these last samples. At each plot center, a soil sample was taken from the top

Figure 5. Extracting a soil sample with auger.

20 cm (8 in) of soil (after scraping away plants and surface litter), bagged in a Ziploc bag, and labeled (Fig. 5). A Dynamax TH_20 soil moisture meter was then inserted at four locations (in approximately the center of each quarter of the plot), after scraping away surface litter, and moisture readings were recorded. Soil samples were processed by A & L Western Agricultural Laboratories in Modesto, California, who analyzed soil saturation percentage (cc H_2O/100 cc soil), Sodium adsorption ratio (SAR), Exchangeable Sodium percentage (ESP), Sodium (Na), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Boron (B), Carbonate, Bicarbonate, and pH, using a saturated soil extract.

Table 2. Sample size for soils by final Alliance type (asterisk indicates too few or no soil samples were taken).

Alliance	n
Agrostis stolonifera	7
Atriplex triangularis	7
Cotula coronopifolia	4
Deschampsia caespitosa	7
Distichlis spicata	7
Eleocharis macrostachya	5
Holcus lanatus	5
Hydrocotyle ranunculoides	7
Juncus leseurii	7
Lolium multiflorum	9
Oenanthe sarmentosa	6
Potamogeton pectinatus	5
Potentilla anserina	5
Salicornia virginica	8
Scirpus maritimus	7
Scirpus microcarpus	*
Spartina densiflora	*
Spergularia marina	4
Typha latifolia	6

7. Elevation Sampling

Elevation data were collected in November 2005 for the same plots that were sampled for soil data. A Spectra Precision Laserplane 500c on a tripod was used with a LaserEye mounted on a stadia rod (Fig. 6). Typically, the tripod was positioned on a levee and visibility to plots was good. In a few cases, shrubs interfered with the laser beam, and the tripod needed to be re-positioned to get a reading. Elevations were tied into a National Geodetic Survey benchmark (Designation L1087, located at milepost 69.85 on eastern side of northbound Hwy 101, on concrete headwall over a culvert). Since elevations were recorded after rains had begun, some areas had become flooded and some of the flags were gone. A combination of navigating to a known point and then examining vegetation was used to pinpoint the sample. Thus, it was possible that some elevation points did not match initial vegetation plots exactly, but were placed within the same alliance type and within a reasonable distance (approximately 3 m).

Figure 6. Positioning of stadia rod at a flag located in a flooded area.

8. Data Archiving

All photographs, the final GIS shapefile containing plot locations (with metadata), and the excel spreadsheets with vegetation and environmental variables are archived at the Lanphere Dunes Unit, Humboldt Bay National Wildlife Refuge.

9. Analysis

Classification. The complete plot by species matrix (originally containing 461 plots and 90 species) was classified in PC-Ord Version 4, using cluster analysis (Euclidian distance measure, Ward's group linkage method). Values of "r" were first transformed to "1." Several iterations of clustering were used to refine the matrix, eventually removing species present in less than 3 plots, and eliminating plots that had extremely low cover or were outliers. The final dendrogram was based on a total of 449 plots and 73 species.

Correlation . Both vegetation and environmental variables from the environmental matrix were subject to a correlation analysis (Pearson's correlation coefficient). The means of the four different moisture readings were used for each plot.

ANOVA. A one-way Analysis of Variance was used on the environmental matrix to discern significant differences among vegetation types for the soil and elevation variables. The ANOVA was followed by post hoc Tukey HSD multiple range tests and Least Significant Difference multiple comparisons. Due to the variability of the data, the significance level for post-hoc tests was set at p=.10.

10. Nomenclature

The National Vegetation Classification System utilizes the nomenclature of Kartesz (1994, 1999). Although the alliances and associations described as a result of this report will eventually be submitted to NCVS for inclusion, scientific names in this report follow the Jepson Manual (Hickman 1993) to avoid confusion for local users (synonyms are provided in Appendix A). Common names follow the NVCS.

RESULTS

1. Classification.

The final dendrogram resolves 19 alliances and 27 associations (Fig. 7). This dendrogram is the result of several iterations in which species occurring in fewer than 3 plots were eventually removed (Table 3). Subsequently, about 20 outlier plots were removed. Most of these consisted of samples that fell in mud or open water (with very low total cover). A few represented an inadequate sample of potential vegetation types only present in one or two isolated locations (e.g. *Carex obnupta-, Chenopodium foliosum- and Triglochin maritimum* -dominated types). Alliances and associations are described and pictured in the Vegetation Descriptions after the Discussion Section. A key to alliance types is presented in Appendix B. Table 4 lists common and scientific alliance names, NVCS alliance code if applicable, and National Wetland Inventory classification code .

Table 3. Species occurring in less than three plots removed from the cluster analysis.

Agrostis microphylla
Agrostis viridis
Alopecurus geniculatus
Anthoxanthum odoratum
Cyperus eragrostis
Equisetum telmateia
Leymus triticoides
Leymus x *vancouverensis*
Mimulus guttatus
Polygonum punctatum
Rumex acetosella
Senecio vulgaris
Trifolium pratense
Trifolium variegatum
Veronica americanum
Vicia tetrasperma

Tundra swans at the Hookton Slough Unit

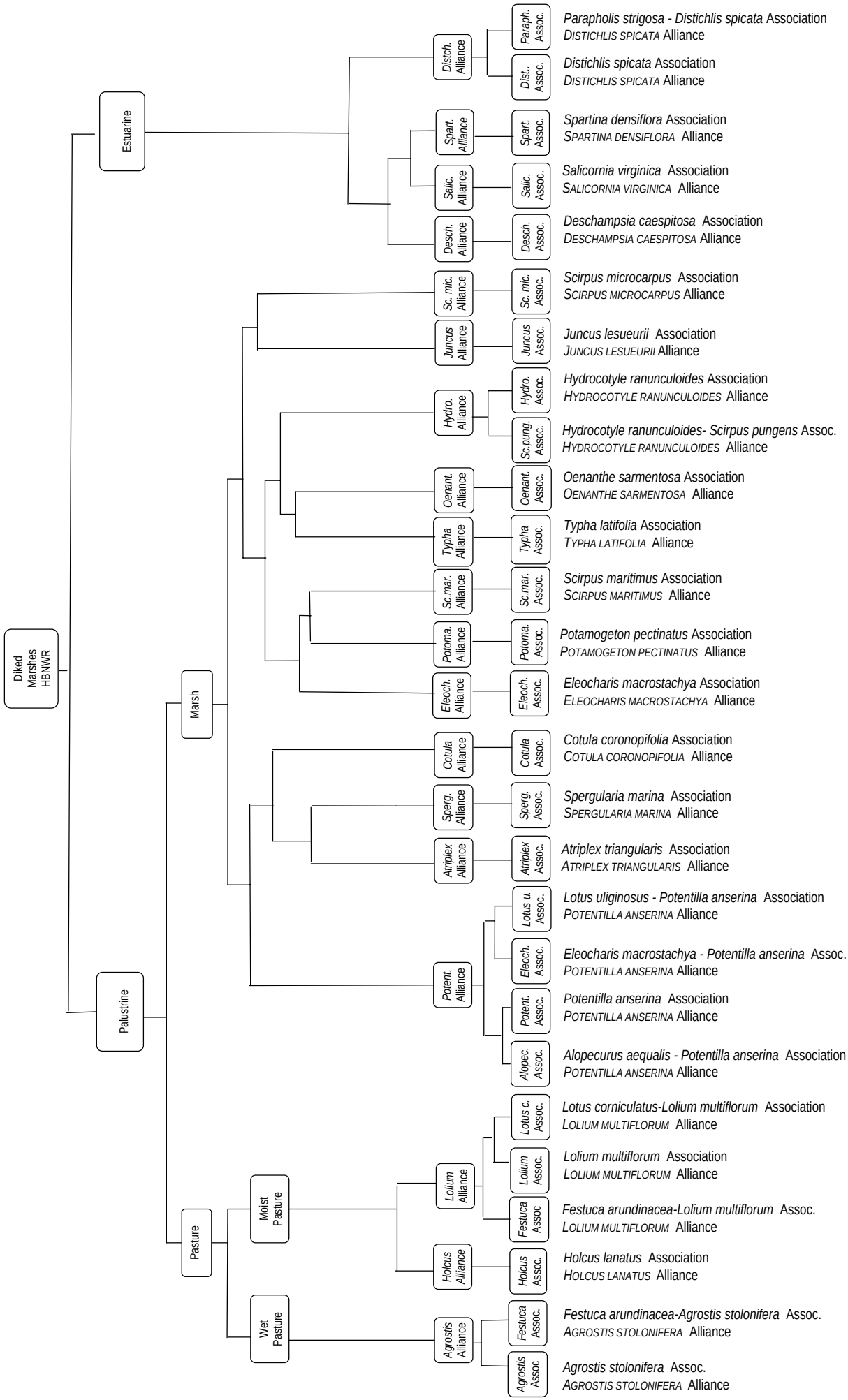


Figure 7. Final dendrogram displaying Alliances and Associations.

Table 4. Scientific and common names of alliances and associations (red font indicates National Vegetation Classification synonym), with alliance code (this report), NVCS code if applicable, National Wetland Inventory code, and sample size (n). Key to NWI codes can be found in Appendix C.

Alliance	Association	NVCS code	All. code	NWI code	n
***Agrostis stolonifera* Herbaceous Alliance** **Spreading bentgrass Herbaceous Alliance**		A.1405	AGR	PEM1C6h	51
	Agrostis stolonifera - Festuca arundinacea Association *(Agrostis stolonifera - Lolium arundinaceum* Association) Spreading bentgrass-tall fescue Association				17
	Agrostis stolonifera Association Spreading bentgrass Association				34
***Atriplex triangularis* Herbaceous Alliance** **(*Atriplex prostrata* Herbaceous Alliance)** **Creeping saltbush Herbaceous Alliance**	*Atriplex triangularis* Association Creeping saltbush Association		ATR	PEM2C5h or E2EM2P5h	14
***Cotula coronopifolia* Herbaceous Alliance** **Brassbuttons Flooded Herbaceous Alliance**	*Cotula coronopifolia* Association Brassbuttons Association		COT	PEM1C-F6h	38
***Deschampsia caespitosa* Herbaceous Alliance** **Tufted hairgrass Herbaceous Alliance**	*Deschampsia caespitosa* Association Tufted hairgrass Association	A.2623	DES	E2EM1P6h	13
***Distichlis spicata* Herbaceous Alliance** **Seashore saltgrass Herbaceous Alliance**		A.1882	DIS	E2EM1P5h	43
	Distichlis spicata-Parapholis strigosa Association Seashore Saltgrass - Hairy sickle-grass Association				5
	Distichlis spicata Association Seashore Saltgrass Association				38
***Eleocharis macrostachya* Herbaceous Alliance** **(*Eleocharis palustris* Herbaceous Alliance)** **Creeping spikerush Herbaceous Alliance**	*Eleocharis macrostachya* Association Creeping spikerush Association	A.1422	ELE	PEM1CC6h	23
***Holcus lanatus* Herbaceous Alliance** **Common velvet grass Herbaceous Alliance**	*Holcus lanatus* Association Common velvet grass Association		HOL	PEMIB6fh	23
***Hydrocotyle ranunculoides* Herbaceous Alliance** **Floating pennywort Herbaceous Alliance**			HYD	PAB4H6h	13
	Hydrocotyle ranunculoides-Scirpus pungens Association *(Hydrocotyle ranunculoides-Schoenoplectus pungens* Association) Floating pennywort-Three-square bulrush Association				4

Table 4 cont'd. Scientific and common names of alliances and associations (red font indicates National Vegetation Classification synonym), with alliance code (this report), NVCS code if applicable, National Wetland Inventory code, and sample size (n). Key to NWI codes can be found in Appendix C.

Alliance	Association	NVCS code	All. code	NWI code	n
***Hydrocotyle ranunculoides* Herbaceous Alliance** **Floating pennywort Herbaceous Alliance**	*Hydrocotyle ranunculoides* Association Floating pennywort Association				5
***Juncus lesueurii* Herbaceous Alliance** **Salt rush Herbaceous Alliance**	*Juncus lesueurii* Association Salt rush Association		JUN	PEM1B6h	17
***Lolium multiflorum* Herbaceous Alliance** **(*Lolium perenne* ssp. *multiflorum* Herbaceous Alliance)** **Italian ryegrass Herbaceous Alliance**			LOL	PEM1B6fh	44
	Lolium multiflorum - Lotus corniculatus Association Italian ryegrass-birds-foot trefoil Association				18
	Lolium multiflorum -Festuca arundinacea Association (*Lolium multiflorum - Lolium arundinaceum* Association) Italian ryegrass-tall fescue Association				4
	Lolium multiflorum Association Italian ryegrass Association				22
***Oenanthe sarmentosa* Herbaceous Alliance** **Water-parsley Herbaceous Alliance**	*Oenanthe sarmentosa* Association Water-parsley Association		OEN	PEM1F6h	16
***Potamogeton pectinatus* Herbaceous Alliance** **(*Stuckenia pectinata* Herbaceous Alliance)** **Sago pondweed Herbaceous Alliance**	*Potamogeton pectinatus* Association (*Stuckenia pectinata* Association) Sago pondweed Association	A.1764	POG	PAB3C-F6h	7
***Potentilla anserina* Herbaceous Alliance** **(*Argentina anserina* Herbaceous Alliance)** **Silverweed Herbaceous Alliance**			POT	PEM1C6h	47
	Potentilla anserina - Alopecurus aequalis Association (*Argentina anserina - Alopecurus aequalis* Association) Silverweed-short awn foxtail Association				10

Table 4 cont'd. Scientific and common names of alliances and associations (red font indicates National Vegetation Classification synonym), with alliance code (this report), NVCS code if applicable, National Wetland Inventory code, and sample size (n). Key to NWI codes can be found in Appendix C.

Alliance	Association	NVCS code	All. code	NWI code	n
***Potentilla anserina* Herbaceous Alliance** **(*Argentina anserina* Herbaceous Alliance)** **Silverweed Herbaceous Alliance**	*Potentilla anserina - Lotus uliginosus* Association *Argentina anserina - Lotus pedunculatus* Association Silverweed-broadleaf birds-foot trefoil Association *Potentilla anserina* Association *Argentina anserina* Association Silverweed Association				4 16
***Salicornia virginica* Herbaceous Alliance** **Virginia glasswort Herbaceous Alliance**	*Salicornia virginica* Association Virginia glasswort Association	A.2618	SAL	E2EM1P5h	23
***Scirpus maritimus* Herbaceous Alliance** **(*Schoenoplectus maritimus* Herbaceous Alliance)** **Salt marsh clubrush Herbaceous Alliance**	*Scirpus maritimus* Association (*Schoenoplectus maritimus* Association) Salt marsh clubrush Association	A.1444	SMA	E2EM1P5h	18
***Scirpus microcarpus* Herbaceous Alliance** **Red-tinge bulrush Herbaceous Alliance**	*Scirpus microcarpus* Association Red-tinge bulrush Association	A.2619	SCI	PEM1F6h	16
***Spartina densiflora* Herbaceous Alliance** **Humboldt cordgrass Herbaceous Alliance**	*Spartina densiflora* Association Humboldt cordgrass Association		SPA	E2EM1P5h	13
***Spergularia marina* Herbaceous Alliance** **(*Spergularia salina* Herbaceous Alliance)** **Salt marsh sand spurrey Herbaceous Alliance**	*Spergularia marina* Association (*Spergularia salina* Association) Salt marsh sand spurrey Association		SPE	PEM2C5h or E2EM2P5h	9
***Typha latifolia* Herbaceous Alliance** **(*Typha* (*angustifolia*, *latifolia*) - (*Schoenoplectus* spp.) Herbaceous Alliance)**	*Typha latifolia* Association	A.1436	TYP	EEM1F6h	18

2. Correlation Analysis

Results of the correlations performed for all variables in the environmental matrix (both vegetation measurement and soil variables) are shown in Table 5a-c. Significant correlations between the percent cover of dominant species of alliances with environmental variables are summarized in Table. 6.

3. Analysis of Variance

One-way Analysis of Variance was performed for the soil variables moisture, elevation, Na, Mg, pH, Cl, B, and saturation to determine whether significant differences existed among vegetation types. ANOVAs for all variables except saturation (p=.33) were significant at p<01. Post-hoc tests (LSD multiple comparisons and Tukey HSD multiple range tests) were used to locate differences (p<.10). Fig. 8a - h displays the mean of each environmental variable ± 1 SE by alliance. Table 7a-g lists homogeneous subsets for each variable for which more than one subset was distinguished (Cl was significant but had only one homogeneous subset).

Table 5a. Results of correlation of species vegetation cover class midpoints (species by species comparisons) for all plots in environmental subsample (Pearson's correlation coefficient, red = p≤.01, black p≤.05). Species codes provided in Appendix A.

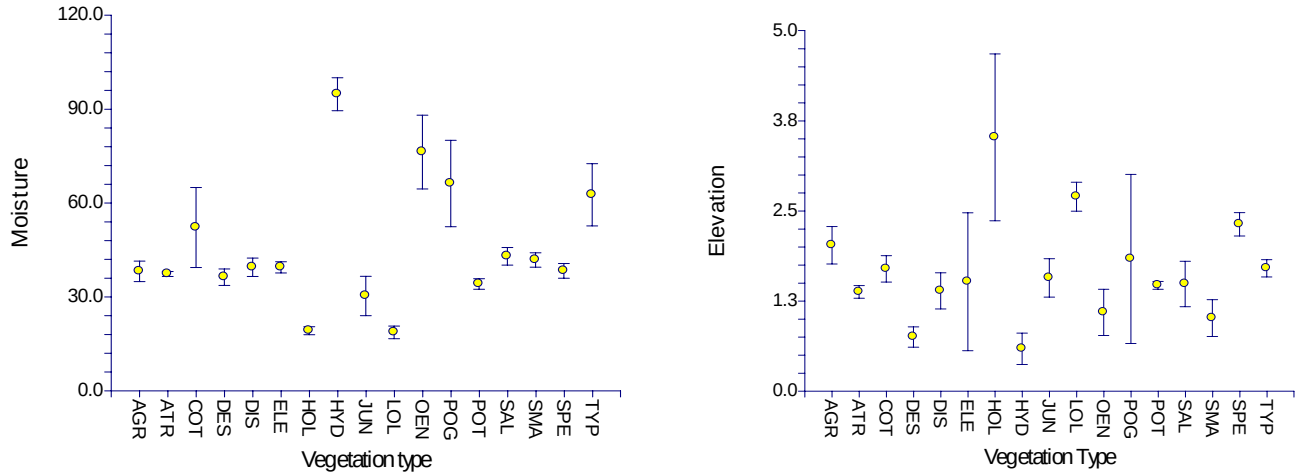
	ACH MIL	AGR STO	ALO AQU	ATR TRI	AZO SPP	BID CER	CHE FOL	CIR VUL	COT COR	DAC GLO	DAU CAR	DES CAE	DIS SPI	ELE MAC	EPI CIL	ERE GLO	FES ARU	GAL APA	GAL TRI	GER DIS	HOL LAN	HOR BRA	HOR MAR	
ACH MIL				.22																	.40	.44		ACH MIL
AGR STO						.30							-.20				.30							AGR STO
ALO AQU																							.54	ALO AQU
ATR TRI																								ATR TRI
AZO SPP																								AZO SPP
BID CER																								BID CER
CHE FOL																								CHE FOL
CIR VUL										.28		.23				.46	.32							CIR VUL
COT COR																					-.19			COT COR
DAC GLO																								DAC GLO
DAU CAR																					.20			DAU CAR
DES CAE																.51								DES CAE
DIS SPI														-.21								.25		DIS SPI
ELE MAC																								ELE MAC
EPI CIL																			.33					EPI CIL
ERE GLO																								ERE GLO
FES ARU																								FES ARU
GAL APA																								GAL APA
GAL TRI																								GAL TRI
GER DIS																					.27			GER DIS
HOL LAN																						.24		HOL LAN
HOR BRA																								HOR BRA

Table 5b. Results of correlation of species vegetation cover class midpoints (species by species comparisons) for all plots in environmental subsample (Pearson's correlation coefficient, red = p≤.01, black p≤.05). Species codes provided in Appendix A.

	HYD RAN	JAU CAR	JUN LES	JUN BUF	LEM MIN	LEO TAR	LOL MUL	LOT COR	OEN SAR	PAR STR	PIC ECH	POA PRA	POL MON	POT PEC	POT ANS	RAN REP	RUM CON	RUM CRI	RUM PUL	SAL VIR	SCI MAR	SCI PUN	SEN SYL	
ACH MIL																		.34						ACH MIL
AGR STO							.27																	AGR STO
ALO AQU				.30		.32	.36																	ALO AQU
ATR TRI																								ATR TRI
AZO SPP														.20										AZO SPP
BID CER				.44											.25									BID CER
CHE FOL															.35			.22						CHE FOL
CIR VUL																								CIR VUL
COT COR				.30									.36											COT COR
DAC GLO							.53			.32		.64												DAC GLO
DAU CAR											.37													DAU CAR
DES CAE		.36																					.61	DES CAE
DIS SPI										.30														DIS SPI
ELE MAC																								ELE MAC
EPI CIL									.24								.23						.27	EPI CIL
ERE GLO																		.22						ERE GLO
FES ARU																								FES ARU
GAL APA			.39																					GAL APA
GAL TRI																	.35						.29	GAL TRI
GER DIS								.53				.57			.42			.34	[illegible]					GER DIS
HOL LAN											.27	.32				.40		.30	.27					HOL LAN
HOR BRA																								HOR BRA
HOR MAR																								HOR MAR
HYD RAN					.37																.38			HYD RAN
JAU CAR																								JAU CAR
JUN LES																								JUN LES
JUN BUF																								JUN BUF
LEM MIN									.60															LEM MIN
LEO TAR							.60	.46																LEO TAR
LOL MUL								.38		.23														LOL MUL
LOT COR												.52							.53					LOT COR
OEN SAR																.21								OEN SAR
PAR STR																								PAR STR
PIC ECH												.64				.40		.23	.75					PIC ECH
POA PRA																.36			.57					POA PRA
POL MON																								POL MON
POT PEC																								POT PEC
POT ANS																		.33						POT ANS
RAN REP																			.43					RAN REP
RUM CON																								RUM CON
RUM CRI																			.34					RUM CRI
RUM PUL																				.36				RUM PUL
SAL VIR																								SAL VIR
SCI MAR																								SCI MAR
SCI PUN																								SCI PUN
SEN SYL																								SEN SYL

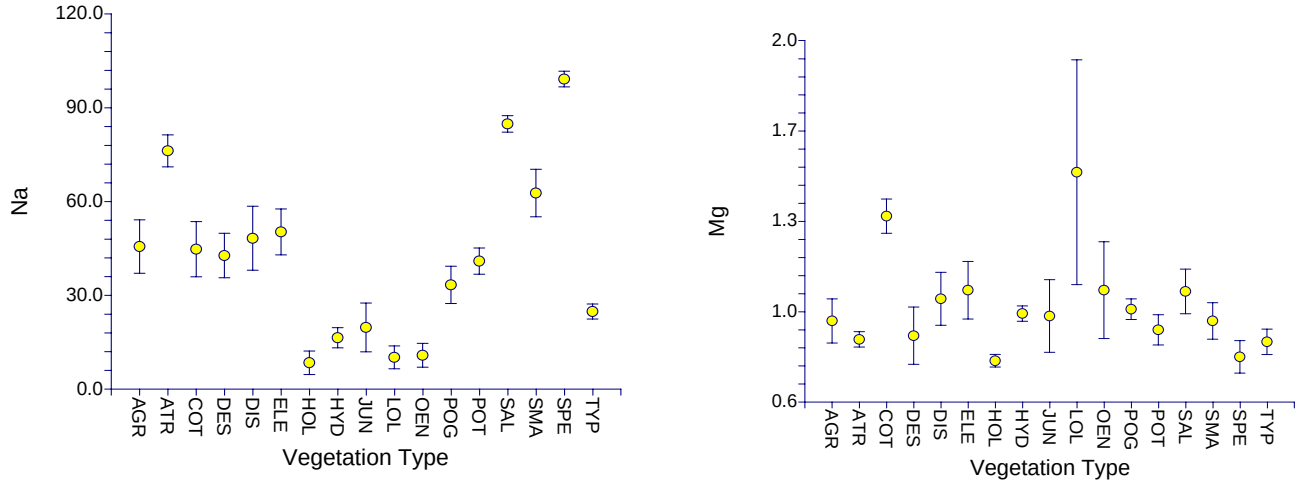
Table 5c. Results of correlation of species vegetation cover class midpoints (species by species comparisons and species by soil variable comparisons) for all plots in environmental subsample (Pearson's correlation coefficient, red = p≤.01, black p≤.05). Species codes provided in Appendix A.

	SON ASP	SON OLE	SPE MAR	TRI DUB	TRI REP	TRI MAR	TRI STR	TYP LAT	VIC SAT	MOISTURE	ELEV	SAR	ESP	NA	CA	MG	PH	HCO3	CONDUCTIV	CL	B	SATURATION	
ACH MIL	.32																						ACH MIL
AGR STO				.21															-.21		-.19		AGR STO
ALO AQU			.21																				ALO AQU
ATR TRI												.29	.09	.41	.36	.33	-.34		.28	.27	.25		ATR TRI
AZO SPP								.35															AZO SPP
BID CER																							BID CER
CHE FOL																							CHE FOL
CIR VUL	.66	.32			.20																		CIR VUL
COT COR			.44									.27	.27	.31		.25	-.21		.24		.23		COT COR
DAC GLO	.29				.48							-.23	-.24				.36	.34					DAC GLO
DAU CAR													-.20										DAU CAR
DES CAE		.37									-.20	.25											DES CAE
DIS SPI													.24						.26		.29		DIS SPI
ELE MAC																							ELE MAC
EPI CIL						.34	.34																EPI CIL
ERE GLO	.46	.70							.34														ERE GLO
FES ARU																							FES ARU
GAL APA																							GAL APA
GAL TRI								.35							-.20								GAL TRI
GER DIS					.35																		GER DIS
HOL LAN					.30				.22	-.32	.32	.41	-.42	-.44	-.36	-.38			-.35	-.24	-.41		HOL LAN
HOR BRA																							HOR BRA
HOR MAR																							HOR MAR
HYD RAN										.55	-.20	-.24	-.23	-.21						-.19		.23	HYD RAN
JAU CAR																							JAU CAR
JUN LES															-.19								JUN LES
JUN BUF			.41																				JUN BUF
LEM MIN							.40			.54				-.25	-.23	-.23			-.23			.21	LEM MIN
LEO TAR					.30				.36			-.24	-.25										LEO TAR
LOL MUL																							LOL MUL
LOT COR				.45	.47					-.23		-.24	-.23								-.20		LOT COR
OEN SAR							.22	.38		.44		-.34	-.34	-.32	-.27	-.25			-.25	-.25			OEN SAR
PAR STR																.22			.26		.27		PAR STR
PIC ECH					.38					-.20			-.19										PIC ECH
POA PRA					.50					-.27	.39	-.36	-.37	-.26			.28	.42	-.19		-.25		POA PRA
POL MON												.24		.34	.29				.27				POL MON
POT PEC										.22							.33						POT PEC
POT ANS												-.19		-.19	-.19								POT ANS
RAN REP					.21							-.26	-.27				.20						RAN REP
RUM CON						.54	.75	.23		.32													RUM CON
RUM CRI	.33	.34							.31	-.20													RUM CRI
RUM PUL																							RUM PUL
SAL VIR														.41	.58	.58	-.20		.64		.63		SAL VIR
SCI MAR											-.24	.27	.27	.23						.33		-.23	SCI MAR
SCI PUN										.40	-.20												SCI PUN
SEN SYL																							SEN SYL
SON ASP		.66			.21				.31														SON ASP
SON OLE									.50														SON OLE
SPE MAR												.24	.23	.38	.24	.30	-.19		.24				SPE MAR
TRI DUB					.51							-.23	-.23					.22					TRI DUB
TRI REP										-.29	.26	-.44	-.45	-.31		-.23			-.23		-.29		TRI REP
TRI MAR							.28	.22													.20		TRI MAR
TRI STR										.27													TRI STR
TYP LAT																							TYP LAT
VIC SAT										-.19													VIC SAT
MOISTURE											-.33											.22	MOISTURE
ELEV												-.26	-.27				.28				-.20		ELEV
SAR													.....	.75	.36	.47	-.32		.50	.45	.50		SAR
ESP														.75	.37	.47	-.32		.50	.46	.50		ESP
NA															.83	.91	-.49		.88	.60	.81	-.21	NA
CA																.96	-.32		.92	.53	.83	-.27	CA
MG																	-.46		.96	.57	.89	-.25	MG
PH																		.47	-.40	-.26	-.36		PH
HCO3																							HCO3
CONDUCT																				.57	.92	-.28	CONDUCT
CL																					.47	-.29	CL
B																							B
SATURATI																							SATURATI



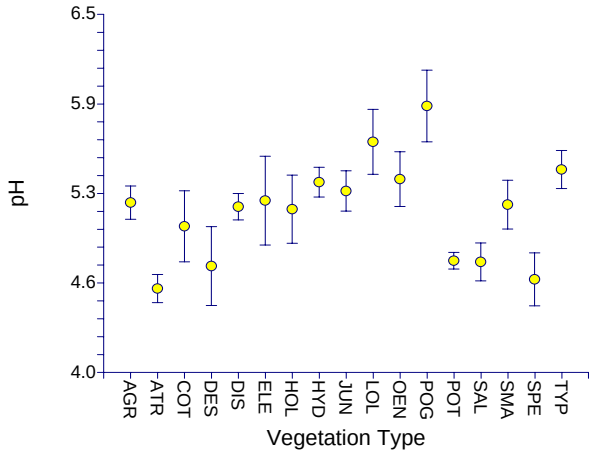
(a) (b)

Figure 8: Mean % moisture (a) and elevation in feet (b) ± SE by alliance (See Table 4 for alliance codes).

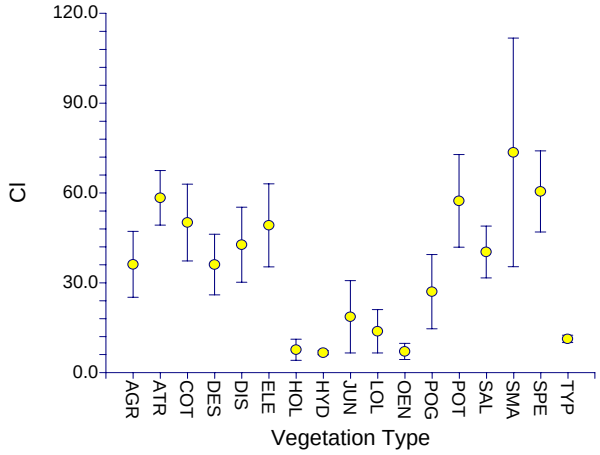


(c) (d)

Figure 8 cont'd: Mean Na in Meq/l (c) and Mg in Meq/l (d) ± SE by alliance (See Table 4 for alliance codes).

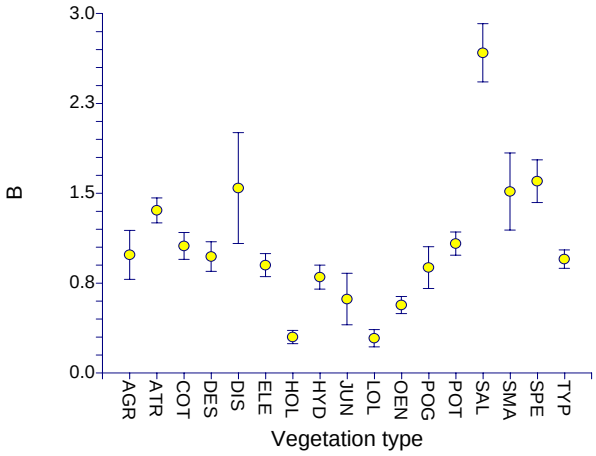


(e)



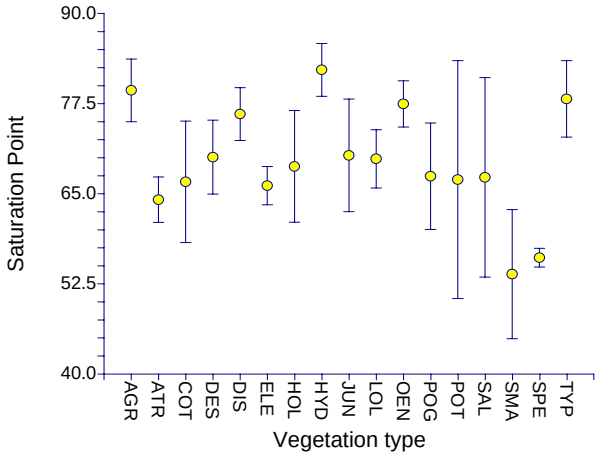
(f)

Figure 8 cont'd: Mean pH (e) and Cl in meq/L (f) ± SE by alliance (See Table 4 for alliance codes).



(g)

(c)



(h)

Figure 8 cont'd. Mean B in ppm (g) and % saturation point (h) ± SE by alliance (See Table 4 for alliance codes).

Table 6. Summary of significant correlations between cover of alliance dominants and environmental variables (p<.05).

Dominant Species	Moisture	Elevation	SAR	ESP	Na	Ca	Mg	pH	HCO3	EC	Cl	B
Agrostis stolonifera										-0.21		-0.19
Atriplex triangularis			0.29	0.09	0.41	0.36	0.33	-0.34		0.28	0.27	0.25
Cotula coronopifolia			0.27	0.27	0.31		0.25	-0.21		0.24		0.23
Deschampsia caespitosa		-0.2	0.25									
Distichlis spicata				0.24						0.26		0.29
Eleocharis macrostachya												
Holcus lanatus	-0.32	0.32	0.41	-0.42	-0.44	-0.36	-0.38			-0.35	-0.24	-0.41
Hydrocotyle ranunculoides	0.55	-0.2	0.24	-0.23	-0.21						-0.19	
Juncus lesueurii						-0.19						
Lolium multiflorum												
Lotus corniculatus	-0.23		-0.24	-0.23								-0.2
Oenanthe sarmentosa	0.44		-0.34	-0.34	-0.32	-0.27	-0.25			-0.25	-0.25	
Potamogeton pectinatus		0.22						0.33				
Potentilla anserina			-0.19		-0.19	-0.19						
Salicornia virginica					0.41	0.58	0.58	-0.2		0.64		0.63
Scirpus maritimus		-0.24	0.27	0.27	0.23						0.33	
Spergularia marina			0.24	0.23	0.38	0.24	0.3	-0.19		0.24		
Typha latifolia												

Table 7a. Mean % moisture for homogeneous subsets of alliances (See Table 4 for alliance codes = vegcode).

Student-Newman-Keuls [a,b]

VEGCODE	N	Subset for alpha = .10				
		1	2	3	4	5
LOL	10	18.6700				
HOL	5	19.1800				
JUN	6	30.3000	30.3000			
POT	5	34.1000	34.1000			
DES	7	36.3143	36.3143			
ATR	7	37.3143	37.3143			
AGR	7	38.1571	38.1571			
SPE	4	38.3000	38.3000			
DIS	7	39.4429	39.4429			
ELE	7	39.4857	39.4857			
SMA	7	41.7857	41.7857			
SAL	7	42.9571	42.9571			
COT	4		55.2750	55.2750		
TYP	6			62.6000	62.6000	
POG	5			66.2200	66.2200	
OEN	6				76.2500	
HYD	7					94.7286
Sig.		.152	.110	.390	.234	1.000

Table 7b. Mean elevation (ft) for homogeneous subsets of alliances (See Table 4 for alliance codes = vegcode).

Student-Newman-Keuls [a,b]

VEGCODE	N	Subset for alpha = .10		
		1	2	3
HYD	7	.5886		
DES	7	.7529	.7529	
SMA	7	1.0143	1.0143	
OEN	6	1.0933	1.0933	
ATR	7	1.3757	1.3757	
DIS	7	1.3914	1.3914	
POT	5	1.4680	1.4680	
SAL	7	1.4871	1.4871	
ELE	7	1.5114	1.5114	
JUN	6	1.5717	1.5717	
TYP	6	1.7050	1.7050	
COT	4	1.7525	1.7525	
POG	4	1.8350	1.8350	
AGR	7	2.0243	2.0243	
SPE	4	2.3150	2.3150	2.3150
LOL	10		2.6970	2.6970
HOL	5			3.5200
Sig.		.244	.108	.122

Table 7c. Mean Na (meq/l) for homogeneous subsets of alliances (See Table 4 for alliance codes = vegcode).

Student-Newman-Keuls [a,b]

VEGCODE	N	Subset for alpha = .10								
		1	2	3	4	5	6	7	8	9
HOL	5	8.460								
LOL	10	10.180	10.180							
OEN	6	10.850	10.850							
HYD	7	16.429	16.429							
JUN	6	19.750	19.750	19.750						
TYP	6	24.833	24.833	24.833	24.833					
POG	5		33.340	33.340	33.340	33.340				
COT	4			40.350	40.350	40.350	40.350			
POT	5			40.960	40.960	40.960	40.960			
DES	7			42.729	42.729	42.729	42.729			
AGR	7				45.600	45.600	45.600			
DIS	7				48.257	48.257	48.257			
ELE	7					52.014	52.014			
SMA	7						62.700	62.700		
ATR	7							76.214	76.214	
SAL	7								84.814	84.814
SPE	4									99.150
Sig.		.459	.115	.120	.138	.377	.178	.137	.342	.115

Table7d. Mean EC (dS/m)for homogeneous subsets of alliances (See Table 4 for alliance codes = vegcode).

Tukey HSD [a,b]

VEGCODE	N	Subset for alpha = .05			
		1	2	3	4
HOL	5	1.440			
LOL	10	1.640			
OEN	6	1.817			
HYD	7	2.571	2.571		
JUN	6	2.767	2.767		
TYP	6	3.217	3.217		
POG	5	5.120	5.120		
COT	4	6.375	6.375		
AGR	7	7.086	7.086		
ELE	7	7.357	7.357		
DES	7	7.586	7.586		
POT	5	8.220	8.220	8.220	
DIS	7	11.457	11.457	11.457	
SCA	7		12.343	12.343	
ATR	7		12.386	12.386	
SPE	4			18.125	18.125
SAL	7				26.400
Sig.		.078	.093	.086	.305

Table 7e. Mean Mg (meq/l) for homogeneous subsets of alliances (See Table 4 for alliance codes = vegcode).

Student-Newman-Keuls[a,b]

VEGCODE	N	Subset for alpha = .10		
		1	2	3
HOL	5	4.080		
JUN	6	4.950		
LOL	10	4.970		
OEN	6	5.083		
TYP	6	7.333		
HYD	7	9.000		
POG	5	13.200	13.200	
COT	4	13.275	13.275	
DES	7	13.443	13.443	
AGR	7	16.071	16.071	
ELE	7	19.943	19.943	
DIS	7	22.757	22.757	
POT	5	23.180	23.180	
SMA	7		28.700	
ATR	7		31.229	
SPE	4			45.650
SAL	7			54.014
Sig.		.146	.124	.194

Table 7f. Mean pH for homogeneous subsets of alliances
(See Table 4 for alliance codes = vegcode).

Student-Newman-Keuls [a,b]

VEGCODE	N	Subset for alpha = .10		
		1	2	3
ATR	7	4.586		
SPE	4	4.650		
DES	7	4.743	4.743	
SAL	7	4.771	4.771	
POT	5	4.780	4.780	
ELE	7	5.100	5.100	5.100
HOL	5	5.140	5.140	5.140
COT	4	5.150	5.150	5.150
DIS	7	5.157	5.157	5.157
SMA	7	5.171	5.171	5.171
AGR	7	5.186	5.186	5.186
JUN	6	5.267	5.267	5.267
HYD	7	5.329	5.329	5.329
OEN	6	5.350	5.350	5.350
TYP	6	5.417	5.417	5.417
LOL	10		5.610	5.610
POG	5			5.860
Sig.		.178	.119	.227

Table 7g. Mean B (ppm) for homogeneous subsets of alliances
(See Table 4 for alliance codes = vegcode).

Student-Newman-Keuls[a,b]

VEGCODE	N	Subset for alpha = .10			
		1	2	3	4
LOL	10	.290			
HOL	5	.300			
OEN	6	.567	.567		
JUN	6	.617	.617		
HYD	7	.800	.800	.800	
POG	5	.880	.880	.880	
ELE	7	.943	.943	.943	
TYP	6	.950	.950	.950	
DES	7	.971	.971	.971	
AGR	7	.986	.986	.986	
COT	4	1.025	1.025	1.025	
POT	5	1.080	1.080	1.080	
ATR	7		1.357	1.357	
SMA	7			1.514	
DIS	7			1.543	
SPE	4			1.600	
SAL	7				2.671
Sig.		.244	.217	.228	1.000

DISCUSSION

1. Classification

A number of the alliances identified in this study have been defined for other areas in California and elsewhere in the U.S. (Table 8). There are few local studies with which to compare the alliance types described here. Previous descriptions of palustrine wetlands have been based upon very localized areas such as the Elk River Wildlife Area. Although Stopher et al. (1981) did not carry out a classification, data were presented that support the *DESCHAMPSIA CAESPITOSA* Alliance. Eicher (1987) described a *Salicornia* and *Spartina* type that are comparable to the alliances described here, although hers were found in an estuarine system. *DISTICHLIS* as a separate alliance has not been previously described locally. The *CAREX OBNUPTA* type described by Newton (1989) was encountered in two plots in the study area. This type has also been described for the Table Bluff Unit of Humboldt Bay National Wildlife Refuge (Pickart 2005). Apparently, it is rare in the study area.

Of the 19 Alliances described, seven represent a first description for California (*AGROSTIS STOLONIFERA, HOLCUS LANATUS, HYDROCOTYLE RANUNCULOIDES, JUNCUS LESUERII, OENANTHE SARMENTOSA, POTENTILLA ANSERINA* (previously described only as a generic stand), and *SPERGULARIA MARINA*). A total of nine alliances described are new to the National Vegetation Classification System (*ATRIPLEX TRIANGULARIS, COTULA CORONOPIFOLIA, HOLCUS LANATUS, HYDROCOTYLE RANUNCULOIDES, JUNCUS LESUEURII, LOLIUM MULTIFLORUM,* and *SPERGULARIA MARINA*). Several of the alliances that are listed by NVCS fit poorly because they have been described for a different water regime or have different associated species than those described in this study. There are also taxonomic complications, e.g. the *ELEOCHARIS MACROSTACHYA* Alliance described here is equated with the *Eleocharis palustris* alliance in NVCS, however, *Eleocharis macrostachya* is now being treated by NVCS as a separate species.

Canada Goose nest, Hookton Slough Unit

Table 8. Alliances in this study that have been previously described.

Alliance Name This Study	Also Described for	Name	Citation
AGROSTIS STOLONIFERA Alliance	Montana, Colorado	*Agrostis stolonifera* Seasonally Flooded Herbaceous Alliance	NatureServe 2006
ATRIPLEX TRIANGULARIS Alliance	Suisun Marsh, California	*Atriplex triangularis* Alliance	California Department of Fish and Game 2000
COTULA CORONOPIFOLIA Alliance	Suisun Marsh, California	*Cotula coronopifolia* Alliance	California Department of Fish and Game 2000
LOLIUM MULTIFLORUM Alliance	Suisun Marsh, California	*Lolium multiflorum* Alliance	California Department of Fish and Game 2000
SCIRPUS MARITIMUS Alliance	Suisun Marsh, California	*Scirpus maritimus* Alliance	California Department of Fish and Game 2000
	California	Sedge Series	Sawyer and Keeler-Wolf 1995
	Western NA (potentially California)	*Schoenoplectus maritimus* Sermipermanently Flooded Herbaceous Alliance	NatureServe 2006
SCIRPUS MICROCARPUS Alliance	California	Sedge Series	Sawyer and Keeler-Wolf 1995
	North Coast, California	Small fruited bulrush Temporarily Flooded Alliance	NatureServe 2003
DESCHAMPSIA CAESPITOSA Alliance	California	Tufted hairgrass Series	Sawyer and Keeler-Wolf 1995
	SF and N. Coast, California	Tufted Hairgrass Alliance	NatureServe 2003
	Washington, British Columbia	*Deschampsia caespitosa* Tidal Herbaceous Alliance	NatureServe 2006
DISTICHLIS SPICATA Alliance	Suisun Marsh, California	*Distichlis spicata* Allilance	California Department of Fish and Game 2000
	North Coast, California	Saltgrass Alliance	NatureServe 2003
	California	Saltgrass Series	Sawyer and Keeler-Wolf 1995
	Washington, British Columbia	*Distichlis spicata* Tidal Herbaceous Alliance	NatureServe 2006
ELEOCHARIS MACROSTACHYA Alliance	San Benito/Fresno Cos., California	*Eleocharis macrostachya* Alliance	Evens et al. 2005
	California	Spikerush series	Sawyer and Keeler-Wolf 1995
	Western NA (potentially California)	*Eleocharis palustris* Seasonally Flooded Herbaceous Alliance	NatureServe 2006
POTAMOGETON PECTINATUS Alliance	California	Pondweeds with submerged leaves series	Sawyer and Keeler-Wolf 1995
	Suisun Marsh, California	*Potamogeton pectinatus* Association	California Department of Fish and Game 2000
	Mid US/Canada (potential California)	*Stuckenia pectinata* Permanently Flooded Herbaceous Alliance	NatureServe 2006
POTENTILLA ANSERINA Alliance	Suisun Marsh, California	*Potentilla anserina* stands	California Department of Fish and Game 2000
TYPHA LATIFOLIA Alliance	Suisun Marsh, California	*Typha angustifolia-latifolia-domingensis* Allaicne	California Department of Fish and Game 2000
	San Benito/Fresno Cos., California	*Typha latifolia* Association	Evens et al. 2005
	California	Cattail series	Sawyer and Keeler-Wolf 1995
	California and NA	*Typha (angustifolia, latifolia) - (Schoenoplectus* spp.) Semipermanently Flooded Herbaceous Alliance	NatureServe 2006
SPARTINA DENSIFLORA Alliance	Humboldt Bay, California	*Spartina* marsh	Eicher 1987
	Humboldt Bay, California	*Spartina* type	Newton 1989
	California	Cordgrass Series	Sawyer and Keeler-Wolf 1995
SALICORNIA VIRGINICA Alliance	Humboldt Bay, California	*Salicornia* marsh	Eicher 1987
	Suisun Marsh, California	*Salicornia virginica* Alliance	California Department of Fish and Game 2000
	North Coast, California	Pickleweed Alliance	NatureServe 2003
	California	Pickleweed Series	Sawyer and Keeler-Wolf 1995
	California	*Salicornia virginca* Tidal Herbaceous Alliance	NatureServe 2006

2. Environmental Influences on Vegetation

Salinity**.** The soil variable that most cleanly differentiated alliances was Na, reflecting the strong estuarine influence on these diked wetlands. Vegetation cleanly grouped into four homogeneous salinity classes based on Na (Table 7c). Electrical conductance within these four classes corresponds to conditions ranging from slightly brackish to subsaline (Stewart and Kantrud 1972) (Table 9). Multiple comparisons suggested finer scale groupings, based on the distinctiveness of each alliance (the number of alliances from which it was significantly different). A total of 8 groups were apparent, ranging from the pasture types *Holcus* and *Lolium* at the low end of the Na continuum to the subsaline types *Salicornia* and *Spergularia* at the high end (Table 10). Using conductivity (rather than Na) to distinguish classes resulted in only three homogeneous classes (Tables 7d and 11), falling within the oligohaline and mesohaline salinity modifiers described by the National Wetland Inventory (Cowardin et al. 1979). Chloride was less discriminating; only a single homogeneous subset was defined in the multiple range tests. However multiple comparisons suggest four groups of relatively Cl concentrations (Table 12). Chloride concentrations were particularly high (although variable) in the *SCIRPUS MARITIMUS* Alliance, and a positive correlation existed between cover of *S. maritimus* and Cl ($r=.33$, $p<.01$).

At the time of sampling the wetlands within the study area were brackish, although only the soils of the brackish and subsaline wetlands qualify as saline soils (conductivity >4 dS/m). These latter include the normally estuarine *SALICORNIA* Alliance, which exhibited the highest EC measurements, as well as the *SPERGULARIA* Alliance (highest Na). The *SCIRPUS MARITIMUS* and *ATRIPLEX* Alliances were distinctive from the other brackish types based on Na and to a lesser extent conductivity. The *SCIRPUS MARITIMUS* Alliance grows along the banks of old tidal creeks periodically receiving saline water as a result of leaky tide gates. The *ATRIPLEX* Alliance occurs in areas of late-season drying, causing concentrations of salts, including chloride. The more glycophytic wetlands, especially the pasture types *HOLCUS* and *LOLIUM,* but also the marsh types *OENANTHE, HYDROCOTYLE, JUNCUS*, and *TYPHA,* have a much lower tolerance to salinity. The dominant species of these and two of the brackish alliances (*POTENTILLA* and *AGROSTIS*) exhibit a small negative correlation with one or more of the salts present in soils (Table 6), indicating that they would likely thrive more in fresher water. Holcus has been shown in previous studies to exhibit sensitivity to soil salinity (Ashraf et al. 1986). Most likely, the salinity of these marshes during the early growing season (while rainfall is still occurring) is closer to fresh. Traditionally, the pasture types *HOLCUS*, *LOLIUM,* and *AGROSTIS* have been referred to as agricultural wetlands; the *OENANTHE, Hydrocotyle*, and *TYPHA* Alliances as freshwater marsh; and the *POTENTILLA, COTULA*, and *JUNCUS LESUEURII* Alliances as brackish (Newton 1989, Barnhart et al. 1992). This study reveals that any grouping of the more freshwater types should include the *JUNCUS LESUEURII* Alliance. Nomenclature based on salinity characteristics measured in this study is suggested for marshes in our area (Table 13). The term “saline” marsh is intended to distinguish palustrine saline marshes from estuarine “salt marsh.”

These results differ somewhat from the draft NCRS soil maps, which classify all of Hookton Slough as the Weott soil, and almost all of Salmon Creek as Arlynda. The soil mapping units are less finely discerned than the alliance types proposed here. One soil type could potentially support multiple alliances, and fine variation in soil types are lumped within a mapping unit. The classification of Hookton Slough Unit into the less saline Arlynda soil corresponds to the presence of freshwater runoff and the significant presence of the fresh to slightly brackish alliances. However, there are also large areas of brackish to subsaline wetlands. Similarly, the lumping of the Salmon Creek Units into

Table 9. Na-based salinity classification of alliances.

Na-based class (see Table 5c)		Stewart and Kantrud classification	
Alliance in homogeneous subset	Mean conductivity (dS/m)	Classification	Conductivity range (dS/m)
HOLCUS	1.440	Slightly brackish	0.8-2.0
LOLIUM	1.640		
OENANTHE	1.816		
HYDROCOTYLE	2.571	Moderately brackish	2.0-5.0
JUNCUS	2.766		
TYPHA	3.216		
POTAMOGETON	5.120	Brackish	5.0-15.0
COTULA	6.375		
POTENTILLA	8.220		
DESCHAMPSIA	7.588		
AGROSTIS	7.085		
DISTICHLIS	11.457		
ELEOCHARIS	7.357		
SCIRPUS MARITIMUS.	12.342		
ATRIPLEX	12.385		
SALICORNIA	26.400	Subsaline	15.0-45.0
SPERGULARIA	18.125		

Table 10. Groups suggested by results of multiple range and multiple comparisons for Na. (X = pairs are significantly different at p<.10).

		Lowest Na																Highest Na
Alliance	Na (meq/L)	*Holcus lanatus*	*Lolium multiflorum*	*Oenanthe sarmentosa*	*Hydrocotyle ranunculoides*	*Juncus lesueurii*	*Typha latifolia*	*Potamogeton pectinatus*	*Cotula coronopifolia*	*Potentilla anserina*	*Deschampsia caespitosa*	*Agrostis stolonifera*	*Distichlis spicata*	*Eleocharis macrostachya*	*Scirpus maritimus*	*Atriplex triangularis*	*Salicornia virginica*	*Spergularia marina*
Holcus lanatus	8.4						X	X	X	X	X	X	X	X	X	X	X	X
Lolium multiflorum	10.2						X	X	X	X	X	X	X	X	X	X	X	X
Oenanthe sarmentosa	10.9							X	X	X	X	X	X	X	X	X	X	X
Hydrocotyle ranunculoides	16.4							X	X	X	X	X	X	X	X	X	X	X
Juncus lesueurii	19.8								X	X	X	X	X	X	X	X	X	X
Typha latifolia	24.8	X	X							X	X	X	X	X	X	X	X	X
Potamogeton pectinatus	33.3	X	X	X	X									X	X	X	X	X
Cotula coronopifolia	40.4	X	X	X	X	X									X	X	X	X
Potentilla anserina	41.0	X	X	X	X	X	X								X	X	X	X
Deschampsia caespitosa	42.7	X	X	X	X	X	X								X	X	X	X
Agrostis stolonifera	45.6	X	X	X	X	X	X								X	X	X	X
Distichlis spicata	48.3	X	X	X	X	X	X								X	X	X	X
Eleocharis macrostachya	52.0	X	X	X	X	X	X	X								X	X	X
Scirpus maritimus	62.7	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Atriplex triangularis	76.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
Salicornia virginica	84.8	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Spergularia marina	99.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		

Table 11. Electrical conductance-based salinity classification of alliances.

EC-based class (see Table x)		Cowardin et al. classification	
Alliance in homogeneous subset	Mean conductivity (dS/m)	Classification	Conductivity range (dS/m)
HOLCUS	1.440	Oligohaline	0.8-8
LOLIUM	1.640		
OENANTHE	1.816		
HYDROCOTYLE	2.571		
JUNCUS	2.766		
TYPHA	3.216		
POTAMOGETON	5.120		
COTULA	6.375		
AGROSTIS	7.085		
ELEOCHARIS	7.357		
DESCHAMPSIA	7.585		
POTENTILLA	8.220		
DISTICHLIS	11.457	Mesohaline	8-30
SCIRPUS MARITIMUS	12.342		
ATRIPLEX	12.385		
SPERGULARIA	18.125		
SALICORNIA	26.400		

Table 12.Groups suggested by results of multiple comparisons for Cl (X = pairs are significantly different at p<.10).

		Low						Medium						High				Very High
Alliance	Cl (meq/L)	*Hydrocotyle ranunculoides*	*Holcus lanatus*	*Oenanthe sarmentosa*	*Typha latifolia*	*Lolium multiflorum*	*Juncus lesueurii*	*Potamogeton pectinatus*	*Deschampsia caespitosa*	*Agrostis stolonifera*	*Salicornia virginica*	*Distichlis spicata*	*Cotula coronopifolia*	*Eleocharis macrostachya*	*Potentilla anserina*	*Atriplex triangularis*	*Spergularia marina*	*Scirpus maritimus*
Hydrocotyle ranunculoides	6.6										X	X	X	X	X	X	X	X
Holcus lanatus	7.6											X		X	X	X	X	X
Oenanthe sarmentosa	7.1										X	X	X	X	X	X	X	X
Typha latifolia	11.2													X	X	X	X	X
Lolium multiflorum	13.8													X	X	X	X	X
Juncus lesueurii	18.6													X	X	X	X	X
Potamogeton pectinatus	27.0																	X
Deschampsia caespitosa	36.1																	X
Agrostis stolonifera	36.1																	X
Salicornia virginica	40.3	X		X														X
Distichlis spicata	42.7	X	X	X														
Cotula coronopifolia	45.8	X		X														
Eleocharis macrostachya	51.8	X	X	X	X	X	X											
Potentilla anserina	57.3	X	X	X	X	X	X											
Atriplex triangularis	58.3	X	X	X	X	X	X											
Spergularia marina	60.5	X	X	X	X	X	X											
Scirpus maritimus	73.5	X	X	X	X	X	X	X	X	X	X							

Table 13. Nomenclature suggested for marshes in the study area (* alliances not tested for soil variables in their presumed category).

Alliance Type	Marsh Nomenclature
HOLCUS	Agricultural Wetland (moist pasture)
LOLIUM	
OENANTHE	Fresh to Slightly brackish Marsh
HYDROCOTYLE	
JUNCUS	
*SCIRPUS MICROCARPUS**	
TYPHA	Brackish Marsh (or wet brackish pasture for *AGROSTIS*)
POTAMOGETON	
COTULA	
AGROSTIS	
ELEOCHARIS	
DESCHAMPSIA	
POTENTILLA	
DISTICHLIS	
SCIRPUS MARITIMUS	
ATRIPLEX	
SPERGULARIA	Saline Marsh
SALICORNIA	
SPARTINA *	

a single type ranging from 0-2 dS/m ignores the ecologically significant presence of the more saline vegetation types present. The completion of vegetation mapping for the refuge should provide valuable collateral data for the finalization of soil mapping.

Some of the brackish and saline wetlands fall within the Estuarine System of the National Wetland Inventory as infrequently flooded intertidal emergent wetlands. This would be the case wherever leaking tidegates or overtopped dikes results in sporadic tidal influence (Cowardin et al. 1979). Saline soils in the study area are the combined result of one or more of the following factors: sporadic direct tidal inundation, salt spray, and residual salts in soils. The latter two factors do not qualify the wetland as estuarine, but it is impossible to know the exact extent of influence of direct tidal inundation without detailed studies. A division of the classification into the Estuarine and Palustrine system is proposed based on a combination of measured Na levels and general knowledge of Humboldt Bay plant ecology. Generally, mesohaline brackish marshes were placed into the Estuarine system (Table14). Although the *DESCHAMPSIA* Alliance was measured as oligohaline, it was included based on the fact that it occurs at the edges of estuarine brackish and salt marshes in undiked systems, and it clustered with other estuarine alliances (conversely, the *SPERGULARIA* Alliance did not cluster with the other estuarine alliances despite its high salinity). The proposed division is coarse, and it is possible that mapping of alliances would not result in a clean boundary between estuarine and palustrine types. Because some mesohaline types also occurred in areas that appeared to be saline as a result of late evaporation rather than leaky tidegates, some of the alliances in the Estuarine System were also placed in the Palustrine system. This issue may be further clarified after mapping is completed.

Other cations were significant in discerning vegetation alliances, but were highly correlated with Na ($r>.80$, $p<.01$) and so were not useful in explaining additional variation. For the most saline alliances, Na had the highest correlation of any cation with

Table 14. Occurrence of alliances in the Estuarine and Palustrine Systems of the National Wetland Inventory (includes alliances for which soils were not analyzed).

Alliance	System: Estuarine	System: Palustrine
TYPHA LATIFOLIA		X
AGROSTIS STOLONIFERA		X
SCIRPUS MICROCARPUS		X
ELEOCHARIS MACROSTACHYA		X
HOLCUS LANATUS		X
HYDROCOTYLE RANUNCULOIDES		X
JUNCUS LESUEURII		X
LOLIUM MULTIFLORUM		X
OENANTHE SARMENTOSA		X
POTAMOGETON PECTINATUS		X
POTENTILLA ANSERINA		X
SPERGULARIA MARINA	X	X
ATRIPLEX TRIANGULARIS	X	X
COTULA CORONOPIFOLIA	X	X
DESCHAMPSIA CAESPITOSA	X	
DISTICHLIS SPICATA	X	
SPARTINA DENSIFLORA	X	
SALICORNIA VIRGINICA	X	
SCIRPUS MARITIMUS	X	

percent cover of the dominant species except for the *SALICORNIA* Alliance. Cover of *Salicornia virginica* over all samples was correlated more highly with Ca than Na (Table 6).

Moisture. Moisture was also useful in categorizing alliances, although only three distinct homogenous groups occurred (Table 7a). The two ends of the moisture gradient are represented by *HYDROCOTYLE* (significantly wetter than all other alliances) and *LOLIUM* (significantly drier than all but the *HOLCUS* and *JUNCUS* Alliances). The two drier homogeneous subsets had considerable overlap. However, the multiple comparisons suggest that the pasture types *LOLIUM* and *HOLCUS* (hereafter referred to as "moist" pasture) represent the driest conditions, closely followed by *JUNCUS* (Table 15). Without more prolonged water table monitoring the distinction between these groups can only be hypothesized. Using the National Wetland Inventory definitions of water regime, *HOLCUS* and *LOLIUM* are saturated, while *JUNCUS* can be saturated or seasonally flooded. *POTENTILLA, DESCHAMPSIA, ATRIPLEX, AGROSTIS, SPERGULARIA, DISTICHLIS, ELEOCHARIS, SCIRPUS MARITIMUS*, and *SALICORNIA* Alliances are intermediate in moisture regime and would qualify as seasonally flooded (or irregularly flooded if they occur in the Estuarine System). All were dry by the end of the growing season. *COTULA* was variable, occurring both in seasonal and semipermanent water regimes, *TYPHA*, *POTAMOGETON* and *OENANTHE* were significantly wetter than 12-13 of the 16 other alliances (Table 15). *TYPHA* and *OENANTHE* retained standing water through the summer, but in some years they dry up by the end of the summer in areas other than the spring-fed Hookton Slough Unit (Lewis, personal communication). These types would therefore qualify as either seasonally or semipermanently flooded. The *POTAMOGETON* Alliance was somewhat

peculiar in that the dominant species is a submergent, but some plots had no standing water at the time of sampling, and most were dry and the plants dead by October (Fig. 9).The species is tuberous and may be able to persist in a state of dormancy until the rainy season resumes. In some places, other species such as *Cotula* replaced *Potamogeton* later in the season. The *HYDROCOTYLE* Alliance had the deepest and most permanent standing water, meriting the intermittently exposed or permanent water regime modifier of the National Wetland Inventory

Table 15. Groups suggested by results of multiple comparisons for moisture. (X = pairs are significantly different at p<.10).

		Saturated		Saturated to Seasonal	Seasonally-flooded										Semi-permanently flooded			Permanently-flooded
Alliance	% Moisture	*Lolium multiflorum*	*Holcus lanatus*	*Juncus lesueurii*	*Potentilla anserina*	*Deschampsia caespitosa*	*Atriplex triangularis*	*Agrostis stolonifera*	*Spergularia marina*	*Distichlis spicata*	*Eleocharis macrostachya*	*Scirpus maritimus*	*Salicornia virginica*	*Cotula coronopifolia*	*Typha latifolia*	*Potamogeton pectinatus*	*Oenanthe sarmentosa*	*Hydrocotyle ranunculoides*
Lolium multiflorum	18.6				X	X	X	X	X	X	X	X	X	X	X	X	X	X
Holcus lanatus	19.1					X	X	X	X	X	X	X	X	X	X	X	X	X
Juncus lesueurii	30.3													X	X	X	X	X
Potentilla anserina	34.1	X												X	X	X	X	X
Deschampsia caespitosa	36.3	X	X											X	X	X	X	X
Atriplex triangularis	37.3	X	X											X	X	X	X	X
Agrostis stolonifera	38.2	X	X											X	X	X	X	X
Spergularia marina	38.3	X	X											X	X	X	X	X
Distichlis spicata	39.4	X	X											X	X	X	X	X
Eleocharis macrostachya	39.5	X	X											X	X	X	X	X
Scirpus maritimus	41.8	X	X												X	X	X	X
Salicornia virginica	43.0	X	X												X	X	X	X
Cotula coronopifolia	55.3	X	X	X	X	X	X	X	X	X	X						X	X
Typha latifolia	62.6	X	X	X	X	X	X	X	X	X	X	X	X					X
Potamogeton pectinatus	66.2	X	X	X	X	X	X	X	X	X	X	X	X					X
Oenanthe sarmentosa	76.3	X	X	X	X	X	X	X	X	X	X	X	X	X				X
Hydrocotyle ranunculoides	94.7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

pH. The soils of the study area tended to be acidic, with mean pH ranging from 4.6 - 5.8 (Table 7f). The least acidic soils were measured for the *POTAMOGETON* Alliance, and a positive correlation was found between *Potamogeton* cover and pH (r=.33 p<.01). The *LOLIUM* pasture type also had relatively high pH (5.6), and these soils have been limed at frequent intervals in the past at the refuge (Bachman et al. 2003). The lowest pH values occurred in the *SPERGULARIA* and late-emerging *ATRIPLEX* Alliances (pH=4.6). These were also the most saline types. Both occur in newly-scraped areas; the *SPERGULARIA* Alliance was exposed earlier and vegetation was present when sampling began in June, while the *ATRIPLEX* Alliance occurred in areas that were either flooded or consisted of exposed bare mud until August-September.

Figure 9a. *POTAMOGETON PECTINATUS* Alliance when sampled on July 17, 2005.

Figure 9b. Same area on Oct. 17, 2005, with *Potamogeton* dormant.

Elevation. Like moisture, elevation was a weak discriminator of alliance types based on homogenous subsets, suggesting a continuum along which alliances overlap. The multiple comparisons indicate that the high and low ends of the continuum are represented by the *HOLCUS LANATUS* and *HYDROCOTYLE RANUNCULOIDES* Alliances respectively (Table 16). *LOLIUM* is distinguished as higher than 11 other alliances; while at the low end, the *HYDROCOTYLE* Alliance was lower than nine other alliances. Elevation was significantly and negatively correlated with moisture (r = -.33). However, the fact that the correlation wasn't stronger and the ordering of alliances along these two axes was different demonstrates the influence of other factors, such as freshwater runoff, complicating the relationship.

Table 16. Results of multiple comparisons for elevation. (X = pairs are significantly different at p≤.10)

		High	Elev.	Intermediate				Elevation								Low	Elev
Alliance	Elevation (ft)	*Holcus lanatus*	*Lolium multiflorum*	*Spergularia marina*	*Agrostis stolonifera*	*Potamogeton pectinatus*	*Cotula coronopifolia*	*Typha latifolia*	*Juncus lesueurii*	*Eleocharis macrostachya*	*Salicornia virginica*	*Potentilla anserina*	*Distichlis spicata*	*Atriplex triangularis*	*Oenanthe sarmentosa*	*Scirpus maritimus*	*Deschampsia caespitosa*	*Hydrocotyle ranunculoides*
Holcus lanatus	3.52			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lolium multiflorum	2.69							X	X	X	X	X	X	X	X	X	X	X
Spergularia marina	2.31	X													X	X	X	X
Agrostis stolonifera	2.02	X														X	X	X
Potamogeton pectinatus	1.84	X																X
Cotula coronopifolia	1.75	X																X
Typha latifolia	1.71	X	X															X
Juncus lesueurii	1.57	X	X															X
Eleocharis macrostachya	1.51	X	X															X
Salicornia virginica	1.48	X	X															
Potentilla anserina	1.46	X	X															
Distichlis spicata	1.39	X	X															
Atriplex triangularis	1.38	X	X															
Oenanthe sarmentosa	1.09	X	X	X														
Scirpus maritimus	1.01	X	X	X	X													
Deschampsia caespitosa	0.75	X	X	X	X													
Hydrocotyle ranunculoides	0.59	X	X	X	X	X	X	X	X	X								

The extreme ends of the two continua are similar; the moist pasture types *HOLCUS LANATUS* and *LOLIUM MULTIFLORUM* are highest and driest, while *HYDROCOTYLE RANUNCULOIDES* Alliance is both lowest and wettest. However, elevation places the brackish *SCIRPUS MARITIMUS* and *DESCHAMPSIA CAESPITOSA* Alliances at the low end of the elevation spectrum, compared with the fresher *TYPHA, POTAMOGETON,* and *OENANTHE* Alliances at the low end of the moisture continuum. The latter are likely to occur in areas of freshwater runoff at either low or intermediate elevation. The *SCIRPUS MARITIMUS* and *DESCHAMPSIA* Alliances are uniquely low elevation for brackish marsh alliances and each seems to fit a particular niche. The *SCIRPUS MARITIMUS* Alliance occurs along scrapes and on the banks of former tidal sloughs, while the *DESCHAMPSIA* Alliance occurs in areas that are both close to dikes (and therefore possibly more subsided) and near tidal influence.

3. Relationship between invasive species, alliances, and soil variables.

The results of the study provided much-needed insight into the role of invasive plant species in diked marshes of the refuge. Prior to this study, only species-specific mapping of high priority species had been carried out (Walter and Clifford 2003, 2006; Clifford and Walter 2005). While these inventories have been extremely useful, allowing refuge staff and volunteers to streamline eradication efforts, they lack the ecological information needed to fully evaluate invasive species impacts and guide management.

Of the 19 alliances described in this study, six (or almost one third) have a non-native species as their dominant/diagnostic species (Table 17). In addition, two of the native alliances have associations dominated by an invasive species. In most cases, these alliances and associations represent single-species invasions that have altered the vegetation sufficiently to qualify as a vegetation type. Other invasive species occur in multiple types, representing either an earlier stage of invasion or a less aggressive invader. Most, but not all of the invaders that have resulted in alliance-level vegetation types have been recognized by the California Invasive Plant Pest Council (2006). The state-wide ranking assigned by Cal-IPC is not always locally appropriate, and a local rating for the study area is provided in Table 17.

The most alarming trend captured in this study is the geographic extent and ecological amplitude observed for the non-native species *Agrostis stolonifera* (spreading bentgrass). This species occurs as a dominant of its own alliance, as well as a constituent of every other alliance present in the study area. Its constancy in other alliances ranged from 8 to 77%, at modal cover values (based on midpoints of cover classes) ranging from 2-62% (Table 18). *Agrostis* exhibited a significant negative correlation with conductivity (r = - .21) and B (r = - .19). This species has previously been shown to be salt sensitive (Ashraf et al. 1986), although resistance varies by genotype (Kik 1989). However, the constancy of *Agrostis* in the saline alliance *SPERGULARIA MARINA* was 44% (albeit at low cover values). The *AGROSTIS* Alliance, in which the species is usually dominant, is characterized as brackish marsh (or wet brackish pasture), indicating that it is most competitive under these conditions. However, the fact that it is negatively correlated with conductivity, and significantly present in the less brackish, native alliance types *OENANTHE, HYDROCOTYLE*, and *JUNCUS* could possibly be an indication that it is invading these types and has not yet reached its maximum abundance.

Based on observations during the course of the study, it appears that *Agrostis stolonifera* is an aggressive species of wide environmental tolerance. It has a long growing season and was observed growing up through the seasonal die-off of other species, such as *Eleocharis*, in the fall (Fig. 10). Its vegetative growth form (stolons) may allow it to spread into areas that are initially less hospitable and then cause changes to soil and water characteristics, such as creating a thatch layer that buffers it from high salinities in underlying soils. *Agrostis stolonifera* has been shown to have a relatively high above-ground:below-ground biomass ratio, and a lower root biomass than *Lolium perenne* (Fustec et al. 2005). These traits contribute to the large thatch it produces. *Agrostis* was observed to be the primarily colonizer of newly “scraped” areas where clayey soils were exposed, despite the high salinities characteristic of these late evaporating areas (Fig. 11). In the 1960s “bentgrass” (presumably *Agrostis stolonifera*) was noted as a dominant of the agricultural wetlands surrounding Humboldt Bay (McLaughlin and Harradine 1965). However, there is little in the way of quantitative data to determine whether its current distribution represents a significant increase since that time. Focused research on the invasion ecology of this species in the Humboldt Bay area is a high priority.

Table 17. Invasive species present in the study area, their status, Cal-IPC (California Invasive Plant Council) listing, and a suggested rating for Humboldt Bay NWR (not inclusive of dune habitats). High Alert species highlighted in yellow.

Invasive species	Status in Alliance	Cal-IPC State Rating	Local Suggested Rating
Agrostis stolonifera	Dominant , constituent	Limited	High
Alopecurus pratensis	Constituent	Not listed	Moderate
Anthoxanthum odoratum	Constituent	Moderate	Moderate
Atriplex triangularis	Dominant, constituent	Not listed	Moderate
Chenopodium foliosum	Constituent	Not listed	Moderate
Cirsium vulgare	Constituent	Moderate	High
Cotula coronopifolia	Dominant, Constituent	Limited	Low
Dipsacus fullonum	Constituent	Moderate	Moderate
Erechtites minima	Constituent (minor)	Moderate	Low
Erechtites glomerata	Constituent	Moderate	High
Festuca arundinacea	Constituent (dominant in Associations)	Moderate	High
Geranium dissectum	Constituent	Limited	Low
Holcus lanatus	Dominant, Constituent	Moderate	High
Hordeum marinum	Constituent	Moderate	Low[1]
Leontodon taraxacoides	Constituent	Not listed	Moderate
Lolium multiflorum	Dominant, Constituent	Moderate	High
Lotus corniculatus	Constituent (dominant in Association)	Considered, not listed	High
Lotus uliginosus	Constituent (dominant in Association)	Not listed	High, Alert
Parentucellia viscosa	Constituent	Limited	Low
Parapholis strigosa	Constituent (dominant in Association)	Not listed	Moderate
Picris echioides	Constituent	Limited	High
Plantago lanceolata	Constituent	Limited	Low
Poa pratensis	Constituent	Limited	Low[1]
Polypogon monspeliensis	Constituent	Limited	Moderate[1]
Ranunculus repens	Constituent	Limited	Moderate[1]
Rumex acetosella	Constituent	Moderate	Low
Rumex conglomeratus	Constituent	Not listed	Moderate
Rumex crispus	Constituent	Limited	Low[1]
Rumex pulcher	Constituent	Not listed	Moderate
Senecio sylvaticus	Constituent	Not listed	High, Alert
Sonchus asper	Constituent	Considered, not listed	High
Sonchus oleraceus	Constituent	Not listed	Moderate
Spartina densiflora	Dominant , Constituent	High, Alert	High
Trifolium dubium	Constituent	Not listed	Low
Trifolium repens	Constituent	Not listed	Moderate

[1]Species would likely receive a higher rating in other parts of Humboldt Bay region, as opposed to in the study area.

Table 18. Occurrence of *Agrostis stolonifera* in all alliances. Cover values are %, and represent the midpoint of the cover class. Alliances highlighted in yellow are those with significant levels of both constancy and cover.

Alliance	*Agrostis* constancy	*Agrostis* minimum cover	*Agrostis* maximum cover	*Agrostis* modal cover
AGROSTIS STOLONIFERA	100	17	95	95
ATRIPLEX TRIANGULARIS	14	2	7	2
COTULA CORONOPIFOLIA	58	2	62	2
DESCHAMPSIA CAESPITOSA	46	2	17	7
DISTICHLIS SPICATA	57	2	82	7
ELEOCHARIS MACROSTACHYA	30	2	17	2
HOLCUS LANATUS	52	2	62	7
HYDROCOTYLE RANUNCULOIDES	54	2	17	17
JUNCUS LESUEURII	35	7	17	17
LOLIUM MULTIFLORUM	77	2	82	62
OENANTHE SARMENTOSA	56	2	82	17
POTAMOGETON PECTINATUS	14	2	2	2
POTENTILLA ANSERINA	64	2	62	7
SALICORNIA VIRGINICA	9	2	2	2
SCIRPUS MARITIMUS	56	2	62	2
SCIRPUS MICROCARPUS	56	2	62	7
SPARTINA DENSIFLORA	8	2	2	2
SPERGULARIA MARINA	44	2	2	2
TYPHA LATIFOLIA	50	2	62	2

Figure 10. *Agrostis* growing up through senesced *Eleocharis*, November 2005.

Figure 11. *Agrostis* colonizing an area of bare mud, Salmon Creek Unit (*Scirpus maritimus* in center).

The *Agrostis stolonifera - Festuca arundinacea Association* is another manifestation of the invasive *AGROSTIS* alliance. Not enough environmental samples were collected to distinguish abiotic variables that might be influencing the distribution of *Festuca arundinacea.* This large, tussock-forming grass causes thick, hummocky,

accumulations of thatch. Some areas were dominated by dead *Festuca* hummocks, perhaps due to increased flooding. The presence of this thatch may be detrimental to the establishment of native species.

Of the other invasives that dominate alliances, *Spartina densiflora* represents the greatest threat. The *SPARTINA* Alliance is currently of very limited extent in the diked marshes, but quite prevalent outside dikes in the salt marshes on the refuge and elsewhere in the bay, where *Spartina* is he dominant intertidal vascular plants species (Pickart 2001). The limited extent of the species is likely due to dispersal limitation, since tidal water is not freely being exchanged through tidegates. The species is expected to expand in the *SALICORNIA* and *DISTICHLIS* Alliances unless it is controlled. Given the small current range and high invisibility of this species, control should be a high priority.

The *COTULA CORONOPIFOLIA* and *ATRIPLEX TRIANGULARIS* Alliances, although dominated by invasive species, are both characteristic of disturbed habitats (including occasional saltwater immersion). The persistence of the *COTULA* Alliance in some areas, such as White Slough, is due to repeated flooding and saltwater inundation which continues to set back vegetation succession. The *ATRIPLEX TRIANGULARIS* Alliance is characteristic of newly scraped areas. Over time, it is expected to give way to native alliances, such as *POTENTILLA*. However, monitoring of these areas is recommended to confirm this expectation.

The moist pasture (agricultural wetland) alliances, *HOLCUS LANATUS* and *LOLIUM MULTIFLORUM*, are mostly confined to the hayed/grazed pastures that are maintained for geese habitat. As such, these areas are of minimal concern ecologically, except as a source of invasive propagules. *HOLCUS* invades other alliances and may constitute a serious threat. Where these alliances occur outside geese-managed areas, it is recommended that vegetation be managed to return species composition to native grasslands. The *DESCHAMPSIA CAESPITOSA* Alliance is a native alternative when salinities are appropriate. Another species to promote is *Leymus triticoides*. This species was found in portions of Hookton slough creating large clonal patches and would be a good target for replacement of *Lolium*, *Holcus* and *Festuca arundinacea.*

The *LOLIUM MULTIFLORUM* Alliance is also expressed as the *Lolium multiflorum - Lotus corniculatus Association*. Most of this alliance was concentrated in the hayed/grazed areas, although it was abundant in the newly created marshes south of the Headquarters building. This entire area should be monitored as it was created recently and is still exhibiting disturbed, early successional vegetation.

The native *DISTICHLIS SPICATA* Alliance is being invaded, particularly at White Slough, by the non-native grass *Parapholis strigosa*, forming its own association. This species has also been noted as invading salt marshes around Humboldt Bay (Gordon and Leppig 2005) and its congener *P. incurva* has been shown to have a negative impact on the rare salt marsh hemiparasite *Cordylanthus maritimus* ssp. *maritimus* by acting as a pseudo-host (Fellows and Zedler 2005).

A new discovery of this study was the widespread invasion of *Lotus uliginosus* in Hookton slough (Fig. 12). This species has not yet been considered by Cal-IPC for ranking. Growing as a taller, shrubbier plant than *L. corniculatus*, it also occurs in much

Figure 12. *Lotus uliginosus.*

wetter areas. As the dominant of an association, it was limited to Hookton Slough, but at least one population was observed at Salmon Creek Unit mixed in with *Lotus corniculatus*. Since it invades the native *POTENTILLA* Alliance, this species poses a serious ecological threat. Research is needed to investigate its ecology and potential control strategies.

A number of other highly ranked invasive species occur in the study area, but do not achieve dominance over large enough areas to be classified as alliance or association types. Although many of these occurred in multiple alliances, some trends were evident. The species *Sonchus asper, S. oleraceus, Erechtites glomerata, Dactylis glomerata*, and *Cirsium vulgare* tended to occur together, showing positive correlations. This group of invasives was found both in the pasture types (as expected) but also in the *DESCHAMPSIA CAESPITOSA* Alliance. Like *Lotus uliginosus, Senecio sylvaticus* was revealed through this study to be a major invasive species in brackish marshes, not previously considered by Cal-IPC. *Senecio* occurred in large patches in the Hookton Slough Unit, invading the *DISTICHLIS* Alliance, and may perhaps have qualified as an association or alliance if these had been sampled more adequately (Fig.13).

Figure 13. *Senecio sylvaticus* (with yellow flowers) dominating large areas of the Hookton slough Unit.

Another grouping of associated invasives, *Trifolium repens, Leontodon taraxacoides*, *Geranium dissectum,* and *Poa pratensis*, tended to be restricted to the non-native pasture types. Invasive *Rumex conglomeratus* showed a strong positive correlation with the native *Triglochin striatum* (r =.75), both occurred in the *Potentilla anserina - Lotus uliginosus* Association and the *SALICORNIA* Alliance. *Polypogon monspeliensis*, an invasive wetland grass, was positively correlated with *Cotula coronopifolia*, and occurred both in the *COTULA CORONOPIFOLIA* and *SALICORNIA VIRGINICA* Alliances.

4. Implications for estuary restoration and vegetation management

Until the mapping project is completed, determining relative abundances of vegetation types in Humboldt Bay National Wildlife Refuge can only be carried out qualitatively based on extensive field work. Of the three units, Hookton Slough had the highest quality fresh to brackish marshes, including a representative sample of all of the native vegetation types except *Spergularia*. The presence of the freshwater springs along the base of Table Bluff maintains persistent standing water that probably varies seasonally from fresh to brackish. As a result, there is rich and diverse mosaic of marsh types (and some unclassified swamp and riparian vegetation) on the unit. These included the relatively rare (on the refuge) alliances *POTAMOGETON PECTINATUS, HYDROCOTYLE RANUNCULOIDES* (and the *Hydrocotyle ranunculoides - Scirpus pungens* Association), and *OENANTHE SARMENTOSA*. The *TYPHA LATIFOLIA* Alliance is abundant in parts of the unit, but not as a monoculture. Instead, it represents a matrix in which are located numerous pockets of other vegetation, including permanent water suitable for nesting waterfowl. During field collection, many birds were encountered in this area, including nesting ducks and marsh wrens. Rails were observed on several occasions. Hookton slough also contained the largest expanse of the native grassland type *DESCHAMPSIA CAESPITOSA*, and several small stands of the native grass *Leymus triticoides*. Large stands of the native *DISTICHLIS* Alliance are of lesser wildlife value; however there are numerous pockets of salt marsh vegetation (*SALICORNIA VIRGINICA* Alliance), a type that is becoming rare in Humboldt Bay due to the expansion of *Spartina densiflora*.

In addition to these large areas of native alliances, there are also extensive stands of the non-native *AGROSTIS STOLONIFERA* Alliance (and the *Agrostis stolonifera - Festuca arundinacea* Association). Although *Agrostis* occurred in every alliance in the study area, it is limited both by salinity and permanent flooding. A focused study is needed on the ecophysiology and management of this species. Given the ability in the Hookton Slough Unit to manage both water levels and salinities, it seems feasible that this unit could be managed to maximize native vegetation and minimize non-native alliances.

A high priority for management in the Hookton Slough Unit is the invasive *Lotus uliginosus.* Although the infestation is large enough to have created its own association, it is not known to be widespread around Humboldt Bay, or elsewhere in California. As such, it should be treated as an Early Detection Rapid Response species. Control may be problematic given its tolerance of persistent water, but a focused study should result in control options.

Given the high quality of vegetation on Hookton slough Unit, it should probably be placed at a higher priority for invasives species management than the Salmon Creek Unit. The invading *Senecio sylvaticus*, similar to *Lotus uliginosus*, represents a new invasion both locally and state-wide. Experimentation is needed to determine an effective control strategy. Other weeds such as *Cirsium vulgare* and *Picris echioides* can be targeted as single-species eradication efforts. There is a small infestation of *Phragmites australis* that needs immediate control.

The White Slough Unit contained very little native vegetation other than the *DISTICHLIS SPICATA* Alliance, which is being invaded by non-native *Parpholis strigosa*. Given the relatively small size of this unit, the absence of biodiverse vegetation, and the availability of freshwater runoff (currently being diverted directly into the slough), this unit would be an ideal site for a demonstration estuary restoration project. The current elevations on the unit would likely support mostly mudflat if dikes were simply breached. The small size makes this an ideal site for experimenting with the use of fill to raise elevations. Fill might come in part from existing dikes or form the creation/enhancement

of tidal channels. The excavation of tidal channels has been shown to jump start salt marsh drainage system development on a restored tidal estuary (Wallace et al. 2005). However, tidal channel presence is also positively correlated with *Spartina densiflora* presence (Falenski unpublished data), so any such experiment should include a *Spartina* control component.

The Salmon Creek Unit is the largest unit and contains a broad spectrum of vegetation types. Of note is the large area of *SALICORNIA VIRGINICA* Alliance in the Salmon Creek Overflow area. This alliance has been described for intertidal areas (Claycomb 1983, Eicher 1987) but is becoming increasingly rare in the Bay due to the continued spread of *Spartina densiflora* (Pickart 2001). Although the overflow area does not function as a tidal marsh, the vegetation it supports can be considered rare and declining in Humboldt Bay. Current plans to flood the overflow as a part of the restoration of the lower reaches of Salmon Creek (Love and Farro 2003) should address the impacts of this loss. Also, a bay-wide inventory of salt marsh alliances is needed in order to quantitatively evaluate the status of this vegetation type in Humboldt Bay.

Other parts of Salmon Creek Unit contain large expanses of non-native alliances. Native alliances present tend to be those that are more common on the refuge and elsewhere, including the *POTENTILLA ANSERINA* and *ELEOCHARIS MACROSTACHYA* Alliances. Again, much of the unit has undergone subsidence, so restoration to estuary would need to consider limited tidal amplitudes or filling to raise elevations. However, from the point of view of vegetation, much of the unit would be appropriate for estuary restoration. Currently, management on the Salmon Creek Unit includes disking on occasion to reduce thatch buildup (Lewis, personal communication). Experiments begun in 2000 indicate that disking has a short term (2-year) effect of increasing disturbance-stimulated exotics (*Atriplex triangularis, Cotula coronopifolia*) and native (*Spergularia marina*) species, and decreasing the native perennials *Eleocharis macrostachya* and *Alopecurus aequalis* (Figures 13-14). *Potentilla anserina* declined after disking but recovered quickly, and *Eleocharis* showed some recovery in the second year. These plots should be repeated in 2006 to determine long term response to disking, so that recommendations for management can be developed.

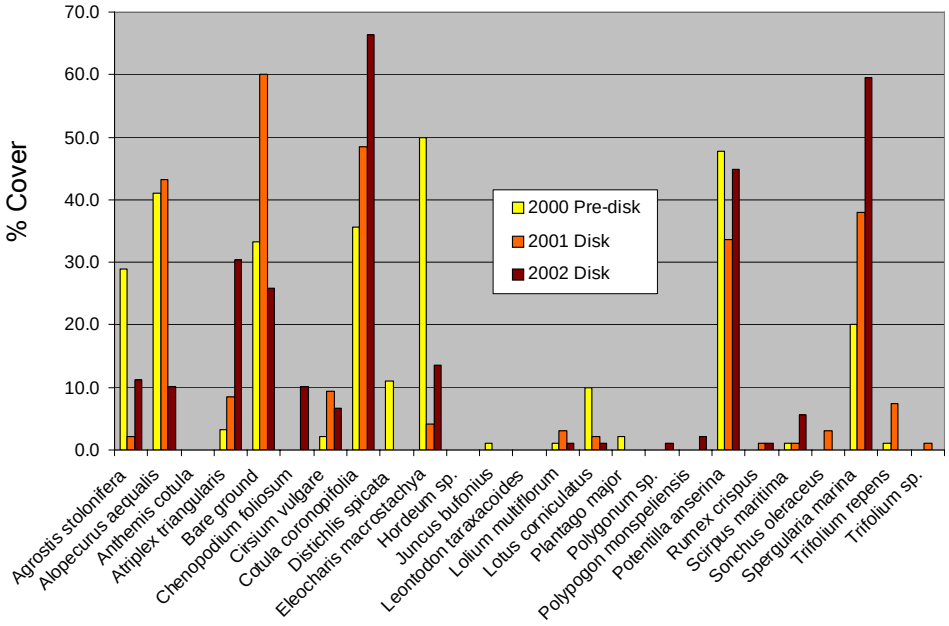


Figure 14. Two-year response by species (in treated plots) to disking in 2000 (USFWS unpublished data)

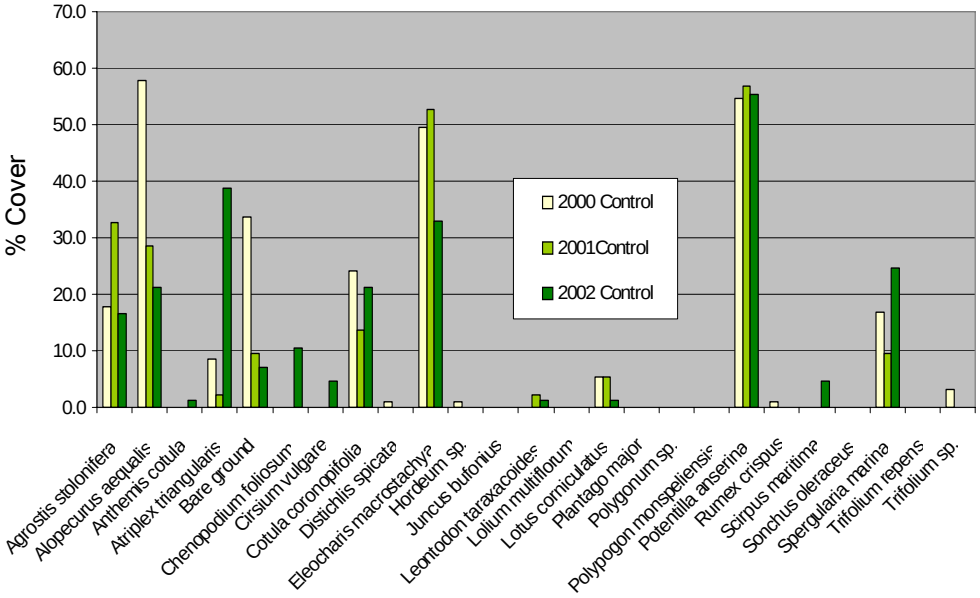


Figure 15. Two-year response by species (in control plots) to disking in 2000 (USFWS unpublished data)

The grazed pasture areas of the Salmon Creek Unit are dominated by non-native vegetation. This vegetation is deemed to be superior to native vegetation as forage for migrating geese and waterfowl (Bachman et al. 2003). Maintaining these areas of shortgrass pasture is an appropriate use for these higher elevation areas. However, it is recommended that further consideration be given to the species composition. There are several species present that are invading native alliances (e.g. *HOLCUS LANATUS*), and there is a severe invasive species problem (*Cirsium vulgare, Sonchus asper, Picris echioides*) that could be brought under control with a relatively modest effort and would prevent these species from spreading to other areas. In the long-term, it would be highly desirable to replace the non-native grasses with native coastal prairie species if they were palatable to geese. Although *Agrostis stolonifera* is an acid-tolerant species, addition of Ca, P, and lime has been shown to improve its growth in acid soils (Kuo 1993a,b). Since liming is currently being carried out in pasture areas, and is recommended as an annual treatment (Bachman et al. 2003), a focused study addressing species composition changes resulting from liming, grazing, haying, and their interaction is recommended. Time of grazing has been shown to be a significant interacting factor in tiller formation of *Agrostis stolonifera* (Bullock et al.1994). Fertilizer supplements have also been considered for pasture areas (Bachman et al. 2003). In addition to creating water quality problems, fertilizers would likely stimulate the invasive species present, and N is known to increase growth of *Agrostis stolonifera* (McCullough et al. 2005), this treatment is discouraged.

The Table Bluff Unit was not included in this study, but has been qualitatively surveyed, and the vegetation mapped (Pickart 2005). The Table Bluff Unit has the following alliances described in this study: *SPARTINA DENSIFLORA, DISTICHLIS SPICATA, JUNCUS LESUEURII*, and *HOLCUS LANATUS*. It also contains high quality examples of the *CAREX OBNUPTA* Alliance that occurred only in isolated locations on the rest of the refuge. In addition, it supports unique woody vegetation not yet classified. In prioritizing management efforts, this unit should be given a high priority for invasive species management (the *HOLCUS* Alliance is invaded by *Erechtites glomerata* and *Cirsium vulgare*). Ultimately, the *HOLCUS* Alliance will probably succeed to the *CAREX OBNUPTA and/or JUNCUS LESUEURII* Alliances, but management could accelerate this.

This study was limited to the vegetation of diked marshes. A more comprehensive sampling effort is needed around the bay to capture additional types, including intertidal salt marsh, riparian, swamps, and dune swales. Until we have an inventory of these vegetation types, it will be very difficult for the Scientific Advisory Committee for Estuary Restoration to carry out their goal of prioritizing areas for estuarine restoration. Also needed for that effort is fine scale topographic mapping for bay's palustrine wetlands.. Complementary studies are needed to tie these vegetation types to fisheries, bird, invertebrate and vertebrate wildlife use. Given past studies showing the high value of grazed and other palustrine wetlands to shorebird and other waterfowl use (Verhey 1992, Long and Ralph 2001, Leeman and Colwell 2005), it is imperative that we understand the impacts of wetland conversion that would accompany large scale estuarine restoration around the bay.

VEGETATION DESCRIPTIONS

The following definitions are used in defining species composition (after Evens et al. 2005):

Dominant/co-dominant: Species occurs in at least 80% of samples, with at least 30% relative cover in all samples.
Characteristic/diagnostic: Species present in at least 80% of samples, with no restriction on cover.
Abundant: Species present in at least 50% of samples, with an average of at least 30% relative cover in all samples.
Frequently occurring: Species present in at least 50% of samples, with no restriction on cover.

It should be noted that the range (min, max), and mode of cover values in species composition tables are based on cover classes and represent absolute and not relative cover. For this reason, it sometimes appears that cover values in the tables are lower than the minimum required for a given cover definition, such as "abundant." Constancy represents the percent of total plots in the alliance in which the species occurred. Species means are based on the midpoint of the cover class (again, reflecting absolute and not relative cover). Total cover mean, min, and max are continuous variables, thus no mode or constancy is recorded.

AGROSTIS STOLONIFERA Alliance
(Spreading bentgrass Alliance)

Alliance Description:

A dense, non-native grassland characterized by 100% total cover except where it is newly colonizing an open area such as a new scrape. Relative cover of *Agrostis stolonifera* > 60%, unless *Festuca arundinacea* or *Eleocharis macrostachya* present >40%. Frequently accompanied by variable cover of *Potentilla anserina*, low cover of *Holcus lanatus* (or by moderate to high cover of *Festuca arundinacea* in that Association). *Alopecurus aequalis* may be locally present at values of up to 30% relative cover. The alliance occurs in seasonally flooded areas of intermediate elevation and salinity (brackish marsh). At higher salinities (such as those resulting from leaking tide gates) it is replaced by the *DISTICHLIS SPICATA* Alliance; however the two may co-occur in a somewhat patchy fashion. The *AGROSTIS* Alliance is characterized by a thick layer of thatch.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	95.5	35	100		
Agrostis stolonifera	67.90	3	7	7	100
Potentilla anserina	13.39	1	6	4	67
Holcus lanatus	2.00	1	3	1	65
Festuca arundinacea	14.04	1	7	5	47
Eleocharis macrostachya	6.31	1	5	3	41
Cotula coronopifolia	1.08	1	2	1	29
Alopecurus aequalis	2.67	1	4	1	26
Rumex crispus	0.43	1	1	1	22
Hordeum brachyantherum	1.18	1	3	1	20
Atriplex triangularis	0.31	1	1	1	16
Juncus lesueurii	4.71	1	7	2	12
Lotus corniculatus	0.24	1	1	1	12

Agrostis stolonifera - Fesutca arundinacea Association
(Spreading bentgrass-Kentucky fescue Association)

Association Description:

A dense, non-native grassland characterized by a combination of tall *Festuca arundinacea* and underlying *Agrostis stolonifera* in varying amounts but together comprising 100% cover. Frequently accompanied by low to moderate cover of *Potentilla anserina* and *Holcus lanatus*. *Juncus leseurii* may occasionally co-occur at high cover values, creating a third height stratum. The association occurs in seasonally flooded brackish marshes of intermediate salinity and intermediate elevation. A thick layer of thatch underlies the association, and a hummocky topography is created by the *Festuca* tussocks.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	100	97	100		
Agrostis stolonifera	49.1	3	6	5	100
Festuca arundinacea	41.0	3	7	5	100
Potentilla anserina	11.4	1	4	4	53
Holcus lanatus	3.1	1	3	2	53
Hordeum brachyantherum	2.1	1	3	2	29
Rumex crispus	0.6	1	1	1	29
Juncus lesueurii	13.0	2	7	2	24
Eleocharis macrostachya	1.5	1	3	2	18
Cotula coronopifolia	0.9	1	2	2	18
Poa pratensis	0.6	1	2	1	18
Atriplex triangularis	0.4	1	1	1	18
Lotus corniculatus	0.4	1	1	1	18
Distichlis spicata	4.4	4	4	4	12
Lolium multiflorum	1.1	1	3	1	12
Lotus uliginosus	0.5	1	2	1	12
Alopecurus aequalis	0.2	1	1	1	12

Agrostis stolonifera Association
(Spreading bentgrass Association)

Association Description:

The *Agrostis stolonifera* Association differs from the parent alliance primarily by the lack of *Festuca arundinacea* (<5%). *Eleocharis macrostachya* also plays a larger role as a frequently occurring species. Total cover is 100% except where the association is newly colonizing an open area. Relative cover of *Agrostis stolonifera* > 60%, unless *Eleocharis* is present (then both > 40%). Frequently accompanied by variable cover of *Potentilla anserina. Alopecurus aequalis* may be locally present at values of up to 30% relative cover. The association occurs in seasonally flooded brackish marshes of intermediate elevation and salinity. The *Agrostis* Association is characterized by a thick layer of thatch.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	93.4	35	100		
Agrostis stolonifera	77.32	4	7	7	100
Potentilla anserina	14.41	1	6	1	74
Eleocharis macrostachya	8.71	1	5	3	53
Cotula coronopifolia	1.15	1	2	1	35
Alopecurus aequalis	3.88	1	4	1	32
Holcus lanatus	1.42	1	3	1	32
Festuca arundinacea	0.56	1	2	1	21
Rumex crispus	0.35	1	1	1	18
Hordeum brachyantherum	0.74	1	3	1	15
Atriplex triangularis	0.29	1	1	1	15
Scirpus maritimus	0.24	1	1	1	12

ATRIPLEX TRIANGULARIS Alliance
(Prostrate saltbush Alliance)

Alliance Description:

These herbaceous stands are dominated by the non-native *Atriplex triangularis* (=*A. prostrata*) sometimes creating extensive monocultures, but frequently accompanied by *Cotula coronopifolia* at low cover values. Total cover ranges from 45-100%, with low total cover occurring in newly colonizing areas. Species diversity is very low. *Spergularia marina* and *Potentilla anserina* are common but minor constituents. Occurring at relatively high salinities, this vegetation type constitutes an ephemeral and early successional seasonally-flooded brackish marsh of intermediate elevation in the study area.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	79.2	45	100		
Atriplex triangularis	70.8	4	7	6	100
Cotula coronopifolia	4.1	1	3	1	64
Spergularia marina	5.1	1	4	1	43
Potentilla anserina	1.6	1	2	1	43
Eleocharis macrostachya	0.6	1	1	1	29
Agrostis stolonifera	0.6	1	2	1	14

COTULA CORONOPIFOLIA Alliance
(Brassbuttons Alliance)

Alliance Description:

Total cover ranges from as low as 20% in newly colonizing areas to 100%. Non-native *Cotula coronopifolia* is dominant. *Atriplex triangularis*, *Potentilla anserina*, *Agrostis stolonifera,* and *Eleocharis macrostachya* frequently co-occur. The *COTULA CORONOPIFOLIA* Alliance occurs as seasonally to semipermanently flooded brackish marsh of moderate salinity and intermediate elevation in the study area. Like the *ATRIPLEX* Alliance, the *COTULA* Alliance is usually found in recently disturbed areas, although the *COTULA* Alliance emerges earlier and is more persistent.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	82.1	22	100		
Cotula coronopifolia	55.9	2	7	6	100
Atriplex triangularis	2.5	1	3	1	68
Potentilla anserina	20.0	2	6	3	67
Agrostis stolonifera	7.8	1	5	1	58
Eleocharis macrostachya	4.9	1	5	1	53
Chenopodium foliosum	1.6	1	4	1	31
Alopecurus aequalis	2.2	1	4	1	24
Distichlis spicata	0.7	1	2	1	21
Scirpus maritima	1.2	1	3	1	15
Spergularia marina	0.7	1	3	1	15

DESCHAMPSIA CAESPITOSA Alliance
(Tufted hairgrass Alliance)

Alliance Description:

Deschampsia is present at values of 60% cover and above. Native *Distichlis spicata* is frequently present at low to moderate cover values. Non-native *Holcus lanatus* is also frequent but low in cover. The invasive weeds *Cirsium vulgare, Lotus corniculatus, Erechtites glomerata*, *Picris echioides* and *Sonchus asper* are currently minor constituents that may pose a potential threat. Total cover is generally close to 100%. A native grassland present in seasonally flooded areas of moderate salinity and relatively low elevation, often near saline ditches or former tidal channels.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	98.6	90	100	100	
Deschampsia caespitosa	74.6	5	7	6	100
Distichlis spicata	11.4	2	4	2	69
Holcus lanatus	2.1	1	2	1	54
Agrostis stolonifera	8.9	1	3	2	46
Potentilla anserina	1.4	1	2	1	38
Cirsium vulgare	0.8	1	2	1	23
Lotus corniculatus	0.8	1	2	1	23
Salicornia virginica	0.8	1	2	1	23
Atriplex triangularis	0.4	1	1	1	23
Erechtites glomerata	0.4	1	1	1	23
Triglochin striata	0.4	1	1	1	23
Scirpus maritimus	1.0	2	2	2	15
Sonchus asper	0.6	1	2	1	15
Picris echioides	0.3	1	1	1	15
Sonchus asper	0.3	1	1	1	15

DISTICHLIS SPICATA Alliance
(Saltgrass Alliance)

Alliance Description:

Distichlis spicata is dominant, with *Atriplex triangularis* frequently occurring at low cover values. Total cover is usually high, with the clonal *Distichlis* creating extensive mats. An exception is in areas of locally high salinity, where bare mud is interspersed, or occasionally where high cover of *Agrostis stolonifera* intermixes with *Distichlis*. The *DISTICHLIS SPICATA* Alliance is common in formerly-grazed pastures where salt water is entering the system from leaking tidegates or overtopping of dikes. *Distichlis spicata* is sometimes dominant in estuarine marshes around the bay, occurring with non-native *Atriplex triangularis* (*A. prostrata*) as observed here. However, associated species in diked wetlands differ, particularly with respect to the commonly co-occurring non-native grass *Agrostis stolonifera,* indicating lower salinity than that found in estuarine marshes.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	94.02	35	100	100	
Distichlis spicata	73.74	4	7	6	100
Atriplex triangularis	0.76	1	1	1	63
Agrostis stolonifera	10.19	1	6	2	47
Potentilla anserina	2.81	1	4	1	35
Hordeum brachyantherum	2.69	1	4	1	33
Rumex crispus	0.52	1	1	1	26
Holcus lanatus	1.79	1	4	1	23
Sonchus asper	2.12	1	4	3	19
Galium triflorum	1.45	1	3	1	19
Cotula coronopifolia	0.74	1	3	1	19
Senecio vulgaris	0.74	1	2	1	19
Epilobium ciliatum	0.38	1	1	1	19
Oenanthe sarmentosa	1.00	1	3	1	16
Parapholis strigosa	6.48	3	6	4	14
Rumex conglomeratus	0.68	1	3	1	14
Lolium multiflorum	0.52	1	2	1	14
Sonchus asper	0.24	1	1	1	14

Distichlis spicata* - *Parapholis strigosa **Association**
(Saltgrass-Hairy sicklegrass Association)

Association Description:

This association is characterized by the presence of the diagnostic species *Parpaholis strigosa*, which occurs as a codominant with *Distichlis*. The sample size for this association is small (n=4). However, based on this sample it appears that species diversity is lower than in the overall alliance, with the majority of species present occurring in only one of the four samples. If this trend holds true over a larger sample size, it could indicate that the invasive *Parapholis* is limiting species diversity.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	100.0	100	100		
Distichlis spicata	80.6	5	7	6	100
Parapholis strigosa	51.0	4	6	4	100
Agrostis stolonifera	1.8	1	2	1	60
Lolium multiflorum	1.8	1	2	1	40
Atriplex prostrata	0.8	1	1	1	40
Cotula coronopifolia	0.8	1	1	1	40
Potentilla anserina	1.4	2	2	2	20
Eleocharis macrostachya	1.4	2	2	2	20
Spergularia marina	1.4	2	2	2	20
Trifolium wormskioldii	0.4	1	1	1	20
Lotus corniculatus	0.4	1	1	1	20
Polypogon monspeliensis	0.4	1	1	1	20
Holcus lanatus	0.4	1	1	1	20
Oenanthe sarmentosa	0.4	1	1	1	20

Distichlis spicata Association
(Saltgrass Association)

Association Description:

The *Distichlis spicata* Association differs from the *Distichlis spicata - Parpaholis strigosa* association in having more homogeneous cover of *Distichlis spicata,* and lacking *Parapholis*. No species other than *Distichlis* occurs with over 50% constancy. Total cover is usually high, with the clonal *Distichlis spicata* creating extensive mats. An exception is in areas of locally high salinity, where areas of bare mud are interspersed. The *Distichlis* Association occurs in seasonally flooded brackish marshes of intermediate salinity and elevation.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	93.2	35	100		
Distichlis spicata	72.8	4	7	6	100
Agrostis stolonifera	11.3	1	6	2	47
Potentilla anserina	3.3	1	4	3	37
Hordeum brachyantherum	2.9	1	4	1	37
Atriplex triangularis	0.7	1	1	1	37
Rumex crispus	0.6	1	1	1	29
Holcus lanatus	2.0	1	4	2	24
Sonchus asper	2.6	1	4	3	21
Galium triflorum	1.6	1	3	1	21
Senecio vulgaris	0.8	1	2	1	21
Epilobium ciliatum	0.4	1	1	1	21
Oenanthe sarmentosa	1.1	1	3	1	16
Cotula coronopifolia	0.7	1	3	1	16
Sonchus oleraceus	0.3	1	1	1	16
Rumex conglomeratus	0.8	1	3	1	11
Lolium multiflorum	0.3	1	2	1	11

ELEOCHARIS MACROSTACHYA Alliance
(Creeping spikerush Alliance)

Alliance Description:

Eleocharis macrostachya occurs at over 70% relative cover, although total cover may be as low as 20%. Species diversity is low, with only seven species occurring at more than 10% constancy, and none greater than 30% constancy. *Lemna minuscula*, although infrequent, is locally abundant in deeper areas. This native brackish marsh type occurs in seasonally flooded areas of intermediate salinity and elevation in the study area. Although *Eleocharis macrostachya* is common as a minor to moderate constituent of many of the alliances described, in this alliance it occurs only at high relative cover.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	67.0	20	100		
Eleocharis macrostachya	61.0	3	7	5	100
Lemna minuscula	6.9	1	6	1	30
Agrostis stolonifera	1.5	1	3	1	30
Potentilla anserina	0.5	1	1	1	26
Scirpus maritima	2.7	1	4	2	17
Potamogeton pectinatus	2.7	1	4	2	17
Cotula coronopifolia	0.3	1	1	1	13
Alopecurus aequalis	2.0	1	4	2	13

HOLCUS LANATUS Alliance
(Common velvet grass Alliance)

Alliance Description:

The non-native pasture grass *Holcus lanatus* is dominant, but cover may fall below 60% when *Ranunculus repens* is present at relatively high values. *Potentilla anserina* frequently co-occurs at moderate to high cover, and *Agrostis stolonifera* at low to moderate cover. *Ranunculus repens* and *Trifolium repens* both reach their maximum cover in the study area in this and the *LOLIUM* Alliance. *Trifolium* is often cultivated in local pastures, while *Ranunculus* is a common, non-native weed of local saturated wetlands.

Considered "agricultural wetland," the *HOLCUS LANATUS* Alliance occurs in saturated areas where the water table is near the surface but water rarely ponds during the growing season. Along with the *LOLIUM MULTIFLORUM* Alliance, this agricultural wetland is characterized by the lowest moisture levels, highest elevations, and lowest salinities in the study area. Both constitute farmed wetlands on the refuge, as they are grazed and/or hayed (albeit primarily to create favorable conditions for migrating geese).

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	99.1	85	100		
Holcus lanatus	68.6	3	7	5	100
Potentilla anserina	21.1	1	7	4	61
Agrostis stolonifera	11.9	1	5	2	52
Lolium multiflorum	4.1	1	3	3	44
Poa pratensis	2.6	1	3	2	44
Lotus corniculatus	2.3	1	3	1	39
Rumex crispus	1.4	1	3	1	39
Ranunculus repens	9.0	1	5	4	35
Trifolium repens	4.1	1	4	2	30
Alopecurus aequalis	0.4	1	1	1	22
Cirsium vulgare	0.3	1	1	1	17
Rumex pulchra	0.3	1	1	1	17
Vicia sativa	0.3	1	1	1	17
Hordeum brachyantherum	3.3	1	4	4	13
Plantago major	0.3	1	1	1	13

HYDROCOTYLE RANUNCULOIDES Alliance
(Floating pennywort Alliance)

Alliance Description:

The native *Hydrocotyle ranunculoides*, a clonal species, is dominant, unless *Scirpus pungens* is present at high cover values. The characteristic species *Lemna minuscula* co-occurs at low cover values. *Oenanthe sarmentosa* and *Agrostis stolonifera* frequently co-occur as relatively minor constituents. The *HYDROCOTYLE RANUNCULOIDES* Alliance is the wettest alliance of the study area, occurring in the relatively fresh (slightly brackish) marshes at the lowest elevation and most permanent water regime (semipermanent).

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	97.8	80	100	100	
Hydrocotyle ranunculoides	73.5	2	7	7	100
Lemna minuscula	4.8	1	3	2	85
Oenanthe sarmentosa	2.4	1	2	1	62
Agrostis stolonifera	6.5	1	3	3	54
Scirpus pungens	18.2	1	6	2	46
Cotula coronopifolia	1.4	1	2	2	31
Scirpus maritimus	0.8	1	2	1	23
Festuca arundinacea	0.5	1	1	1	23
Eleocharis macrostachya	1.5	1	3	1	15
Holcus lanatus	0.3	1	1	1	15
Potentilla anserina	0.3	1	1	1	15

Hydrocotyle ranunculoides - Scirpus pungens Association
(Floating pennywort - three-square bulrush Association)

Association Description:

The *Hydrocotyle ranunculoides - Scirpus pungens* contains the diagnostic native bulrush *Scirpus pungens*. Characteristic species include *Hydrocotyle ranunculoides* (its relative importance inversely proportionate to *Scirpus pungens*), *Agrostis stolonifera, Oenanthe sarmentosa*, and *Lemna minuscula*. The relatively large number of characteristic species is probably an artifact of the small sample size (n=4). Total cover ranges from 80-100%. Like the parent alliance, this association occurs in relatively fresh (slightly brackish) marshes at the lowest elevation and most permanent water regime (semipermanent).

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	99.0	80	100	100	
Scirpus pungens	58.3	2	6	6	100
Hydrocotyle ranunculoides	31.5	2	7	2	100
Agrostis stolonifera	17.0	1	3	3	100
Oenanthe sarmentosa	3.3	1	2	1	100
Lemna minuscula	2.0	1	3	1	100
Festuca arundinacea	1.0	1	1	1	50
Potentilla anserina	1.0	1	1	1	50
Eleocharis macrostachya	4.3	1	3	1	25
Juncus lesueurii	4.3	3	3	3	25
Holcus lanatus	0.5	1	1	1	25
Galium triflorum	0.5	1	1	1	25

Hydrocotyle ranunculoides Association
(Floating pennywort Association)

Association Description:

In the *Hydrocotyle ranunculoides* Association, *Hydrocotyle ranunculoides* is present at > 90% relative cover. *Lemna minuscula* is the only frequent associate. Like the parent alliance, this association occurs in relatively fresh (slightly brackish) marshes at the lowest elevation and most permanent water regime (semipermanent).

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	97.8	80	100	100	
Hydrocotyle ranunculoides	93.6	6	7	7	100
Lemna minuscula	5.4	1	3	2	77
Cotula coronopifolia	2.0	1	2	2	44
Oenanthe sarmentosa	1.4	1	2	1	44
Agrostis stolonifera	2.9	1	3	2	33
Scirpus maritimus	1.2	1	2	1	33
Scirpus pungens	1.0	1	2	1	22
Bidens cernuous	0.2	1	1	1	11
Eleocharis macrostachya	0.2	1	1	1	11
Festuca arundinacea	0.2	1	1	1	11
Potentilla anserina	0.2	1	1	1	11

JUNCUS LESUEURII Alliance
(Salt rush Alliance)

Alliance Description:

Cover of the dominant and diagnostic *Juncus lesueurii* is always greater than 60%, however, *Potentilla anserina* and *Holcus lanatus* are both frequent to abundant, overlapping with *Juncus* at cover values of up to 50-60%. Total cover is 100%. The saturated to seasonally-flooded J*UNCUS LESUEURII* Alliance occurs in slightly brackish marshes at intermediate elevations. *Juncus lesueurii* characteristically creates circular clones, sometimes resulting in pure stands.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	100.0	100	100		
Juncus lesueurii	91.8	5	7	7	100
Potentilla anserina	15.6	1	5	3	59
Holcus lanatus	4.1	1	4	1	59
Agrostis stolonifera	5.4	2	3	3	35
Eleocharis macrostachya	0.9	1	2	2	18
Galium triflorum	0.5	1	2	1	12
Hordeum brachyantherum	0.2	1	1	1	12
Oenanthe sarmentosa	0.2	1	1	1	12
Vicia sativa	0.2	1	1	1	12

LOLIUM MULTIFLORUM Alliance
(Italian ryegrass Alliance)

Alliance Description:
The non-native pasture grass *Lolium multiflorum* is dominant unless *Lotus corniculatus* or *Festuca arundinacea* are present at cover values equal to or greater than those of *Lolium*. *Agrostis stolonifera*, *Trifolium repens, Poa pratensis, Holcus lanatus*, and the invasive *Leontodon taraxacoides* are frequently present. *Alopecurus aequalis* is infrequent but may occur locally at high cover values (up to 90%). Total cover is 100%.

This alliance has the highest species diversity of any in the study area, but the majority of species are non-native, and include the highly invasive species *Cirsium vulgare, Picris echioides*, and *Sonchus asper*. Like the *HOLCUS LANATUS* Alliance, this vegetation type is termed "agricultural wetland." The *LOLIUM MULTIFLORUM* Alliance occurs in saturated areas where the water table is near the surface but water rarely ponds during the growing season. Along with the *HOLCUS* Alliance, this agricultural wetland is characterized by the lowest moisture levels, highest elevations, and lowest salinities in the study area. Both constitute farmed wetlands on the refuge, as they are grazed and/or hayed (albeit primarily to create favorable conditions for migrating geese).

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	100.0	100	100		
Lolium multiflorum	29.3	1	7	3	91
Lotus corniculatus	32.0	1	7	7	82
Agrostis stolonifera	20.3	1	6	5	77
Trifolium repens	11.5	1	5	2	69
Poa pratensis	3.2	1	3	2	64
Holcus lanatus	10.5	1	5	1	61
Leontodon taraxacoides	8.5	1	5	1	50
Alopecurus aequalis	4.8	1	6	1	45
Potentilla anserina	4.5	1	4	3	34
Cirsium vulgare	1.3	1	3	1	27
Festuca arundinacea	4.9	1	5	1	25
Sonchus asper	0.6	1	2	1	18
Trifolium dubium	0.6	1	2	1	18
Rumex crispus	0.4	1	1	1	18
Vicia sativa	0.4	1	2	1	16
Hordeum brachyantherum	0.8	1	3	1	14
Trifolium wormskjoldii	1.6	1	3	3	11
Eleocharis macrostachya	0.7	1	3	1	11
Hordeum maritimum	0.2	1	1	1	11

Lolium multiflorum - *Lotus corniculatus* Association
(Itlalian ryegrass - birds-foot trefoil Association)

Association Description:

In the *Lolium multiflorum - Lotus corniculatus* Association, invasive *Lotus corniculatus* is the diagnostic species, ranging from 10-100%, while *Lolium* becomes a frequently co-occurring species. *Agrostis stolonifera* is also frequent, and may reach cover values locally of 90%. Other frequently occurring species are *Trifolium repens, Alopecurus aequalis, Holcus lanatus, Poa pratensis*, and the *invasive Leontodon taraxacoides*. This Association occurs in saturated areas where the water table is near the surface but water rarely ponds during the growing season.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	100.0	100	100		
Lotus corniculatus	66.8	3	7	7	100
Agrostis stolonifera	24.3	1	6	3	78
Lolium multiflorum	8.8	1	4	3	78
Holcus lanatus	10.6	1	5	1	56
Trifolium repens	9.4	1	5	2	56
Alopecurus aequalis	7.2	1	6	1	56
Poa pratensis	3.3	1	3	2	56
Leontodon taraxacoides	8.5	1	4	1	50
Potentilla anserina	4.1	1	3	3	39
Trifolium wormskjoldii	3.9	1	3	3	39
Hordeum brachyantherum	1.9	1	3	2	28
Eleocharis macrostachya	1.3	1	3	1	22
Polypogon monspeliensis	3.7	1	5	1	17
Trifolium dubium	0.5	1	2	1	11
Rumex crispus	0.2	1	1	1	11

Lolium multiflorum - *Festuca arundinacea* Association
(Italian ryegrass - Kentucky fescue Association)

Association Description:

The *Lolium multiflorum - Festuca arundinacea Association* is characterized by the presence of *Festuca arundinacea* (>20%), and *Trifolium repens* (>5%) along with *Lolium multiflorum*. The sample size is small (n=4) making this association weakly defined. *Lotus corniculatus, Holcus lanatus*, and *Agrostis stolonifera* frequently co-occur. This Association occurs in saturated areas where the water table is near the surface but water rarely ponds during the growing season.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	100.0	100	100		
Festuca arundinacea	44.5	3	5	5	100
Trifolium repens	23.3	2	5	2	100
Lolium multiflorum	9.5	2	3	2	100
Poa pratensis	4.5	1	2	2	100
Lotus corniculatus	20.3	1	5	3	75
Holcus lanatus	15.3	2	4	3	75
Agrostis stolonifera	2.8	1	2	1	75
Cirsium vulgare	2.3	1	2	1	50
Potentilla anserina	1.0	1	1	1	50
Leontodon taraxacoides	1.8	2	2	2	25
Sonchus asper	1.8	2	2	2	25
Alopecurus aequalis	1.0	1	1	1	25
Hordeum maritimum	1.0	1	1	1	25
Picris echioides	0.5	1	1	1	25
Trifolium dubium	0.5	1	1	1	25
Ranunculus repens	0.5	1	1	1	25
Rumex crispus	0.5	1	1	1	25
Dactylis glomerata	0.5	1	1	1	25
Trifolium pratense	0.5	1	1	1	25

Lolium multiflorum Association
(Italian ryegrass Association)

Association Description:

In the *Lolium multiflorum* Association, *Lolium multiflorum* is dominant. However, *Agrostis stolonifera, Trifolium repens*, *Holcus lanatus,* and the invasive *Leontodon taraxacoides frequently* co-occur and may locally equal or exceed cover of *Lolium*. *Poa pratensis* is found frequently but at lower cover values. The highly invasive *Cirsium vulgare, Picris echioides*, and *Sonchus asper* occur with higher constancy than in the *Lolium multiflorum - Lotus corniculatus* Association and the alliance overall. Like the *LOLIUM* Alliance, the association occurs in agricultural wetlands with saturated soils and low salinity (slightly brackish). Total cover is 100%.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	100.0	100	100		
Lolium multiflorum	49.6	2	7	5	100
Agrostis stolonifera	20.2	1	5	4	77
Trifolium repens	11.0	1	5	2	72
Lotus corniculatus	5.7	1	4	2	68
Holcus lanatus	9.7	1	5	1	64
Poa pratensis	2.9	1	2	2	64
Leontodon taraxacoides	9.7	1	5	2	56
Cirsium vulgare	2.2	1	3	1	41
Alopecurus aequalis	3.5	1	4	1	36
Potentilla anserina	5.5	2	4	3	27
Festuca arundinacea	1.7	1	3	1	27
Sonchus asper	0.8	1	2	1	27
Vicia sativa	0.8	1	2	1	27
Picris echioides	1.4	1	3	1	23
Trifolium dubium	0.7	1	2	1	23
Rumex crispus	0.5	1	1	1	23
Rumex pulchra	0.3	1	1	1	14

OENANTHE SARMENTOSA Alliance
(Water-parsley Alliance)

Alliance Description:

The native species *Oenanthe sarmentosa* and *Potentilla anserina are* codominant and diagnostic species for this alliance. *Agrostis stolonifera, Lemna minuscula*, and *Eleocharis macrostachya* are frequent associates. Total cover ranges from 75-100%. The semi-permanently-flooded *OENANTHE SARMENTOSA* Alliance occurs in slightly brackish marshes at intermediate elevations in the study area.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	97.9	75	100	100	
Oenanthe sarmentosa	64.5	3	6	6	100
Potentilla anserina	17.9	4	5	2	81
Agrostis stolonifera	14.2	1	6	3	56
Lemna minuscula	13.6	2	5	2	56
Eleocharis macrostachya	13.6	1	5	1	56
Holcus lanatus	1.1	1	2	1	38
Rumex conglomeratus	1.9	1	3	1	31
Typha latifolia	4.4	3	4	3	19
Galium triflorum	1.7	1	3	2	19
Festuca arundinacea	0.7	1	2	1	19
Hydrocotyle ranunculoides	2.8	2	4	4	13
Scirpus pungens	1.5	2	3	2	13
Epilobium ciliatum	0.6	1	2	1	13

POTAMOGETON PECTINATUS Alliance
(Sago pondweed Alliance)

Alliance Description:
The dominant species, the submergent *Potamogeton pectinatus,* occurs at values of at least 50%. *Lemna minuscula* frequently co-occurs but contributes little to total cover, which ranges from 60-100%. *Eleocharis macrostachya* may also occur (up to 25%), especially near ecotones with the *ELEOCHARIS* Alliance.

The *POTAMOGETON PECTINATUS* Alliance is relatively rare in the study area. It occurs in seasonally to semipermanently flooded areas of fresh to slightly brackish water at variable elevations. This alliance has the lowest species diversity of any in the study area. This alliance was associated with relatively high soil pH values.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	85.7	60	100		
Potamogeton pectinatus	81.9	5	7	7	100
Lemna minuscula	0.9	1	1	1	43
Eleocharis macrostachya	2.4	3	3	3	20
Scirpus maritimus	8.9	5	5	5	14
Agrostis stolonifera	0.3	1	1	1	14
Azolla sp.	0.3	1	1	1	14
Cotula coronopifolia	0.3	1	1	1	14

POTENTILLA ANSERINA Alliance
(Silverweed Alliance)

Alliance Description:

Potentilla anserina is dominant, although *Eleocharis macrostachya*, *Alopecurus aequalis*, or the invasive *Lotus uliginosus* may exceed *Potentilla* cover locally. *Agrostis stolonifera* frequently co-occurs. Total cover ranges from 65-100%. This widespread native alliance occurs in seasonally flooded brackish marshes of intermediate salinity and elevation.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	94.53	65	100		
Potentilla anserina	52.68	1	7	4	100
Eleocharis macrostachya	23.89	1	7	4	70
Agrostis stolonifera	8.64	1	5	2	64
Alopecurus aequalis	10.60	1	6	8	49
Cotula coronopifolia	2.23	1	4	1	49
Atriplex triangularis	1.66	1	4	1	43
Rumex crispus	0.32	1	1	1	32
Chenopodium foliosum	0.34	1	2	1	21
Lolium multiflorum	0.40	1	2	1	15
Lotus corniculatus	0.15	1	1	1	15
Lotus uliginosus	4.94	1	7	4	11
Holcus lanatus	0.45	1	3	1	11
Rumex conglomeratus	0.36	1	2	1	11
Poa pratensis	0.23	1	2	1	11

Potentilla anserina - Alopecurus aequalis Association
(Silverweed - short-awn foxtail Association)

Association Description:

The *Potentilla anserina - Alopecurus aequalis* is dominated by the diagnostic native aquatic grass *Alopecurus aequalis*. *Potentilla anserina* is abundant, but doesn't exceed 75% cover. Like the *POTENTILLA* Alliance, this association occurs in seasonally flooded brackish marshes of intermediate salinity and elevation. The Alliance is relatively rare in the study area.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	94.0	65	100	100	
Alopecurus aequalis	41.5	2	6	5	100
Potentilla anserina	24.6	1	5	4	80
Agrostis stolonifera	21.9	2	5	2	70
Eleocharis macrostachya	6.3	1	4	2	40
Cotula coronopifolia	5.3	1	4	2	40
Polypogon monspeliensis	5.6	1	4	3	30
Rumex crispus	0.6	1	1	1	30
Atriplex triangularis	3.9	1	4	1	20
Hordeum brachyantherum	2.4	2	3	2	20
Lotus corniculatus	0.4	1	1	1	20
Lolium multiflorum	1.4	2	2	2	10
Leontodon taraxacoides	0.7	2	2	2	10
Scirpus cernuus	0.7	2	2	2	10
Holcus lanatus	0.2	1	1	1	10
Scirpus maritimus	0.2	1	1	1	10
Typha latifolia	0.2	1	1	1	10

Potentilla anserina - *Eleocharis macrostachya* Association
(Silverweed - creeping spikerush Association)

Association Description:

Potentilla anserina and *Eleocharis macrostachya* share dominance, with frequently co-occurring *Agrostis stolonifera, Cotula coronopifolia*, and *Atriplex triangularis*. These brackish marshes often occur in localized low areas (scrapes) within agricultural wetlands. They are seasonally flooded and of intermediate elevation and salinity (brackish marsh).

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	93.35	70	100		
Eleocharis macrostachya	57.24	3	7	4	100
Potentilla anserina	49.53	3	7	4	100
Agrostis stolonifera	7.41	1	4	2	71
Cotula coronopifolia	1.88	1	3	1	59
Atriplex triangularis	0.59	1	1	1	59
Rumex crispus	0.41	1	1	1	41
Alopecurus aequalis	3.65	1	3	1	35
Chenopodium foliosum	0.59	1	2	1	24
Lolium multiflorum	0.18	1	1	1	18
Lotus corniculatus	0.18	1	1	1	18
Distichlis spicata	3.18	3	4	3	12
Trifolium dubium	0.12	1	1	1	12

Potentilla anserina* - *Lotus uliginosus Association
(Silverweed-large bird's-foot trefoil Association)

Association Description:

The invasive *Lotus uliginosus* is dominant (over 25%) and diagnostic along with lesser *Potentilla anserina, Elocharis macrostachya* (< 25%) and *Rumex conglomeratus* (<10%). *Epilobium ciliatum* is a frequent associate at low cover values. Occasional localized *Juncus effusus* ssp. *pacificus*. This association was found only on the Hookton Slough Unit, in brackish mashes of intermediate elevation.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	100.0	100	100		
Lotus uliginosus	57.8	4	7	4	100
Eleocharis macrostachya	14.5	2	3	3	100
Potentilla anserina	14.5	2	3	3	100
Rumex conglomeratus	4.5	1	2	2	100
Epilobium ciliatum	1.5	1	1	1	75
Oenanthe sarmentosa	11.0	2	4	4	50
Juncus bolanderi	9.8	1	4	4	50
Agrostis stolonifera	3.5	2	2	2	50
Holcus lanatus	1.0	1	1	1	50
Lotus corniculatus	1.0	1	1	1	50
Juncus effusus ssp. *pacificus*	9.3	4	4	4	25
Triglochin striata	4.3	3	3	3	25
Poa pratensis	3.3	1	1	1	25
Juncus lesueurii	1.8	2	2	2	25
Alopecurus aequalis	0.5	1	1	1	25
Festuca arundinacea	0.5	1	1	1	25
Lolium multiflorum	0.5	1	1	1	25
Plantago lanceolata	0.5	1	1	1	25
Rumex crispus	0.5	1	1	1	25
Trifolium wormskioldii	0.5	1	1	1	25
Veronica americana	0.5	1	1	1	25

Potentilla anserina Association
(Silverweed Association)

Association Description:

In this Association *Potentilla anserina* always occurs at values over 50% (and usually over 90%), while *Eleocharis macrostachya and Alopecurus aequalis* are generally absent or present at no more than 5%. Otherwise, the association is similar to the parent alliance, with frequently co-occurring *Agrostis stolonifera, Cotula coronopifolia*, and *Atriplex triangularis*. The association is found in seasonally flooded brackish marshes of intermediate elevation and salinity.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	95.06	70	100		
Potentilla anserina	79.29	4	7	6	100
Agrostis stolonifera	2.76	1	3	1	56
Cotula coronopifolia	1.24	1	2	1	56
Atriplex triangularis	1.76	1	3	1	50
Eleocharis macrostachya	2.76	1	3	1	44
Chenopodium foliosum	0.35	1	1	1	38
Alopecurus aequalis	4.82	1	3	1	25
Rumex crispus	0.24	1	1	1	25
Holcus lanatus	1.06	1	3	1	13
Distichlis spicata	0.41	1	1	1	13
Juncus lesueurii	0.12	1	1	1	13

SALICORNIA VIRGINICA Alliance
(Virginia glasswort Alliance)

Alliance Description:

This alliance is relatively homogeneous, with *Salicornia virginica* dominant. *Distichlis spicata* frequently co-occurs, and minor constituents include *Atriplex triangularis, Cotula coronopifolia*, and *Triglochin striata*.

Soils underlying the *SALICORNIA* Alliance have the highest salinities measured in the study area. Technically termed "euhaline," these marshes are referred to as saline marshes to distinguish them from true intertidal *Salicornia* "salt marsh." *Salicornia* marshes occur at variable elevations in the study area. Although the *DESCHAMPSIA* Alliance occupies a lower mean elevation, the S*ALICORNIA* Alliance can sometimes found in created depressions at the lowest depth, with concentric outer zones of *Distichlis* and then *Deschampsia*. *Salicornia* is the last zone to dry out and concentrates salts.

The *SALICORNIA VIRGINICA* Alliance has been described for regularly flooded intertidal estuarine salt marshes, but not previously for diked marshes. In the study area, it occurs where leaking tidegates result in irregular seawater inputs. The *SALICORNIA* Alliance has been previously described for Humboldt Bay (Eicher 1987), but has become extremely limited as a vegetation type due to the continued expansion of invasive *Spartina densiflora*. *Spartina* is only a minor constituent of this alliance in the study area, probably because dispersal through tidegates is limited.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	80	22	100		
Salicornia virginica	58.8	3	7	7	100
Distichlis spicata	13.6	1	6	1	83
Atriplex triangularis	1.0	1	2	1	30
Cotula coronopifolia	5.5	1	5	1	26
Triglochin striatum	5.2	1	4	4	22
Deschampsia caespitosa	0.3	1	1	1	17
Polypogon monspeliensis	0.3	1	1	1	13
Spartina densiflora	0.6	2	2	2	10

SCIRPUS MARITIMUS Alliance
(Salt marsh clubrush Alliance)

Alliance Description:

Scirpus maritimus is dominant and diagnostic. *Eleocharis macrostachya* and *Agrostis stolonifera* are frequent components at low to moderate cover vales. The *SCIRPUS MARITIMUS* alliance occurs at intermediate elevations that are seasonally flooded but characterized by relatively high salinity. It is often the first species to colonize newly excavated areas that are receiving saline inputs, thus total cover in newly colonizing areas is as low as 45%. This alliance was associated with the highest Cl levels measured in the study area. The *SCIRPUS MARITIMUS* Alliance often occurs along the banks of former tidal ditches with leaking tidegates or in other areas where salt water is entering the system.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	80.2	45	100		
Scirpus maritimus	60.7	3	7	5	100
Eleocharis macrostachya	7.6	1	4	2	72
Agrostis stolonifera	16.1	1	5	1	56
Cotula coronopifolia	1.4	1	2	1	44
Lemna minuscula	5.1	1	6	1	33
Atriplex triangularis	0.7	1	2	1	22
Potentilla anserina	1.4	1	3	2	17
Distichlis spicata	0.8	2	2	2	11
Chenopodium foliosum	0.2	1	1	1	11
Spergularia marina	0.2	1	1	1	11
Typha latifolia	0.2	1	1	1	11

SCIRPUS MICROCARPUS Alliance
(Red-tinge bulrush Alliance)

Alliance Description:

This alliance is characterized by the dominant native, clonal species, *Scirpus microcarpus* (> 90%). *Potentilla anserina* is also characteristic at low to moderate cover values. *Agrostis stolonifera* frequently co-occurs at low to high cover. No environmental samples were taken for this alliance, however, it was observed to occur in seasonally flooded marshes, and was usually found adjacent to riparian areas. *Scirpus microcarpus* is a common understory component of riparian forests in the study area. However, the alliance was also found in areas that were near but not contiguous with riparian areas.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	100.0	100	100	100	
Scirpus microcarpus	90.9	6	7	7	100
Potentilla anserina	10.0	2	4	2	100
Agrostis stolonifera	8.0	1	5	2	56
Holcus lanatus	3.6	1	4	1	38
Oenanthe sarmentosa	2.7	1	3	3	25
Rumex conglomeratus	0.5	1	1	1	25
Atriplex triangularis	0.7	1	2	1	19
Ranunculus repens	3.4	3	4	3	13
Lotus uliginosus	1.2	1	3	1	13
Picris echioides	0.6	1	2	1	13
Juncus effusus	0.4	1	1	1	13
Polypogon monspeliensis	0.4	1	1	1	13
Rumex crispus	0.3	1	1	1	13

SPARTINA DENSIFLORA Alliance
(Humboldt cordgrass Alliance)

Alliance Description:

This alliance is characterized by low species diversity, with invasive *Spartina densiflora* the dominant and characteristic species. Total cover is high unless *Spartina* is newly colonizing a bare substrate. The only other species occurring with frequency is *Distichlis spicata*, common at low cover values as it fills the spaces between *Spartina* tussocks.

Although no environmental samples were taken for this alliance, it is clearly at the saline end of the spectrum and occurs in former tidal channels and other areas that receive salt water inputs from leaking tidegates. Although the *SPARTINA* alliance now dominates the tidal marshes of Humboldt Bay, it is relatively rare in the saline, diked marshes and eradication of the species is still quite feasible. The *SPARTINA DENSIFLORA* Alliance occurs in the estuarine salt marshes surrounding Humboldt Bay as well as in the diked wetlands of the study area.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	Min	Max	Mode	Constancy
Total cover	93	65	100	100	
Spartina densiflora	82.4	5	7	6,7	100
Distichlis spicata	4.9	1	3	1	54
Atriplex triangularis	2.7	1	3	2	39
Salicornia virginica	2.5	1	3	2	30
Scirpus maritimus	1.2	1	2	2	23

SPERGULARIA MARINA Alliance
(Salt marsh sand spurrey Alliance)

Alliance Description:

The *SPERGULARIA MARINA* Alliance occurs on seasonally flooded, newly scraped areas exposing mudflats of high salinity and is likely an ephemeral, early successional vegetation type. The dominant species is the native annual *Spergularia marina*, but the non-native *Cotula coronopifolia* is also characteristic. *Atriplex triangularis* (invasive) and *Potentilla anserina* (native) are frequent but of low cover. The *SPERGULARIA* Alliance was found on soils with the highest Na levels in the study area.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	90.8	80	100	100	
Spergularia marina	77.6	5	6	6	100
Cotula coronopifolia	30.1	1	6	2	90
Atriplex triangularis	3.2	1	3	1	78
Potentilla anserina	3.3	1	3	1	56
Eleocharis macrostachya	1.4	1	2	1	44
Scirpus maritimus	1.4	1	2	1	44
Agrostis stolonifera	0.9	1	1	1	44
Alopecurus aequalis	2.9	1	3	2	33
Polypogon monspeliensis	1.2	1	2	1	33
Chenopodium foliosum	7.7	2	5	2	22
Distichlis spicata	0.8	2	2	2	11
Juncus bufonius	0.8	2	2	2	11
Lotus uliginosus	0.2	1	1	1	11

TYPHA LATIFOLIA Alliance
(Broadleaf cattail Alliance)

Alliance Description:

Typha latifolia is dominant and diagnostic, occurring at high cover values (>50% cover). Frequent associates are *Lemna minuscula, Potentilla anserina,* and *Agrostis stolonifera*. The *TYPHA LATIFOLIA* Alliance occurs in semi-permanently flooded, slightly brackish marsh of intermediate elevations. In the study area, the *TYPHA LATIFOLIA* Alliance often occurs as a widespread matrix in which localized pockets of deeper water conditions support other alliances, including *HYDROCOTYLE, POTAMOGETON* and *OENANTHE*.

Species composition (species occurring with greater than 10% constancy). Mean cover of individual species is calculated from midpoint of cover classes.

	Mean	**Min**	**Max**	**Mode**	**Constancy**
Total cover	92.2	50	100	100	
Typha latifolia	70.5	5	7	5	100
Potentilla anserina	6.9	1	4	3	56
Lemna minuscula	20.2	1	6	4	50
Agrostis stolonifera	6.6	1	5	1	50
Oenanthe sarmentosa	9.6	2	4	4	33
Eleocharis macrostachya	4.6	1	4	3	33
Atriplex triangularis	1.9	1	3	2	28
Galium triflorum	1.0	1	2	1	22
Cotula coronopifolia	0.3	1	1	1	16
Rumex conglomeratus	1.1	1	3	1	11
Azolla sp.	0.5	1	2	1	11
Hordeum brachyantherum	0.1	1	1	1	11

CONCLUSIONS

- The study described 19 alliances and 27 associations. Seven alliances are newly described for California (*Agrostis stolonifera, Holcus lanatus, Hydrocotyle ranunculoides, Juncus lesuerii, Oenanthe sarmentosa, Potentilla anserina*, and *Spergularia marina*); ten alliances have not yet been included in the National Vegetation Classification System (*Atriplex triangularis, Cotula coronopifolia, Holcus lanatus, Hydrocotyle ranunculoides, Juncus lesueurii, Lolium multiflorum,* and *Spergularia marina*). There are additional native Alliances that occur outside the refuge that were not captured in this study, including the *Carex obnupta* (at Table Bluff Unit and not included in this study), *Juncus effusus* and *Carex lyngbei* Alliances.

- A complete, bay-wide classification and map of vegetation types (including dune, intertidal marsh, and riparian/swamp) is needed in order to prioritize restoration efforts.

- Additional research and information synthesis is needed to tie vegetation types to wildlife values.

- Nomenclature for the diked herbaceous wetlands of the refuge is suggested: agricultural wetland/moist pasture (*Holcus* and *Lolium* Alliances), fresh to slightly brackish marsh (*Oenanthe, Hydrocotyle, Scirpus maritimus* and *Juncus* Alliances), brackish marsh (*Typha, Potamogeton, Cotula, Agrostis, Eleocharis, Deschampsia, Potentilla, Distichlis, Scirpus maritimus,* and *Atriplex* Alliances), and saline marsh (*Salicornia, Spergularia* and *Spartina* Alliances).

- The diked herbaceous wetlands of the refuge fall into four hydrologic classes: saturated (*Holcus* and *Lolium* Alliances), seasonally flooded (*Juncus*, *Scirpus maritimus, Cotula, Agrostis, Eleocharis, Deschampsia, Potentilla, Distichlis, Scirpus maritimus,* and *Atriplex* Alliances, semipermanently flooded (*Oenanthe, Typha,* and *Potamogeton* Alliances), and permanently flooded (*Hydrocotyle* Alliance).

- The soils of the study area are acidic, with mean pH ranging from 4.6 - 5.8. The least acidic soils underlie the *Potamogeton* Alliance. The limed *Lolium* pasture type also had relatively high pH.

- The White Slough Unit is an ideal site to carry out a demonstration project for estuary restoration incorporating modification of elevation to facilitate appropriate vegetation.

- The Hookton Slough Unit contains diverse vegetation types, including relatively rare types and those of high wildlife value. This Unit is not considered appropriate for estuary restoration at this time, but is a high priority for invasives species management.

- The north-western Salmon Creek Unit contains a lower diversity of vegetation types, most of which are relatively common. From a vegetation perspective it would be

suitable for restoration in terms of sustaining impacts from vegetation conversion. However, current elevations may pose a challenge for re-establishing intertidal marsh.

- The Salmon Creek Overflow area supports significant stands of the *SALICORNIA VIRGINICA* Alliance, which has become rare in salt marshes around Humboldt Bay due to the spread of invasive *Spartina densiflora*.

- The agricultural wetlands of the refuge (grazed and hayed to produce shortgrass habitat for migrating geese) consist of stands of the moist pasture *LOLIUM MULTIFLORUM* and *HOLCUS LANATUS* Alliances interspersed with lower areas of seasonally flooded alliances. *Holcus* invades other alliances and may constitute a serious threat. Where these alliances occur outside geese-managed areas, it is recommended that vegetation be managed to return species composition to native grasslands including the *DESCHAMPSIA CAESPITOSA* Alliance and the native species *Leymus triticoides*. The moist pasture alliances have significant populations of highly ranked invasive species such as *Cirsium vulgare* which should be controlled both to improve pastures and to prevent their spread to other areas.

- The *AGROSTIS* Alliance is widespread on the refuge, and dominated by invasive *Agrostis stolonifera.* Agrostis stolonifera is an aggressive, stoloniferous species of wide environmental tolerances and poses a significant threat to the vegetation and biodiversity of the refuge. More focused research is needed on the ecology and control of this species.

- Two invasive species not previously ranked in the state have made major inroads into native vegetation: *Lotus uliginosus* and *Senecio sylvaticus*. Additional, focused research is needed on the ecology and control of these species.

- Of the other invasives that dominate alliances, *Spartina densiflora* represents the greatest threat. The *SPARTINA* Alliance is currently of very limited extent in the diked marshes, likely due to dispersal limitation. *Spartina* is expected to expand in the *SALICORNIA* and *DISTICHLIS* Alliances unless it is eradicated. Given the small current range and high invasibility of this species, its control should be a high priority.

- The *COTULA CORONOPIFOLIA* and *ATRIPLEX TRIANGULARIS* Alliances, although dominated by invasive species, are both characteristic of disturbed habitats and over time are expected to give way to native alliances, such as *POTENTILLA*. However, monitoring of these areas is recommended to confirm this expectation.

- Experiments from 2000-2003 suggest that *Cotula* and other disturbance-related species increase following disking. Continuation of this experiment will allow managers to conclude whether disking is a beneficial treatment.

- Invasive *Lotus corniculatus* was mostly confined to grazed areas supporting the *Lolium multiflorum - Lotus corniculatus Association*. However, the Association was abundant in the newly created marshes south of the Headquarters building. This entire area should be monitored as it was created recently and is still exhibiting disturbed, early successional vegetation.

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APPENDIX A. SPECIES LIST

Species	NVCS Common Name	Species Code	NVCS Synonyms	Status
Achillea millefolium L.	Common yarrow	ACH MIL		N
Agrostis stolonifera L.	Spreading bentgrass	AGR STO		E.I
Agrostis viridis Gouan	Beardless rabbit's-foot grass	AGR VIR	*Polypogon viridis* (Gouan) Breistr.	E
Alopecurus aequalis Sobol.	Short-awn foxtail	ALO AQU		N
Alopecurus geniculatus L.	Meadow foxtail	ALO GEN		N
Alopecurus pratensis L.	Meadow foxtail	ALO PRA		E,I
Anthoxanthum odoratum L.	Sweet vernal grass	ANT ODO		E,I
Aster chilensis Nees	Pacific American aster	AST CHI	*Symphyotrichum chilense* (Nees)	M
Atriplex triangularis Willd.	Creeping saltbush	ATR TRI	*Atriplex prostrata* Boucher ex DC	E,I
Azolla sp.	Mosquito fern	AZO SPP		N
Bidens cernua L. var. *cernua*	Nodding beggarticks	BID CER		N
Callitriche stagnalis Scop.	Pond water-starwort	CAL STA		E
Carex obnupta L. Bailey	Slough sedge	CAR OBN		N
Chenopodium foliosum (Moench) Asch.	Leafy goosefoot	CHE FOL		E, I
Cirsium vulgare (Savi) Ten.	Bull thistle	CIR VUL		E,I
Cotula coronopifolia L.	brassbuttons	COT COR		E
Cyperus eragrostis Lam.	Tall flatsedge	CYP ERA		N
Dactylis glomerata L.	Orchard grass	DAC GLO		E
Daucus carota L.	Wild carrot	DAU CAR		E
Deschampsia caespitosa (L.) Beauv. var. *holciformis* (C. Presel) W.E. Lawr.	Pacific hairgrass	DES CAE	*Deschampsia holciformis* - J. Presl	N
Dipsacus fullonum L.	Fuller's teasel	DIP FUL		E,I
Distichlis spicata (L.) E. Greene	Seashore saltgrass	DIS SPI		N
Eleocharis macrostachya Britton	Creeping spikerush	ELE MAC		N
Epilobium ciliatum Raf. ssp. *watsonii* (Barbey) P. Hoch & Raven	Fringed willowherb	EPI CIL		N
Equisetum telmateia Ehrh. ssp. *braunii* (Milde) R.L.Hauke	Giant horsetail	EQU TEL	*Equisetum telmateia* Ehrh. var. *braunii* (Milde) R.L.Hauke	N
Erechtites glomerata (Poiret) DC.	Cutleaf burnweed	ERE GLO		E,I
Erechtites minima (Poiret) DC.	Toothcoast burn	ERE MIN		E,I
Festuca arundinacea Schreber	Kentucky fescue	FES ARU	*Lolium arundinaceum* (Schreb.) S.J.	E,I
Galium aparine L.	Catchweed bedstraw	GAL APA		N
Galium triflorum Michaux	Sweet-scent bedstraw	GAL TRI		N
Geranium dissectum L.	Cutleaf crane's-bill	GER DIS		E
Holcus lanatus L.	Common velvet-grass	HOL LAN		E,I
Hordeum brachyantherum Nevski ssp. *brachyantherum*	Meadow barley	HOR BRA		N

APPENDIX A. SPECIES LIST

Species	NVCS Common Name	Species Code	NVCS Synonyms	Status
Hordeum marinum Hudson ssp. *gussoneanum* (Parl.) Thell.	knee barley	HOR MAR		E,I
Hydrocotyle ranunculoides L.f.	Floating pennywort	HYD RAN		N
Jaumea carnosa (Less.) A. Gray	Fleshy jaumea	JAU CAR		N
Juncus balticus Willd.	Baltic rush	JUN BAL		N
Juncus bolanderi Engelm.	Bolander's rush	JUN BOL		N
Juncus bufonius L.	Toad rush	JUN BUF		N
Juncus effusus L. var. *brunneus* Engelm.	Soft rush	JUN EFB		N
Juncus effusus L. var. *pacificus* Fern. & Wieg.	Soft rush	JUN EFP		N
Juncus lesueurii Bolander	Salt rush	JUN LES		N
Lemna minuscula Herter	Least duckweed	LEM MIN	*Lemna minuta* Kunth	N
Leontodon taraxacoides (Villars) Mérat ssp. *taraxacoides*	Lesser hawkbit	LEO TAR		E,I
Leymus triticoides (Buckley) Pilger	Beardless lyme grass	LEY TRI		N
Leymus xvancouverensis (Vasey) Pilger	Vancouver wild-rye	LEY XVA		N
Lolium multiflorum Lam.	Italian ryegrass	LOL MUL	*Lolium perenne* ssp. *multiflorum* (Lam.) Husnot	E,I
Lotus corniculatus L.	Bird's-foot trefoil	LOT COR		E,I
Lotus uliginosus Schk.	Large bird's-foot trefoil	LOT ULI	*Lotus pedunculatus* Cav.	E,I
Mimulus guttatus DC.	Common large monkeyflower	MIM GUT		N
Oenanthe sarmentosa J.S. Presel	Water-parsley	OEN SAR		N
Parapholis strigosa (Dumort) C.E. Hubb.	Hairy sicklegrass	PAR STR		E,I
Parentucellia viscosa (L.) Caruel	Yellow parentucellia	PAR VIS		E,I
Picris echioides L.	Bristly oxtongue	PIC ECH		E
Plantago lanceolata L.	English plantain	PLA LAN		E
Plantago major L.	Nipple-seed plantain	PLA MAJ		E
Poa pratensis L. ssp. *pratensis*	Kentucky bluegrass	POA PRA		E,I
Polygonum punctatum Elliot	Dotted smartweed	POL PUN		N
Polypogon monspeliensis (L.) Desf.	Annual rabbit's-foot grass	POL MON		E,I
Potamogeton pectinatus L.	Sago pondweed	POT PEC	*Stuckenia pectinata* (L.) Boerner	N
Potentilla anserina L. ssp. *pacifica* (Howell) Rousi	silverweed	POT ANS	*Argentina anserina*(L.) Rydb.	N
Ranunculus repens L.	Creeping buttercup	RAN REP		E,I
Raphanus raphanistrum L.	Wild radish	RAP RAP		E
Rumex acetosella L.	Sheep sorrel	RUM ACE		E,I
Rumex conglomeratus Murr.	Clustered green dock	RUM CON		E
Rumex crispus L.	Curly dock	RUM CRI		E,I

APPENDIX A. SPECIES LIST

Species	NVCS Common Name	Species Code	NVCS Synonyms	Status
Rumex pulcher L.	Fiddle dock	RUM PUL		E, I
Salicornia virginica L.	Virginia glasswort	SAL VIR		N
Scirpus cernuus (Roemer & Schultes) Vahl.	Low bulrush	SCI CER	*Isolepis cernua* (Vahl) Roemer & J.A.	N
Scirpus maritimus L.	Saltmarsh bulrush	SCI MAR	*Schoenoplectus maritimus* - (L.) Lye	N
Scirpus microcarpus C. Presl	Small-fruit bulrush	SCI MIC		N
Scirpus pungens Vahl	Three-square bulrush	SCI PUN	*Schoenoplectus pungens* (Vahl) Palla	N
Senecio sylvaticus L.	Woodland groundsel	SEN SYL		E,I
Senecio vulgaris L.	Old-man-in-the-spring	SEN VUL		E,I
Sonchus asper ssp. *asper* (L.) Hill	Spiny-leaf sowthistle	SON ASP		E,I
Sonchus oleraceus L.	Common sowthistle	SON OLE		E,I
Spartina densiflora Brongn.	Humboldt cordgrass	SPA DEN		E,I
Spergularia macrotheca (Hornem.) Heynh. var. *macrotheca*	Beach sandspurrey	SPE MAC		N
Spergularia marina (L.) Griseb.	Saltmarsh sandspurrey	SPE MAR	*Spergularia salina* J.& K. Presl	N
Trifolium dubium Sibth.	Suckling clover	TRI DUB		E,I
Trifolium pratense L.	Red clover	TRI PRA		E
Trifolium repens L.	White clover	TRI REP		E,I
Trifolium variegatum Nutt.	White-tip clover	TRI VAR		N
Trifolium wormskioldii Lehm.	Wormskjold's Clover	TRI WOR		N
Triglochin maritima L.	Common bog arrow-grass	TRI MAR		N
Triglochin striata Ruiz Lopez & Pavon	Three-ribbed arrow-grass	TRI STR		N
Typha latifolia L.	Broadleaf cattail	TYP LAT		N
Veronica americana (Raf.) Schein.	American speedwell	VER AME		N
Vicia sativa L. ssp. *nigra (*L.)	Narrow-leaved vetch	VIC SAT		E
Vicia tetrasperma (L.) Schreber	Lentil vetch	VIC TET		E

Appendix B. Key to alliances and associations, diked herbaceous wetlands of Humboldt Bay National Wildlife Refuge

A grass is dominant or shares dominance

Deschampsia caespitosa dominant.....*DESCHAMPSIA CAESPITOSA* Herbaceous Alliance

Distichlis spicata dominant or shares dominance with *Parapholis strigosa* .....*DISTICHLIS SPICATA* Herbaceous Alliance
- *Parapholis strigosa* > 25% relative cover.....*Distichlis spicata - Parapholis strigosa* Association
- *Parapholis strigosa* < 25% relative cover.....*Distichlis spicata* Association

Lolium multiflorum, Lotus corniculatus, Festuca arundinacea and/or *Agrostis stolonifera* dominant or co-dominant
- *Lolium multiflorum* or *Lotus corniculatus* > 10%.....*LOLIUM MULTIFLORUM* Herbaceous Alliance
  - Festuca arundinacea > 10%.....*Lolium multiflorum - Festuca arundinacea* Association
  - Festuca arundinacea < 10%.....*Lolium multiflorum* Association
- *Lolium multiflorum* <10%.....*AGROSTIS STOLONIFERA* Herbaceous Alliance
  - *Festuca arundinacea* > 25%.....*Agrostis stolonifera - Festuca arundinacea* Association
  - *Festuca arundinacea* < 25%.....*Agrostis stolonifera* Association

Holcus lanatus dominant.....*HOLCUS LANATUS* Herbaceous Alliance

Spartina densiflora dominant, or co-dominant with *Salicornia virginica* and/or *Distichlis spicata*.....*SPARTINA DENSIFLORA* Herbaceous Alliance

Typha latifolia dominant, or co-dominant with *Oenanthe sarmentosa, Agrostis stolonifera,* or *Eleocharis macrostachya*.....*TYPHA LATIFOLIA* Herbaceous Alliance

Alopecurus aequalis dominant, or shares dominance with *Potentilla anserina*.....*Alopecurus aequalis - Potentilla anserina* Association, *POTENTILLA ANSERINA* Herbaceous Alliance

Juncus or *Scirpus* dominant or shares dominance with *Potentilla anserina*

Juncus lesueurii dominant, or co-dominant with *Potentilla anserina*.....*JUNCUS LESUEURII* Herbaceous Alliance

Scirpus microcarpus dominant or codominant with *Potentilla anserina* .....*SCIRPUS MICROCARPUS* Herbaceous Alliance

Scirpus pungens dominant.....*Scirpus pungens - Hydrocotyle ranunculoides* Association, *HYDROCOTYLE RANUNCULOIDES* Herbaceous Alliance.

Other Herbs dominant or share dominance

Atriplex triangularis dominant, or co-dominant with *Chenopodium foliosum* and/or *Cotula coronopifolia*.....*ATRIPLEX TRIANGULARIS* Herbaceous Alliance

Cotula coronopifolia dominant.....*COTULA CORONOPIFOLIA* Herbaceous Alliance

Hydrocotyle ranunculoides dominant..... *HYDROCOTYLE RANUNCULOIDES* Herbaceous Alliance

Scirpus pungens >10%.....*Hydrocotyle ranunculoides - Scirpus pungens* Association

Scirpus pungens absent or <10%.....*Hydrocotyle ranunculoides* Association

Potamogeton pectinatus dominant, or co-dominant with *Eleocharis macrostachya*.....*POTAMOGETON PECTINATUS* Herbaceous Alliance

Spergularia marina dominant, or co-dominant with *Cotula coronopifolia* or *Atriplex triangularis*.....*SPERGULARIA MARINA* Herbaceous Alliance

Salicornia virginica dominant, or co-dominant with *Distichlis spicata* and/or *Cotula coronopifolia*.....*SALICORNIA VIRGINICA* Herbaceous Alliance

Eleocharis macrostachya > 70% relative cover.....*ELEOCHARIS MACROSTACHYA* Herbaceous Alliance

Oenanthe sarmentosa dominant, or co-dominant with *Potentilla anserina*.....*OENANTHE SARMENTOSA* Herbaceous Alliance

Potentilla anserina dominant, or co-dominant with *Alopecurus aequalis, Lotus uliginosus*, or *Eleocharis macrostachya*..... *POTENTILLA ANSERINA* Herbaceous Alliance

Lotus uliginosus > 25%.....*Potentilla anserina - Lotus uliginosus* Association

Lotus uliginosus < 25%.

Alopecurus aequalis > 10%.....*Potentilla anserina - Alopecurus aequalis* Association

Alopecurus aequalis absent or < 10%

Eleocharis macrostachya > 25%.....*Potentilla anserina - Eleocharis macrostachya* Association

Eleocharis macrostachya absent or < 25%.....*Potentilla anserina* Association

Appendix C. Key to National Wetland Inventory Codes (http://wetlandsfws.er.usgs.gov/NWI/codes.html)

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

SYSTEM — **M - MARINE**

SUBSYSTEM — **1 - SUBTIDAL**

CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	RF - REEF	OW - *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 3 Rooted Vascular *5 Unknown Submergent*	1 Coral 3 Worm	

SUBSYSTEM — **2 - INTERTIDAL**

CLASS	AB – AQUATIC BED	RF– REEF	RS – ROCKY SHORE	US - UNCONSOLIDATED SHORE
Subclass	1 Algal 3 Rooted Vascular *5 Unknown Submergent*	1 Coral 3 Worm	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic

SYSTEM — **E - ESTUARINE**

SUBSYSTEM — **1 - SUBTIDAL**

CLASS	RB - ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	RF – REEF	OW - *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 3 Rooted Vascular 4 Floating Vascular *5 Unknown Submergent* *6 Unknown Surface*	1 Mollusc 2 Worm	

SUBSYSTEM — **2 - INTERTIDAL**

CLASS	AB – AQUATIC BED	RF– REEF	SB – STREAMBED	RS - ROCKY SHORE	US – UNCONSOLIDATED SHORE	EM -EMERGENT	SS – SCRUB-SHRUB	FO – FORESTED
Subclass	1 Algal 3 Rooted Vascular 4 Floating Vascular *5 Unknown Submergent* *6 Unknown Surface*	1 Mollusc 2 Worm	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Persistent 2 Nonpersistent	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead *6 Deciduous* *7 Evergreen*	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead *6 Deciduous* *7 Evergreen*

SYSTEM — **R - RIVERINE**

SUBSYSTEM	1 – TIDAL	2 – LOWER PERENNIAL	3 – UPPER PERENNIAL	4 – INTERMITTENT	5 – *UNKNOWN PERENNIAL*
CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	*SB – STREAMBED	AB – AQUATIC BED	RS – ROCKY SHORE	US – UNCONSOLIDATED SHORE	**EM – EMERGENT	OW – *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Bedrock 2 Rubble 3 Cobble Gravel 4 Sand 5 Mud 6 Organic 7 Vegetated	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular *5 Unknown Submergent* *6 Unknown Surface*	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	2 Nonpersistent	

* STREAMBED is limited to TIDAL and INTERMITTENT SUBSYSTEMS, and comprises the only CLASS in the INTERMITTENT SUBSYSTEM.
** EMERGENT is limited to TIDAL and LOWER PERENNIAL SUBSYSTEMS.

Classification of Wetlands and Deepwater Habitats of the United States
Cowardin ET AL. 1979 as modified for National Wetland Inventory Mapping Convention

Appendix C continued. Key to National Wetland Inventory Codes

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

SYSTEM — **L- LACUSTRINE**

SUBSYSTEM — **1 - LIMNETIC**

CLASS	Subclass
RB – ROCK BOTTOM	1 Bedrock 2. Rubble
UB – UNCONSOLIDATED BOTTOM	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
AB – AQUATIC BED	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*
OW – *OPEN WATER/ Unknown Bottom*	

SUBSYSTEM — **2 - LITTORAL**

CLASS	Subclass
RB – ROCK BOTTOM	1 Bedrock 2. Rubble
UB – UNCONSOLIDATED BOTTOM	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
AB – AQUATIC BED	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*
RS – ROCKY SHORE	1 Bedrock 2. Rubble
US – UNCONSOLIDATED SHORE	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated
EM – EMERGENT	2 Nonpersistent
OW – *OPEN WATER/ Unknown Bottom*	

SYSTEM — **P - PALUSTRINE**

CLASS	Subclass
RB – ROCK BOTTOM	1 Bedrock 2. Rubble
UB – UNCONSOLIDATED BOTTOM	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
AB – AQUATIC BED	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*
US – UNCONSOLIDATED SHORE	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated
ML – MOSS-LICHEN	1 Moss 2 Lichen
EM – EMERGENT	1 Persistent 2 Nonpersistent
SS – SCRUB-SHRUB	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*
FO – FORESTED	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*
OW – *OPEN WATER/ Unknown Bottom*	

MODIFIERS

In order to more adequately describe the wetland and deepwater habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

WATER REGIME				WATER CHEMISTRY			SOIL	SPECIAL MODIFIERS	
Non-Tidal		**Tidal**		**Coastal Halinity**	**Inland Salinity**	**pH Modifiers for all Fresh Water**			
A Temporarily Flooded	H Permanently Flooded	K *Artificially Flooded*	*S Temporary-Tidal	1 Hyperhaline	7 Hypersaline	a Acid	g Organic	b *Beaver*	h *Diked/Impounded*
B Saturated	J Intermittently Flooded	L Subtidal	*R Seasonal-Tidal	2 Euthaline	8 Eusaline	t Circumneutral	n Mineral	d *Partially Drained/Ditched*	r Artificial Substrate
C Seasonally Flooded	K Artificially Flooded	M Irregularly Exposed	*T Semipermanent-Tidal	3 Mixohaline *(Brackish)*	9 Mixosaline	i Alkaline		f Farmed	s *Spoil*
D *Seasonally Flooded/ Well Drained*	W Intermittently Flooded/Temporary	N Regularly Exposed	*V Permanent-Tidal	4 Polyhaline	0 Fresh				x Excavated
E *Seasonally Flooded/ Saturated*	Y Saturated/Semipermanent/ Seasonal	P Irregularly Flooded	U *Unknown*	5 Mesohaline					
F Semipermanently Flooded	Z Intermittently Exposed/Permanent			6 Oligohaline					
G Intermittently Exposed	U *Unknown*			0 Fresh					

*These water regimes are only used in tidally influenced, freshwater systems.

NOTE: Italicized terms were added for mapping by the National Wetlands Inventory program.