Enhanced wetlands mapping and inventory in Point Reyes National Seashore and Golden Gate National Recreation Area

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Examples of various wetlands at Point Reyes National Seashore: (left) Drake's Estero at low tide; (middle) wetlands mappers Scott Willis and Laura Castellini conducting field work in a cattail *(Typha latifolia)* marsh; and (right) Tomales Bay mudflats at low tide.

California has lost a greater proportion (more than 90%) of its original wetland area than any other state, and much of the remaining acreage is degraded (Dahl 1990). Point Reyes National Seashore, California, was established "to save and preserve, for the purpose of public recreation, benefit and inspiration, a portion of the diminishing seashore of the United States that remains undeveloped." The seashore protects a range of wetland habitat types including salt, brackish, and freshwater marshes; riparian wetlands; wet meadows; and seasonal ponds. The seashore has high quality, diverse wetlands, which are particularly rare in coastal California. Wetlands are extremely important resources to the seashore, and to meet the enabling legislation and other legal requirements, wetlands must be preserved, protected, and restored where practicable.

Past land-use practices have degraded many of the wetlands.

The wetlands in Point Reyes National Seashore and Golden Gate National Recreation Area (the parks) are designated critical habitat for the federally threatened red-legged frog *(Rana aurora draytonii)* and support several federal and state-listed plant, vertebrate, and invertebrate species (table 1). These wetlands also provide critical wintering grounds for tens of thousands of migratory waterbirds and shorebirds along the Pacific flyway.

Currently, hazardous material spills, failing septic systems, mariculture (cultivation of marine organisms), beef and dairy operations, and construction and maintenance of facilities threaten the parks' wetlands. Past land-use practices have degraded many of the wetlands. Without adequate reference information on the location, extent, and type of wetlands, managers cannot evaluate and prevent wetland degradation or loss, or design and prioritize restoration prescriptions. Therefore, beginning in 2000, we began a mapping and inventory project to acquire accurate and current information on our wetland resources to help guide management decisions and to serve as reference data for future monitoring and research. The map and inventory resulting from this project also will facilitate compliance with Section 404 of the Clean Water Act, the Coastal Zone Management Act, the NPS Organic Act, the National Environmental Policy Act, and the NPS Director's Order #77-1 (the policy directive addressing wetland protection in the National Park System).

Methods

We divided the project into two phases. Phase one included: (1) assessing the accuracy of data gathered during the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI), specifically looking for areas that are wetlands but were not detected during NWI (errors of omission) (USFWS 1991) and (2) testing the applicability of using the parks' draft vegetation map (Environmental Systems Research Institute 2000) to detect wetlands throughout Point Reyes National Seashore (about 71,000 acres; 28,734 ha) and the north district of Golden Gate National Recreation Area (about 15,000 acres; 6,071 ha).

In phase two we conducted detailed mapping and an inventory to accurately delineate, describe, and classify wetlands in the Abbotts Lagoon watershed (about 4,000 acres; 1,619 ha) (fig. 1, page 36). We also collected data on wetland function and threats during phase two. Later, after completing phase two, we used the detailed map of the Abbotts Lagoon watershed as a point of reference for comparing and evaluating NWI data and the parks' draft vegetation map.

Phase one

The parks' draft vegetation map and data from NWI maps served as the foundation in choosing sampling locations for the wetland inventory during phase one. The U.S. Fish and Wildlife Service created the NWI digital maps (1:24,000) using photo-interpretation of color

Table 1. Rare wetland plant and animal species at Point Reyes National Seashore and the North District of Golden Gate National Recreation Area

Common name	Scientific name	Status	Presence
Invertebrate			
Myrtle's silverspot	*Speyeria zerene myrtleae*	E	Permanent
California freshwater shrimp	*Syncaris pacifica*	E	Permanent
Fish			
Tidewater goby	*Eucyclogobius newberryi*	E	Permanent
Coho salmon	*Oncorhynchus kisutch*	T	Seasonal
Central California steelhead	*Oncorhynchus mykiss*	T	Seasonal
Amphibian/reptile			
California red-legged frog	*Rana aurora draytonii*	T	Permanent
Bird			
California clapper rail	*Rallus longirostris obsoletus*	E	Seasonal
Brown pelican	*Pelecanus occidentalis californicus*	T	Seasonal
Western snowy plover	*Charadrius alexandrinus nivosus*	T	Permanent
Mammal			
Point Reyes jumping mouse	*Zapus trinotatus orarius*	State SOC	Permanent
Salt marsh harvest mouse	*Reithrodontomys raviventris*	T	Permanent
Pacific harbor seal	*Phoca vitulina richardii*	MMPA	Permanent
Plant			
Sonoma Alopecuras	*Alopecurus aequalis* var. *sonomensis*	E	Permanent
Sonoma spineflower	*Chorizanthe valida*	E	Permanent
Robust spineflower	*Chorizanthe robusta*	E	Permanent
Marsh milkvetch	*Astragalus pycnostachyus* var. *pycnostachyus*	State-1B	Permanent
Swamp hairbell	*Campanula californica*	State-1B	Permanent
Point Reyes bird beak	*Cordylanthus maritimus* ssp. *palustris*	State-1B	Permanent
San Francisco gum plant	*Grindelia hirsutula* var. *maritima*	State-1B	Permanent
Gairdner's yampah	*Perideridia gairdneri* ssp. *gairdneri*	State-4	Permanent
Marin knotweed	*Polygonum marinense*	State-3	Permanent
Point Reyes checkerbloom	*Sidalcea calycosa* ssp. *rhizomata*	State-1B	Permanent

Note: T = federally listed as threatened; E = federally listed as endangered; State 1B = rare, threatened, or endangered in California and elsewhere; State 3 = more information about this plant is needed (Review List); State 4 = limited distribution (Watch List); State SOC = species of concern; MMPA = Marine Mammal Protection Act.

Figure 1. The study area at Point Reyes National Seashore and north district of Golden Gate National Recreation Area.

infrared aerial photography (1:56,000) flown in April 1984. They did not field-verify any of the data. Environmental Systems Research Institute (ESRI) under contract with Point Reyes National Seashore created the draft vegetation map interpreted from true-color aerial photographs (1:24,000), which delineates 79 plant communities. Along with the draft vegetation map, they provided a plant community classification and key, based on an ordination analysis of 366 highly detailed vegetation plots. Using the wetland indicator status of dominant plants (Reed 1996), we considered as highly likely to contain wetlands: nine freshwater, brackish, or saltwater communities; four willow communities; and one alder plant community (Sawyer and Keeler-Wolf 1995) (table 2).

Table 2. Plant communities with high and moderate potential to occur in wetlands

Map code	Alliance or association	Typical plant species in alliance or association	Wetland indicator status of dominants
7060	Willow super alliance**	*Salix ludica, S. lasiolepis, S. leavigata*	OBL-FACW
7070	Red alder**	*Alnus rubra*	FACW
7071	Red alder/salmonberry/red elderberry**	*Rubus spectabilis, Sambucus racemosa*	FACW-FAC
7072	Red alder/arroyo willow**	*Alnus rubra , S. lasiolepis*	FACW
24063	Coyotebrush/sedge/rush**	*Baccharis pilularis, Carex* sp., *Juncus* sp.	FACW-UPL
32080	Arroyo willow**	*Salix lasiolepis*	FACW
46022	Pacific reedgrass/sedge/rush**	*Calamagrostis nutkaensis, Carex* sp., *Juncus* sp.	OBL-FACW
51010	Saltgrass**	*Distichlis spicata*	FACW
52030	Rush/sedge/bulrush**	*Juncus* sp., *Carex* sp., *Scirpus* sp.	OBL-FAC
55020	Bulrush/cattail**	*Scirpus* sp., *Typha* sp.	OBL-FACW
56010	Cordgrass**	*Spartina foliosa*	OBL-FACW
64030	Pickleweed**	*Salicornia virginica*	OBL
64032	Pickleweed/saltgrass/Jaumea**	*Salicornia virginica, Distichlis spicata, Jaumea carnosa*	OBL-FACW
64031	Pickleweed/arrowgrass**	*Salicornia virginica, Triglochin* sp.	OBL
1012	California bay/sword fern*	*Umbellularia californica, Polystichum munitum*	FAC-FACU
20010	California wax myrtle*	*Myrica californica*	FAC+
30050	Salmonberry*	*Rubus spectabilis*	FAC+
47030	Introduced perennial grassland*	*Holcus lanatus, Lolium perenne, Festuca arundinacea*	FAC-UPL
52040	Tufted hairgrass*	*Deschampsia caespitosa*	FACW

Notes: Wetland indicator status follows Reed (1996).
** indicates high potential.
* indicates moderate potential.

OBL = obligate, always found in wetlands (>99 percent of the time).
FACW = facultative wetland, usually found in wetlands (67–99% of the time).
FAC = facultative, equal in wetlands or non-wetlands (34–66% of the time).
FAC+ = subcategory of facultative, equal in wetlands or non-wetlands (50–66% of the time).
FACU = facultative upland, usually found in non-wetlands (1–33% of the time).
UPL/NI = upland/no indicator, not found in local wetlands (<1% of the time).

We also used data from soil surveys of Marin County (Kashiwagi 1985, U.S. Department of Agriculture 1992). The portion of the digital soil surveys that occurs in the study area did not contain any hydric (characterized by an abundance of moisture) soils, but did contain some soils that were known to have small unmapped inclusions of persistently moist soils. We included the five plant communities with a moderate potential to support wetlands (see table 2) only when they occurred over soils described as containing hydric inclusions.

Staff at Point Reyes National Seashore assessed the draft vegetation map for accuracy. Although significant errors exist in the parks' draft vegetation map, with respect to the wetland plant communities, the vast majority of the errors are confusion with other wetland types (table 3). Therefore, even though the vegetation mappers mislabeled many of the plant communities, when considering wetland plant communities as a whole, the parks' draft vegetation map is quite accurate. This feature makes our vegetation map highly suitable for locating areas likely to contain NWI wetlands.

Table 3. Accuracy of wetland plant communities in the draft vegetation map

Plant community type	% correctly classified at the plant community level	% correctly classified as a wetland
Upland	90	NA
Cold wet forest form	0	100
Willow super alliance	23	93
Red alder alliance	76	96
Coyote brush sedge	58	75
Arroyo willow alliance	65	87
Pacific reedgrass-sedge	71	90
Intro perennial grassland	33	65
Saltgrass alliance	43	100
Rush superalliance	35	81
Tufted hairgrass alliance	25	25
Saturated grass form	0	100
Bullrush alliance	50	90
Cordgrass alliance	50	100
Saturated forb form	0	100
Pickleweed alliance	57	100

Based on the wetland plant communities (table 2) and soil data, we selected a total of 1,084 individual land-cover polygons within the study area from the draft vegetation map. Because a primary objective of this phase of the project was to identify wetlands potentially missed in the NWI effort, we included all polygons representing wetland plant communities from the draft vegetation map that did not have overlapping boundaries with NWI polygons. This selection of polygons yielded a total of 484 locations as potential errors of omission in the NWI data. Field crews visited 210 of these localities. We used the existing boundaries of the polygons on the vegetation map as the assessment area for wetland determination and classification. Field crews applied the same criteria during phase two to determine whether the polygons contained wetlands.

Phase two

The polygons selected during phase one identified potential locations within the Abbotts Lagoon watershed to initiate the detailed mapping and inventory in phase two. We performed a wetland assessment at each of 259 sites to make an initial wetland determination, identify and map wetland boundaries, classify the wetland type using Cowardin et al. (1979), collect vegetation composition and cover data, and assess wetland function.

To determine whether a site is a wetland, as defined by Cowardin et al. (1979), one of the following criteria must be present: (1) the land supports more than 50% cover of hydrophytic (living in water-logged conditions) plant species (as listed in Reed 1996) at least periodically during the growing season, (2) the substrate is predominately undrained hydric soil, or (3) the substrate is a non-soil and is annually saturated with water or covered by shallow water at some time during the growing season. We collected and evaluated hydrophytic vegetation (criterion 1) and hydrology data (criterion 3) in making this determination. We evaluated hydric soil (criterion 2) if uncertainty existed in the other two criteria.

The hierarchical structure of the classification system we used is composed of three levels: system, subsystem, and class (Cowardin et al. 1979; see also table 1, page 20). The systems are subdivided into five subsystems: marine, estuarine, riverine, lacustrine (e.g., lakes and ponds), and palustrine (e.g., marshes and wet meadows). Dominant plant life-form and composition of the substrate determine the class. Water regime modifiers describe specific hydrologic conditions that affect the periodicity and duration of inundation. Special modifiers describe wetlands that have been created or highly modified by human activities. This includes wetlands that are diked or impounded, excavated, farmed, drained or ditched, grazed by cattle, filled with artificial substrate, or dammed by beavers.

Classifying systems, subsystems, and classes is straightforward and precise. However, the extent and duration of saturation or inundation (water regime modifier) was often difficult to determine during drier summer months. To determine whether hydrology sources are perennial,

seasonal, or ephemeral often required a second field visit to verify the water regime designation immediately following winter rains.

The criteria for wetland polygon boundary delineation were determined by changes at any level in the Cowardin classification. Wetland boundary mapping was performed mainly by on-screen digitizing, using multispectral high-resolution (11-ft^2, 1-m^2) ortho-imagery acquired in October 2001, and 10-ft (3-m) contour data derived from 3.2-ft^2 (0.3-m^2) ortho-imagery. We used GPS receivers to map wetland boundaries when they were not easily discerned on the imagery. The minimum field-mapping unit (MMU) was 0.24 acres (100 m^2). We reduced the MMU to 0.002 acres (9 m^2) for wetlands in coastal dune swales to support an ongoing dune restoration project. We documented seeps and springs, which fell below the MMU, as "point features" because they are often main water sources for wetland systems and provide pertinent wetland classification information.

We digitized wetland line and polygon shape files using ArcView GIS 3.2 software. We converted shape files into coverages and edited using ArcInfo software. Our GIS data and the associated metadata record are available at www.nps.gov/gis/park_gisdata/california/pore.htm.

Results and discussion

Phase one

We found 146 locations (70%) of the sampled polygons to support wetlands (table 4). We classified 80% of the polygons as palustrine systems (117 polygons) and 20% as estuarine systems (29 polygons). We found no marine, riverine, or lacustrine systems. Of the three wetland criteria, the first one ("at least periodically the land supports predominantly hydrophytes") was met most often.

Table 4. Sampled sites found to support wetlands in each alliance or association

Alliance or association	# polygons sampled	Indicator status	Indicator category	% wetlands
Cordgrass alliance	2	OBL	1	100
Pickleweed alliance	15	OBL	1	100
Slough sedge alliance	9	OBL	1	100
Arroyo willow association	8	FACW	2	88
Pacific reedgrass association	12	OBL/FACW	2	92
Red alder alliance	6	FACW	2	100
Red alder/arroyo willow association	5	FACW	2	100
Rush super alliance	20	OBL/FACW	2	95
Saltgrass alliance	9	FACW	2	100
Tufted hairgrass alliance	1	FACW	2	100
Scirpus/spikerush association	3	OBL/FACW	2	100
Willow super alliance	16	OBL/FACW	2	93
Coyote brush/sedge/rush association	7	FACW/UPL	3	57
Red alder/salmonberry/red elderberry association	12	FACW/FAC	3	100
Salmonberry alliance	2	FAC	3	50
California bay/sword fern association	12	FAC/FACU	4	33
California wax myrtle alliance	3	FAC+	4	100
Coyote brush alliance	19	FAC/UPL	4	16
Coyote brush/Rubus weedy association	6	FAC+/UPL	4	17
Grassland (annual, weedy) alliance	4	FAC/UPL	4	25
Grassland (perennial, weedy) alliance	21	FAC/UPL	4	19
Water, mudflat	2	--	--	--
Poison oak association	1	--	--	--
Unclassified	15	--	--	--
Total	210	--	--	70*

Note: Indicator status and indicator category follow Reed (1996).
*Among all the alliances or associations combined, 70% were wetlands.

OBL = obligate, always found in wetlands (>99 percent of the time).
FACW = facultative wetland, usually found in wetlands (67–99% of the time).
FAC = facultative, equal in wetlands or non-wetlands (34–66% of the time).
FAC+ = subcategory of facultative, equal in wetlands or non-wetlands (50–66% of the time).
FACU = facultative upland, usually found in non-wetlands (1–33% of the time).
UPL/NI = upland/no indicator, not found in local wetlands (<1% of the time).

During sampling, we found sites that supported wetlands in each alliance or association (table 4). Plant communities dominated by plants that only grow under wet conditions (wetland obligates), such as pickleweed, were wetlands 100% of the time, compared to 33% for vegetation types dominated by plant species that tolerate wet or drier conditions (facultative species), such as California bay. The pattern of incremental decrease in the likelihood of a polygon on the vegetation map to contain a wetland, with respect to how dependent the dominant plant species is on wet conditions (table 4), follows a pattern similar to the U.S. Fish and Wildlife Service (Reed 1996) wetland indicator categories. This shows that using a vegetation map to locate potential wetland areas is a valuable tool to refine wetland inventories.

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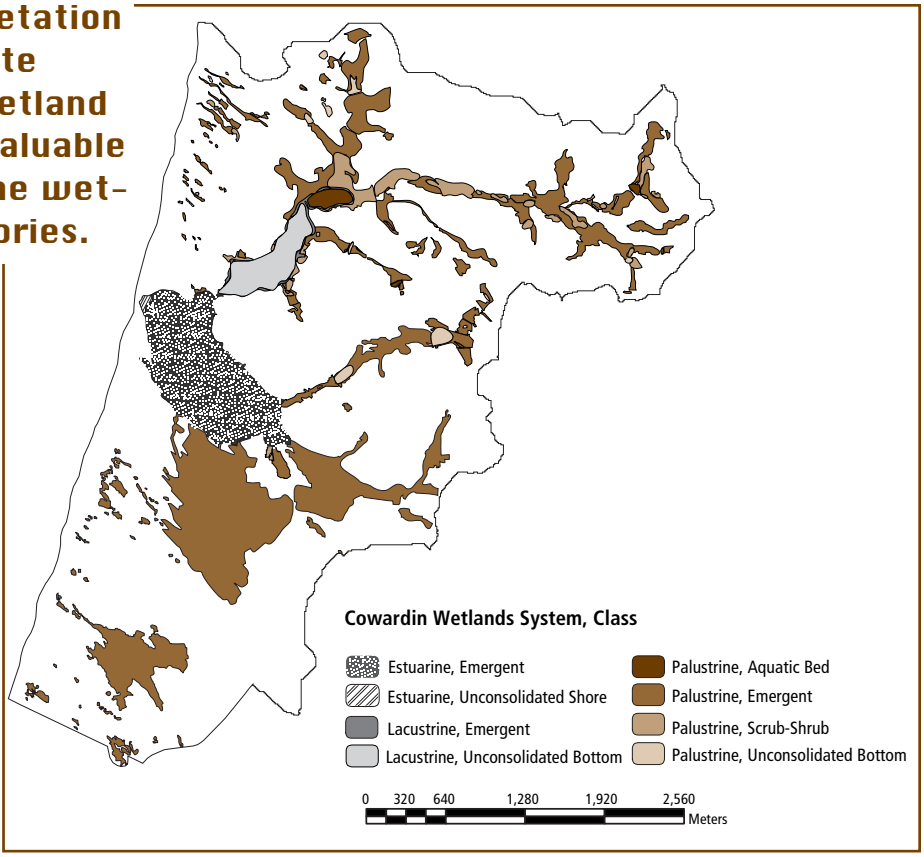

Figure 2a. The exhaustive field survey mapped 989 acres (400 ha) of wetlands within 259 polygons. Field investigators identified 53 different classes of wetlands based on the Cowardin system.

Phase two

Exhaustive Field Survey

Field crews conducted an exhaustive inventory and GPS-based mapping of Abbotts Lagoon watershed (fig. 2a). They mapped a total of 989 acres (400 ha) of wetlands within 259 polygons and classified a total of 53 different types of wetlands, when displayed at the water regime modifier level. We considered this to be the "ground truth" when comparing these results with published NWI data and with the parks' vegetation map.

NWI Data

National Wetlands Inventory's aerial photo interpreters mapped 550 acres (223 ha) of wetlands within 61 polygons (fig. 2b). When compared with the exhaustive field map of the Abbotts Lagoon watershed, 429 acres (174 ha) (44.5%) of wetlands were not identified on the NWI maps. Furthermore, nine different types of wetlands appeared on the NWI maps compared to 53 types detected by field staff, when considered at the special modifier level.

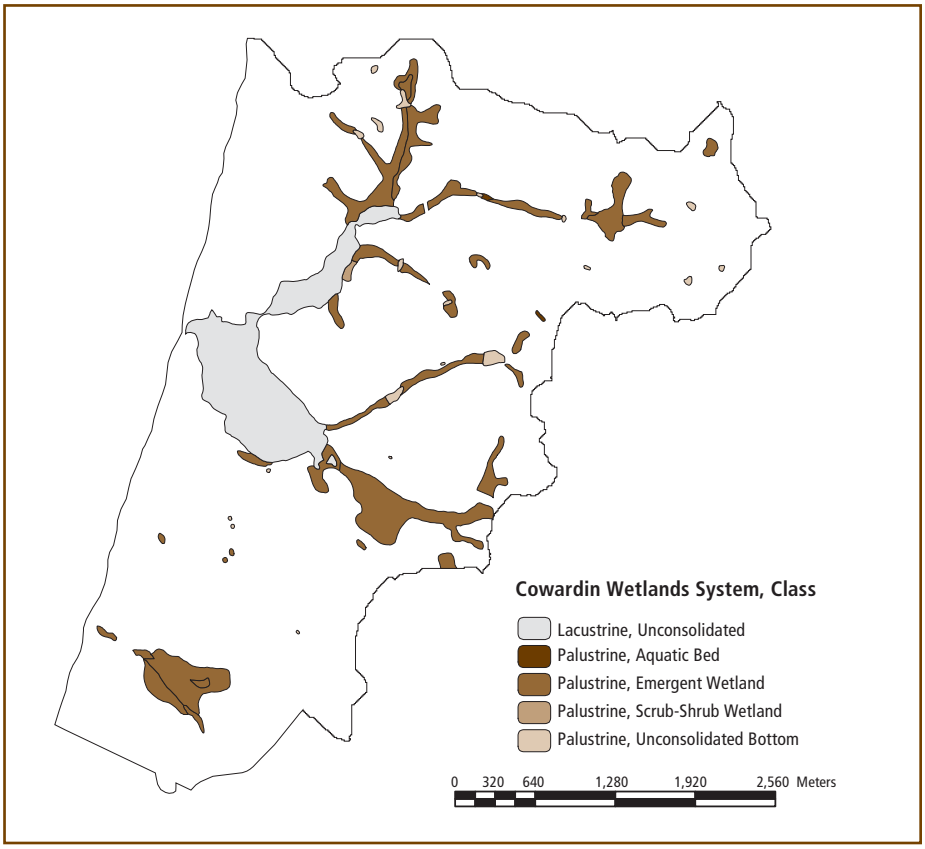

Figure 2b. National Wetlands Inventory (NWI) investigators mapped 550 acres (223 ha) within 61 polygons and identified nine Cowardin wetland types. The NWI data underestimated the wetland area by 44.5% when compared to the exhaustive field-based maps.

Vegetation Map

The draft vegetation map contains 1,046 acres (423 ha) of wetland vegetation within 82 polygons. From this, we selected 14 plant communities as highly likely to contain wetlands and five plant communities as moderately likely to contain wetlands (fig. 2c). We extracted these polygons from the draft vegetation map. The vegetation map overestimated wetlands by 81 acres (33 ha) (8.4%) when compared with the exhaustive field map of the Abbotts Lagoon watershed. The draft vegetation map identifies eight plant communities (associations), significantly less than the 53 wetland types that our field crews mapped in the study area. The vegetation map did a good job of delineating wetlands but without the thematic resolution of the field-based GIS data.

A systematic field effort is necessary to adequately inventory and map wetlands.

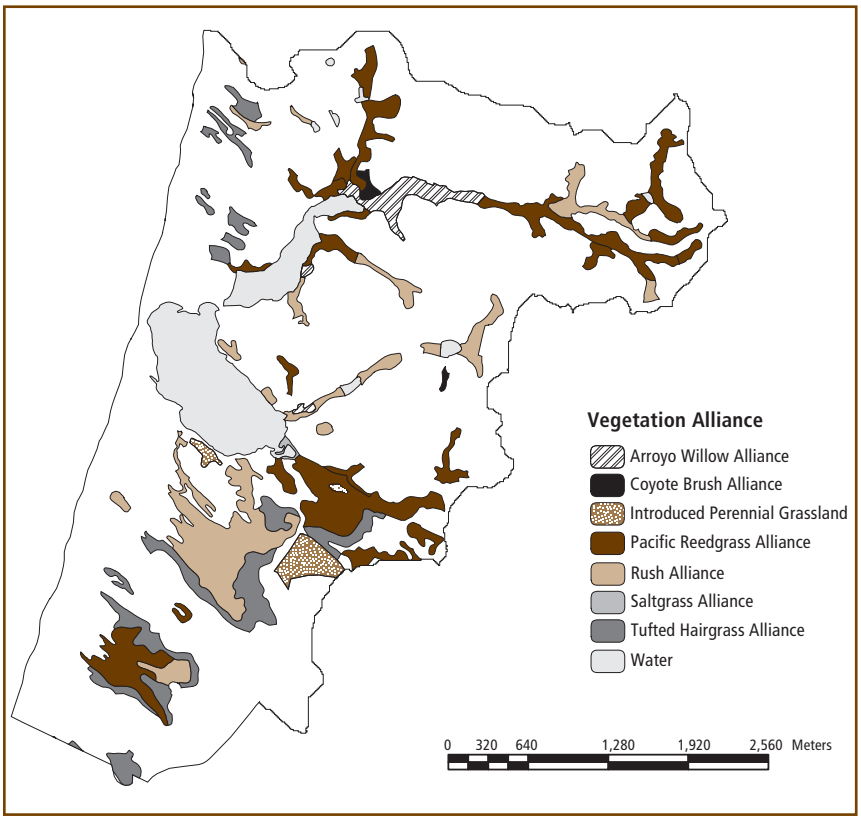

Figure 2c. The parks' plant community map contains 1,046 acres (423 ha) of wetlands within 82 polygons and identifies 5 of 19 wetland plant communities. The plant community map overestimated wetlands by 8.4% when compared to the exhaustive field survey.

Conclusions

Many units in the National Park System where wetlands are an important natural resource could benefit from the enhanced wetlands mapping approach implemented at Point Reyes National Seashore and the north district of Golden Gate National Recreation Area. Clearly managers should carefully evaluate existing NWI data before using them as an inventory of a park's wetland resources. In some areas, small isolated wetlands contribute significantly to species richness and may harbor species of concern. Maps created during the National Wetlands Inventory typically miss such wetlands because of the scale at which they are created. A systematic field effort is necessary to adequately inventory and map wetlands. Current vegetation maps, such as our draft vegetation map, may focus field efforts and provide a broad picture of where wetlands are likely to occur.

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