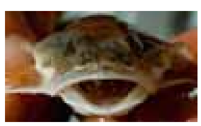
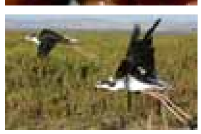
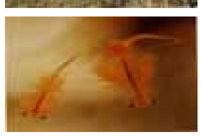
Habitat Restoration Monitoring for the Napa-Sonoma Marsh Restoration Project, Oct 2003 - Jun 2005





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U. S. Geological Survey, Western Region

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Habitat Restoration Monitoring for the Napa-Sonoma Marsh Restoration Project Progress Report 2005

*****Preliminary Results. Do Not Cite Without Permission*****

EXECUTIVE SUMMARY

- Managers and conservation organizations have supported conversion of salt ponds to tidal wetlands to benefit tidal marsh resident species of concern. Additionally, project managers have acknowledged that some ponds should remain as managed salt ponds, as artificial salt evaporation pond systems have become integral habitat for wildlife in the estuary during the past century and currently support massive diverse and unique communities of migratory birds, invertebrates, and fishes

- USGS initiated a research and monitoring program in 1998 under the USGS Priority Ecosystems Program to document baseline conditions in the ponds, and in 2002 initiated a one-year program, with support from the state Coastal Conservancy, to monitor the biophysical changes resulting from the August 2002 unplanned Pond 3 breaches (Takekawa *et al.* 2004). This report summarizes data from the first year of a three-year habitat monitoring program to document conditions before and during construction activities at Napa-Sonoma Marshes Ponds 3, 4, and 5.

- Nutrients, chlorophyll *a*, and invertebrates were collected from Ponds 1, 2, 3, 4, 5, and 7 in November 2003, February, May, August, and November 2004, and May 2005.

- A total of 4,603 fish represented by 17 species and 11 families was caught between July 2004 and July 2005. From gill net catches, fish abundance was highest in Pond 3 (113 fish), followed by Pond 2 (96 fish) and Pond 1 (26 fish) and lowest in Pond 4 (2 fish). By comparison, bag seine and minnow trap catches suggested that fish abundance was highest in Pond 4 (446 and 3,119 fish), followed by Pond 1 (163 and 46 fish), Pond 2 (124 and 16 fish), and Pond 3 (5 and 1 fish).

- Eighty species and estimates of over 900,000 birds were recorded from October 2003 to June 2005 in Napa-Sonoma salt ponds 1, 1A, 2, 2A, 3, 4, 5, 6, 6A, 7, 7A, 8, 9, 10, and the salt crystallizer ponds. Shorebirds comprised 64% of all birds counted at Napa-Sonoma salt ponds, while diving benthivores (18%), dabblers (15%), gulls and terns (2%), fish eaters (1%), eared grebes, and herons made up the remainder. Counts varied by season and by pond, with Ponds 3 and 4 containing the greatest proportion of the total count overall (40% and 29%, respectively).

- Temperature in the ponds followed a seasonal signal with highest temperatures in the summer. Salinity in the ponds was influenced primarily by rainfall during the wet winter season, and evaporation and water transfers during the dry season. Highest salinities were typically seen in the late summer and fall, especially for the higher salinity ponds.

Of Ponds 3, 4, and 5, Pond 5 was furthest removed from the South Slough breach on Pond 3 and showed the highest summer salinity increase.

- The Pond 3 breach at South Slough increased 8.5 m from October 2003 to April 2005, while the breach at Dutchman Slough increased 1.5 m. Pond 3 erosion pins reflected an average sediment loss of 4 cm at the lowest pins, 2 cm at the mid-height pins, and no change at the highest pins. Erosion pins in sloughs showed no major change in levee extent.

- We detected 8 plant species during our September-October 2004 Pond 3 vegetation survey. Common pickleweed was the most common colonizer, especially on mudflats in the southeast portion of the pond. *Spartina* occurred along the interior margins of the pond. Alkali heath, fat hen, western sea-purselane, sand spurry, gum plant, and brass buttons were found on the island in the southeast portion of the pond.

- Bathymetric surveys of the South Slough breach in July 2004, winter 2005, and July 2005 suggest continued moderate deepening of the South Slough scour hole, but no loss of fringing marsh.

- Fringing marsh rail surveys in April 2004 resulted in detection of California black rails, sora, and Virginia rails in the marshes surrounding Ponds 3-5.California clapper rails were not detected. Small mammal surveys detected high densities of salt marsh harvest mice. Fringe marsh vegetation and passerine surveys were scheduled for spring and summer 2006.

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INTRODUCTION

San Francisco Bay Estuary has undergone topographical and ecological changes resulting from human growth and development during the past 200 years. In this time, over 78% of historic salt marshes have been lost, resulting in diminished habitat for native marsh species (Goals Project 1999) and fragmentation of remaining marshlands. Commercial salt ponds were constructed around the fringes of the bay and have been a part of San Francisco Bay's landscape since 1856 (Josselyn 1983). Four thousand hectares of former Cargill salt evaporation ponds along the Napa River northwest of Vallejo were purchased in 1992 for their outstanding wildlife value, and the former Napa Crystallizer Plant (567 ha) was purchased in 2003 for its restoration potential. Restoration of former salt ponds to tidal marsh is intended to reverse a severe decline in habitat (Josselyn 1983, Nichols *et al*. 1986), benefiting obligate tidal marsh species such as the California clapper rail (*Rallus longirostris obsoletus*), salt marsh harvest mouse (*Reithrodontomys raviventris*), and steelhead (*Oncorhynchus mykiss*). However, salt ponds also are important for migratory birds and include other listed species such as the snowy plover (*Charadrius alexandinus*) that nest on salt pond levees.

No guidelines, model, or management strategies exist for converting ponds to tidal wetlands, or for maintaining salt ponds at desired depths and salinities when ponds are no longer part of a salt-making system. Because very high bird densities have been observed on a few ponds, managers hope to optimize features of the managed ponds remaining after restoration to support past numbers of migratory and wintering birds. However, avian pond selection criteria are not fully understood, and seemingly similar ponds often show high variation in bird use. More information will be needed to successfully manage habitat that will support the historic bird numbers that make San Francisco Bay an important migratory stopover site on the Pacific Flyway and a Western Hemispheric Shorebird Reserve Network area of hemispheric importance.

A final EIS for the Napa-Sonoma Marshes Wildlife Area was completed in May 2004 (COE, 2004) and restoration actions were planned for Ponds 3, 4, and 5, mid-system ponds immediately west of the Napa River. The primary objectives in the draft Napa River Salt Marsh Restoration Draft Feasibility Report (COE, 2003) are to: 1) create a mix of tidal and managed pond habitats for a broad range of wildlife; 2) restore large areas along the Napa River to benefit fish and aquatic animals with connections between patches; and 3) improve the ability to manage water depths and salinities to maximize habitat for birds. Phase I of the restoration project includes levee repairs, water control structures, habitat restoration components, and salinity reduction (COE 2003).

USGS initiated a research and monitoring program in 1998 under the USGS Priority Ecosystems Program to document baseline conditions in the ponds (Miles *et al.* 2000, Takekawa *et al.* 2000, Takekawa *et al. in press*, Takekawa *et al.* 2004). With support from the State Coastal Conservancy (SCC) through the Calfed science program, we initiated a three-year habitat monitoring program in late spring 2004. The objectives were to: 1) summarize and continue baseline monitoring of primary productivity, macroinvertebrate, fish, and bird use to assess effects on wildlife for the Phase I Restoration; 2) conduct construction and post-construction surveys with emphasis on Ponds 3-5 to track changes during the Phase I Restoration; and 3) establish avian point counts for passerines and rails and small mammal surveys on Ponds 3-5 to characterize fringing marshes and determine construction effects on tidal marsh species.

However, completion of regulatory review and the Final Monitoring and Adaptive Management Plan resulted in a delayed construction schedule. Following a conference call with planning partners including the Department of Fish and Game (CDFG), H. T. Harvey & Associates, Phillip Williams and Associates (PWA), the SCC, and GAIA, Inc., we modified the scope of work in October 2004 to remove the influence of construction stage on monitoring and to shift efforts towards maximizing the acquisition of information that would be most useful for short and long-term planning under the revised construction schedule. Monitoring efforts are focused on characterizing conditions in salt ponds and fringing marshes before and during construction to provide necessary information for adaptive management as restoration actions proceed.

OBJECTIVES

The primary goal of the salt ponds study is to examine the ecological function of the salt ponds, particularly with respect to their importance for waterbirds. This includes integrated studies of physical parameters, primary productivity, macroinvertebrates, fishes, and waterbirds at the Napa-Sonoma salt pond, Napa Sonoma Marshes Wildlife Area (Figure 1).

Objective 1. Summarize and continue baseline monitoring of primary productivity, macroinvertebrate, fish, and bird use to assess effects on wildlife for the Phase I Restoration.

Objective 2. Continue monitoring of physical parameters including pond water quality, slough erosion, and physical changes in response to the 2002 breaching of Pond 3; track changes in physical parameters during 2006-2007 restoration actions focusing on Ponds 3-5.

Objective 3. Characterize pre-construction fringing marsh habitats surrounding Ponds 3-5 by conducting a vegetation survey, avian point counts for passerines and rails, and small mammal surveys to provide baseline data to determine effects of construction on tidal marsh species.

METHODS

Objective 1. Summarize and continue baseline monitoring of primary productivity, macroinvertebrate, fish, and bird use to assess effects on wildlife for the Phase I Restoration.

Nutrient Data

Three water samples were collected from each of the Napa-Sonoma salt ponds 1, 2, 3, 4, 5, and 7. Water samples were collected in November 2003; February, May, August, and November 2004; and May 2005. The University of California, Department of Natural Resources Analytical Laboratory analyzed these samples for total and soluble Phosphorous (TP, SP), Sulfate (SO_4), and Ammonium (NH_4) and Nitrate (NO_3) to derive nitrogen conditions.

Primary Productivity

We determined Chlorophyll-*a* levels in ponds 1, 2, 3, 4, 5, and 7 using a SCUFA® submersible fluorometer (Turner Designs, Sunnyvale, California), calibrated against a spectrophotometer. The SCUFA was submerged in each sample and temperature-corrected fluorescence values were recorded. Water samples were placed on ice and filtered in a laboratory within 24 hours of collection using 1.2-µm glass fiber filters (Whatman International, Maidstone, England) and frozen at least 24 hours. Extraction solvent (90% acetone) was then added to the filters no later than 48 hours after filtration. Absorbance of the extracts was read using a spectrophotometer at 750, 660, and 664 nm. Chlorophyll-*a* concentration was calculated using the Monochromatic method (Wetzel and Likens 1991).

Benthic Macroinvertebrates

We continued to monitor macroinvertebrates at Napa-Sonoma Ponds 1, 2, 3, and 4 in November 2003, May, November and August 2004, and May 2005. We characterized the taxa composition, distribution and abundance of benthic macroinvertebrate (>1.0 mm) assemblages with the goal of identifying their relation to salinity, pH, dissolved oxygen, water depth, turbidity, and biological influences.

Benthic macroinvertebrates were sampled from a 3.5 m flat-bottom boat with a modified shallow-water outboard motor, using a standard Ekman grab sampler (15.2 cm x 15.2 cm x 15.2

cm) to collect invertebrates. Samples were collected by lowering the dredge into the water slowly, holding it level on the substrate and releasing the 'jaws'. Muddy soft substrates consistently produced samples that filled the dredge, whereas on hard substrates only a small portion of the dredge was filled (dredge cannot 'bite' deeply into hard surface). Grab samples were washed in the field using a 1-mm mesh screen and preserved in 70% ethyl alcohol and rose bengal dye. Sweep samples were collected from the slowly moving boat by placing a D-ring dip net (0.5-mm mesh) in the water column for a 10-m distance.

Samples were collected from 4 randomly selected grids. Within each grid, we collected 3 cores from randomly selected areas. If water level in the ponds was too low and the ponds too large to navigate the boat through the middle of the ponds, we followed borrow ditches which run along the inner perimeters of these ponds. We then moved the boat away from the ditch and towards the inner part of the grid for sample collection.

Samples were sorted and invertebrates identified and enumerated with the assistance of lab technicians using appropriate keys under the guidance of the project coordinator (Usinger 1971, Merritt and Cummins 1978, Pennak 1989, Smith and Johnson 1996). Wet weight and dry weight biomass of selected groups of organisms were determined using an Ohaus, Model 3130 scale (Ohaus Corporation, Pine Brook, New Jersey). Individual wet and dry weights were determined for each taxonomic group.

Water quality data were collected using a multiprobe meter (Datasonde, Hydrolab-Hach Company, Loveland, CO). We collected specific conductivity, dissolved oxygen, pH, salinity, temperature, and turbidity during invertebrate sample collections. Water depth was measured with a depth recorder or meter stick. The parameters were recorded once for each grid sampled.

The substrate was visually characterized in two ways for each grid sampled. First, we estimated whether the substrate was soft, hard or medium in penetrability. Second, we estimated the predominant grain size of the substrate and also made notes of outstanding features, such as abundant shell bits, large organic debris, salt crystals, etc.

Fish Abundance and Diversity

We sampled fish semi-annually (wet and dry seasons) from 3 fixed sites in Ponds 1-4 (Pond 5 was generally too saline for fishes). Sampling was conducted during July 2004 and January and July 2005. Ponds were selected to replicate previous sampling effort (Miles *et al.* 2000, Takekawa *et al.* 2000) and to represent the salinity gradient within the pond system, but ponds > 70 ppt were not sampled because this is beyond the tolerance limit of most species. Because excessive current tangled gill nets, sampling was restricted to periods of slack tide (little or no current). To document environmental conditions at each sampling site, we measured water temperature, dissolved oxygen, pH, conductivity (internally converted to salinity), and turbidity with a Hydrolab DataSonde 3 multiprobe (Hydrolab-Hach Company, Loveland, CO). We measured sample depth with a calibrated cord attached to the multiprobe unit.

Fish were sampled with two floating monofilament gill nets fished for 2 hrs, five baited minnow traps fished for 1 hr, and one bag seine hauled over a 15-m distance. The gill nets were 38-m long by 1.8-m deep, and consisted of square-mesh measuring 12.7 mm, 15.4 mm, 38.1 mm, 50.8

mm, and 63. 5 mm. The minnow traps were 25.4-cm high, 25.4-cm wide, and 43.2-cm long, with 0.3-cm square-mesh. Each minnow trap was baited with fish-flavored canned cat food. The bag seine was 5.5-m long and 1.8-m deep, with a mesh size of 3.2 mm. Captured fish were identified to species (Miller and Lea 1972, Moyle 2002, Eschmeyer *et al.* 1983, McGinnis 1984) and measured for total and standard lengths.

Avian Diversity and Abundance

Bird surveys following existing avian census survey protocols (Miles *et al.* 2000, Takekawa *et al.* 2000) were conducted monthly or bimonthly on all ponds (1, 1A, 2, 2A, 3, 4, 5, 6, 6A, 7, 7A, 8, 9, 10, and the Napa plant site ponds) to document changes in the distribution of bird communities in response to hydrologic and biotic changes. Because shorebirds occurred at higher densities in salt ponds during high tide when tidal mud flats are inundated (Warnock *et al.* 2002), consistent count comparisons were obtained by restricting bird surveys to within 3 hours of high tides. To facilitate spatial analysis of bird distribution and associated pond characteristics, each pond was divided into 250m x 250m grids based on UTM coordinates. Birds were identified to species, enumerated with behavioral activity (feeding, roosting on pond, roosting on levee), and assigned to the geographic grid in which they were observed.

Waterbirds were separated into guilds to examine differences among foraging groups rather than differences among species. These foraging guilds included: 1) small shorebirds – foraged in the top layer (< 3 cm) of sediments, e.g., *Calidris mauri* (western sandpiper); 2) medium shorebirds – reached deeper into the substratum than small shorebirds, e.g., *Limosa fedoa* (marbled godwit), *Recurvirostra americana* (American avocet); 3) dabbling ducks – fed in the upper water column, e.g., *Anas acuta* (northern pintail); 4) diving ducks – fed in deeper water on benthic invertebrates, e.g., *Aythya affinis* (lesser scaup); 5) fish eaters – fish consumers, e.g., *Pelecanus erythrorhynchos* (American white pelican); and 6) gulls and terns – e.g., *Larus* spp. (gulls); and 7) herons – herons and egrets.

Objective 2. Continue monitoring of physical parameters including pond water quality, slough erosion, and physical changes in response to the 2002 breaching of Pond 3; track changes in physical parameters during 2006-2007 restoration actions.

Water Quality

Water quality measurements were collected monthly at Ponds 3-5 beginning in October 2003 and during bird surveys at Ponds 1, 1A, 2, 3, 4, 5, 6, 6A, 7, 7A, 8, and CB3 (Napa plant site) from November 2004 through June 2005. Two to five sampling locations were established for each pond with measurements typically collected near the corners of the ponds. A Hydrolab Minisonde (Hydrolab-Hach Company, Loveland, CO) was used to measure conductivity (internally converted to salinity using the 1978 Practical Salinity Scale), pH, turbidity, temperature and dissolved oxygen at each location. The sensors on the Hydrolab were calibrated prior to each use and a calibration check was performed after sampling. Since the salt ponds were known to stratify under certain conditions, readings from the near-surface and near-bottom of the water column were collected at sampling locations where the water depth exceeded 60 cm. The specific gravity of each pond was measured with a hydrometer (Ertco, West Paterson, New Jersey) scaled for the appropriate range in addition to Hydrolab measurements, because Hydrolab sondes may not accurately measure conductivity above 40 ppt. At salinities above 70 ppt, only the hydrometer was used to measure salinities. Specific gravity was corrected for temperature and converted to salinity. Water depth at the sampling location was measured with a depth recorder or meter stick, and pond water level was recorded from staff gages.

Breach Measurements

South Slough--Pond 3 was breached to South Slough at its northern levee during August 2002. Initially, monthly measurements of breach width were made using laser level rods at three locations (slough-side, mid-levee, and pond-side) along the length of the breaches. The original breach was located at the narrowest portion of the levee, and erosion during winter 2002 washed this portion of the levee away. The levee that remained was more than twice as wide as at the original breach location, and changes in levee width caused us to modify our measurement protocol. Permanent markers on the levee (east and west of the breach) were set to indicate a known distance (determined by laser level), and this single location, usually the narrowest portion of the breach, was subsequently used to track changes in breach width. In 2004, a series of flags were installed every three meters on both the east and west sides of the levee breach with similar orientation. The distance between the flags and breach edge were measured on both sides of the breach, and the sum of the distances was subtracted from the known distance to calculate breach width. Width measurements were initially completed monthly during the period of rapid evolution, but were changed to quarterly in October 2004 when the rate of change slowed down.

Dutchman Slough.--The Dutchman Slough breach at the southeast corner of Pond 3 was opened by CDFG in September 2002 as an emergency measure to lessen the immediate effects of the

South Slough breach. Three locations (pond side, slough side, and middle) were flagged for consistent measurement. In contrast to the South Slough breach, the breach at Dutchman Slough remained sufficiently narrow to permit the three width measurements to be obtained with a standard tape measure. Breach depth was measured with a digital level, tripod, and survey rod, and referenced to an arbitrary benchmark.

Slough and Pond 3 Erosion Measurements

To measure erosion or deposition along the interior levee walls in Pond 3, we placed 5 sets of 3 erosion pins (2" PVC pipe buried to 3') spaced 1 m apart along transects of levee walls (Figure 2). The lowest erosion pin was placed in the water, the middle erosion pin was placed at the water's edge, and the high erosion pin was placed above the water level on the levee (Figure 3). The erosion pins were installed in February 2003, before significant tidal action had been restored, and measured monthly to quarterly with a flat-bottomed measuring pole. In November 2004, two additional sets of erosion pins were installed in China Slough to document potential changes in channel morphology that may result from hydrologic changes in the Napa-Sonoma Marshes slough system (Figure 4).

To document early changes in slough channel morphology that may have been caused by increased flow in the regions immediately outside the Pond 3 breaches, we established transects in South Slough and Dutchman Slough, east and west of each breach. We marked the north and south endpoints of each transect with 2" PVC poles, and used a Hondex depth sounder (Depthmate SM-5A, Speedtech Instruments, Great Falls, VA) with 10-cm precision to create relative depth profiles. These surveys were conducted monthly or bimonthly November 2002 - February 2004, then were replaced with more detailed semi-annual bathymetric surveys (discussed below) of the portion of South Slough immediately outside the breach.

Bathymetric Coverages

South Slough breach and scour hole.--Bathymetry of the Pond 3 breach and South Slough were measured during July 2004 (WRD), winter 2004 (WERC), and July 2005 (WRD). During July 2004 and July 2005, USGS-WRD completed measurements with a vessel-mounted ADCP interfaced with a Leica differential global positioning system (DGPS). Depths were measured in South Slough with the ADCP both seaward and landward of the breach and within the breach when slack tide allowed for a safe approach. A contour plot of bathymetry was developed for each sampling period with Geographic Information System (GIS) software (ArcMap8.3, Environmental Systems Research Institute, Redlands CA). The amount of erosion was calculated by creating triangulated area network (TIN) three-dimensional spatial coverages for each sampling period, then computing the volumetric differences between these two times. Volumetric differences within the study area were then plotted as a separate spatial coverage for display purposes.

Elevation of the sediment was calculated from water levels recorded by an observer who recorded staff gage readings every 10 minutes to capture differences in water level at varying tide stage. The system recorded the boat location every 1 s (1 m precision) and the water depth every 0.05 s (1 cm precision). The sounder worked in areas of >10 cm of water. Depth was then adjusted to NAVD88 by adjusting water level to staff gages surveyed from project benchmarks. Bathymetric grids (2 m) were created with the inverse distance weighting method, and contour profiles were generated from elevation datasets (Geostatistical Analyst; ArcGIS, ESRI).

Pond 3 bathymetry.--We completed a comprehensive bathymetric survey of Pond 3 and the South Slough breach during winter 2004. We developed a shallow-water sounding system comprised of an acoustic profiler (Reson, Inc.; Slangerup, Denmark, Navisound 210), differential global positioning system unit (DGPS; Trimble, Ag132), and laptop computer mounted on a shallow-draft, portable flat-bottom boat (Bass Hunter, Cabelas, Sidney, NE). The boat was equipped with an electric trolling motor and 12V marine batteries.

A variable frequency transducer was mounted on the front of the boat and wired to the sounder; the sounder worked in areas of >10 cm of water. Twenty depth readings and one GPS location were recorded each second; we obtained the average of twenty depth values per location during post-collection processing (SAS Institute, 1990). We calibrated the system before each use with a bar check plate, and adjusted the sound velocity for salinity and temperature differences.

We surveyed north-south and east-west transects at 125-m intervals across Pond 3 from 14 December 2004 to 4 February 2005, and across both pond breaches and adjacent sloughs from 23 January to 23 February 2005. Both surveys were conducted primarily during slack high tide to minimize water level fluctuations and for safety concerns. Transects were not at fixed intervals but were opportunistic due to the short slack tide period (<15 minutes) and equipment limitations.

We adjusted water depth to sediment elevation based on NAVD88-adjusted water height. Staff gages were established in each of six sections of the pond and surveyed to project benchmarks or arbitrary height (Figure 5) with a level and rod. An observer recorded staff gage readings at 10-minute intervals to quantify the relationship between tide stage and water height inside the pond. Bathymetric grids (25 m) were created with the inverse distance weighting method, and contour profiles were generated from elevation datasets (Geostatistical Analyst; ArcGIS, ESRI).

Objective 3. Characterize pre-construction fringing marsh habitats by conducting a vegetation survey, avian point counts for passerines and rails, and small mammal surveys at the marshes surrounding Ponds 3-5 to provide baseline data to determine construction effects on tidal marsh species.

Fringing marsh vegetation survey

Vegetation surveys were scheduled to be completed in spring or summer of 2006.

Fringing marsh passerine point count

Passerine point counts were scheduled to be completed in fall of 2005.

Fringing marsh rail survey

Rail surveys were conducted along the fringe marshes of Ponds 3-5 according to U. S. Fish and Wildlife Service (FWS) California Clapper Rail (CLRA) draft survey protocol (USFWS 2000), and after consultation with leading CLRA experts and permitting agencies (J. Browning, USFWS; G. Downard, USFWS; J. Evens, Avocet Research Associates; N. Warnock, PRBO; C. Wilcox, CDFG).

Transects with listening stations spaced roughly 250 m apart were established in areas near proposed breach locations of Ponds 3, 4, and 5 (A. Borgonovo, PWA 2004) with considerable fringe marsh. One CLRA station was established in the Pond 3 marshes, 11 in the Pond 4 marshes (including Napa Centennial Marsh), and 6 in the Pond 5 marshes (Figure 6). Surveys were conducted 45 minutes before until 1.25 hours after sunrise or 1.25 hours before to 45 minutes after sunset. Ten-minute listening surveys were conducted 16-17 and 28-31 March 2004, followed by a listening and tape playback survey 12-13 April 2004.

Fringing marsh small mammal survey

Small mammal surveys were completed in fall 2005. We conducted small mammal surveys at Pond 4 and 5 of the Napa-Sonoma Marshes from 9-11 September 2005. Surveys occurred at 5 locations along the fringe marshes along P4 and P5 with Sherman live traps. The traps were placed in a grid pattern or along transects with 10-m spacing between each trap. Traps were set for 3 consecutive evenings, checked the following morning, and were closed during the day. Polyester batting was placed within each trap to keep small mammals warm. Wooden shingles were placed on top of each trap to protect captured animals from exposure. Traps were baited with a mixture of dry seeds, chopped walnuts, and meal worms.

Species identification, sex, age, mass (mg), reproductive condition, body length, tail length, and presence of wounds or parasites were recorded for all individuals. Reproductive condition in males was characterized by presence and development of the testes. Reproductive condition in females was characterized by the presence and development of mammaries and whether or not the animal was pregnant. Animals captured and identified to the genus *Reithrodontomys* also included records of tail width 20-mm from the base of the tail, hind foot length, ear length, venter coloration of tail and belly, bicoloration of tail, and behavior (e.g., aggressiveness). Captured individuals were uniquely marked by clipping fur with small scissors to identify recaptures.

Pond 3 pre-construction vegetation survey

Vegetation photopoints were established in September 2003 and visited quarterly to visually document plant colonization in Pond 3 (Figure 7). During October 2004, ocular estimates of vegetation presence were performed by standing on the levee of Pond 3 during low tide and estimating patch size and density through binoculars and scopes. Plants were identified to species, and if possible it was noted whether the plant was adult or juvenile. We assumed that short, unbranched plants were first-year growth. We measured length, width, and density of individuals in clumps.

A subsample of vegetated areas was surveyed with 15m point-intercept transects with 0.5-m intervals. Three 0.25-m^2 quadrats were placed on each transect at the start, middle, and end of each transect. Within each quadrat, we identified plants to species and recorded percent cover, density and maximum height.

RESULTS AND DISCUSSION

Objective 1. Summarize and continue baseline monitoring of primary productivity, macroinvertebrate, fish, and bird use to assess effects on wildlife for the Phase I Restoration.

Nutrient Data

We summarized existing conditions for Ammonium (NH_4), Nitrate (NO_3), Soluble Phosphorous (SP), Total Phosphorous (TP), and Sulfate (SO_4) levels for ponds 1-4 from November 2003 to November 2004 (Tables 1-6).

Primary Productivity

Water samples were collected from Ponds 1-5 and 7 in November 2003, February, May, August, and November 2004, and May 2005. A database was developed for all dates excluding May 2005 (Table 7).

Benthic Macroinvertebrates

Samples were collected on a regular basis since 1999 and were sorted in chronological order. Samples had been sorted through November 2002, but samples collected during and after November 2003 were scheduled for sorting and identification.

Fish Abundance and Diversity

Water temperature and dissolved oxygen fluctuated among sampling dates, with higher temperatures and lower dissolved oxygen concentrations occurring during July of 2004 and 2005 (Table 8). Mean pH values were highest in Pond 2 and lowest in Pond 3. Mean salinity values were highest in Ponds 1, 2, and 4 and lowest in Pond 3. The relatively low salinity in Pond 3 was most likely due to dilution from the Napa River.

A total of 4,603 fish represented by 17 species and 11 families was caught during the July 2004, July 2005 time period (Table 9). Gill nets yielded 237 fish (5.7%), bag seines yielded 738 fish (17.8%) and minnow traps yielded 3,182 fish (76.5%). From gill net catches, fish abundance was highest in Pond 3 (113 fish), followed by Pond 2 (96 fish) and Pond 1 (26 fish) and lowest in Pond 4 (2 fish). By comparison, bag seine and minnow trap catches indicated that fish abundance was highest in Pond 4 (446 and 3,119 fish), followed by Pond 1 (163 and 46 fish), Pond 2 (124 and 16 fish), and Pond 3 (5 and 1 fish). In Pond 4, which had the largest bag seine and minnow trap catch, most fish were caught were during the July 2005 sampling event. Small bag seine and minnow trap catches in Pond 3 may have been influenced by close proximity of the sampling sites to the breach location which was associated with high flow velocities that scoured the banks and pond bottom, making them steep and difficult to sample. The scoured bottom also made this area an unlikely habitat for benthic fish species.

Gill nets, bag seines, and minnow traps targeted different portions of fish communities in the ponds (Table 9). Gill nets generally captured larger fish whereas bag seines and minnow traps captured small fish. Although the minnow trap catches yielded the highest numbers of fish, they collectively represented the fewest numbers of species sampled (minnow traps, 5 species; bag seines, 7 species; gill nets, 11 species). Gill net catches consisted mostly of striped bass followed by splittail and topsmelt. By comparison, seines and minnow traps captured mostly rainwater killifish and threespine stickleback.

Avian Diversity and Abundance

Eighty species and estimates of over 900,000 birds were recorded from October 2003 to June 2005 in Napa-Sonoma salt ponds 1, 1A, 2, 2A, 3, 4, 5, 6, 6A, 7, 7A, 8, 9, 10, and the salt crystallizer ponds (Table 10, Figure 8). Shorebirds comprised 64% of all birds counted at Napa-Sonoma salt ponds, while diving benthivores (18%), dabblers (15%), gulls and terns (2%), fish eaters (1%), eared grebes, and herons made up the remainder. Counts varied by season and by pond, with Ponds 3 and 4 containing the greatest proportion of the total count overall (40% and 29%, respectively) (Table 10, Figure 9). Relative use of ponds varied somewhat by season; although Pond 3 was the most heavily used pond overall and supported over 25% of all salt pond birds in 19 of 22 months surveyed, monthly use of Pond 3 varied from over 67% of the total count in September 2004 to under 20% in April 2004. Pond 4 supported over 25% of all salt pond birds in half of the 22 months surveyed, but monthly use varied from over 59% to less than 2%. Additionally, relative bird use at Ponds 1, 2, 5, and 6, which each supported less than 9% of salt pond birds overall, all exceeded 23% of the total bird count during at least one month. However, Ponds 3-5, the restoration ponds, accounted for the majority of bird counted overall (76% of the total) and by month (55-97% of monthly totals) (Figure 10).

Avian diversity (species and abundance) and distribution between the ponds seem to be influenced more by water depth or other factors than by salinity in certain ponds. Ponds 1, 1A, and 2 were similar in salinity, but Pond 1 supported more species (41) than Pond 1A (33) or Pond 2 (38). Pond 1 was more spatially variable in water depth, which enabled it to support a wider variety of species from all foraging guilds in all months, although proportions varied by month (Figure 9, Figure 11). In Pond 1A, 74% of birds counted were diving benthivores, but

11% were shorebirds that used the pond’s islands and shallow areas, particularly during the fall (Figure 9, Figure 12). Pond 2 was more uniform in depth, with no islands or shallow water areas, and supported a variety of wintering diving benthivores (which comprised 88% of birds counted), wintering dabbling ducks (8%), and other diving birds such as terns and pelicans (Figure 9, Figure 13).

Ponds 3-5 are scheduled for restoration to tidal marsh in 2005 and 2006, but supported a disproportionately large number and variety of salt pond migratory birds throughout the study period. Pond 3 supported 51 species and represented 40% of total bird abundance (Table 11, Figure 9), of which 71% were shorebirds and 27% were dabbling (18%) and diving (9%) ducks. Shorebirds dominated the counts in most months with peaks during fall and spring migration periods, but few shorebirds or waterfowl were present during the summer (Figure 14). Although bird use in Pond 3 increased following the unplanned initial 2002 breaching, this increase was likely temporary as vegetation colonization should decrease available foraging habitat in the next few years. Pond 4 was similar to Pond 3 in that it supported 54 species and 29% of the total birds counted in the ponds (Table 11), of which 71% were shorebirds and 25% were dabbling (11%) and diving (14%) ducks. Although Pond 4 supported a majority of small shorebirds, it had more variable water depth and supported proportionately more medium shorebirds and diving ducks in the winter months than Pond 3 (Figure 15). Pond 5, although it supports fewer species (42) and lower overall abundance (5%) than Ponds 3 and 4 (Figure 9), nevertheless reflects similar guild composition and has comprised a disproportionate number of birds counted during several months (Figure 10). Although less than 5% of the birds counted in Pond 5 were ducks, shorebirds comprised over 90% of birds. Highest counts of small shorebirds on Pond 5 were in

April during the peak migration period for western sandpipers (*Calidris mauri*), dunlin (*C. alpina*), and other shorebirds (Figure 16).

Ponds 6 and 6A were located west of Pond 5 and together comprised 10% of the total salt pond counts (Figure 9). Although Pond 6 generally supported few birds, relative bird use varied widely by month (Figure 10), with the majority of birds counted in 6 of 22 surveys. During November 2003 and April 2004, Pond 6 supported over 13% and 28% of the total count; these two months accounted for 50% of the birds (primarily small shorebirds) counted at Pond 6 (Figure 17). Thirty-six species were recorded at Pond 6A, which supported less than 4% of birds overall (Figure 9). Highest relative monthly usage of the pond was in January, when diving ducks were the primary foraging guild present (Figure 18).

Ponds 7, 7A, and 8 were north of Ponds 5 and 6A and together accounted for only 3% of all birds counted (Figure 9). The majority of these birds (2% of the total) and 35 species were recorded at Pond 7A. Although diving ducks, gulls, and eared grebes used the pond seasonally, the highest proportion of birds at Pond 7A were shorebirds during fall migration (Figure 19). Pond 8 was smaller than pond 7A and supported only about half the number of birds (Figure 9), but more species (40). Primary foraging guilds were dabbling ducks (32% of Pond 8 birds) and diving benthivores (44%), especially during winter months (Figure 20). Pond 7 had very low use overall; no birds were counted on many surveys, and when birds were observed they were roosting on pond levees (Figures 9, 21). Because Pond 7 was a bittern pond, fish and invertebrates were not present and this pond had no foraging value to birds.

The 567-ha (1400-acre) Napa Plant Site was acquired by CDFG in March 2003 and is the subject of a proposed restoration and pond management project. This land was in production as a commercial salt harvesting plant until the existing salt could be extracted, and salinity levels on all ponds but CB3 prevented the use of ponds by invertebrates or fish. Birds at Ponds 9, 10 and the salt crystallizer ponds made up only 0.5% of the total salt pond count during the study period (Figure 9), and 98% of birds counted at all ponds but CB3 were roosting on pond levees (Figure 22). Pond CB3 supported the largest number of birds in the Napa Plant Site (Figure 23) and over 78% of birds counted were observed foraging (Figure 22).

Pond 2A was breached in 1995 and was mostly re-vegetated marsh with shallow, open water areas. Total waterbird abundance was low compared to other salt ponds (Table 11), but many marsh species have been recorded in this pond (Table 12), including a single California clapper rail recorded on 4 occasions. Pond 2A supported primarily dabbling ducks (19%) in October 2003 to July 2004, but marsh species (50%) dominated the count from August 2004 to June 2005 (Figure 24).

Objective 2. Continue monitoring of physical parameters including pond water quality, slough erosion, and physical changes in response to the 2002 breaching of Pond 3; track changes in physical parameters during 2006-2007 restoration actions.

We previously reported on physical and ecological changes following the breaching of Pond 3 (Takekawa *et al.* 2004) prior to the commencement of this study (through July 2003).

Water Quality

We recorded the monthly temperature, conductivity (internally converted to salinity), turbidity, dissolved oxygen (DO) and pH (and associated variability) in the Napa-Sonoma salt ponds

(Figures 25-44, Table 13). Temperature in the ponds followed a seasonal signal with highest temperatures in the summer. Salinity in the ponds was influenced primarily by rainfall during the wet winter season, and evaporation and water transfers during the dry season. Highest salinities were typically seen in the late summer and fall, especially for the higher salinity ponds. Pond 5 was the farthest removed of Ponds 3-5 from the Pond 3 South Slough breach and showed the highest summer salinity increase (Figure 26). Although Pond 3 salinity was fairly uniform, salinity in Pond 4 was lower near South Slough and higher at the northern portion of the pond, resulting in high variability (Figure 26). Trends in turbidity, DO and pH between ponds and seasons were not obvious. The between-pond differences appeared to be greater during the summer dry season, which was expected since these differences may be influenced by a number of physical factors including pond depth, wind speed, fetch, solution density and amount of water influx (rainfall or water transfers).

Breach Measurements

South Slough.--The breach at South Slough increased from 24.0 m in October 2003 to 32.5 m in April 2005 for a total increase of 8.5 m. Most incremental changes were small, but the greatest increase in breach width occurred between January and February 2005, when the width increased 3.3 m (Figure 45).

Dutchman Slough.--The average of pond side, middle, and slough-side measurements reflected a 1.5-m increase in width of the breach on Pond 3 at Dutchman Slough. Breach width was narrowest in the middle of the levee and widest slough-side until after August 2004. Between

August and November 2004, pond-side width increased by 2.4 m. Middle and slough-side width also increased steadily (Figure 46).

Slough and Pond 3 Erosion Measurements

Pond 3 erosion pins reflected an average sediment loss of 4 cm at the lowest pins, 2 cm at the mid-height pins, and no change at the highest pins (Figure 47). Most sediment loss occurred at sites 3 and 4, on the southern pond levee at the center and western end of the pond (Figure 2, Figure 47). Erosion pins in sloughs showed no change.

Bathymetric Coverages

A bathymetric grid produced from July 2004 data (Figure 48) showed deepest areas at the widest portion of the breach. A scour hole also developed in South Slough, which had deepened by January 2005 (Figure 49). July 2005 data were collected, and preliminary analysis suggested that the scour hole in South Slough had deepened further. However, no scouring of fringe marshes was apparent. A comprehensive bathymetric survey of Pond 3 was completed, but data were not yet processed.

Objective 3. Characterize pre-construction fringing marsh habitats by conducting a vegetation survey, avian point counts for passerines and rails, and small mammal surveys

at the marshes surrounding Ponds 3-5 to provide baseline data to determine construction effects on tidal marsh species.

Fringing marsh rail survey

After three CLRA passive listening sessions and one tape playback survey, no CLRA were detected, although a single CLRA was detected in the revegetated Pond 2A on four occasions (Table 12). In the fringe marshes, California black rails (BLRA) were the most common rail species recorded, with two detections each at the marshes surrounding Ponds 4 and 5. In addition to BLRA, Sora and Virginia rails (VIRA) were detected in Napa Centennial Marsh south of Pond 4 (Figure 50), the largest fringing marsh area studied. These species have also been detected in nearby Pond 2A (Table 12); their absence from the other fringe marsh areas suggests a correlation between rail species richness and marsh size.

Fringing marsh small mammal survey

We conducted small mammal surveys (345 trap nights) on Ponds 4 and 5 and captured 42 salt marsh harvest mice (SMHM; *Reithrodontomys raviventris*), 18 California voles (*Microtus californicus*), and 5 house mice (*Mus musculus*) (Table 14). We caught adult, subadult, and juvenile SMHM at varying reproductive stages. This study documented one of the highest indices of SMHM per 100 trap nights in the San Francisco Bay area (Table 15). Grids were located near areas proposed for construction in the restoration project (Figure 51), but the specific trap locations were limited to pickleweed marsh at tidal elevations where the traps would not be inundated.

Pond 3 pre-construction vegetation survey

We subsampled and surveyed areas with vegetative cover along the southern portion of Pond 3 using a point intercept transect (0.5-m intervals) and 0.25 m^2 quadrats. We detected eight species during our September and October 2004 vegetation survey within Pond 3: common pickleweed (*Salicornia virginica*), alkali heath (*Frankenia salina*), fat hen (*Atriplex triangularis*), cordgrass (*Spartina foliosa*), western sea-purselane (*Sesuvium verrucosum*), sand spurry (*Spergularia macrotheca*), gum plant (*Grindelia stricta*), and brass buttons (*Cotula coronipifolia*). The majority of colonizers were common pickleweed, especially on the mudflats in the southern portions of Pond 3 that were exposed during low tides. Pickleweed, the sole colonizer on newly formed mudflats in the southeast portion of Pond 3 in 2004, likely germinated in spring 2004 as plant heights were short (2-28 cm; Figure 52) and mean percent cover was low (10%). *Spartina* occurred along the interior margins of the pond with an average height of 12 cm. Alkali heath, fat hen, western sea-purselane, sand spurry, gum plant, and brass buttons were found on the island in the southeast portion of the pond, which remains dry except during the highest tides of the year. Pickleweed height (1-55 cm) and percent cover (range 3-100% cover; average 48% cover) indicates that some pickleweed plants were well established (Figure 53). Photopoints were established at four sites on Pond 3 (Figure 54).

LOGISTICAL ISSUES

In winter and spring, rainfall created muddy levees, preventing access to some of the ponds. We were unable to conduct invertebrate, fish, water quality, or bird sampling during these times.

Pond 3 fish sampling may have been influenced by close proximity of the sampling sites to the breach location which was associated with high flow velocities that scoured the banks and pond bottom, making them steep and difficult to sample. Work at or around the Pond 3 breaches was limited to slack tide due to high flow.

SUMMARY AND RECOMMENDATIONS

Our ongoing research will focus on biophysical interactions between ponds and surrounding sloughs and effects of the breaches. We will continue to monitor hydrological and biological changes in all of the Napa-Sonoma salt ponds due to breaches and restoration activities. With support from the State Coastal Conservancy (SCC), we will continue bimonthly bird surveys and seasonal invertebrate and water quality sampling in the Napa-Sonoma salt ponds to examine inter-annual variation in these communities. The occurrence of SMHM at every trapping location on fringe marshes suggests that the SMHM are likely present in much of the fringe marsh of Ponds 4 and 5. Thus, construction activities should be managed to minimize disturbance to SMHM. Further research effort will include characterizing avian communities in the fringe marshes.

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TABLES AND FIGURES

Table 1. Pond 1 average dissolved nutrient concentrations (mg/l), Napa-Sonoma salt ponds, San Francisco Bay, CA.

Date	Ammonium (NH_4)	Nitrate (NO_3)	Phosphorous (P Soluble)	Phosphorous (P Total)	Sulfate (SO_4)
November-03	1.31	<0.05	0.88	0.80	–
February-04	0.00	0.00	0.51	0.60	528.40
May-04	0.41	0.00	0.70	0.80	733.50
August-04	0.05	0.23	0.50	0.55	839.00
November-04	0.16	0.06	0.45	0.40	823.00

Table 2. Pond 2 average dissolved nutrient concentrations (mg/l), Napa-Sonoma salt ponds, San Francisco Bay, CA.

Date	Ammonium (NH_4)	Nitrate (NO_3)	Phosphorous (P Soluble)	Phosphorous (P Total)	Sulfate (SO_4)
November-03	0.21	<0.05	0.64	0.50	–
February-04	0.14	0.00	0.29	0.28	411.40
May-04	0.16	0.00	0.89	0.85	496.50
August-04	0.08	<0.05	0.93	0.83	663.00
November-04	0.50	0.12	0.42	0.53	676.00

Table 3. Pond 3 average dissolved nutrient concentrations (mg/l), Napa-Sonoma salt ponds, San Francisco Bay, CA.

Date	Ammonium (NH_4)	Nitrate (NO_3)	Phosphorous (P Soluble)	Phosphorous (P Total)	Sulfate (SO_4)
November-03	0.18	0.39	0.11	0.05	–
February-04	0.15	0.23	0.13	0.20	281.00
May-04	0.17	0.15	0.14	0.20	–
August-04	0.20	0.08	0.30	0.36	499.60
November-04	0.27	0.39	0.13	0.15	489.67

Table 4. Pond 4 average dissolved nutrient concentrations (mg/l), Napa-Sonoma salt ponds, San Francisco Bay, CA.

Date	Ammonium (NH_4)	Nitrate (NO_3)	Phosphorous (P Soluble)	Phosphorous (P Total)	Sulfate (SO_4)
November-03	0.32	<0.05	0.10	0.10	–
February-04	0.11	0.00	0.05	0.37	1323.33
May-04	0.26	0.14	0.23	0.70	–
August-04	0.26	0.13	0.26	0.57	3125.33
November-04	0.16	<0.05	0.14	0.40	1929.00

Table 5. Pond 5 average dissolved nutrient concentrations (mg/l), Napa-Sonoma salt ponds, San Francisco Bay, CA.

Date	Ammonium (NH_4)	Nitrate (NO_3)	Phosphorous (P Soluble)	Phosphorous (P Total)	Sulfate (SO_4)
November-03	0.20	<0.05	0.17	0.80	–
February-04	0.11	0.00	0.05	0.37	1323.33
May-04	0.26	0.14	0.23	0.70	–
August-04	0.26	0.13	0.26	0.57	3125.33
November-04	0.16	<0.05	0.14	0.40	1929.00

Table 6. Pond 7 average dissolved nutrient concentrations (mg/l), Napa-Sonoma salt ponds, San Francisco Bay, CA.

Date	Ammonium (NH_4)	Nitrate (NO_3)	Phosphorous (P Soluble)	Phosphorous (P Total)	Sulfate (SO_4)
November-03	48.72	0.26	0.64	0.10	–
February-04	10.72	0.24	0.20	<0.01	6005.00
May-04	6.38	0.19	–	–	16706.00
August-04	53.32	<0.05	–	1.33	6488.67
November-04	10.39	0.24	–	<0.01	12993.75

Table 7. Chlorophyll-*a* concentrations (mg/m^3), Napa-Sonoma salt ponds 1, 2, 3, 4, 5, and 7.

Date	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 7
Nov-03	2.55	1.81	0.57	2.62	26.88	1.48
Feb-04	6.25	7.50	15.13	40.21	21.72	0.48
May-04	78.90	8.22	13.27	30.77	80.84	0.00
Aug-04	36.52	23.42	13.43	13.19	38.57	0.00
Nov-04	6.64	59.30	7.23	34.10	68.31	8.46

Table 8. Summary of water temperature, dissolved oxygen (DO), pH, and salinity measured concurrently with fish sampling events in July 2004, January 2005, and July 2005. Values are weighted geometric means.

	temperature	*n*	DO	*n*	pH	*n*	salinity	*n*	sample depth (cm)	*n*
Pond 1										
July 2004	19.66	12	5.75	12	7.75	12	36.05	12	30.00	4
January 2005	7.57	10	11.50	10	8.52	10	16.07	10	46.67	6
July 2005	17.43	7	5.74	7	8.19	7	15.59	7	50.00	6
Combined dates	***14.95***	29	***7.73***	29	***8.12***	29	***24.22***	29	***43.75***	16
Pond 2										
July 2004	21.67	10	6.23	10	8.67	10	25.46	10	90.00	4
January 2005	11.14	11	16.80	11	9.01	11	18.63	11	86.67	6
July 2005	20.31	4	5.61	4	8.53	4	10.83	4	100.00	3
Combined dates	***16.82***	25	***10.78***	25	***8.80***	25	***20.11***	25	***90.77***	13
Pond 3										
July 2004	19.96	9	5.62	9	7.66	9	18.13	9	116.67	3
January 2005	8.33	11	9.78	11	7.67	11	4.96	11	75.00	8
July 2005	18.14	6	7.74	6	7.54	6	7.57	6	100.00	6
Combined dates	***14.62***	26	***7.87***	26	***7.64***	26	***10.12***	26	***91.18***	17
Pond 4										
July 2004	18.70	9	4.29	9	8.09	9	23.18	9	50.00	4
January 2005	10.75	11	10.12	11	8.37	11	16.83	11	89.17	6
July 2005	19.34	6	4.91	6	8.23	6	10.03	6	150.00	2
Combined dates	***15.48***	26	***6.90***	26	***8.24***	26	***17.46***	26	***86.25***	12

Table 9. Species composition of fish captured during 2004 and 2005. Values are number of individuals or percent. [1]Codes: I, introduced; N, native.

Family	Species		Gill net								Bag seine[2]							
	Scientific Name	Common name[1]	Pond 1		Pond 2		Pond 3		Pond 4		Pond 1		Pond 2		Pond 3		Pond 4	
			n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Engraulididae	*Engraulis mordax*	Northern anchovy (N)	5	19	0	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Moronidae	*Morone saxatilis*	Striped bass (I)	1	3.8	86	89.6	66	58.4	1	50.0	0	0.0	0	0.0	0	0.0	0	0.0
Cottidae	*Leptocottus armatus*	Staghorn sculpin (N)	1	3.8	0	0	0	0.0	1	50.0	0	0.0	0	0.0	0	0.0	0	0.0
Mugilidae	*Mugil cephalus*	Striped mullet (N)	1	3.8	0	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Clupeidae	*Dorosoma petenense*	Threadfin shad (I)	2	7.7	0	0	1	0.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Atherinopsidae	*Atherinops affinis*	Topsmelt (N)	15	58	1	1.04	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Gobiidae	*Acanthogobius flavimanus*	Yellowfin goby (I)	1	3.8	7	7.29	0	0.0	0	0.0	5	3.1	6	4.8	3	60.0	0	0.0
Clupeidae	*Alosa sapidissima*	American shad (I)	0	0	2	2.08	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyprinidae	*Cyprinus carpio*	Common carp (I)	0	0	0	0	1	0.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyprinidae	*Pogonichthys macrolepidotus*	Sacramento splittail (N)	0	0	0	0	44	38.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ictaluridae	*Ameiurus catus*	White catfish (I)	0	0	0	0	1	0.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Gasterosteidae	*Gasterosteus aculeatus*	Threespine stickleback (N)	0	0	0	0	0	0.0	0	0.0	102	62.6	2	1.6	0	0.0	0	0.0
Atherinopsidae	*Menidia beryllina*	Inland silverside (I)	0	0	0	0	0	0.0	0	0.0	48	29.4	6	4.8	1	20.0	0	0.0
Cottidae	*Cottus asper*	Prickly sculpin (N)	0	0	0	0	0	0.0	0	0.0	0	0.0	3	2.4	0	0.0	0	0.0
Fundulidae	*Lucania parva*	Rainwater killifish (I)	0	0	0	0	0	0.0	0	0.0	6	3.7	107	86.3	0	0.0	445	99.8
Gobiidae	*Gillichthys mirabilis*	Longjaw mudsucker (N)	0	0	0	0	0	0.0	0	0.0	2	1.2	0	0.0	0	0.0	1	0.2
Gobiidae	*Tridentiger bifasciatus Steindacher*	Shimofuri goby (I)	0	0	0	0	0	0.0	0	0.0	0	0.0	0	0.0	1	20.0	0	0.0
		Total	**26**	**100**	**96**	**100**	**113**	**100**	**2**	**100**	**163**	**100**	**124**	**100**	**5**	**100**	**446**	**100**

Table 9 Continued.

Family	Species		Minnow trap							
	Scientific Name	Common name[1]	Pond 1		Pond 2		Pond 3		Pond 4	
			n	%	*n*	%	*n*	%	N	%
Engraulididae	*Engraulis mordax*	Northern anchovy (N)	0	0.0	0	0.0	0	0.0	0	0.0
Moronidae	*Morone saxatilis*	Striped bass (I)	0	0.0	0	0.0	0	0.0	0	0.0
Cottidae	*Leptocottus armatus*	Staghorn sculpin (N)	0	0.0	0	0.0	0	0.0	0	0.0
Mugilidae	*Mugil cephalus*	Striped mullet (N)	0	0.0	0	0.0	0	0.0	0	0.0
Clupeidae	*Dorosoma petenense*	Threadfin shad (I)	0	0.0	0	0.0	0	0.0	0	0.0
Atherinopsidae	*Atherinops affinis*	Topsmelt (N)	0	0.0	0	0.0	0	0.0	0	0.0
Gobiidae	*Acanthogobius flavimanus*	Yellowfin goby (I)	2	4.3	5	31.3	0	0.0	0	0.0
Clupeidae	*Alosa sapidissima*	American shad (I)	0	0.0	0	0.0	0	0.0	0	0.0
Cyprinidae	*Cyprinus carpio*	Common carp (I)	0	0.0	0	0.0	0	0.0	0	0.0
Cyprinidae	*Pogonichthys macrolepidotus*	Sacramento splittail (N)	0	0.0	0	0.0	0	0.0	0	0.0
Ictaluridae	*Ameiurus catus*	White catfish (I)	0	0.0	0	0.0	0	0.0	0	0.0
Gasterosteidae	*Gasterosteus aculeatus*	Threespine stickleback (N)	44	95.7	1	6.3	0	0.0	0	0.0
Atherinopsidae	*Menidia beryllina*	Inland silverside (I)	0	0.0	1	6.3	0	0.0	2	0.1
Cottidae	*Cottus asper*	Prickly sculpin (N)	0	0.0	8	50.0	1	100.0	0	0.0
Fundulidae	*Lucania parva*	Rainwater killifish (I)	0	0.0	1	6.3	0	0.0	3117	99.9
Gobiidae	*Gillichthys mirabilis*	Longjaw mudsucker (N)	0	0.0	0	0.0	0	0.0	0	0.0
Gobiidae	*Tridentiger bifasciatus Steindacher*	Shimofuri goby (I)	0	0.0	0	0.0	0	0.0	0	0.0
		Total	**46**	**100**	**16**	**100**	**1**	**100**	**3119**	**100**

Table 10. Total counts of waterbirds in foraging guilds by month, Napa-Sonoma salt ponds, San Francisco Bay, CA. Surveys completed October 2003 - June 2005.

	2003			2004											2005					
Species	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Dabbling duck																					
American coot	4	19	136	130	412	385	433	0	1	1	0	13	8	239	1374	2311	892	1565	537	6	0
American wigeon	530	199	485	598	1444	829	111	1	0	0	2	0	0	47	1595	654	2913	875	443	14	0
cinnamon teal	1	155	10	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
unidentified dabbler	0	0	0	0	0	0	0	0	0	0	0	0	272	0	0	0	0	40	20	3	0
unidentified duck	0	0	0	0	0	0	0	0	0	0	0	0	0	27	947	0	0	0	0	1	4
gadwall	240	112	90	629	425	753	892	221	1029	332	371	154	4	349	142	1256	458	118	74	206	1014
green-winged teal	9	170	64	66	2	52	382	0	0	0	0	0	5	20	222	20	135	64	4	0	0
mallard	81	303	227	447	27	155	343	360	43	13	34	6154	2446	49	47	101	61	58	79	248	211
northern pintail	5851	4513	1848	921	1054	1259	125	4	2	0	0	3923	4503	1431	8079	2358	941	769	30	19	0
northern shoveler	3120	3166	3281	928	2254	4926	1264	36	0	0	0	568	298	1252	1310	1243	6717	5810	757	23	0
Diving duck																					
Barrow's goldeneye	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
bufflehead	0	119	1687	2130	1924	507	34	1	0	0	0	0	9	869	2294	1986	2173	379	198	11	0
canvasback	0	0	1392	320	472	397	0	4	0	0	0	0	0	11	2419	581	1192	905	11	2	0
common goldeneye	2	65	27	17	283	153	29	1	1	1	1	0	2	142	143	98	36	133	37	2	0
redhead	0	0	0	40	0	5	0	5	0	0	0	0	0	0	488	556	21	7	0	16	0
ruddy duck	582	1517	3361	9957	10257	7998	4051	83	1	4	10	113	1650	3554	6512	14726	8914	8252	914	94	50
scaup (lesser, greater)	12	168	214	9105	8809	8582	1860	145	24	0	10	70	1	71	1515	6656	7896	4949	972	353	0
Eared grebe																					
eared grebe	22	123	293	401	635	826	204	3	2	2	0	14	17	10	25	118	103	104	20	1	0
Fish eater																					
American white pelican	222	366	5	26	16	3	4	124	244	433	404	1139	739	76	8	2	5	19	5	109	328
common merganser	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
double-crested cormorant	93	179	5	143	61	70	224	221	185	305	56	108	122	62	77	22	12	68	232	291	224

Table 10 continued.

	2003			2004												2005					
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
unidentified grebe	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
horned grebe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
pied-billed grebe	12	19	1	1	2	1	0	1	0	1	0	41	83	60	40	22	32	11	2	0	0
western grebe	2	2	0	0	7	8	5	0	0	0	0	0	10	55	5	9	0	1	1	1	0
Flamingo																					
greater flamingo	2	2	2	1	0	2	0	0	0	1	0	0	0	0	2	0	2	2	0	0	0
Goose																					
Canada goose	0	0	0	30	26	27	12	17	26	43	0	0	0	2	0	74	73	23	4	65	38
mute swan	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
trumpeter swan	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
tundra swan	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gull and tern																					
Bonaparte's gull	20	239	866	531	259	0	0	2	0	0	0	0	0	161	233	139	1689	182	1	0	24
California gull	49	55	2	2	1	21	0	15	0	15	390	57	200	45	10	37	94	1	4	203	142
glaucous-winged gull	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	9	0	0
herring gull	0	0	0	0	11	0	0	0	0	0	0	0	0	2	38	1	0	2	0	0	0
mew gull	0	0	0	0	0	0	0	0	0	0	0	0	0	74	0	0	0	0	0	0	0
ring-billed gull	27	13	138	373	227	14	54	18	7	73	141	563	132	64	65	42	10	23	81	0	0
Sabine's gull	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
western gull	164	23	3	50	16	20	1	12	0	0	0	0	0	31	9	8	15	21	1	20	1
unidentified gull species	0	13	48	1	0	0	5	35	73	179	174	9	0	0	5	7	4042	2	2	6	82
Forster's tern	16	47	1	5	26	15	107	188	351	180	66	32	63	90	49	79	44	49	57	379	174
Caspian tern	0	0	0	0	0	0	85	281	244	31	152	1	22	0	0	0	0	0	26	209	0
Heron																					
great blue heron	8	12	4	4	3	0	3	1	0	1	1	5	7	5	6	4	9	5	3	5	1
great egret	10	18	7	3	4	0	0	8	44	17	35	31	73	52	35	10	16	7	8	34	68

Table 10 continued.

	2003			2004												2005					
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
snowy egret	54	119	66	37	46	21	22	42	25	110	45	36	185	110	39	3	6	11	20	50	310
Medium shorebird																					
American avocet	7346	5141	6597	3695	3187	1734	1519	1554	1142	2992	3520	4725	6527	7919	6712	2811	4470	2351	8	563	471
black-bellied plover	2147	687	201	142	1	13	158	8	3	10	162	588	260	224	301	0	30	24	66	1	4
black-necked stilt	768	943	646	112	363	0	39	46	7	145	298	540	421	369	323	0	21	17	2	52	44
greater yellowlegs	18	36	13	2	5	0	2	1	0	0	0	32	84	28	13	0	0	0	0	3	0
killdeer	4	5	0	1	0	0	1	0	4	1	1	4	6	0	0	3	1	0	2	0	0
long-billed curlew	684	142	185	260	201	96	0	3	7	41	271	788	646	158	764	0	38	61	0	1	155
lesser yellowlegs	2	1	8	0	0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0
marbled godwit	1311	1453	2057	1577	1294	247	127	102	561	293	1097	688	1359	2038	1989	78	358	596	136	35	29
unidentified shorebird	0	0	0	0	0	0	0	0	0	0	0	0	80	10	0	0	0	0	0	0	0
stilt sandpiper	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
whimbrel	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
willet	811	1209	1521	1032	489	617	300	54	541	635	423	697	431	1012	879	0	603	301	275	6	207
Phalarope																					
red-necked phalarope	28	47	0	0	0	0	0	0	10	0	1	82	0	0	0	0	0	0	0	0	0
Small shorebird																					
Baird's sandpiper	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
dowitcher (long, short-billed)	268	1908	523	155	0	0	134	11	13	92	643	62	3194	5244	250	0	8	20	124	15	0
dunlin	243	30058	8875	1369	1857	1445	32888	46	1463	146	170	1368	2965	15685	8471	230	1482	0	18837	5	0
least sandpiper	13085	1050	99	1040	94	68	1891	0	0	0	9	4109	1706	1030	427	0	2	0	77	0	0
western sandpiper	9531	63412	11834	17770	10499	2736	33020	10	2891	17142	11915	28234	15954	18522	4385	44	17331	14185	20172	13	1032
unidentified sandpiper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	13015	0	235
semipalmated plover	97	19	0	134	0	0	0	7	0	2	0	197	120	18	1	0	0	0	0	5	0
snowy plover	1	0	0	1	0	19	19	0	8	2	0	0	0	0	0	0	0	0	2	9	0
Total	**47518**	**117850**	**46823**	**54193**	**46694**	**34018**	**80348**	**3671**	**8952**	**23243**	**20402**	**55146**	**44605**	**61224**	**52254**	**36289**	**62846**	**42020**	**57268**	**3079**	**4848**

Table 11. Total counts of waterbirds by pond, Napa-Sonoma salt ponds, San Francisco Bay, CA. Surveys completed October 2003- June 2005.

Species		1	2	1A	2A	3	4	5	6	7	6A	7A	8	9	10	Cryst	CB3
Dabbling duck																	
American coot	*Fulica americana*	217	497	47	37	3293	3576	17	0	0	0	0	782	0	0	0	0
American wigeon	*Anas americana*	314	1439	807	9	4756	2118	0	672	0	245	166	214	0	0	0	0
cinnamon teal	*Anas cyanoptera*	0	0	0	1	176	0	0	0	0	0	0	0	0	0	0	0
gadwall	*Anas strepera*	20	700	238	58	5566	1199	35	599	0	128	29	229	0	0	0	68
green-winged teal	*Anas crecca*	10	1	0	10	973	145	0	76	0	0	0	0	0	0	0	0
mallard	*Anas platyrhynchos*	9	26	18	213	4847	5862	92	119	0	102	25	168	0	0	0	6
northern pintail	*Anas acuta*	392	450	140	126	30118	4766	49	1066	0	401	0	84	0	0	0	38
northern shoveler	*Anas clypeata*	761	202	712	1	12061	8984	248	4213	0	9498	207	20	0	0	0	46
unidentified dabbler	*Anas* spp.	0	0	0	3	270	35	0	0	0	27	0	0	0	0	0	0
unidentified duck	*Anas* spp.	0	400	0	0	6	117	0	456	0	0	0	0	0	0	0	0
Diving duck																	
Barrow's goldeneye	*Bucephala islandica*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
bufflehead	*Bucephala albeola*	408	823	259	61	1272	6536	1828	296	0	675	1847	314	0	0	0	2
canvasback	*Aythya valisineria*	201	388	11	1	6882	177	0	20	0	0	0	26	0	0	0	0
common goldeneye	*Bucephala clangula*	18	107	78	2	182	363	88	2	0	17	164	108	0	0	0	44
redhead	*Aythya Americana*	0	816	0	0	263	0	0	52	0	0	0	7	0	0	0	0
ruddy duck	*Oxyura jamaicensis*	7943	19687	16417	55	12003	13897	530	1947	0	8708	438	975	0	0	0	0
scaup (greater, lesser)	*Aythya marila, A. affinis*	339	17316	51	0	10196	13277	78	8502	0	806	225	614	0	0	0	8
Eared grebe																	
eared grebe	*Podiceps nigricollis*	9	116	3	0	45	154	286	145	0	27	2044	94	0	0	0	0
Fish eater																	
American white pelican	*Pelecanus erythrorhynchos*	327	574	37	0	897	2331	15	0	0	26	0	70	0	0	0	0
common merganser	*Mergus merganser*	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0
double-crested cormorant	*Phalacrocorax auritis*	158	126	14	5	1348	170	843	0	25	15	7	48	0	0	0	1
horned grebe	*Podiceps auritus*	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0

Table 11 continued.

		1	2	1A	2A	3	4	5	6	7	6A	7A	8	9	10	Cryst	CB3
pied-billed grebe	*Podilymbus podiceps*	2	61	0	0	2	17	8	7	0	3	23	205	0	0	0	1
western grebe	*Aechmophorus occidentalis*	4	31	1	0	6	7	52	0	0	1	0	4	0	0	0	0
unidentified grebe		0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Flamingo																	
greater flamingo	*Phoenicopterus ruber roseus*	0	0	3	0	2	5	4	2	0	0	0	0	0	0	0	0
Goose																	
Canada goose	*Branta canadensis*	3	10	34	0	101	40	26	115	0	25	96	7	0	0	0	3
mute swan	*Cygnus olor*	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
trumpeter swan	*Cygnus buccinator*	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
tundra swan	*Cygnus columbianus*	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
Gull and tern																	
Bonaparte's gull	*Larus philadelphia*	13	1	52	0	19	66	1565	541	0	1	2074	14	0	0	0	0
California gull	*Larus californicus*	304	5	23	0	449	111	233	82	0	31	87	3	0	0	15	0
glaucous-winged gull	*Larus glaucescens*	0	0	0	0	9	1	0	0	0	0	0	0	0	0	0	0
herring gull	*Larus argentatus*	11	0	0	0	5	5	33	0	0	0	0	0	0	0	0	0
mew gull	*Larus canus*	0	0	0	0	0	0	74	0	0	0	0	0	0	0	0	0
ring-billed gull	*Larus delawarensis*	108	6	19	0	614	353	204	15	0	19	580	72	0	0	75	0
Sabine's gull	*Xema sabini*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
western gull	*Larus occidentalis*	30	6	1	0	171	110	45	13	0	2	3	14	0	0	0	0
unidentified. gull species	*Larus* spp.	0	3	32	0	475	3714	72	0	0	2	0	0	0	0	385	0
Forster's tern	*Sterna forsteri*	542	601	136	1	149	372	72	0	0	9	81	55	0	0	0	0
Caspian tern	*Sterna caspia*	71	3	0	0	963	13	1	0	0	0	0	0	0	0	0	0
Heron																	
great blue heron	*Ardea herodias*	1	4	3	3	13	27	22	0	0	5	2	3	1	0	1	2
great egret	*Ardea alba*	42	36	50	4	81	203	6	0	0	28	3	27	0	0	0	0
snowy egret	*Egretta thula*	128	218	78	2	192	592	17	13	0	56	11	50	0	0	0	0

Table 11 continued.

		1	2	1A	2A	3	4	5	6	7	6A	7A	8	9	10	Cryst	CB3
Medium shorebird																	
American avocet	*Recurvirostra americana*	8119	0	1833	0	28358	28080	4706	528	0	1644	1563	86	0	0	0	67
black-bellied plover	*Pluvialis squatarola*	810	0	3	0	3156	508	72	317	0	56	1	1	0	31	75	0
black-necked stilt	*Himantopus mexicanus*	376	0	307	0	70	161	3619	54	0	43	492	23	0	0	0	11
greater yellowlegs	*Tringa melanoleuca*	1	1	0	8	21	59	24	10	0	2	37	22	0	0	0	52
killdeer	*Charadrius vociferus*	9	0	0	1	2	3	0	3	0	2	0	8	0	0	4	1
long-billed curlew	*Numenius americanus*	644	0	34	0	1165	2653	0	0	0	0	0	1	0	0	4	0
lesser yellowlegs	*Tringa flavipes*	0	0	0	0	0	6	2	0	0	0	6	2	0	0	0	0
marbled godwit	*Limosa fedoa*	1291	0	181	0	7142	8675	88	12	0	7	12	17	0	0	0	0
stilt sandpiper	*Calidris himantopus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
whimbrel	*Numenius phaeopus*	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
willet	*Catoptrophorus semipalmatus*	705	2	100	0	3716	3812	2605	374	0	102	339	24	0	0	2	260
unidentified shorebird		0	0	0	0	0	0	0	90	0	0	0	0	0	0	0	0
Phalarope																	
red-necked phalarope	*Phalaropus lobatus*	0	0	82	0	0	10	76	0	0	0	0	0	0	0	0	0
Small shorebird																	
Baird's sandpiper	*Calidris bairdii*	0	0	0	0	0	0	0	0	0	0	0	39	0	0	0	0
dowitcher (long, short-billed)	*Limnodromus scolopaceus, L. griseus*	1798	0	26	0	2934	7240	77	229	0	134	199	0	0	0	1	26
dunlin	*Calidris alpina*	2601	0	324	27	19931	37381	30572	29266	0	4596	2589	5	0	40	0	271
least sandpiper	*Calidris minutilla*	5187	2	11	82	6912	6482	2296	1045	15	1008	1454	22	0	10	24	137
western sandpiper	*Calidris mauri*	4212	17	485	48	162447	71555	23761	19469	0	13725	4088	235	0	188	261	265
unidentified sandpiper	*Calidris* spp.	225	0	3	7	8648	2010	2365	0	0	0	0	0	0	0	0	0
semipalmated plover	*Charadrius semipalmatus*	246	0	10	0	230	8	7	4	0	3	0	0	0	0	92	0
snowy plover	*Charadrius alexandrinus*	0	0	0	0	0	5	14	6	0	0	34	0	0	0	2	0
Total		**38611**	**44679**	**22663**	**765**	**343147**	**238015**	**76838**	**70375**	**54**	**42181**	**18928**	**4708**	**19**	**289**	**941**	**1310**

Table 12. Passerine and rail species observed utilizing Pond 2A, Napa-Sonoma salt ponds, San Francisco Bay, CA. Surveys completed October 2003 - June 2005.

Common name	Scientific name	count
Passerines		
American crow	*Corvus brachyrhynchos*	2
black phoebe	*Sayornis nigricans*	3
cliff swallow	*Petrochelidon pyrrhonota*	39
common yellowthroat	*Geothlypis trichas*	64
marsh wren	*Cistothorus palustris*	301
song sparrow	*Melospiza melodia*	424
Rails		
black rail	*Laterallus jamaicensis*	2
clapper rail	*Rallus longirostris*	4
sora	*Porzana carolina*	4
Virginia rail	*Rallus limicola*	4
unidentified rail species		1

Table 13. Average water quality values ± SD for the Napa-Sonoma salt ponds, San Francisco Bay, CA. Data collected November 2004- June 2005.

Pond	Salinity (ppt)	DO (mg/L)	pH	Turbidity (NTU)	Temperature (ºC)
1	18.0 ± 1.5	8.1 ± 3.1	8.00 ± 0.30	121 ± 185	19.45 ± 7.33
1A	22.8 ± 4.5	10.5 ± 3.2	8.82 ± 0.16	112 ± 185	20.71 ± 7.77
2	16.8 ± 7.6	11.3 ± 2.3	8.51 ± 0.32	127 ± 169	15.20 ± 4.41
3	10.2 ± 5.7	10.2 ± 4.3	7.84 ± 2.82	42 ± 60	15.36 ± 7.68
4	23.3 ± 8.5	12.2 ± 5.6	8.43 ± 3.38	12 ± 17	16.77 ± 8.64
5	41.4 ± 14.0	11.3 ± 5.0	8.94 ± 3.47	17 ± 28	17.29 ± 8.00
6	46.3 ± 14.3	11.6 ± 3.1	8.91 ± 0.42	19 ± 27	16.85 ± 3.83
6A	25.0 ± 4.5	9.4 ± 0.8	8.29 ± 0.14	53 ± 83	17.26 ± 4.62
7A	42.6 ± 11.5	8.2 ± 2.4	8.01 ± 0.23	46 ± 93	17.09 ± 3.17
7	236.6 ± 106.0	5.6 ± 0.5	5.33 ± 0.79	–	19.34 ± 3.71
8	7.4 ± 3.8	12.3 ± 1.3	8.21 ± 0.38	–	17.44 ± 3.08
CB3	117.6 ± 26.1	5.3 ± 1.4	6.45 ± 0.23	44 ± 105	17.62 ± 6.38

Table 14. Number of individual small mammals captured by species (excluding recaptures) along Pond 4 and 5 of the Napa Sonoma Marshes.

Location	California vole	House mouse	Salt marsh harvest mouse
Pond 4	10	2	14
Pond 5	8	3	28
Total	**18**	**5**	**42**

Table 15. Comparison of salt marsh harvest mice captures compared to this study.

Study	(# Captures/ trap night) * 100	Location	Capture year
This study	12.2	P4 and P5, Napa-Sonoma Marshes	2005
Wondolleck, J. T., W. Zolan, and G. L. Stevens. 1976. A population study of the harvest mice (*Reithrodontomys raviventris* Dixon) in the Palo Alto Baylands salt marsh. Wasmann J. of Biology. 34(1): 52-64.	8.3	Palo Alto Baylands, Santa Clara County	1972
Bias, M. A. 1994. Ecology of the salt marsh harvest mouse in San Pablo Bay. Unpubl. PhD Dissertation. UC Berkeley.	7.5 (over all sites and years)	Mare Island, San Pablo Bay	1989-1992
Takekawa, J. Y., M. A. Bias, I. Woo, K. L.Turner, A. R. Westhoff, G. T. Downard and F. A. Reid. 2005. Restoration Research and Monitoring in Bayland Wetlands of San Francisco Bay: The Tolay Creek Restoration Project, 2004 Progress Report. U. S. Geological Survey, Unpubl. Prog. Rep. Vallejo, CA. 67pp.	7.3	Tolay Creek, San Pablo Bay	2003 (fall)
Shellhammer, H. S., R. Jackson, W. Davilla, A. M. Gilroy, H. T. Harvey, and L. Simons. 1982. Habitat preferences of the salt marsh harvest mice (*Reithrodontomys raviventris*). Wasmann J. of Biology. 40: 102-114	Alviso: 4.2 Baywide: 0.4 NBay: 1.2 Suisun: 0.4	San Francisco Bay	1979, 1980
Shellhammer, H. S., R. Duke, H. T. Harvey, V. Jennings, V. Hohnson, and M. Newcomer. 1988. Salt marsh harvest mice in the dikes salt marshes of Southern San Francisco Bay. Wasmann J. of Biology. 46:89-103	0.0 to 3.0	Southern Alameda and northern Santa Clara Counties. 22 diked marshes, 2 tidal	1983-1986
Padgett-Flohr, G. E. and L. Isakson. 2003. A random samping of salt marsh harvest mice in a muted tidal marsh	1.9 (random point sampling, non-transect, non-grid)	New Chicago Marsh, San Francisco Bay National Wildlife Refuge	1997
Clark Jr., D. R., K. S. Foerster, C. M. Marn, and R. L. Hothem. 1992. Uptake of environmental contaminants by small mammals in pickleweed habitats at San Francisco Bay, California. Arch. Environ. Contam. Toxicol. 22: 389-396	1.4 (over all sites)	San Francisco Bay: 12 sites	1989

Figure 1. Study area. Napa-Sonoma Marshes Wildlife Area. San Francisco Bay, CA.

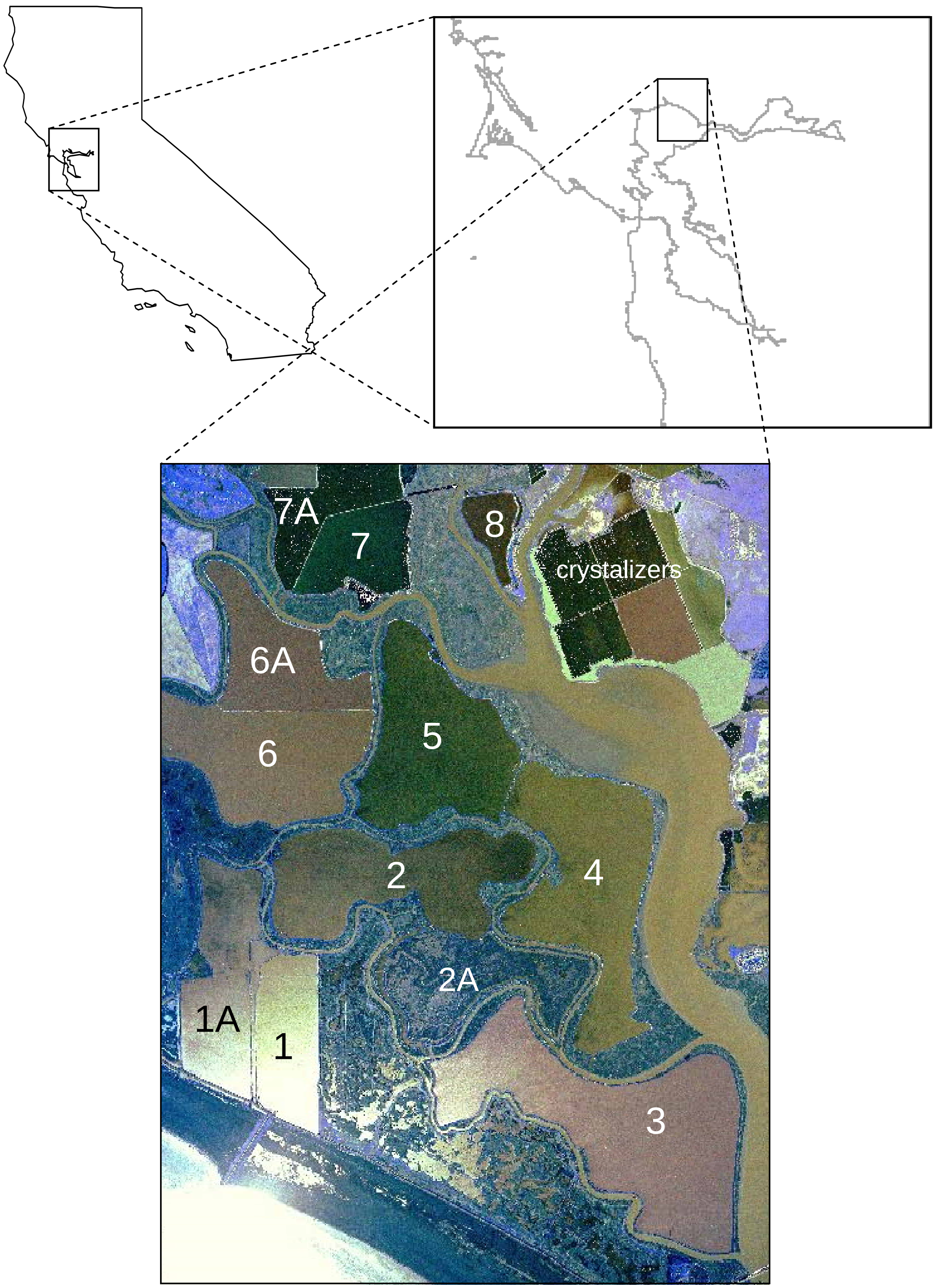

Figure 2. Location of erosion pins installed on the pond side Pond 3 levee, Napa-Sonoma Marshes Wildlife Area, CA.

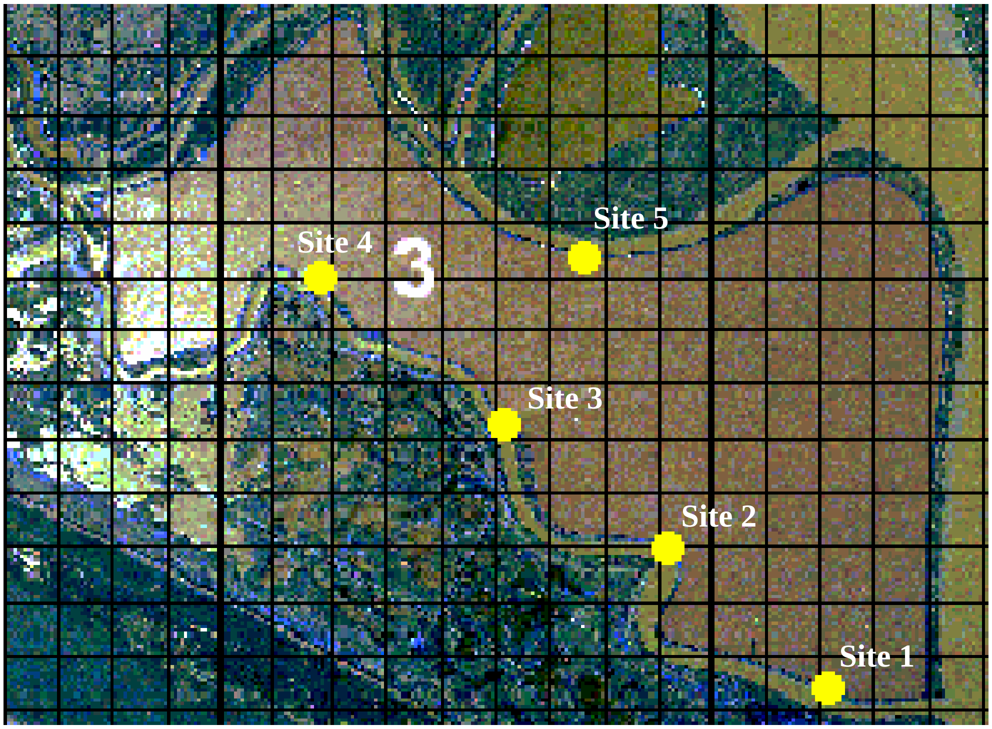

Figure 3. Erosion pins installed on the pond side of the southern levee of Pond 3, Napa-Sonoma Marshes Wildlife Area, CA.

Figure 4. Location of erosion pins (indicated by yellow circles) installed at China Slough, Napa-Sonoma Marshes Wildlife Area, CA.

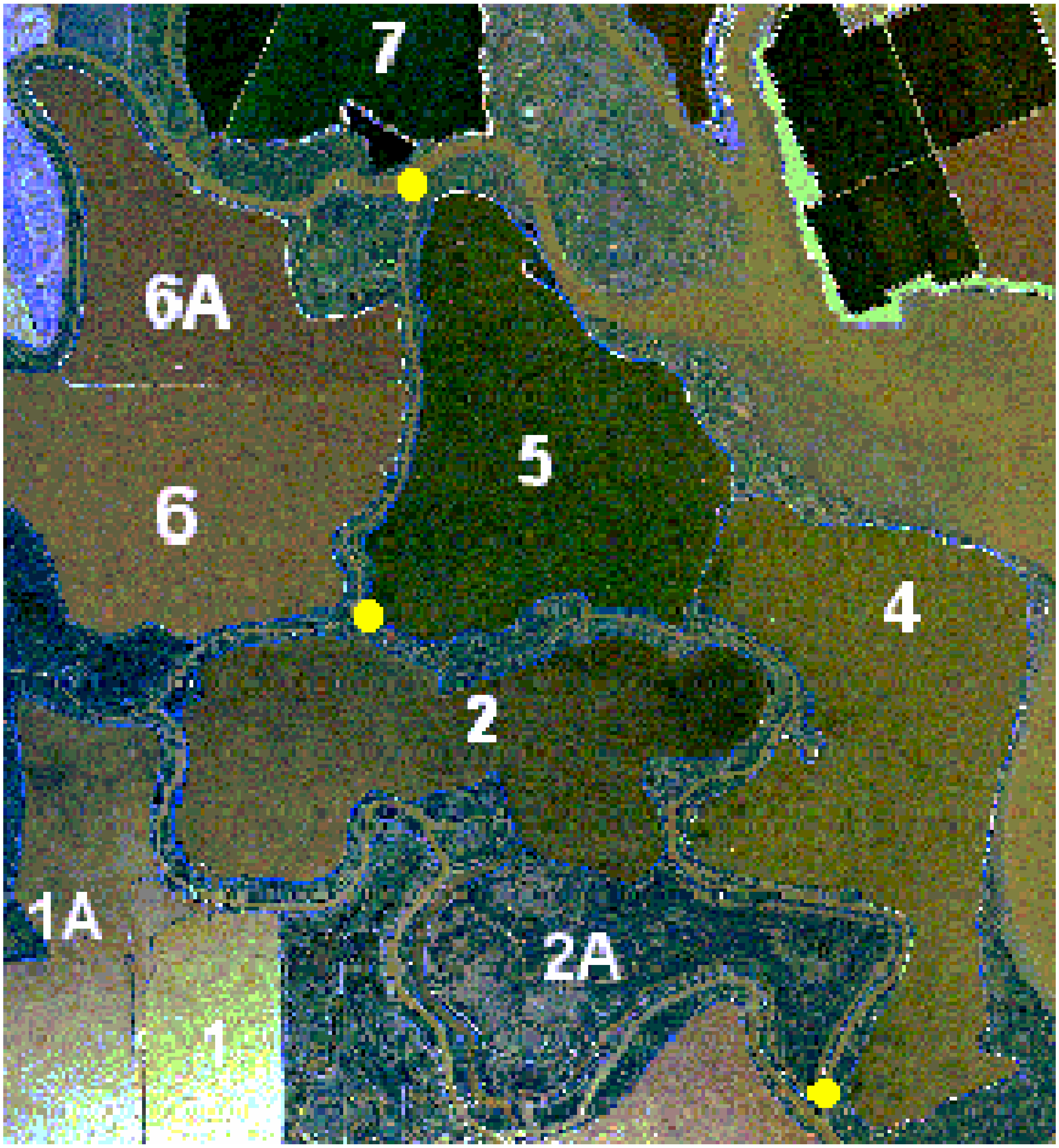

Figure 5. Location of benchmarks and staff gages used during the winter 2004 bathymetric survey of Pond 3, Napa-Sonoma Marshes Wildlife Area, CA.

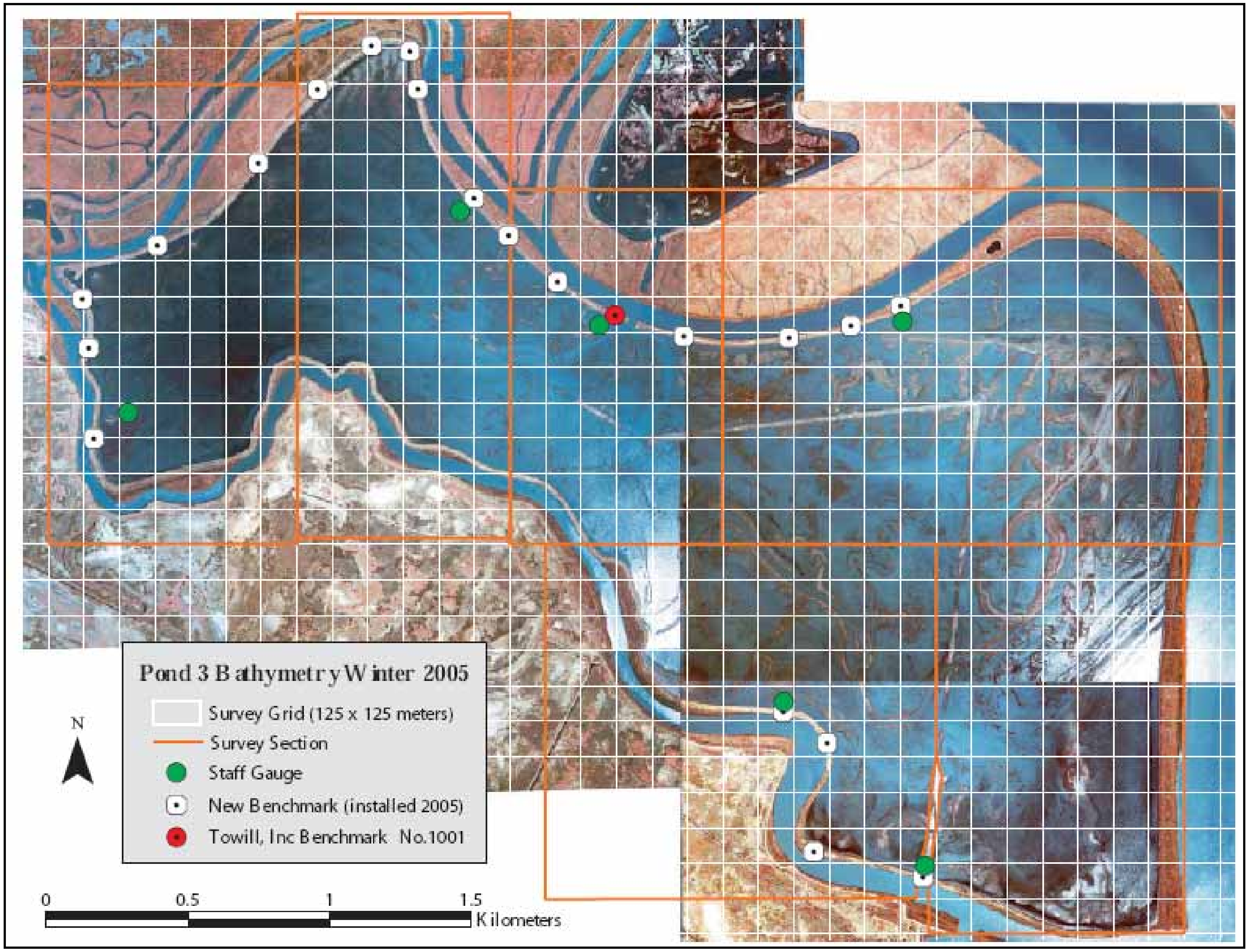

Figure 6. Locations of fringing marsh rail survey points at Ponds 3, 4, and 5, Napa-Sonoma Marshes Wildlife Area, CA. Survey locations indicated with a yellow star.

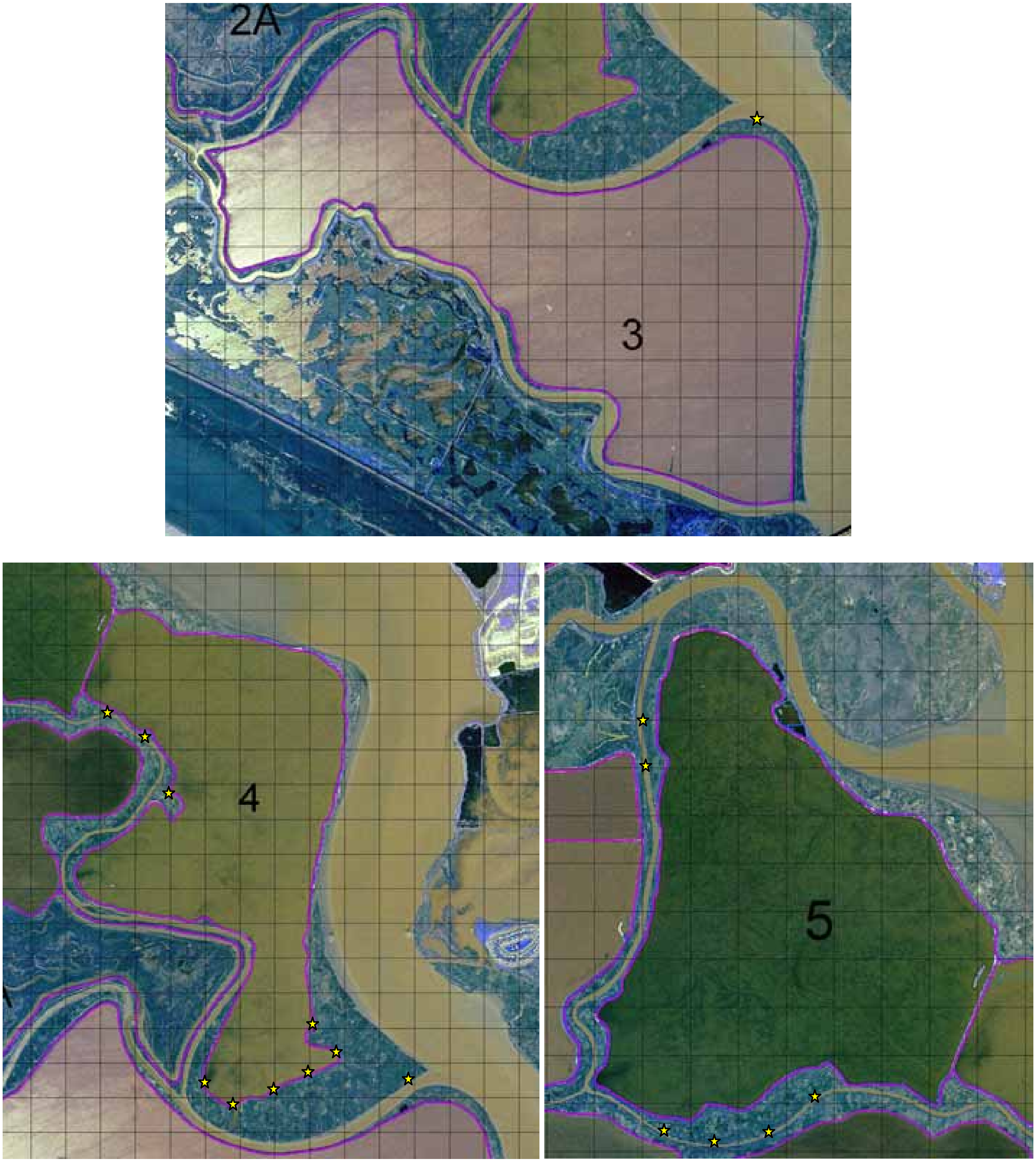

Figure 7. Locations of vegetation photopoints established at Pond 3, Napa-Sonoma Marshes Wildlife Area, CA.

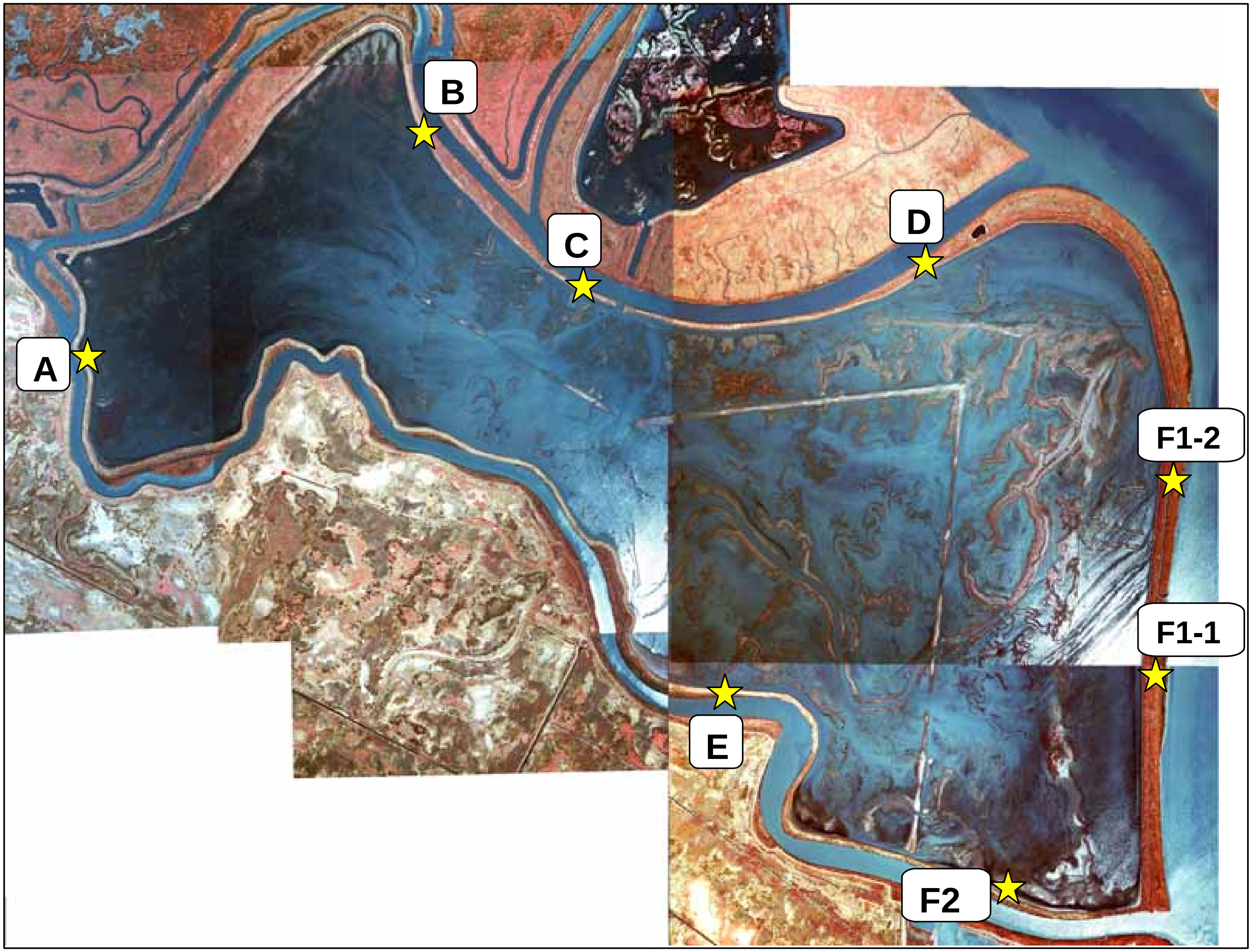

Figure 8. Monthly total bird counts by pond, Napa-Sonoma Marshes Wildlife Area, CA.

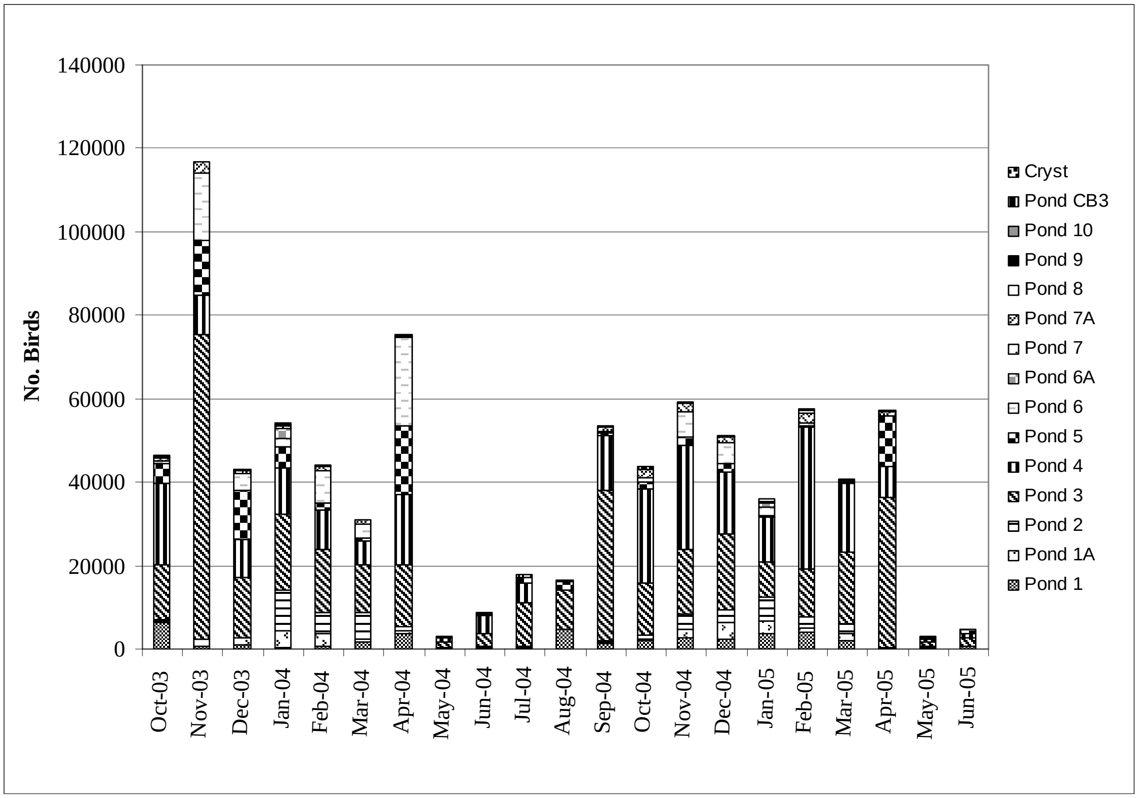

Figure 9. Proportion of birds counted Oct03-Jun05, by foraging guild, at each salt pond in the Napa-Sonoma Marshes Wildlife Area, CA.

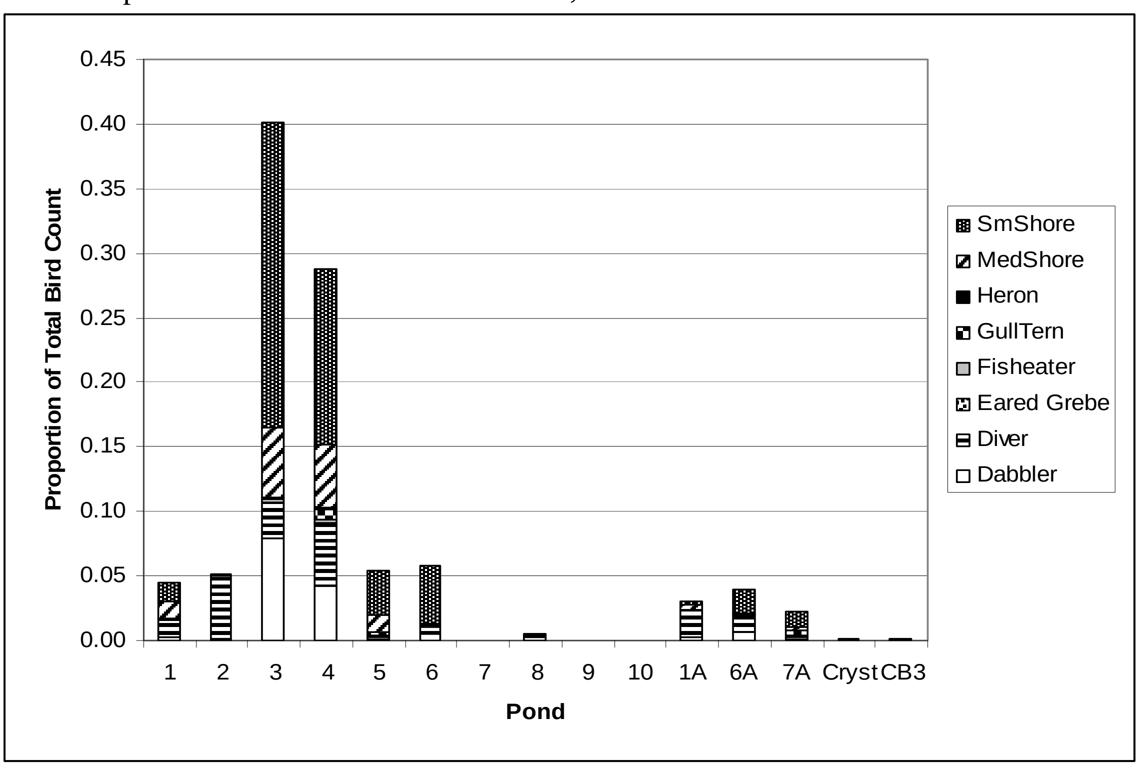

Figure 10. Proportion of total monthly bird counts by pond, Napa-Sonoma Marshes Wildlife Area, CA.

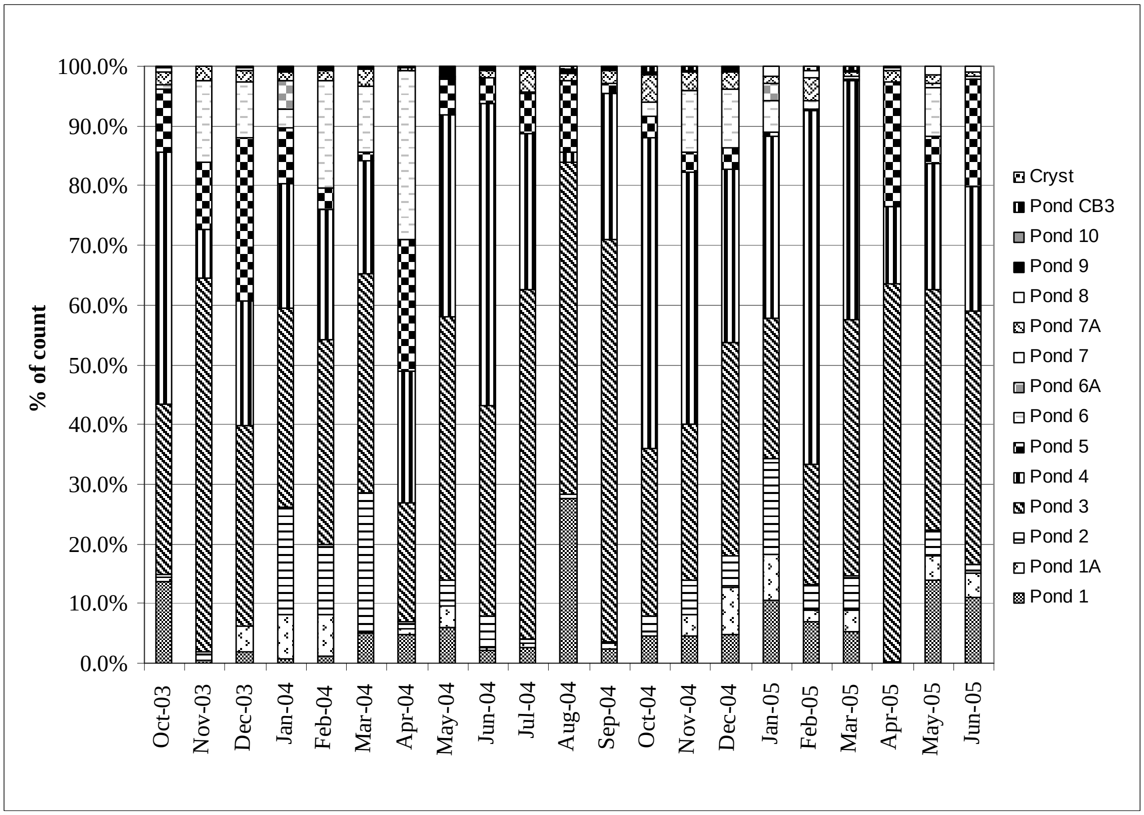

Figure 11. Proportion of birds counted on Pond 1 by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

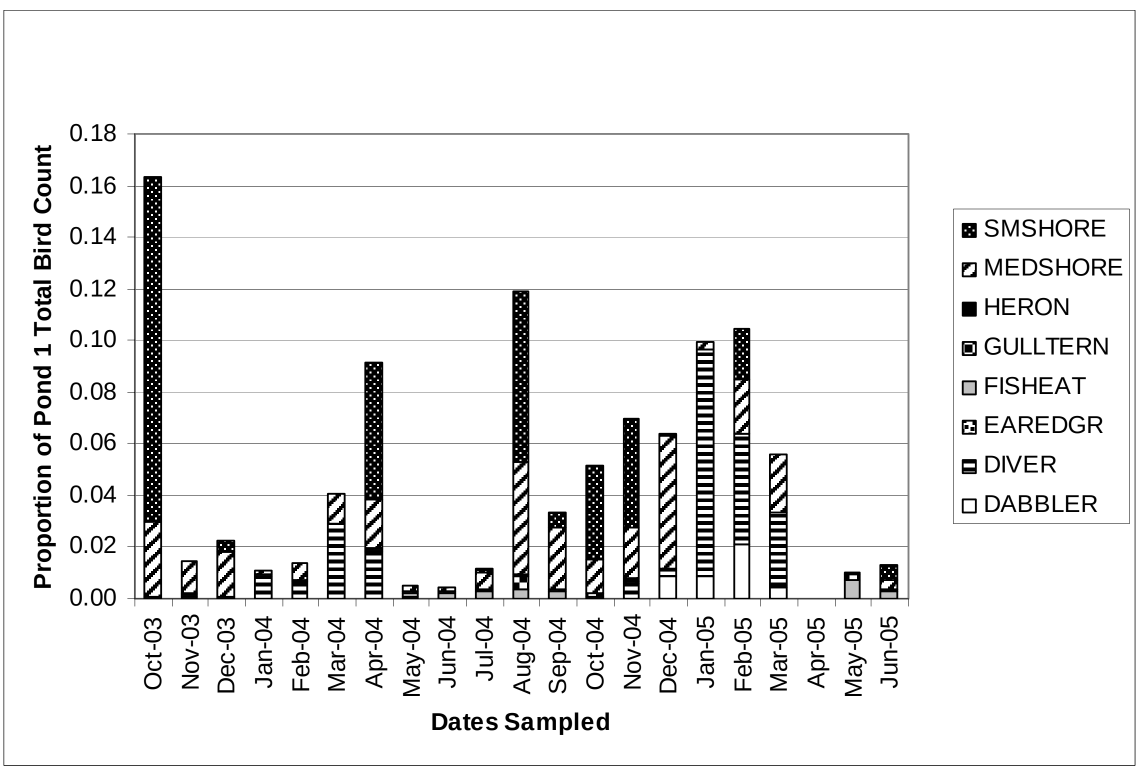

Figure 12. Proportion of birds counted on Pond 1A by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

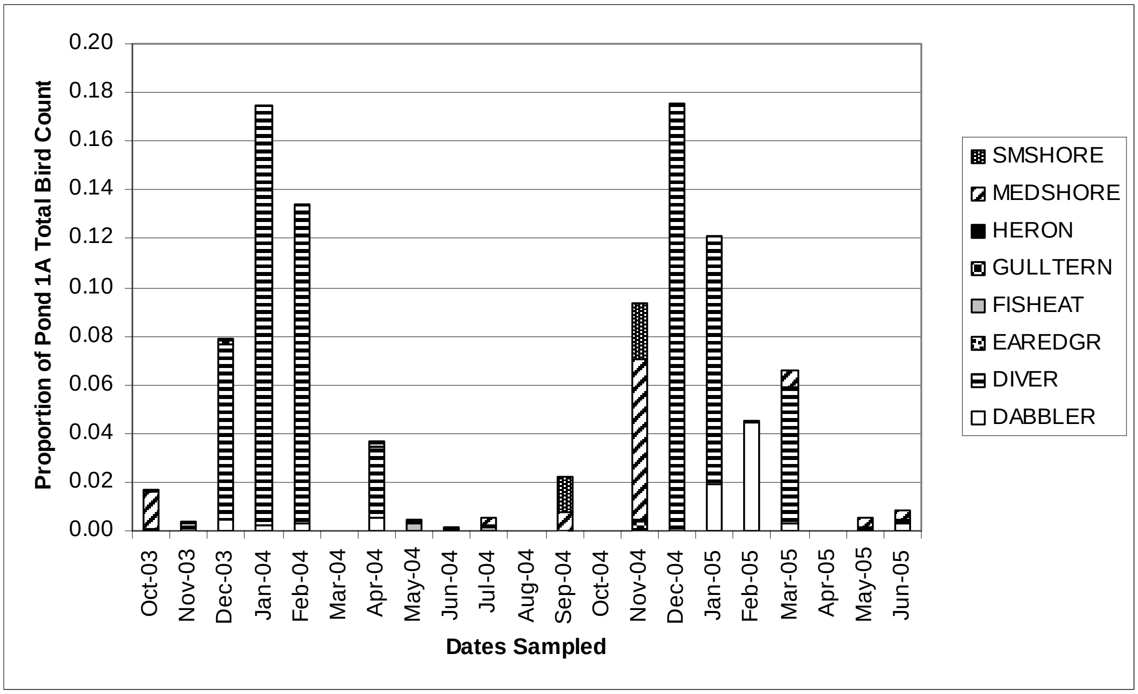

Figure 13. Proportion of birds counted on Pond 2 by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

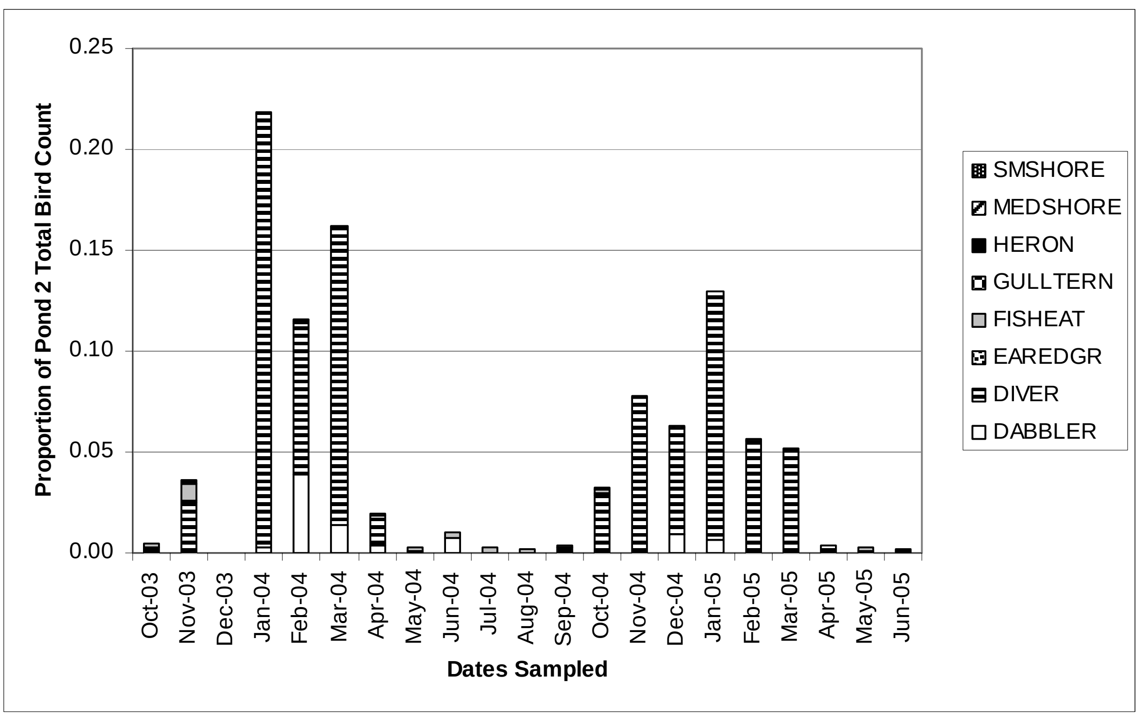

Figure 14. Proportion of birds counted on Pond 3 by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

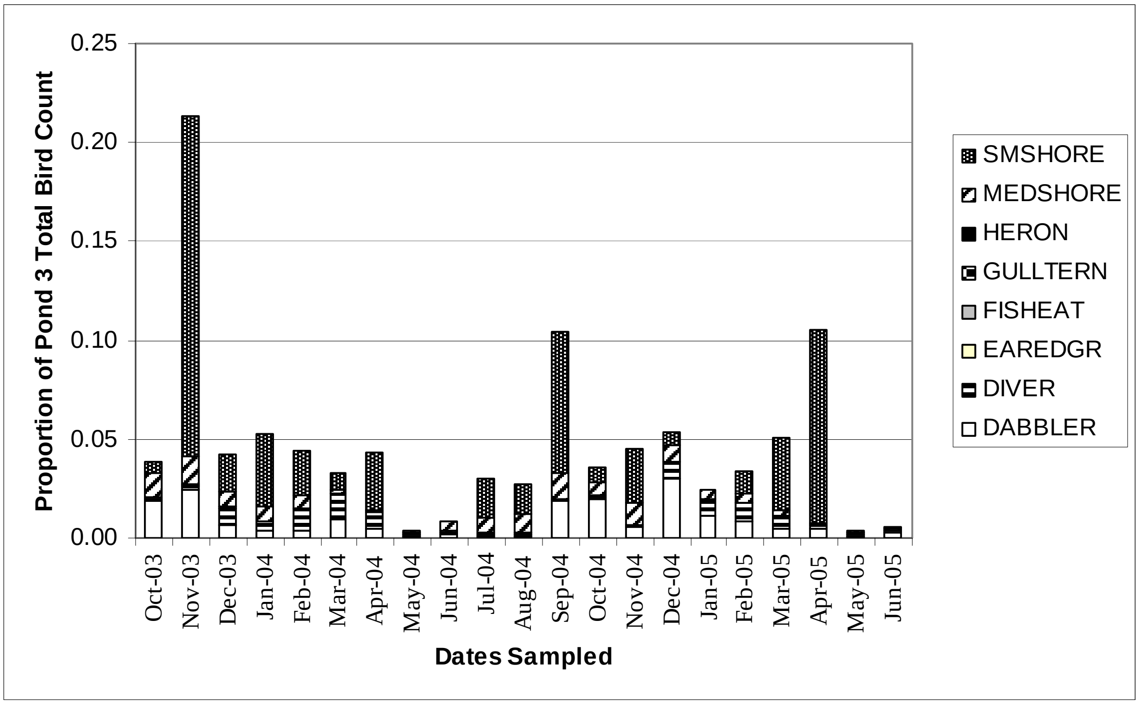

Figure 15. Proportion of birds counted on Pond 4 by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

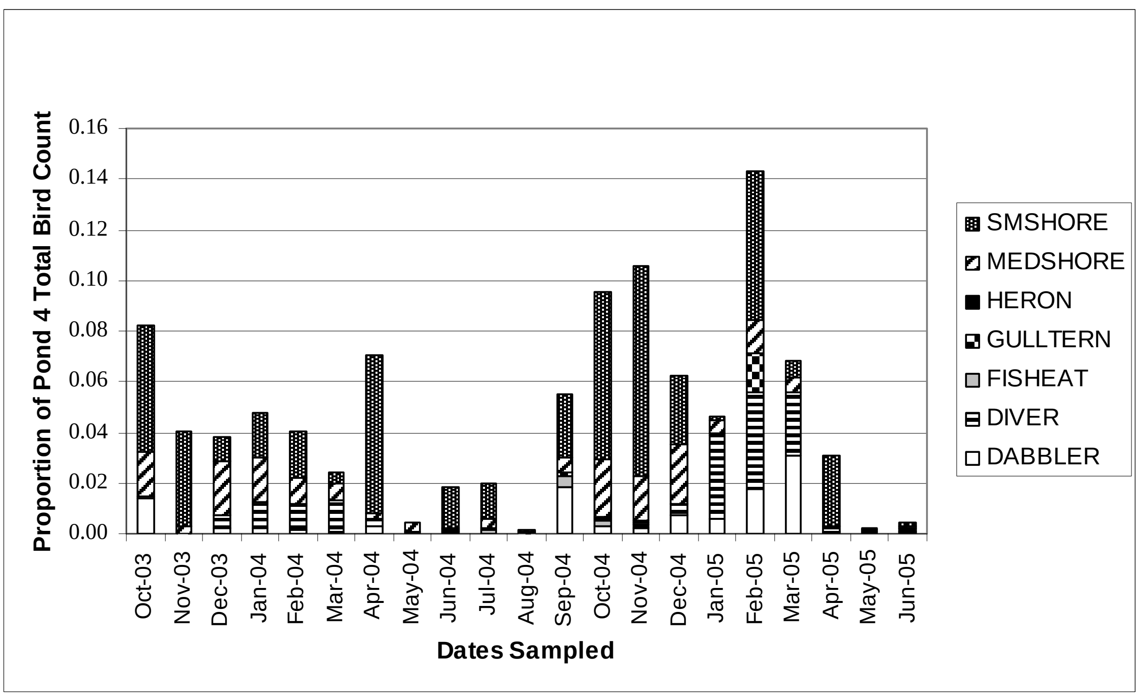

Figure 16. Proportion of birds counted on Pond 5 by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

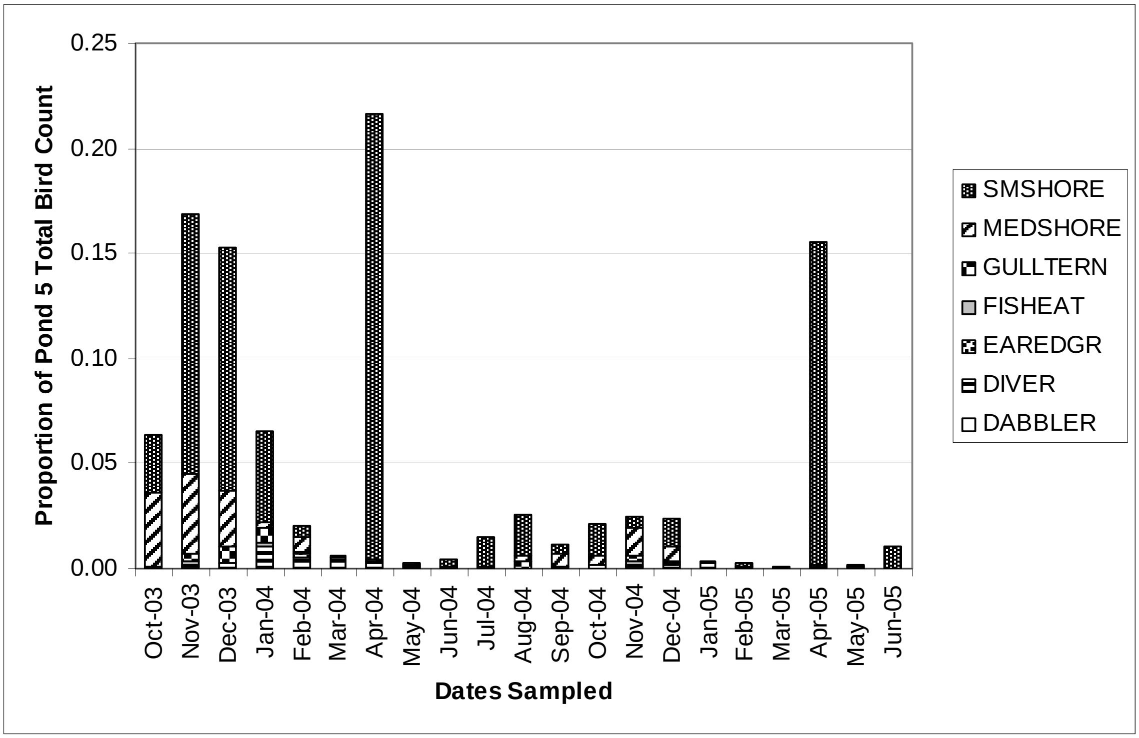

Figure 17. Proportion of birds counted on Pond 6 by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

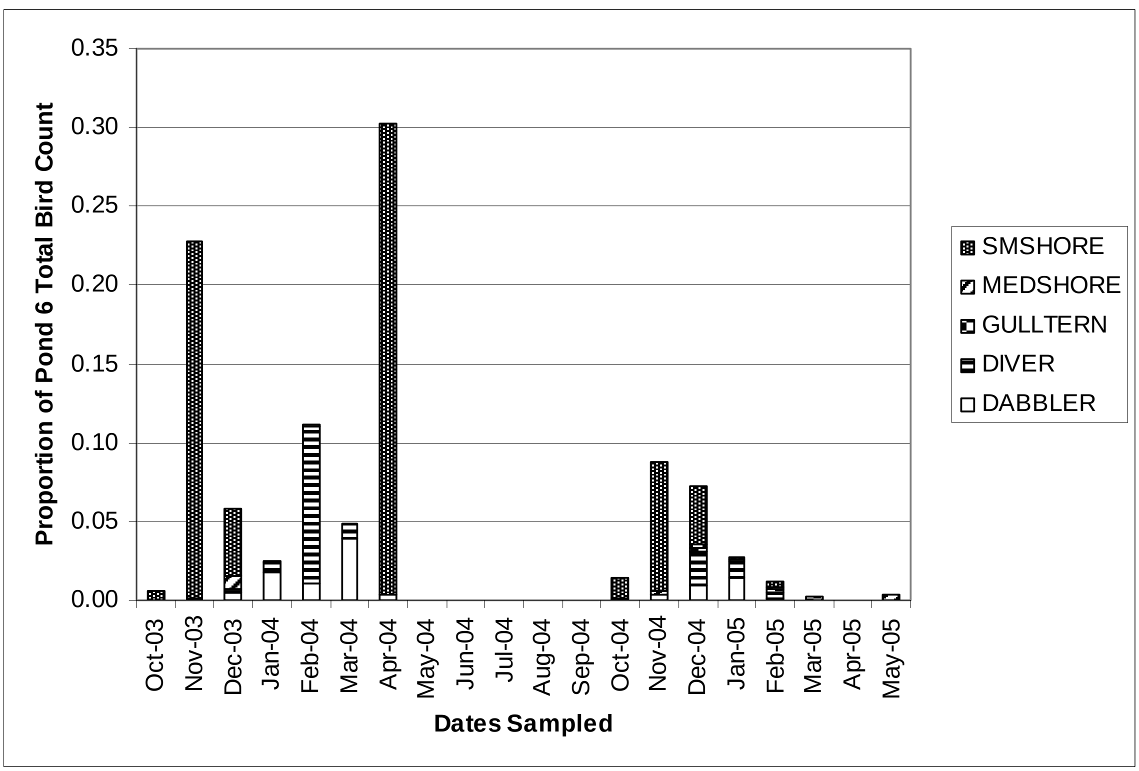

Figure 18. Proportion of birds counted on Pond 6A by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

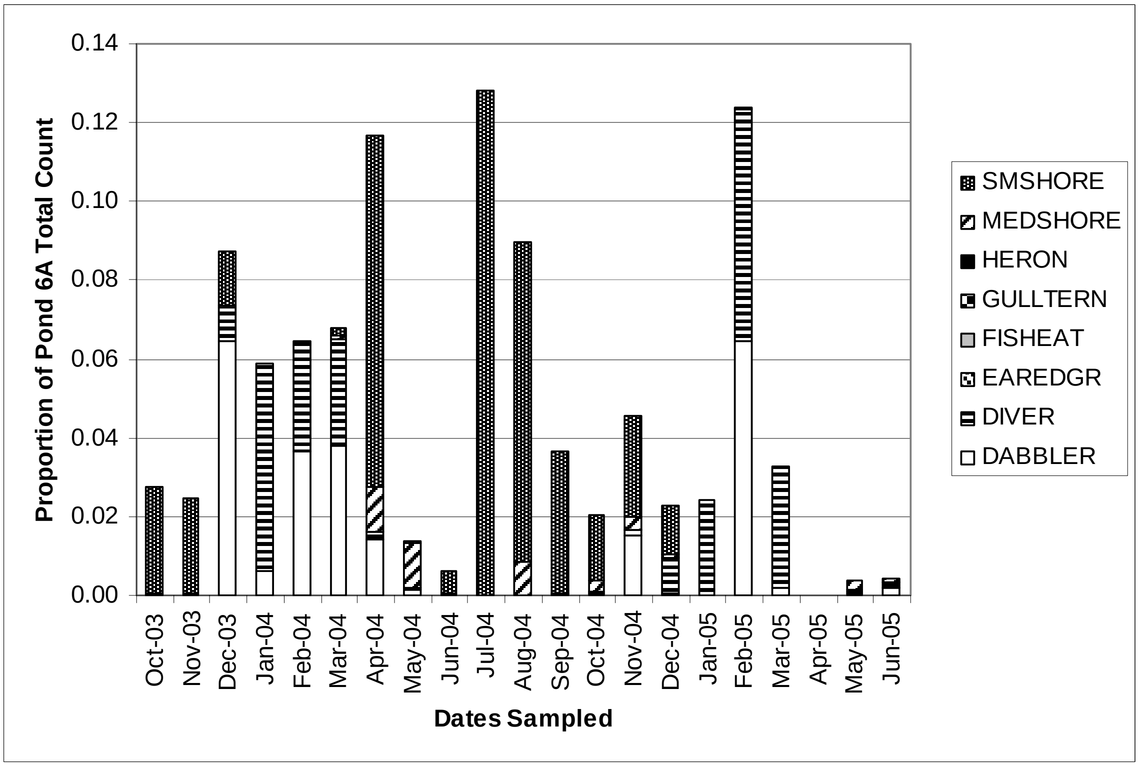

Figure 19. Proportion of birds counted on Pond 7A by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

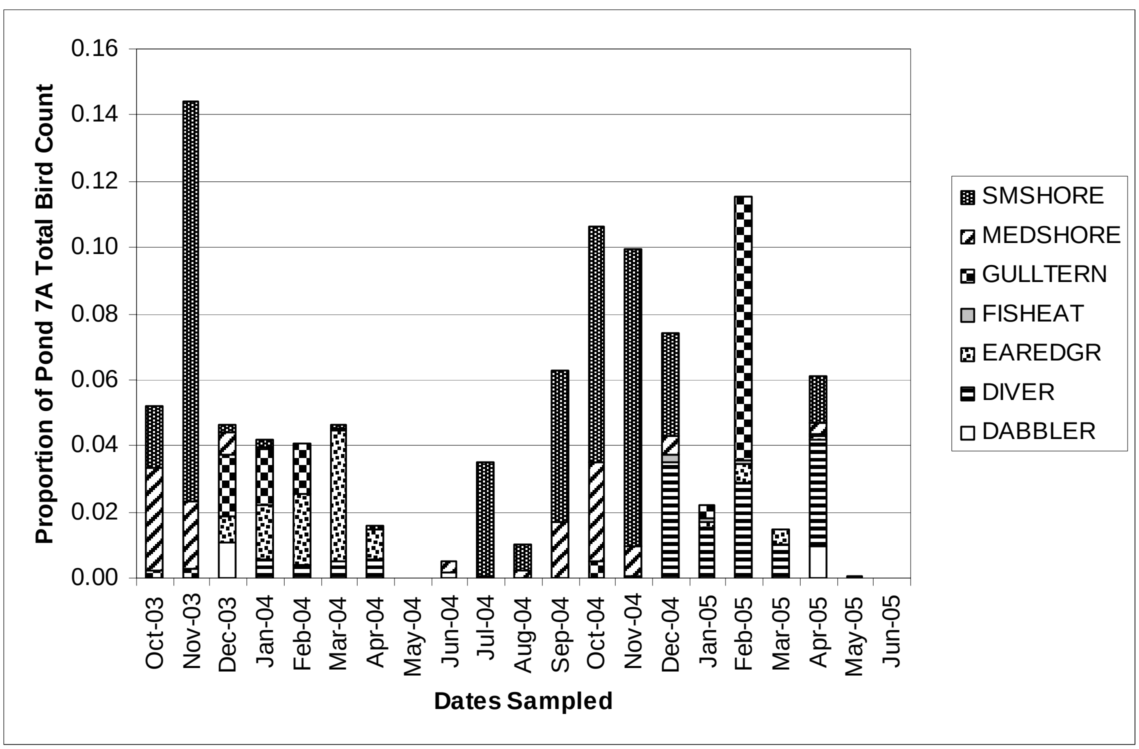

Figure 20. Proportion of birds counted on Pond 8 by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

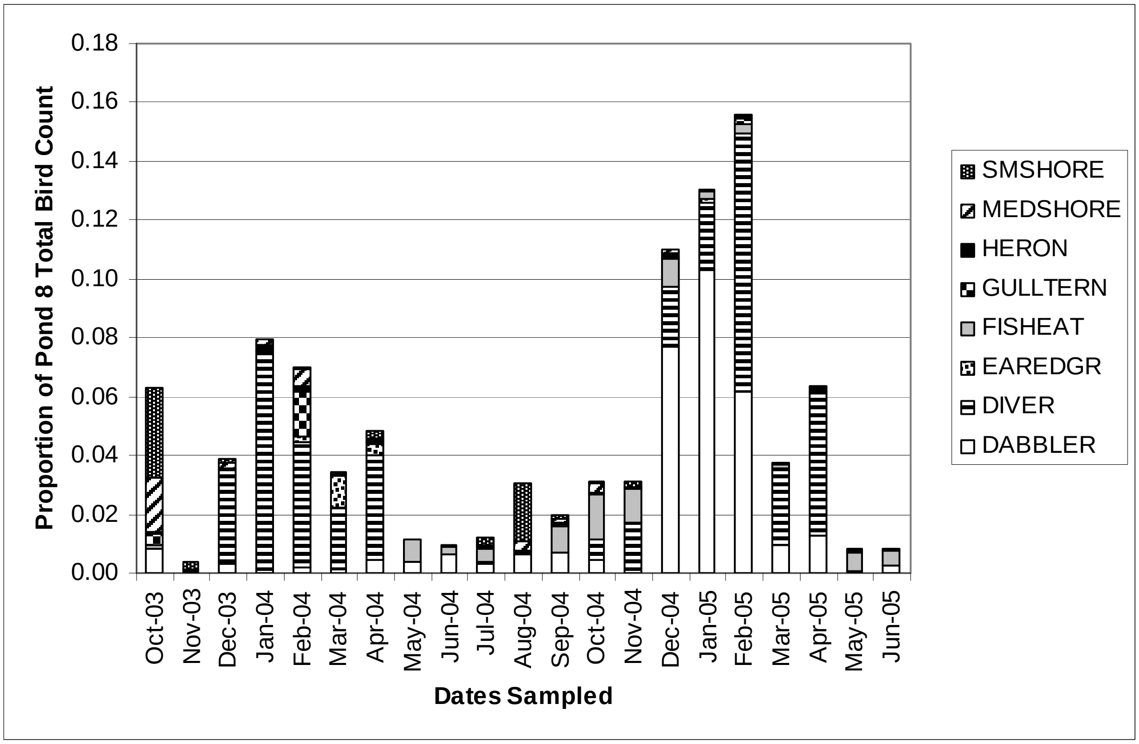

Figure 21. Proportion of birds counted on Pond 7 by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

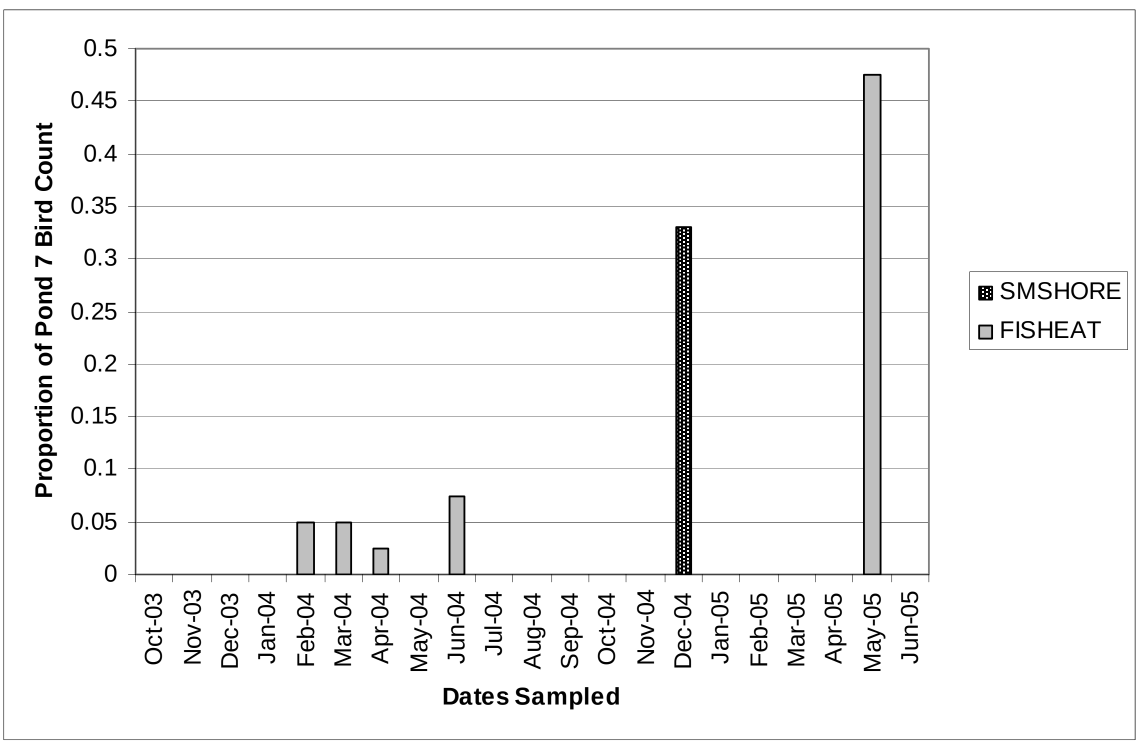

Figure 22. Proportion of birds foraging on Ponds 9, 10, and the Napa Plant crystallizer ponds, October 2003 – June 2005, Napa-Sonoma Marshes Wildlife Area, CA.

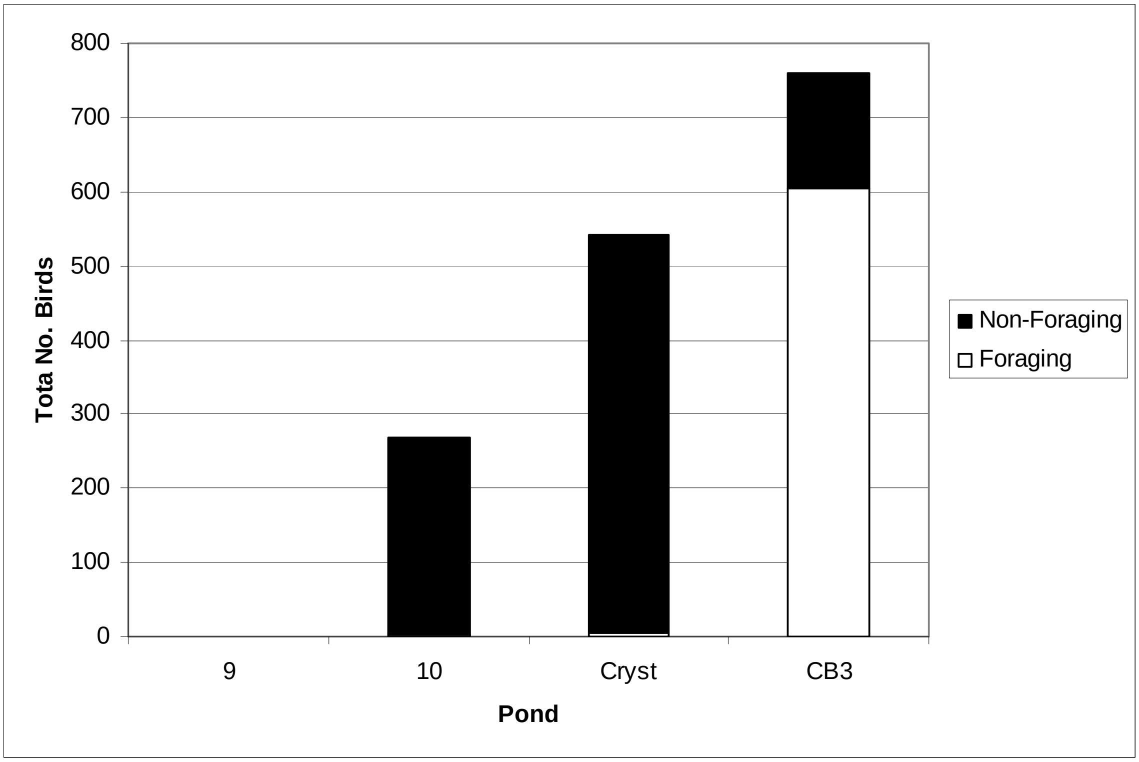

Figure 23. Proportion of birds counted on Ponds 9, 10, and the Napa Plant crystallizer ponds by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

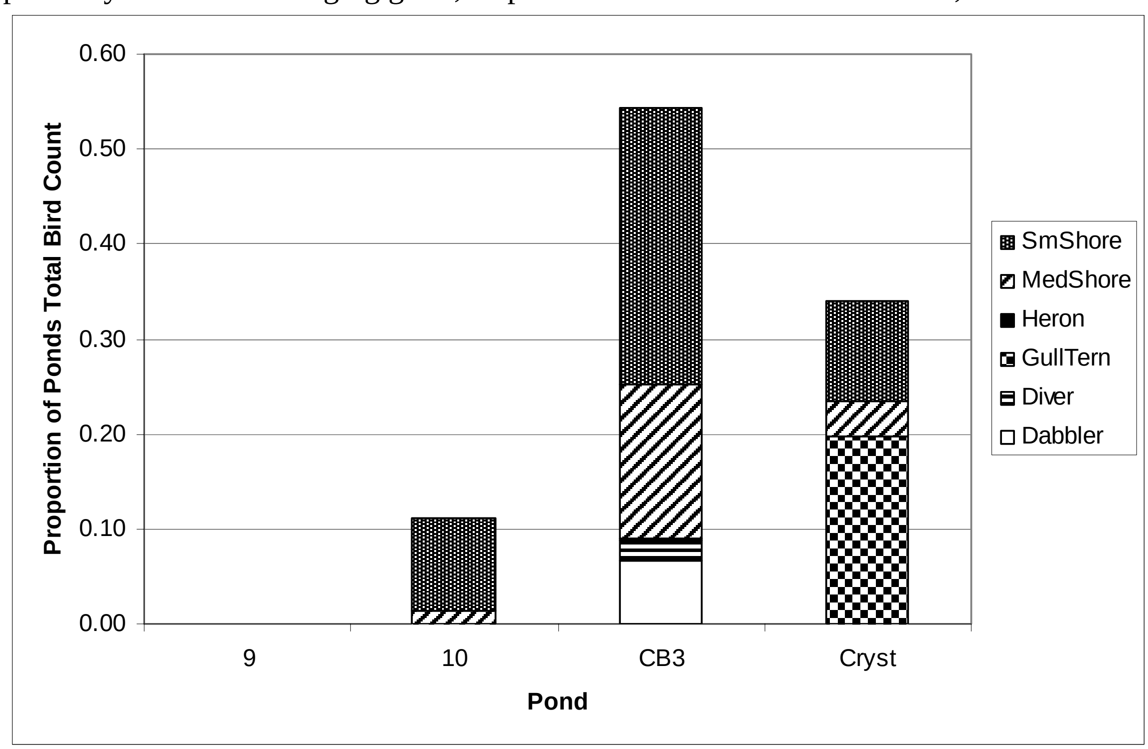

Figure 24. Proportion of birds counted on Pond 2A by month and foraging guild, Napa-Sonoma Marshes Wildlife Area, CA.

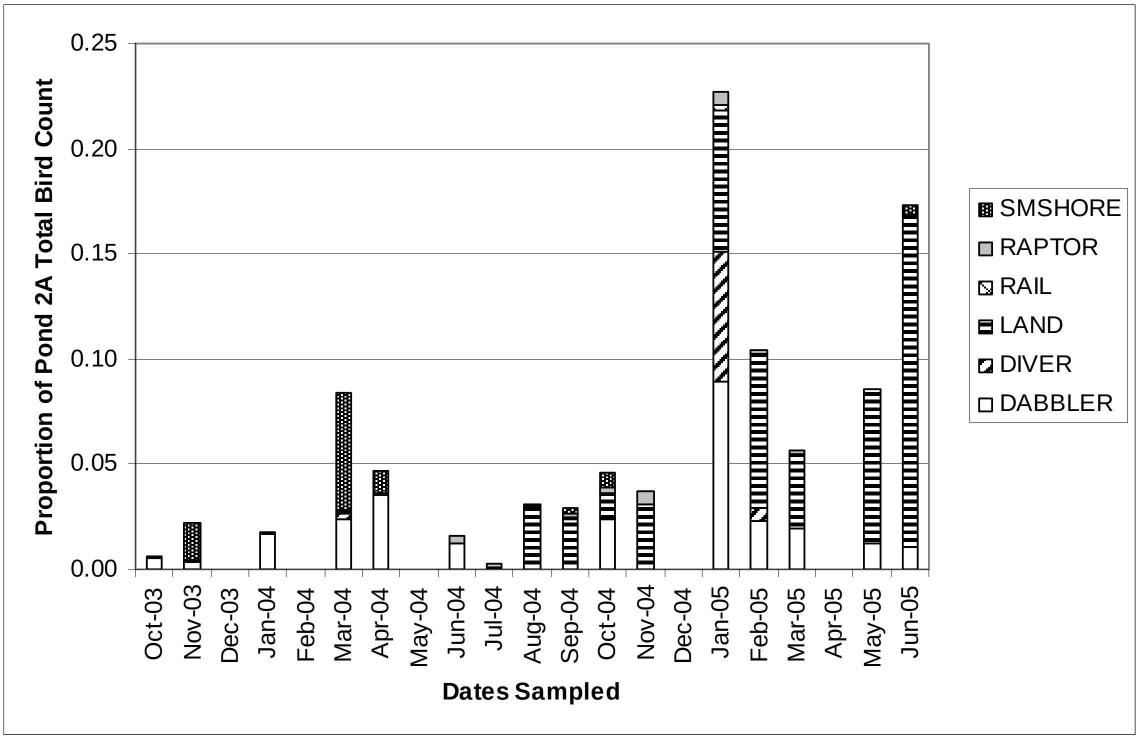

Figure 25. Salinity of Ponds 1, 1A, and 2 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

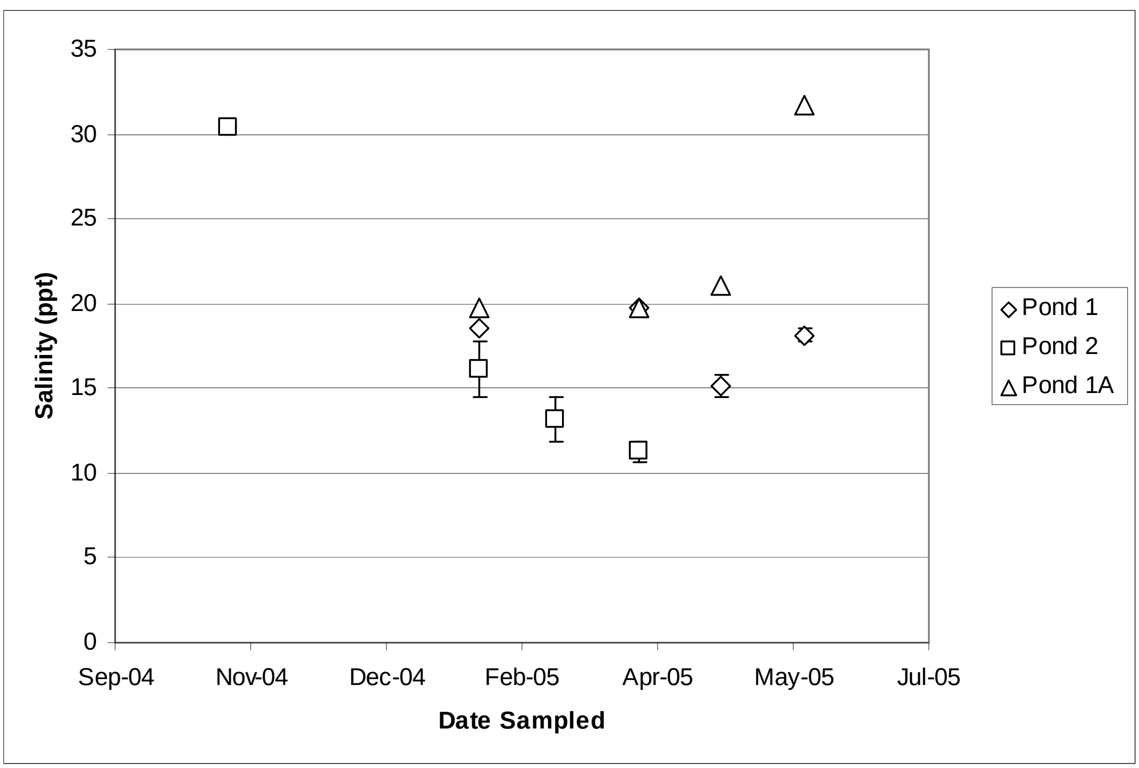

Figure 26. Salinity of Ponds 3, 4, and 5 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

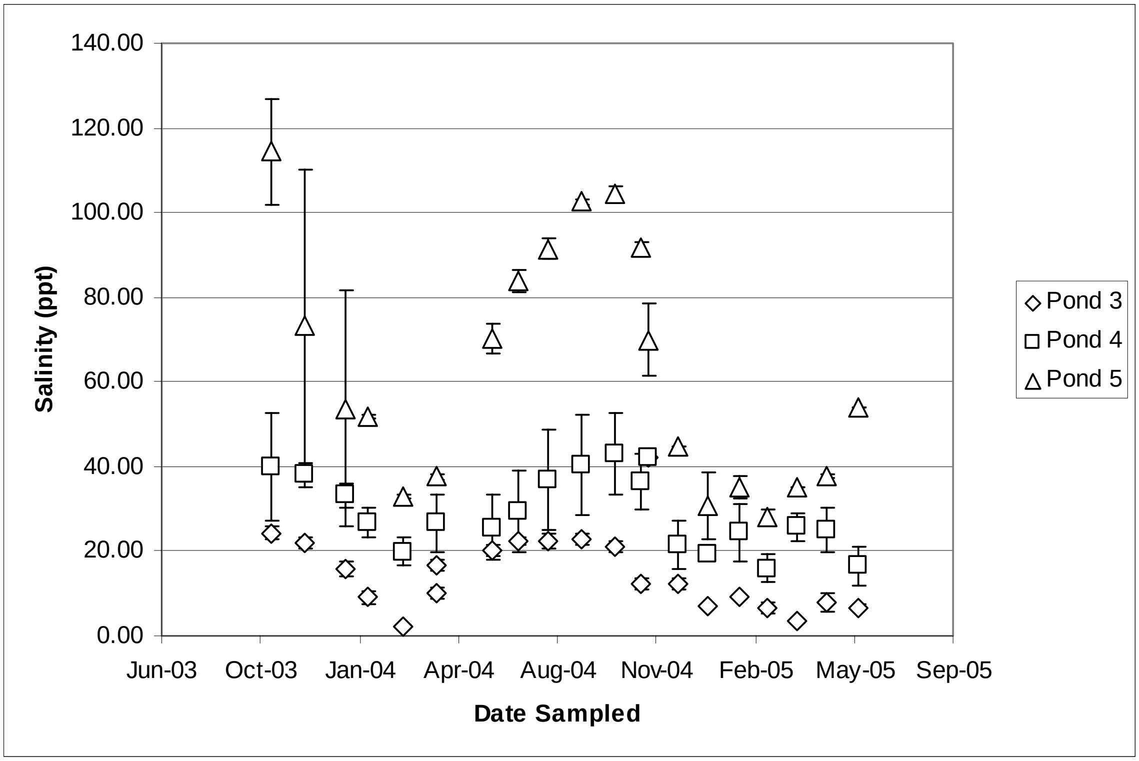

Figure 27. Salinity of Ponds 6, 6A, 7A, and 8 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

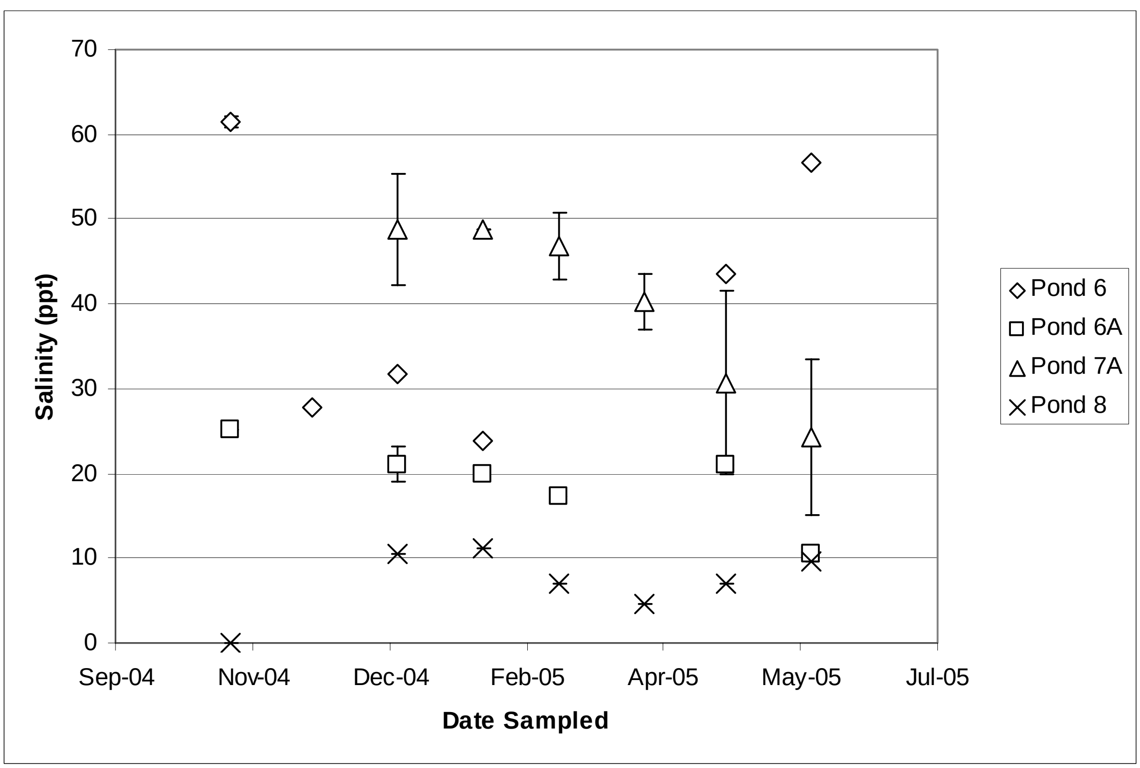

Figure 28. Salinity of Ponds 7 and CB3 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

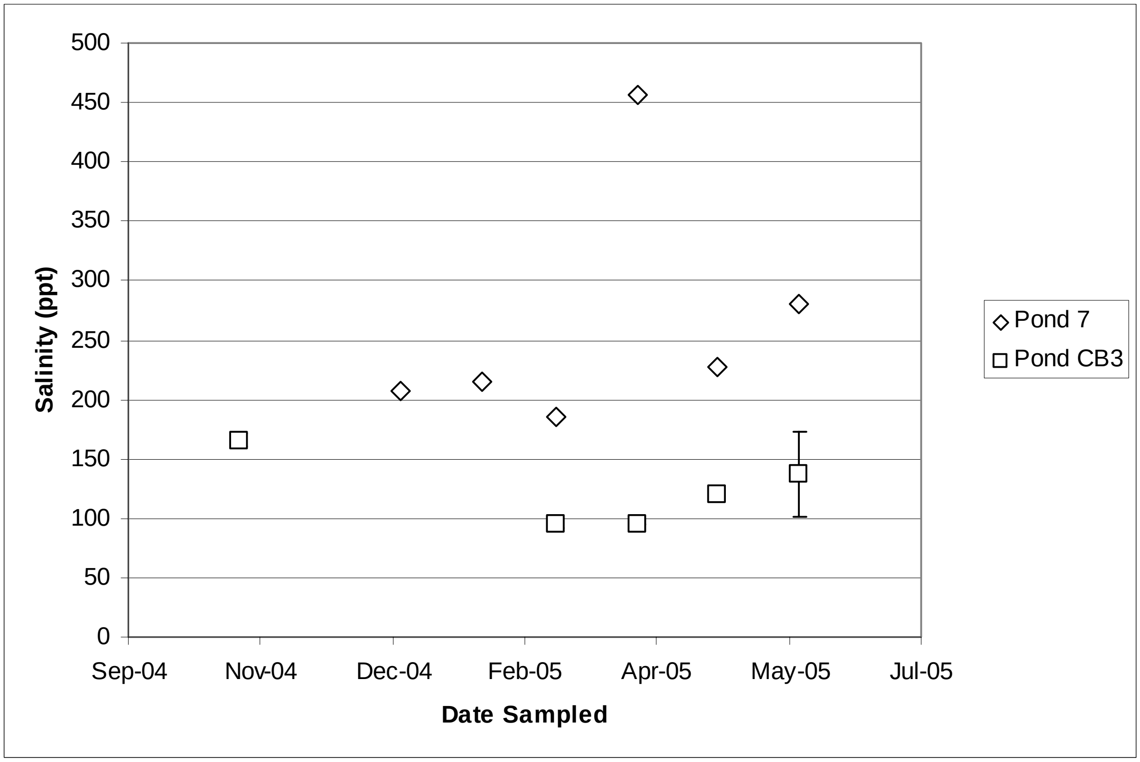

Figure 29. Dissolved oxygen of Ponds 1, 1A, and 2 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

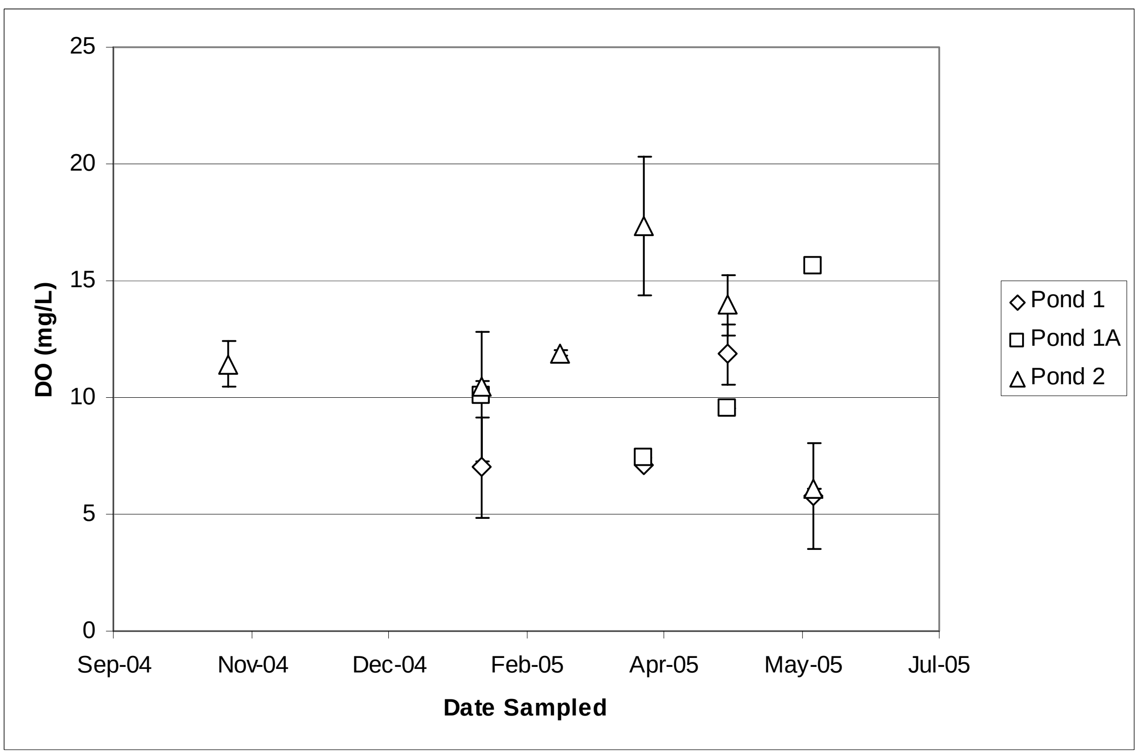

Figure 30. Dissolved oxygen of Ponds 3, 4, and 5 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

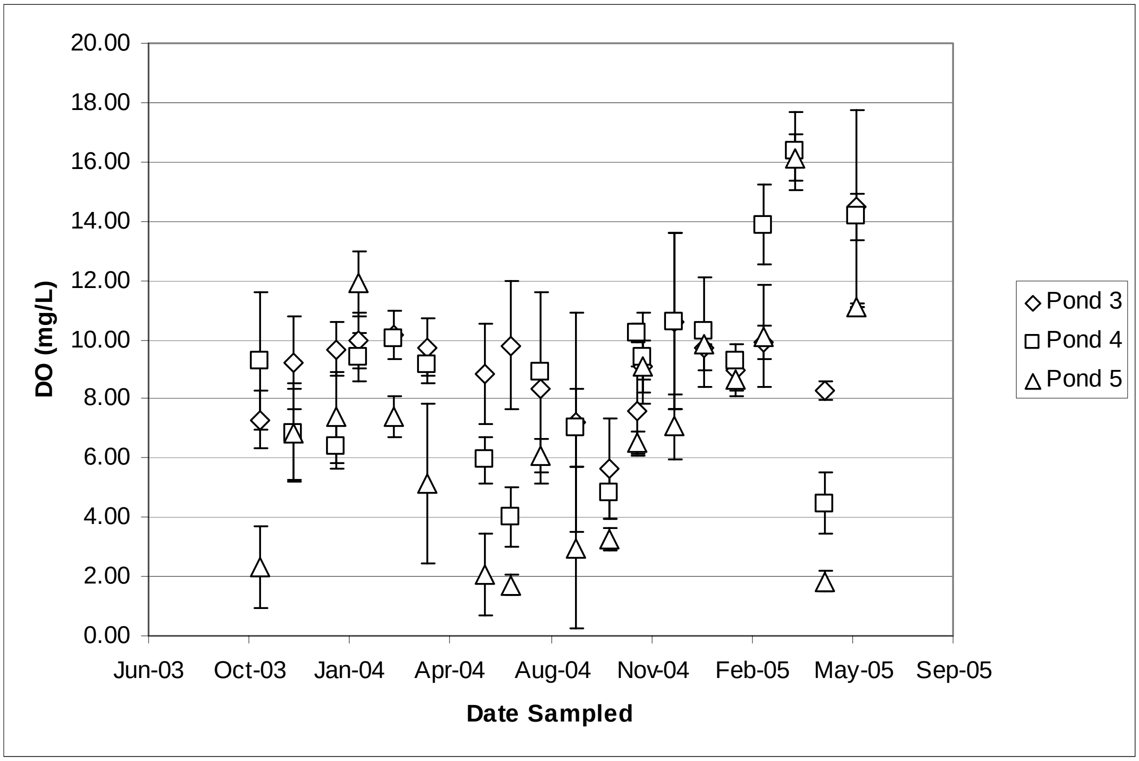

Figure 31. Dissolved oxygen of Ponds 6, 6A, 7A, and 8 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

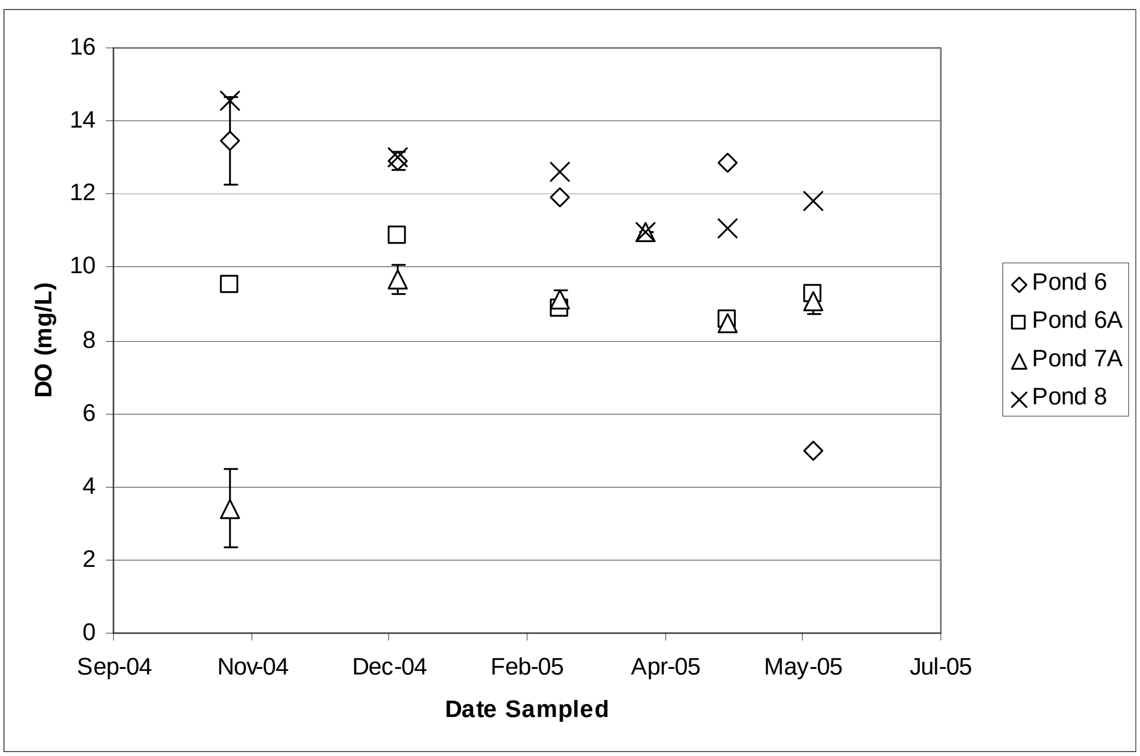

Figure 32. Dissolved oxygen of Ponds 7 and CB3 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

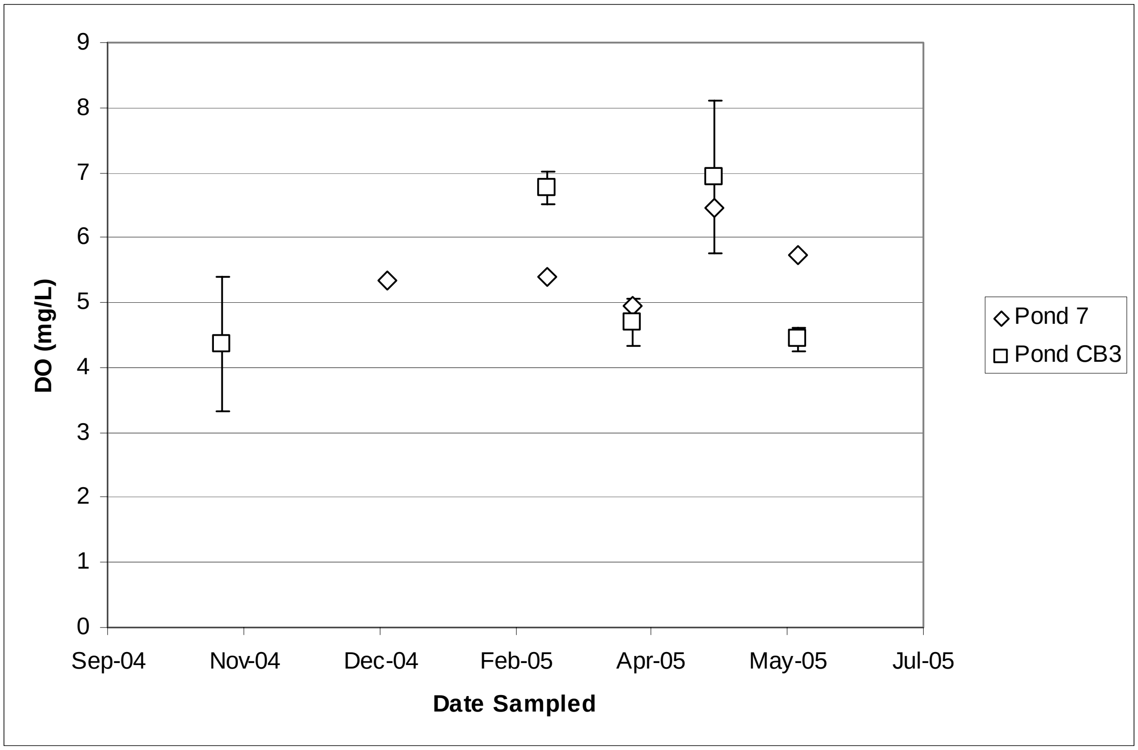

Figure 33. pH of Ponds 1, 1A, and 2 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

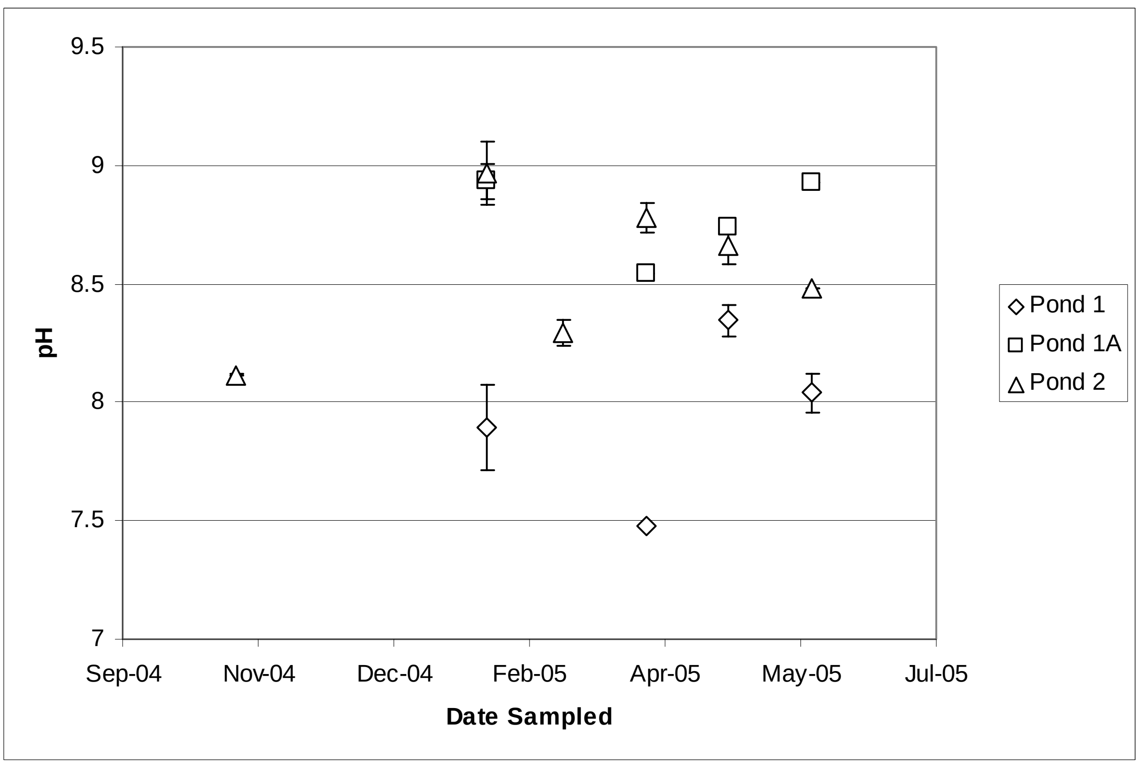

Figure 34. pH of Ponds 3, 4, and 5 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

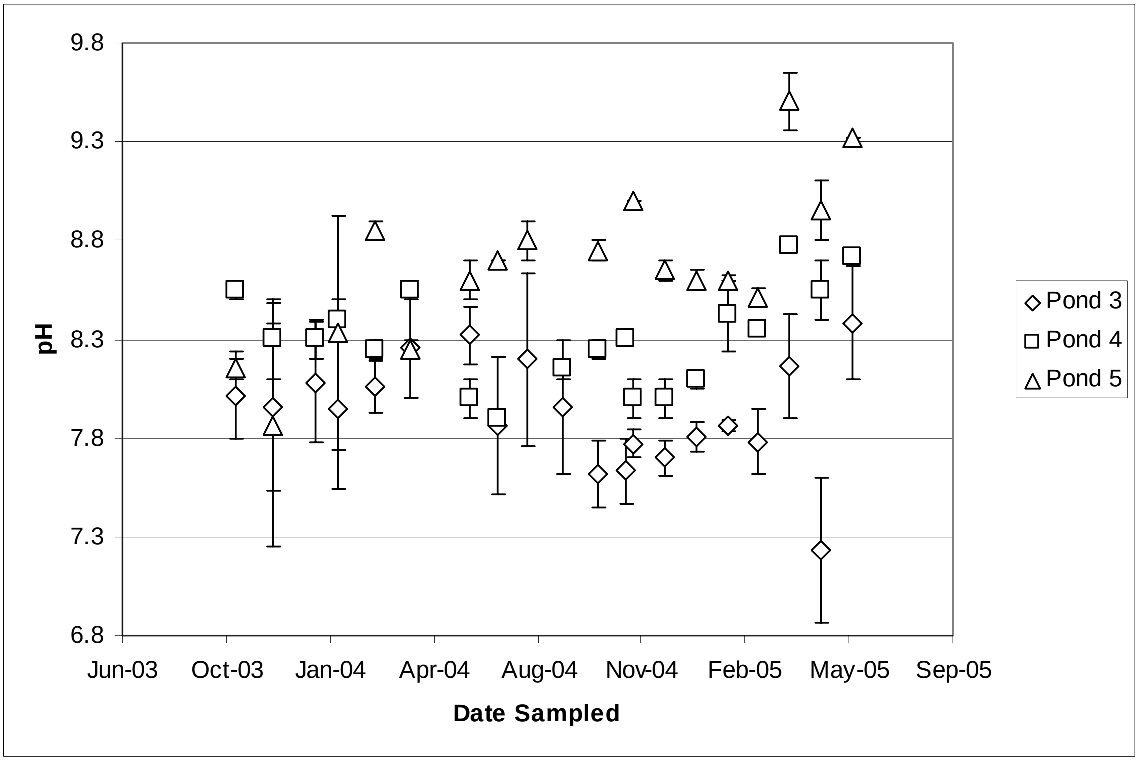

Figure 35. pH of Ponds 6, 6A, 7A, and 8 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

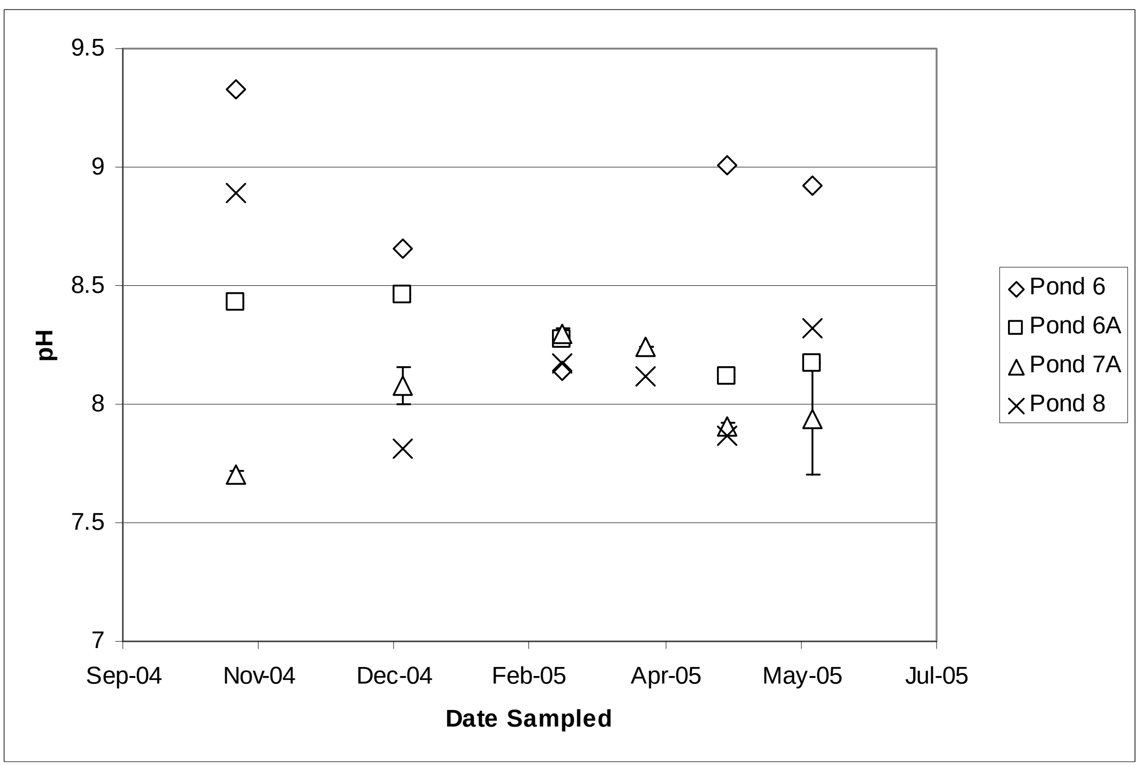

Figure 36. pH of Ponds 7 and CB3 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

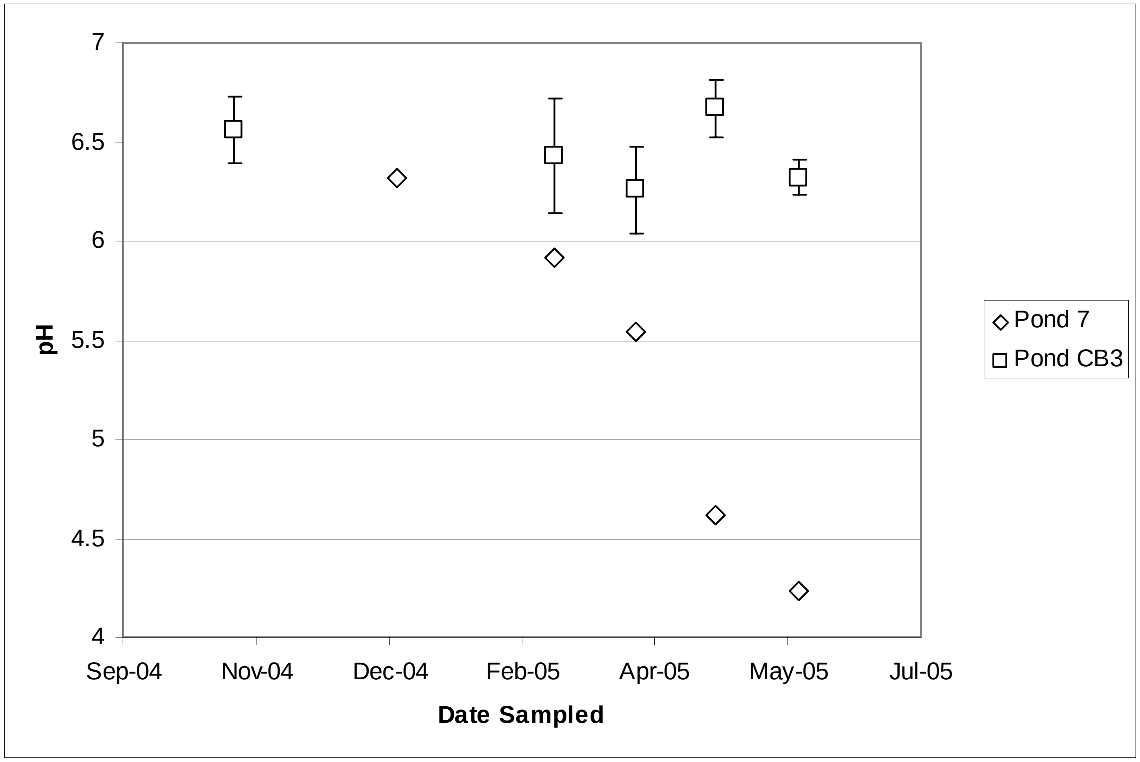

Figure 37. Temperature of Ponds 1, 1A, and 2 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

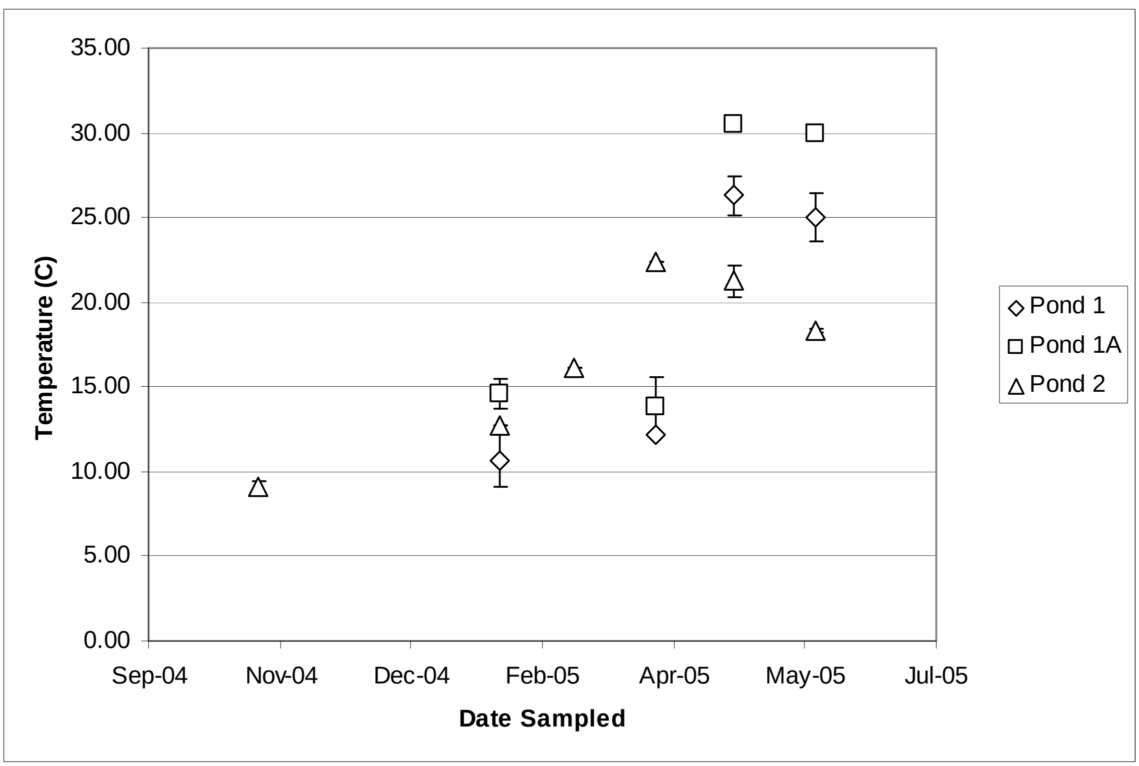

Figure 38. Temperature of Ponds 3, 4, and 5 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

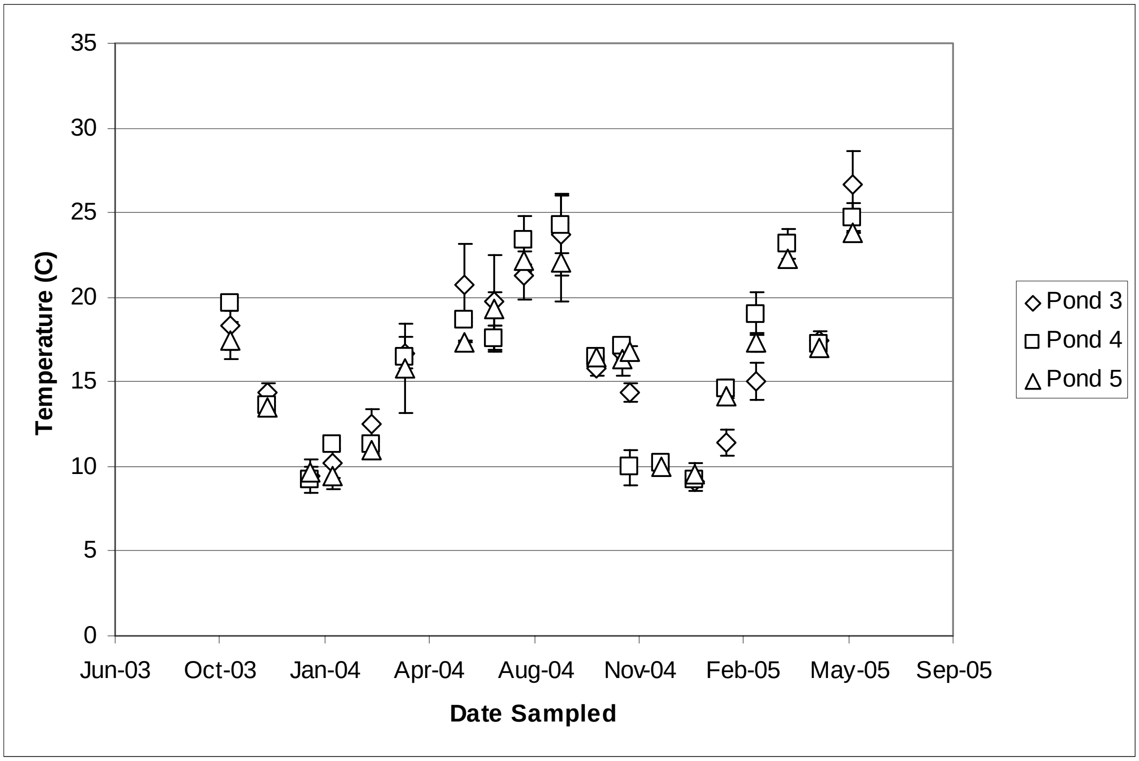

Figure 39. Temperature of Ponds 6, 6A, 7A, and 8 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

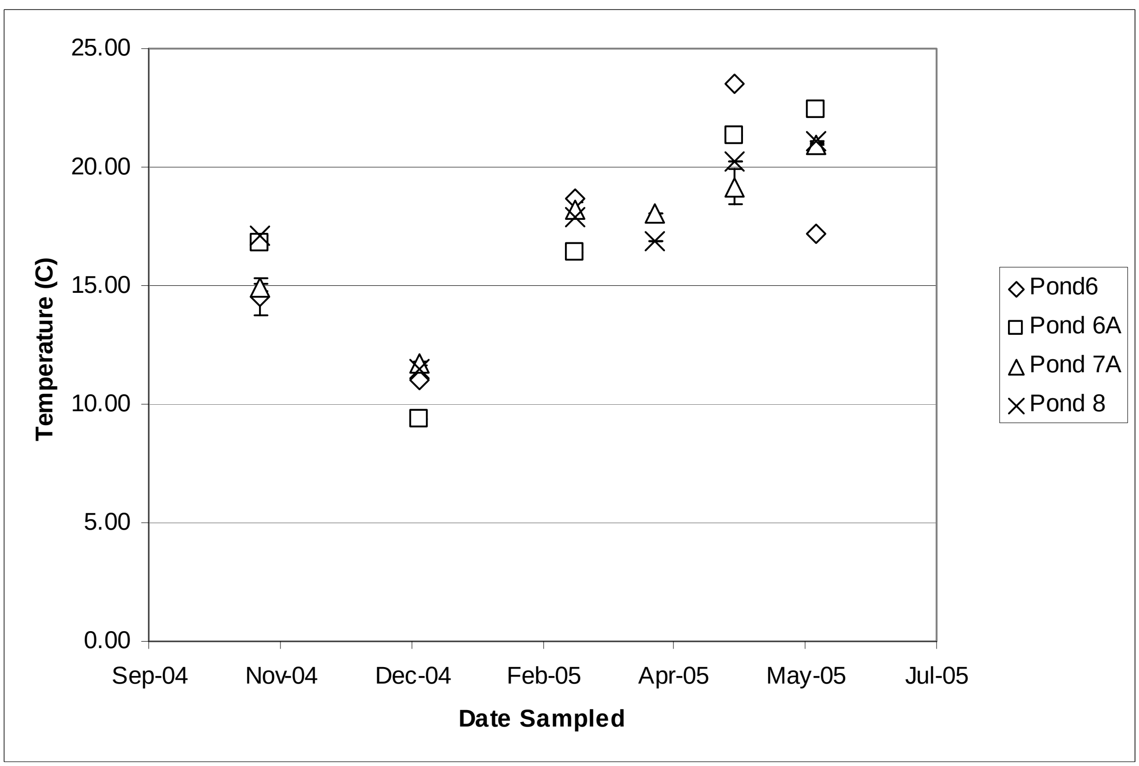

Figure 40. Temperature of Ponds 7 and CB3 (± SD) by month, Napa-Sonoma Marshes Wildlife Area, CA.

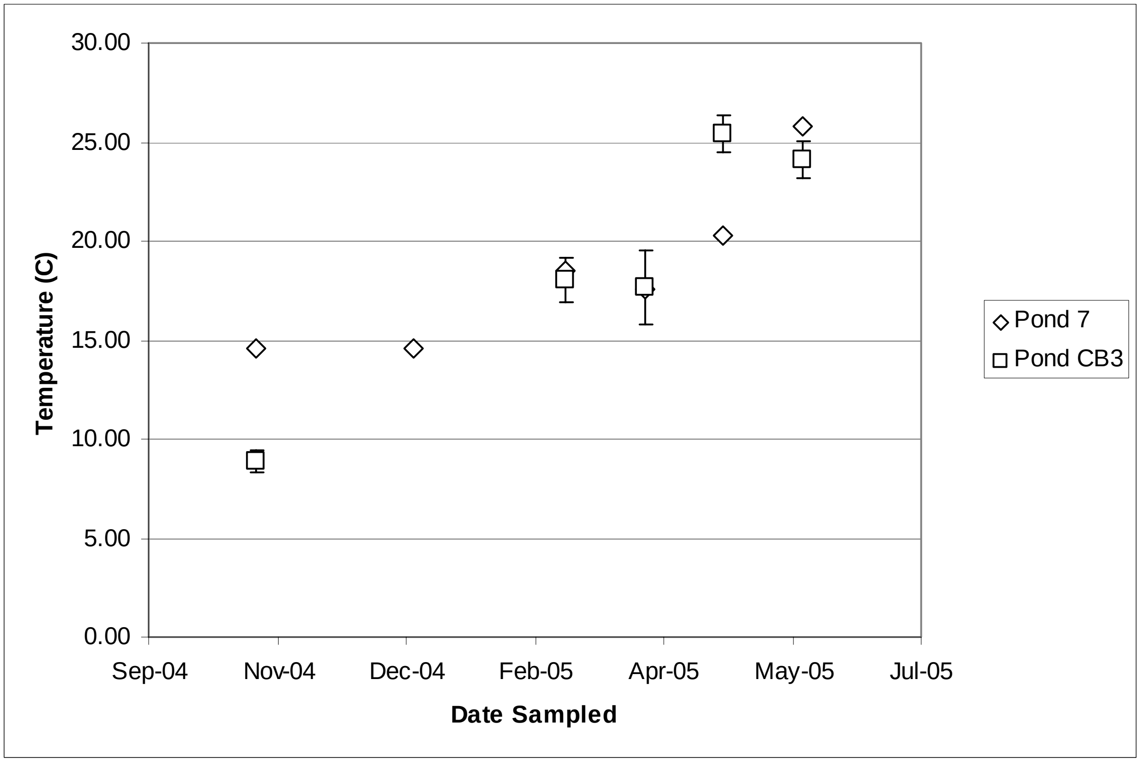

Figure 41. Turbidity of Ponds 1, 1A, and 2 by month, Napa-Sonoma Marshes Wildlife Area, CA.

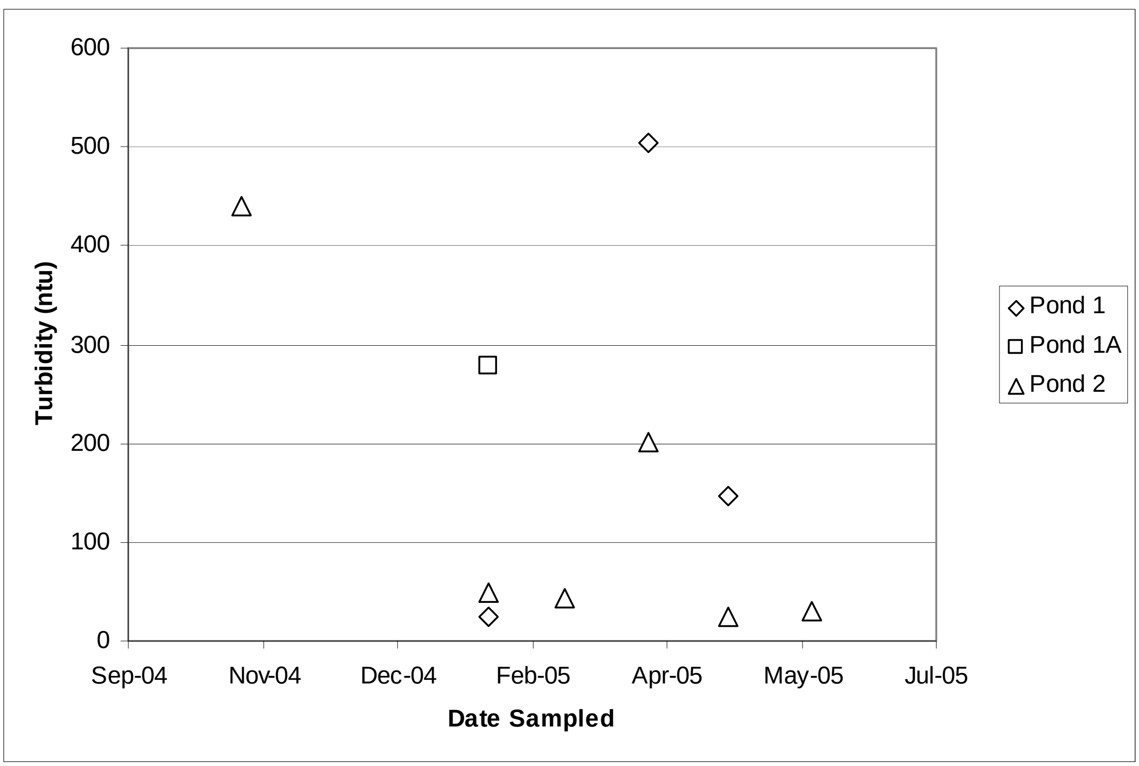

Figure 42. Turbidity of Ponds 3, 4, and 5 by month, Napa-Sonoma Marshes Wildlife Area, CA.

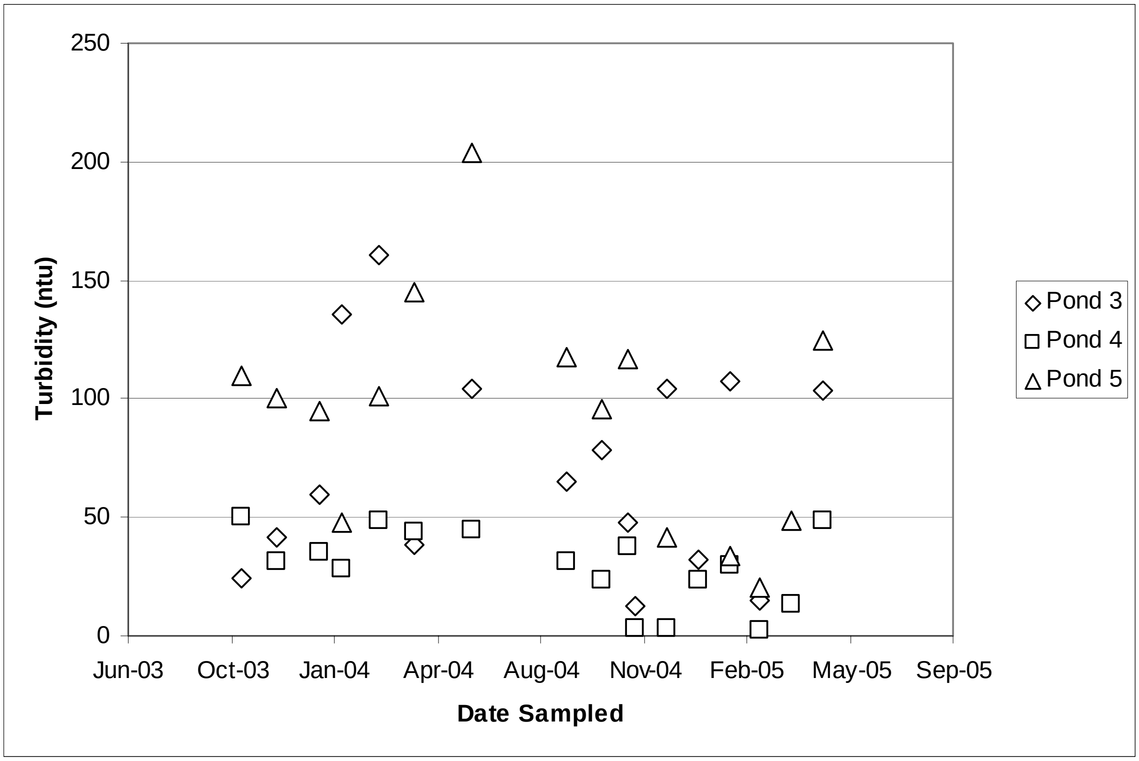

Figure 43. Turbidity of Ponds 6, 6A, and 7A by month, Napa-Sonoma Marshes Wildlife Area, CA.

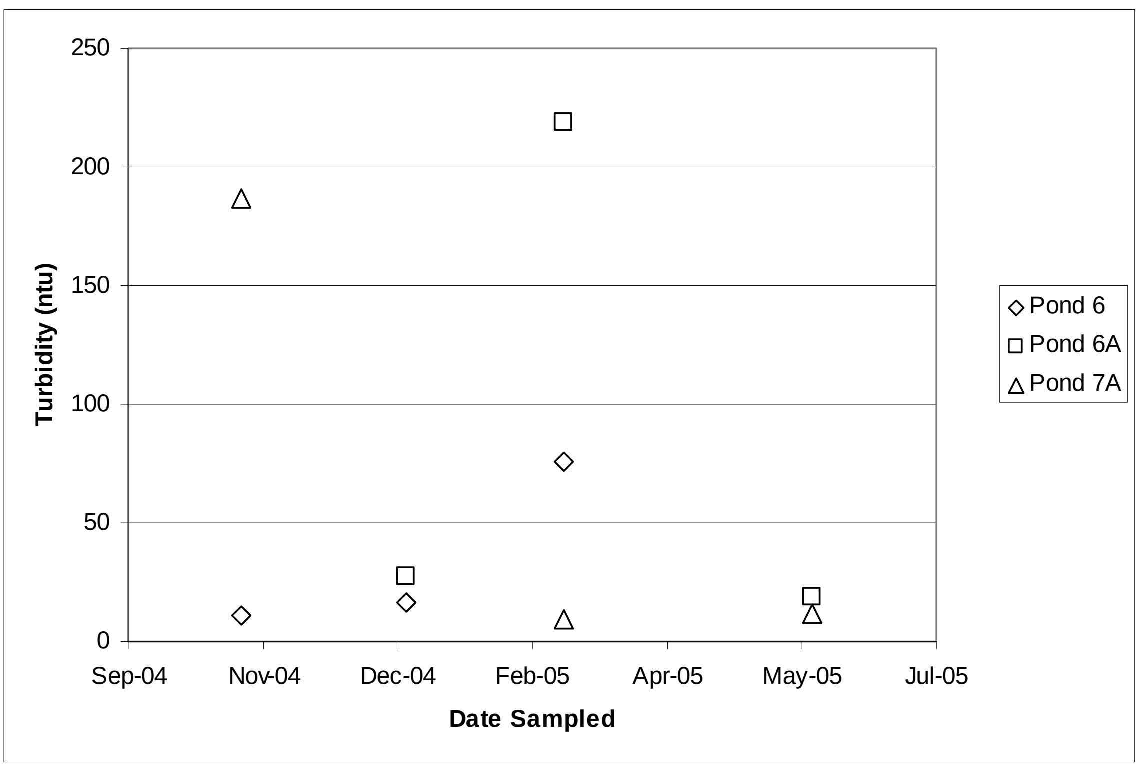

Figure 44. Turbidity of Pond CB3 by month, Napa-Sonoma Marshes Wildlife Area, CA.

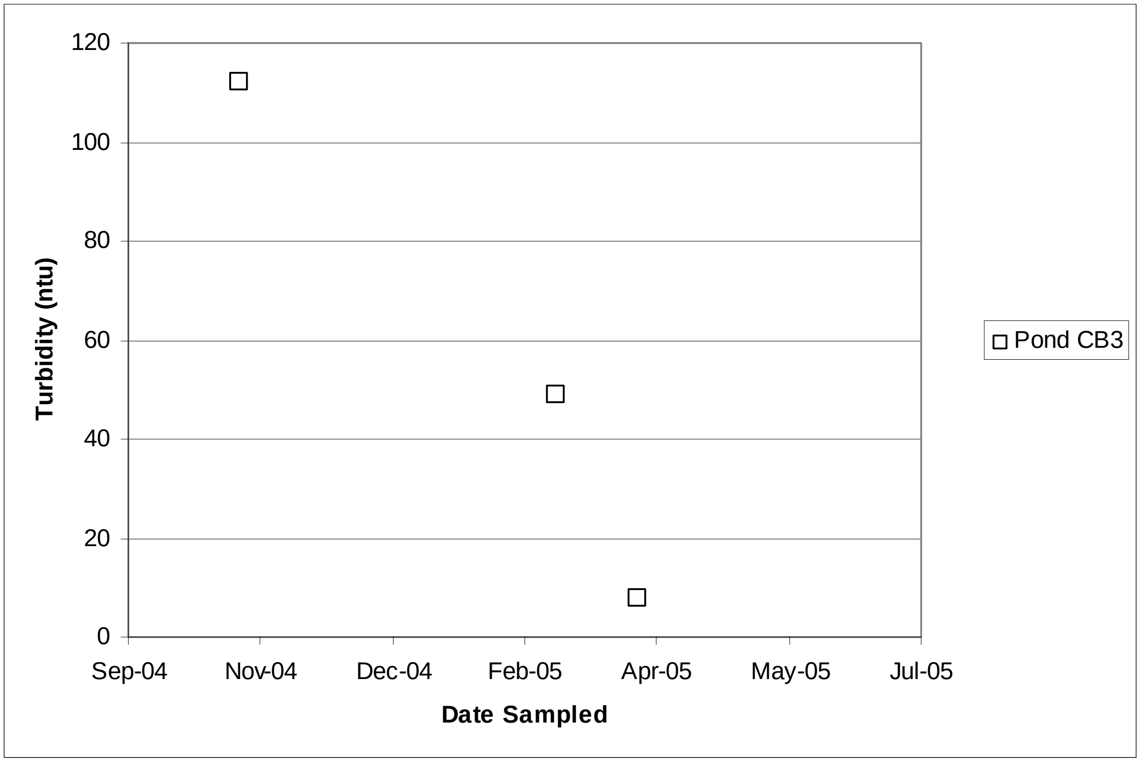

Figure 45. Width of the Pond 3 breach at South Slough, Napa-Sonoma Marshes Wildlife Area, CA.

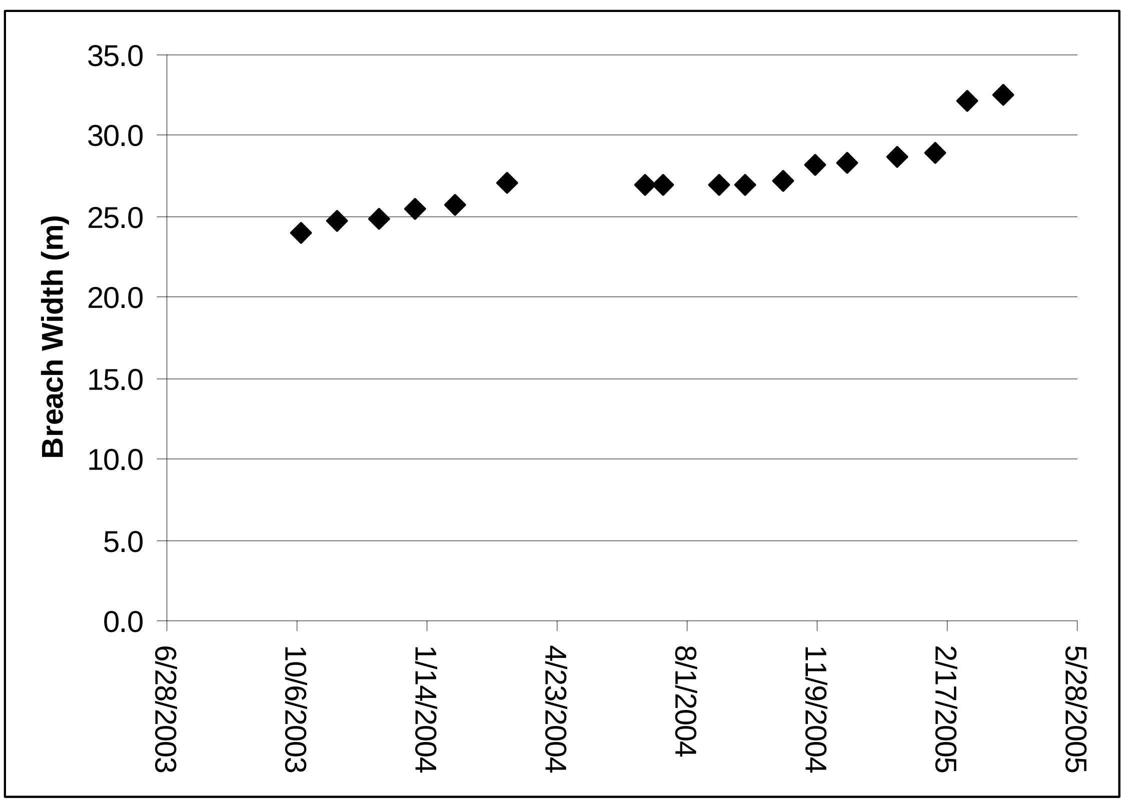

Figure 46. Width of the Pond 3 breach at Dutchman Slough, Napa-Sonoma Marshes Wildlife Area, CA.

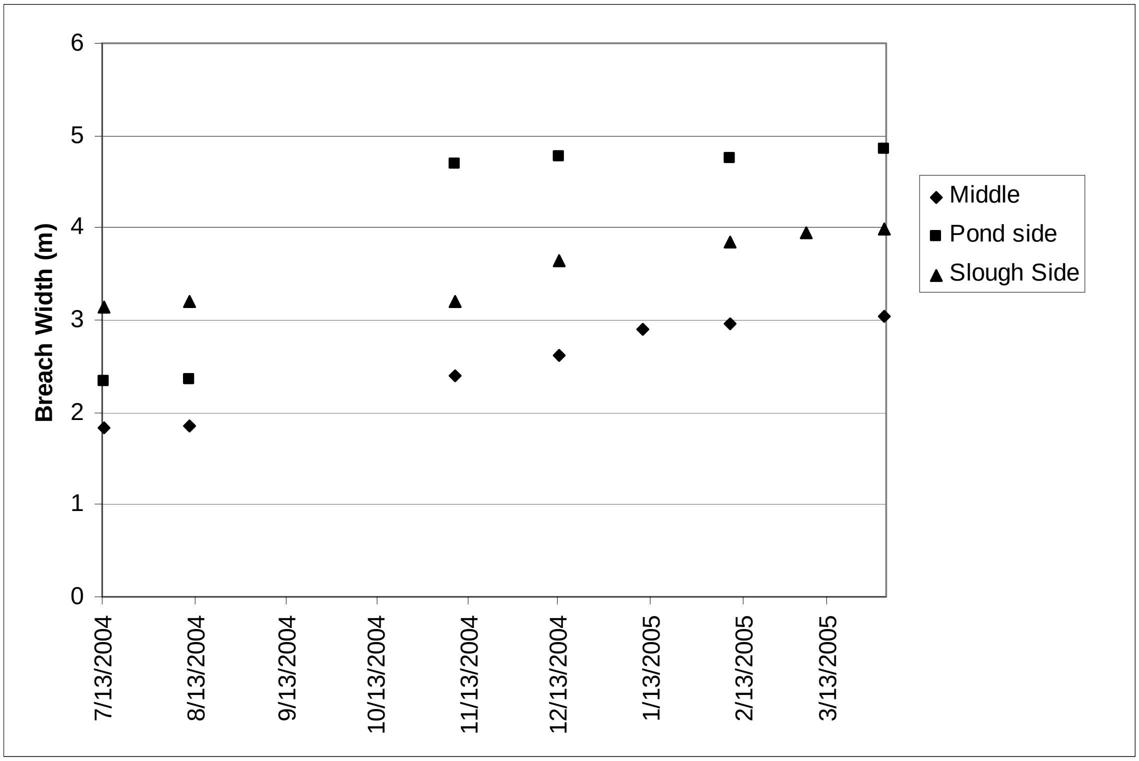

Figure 47. Sediment change measured at 5 erosion pin sites at Pond 3, Napa-Sonoma Marshes Wildlife Area, CA.

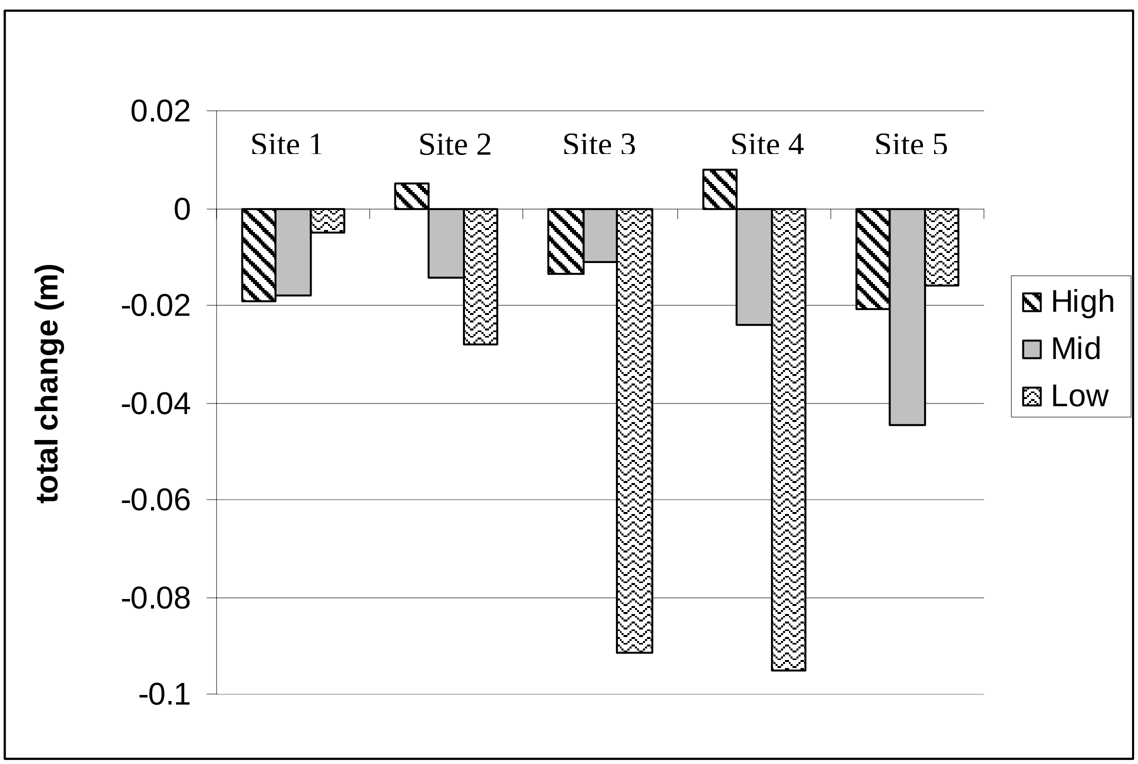

Figure 48. Relative bathymetry of South Slough and the Pond 3 breach, July 2004, Napa-Sonoma Marshes Wildlife Area, CA. Circles show data points; darker areas of bathymetric grid are deeper.

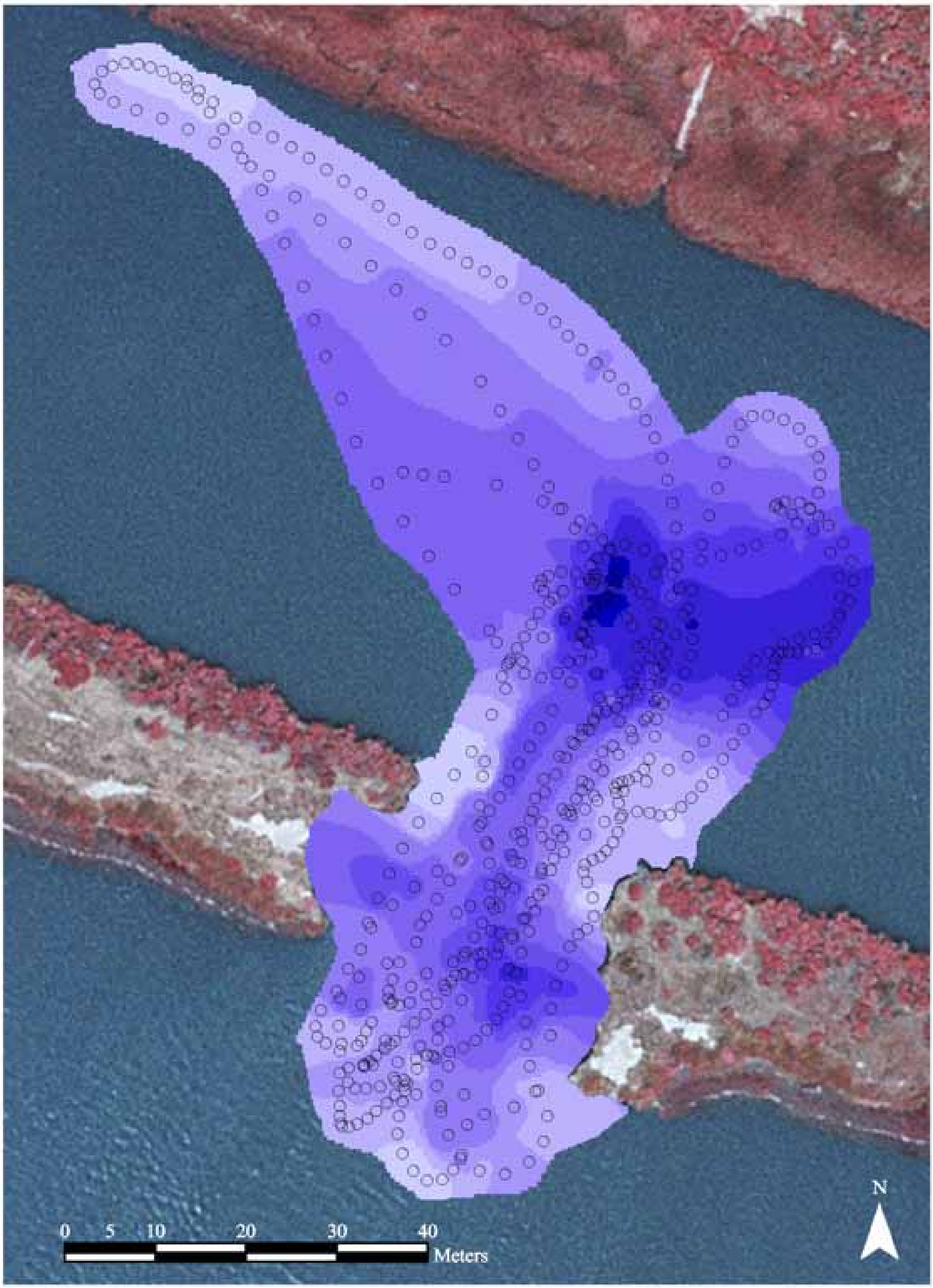

Figure 49. Relative bathymetry of South Slough and the Pond 3 breach, winter 2004-2005, Napa-Sonoma Marshes Wildlife Area, CA. Circles show data points; darker areas of bathymetric grid are deeper.

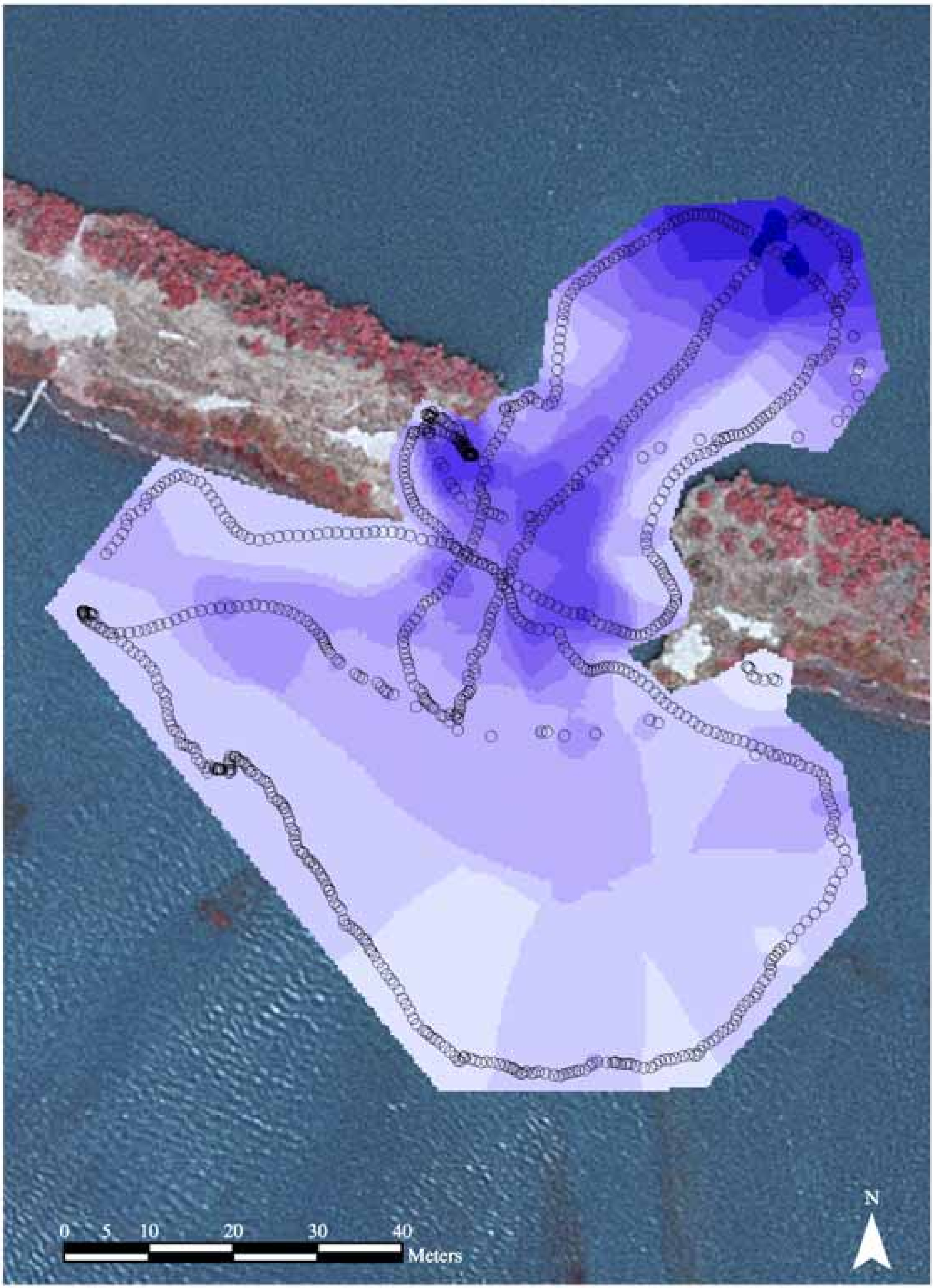

Figure 50. BLRA was detected in 2 of the 11 stations in the Pond 4 fringe marshes and 2 out of 6 stations in the Pond 5 fringe marshes (☆). Sora and VIRA were each detected in 1 location in the Pond 4 fringe marshes (Sora, ☆; VIRA, ☆). No rails were detected around Pond 3 fringe marshes.

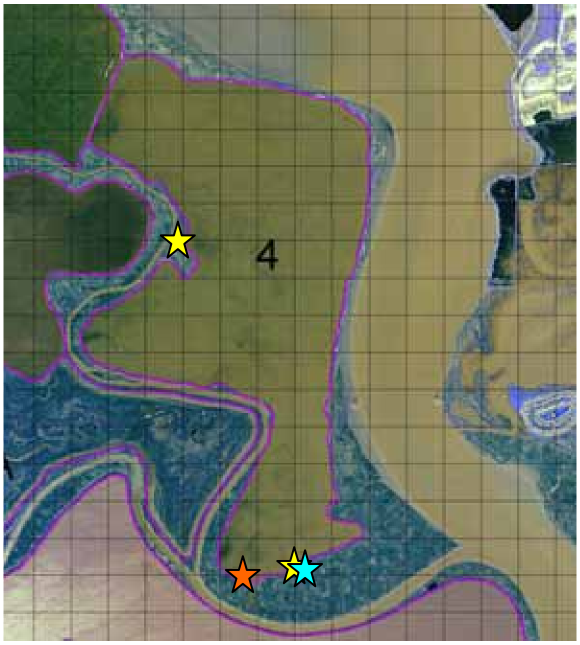

Figure 51. Location of small mammal grids or transects and number of individual salt marsh harvest mice captured along Pond 4 and Pond 5 of the Napa-Sonoma Marshes. Proposed construction breach locations and levee lowering sites are shown based on the restoration plan.

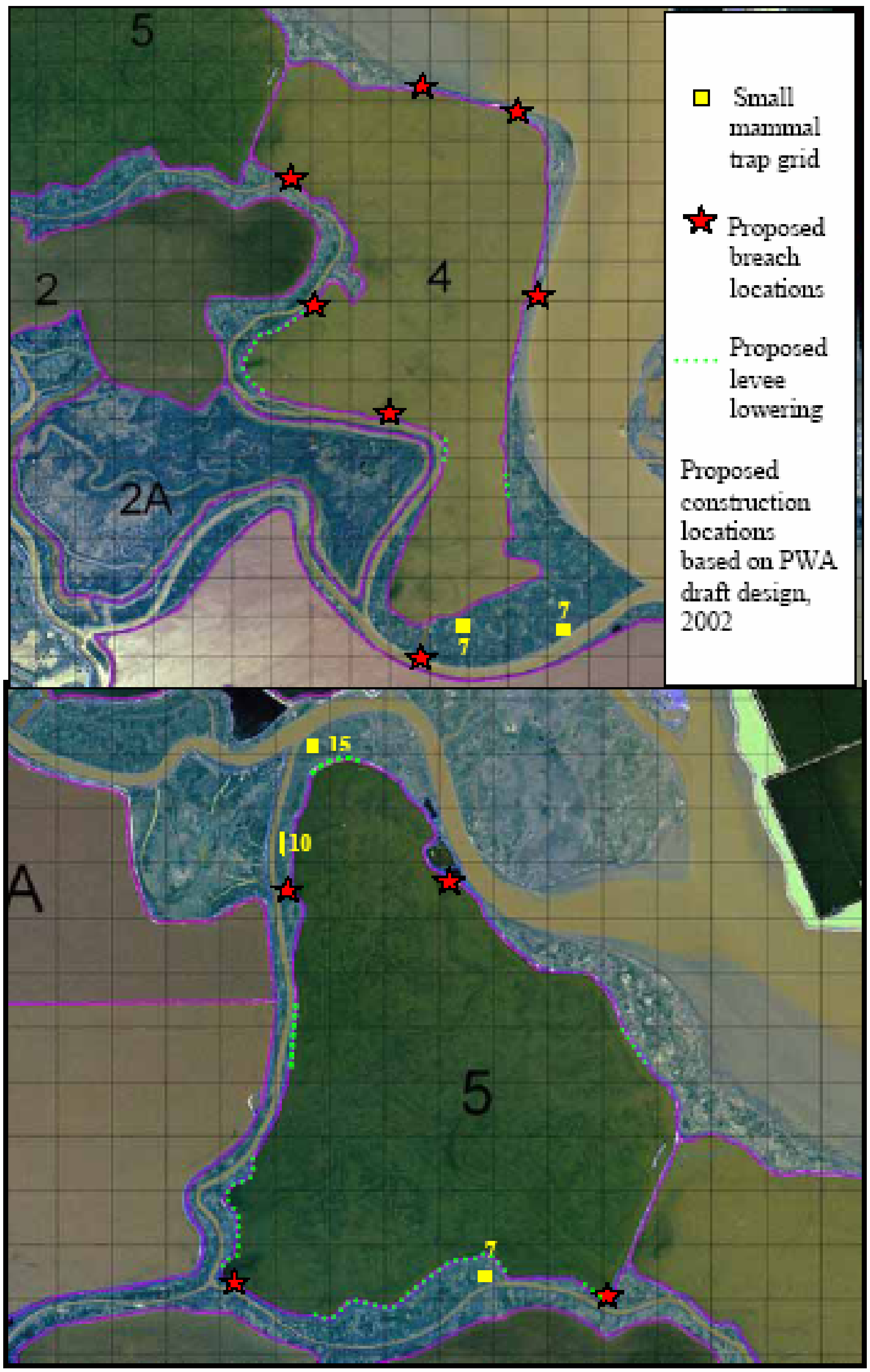

Figure 52. Height frequency of *Salicornia virginica* on Pond 3 during October 2004, Napa-Sonoma Marshes Wildlife Area, CA.

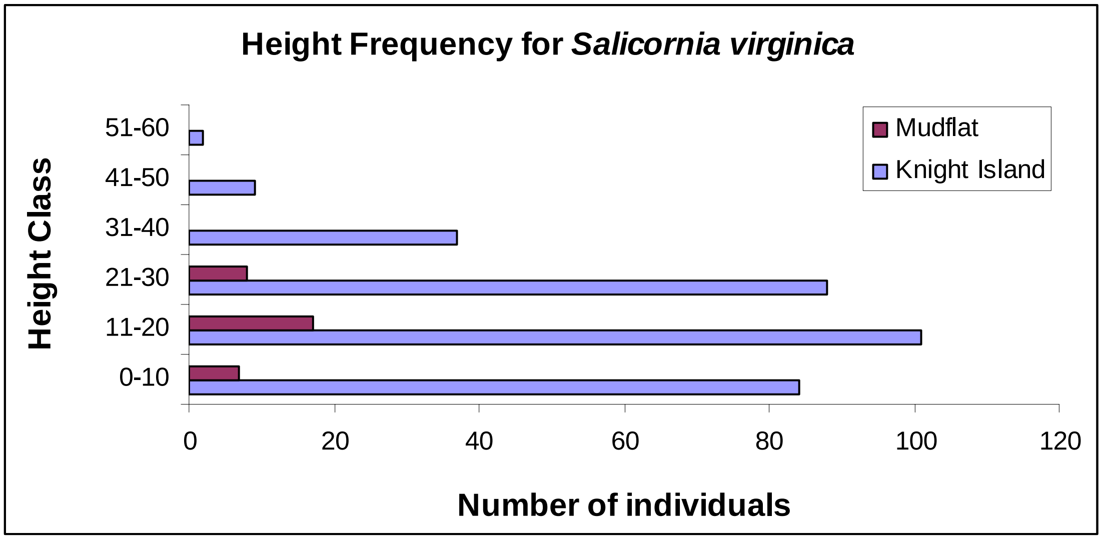

Figure 53. Proportional area of vegetation on Pond 3, Napa-Sonoma salt marshes, San Francisco Bay, CA, October 2004.

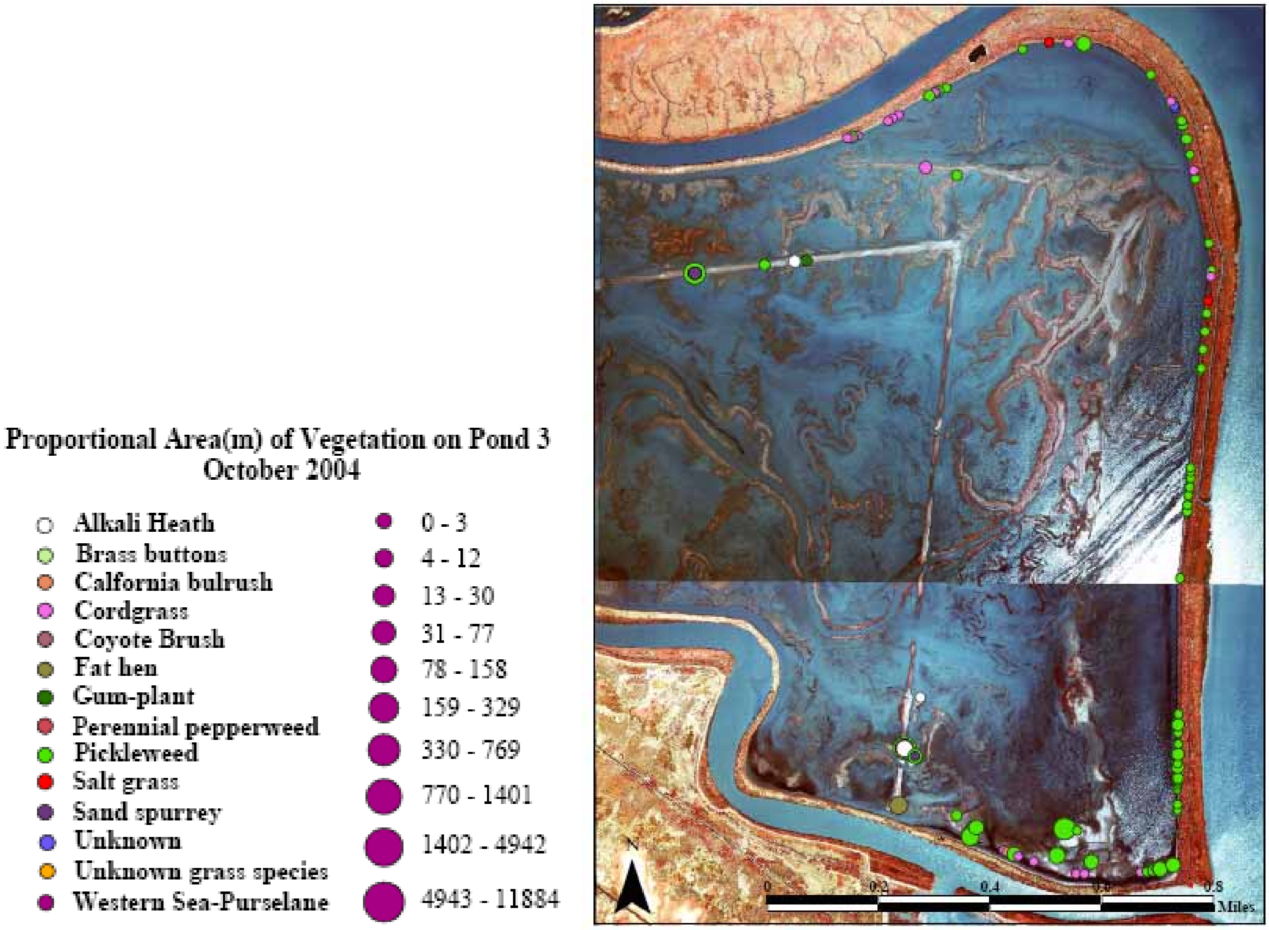

Figure 54. Photographic viewpoints of Pond 3, Napa-Sonoma salt marshes, San Francisco Bay, CA, September 2004.

Site 1

Site 2

Site 3

Site 4