Assessing early tidal marsh restoration at the Napa Plant Site Restoration Project within the Green Island Unit of the Napa-Sonoma Marshes Wildlife Area

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 Do Not Cite Without Permission***

EXECUTIVE SUMMARY

- We examined early tidal marsh restoration at the Green Island Unit comprising the Napa Plant Site Restoration Project within the Napa-Sonoma Marshes Wildlife Area. The Green Island Unit includes the North, Central and South Units of the Napa Plant Site Restoration Project (Napa Plant Site) though the North Unit may transfer to the adjacent Fagan Marsh Ecological Reserve once monitoring is complete. For the purposes of this report, Napa Plant Site will be used to identify all three units (North, Central, and South Units). The goal of the restoration project was to breach former salt evaporation and crystallizer ponds and restore them to tidal marsh. During 2011, we documented early biophysical changes in the restoration process, including sediment changes following breaches, as well as changes to the invertebrate, small mammal, and avian communities following restoration actions.

- To provide a comparison to bathymetric surveys conducted in 2010, we conducted a second set of surveys of the North Unit, the Central Unit, and the South Unit in the fall of 2011. The North Unit was merged into a single pond through levee-lowering and was opened to tidal flow in October 2008. The mean bottom elevation of the North Unit was 0.77 ± 0.37 m ($\bar{x}$ ± SD; NAVD88 meters) by 2011, ranging from -1.32 m to 1.58 m. The Central Unit was opened to tidal flow through a single breach after levee-lowering in September 2009, and by 2011, its mean elevation was 1.06 ± 0.28 m ($\bar{x}$ ± SD), ranging from 0.01 to 1.71 m. Finally, the South Unit underwent internal levee lowering and was opened to tidal flow at three breaches in Aug-Sep 2010. In 2011, the South Unit mean bottom elevation was estimated at 0.81 ± 0.29 m ($\bar{x}$ ± SD), ranging from -1.48 m to 1.86 m. We observed both sediment accretion and loss that was spatially distributed within all three units.

- We measured the width of Fagan Slough using aerial imagery to assess erosion of the neighboring marshes as a result of the breaching of the North Unit. Based on repeat aerial photographs, we observed widening of the slough width near the Napa River and narrowing or stable slough width near the North Unit breach. Upon visual inspection, however, we observed stretches of bank undercutting, slumping, and collapse that were not discernible in the aerial imagery.

- Colonization of the benthic invertebrate community was measured in the North Unit of the Napa Plant Site after restoration of tidal flows from Fagan Slough in October 2008 and compared with the benthic community along Fagan Slough and the Napa River. Invertebrate colonization and abundance varied by taxa and location within the North Unit. Colonization occurred rapidly, with noticeable abundances within 7 months of

restoration by May 2009. Cumaceans (Crustacea), polychaetes (Annelida), amphipods (Crustacea), ostracods (Crustacea), and nematodes (Nematoda) were the five most abundant colonizers, with cumaceans as the dominant taxa reaching a peak mean density of 23,631 individuals/m² in July 2010 within the North Unit. The restored North Unit had the greatest overall average density with 8,580 invertebrates/m² over time and locations, compared with the adjacent Fagan Slough with 5,072 invertebrates/m² and Napa River with 5,980 invertebrates/m². We also documented a rapid response of waterbirds that likely benefited from colonization of the invertebrate community providing a new food resource.

- We examined composition and relative abundance of small mammals at two sites in Fagan Marsh, one along Fagan Slough and the other along Steamboat Slough, to examine the potential source for colonization of the North Unit as it is restored to tidal marsh. We detected four species: the native California vole (*Microtuscalifornicus*; MICA), the endangered salt marsh harvest mouse (*Reithrodontomysraviventrishalicoetes*; RERA), shrew (*Sorexornatus*, subspecies unknown, SOOR) and the non-native house mouse (*Musmusculus*; MUMU). We captured 38 unique individuals: 16 MICA, 15 RERA, 1 SOOR and 6 MUMU. Only three individuals were juveniles. Captures were 2-times higher at the southern site (24) than in the northern site (14), and we detected almost three times the number of RERA (11 vs. 4). Relative capture efficiency at the southern site was 6.7 for MICA, 7.33 for RERA, and 1.33 for MUMU, compared with for 4.1 MICA, 2.7 for RERA, and 2.7 for MUMU at the northern site. These capture efficiencies were lower than what was observed in a neighboring site in Fagan Marsh in 2010.

- We measured salinity, dissolved oxygen, temperature, and pH in the North, Central, and South Unit at the Napa Plant Site. The North and Central Units were sampled from one location each, and after the breach, the South Unit was sampled from three locations around the pond perimeter. Prior to the breach, the South Unit was sampled in 7 locations. Dissolved oxygen and pH in the North and Central Unit were stable, with seasonal fluctuation of salinity and temperature. Dissolved oxygen values never dropped below 5.64 mg L^{-1}, and pH was neutral at 7.6 and 7.5 in the North and Central Units, respectively. The South Unit clearly displayed a shift in water quality with the restoration of tidal flow. Prior to the breach, salinity ranged from 99.77 – 360.25 psu, and average pH was an acidic 3.23. DO and temperature both ranged widely from 2.21 – 9.71 mg L^{-1}, and 6.94 – 31.78 °C, respectively. Post-breach, water quality in the South Unit mirrored that of the North and Central Units. Salinity plummeted and did not exceed 27.74 psu, and the temperature range narrowed to 11.12 – 28.15 °C. Dissolved oxygen and pH both increased to an average of 9.50 mg L^{-1} and a neutral 7.85, respectively. The restoration of tidal exchange has improved water quality at the Napa Plant Site, particularly in the South Unit.

- We surveyed waterbirds at the Napa Plant Site monthly, from January 2011 through December 2011. We detected 55 avian species at high tide, 58 species at low tide, and 61 species across both tides. When high and low tide surveys were combined, the waterbird assemblage was comprised primarily of small shorebirds (45%), dabbling ducks (32%), medium shorebirds (10%), and diving ducks (10%). To understand the impact of restoration actions, we assessed waterbird trends from 2006 through December, 2011 across the North, Central, and South Units of the Napa Plant Site.

- The North Unit supported no ducks and fewer than 250 shorebirds prior to the restoration of tidal flow at the end of 2008. By winter 2011, a seasonal average of 598 and 946 medium and small shorebirds, respectively, were using the site at low tide. At high tide, dabbling duck average winter abundance increased from 181 in 2009 to 1,694 in 2012. At high tide, diving duck average winter abundance increased from 199 in 2009 to 435 in 2012.

- The Central Unit, while smallest in area, began to support shorebirds and ducks within a few months after the introduction of tidal flow. The highest observed seasonal abundances for medium shorebirds occurred in winter of 2011 with a maximum of 772 birds at low tide, and for small shorebirds occurred in winter of 2012 with a maximum of 3,154 birds at low tide. During high tide, dabbling ducks reached a post-breached maximum of 697 birds in the Central unit in winter 2012.

- By 2011, the South Unit supported > 75% of all birds at the Napa Plant Site at high tide, and > 65% at low tide. There were more waterbirds on the South Unit in winter 2012 than previously observed at the entire Napa Plant Site, particularly due to more than 16,000 small shorebirds and 600 medium shorebirds at low tide, and over 6,000 dabbling ducks and 2,500 diving ducks observed at high tide. However, the abundance of roosting shorebirds at high tide decreased substantially in the South Unit after the introduction of tidal flow, suggesting loss of this roost site.

- *Monitoring Needs*: Repeat elevation surveys combined with vegetation surveys would enable assessment of sedimentation patterns at the Napa Plant Site and projection of the timing of vegetation colonization. Continuous monitoring water level loggers would help evaluate tidal inundation, a key factor driving colonization. Sampling of invertebrate densities conducted in the Central and South Units would allow an understanding of colonization and persistence of invertebrates following breaching across sites, and continued sampling in the North Unit would provide insights into the duration of colonization dynamics and transitional invertebrate abundances that are important waterbird prey in breached salt ponds. Small mammal surveys showed potential for colonization by endangered salt marsh harvest mouse (*Reithrodontomysraviventris*), although further work is needed to assess habitat characteristics of marshes (e.g. patch size, shape, context, elevation, vegetation height and composition) that influence their value in species recovery. Water bird guilds have changed dramatically during the early restoration, and continued surveys will illuminate population-level responses to these changes such as shifting foraging and roosting habitat across ponds that are critical to maintaining waterbird abundances at landscape scales to meet multi-species management goals and ensure overall restoration success. Monitoring provides quantifiable results showing how costs of the restoration project benefit wetland ecosystems and associated resource values. It provides critical information for assessing restoration with the Napa Sonoma Marshes Wildlife Area as well as informing numerous ongoing or proposed restoration projects within the San Francisco Bay estuary and in other coastal estuaries.

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INTRODUCTION

Over the past two centuries, the San Francisco Bay estuary has undergone dramatic ecological changes resulting from human growth and development. In this time, over 78% of historic salt marshes have been lost, resulting in diminished habitat for native marsh species and fragmentation of remaining marshlands (Goals Project 1999). Commercial salt ponds were constructed around the edge of the bay and have been a part of the landscape since 1856 (Josselyn 1983). In the first major salt pond transfer to a natural resource agency in 1994, most of the former Cargill salt evaporation ponds (4000 ha) along the Napa River near Vallejo were purchased for their outstanding potential wildlife value. California Department of Fish and Game (CDFG) became the agency responsible for managing the new Napa River Salt Marsh Restoration Project (NSMRP) on the west side of the Napa River within the Napa-Sonoma Marshes Wildlife Area (NSMWA). The NSMRP was the forerunner to what has become a major restoration effort in the San Francisco Bay area, and an additional 53 South Bay salt ponds along with the former Napa Plant Site (6100 hectares) were purchased in 2003 for their restoration potential.

The areas surrounding the NSMWA, including the NSMRP and Napa Plant Site (NPS) Restoration Project, comprise over 4500 ha of wildlife habitat and thus have become the focus of intense planning efforts to achieve restoration and wildlife management goals. In 1998, the State Coastal Conservancy (SCC) joined with CDFG to develop a Napa River Marsh Feasibility Study under the U. S. Army Corp of Engineers (COE) restoration program to determine alternatives for maximizing wildlife values (COE 2004). Thus far, there has been substantial emphasis on tidal marsh restoration. In 2002, Pond 3 was initially breached, and in 2006 engineered breaches were implemented in Ponds 3, 4, and 5, all of which have undergone successful early restoration (Brand et al. 2012).

An Environmental Impact Report was completed for the Napa Plant Site Restoration Project in 2006, defining the primary goal of restoring and enhancing wetlands and transitional habitats on the Napa River. The Napa Plant Site was the salt harvesting and processing facility for the North Bay salt ponds in San Francisco Bay Estuary, California. The site was subdivided into three units, North Unit, Central Unit, and South Unit, for the final stages of salt processing, which included pickle ponds, wash ponds, and crystallizer beds, and each of the 3 units were subdivided into smaller units by internal levees. The North Unit of the Napa Plant Site was breached in October 2008 and the Central Unit was breached in September 2009. The South Unit levees were breached in three locations, beginning with the salinity reduction breach in August 2010, widening the salinity reduction breach in September 2010, followed by construction of the southern breach and the breach to the barge channel in October 2010. Between the three units approximately 566 ha of former concentrator and crystallizer ponds are in the process of restoration to tidal salt marsh.

Monitoring results from the Napa Plant Site project can provide valuable management guidance within the study area and for the larger salt pond restoration efforts in the San Francisco Bay. The U. S. Geological Survey (USGS) initiated a research and monitoring program on the ecology of salt ponds in the NSMWA in 1998 and has a long-term dataset to assess abiotic and biotic responses to restoration efforts. The USGS has continued monitoring at the NSMWA over the past decade with support from several funding agencies (*see* Miles et al. 2000, Takekawa et al. 2001*a*, Takekawa et al. 2001*b*, Warnock et al. 2002, Miles et al. 2004, Takekawa et al. 2005, Athearn et al. 2009, Takekawa et al. 2009*a*, Takekawa et al. 2009*b*, Takekawa et al. 2009*c*, Brand et al. 2010, and Brand et al. 2012).

The overarching goal of the U. S. Geological Survey effort is to assess the benefits and impacts of salt pond restoration and to document these scientific outputs for restoration planning within an adaptive management framework. At the request of Ducks Unlimited, Inc. and the Wildlife Conservation Board, we conducted surveys to examine early tidal marsh restoration at the Napa Plant Site. In this report, we present the results of the monitoring work completed during 2011, which has included geomorphic changes following breaches at the three units (North, Central, and South) of Napa Plant Site. We have also studied a range of invertebrate (prey base) and vertebrate responses that have occurred post-breach. The results of these studies provide a framework to assess the success of early restoration efforts for this region, and will inform numerous other ongoing or proposed restoration projects (e.g., South Bay Salt Ponds Restoration Project, Sears Point Restoration Project, Cullinan Ranch Restoration Project, Hamilton and Bel Marin Keys Wetland Restoration Projects) within the San Francisco Bay Area.

OBJECTIVES

The primary goal of our monitoring effort during 2011 was to assess the status of early restoration efforts of the Napa Plant Site within the NSMWA. Our objectives were to assess the abiotic changes as a result of restoring tidal exchange to all three units. We also assessed animal responses to restoration, including benthic invertebrates at the North Unit, small mammals at Fagan Slough, and birds within all three units. Our specific objectives were as follows:

Objective 1. Take elevations of the Napa Plant Site using a bathymetric survey.

Objective 2. Measure bank erosion with erosion markers as well as aerial interpretation at North Unit breach to Fagan Slough.

Objective 3. Sort invertebrates to assess the colonization rates in the North Unit after breach and in reference to Fagan Slough and Napa River.

Objective 4. Survey Napa Plant Site for the endangered Salt Marsh Harvest Mouse at Fagan Slough.

Objective 5. Conduct area counts of birds on the Napa Plant Site at high and low tide to document changes in the distribution and abundance of avian guilds responding to restoration.

Objective 6. Assess changes in water quality associated with restoration actions at the Napa Plant Site through monthly collection of temperature, salinity, dissolved oxygen, and pH.

METHODS

1. Bathymetry at Napa Plant Site

Objective 1. *Take elevations of the Napa Plant Site using a bathymetric survey.*

Measuring sedimentation patterns in restored ponds and breaches of the Napa Plant Site provides an assessment of baseline conditions and initial changes necessary to understand the trajectory of restoration over the longer term. Studying rates of sediment accretion will help predict the time required to reach elevations favorable for plant colonization and marsh plain establishment. In addition, assessing the elevations in and around breach areas will help assess whether they are sustaining hydrologic functions. Our objective was to conduct a second bathymetric survey at the three units of the Napa Plant Site to estimate pond elevations and determine sedimentation rates over one year.

We used a shallow-water echo-sounding system (Takekawa et al., 2010, Brand et al. 2012) comprised of an acoustic profiler (Reson, Inc.; Slangerup, Denmark, Navisound 210), RTK (Real Time Kinematics) Leica Smartpole 1200 GPS unit with the RTK Max network, and laptop computer mounted on a shallow-draft, portable flat-bottom boat (Bass Hunter, Cabelas, Sidney, NE). The RTK GPS obtained high resolution elevations of the water surface (reported precision <1 cm; estimated accuracy ± 3 cm). The rover positions were received from the Leica Smartnet system (www.lecia-geosystems.com) and referenced to a National Geodetic Survey benchmark (X 552 1956 Mare Island). The unit averaged ± 2.5 cm vertical error at the reference benchmark, which is within the stated error of the survey unit. 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 calibrated the system before use with a bar-check plate and adjusted the sound velocity for salinity and temperature differences. The bar-check plate was suspended below the transducer at a known depth that was verified against the transducer readings.

We used a slightly different sampling protocol for 2010 and 2011 surveys. For the 2010 survey, we used the shallow-draft boat to conduct all surveys. We conducted north-south and east-west transects at 100 m intervals across the North and Central Units. We also conducted north-south and east-west transects at 200 m intervals across the South Unit. We obtained bathymetric transects in 2 of the 3 South Unit breaches (the salinity reduction breach and the southern breach), the Central Unit breach, and the breach in the North Unit. Data collection was limited to periods when the tide was sufficiently high (>1.83 m or 6.0ft at Brazos Drawbridge) and long enough to provide sufficient water to navigate across the ponds. Windy conditions, inclement winter weather, and problems with the RTK Max network affected data collection efforts as well and further limited our survey windows.

In 2011 we modified our bathymetry system to operate on a 19-foot catamaran (Flats Cat) boat and used this boat to survey the South Unit and the North Unit. We continued to survey the Central Unit with the shallow-draft boat. Similar to our 2010 surveys, we conducted north-south and east-west transects at 100 m intervals across the North and Central Units and 200 m intervals in the South Unit. We conducted bathymetric surveys of the salinity reduction breach and the northern breach in the South Unit and of the breach in the North and Central Units.

In both years, our bathymetric data collection system collected two independent datasets: (1) the depth of the water, and (2) the elevation from the surface of the water. We integrated these two datasets in R2.13.1 (R Development Core Team 2011) to obtain final sediment surface elevations. We used Spatial Analyst in ArcGIS 9.3.1 (ESRI, Redlands, CA) to create a digital elevation model with 25 m^2 GIS grids of elevation surfaces. We used inverse-distance weighting with barrier polylines to interpolate point data using known pond features (from aerial imagery) as guidance. In 2010 no imagery was available to map the newly constructed pond features in the South Unit as barrier polylines. However, for our 2011 bathymetric analysis, barrier polylines were created using 2011 USGS imagery and the 2010 bathymetry data was re-analyzed. Each pond's mean elevation and elevation range was determined from the results of the digital elevation model. Data were collected and reported in the horizontal datum UTM NAD83 and vertical datum NAVD88 in meters.

We compared bathymetric data from 2011 with our 2010 surveys to assess the site evolution during the early restoration. This comparison allows us to determine the net change in elevation and sediment volume within the ponds, the spatial distribution of sediment across the ponds, and the net changes in elevation and configuration of the breaches. Due to high flows we were unable to survey the entire salinity reduction breach in the South Unit. Therefore we only compared a portion of the breach between years. We determined the volume of sediment gained or lost in each pond between years with the Spatial Analyst tool Cut/Fill (Price 2002). This tool calculates volume by multiplying the elevation difference of each grid cell by the area. This volumetric analysis is a more sensitive measure of sedimentation change across the pond than the mean elevation value of the pond.

2. Bank erosion at Fagan Slough

Objective 2*.Measure bank erosion with erosion markers as well as aerial interpretation at North Unit breach to Fagan Slough.*

Restoration of tidal action to the Napa Plant Site is expected to increase the tidal prism in Fagan Slough, and there was some concern that this may result in erosion of the adjacent marsh plain. We used aerial interpretation and photography at the North Unit breach to Fagan slough to document the potential marsh erosion as an inadvertent impact of restoring tidal action.

We used USGS 30-cm imagery from 2008 and 2011 analyzed in ArcGIS 9.3.1 (ESRI, Inc., Redlands, CA) to compare changes in Fagan Slough before and after the breaching of the North Unit. We selected three locations along the slough close to the Napa River (site A), 125 m west of the breach (site B), and just east of the breach (site C; Figure 1.2). We denoted the cross section location with points and measured the distance between the vegetation lines on either side of the slough. Given the image resolution, it was not possible to identify individual plants in the imagery; thus, we used adjacent pixels that distinguished marsh vegetation versus channel based on coloration to demarcate the channel edge. However, the pixel size of the imagery limited our ability to detect the marsh edge with a high degree of certainty. Thus we conducted a site visit to assess erosion by visual inspection as a means to ground-truth our image interpretation.

We were unable to obtain permission to enter the Fagan Marsh private property to properly assess marsh edge sloughing from the ground or to measure the sediment erosion pins. Thus our interpretation of erosion is limited to aerial interpretation and visual inspection from within Fagan Slough.

3. Invertebrate changes in the North Unit

Objective 3*.Sort invertebrates to assess the colonization rates in the North Unit after breach and in reference to Fagan Slough and Napa River.*

Prior to breach, the North Unit at the Napa Plant Site was dry and maintained low avian abundances. Bird abundance increased dramatically in the North Unit following the breach of December 2008 including a large number of foraging shorebirds (Brand et al. 2010). To assess invertebrate colonization as potential prey sources for shorebirds at low tide, we collected sediment cores from the Napa River, Fagan Slough, and the North Unit.

We collected and processed monthly benthic sediment cores to characterize invertebrate colonization and monitor changes in the invertebrate community over time. Our sampling consisted of ten core locations in the newly restored North Unit, two locations in Fagan Slough, and two locations in the Napa River (Figure 3.1, 3.2). In the North Unit, ten sampling locations (N1-N10) were established at approximately 100 m intervals along the main channel, beginning at the breach and extending to the north-east corner of the pond. We sampled at the edge of the channel since the remainder of the pond was too shallow to access by boat. Four comparison locations were established in the adjacent Fagan Slough (FS1-FS2) and Napa River (NR1-NR2; Figure 3.1).

Field data collection

Benthic cores were collected monthly by boat from December 2008 through October 2011 (with the exception of June 2009 when tides were insufficient for sampling). Each core was 10 cm diameter x 10 cm long. Three replicates were collected from each sampling location; however, we processed a single, representative core per location from these samples. Site access for coring within the North Unit channel was challenging, and we incorporated specialty gear custom made for shallow water. To improve site access, we used a 19-ft., shallow-draft FlatsCat® boat that can operate in water less than half a meter deep. We used a custom built stainless-steel deep water corer and installed a coring table on the boat that was fabricated for ease of collection (Figure 3.3). The late spring and summer tides were not high enough for boat access, so during six months of the monitoring period (May 2009 [cores NU7-NU10 and FS2, NR1, NR2], April 2010-May 2010 [cores NU1-NU10], June 2010 – August 2010 [all cores]) some samples were collected during the low tide with a hand core from a small boat (Bass Hunter; Figure 3.4). All samples were brought back to the San Francisco Bay Estuary Field Station Invertebrate Laboratory in Vallejo, CA and refrigerated for no longer than one week until processed.

Invertebrate core processing in laboratory

Within one week of collection, all samples were washed using the elutriation sieving method. The samples were placed in a bucket of clean water and the largest, heaviest sediments settled to the bottom and the water with suspended invertebrates was then poured onto the 0.5 mm sieve (Figure 3.5). The sieve was scanned, and any invertebrates were picked from the sieve and placed into a labeled 40 mL vial containing 70% ethanol for preservation. This process was repeated until the core was completely broken up and rinsed into the sieve. The remaining sample matrix was placed into labeled jars containing ethanol and rose bengal dye solution. Samples with a large amount of organic matter required a higher concentration of ethanol (95%) for adequate preservation. The rose bengal dye successfully stained animal tissue vivid pink while not affecting most vegetation and inorganic debris.

Extensive amounts of vegetation, clay, and salt crystal debris (Figure 3.6) in all North Unit samples, more than quadrupled processing time so we chose a sub-sampling scheme for greater efficiency that allowed us to examine colonization trends and compare the North Unit to the Napa River and Fagan Slough. All four references cores (NR1, NR2, FS1, FS2) and five cores within the North Unit (NU1, NU3, NU5, NU7, NU10) were processed monthly. To investigate more fine-scale spatial trends over the monitoring period, we additionally processed the remaining five cores from the North Unit from 5 sampling periods (December 2008, January 2009, November 2009, September 2010, and November 2010; Figure 3.1). Remaining samples (NU2, NU4, NU6, NU8, NU9) were archived.

The invertebrate samples were then sorted under stereo dissection microscopes in petri dishes at a magnification range of 7-35x. Animal tissue was picked from the plant debris and gypsum crystals then stored in vials containing 70% ethanol. Invertebrates were later identified by experienced invertebrate technicians to the lowest possible taxonomic unit from December 2008 to May 2009 (Table 3.1). Thereafter, broader taxonomic groups were selected to relate invertebrates to guilds (e.g., detritivores) and as available prey for higher trophic levels (Table 3.2). Taxa were enumerated and density was reported in individuals/m². Non-detected taxa were represented as 0 for any given core. All trends are presented as mean densities/m². All bivalves were identified to species level and separated into size classes (0-2 mm, 2-4 mm, 4-6 mm, 6-12 mm, 12-18 mm, 18-24 mm) based on beak sizes of potential bird predators. Bivalve biomass equations have been previously established by the San Francisco Bay Estuary Field Station Invertebrate Laboratory for common species-size class combinations. Bivalve species in underrepresented size classes were dried at 80° C for 24 hours for biomass determination. Biomass is presented as average mg dry weight/m².

Invertebrate technicians conformed to our internal QA/QC procedures for a sorting efficiency of 90%. Identification for all samples was conducted by two senior technicians who checked and confirmed identifications with laboratory manuals, taxonomic guides, reference collections, or an invertebrate specialist.

4. Small mammal source populations for restoration in the North Unit

Objective 4. *Survey Napa Plant Site for the endangered Salt Marsh Harvest Mouse at Fagan Slough.*

Restoration of salt ponds to tidal marsh such as the NSMWA, including the Napa Plant Site, are expected to benefit several tidal marsh endemic species including the federally and state endangered California clapper rail (CLRA, *Rallu slongirostrisobsoletus*) salt marsh harvest mouse (SMHM, *Reithrodontomys raviventrishalicoetes*), and state threatened California Black Rail (BLRA, *Laterallus jamaicensiscoturniculus*; Gill 1979, Harvey et al. 1992, Goals Project 1999). Existing patches historic, or ‘fringe’ marshes within the Napa Plant Site landscape may provide source populations for colonization into restored marsh habitat. Fagan Slough is an old marsh system that serves as a potential colonization source for the Napa Plant Site, yet little is known about the small mammal diversity, small mammal abundance, or SMHM presence. Small patches of fringe marsh may also provide sources for colonization of small mammals.

We set out traps along a transect as in Pearson and Ruggiero (2003) that spanned the marsh platform across pickleweed (*Sarcocornia pacifica*) and sedge (*Schoenoplectus* spp.) areas in Fagan Marsh north of Fagan Slough (southern marsh) and south of Steamboat Slough (northern marsh) (Figure 4.1). We conducted our trapping session from 12-14October 2011 based on tides and predicted weather conditions, which were mild and clear (no rain). At each site we set out five transects, and each transect consisted of 10 traps at 10m intervals, for a total of 100 traps. Trapping occurred for three consecutive nights led by staff with Federal and State permits to handle salt marsh harvest mice (*Reithrodontomys raviventris*). Traps were set before dusk and checked within 3 hours of sunrise. Polyester batting was used to keep animals warm and a wooden shingle was placed on each trap to protect captured animals from exposure to the elements. We baited traps with a mixture of dry seeds, chopped walnuts and dried meal worms (for incidental insectivorous shrews). We accessed the sites by boat and walked into the marsh following the US Fish and Wildlife Service Walking in the Marsh Protocol (San Pablo Bay NWR memo) to reduce and limit impacts.

Each captured animal was identified, sexed, weighed, measured for body and tail length, and examined for reproductive condition (Figure 4.2). A small area of fur was clipped on the right (first day) or left flank (second day) of each mammal to identify recaptures. Additionally, individuals were marked with colored paint pens with unique color markings on the ear and tail to identify recaptured individuals. Additional measurements were taken for captured *Reithrodontomys* genus to distinguish the salt marsh harvest mice from western harvest mice including: body length, ventral pattern, tail length, tail diameter at 20mm from the rump, bi-coloration of the tail, and behavior. Analyses of capture efficiency by effort included a 0.5 trap night correction for closed but empty traps (Nelson and Clark 1973) and data are presented as the number of new individuals captured per 100 trap nights as an index of capture efficiency (capture index). We calculated the number of trap nights = (# traps*# nights) – 0.5(# of empty but closed traps). We calculated the capture index = (# of individuals/total trap nights)*100%.

5. Waterbird changes at the Napa Plant Site

Objective 5. *Conduct area counts of birds on the Napa Plant Site at high and low tide to document changes in the distribution and abundance of avian guilds in response to restoration.*

High tide and low tide surveys

We conducted monthly bird surveys at high and low tide to document changes in distribution and abundance of the bird community in response to the restoration effort at the Napa Plant Site. USGS collected baseline data through monthly or bimonthly high tide surveys since April, 2003 and monthly low tide surveys since April, 2009. Surveys were conducted following existing protocols (Miles et al. 2000, Takekawa et al. 2001*a*). Ponds were divided into

250m x 250m grids (6.25 ha). We counted all birds when the predicted tide values at the Vallejo, Mare Island Strait tide gage were above 4.0ft for a high tide survey, or below 2.0ft for a low tide survey, or when the water level in the study site was low enough to expose a substantial area of tidal mud flat. We counted all birds within 3-hours of the predicted high or low tide. Birds were identified to species, enumerated, and recorded in a grid. Foraging and roosting (i.e. roosting, preening, socializing, etc.) behaviors were recorded. We later attributed each species to one of 12 guilds based on taxonomy and foraging strategy: dabbling ducks, diving ducks, eared grebes, fish-eating birds (not included in other guilds), geese, gulls, herons, phalaropes, raptors, medium shorebirds, small shorebirds, and terns.

Our goal was to document changes in the bird community over time following the breach of the North Unit in the fall of 2008, the Central Unit in the fall of 2009, and the South Unit in the fall of 2010. Prior to breach, each of these Units consisted of two or more sub-ponds – for example, the North Unit previously consisted of Ponds 9 and 10 – and we collapsed the bird counts across sub-ponds to provide a comparison of the changes across similar pre- and post-breach pond areas within the Napa Plant Site. We estimated the monthly average number of birds observed among seasons and years for the dominant bird guilds: small and medium sized shorebirds and dabbling and diving ducks from December 2005 through December 2011. Seasons were defined as winter (Dec – Feb), spring (Mar – May), summer (Jun – Aug), and fall (Sep – Nov). Because the study period ended in 2011, we were able to use only a single month, December, 2001, to characterize winter 2012.

6. Water quality changes at the Napa Plant Site

Objective 6. *Assess changes in water quality associated with restoration actions at the Napa Plant Site through monthly collection of temperature, salinity, dissolved oxygen, and pH*

We collected monthly water quality measurements during high tide bird surveys from January 2006 to December 2011at the Napa Plant Site. We began taking water quality measurements for the North Unit in May 2009, and for the Central Unit in December 2009. After restoration of tidal flow, the North and Central Units each formed one larger pond and so we took one water quality measurement in the middle of each to represent the new larger units. From 2006 until August 2010 we collected the South Unit water quality measurements from the subunits C3, C4, C9, CB1, CB2, CB3, and Unit 3 when sufficient water was present. After it was breached, we took samples from three locations on the perimeter of the South Unit to account for spatial variation — the former units C2, C5, and CB2. The samples were averaged to provide a monthly mean value for each water quality parameter (±SE). We used a Hydrolab Minisonde (Hydrolab-Hach Company, Loveland, CO) to measure salinity (psu), pH, temperature (°C), and dissolved oxygen (DO; mg L^{-1}) at each location. We performed a calibration check of Hydrolab sensors prior to each sampling event. We also measured the specific gravity of each pond with a hydrometer (Ertco, West Paterson, New Jersey) scaled for the appropriate range, because Hydrolabminisondes may not accurately measure conductivity above 70 psu; we only used hydrometers to estimate salinities above 70 psu. Specific gravity was converted to salinity if a minisonde salinity reading was unavailable. Thus the salinity values reported are the best available data for the salinity range.

RESULTS AND DISCUSSION

1. Bathymetry at Napa Plant Site

We conducted bathymetric surveys in the breaches and pond interiors for the Napa Plant Site in 100-200 m transects (Figures 1.1). On the North Unit we conducted 1 breach survey, 7 east-west, and 15 north-south transects that totaled over 11,000 data points. On the Central Unit, we conducted 1 breach survey, 6 east-west and 10 north-south transects covering over 13,000 data points. On the South Unit, we conducted 2 breach surveys, 11east-west and 14 north-south transects that comprised over 31,000 data points.

North Unit elevation

The mean elevation of the North Unit during the fall of 2010 was 0.78 ± 0.39 m NAVD 88 ($\bar{x}$ ± SD) with an elevation range from -1.18 m to 1.74 m (Figure1.2). The mean elevation during fall of 2011 was 0.77 ± 0.37 m NAVD 88 with an elevation range from -1.32 m to 1.58 m (Figure 1.2). The unit's primary channel had the lowest elevations and the north-east corner of the unit had the highest elevations.

A comparison of our 2011 survey with our 2010 surveys suggests that the average elevation was stable. We estimated that the North Unit lost approximately 1,000 m^3 of sediment between surveys, which is equivalent to a < 0.25 cm layer of sediment throughout the unit. Areas of erosion and sedimentation were equally distributed across the unit (Figure 1.2).

Central Unit elevation

The mean elevation of the Central Unit during fall 2010 was 1.09 ± 0.25 m NAVD88 ($\bar{x}$ ± SD) with an elevation range from 0.11 to 1.64 m (Figure 1.3). The mean elevation of the Central Unit during fall 2011 was 1.06 ± 0.28 m NAVD88 ($\bar{x}$ ± SD) with an elevation range from 0.01 to 1.71 m (Figure 1.3). The lowest elevations of the unit occurred in the primary channel that drains to the breach. The highest elevations were along the levee edge and in the south-western section of the unit. While no recent vegetation surveys have been conducted, we have visually seen an increase in vegetation in the north-eastern and south-western regions over the past two years.

A comparison of our 2011 survey with our 2010 surveys suggests that average elevation may have decreased in the Central Unit. We estimated a net volume loss of more than 11,000 m^3 which represents an average decrease of 3.2 cm elevation across the pond, an overall level of elevation change that is within the error of the survey unit. We did observe spatial heterogeneity in sedimentation in this site, with areas of erosion and sedimentation distributed across the unit (Figure 1.4). Erosion primarily occurred in the north-west section with accretion in the south-west section of the pond. Elevation surveys over multiple years are required to reliably evaluate sedimention that is expected to change over many years following breach.

South Unit elevation

The mean elevation of the South Unit, excluding islands, during the fall of 2010 was 0.86 ± 0.29 m NAVD88 ($\bar{x}$ ± SD) with an elevation range from -1.00 m to 1.65 m (Figure 1.5). The mean elevation of the South Unit, excluding islands, during the fall of 2011 was 0.81 ± 0.29 m NAVD88 ($\bar{x}$ ± SD) with an elevation range from -1.48 m to 1.86 m (Figure 1.5). While presented at the same resolution as the North and Central Units, this result is based on fewer transects per area and is comparable to the bathymetric surveys conducted on Napa-Sonoma Marsh Ponds 3, 4, and 5 in 2008-2009 (Takekawa et al. 2009c, Brand et al. 2012). This large unit has a relatively flat surface with lower elevations primarily in the main channel that flows out of the salinity reduction breach. The highest elevations (with the exception of islands) occurred in the locations of former levees that had been lowered as part of the restoration construction and along the eastern levee.

A comparison of our 2011 survey with our 2010 surveys suggests that the average elevation decreased. We found a net volume loss of more than 169,000 m^3 which represents an average decrease of 4.1 cm across the pond. This change is only slightly greater than the error of the survey unit, though sediment loss appears to have occurred in scoured channels and some internal levees (Figure 1.6). Additionally, there was a layer of salt at the time of breach that may have dissolved between the first and second survey, thus the elevation change may reflect the successful reduction of salinity at the South Unit which fell from > 200 ppt to < 20 ppt post-breach (Figure 6.3). We did observe areas of sedimentation along the north-east levee, an area in which marsh vegetation has begun to colonize (Figure 1.6).

North Unit breach

In 2010 the North Unit breach had a mean elevation of -0.26 ± 0.30 m ($\bar{x}$ ± SD) and an elevation range of -0.81 m to 0.80 m (Figure 1.7). In 2011 the North Unit breach had a mean elevation of -0.45 ± 0.25 m ($\bar{x}$ ± SD) and an elevation range of -1.19 m to 0.17 m (Figure 1.7). Between 2010 and 2011 over 1,000 $m^3$of sediment eroded from the breach. The areas of highest erosion were along the levee edges while portions of the breach center had sediment accretion.

Central Unit breach

In 2010, the Central Unit breach had a mean elevation of -0.28 ± 0.19 m with a range from -0.21 m to 0.66 m (Figure 1.8). In 2011 the Central Unit breach had a mean elevation of 0.16 ± 0.22 m with a range from -0.19 m to 0.98 m (Figure 1.8). Despite an increase in mean elevation, the breach lost 179 m^3 of sediment.

South Unit breaches

The northern salinity reduction breach elevation of the South Unit during 2010 averaged -0.18 ± 0.44 m NAVD88 ($\bar{x}$ ± SD) with an elevation range of -0.94 m to 0.82 m (Figure 1.9). In 2011, the breach elevation averaged -0.47 ± 0.21 m NAVD88 ($\bar{x}$ ± SD) with an elevation range of -0.92 m to -0.05 m (Figure 1.9). Between 2010 and 2011 the breach lost over 450 m^3 or a 2.9 cm layer of sediment. In 2011 the northern breach of the South Unit had an elevation of -0.34 ± 0.62 m NAVD88 ($\bar{x}$ ± SD) and an elevation range of –1.70 m to 0.22 m (Figure 1.10).

Elevation Comparisons

Comparison of elevations from 2010 to 2010 allows an initial evaluation of early restoration progress. The three units are expected to develop into tidal marsh, which requires an increase in elevation to support the colonization of tidal marsh plants. The small average elevation changes we observed between 2010 and 2011 suggest that elevation changes are slow, as expected at large sites. However, this single value is not representative of the entire surface and our digital elevation models (Figures 1.2 to 1.6) are more informative as they provide the spatial distribution of erosion and sedimentation patterns across the pond areas. We would expect erosion to occur in some pond regions as existing channels scour and new ones form, which is important for development of a drainage network (Brand et al. 2010). The spatial location of accretion was dispersed within the units, with some accretion occurring along the levee edges. Marsh vegetation has been observed colonizing the higher elevation areas adjacent to the unit edges.

Large restoration sites with slow accretion rates require long term monitoring to assess the success of the restoration effort. We previously collected bathymetric data on Pond 3 on the west side of the Napa River in the NSMWA. Our data collection periods were four years apart and specific regions of the pond had a high level of accretion (Brand et al. 2012). A period of one-year between bathymetric surveys, as is the case in the Napa Plant Site, is not sufficient to estimate an accretion rate or to project the sites' future accretion patterns.

2. Bank erosion at Fagan Slough

Our imagery interpretation of the regions selected in Fagan Slough revealed slight changes between 2008 and 2011. We found that Fagan Slough at Site A was 26.5 m wide in 2008 and 27.4 m wide in 2011, suggesting that the detectable edge of the vegetation has receded from the slough by about 1 m (Figure 2.1). In contrast, we found that the slough width at Site B changed from 34.4 m in 2008 to 32.9 m in 2011. The slough width at Site C changed from 30 m in 2008 to 29.7 m in 2011, less drastic of a change than the other sites. Thus erosion of Fagan Marsh was detected near the confluence of Fagan Slough and the Napa River but not near the North Unit breach.

We visited the site to ground-truth the aerial imagery. Upon visual inspection of the marsh edge at low tide we observed areas along the north bank of Fagan Slough with signs of erosion. We observed areas of bank undercutting and bank collapse into the slough (Figure 2.2). The collapsed bank still contained vegetation and would appear as marsh edge in the imagery, which likely caused underestimation of slough width and erosion in the aerial photo analysis. We also observed cracks at marsh plain elevation set back 0.5 to 2 meters from the current bank edge, indicating possible future erosion in some sections (Figures 2.3, 2.4). This erosion likely results from both slumping and corrasion perhaps related to increased water flow levels in Fagan Slough following breach (Hooke 1979).The marsh edge on the north side of Fagan Slough appeared to have more erosion occurring than that on the south side. Bank erosion could be due to increased water volume and velocity following the breach, since Fagan Slough is a primary conduit of water to or from Napa River and the North Unit.

3. Invertebrate changes in the North Unit

Bird abundance increased dramatically in the North Unit following the breach of October 2008, including a large proportion of foraging shorebirds. We hypothesized that invertebrates may have increased as a prey resource for birds following breach, but prior studies on invertebrate colonization of breached salt ponds were lacking. We assessed invertebrate abundance and density of different taxa over time in the North Unit to compare with the Napa River and Fagan Slough, in order to investigate colonization of a the newly exposed mud flat in the former salt pond.

Napa River and Fagan Slough

The most abundant taxa in the Napa River were amphipods (Crustacea, 29%), followed by polychaetes (Annelida, 22%), oligochaetes (Annelida, 16%), cumaceans (Crustacea, 16%) and bivalves (Mollusca, 13%; Figure 3.7, Table 3.3). Differences in invertebrate composition within Fagan Slough were more pronounced and taxon equitability was reduced with the presence of one dominant taxa. Fagan Slough samples contained amphipods (Crustacea, 45%), polychaetes (Annelida, 17%), clams (Bivalvia, 13%), oligochaetes (Annelida, 10%), and tanaids (Crustacea, 8%; Figure 3.8, Table 3.3).

North Unit colonization

Invertebrate colonization following the October 2008 breach was rapid with colonizers detected after seven months in May 2009, but greater abundance of the major taxa (cumaceans) occurred in spring 2010 (Figure 3.9, Table 3.4). The North Unit macrobenthic community was characterized by cumaceans (Crustacea, 29%), polychaetes (Annelida, 22%), amphipods (Crustacea, 15%), ostracods (Crustacea, 12%), and nematodes (Nematoda, 8%), which collectively comprised 86% of all individuals (Table 3.3). Large amounts of plant and hay debris were collected in cores, reflecting one of the historical land uses (hay farming) prior to conversion to salt pond and eventual restoration. As the salt crust dissolved and the underlying plant material decomposed, benthic invertebrates were able to colonize and use the available plant food resources.

Invertebrate abundances by taxa

Cumaceans were among the first invertebrates to colonize the North Unit (detected in low numbers as early as January 2009), and a significant population spike occurred in May and July 2009 (mean abundances of 4,253 individuals/m² and 6,443 individuals/m², respectively). Such large densities were not detected again until March 2010 with a mean of 1,579 individuals/m² and peak mean abundance of 23,631 individuals/m² in July 2010 (Figure 3.10). In 2011, the late spring-early summer peak was observed, but densities were not as high as 2010 (peak mean density of 4,125 individuals/m² in July 2011). Cumaceans are known as “hooded shrimp” and are detritivores that feed on small particles, and some species feed on diatoms (Blazewica-Paszkowycz and Ligowski 2002). Cumaceans have relatively limited dispersal potential because of their lack of a planktonic larval stage (Corey 1981) and likely colonized from Fagan Slough because of its proximity, although it had a lower cumacean density compared to the Napa River. Cumacean numbers likely reflected abundant detritus-based food resources found within the North Unit shortly after restoration.

Amphipods, the second most successful colonizer, possess a similar life history strategy to the cumaceans, where adults brood embryos and release juveniles locally with no planktonic period to assist with dispersal (Franz and Mohamed 1989). Initial detection occurred as early as February 2009 and populations in the North Unit rivaled both Fagan Slough and Napa River by September 2009 (7,920 individuals/m²; Figure 3.11). Amphipod density dropped between February and April 2010, followed by a steady increase in early summer (peak density of 7,487 individuals/m² in August 2010), following the same basic seasonal trend as Fagan Slough and the Napa River (Figure 3.11). In 2011, amphipod densities followed the same seasonal patterns, and like the cumaceans, overall densities were much lower in the North Unit (peak density of 3,473 individuals/m² in August 2011) in 2011 compared with 2010.

Polychaetes were initially detected in January 2009 but were not detected in large abundances until October 2009 (Figure 3.12). The polychaete populations in the North Unit were composed primarily of the Capitellidae family, a group commonly used as a bioindicator due to their high physiological tolerance (Dean 2008, Rivero 2005, Weisberg et al 2008). Polychaete abundance throughout the pond remained consistent until an increase in August 2010 (7,461 individuals/m²), but the result is partially driven by a single sample (core NU3) which contained a high abundance of the family Sabellidae. Polychaetes in the North Unit maintained high densities throughout January 2011 (peak mean densityof 13,496 individuals/m²). During 2011, the polychaete population exhibited the same seasonal summer peak as the previous year, although the observed densities were much lower (peak mean density of 2,419 in July 2011).

The Tanaidacea did not colonize the North Unit until July 2009, with the exception of 5 individuals detected. They were detected in large densities in October and December 2009, and again in June through August 2010 (peak mean densityof 4,966 individuals/m² in July 2010; Figure 3.13). After summer 2010, tanaids were only observed in the pond at very low densities (peak mean density of 102 individuals/m²) and were not detected during the last five sampling months within the North Unit (Table 3.4). While the Tanaidacea, like the cumaceans, were not detected in cores NU1 or NU10, their distribution was extremely patchy and exhibited significant spatial and temporal variation.

Ostracods were virtually undetected in 2009 and the first three months of 2010 at all sites. Although we did not detect ostracods in the Napa River or Fagan Slough throughout the duration of the monitoring period, we saw a dramatic colonization in the late summer of 2011 (peak mean density 18,666 individuals/m² in July 2011). In July 2011 at core NU10, 83,397 individuals/m² were measured, however the following month August 2011, no individuals were detected at the same location, whereas 31,958 individuals/m² were observed at station NU3 (Figure 3.14, Table 3.4). Ostracod abundance was extremely patchy and did not follow any predictable spatial or temporal patterns.

Bivalves comprised 13% of relative invertebrate abundance at both Napa River and Fagan Slough, however only represented 1.5% of the invertebrate abundance in the North Unit (Table 3.3). Four species were detected throughout the monitoring period, with *Macomapetalum* and *Corbulaamurensis* being the two dominant species (55% and 45% of relative bivalve abundance, respectively; Figure 3.15) and the only two species detected in the North Unit. Although the two species (*M. petalum* and *C. amurensis*) had similar mean densities across sites (267 individuals/m² and 232 individuals/m², respectively), 84% of the bivalve biomass was attributed to *M. petalum,* due to the abundance of larger size classes (Figure 3.16).

Macomapetalum is a native clam that filter feeds but can employ an additional feeding mode (facultative deposit feeding) to utilize alternative food sources when phytoplankton blooms are low (Poulton et al. 2004). *M. petalum* was abundant in the Napa River and Fagan Slough throughout the entire monitoring period, and was first detected in the North Unit in May 2009 at NU7 (Figure 3.17). By August 2009, the *M. petalum* North Unit population had similar densities to that of the Napa River and Fagan Slough (573 individuals/m² at Napa River, 764 individuals/m² at Fagan Slough and 560 individuals/m² within the North Unit) and followed the same seasonal trends. Average biomass was greatest throughout the Napa River (67,293 mg dry weight/m²), followed by Fagan Slough (26,989 mg dry weight/m²), and the North Unit (10,889 mg dry weight/m²; Figure 3.18).

Corbula amurensis, the invasive Asian clam, was discovered in Suisun Bay in 1986 and dominated the northern San Francisco Bay benthos by 1990 with densities as high 48,000 individuals/m² (Cohen and Carlton 1995). *C. amurensis* was not detected in the North Unit until July 2009 at NU1. *C. amurensis* exhibited a much patchier distribution than *M. petalum* and reached peak abundances during the summer months (Figure 3.19). Biomass of *C. amurensis* was much lower than that of *M. petalum* and was greatest in Fagan Slough (11,670 mg dry weight/m²), followed by Napa River (1,879 mg dry weight/m²) and the North Unit (499 mg dry weight/m²; Figure 3.20). Additionally, two individual *Myaarenaria* clams were collected (one from the Napa River and one from Fagan Slough); and one individual *Musculistasenhousia* was collected (from the Napa River) throughout the duration of the monitoring period.

Seasonality

Overall invertebrate density and richness was highest in the North Unit from April 2010 through September 2010 which may be related to the absence of migratory shorebirds during this time. Three marked density peaks occurred across all common taxa throughout the monitoring period with high densities in May – July 2009, April – August 2010 and April – August 2011 (Figure 3.9). Invertebrate communities in Fagan Slough and Napa River exhibited similar temporal trends as the North Unit (Figure 3.7 and 3.8).

Spatial trends

Amphipods were the most dominant taxa in both reference sites and comprised 45% of the community in Fagan Slough but only 29% in the Napa River. The benthic matrix in Fagan

Slough was more heavily vegetated and likely provided ample food resources for the detritivores. Fagan Slough and Napa River contained high relative abundances of bivalves and oligochaetes that were rare in the North Unit (Figure 3.21). Cumaceans showed the greatest abundance in the North Unit compared with the two reference sites (Figure 3.21).

Within the North Unit, the taxonomic composition varied between cores (Figures 3.22 – 3.26). The dominant taxa by location was consistent over time suggesting that local-scale habitat suitability played a role in addition to the time since breach. While amphipods dominated the cores closest to the breach and Fagan Slough (NU1; Figure 3.22), the most dominant taxa, Cumacea were absent from this core but were well established in the center of the pond (NU3, NU5, and NU7; Figure 3.23-3.25). The sampling location farthest from the breach (NU10) had the lowest overall abundances (Figure 3.26) and was primarily dominated by polychaetes and ostracods.

The fine scale spatial data, representing five months where all core locations were processed (December 2008, January 2009, November 2009, September 2010 and November 2010) illustrated the establishment of a benthic invertebrate population subsequent to restored tidal flow (Figure 3.27). The December 2008 data showed absence of invertebrates from all cores within the North Unit immediately subsequent to the breach, and appearance of a few colonizers only three months later. By September and November 2010, it is clear that a wide array of benthic invertebrates had established local populations within the North Unit with densities rivaling the two reference sites (Napa River and Fagan Slough).

Overall, the Napa River and Fagan Slough were associated with the greatest species richness and evenness, while the North Unit contained the greatest overall invertebrate abundance. Our findings support the idea that a recently-breached former salt pond likely provides a food-rich environment for foraging birds (shorebirds at low tide and ducks at high tide). However, this highly rich environment is likely transitional, since the pond will be expected to accrete over time in its transition to tidal marsh. Furthermore, invertebrate abundances are not the best indicator of habitat health (Weisberg et al 2008). Continued monitoring of the benthic invertebrate community composition during early restoration will enable us to establish a longer time series to better understand the duration of this transition and its importance for waterbirds in the San Francisco Bay.

4. Small mammal source populations for restoration in the North Unit

We detected four species: the native California vole (*Microtuscalifornicus;*MICA), the endangered salt marsh harvest mouse (*Reithrodontomysraviventris*, RERA), the non-native house mouse (*Musmusculus*; MUMU), and shrew (*Sorexornatus*, subspecies unknown, SOOR). We captured 38 unique individuals, of which 16 were MICA, 15 RERA, 6 MUMU, and 1 SOOR (Figure 4.3). We recaptured 0 MICA, 7 RERA, 4 MUMU, and 0 SOOR for a total of 11 recaptures.

The adult male:female ratio was skewed towards females for MUMU (0.5:1) and RERA (0.88:1), but skewed towards males for MICA (1.67:1; Figure 4.4). We surveyed small mammals in the fall to capture the young from the spring and also because animals are still in reproductive condition. However, we only captured 3subadult or juvenile individuals (1 RERA; 2 MICA). Newborns are rarely observed and none were captured this year. For females, 83% of MICA, 63% of RERA, and 50% of MUMU adults were captured in reproductive condition (i.e.

developed mammary glands, pregnant, post lactating; Figure 4.4). For males, 20% of MICA, 29% of RERA, and 50% of MUMU were in reproductive condition (testes descended).

We captured almost twice the number of small mammals in the southern marsh (24), than in the northern marsh (14; Figure 4.5). The northern marsh was comprised of 6 MICA, 4 RERA, and 4 MUMU compared to the southern marsh, which had 10 MICA, 11 RERA, 2 MUMU, and 1 SOOR. We also detected a greater number of native MICA and RERA in reproductive condition in the southern marsh than at the northern marsh (Figure 4.5).

Overall capture index was moderate: 5.4 for MICA, and 5.0 for RERA, 2.0 for MUMU, and 0.3 for SOOR (Figure 4.6). Thus we also calculated the capture index for the two sites separately. The northern marsh had lower capture index for native species(4.1 for MICA, 2.7 for RERA, and 2.7 for MUMU) than the southern marsh (6.7 for MICA, 7.33 for RERA, 1.33 for MUMU and 0.7 for SOOR). In 2010 we conducted a small mammal survey in Fagan Marsh west of our 2011 southern marsh site. This site had a capture index for native species (29.5 for MICA, 13.5 for RERA, and 5.9 for MUMU) that far exceeded our 2011 southern marsh. In comparison, the US Fish and Wildlife Service (USFWS) draft 2010 Tidal Marsh Recovery Plan recommended a capture index of 5.0 for RERA. Overall the southern marsh (7.3 for RERA) is above the capture index; however, the northern marsh (2.7 for RERA) fell short of this goal during our sampling period.

Our results reflect a single time period and must be interpreted with caution. Capture indices can vary drastically from year to year (Woo, Block, and others, unpublished data), reproductive status varies by season (Fisler 1965, Bias 1994), and capture locations represent a relatively small portion of Fagan Marsh. In addition, the population recovery criteria for RERA are based solely on measurements of capture index (USFWS 2010). Population estimates that include detection probabilities (i.e. trap-happy vs. trap shy) would require a larger sampling effort but would allow a more accurate assessment of status and trends of the population, and ultimately a better assessment of the restoration effectiveness for RERA.

Overall, our small mammal survey session showed promising colonizing potential for the endangered salt marsh harvest mouse, yet our results suggest a discrepancy in the quality of habitat within Fagan Marsh. Salt marsh harvest mouse source densities in Fagan Marsh from 2010 are one of the highest documented in the San Pablo Bay (Woo, unpublished data), especially for breeding RERA. In contrast, the northern marsh had 54% of the RERA USFWS capture index and 37% of the southern marsh capture index. Habitat quality of fringe marshes is a critical topic for the recovery of RERA in recently breached salt ponds in the NSMWA generally, given that existing patches of fringe marsh would be the primary colonization sources of RERA for restored salt ponds 3, 4, and 5. Fringe marshes may not be adequate sources of dispersal for colonizing RERA to newly restored sites, and the characteristics of fringe marshes that influence habitat quality (e.g. patch size, vegetation composition, etc.) are not well understood.

One of the greatest challenges in restoration is to understand and manage for habitat attributes that best support wildlife populations. Tidal marsh restoration requires an understanding of habitat requirements of endemic species so that sites do not become ecological traps where animals settle in poor-quality habitats, resulting in reduced survival and productivity. Even the most careful restoration designs can result in inadequate canopy structure or unintended outcomes (Zedler 1993, USFWS 2010). In future studies, comparison of historic and fringe marsh patches would allow us to assess source-sink populations within this landscape.

5. Waterbird changes at the Napa Plant Site

Napa Plant Site waterbird abundance between December 2010 and December 2011

We detected 61 species of waterbirds in all twelve guilds at the Napa Plant Site from December 2010 through December 2011. Fifty-five species were detected at high tideand 58 species were detected at low tide (Tables 5.1 and 5.2). When low and high tide surveys were combined, small shorebirds were the most abundant guild (45% of all birds), followed by dabbling ducks (32%), medium shorebirds (10%), and diving ducks (10%). These four guilds comprised approximately 97% all birds observed at high tide, low tide, and both tide heights combined.

Abundance within and among guilds varied between high and low tide, although the difference was most apparent in dabbling ducks and small shorebirds. The monthly average abundance at high tide in 2011 was dominated by dabbling ducks (3,101.3 ± 1078.9; 52%), followed by small shorebirds (1,189 ± 367.3; 20%), diving ducks (804.8 ± 281.9; 13%), and medium shorebirds (729.7 ± 225.1; 12%, Table 5.1). At low tide, however, small shorebirds were the most dominant guild (6249.7 ± 2088.6; 60%), followed by dabbling ducks (2205.4 ± 844.5; 21%), medium shorebirds (977.8 ± 199.6; 9%), and diving ducks (758.7 ± 253.0; 7%, Table 5.2).

Furthermore, shorebird and duck abundance varied by unit. The South Unit had the highest average abundance of all four guilds at both high and low tide, with the exception of medium shorebirds at low tide (Tables 5.3 and 5.4). We expect this result given the large geographic extent of the South Unit compared with the North and Central Units. The Central

Unit, the smallest of the units, had the lowest abundance of all guilds across high and low tides, with the exception of medium shorebirds at low tide (Tables 5.3 and 5.4)

Napa Plant Site waterbird trends from 2006 to 2012

*North Unit.*Post-breach, shorebird and duck abundance increased substantially in the North Unit during winter and spring. Between 2006 and 2008 fewer than 250 shorebirds and zero ducks were using the North Unit (Figures 5.1 – 5.5). The small and medium shorebirds observed pre-breach were likely using the area as a high tide roost. However, post-breach, no small shorebirds were roosting in the unit at high tide (Figure 5.1). In contrast, medium shorebirds have continued to use the unit at high tide and their abundance has increased (Figure 5.2).

The reconnection to tidal flow has allowed invertebrate colonization and an exposed mudflat at low tide. As a result, small and medium shorebird abundance increased during low tide at the North Unit (Figures5.1, 5.2, and 5.5). In spring 2009 (the first season with low tide surveys), the highest abundance was 36 medium shorebirds and 21 small shorebirds. In the winter of 2011 the average abundance was 598 medium shorebirds and 946 small shorebirds.

Dabbling and diving ducks were observed in the unit post-breach (Figures 5.3 and 5.4). In winter 2009, dabbling duck abundance began to increase from 181 at high tide and 205 at low tide. By winter 2012 dabbling duck numbers had increased to1,694 at high tide and 1,067 at low tide. Diving ducks were higher in abundance in winter 2009 than dabbling ducks, with 199 at high tide and 679 at low tide. However, by winter 2012 diving ducks were lower in abundance than dabbling ducks, with 435 at high tide and 692 at low tide (Figure 5.5).

Central Unit. While the North Unit began providing habitat to thousands of shorebirds and ducks in winter 2009, the Central Unit remained unoccupied until after it was breached the following year (Figure 5.6). In 2010 small and medium shorebirds were using the Central Unit as a high tide roost and a low tide foraging habitat (Figures 5.1 and 5.2). Medium shorebird abundance peaked at low tide in winter 2011 (772). Small shorebird abundance peaked at low tide in winter 2012 (3,154).

In contrast to shorebirds, duck abundance in the Central Unit was relatively low (Figure 5.3 and 5.4). Few dabbling ducks were present until winter 2012 when the average abundance reached 697 at high tide and 655 at low tide. The abundance of diving ducks peaked in winter 2010 at high tide with 143 birds and then declined to 26 birds in winter 2012.

South Unit. Prior to the restoration of tidal flow, the South Unit functioned primarily as a high tide roost for shorebirds (Figure 5.7). The unit supported over 88% of roosting small shorebirds at the Napa Plant Site in nearly every season since 2005 (Brand et al. 2010). The average abundance of medium shorebirds during spring and winter of 2006 to 2010 ranged from 39 to 482 at high tide (Figure 5.2). The average abundance of small shorebirds during spring and winter of 2006 to 2010 ranged from 391 to 5,806 at high tide (Figure). Relatively few small (0-11) and medium (1-71) shorebirds were observed during the 2009-2010 low tide surveys (Figure 5.7).

The introduction of tidal flow in August 2010 eliminated a large expanse of high tide shorebird roosting habitat while creating low tide shorebird foraging habitat. By winter 2012 the average number of small shorebirds declined to 826 at high tide. However, the number increased to 16,090 at low tide. Medium shorebirds increased in abundance during winter and spring at both high and low tide (Figure 5.2). In the winter of 2012 the average abundance of medium shorebirds at high and low tide was 673.

While shorebirds had used the South Unit before breaching occurred, ducks did not occupy the area until tidal flow was introduced (Figure 5.7). During the winter and spring of 2006 through 2010 the high tide average abundance of dabbling and diving ducks ranged from zero to nine birds. No diving ducks and fewer than 10 dabbling ducks were present during low tide. By winter 2012, the average abundance of dabbling ducks reached 6,312 at high tide and 3,638 at low tide (Figure 5.3). Northern Pintail and American Coot represented the majority of this guild, though Gadwall and American Wigeon were also prominent at low tide (Tables 5.1 and 5.2). By winter 2012, the average abundance of diving ducks reached 2,740 at high tide and 1,546 at low tide (Figure 5.4), the majority of which were Ruddy Duck (Tables 5.1 and 5.2). These increases correspond withthe increase in available habitat following the breach of the South Unit and winter 2012 represents the greatest abundance of dabbling and diving ducks observed at the Napa Plant Site during the study period.The dramatic increase in waterbird abundance and the shift in guild composition illustrate the importance of the restoration even during the early stage.

Napa Plant Site waterbird foraging behavior

While the three units were breached in different years, we found important differences in habitat use by shorebirds during low and high tides between September 2009 and December 2011. Across all seasons and years the majority of medium shorebirds foraged at low tide and roosted at high tide (Figure 5.8). Similarly, nearly 100% of small shorebirds foraged at low tide (Figure 5.8). Between fall 2009 and summer 2010 nearly all small shorebirds roosted at high tide (Figure 5.8). However, beginning in the fall of 2010, approximately 20% of small shorebirds foraged at high tide. This percentage peaked to over 50% in the spring and fall of 2011 (Figure

5.8). These shifts in high tide foraging correspond with the breaching of the South Unit in 2010. The eastern edges of the South Unit have a gradual slope and this may provide additional shorebird foraging habitat as the tide slowly fills the unit at high tide.

While shorebirds were generally limited to foraging at low tide, ducks did not have a pronounced difference in their behaviors between high and low tide (Figure 5.9). Dabbling ducks exhibited more seasonality in behavior between tides, with more foraging occurring at high tide during winter and spring (Figure 5.9). In contrast, they equally foraged and roosted at low tide (Figure 5.9). Diving ducks primarily roosted during both high and low tides (Figure 5.9). Approximately 20% of diving ducks were foraging during high and low tides each season (Figure5.9), with an average of approximately 70 foraging and 400 roosting individuals. Overall, the introduction of tidal flow in the Napa Plant Site has provided valuable foraging habitat for shorebirds at low tide and for dabbling ducks during both high and low tides (Figure 5.10).

6. Water quality changes at the Napa Plant Site

We recorded monthly salinity, dissolved oxygen, pH, and temperature in the North, Central, and South Unit at the Napa Plant Site from May 2009 through December 2011 (Figures 6.1 – 6.3). Salinity and temperature were lower during the wet seasons (November – April) likely due to the influx and mixing of rainwater, cooler air temperature, and lesser solar intensity. Dissolved oxygen levels were slightly variable from month to month. However, this is likely an artifact of the sampling regime because dissolved oxygen typically follows a diurnal cycle, and our sampling effort corresponded with high tide rather than time of day. The pH levels were stable and consistent at all Units post-breach.

Water quality parameters in the North Unit were seasonally variable (Figure 6.1). During the wet season, salinity approached freshwater levels, with a minimum of 0.44 psu in March 2011. During the dry season, salinity increased to a study maximum of 24.12 psu (September 2010). Temperature also followed a clear seasonal trend with a maximum of 23.9 °C during the dry season (September 2010) and a minimum of 10.94 °C during the wet season (January 2011). The average pH level of the unit was stable at a neutral 7.6 ± 0.08. Dissolved oxygen was also fairly stable, hovering around 8.3 ± 0.25 mg L^{-1}, with a minimum of 5.64 mg L^{-1} during the dry season (September 2010), and maximum of 8.56 mg L^{-1} observed during November 2011.

The Central Unit also displayed seasonal variability (Figure 6.2). During the wet season, salinity dropped to a minimum of 1.45 psu (January 2010), with the high of 26.35 psu reached during the dry season (August 2010). Temperature was at a minimum (6.51 °C) during the wet season (December 2009), and reached a study maximum, 28.02 °C in the dry season (June 2011). The pH was stable at a neutral 7.61 ± 0.11. Dissolved oxygen was also fairly stable, with an average of 9.55 ± 0.31 mg L^{-1}, and with values never dropping below 7.4mg L^{-1} (October 2010).

Water quality parameters in the South Unit exhibited a distinct shift which corresponded with the breach (Figure 6.3). Average temperature and salinity varied greatly with season prior to the breach. Before the breach, the average temperature ranged from 6.94 °C to 31.78 °C. After the breach, the average temperature range for the new, undivided South Unit narrowed to a minimum of 11.12 °C and maximum of 28.15 °C. The shift in salinity was even more dramatic, with a pre-breach range of 99.77 – 360.25 psu. Within a month of the breach, salinity had plummeted from an average of 286.67 to 27.74 psu. Post-breach, the average salinity was comparable to the North and Central Units, and ranged from 2.7 in the wet season to 27.74 psu in the dry season. The average pH in the pre-breach South Unit exhibited a wide range, but was most consistently acidic, with an average pH of 5.22 and minimum pH of 2.21. After the breach, pH increased to a neutral state ; the pH average was 7.85, with a range between 7.44 and 8.41. Dissolved oxygen levels also increased post-breach. Before the breach, average dissolved oxygen was 5.22 mg L^{-1}, with a range between 2.21 and 9.71 mg L^{-1}. After the breach, average dissolved oxygen increased to 9.50 mg L^{-1}, with a range between 6.96 and 11.92 mg L^{-1}. Overall, restoration of tidal flow has improved the water quality in the South Unit. Prior to the restoration efforts, high salinity and low dissolved oxygen precluded the survival of fish and most invertebrates. However, since tidal exchange was restored, salinity has dropped to mirror those of the North and Central Units, and dissolved oxygen levels have increased and stabilized. It is likely that increased water quality facilitated colonization of the South Unit by fish and benthic invertebrates. The increase in waterbird abundance on the South Unit is likely a response to this effect on prey availability.

FUTURE APPLIED SCIENCE AND MONITORING

Sedimentation. In previously subsided salt ponds, tidal marsh restoration requires sedimentation to sufficient elevations for the development of the marsh plain. In prior studies of Ponds 3, 4, and 5 on the Napa-Sonoma Marsh Wildlife Area, we have documented sedimentation rates of 2.4 cm per year in Pond 3 (Takekawa et al. 2009c, Brand et al. 2012). We have now documented two years of elevations at the Napa Plant Site units and have calculated elevation changes that indicate areas of sediment accretion and erosion across the three Units. Sedimentation rates vary as a function of numerous factors, including suspended sediment concentrations, tidal prism, and the location and size of breaches. Repeat bathymetric surveys over multiple years will allow us to assess sedimentation patterns at the Napa Plant Site to predict accretion rates and assess the trajectory of early tidal marsh restoration at this site. Water level loggers provide continuous water elevations to evaluate tidal inundation and flow patterns, a key factor driving colonization.

Invertebrates. Densities of invertebrates in the newly exposed mud flats of the North Unit have exceeded reference sites at Fagan Slough and the Napa River. These data are unique in San Francisco Bay and have important implications for the hundreds of restoration projects in the estuary. Scouring from large disturbance events that create new mud flats likely occurred at regular intervals in the historic marshes prior to channeling and diking. Large numbers of birds use these areas for foraging at both high and low tide, but continued surveys will document how long these transitional areas are valuable for waterbirds as they convert to tidal marsh.

Small mammals. A primary goal of tidal marsh restoration is to provide habitat for re-colonization by endemic species including the endangered salt marsh harvest mouse. Our surveys showed that Fagan Marsh has a population of native small mammal species available that could potentially colonize the North Unit. However, our surveys documented substantial differences in capture efficiencies between sampled sites in 2010 and 2011, suggesting the value of research to evaluate habitat features that support or enhance recovery of the species. Further work is also needed to assess isolation effects, since the distances small mammals may disperse from Fagan Marsh to serve as a source population for newly restored sites is not known.

Waterbirds. Waterbird abundance at the Napa Plant Site has increased substantially since the restoration began in 2008. Continued surveys would allow for detection of trends in bird populations to further establish the benefits and impacts of the restoration actions. By relating these findings to biophysical predictors, we can better understand the factors and restoration processes that affect waterbird abundance, distribution, and species composition. Water bird guilds have changed dramatically during the early restoration over the NSMWA, and continued surveys will illuminate population-level responses to these changes such as shifting foraging and roosting habitat across ponds that are critical to maintaining waterbird abundances at landscape scales to meet multi-species management goals and ensure overall restoration success. Monitoring provides quantifiable results demonstrating the benefits of restoration in the NSMWA and San Francisco Bay. Long-term datasets are rare, and continued collection of these data would be exceptionally valuable for understanding restoration science.

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TABLES AND FIGURES

Table 3.1. Lowest taxonomic identification within the three study sites. NR = Napa River, FS = Fagan Slough, and NU = North Unit. Taxonomic resolution used from Dec 2008 – May 2009.

	Taxonomic Resolution
Phylum CNIDARIA	
Class Anthozoa	Class
Phylum NEMATODA	Phylum
Phylum ANNELIDA	
Class Polychaeta	
Eteone lighti	Species
Capitellidae	Family
Sabellidae	Family
Streblospio benedicti	Species
Class Oligochaeta	Subclass
Phylum MOLLUSCA	
Class Bivalvia	
Macoma petalum	Species
Corbula amurensis	Species
Mya arenaria	Species
Musculista senhousia	Species
Phylum ARTHROPODA	
Class Maxillopoda	
Copepoda	Subclass
Class Ostracoda	
Podocopa	Subclass
Class Malacostraca	
Order Amphipoda	
Ampelisca abdita	Species
Corophium spp.	Genus
Monocorphium spp.	Genus
Grandidierella japonica	Species
Order Isopoda	
Gnorimosphaeroma oregonense	Species
Order Tanaidaceae	
Pancolus californiensis	Species
Order Cumacea	Order
Class Insecta	
Order Diptera	
Ephydridae	Family
Order Hemiptera	
Corixidae	Family

Table 3.2. Taxonomic classification of invertebrates and their presence at the three study sites. NR = Napa River, FS = Fagan Slough, and NU = North Unit. Taxonomic resolution used from May 2009 – October 2011. * indicates taxa representing < 1% and categorized as 'other.'

	Taxonomic Resolution	Sites Present
Phylum CNIDARIA		
Class Anthozoa*	Class	NU
Class Hydrozoa*	Class	NR, FS
Phylum NEMATODA	Phylum	NR, FS, NU
Phylum ANNELIDA		
Class Polychaeta	Class	NR, FS, NU
Class Oligochaeta	Class	NR, FS, NU
Phylum MOLLUSCA		
Class Gastropoda*	Class	NR, NU
Class Bivalvia		
Macoma petalum	Species	NR, FS
Corbula amurensis	Species	NR, FS
Mya arenaria	Species	NR, FS
Musculista senhousia	Species	NR
Phylum ARTHROPODA		
Class Maxillopoda		
Copepoda*	Subclass	NR, FS, NU
Balanidae*	Family	FS
Class Ostracoda	Class	NR, FS, NU
Class Malacostraca		
Order Amphipoda	Order	NR, FS, NU
Order Isopoda*	Order	NR, FS, NU
Order Tanaidaceae	Order	NR, FS, NU
Order Cumacea	Order	NR, FS, NU
Order Decapoda		
Brachyura*	Infraorder	NR, FS, NU
Order Mysida*	Order	NR, NU
Class Insecta	Class	NR, FS, NU
Ephydridae larvae	Family	NU
Chironomidae larvae	Family	NU
Coleoptera larvae	Order	NU
SubPhylum HEXAPODA*	Subphylum	NU
Collembola*	Subclass	NR, NU
Phylum BRYOZOAN*	Phylum	NR, FS

Table 3.3. Overall mean invertebrate abundance (individuals/m^2) and percent relative abundance by taxa within the Napa River, Fagan Slough, and North Unit.

Taxa	Napa River		Fagan Slough		North Unit	
Nematoda	116	1.9%	84	1.7%	666	7.8%
Bivalvia	751	12.6%	667	13.1%	127	1.5%
Polychaeta	1,286	21.5%	869	17.1%	1,851	21.6%
Oligochaeta	968	16.2%	502	9.9%	434	5.1%
Amphipoda	1,715	28.7%	2,277	44.9%	1,242	14.5%
Cumacea	959	16.0%	131	2.6%	2,499	29.1%
Tanaidacea	127	2.1%	380	7.5%	521	6.1%
Ostracoda	2	0.0%	2	0.0%	990	11.5%
Insecta	4	0.1%	36	0.7%	144	1.7%
Other	52	0.9%	125	2.5%	106	1.2%

Table 3.4. Overall mean invertebrate abundance (individuals/m²) by month and site (NR = Napa River, FS = Fagan Slough, NU = North Unit).

		2008 Dec	2009 Jan	Feb	Mar	Apr	May	Jul	Aug	Sep	Oct	Nov	Dec
NEMATODA	**NR**	0	0	0	0	0	0	64	0	0	0	0	64
	FS	64	64	64	0	0	0	0	637	0	0	0	127
	NU	0	0	0	0	0	25	0	0	0	76	25	280
BIVALVIA (all spp.)	**NR**	1,337	637	255	318	382	1,528	1,273	764	191	127	509	828
	FS	509	764	318	318	64	1,146	573	4,202	255	318	255	318
	NU	0	0	0	0	0	51	306	586	51	51	153	102
Corbula amurensis	**NR**	0	0	127	127	64	573	700	191	0	0	0	0
	FS	0	64	64	0	0	509	318	3,374	0	64	0	127
	NU	0	0	0	0	0	0	0	0	0	0	0	0
Macoma petalum	**NR**	1,337	637	127	64	318	891	509	573	191	127	509	764
	FS	446	573	255	318	64	637	255	764	255	191	255	127
	NU	0	0	0	0	0	51	204	560	51	25	153	102
POLYCHAETA	**NR**	700	1,273	509	382	255	127	1,273	1,401	700	255	382	1,146
	FS	1,655	1,146	1,528	637	64	318	446	828	1,019	64	127	0
	NU	0	0	0	25	0	178	357	51	25	1,502	1,451	3,336
OLIGOCHAETA	**NR**	1,592	1,974	255	446	64	255	764	127	64	127	127	764
	FS	318	573	1,146	0	0	382	64	2,355	0	0	0	255
	NU	0	25	0	25	76	0	25	0	25	25	0	25
AMPHIPODA	**NR**	4,074	1,210	1,019	318	1,337	4,520	2,419	891	700	191	764	573
	FS	8,849	6,685	6,621	764	127	6,621	4,966	1,910	3,629	2,101	1,528	3,374
	NU	0	0	51	0	102	76	1,579	153	7,920	4,304	1,706	1,579
CUMACEA	**NR**	3,692	509	191	2,419	255	1,401	764	64	64	127	64	700
	FS	127	64	0	0	0	255	0	0	0	0	191	0
	NU	0	204	102	178	25	4,253	6,443	127	127	127	331	484
TANAIDACEA	**NR**	0	0	0	0	0	0	828	0	0	0	0	255
	FS	64	0	64	0	0	828	382	1,719	0	0	0	64
	NU	0	0	0	0	0	0	153	25	382	2,801	153	1,783
OSTRACODA	**NR**	64	0	0	0	0	0	0	0	0	0	0	0
	FS	0	0	0	0	0	0	0	0	0	0	0	0
	NU	0	0	0	0	0	0	0	0	0	0	0	153
INSECTA	**NR**	0	0	0	0	0	0	0	0	64	0	0	0
	FS	0	0	0	0	0	0	0	0	0	0	0	0
	NU	0	0	0	25	0	2,979	25	25	127	0	25	0
OTHER	**NR**	0	0	0	0	0	0	0	0	0	0	0	191
	FS	127	0	191	0	0	0	64	191	318	446	64	0
	NU	0	0	0	0	0	993	51	25	0	0	0	25

Table 3.4 Continued.

		2010 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NEMATODA	**NR**	64	0	0	0	0	0	64	700	64	255	0	255
	FS	0	0	0	0	0	0	0	191	127	0	0	0
	NU	25	0	51	229	51	4,558	178	6,035	1,324	1,553	280	815
BIVALVIA (all spp.)	**NR**	1,019	573	573	764	1,019	1,273	3,247	955	255	764	382	1,019
	FS	446	191	191	318	191	1,719	2,228	1,019	0	828	318	1,146
	NU	357	153	25	51	178	484	229	127	204	204	127	76
Corbula amurensis	**NR**	64	0	0	255	573	1,019	3,183	127	0	0	0	127
	FS	127	64	0	127	191	1,846	1,910	127	0	700	191	1,146
	NU	0	0	0	0	0	0	0	0	0	0	0	0
Macoma petalum	**NR**	955	509	573	446	446	382	64	828	255	764	382	828
	FS	318	127	191	191	0	0	318	891	0	127	127	0
	NU	306	153	25	51	102	280	76	102	127	204	127	76
POLYCHAETA	**NR**	1,082	0	64	573	446	0	1,337	764	1,592	2,355	509	2,674
	FS	446	446	0	446	64	0	318	1,592	1,528	255	1,655	891
	NU	917	789	306	1,681	1,095	968	1,146	7,461	2,114	6,926	1,502	3,361
OLIGOCHAETA	**NR**	2,292	1,592	64	1,273	191	0	446	1,655	1,082	1,082	0	4,138
	FS	0	255	0	446	64	127	127	7,894	0	0	446	64
	NU	280	25	51	51	866	127	535	51	458	1,070	357	942
AMPHIPODA	**NR**	1,146	637	700	955	1,273	191	1,719	1,210	1,655	3,820	1,719	7,958
	FS	1,846	1,846	573	509	1,337	2,610	5,029	4,265	573	2,865	1,846	1,592
	NU	891	204	204	127	1,197	204	2,215	7,487	280	4,711	458	1,910
CUMACEA	**NR**	700	255	318	5,984	1,974	637	2,165	1,910	64	127	255	64
	FS	64	0	0	573	64	0	446	1,401	0	0	0	0
	NU	1,171	433	1,579	7,181	8,047	10,695	23,631	2,012	764	127	127	611
TANAIDACEA	**NR**	255	0	0	0	64	0	0	0	0	0	0	2,674
	FS	191	127	382	573	318	446	64	1,528	0	255	0	1,019
	NU	0	102	153	815	255	2,139	4,966	3,641	25	0	0	76
OSTRACODA	**NR**	0	0	0	0	0	0	0	0	0	0	0	0
	FS	0	0	0	0	0	0	0	0	0	0	0	0
	NU	0	0	0	204	25	178	688	51	76	153	51	102
INSECTA	**NR**	0	0	0	0	0	0	0	0	0	0	0	0
	FS	0	0	0	0	0	0	64	0	0	0	0	0
	NU	51	0	0	0	127	25	51	0	0	0	0	0
OTHER	**NR**	0	0	0	0	0	318	127	0	0	0	64	0
	FS	255	0	191	127	191	0	0	700	64	64	64	64
	NU	178	25	51	560	25	306	76	484	0	76	153	229

Table 3.4 Continued.

		2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
NEMATODA	**NR**	255	318	255	127	0	64	764	127	191	318
	FS	64	0	0	0	0	0	955	446	0	127
	NU	4,533	306	586	331	51	153	458	229	127	357
BIVALVIA (all spp.)	**NR**	573	509	255	318	446	1,082	573	828	318	637
	FS	1,974	255	64	0	0	382	1,019	637	191	509
	NU	0	76	0	102	51	51	204	178	25	102
Corbula amurensis	**NR**	0	0	0	0	64	573	0	64	0	64
	FS	1,974	127	64	0	0	382	1,019	637	191	446
	NU	0	0	0	0	0	0	0	0	0	0
Macoma petalum	**NR**	573	509	255	318	382	637	573	764	318	573
	FS	0	127	0	0	0	0	0	0	0	64
	NU	0	76	0	76	51	25	102	25	25	102
POLYCHAETA	**NR**	6,112	255	382	1,273	764	382	13,750	382	382	255
	FS	191	382	764	127	127	255	10,886	891	255	191
	NU	13,496	1,859	255	2,165	2,139	2,114	2,419	1,833	255	1,222
OLIGOCHAETA	**NR**	700	2,610	1,019	637	255	446	5,157	191	1,019	509
	FS	191	127	0	64	0	127	1,910	0	0	127
	NU	2,597	637	51	331	25	4,431	789	586	76	178
AMPHIPODA	**NR**	7,130	573	2,292	255	191	573	891	3,310	446	1,655
	FS	637	446	828	0	127	191	828	1,719	382	191
	NU	102	51	0	0	0	25	407	3,743	102	433
CUMACEA	**NR**	828	382	1,210	1,273	637	382	955	1,273	637	318
	FS	0	0	255	191	0	0	637	127	0	64
	NU	1,044	331	127	2,190	2,445	3,361	4,125	917	637	993
TANAIDACEA	**NR**	0	255	0	0	0	0	0	0	0	0
	FS	255	509	255	0	0	0	318	2,355	1,146	64
	NU	102	25	25	25	51	0	0	0	0	0
OSTRACODA	**NR**	0	0	0	0	0	0	0	0	0	0
	FS	0	0	0	0	0	0	64	0	0	0
	NU	178	637	127	127	0	535	18,666	6,392	3,412	1,910
INSECTA	**NR**	0	0	0	0	0	0	64	0	0	0
	FS	0	0	0	0	0	0	700	446	0	0
	NU	0	0	0	25	25	51	993	331	0	0
OTHER	**NR**	318	255	127	0	64	0	318	0	0	0
	FS	0	64	0	64	0	0	764	255	0	0
	NU	204	51	0	0	25	25	25	0	0	25

Table 5.1. Total number of birds detected by guild and species across all ponds in the Napa Plant Site (North, Central, and South Units) at high tide from Dec. 2010 through Dec. 2011.

	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Dabbling Ducks	**1852**	**1326**	**1233**	**1549**	**351**	**156**	**325**	**8**	**14**	**6973**	**9030**	**8797**	**8703**	**40317**	**3101.3**	**1078.9**
American Coot	337	201	513	290	43	0	0	0	0	19	3226	6572	6159	17360	1335.4	691.5
American Green-winged Teal	112	37	4	118	16	0	0	0	0	0	272	182	237	978	75.2	28.6
American Wigeon	735	196	289	16	45	0	0	0	0	2	1049	698	1457	4487	345.2	140.1
Cinnamon Teal	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0.3	0.3
Gadwall	521	725	365	225	62	119	126	2	7	930	908	1230	516	5736	441.2	116.4
Mallard	115	55	16	14	114	28	199	6	7	357	171	47	49	1178	90.6	29.4
Northern Pintail	4	19	0	0	3	0	0	0	0	5559	3054	20	233	8892	684.0	487.4
Northern Shoveler	28	93	46	886	68	9	0	0	0	106	350	48	48	1682	129.4	70.8
Diving Ducks	**1455**	**1025**	**451**	**787**	**674**	**13**	**2**	**0**	**2**	**21**	**654**	**2178**	**3201**	**10463**	**804.8**	**281.9**
Bufflehead	7	15	8	6	0	0	0	0	0	0	0	21	118	175	13.5	9.3
Canvasback	76	670	29	107	0	0	0	0	0	0	0	33	434	1349	103.8	59.9
Common Goldeneye	2	3	11	6	1	0	0	0	0	0	1	9	5	38	2.9	1.1
Redhead	2	0	0	0	0	0	0	0	0	0	0	0	1	3	0.2	0.2
Ruddy Duck	1368	337	390	505	149	5	0	0	0	21	653	2112	2627	8167	628.2	251.0
Greater and Lesser Scaup	0	0	13	163	524	8	2	0	2	0	0	3	16	731	56.2	42.5
Eared Grebes	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**3**	**0.2**	**0.1**
Fish-Eaters	**1**	**8**	**7**	**9**	**14**	**7**	**59**	**12**	**6**	**199**	**63**	**51**	**31**	**467**	**35.9**	**15.5**
American White Pelican	0	0	0	0	0	0	54	7	3	33	27	1	0	125	9.6	5.0
Clark's Grebe	0	0	0	3	2	0	0	0	0	0	0	0	2	7	0.5	0.3
Double-crested Cormorant	1	0	1	4	1	1	2	2	3	166	36	16	10	243	18.7	13.1
Red-breasted Merganser	0	0	0	0	0	0	0	0	0	0	0	1	2	3	0.2	0.2
Pied-billed Grebe	0	0	0	0	0	0	0	0	0	0	0	24	1	25	1.9	1.9
Western Grebe	0	8	5	2	11	6	2	3	0	0	0	9	14	60	4.6	1.4
Western or Clark's Grebe	0	0	1	0	0	0	1	0	0	0	0	0	2	4	0.3	0.2

Table 5.1. Continued.

	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Geese	**0**	**34**	**0**	**13**	**15**	**54**	**62**	**130**	**207**	**32**	**2**	**116**	**1**	**666**	**51.2**	**18.3**
Canada Goose	0	34	0	13	15	54	62	130	207	32	2	116	1	666	51.2	18.3
Gulls	**32**	**98**	**35**	**20**	**39**	**0**	**5**	**136**	**44**	**115**	**33**	**195**	**32**	**784**	**60.3**	**16.7**
California Gull	0	26	0	3	21	0	4	10	9	82	0	43	5	203	15.6	6.8
Glaucous-winged Gull	0	0	0	4	0	0	0	0	0	0	0	0	0	4	0.3	0.3
Herring Gull	16	27	9	8	0	0	0	0	0	7	24	134	21	246	18.9	10.4
Ring-billed Gull	2	1	4	1	9	0	1	124	10	20	6	1	2	181	13.9	9.7
Western Gull	5	44	22	4	9	0	0	2	25	6	3	17	4	141	10.8	3.7
Unidentified Gull	9	0	0	0	0	0	0	0	0	0	0	0	0	9	0.7	0.7
Herons	**9**	**1**	**3**	**2**	**2**	**3**	**5**	**8**	**10**	**22**	**13**	**8**	**5**	**91**	**7.0**	**1.7**
Great Blue Heron	4	0	1	0	0	1	0	3	4	6	7	2	2	30	2.3	0.7
Great Egret	1	1	2	2	1	1	2	5	4	10	3	1	1	34	2.6	0.7
Snowy Egret	4	0	0	0	1	1	3	0	2	6	3	5	2	27	2.1	0.6
Medium Shorebirds	**724**	**836**	**814**	**3071**	**143**	**76**	**14**	**54**	**546**	**818**	**804**	**799**	**787**	**9486**	**729.7**	**225.1**
American Avocet	502	0	0	2271	3	4	14	0	188	77	93	39	5	3196	245.8	180.2
Black-bellied Plover	203	77	585	297	23	4	0	0	168	101	260	229	468	2415	185.8	53.2
Black-necked Stilt	7	0	0	0	0	0	0	0	0	0	0	0	0	7	0.5	0.6
Greater Yellowlegs	1	0	0	1	0	0	0	0	0	0	0	0	0	2	0.2	0.1
Killdeer	11	2	0	1	0	1	0	2	4	13	3	2	1	40	3.1	1.2
Lesser Yellowlegs	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0.2	0.2
Long-billed Curlew	0	1	0	38	11	0	0	0	5	2	1	0	6	64	4.9	3.0
Marbled Godwit	0	458	179	339	42	4	0	26	99	271	230	151	71	1870	143.8	42.0
Willet	0	298	50	124	64	63	0	26	82	354	217	375	236	1889	145.3	38.8
Phalaropes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**2**	**0.2**	**0.2**
Red-necked Phalarope	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0.2	0.2

Table 5.1. Continued.

	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Raptors	**2**	**3**	**1**	**1**	**2**	**1**	**5**	**3**	**7**	**10**	**0**	**1**	**1**	**37**	**2.8**	**0.8**
American Kestrel	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1	0.1
Northern Harrier	1	0	0	0	1	0	0	1	1	0	0	0	0	4	0.3	0.1
Osprey	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0.1	0.1
Peregrine Falcon	1	0	1	1	0	0	0	0	0	0	0	1	0	4	0.3	0.1
Red-tailed Hawk	0	3	0	0	0	1	1	1	0	1	0	0	1	8	0.6	0.3
Turkey Vulture	0	0	0	0	0	0	3	1	4	7	0	0	0	15	1.2	0.6
White-tailed Kite	0	0	0	0	0	0	0	0	2	2	0	0	0	4	0.3	0.2
Small Shorebirds	**2890**	**81**	**2447**	**1123**	**4002**	**0**	**405**	**119**	**1815**	**1400**	**282**	**76**	**826**	**15466**	**1189.7**	**367.3**
Long- and Short-billed Dowitcher	0	0	0	0	2	0	0	0	0	0	0	6	0	8	0.6	0.5
Dunlin	7	0	2400	288	1438	0	0	0	0	1	134	20	517	4805	369.6	211.2
Least Sandpiper	2375	0	12	200	1979	0	0	99	501	6	11	0	2	5185	398.8	232.6
Semipalmated Plover	382	0	0	0	25	0	0	0	11	76	2	0	0	496	38.2	30.5
Western Sandpiper	126	81	35	635	558	0	405	20	1303	1317	135	50	307	4972	382.5	133.0
Terns	**0**	**0**	**0**	**1**	**9**	**2**	**3**	**2**	**2**	**0**	**0**	**0**	**0**	**19**	**1.5**	**0.7**
Caspian Tern	0	0	0	0	9	0	2	1	1	0	0	0	0	13	1.0	0.7
Least Tern	0	0	0	1	0	2	1	1	1	0	0	0	0	6	0.5	0.2
Total	**6966**	**3413**	**4991**	**6576**	**5251**	**312**	**885**	**472**	**2653**	**9590**	**10884**	**12221**	**13587**	**77801**	**5984.7**	**1298.5**

Table 5.2. Total number of birds detected by guild and species across all ponds in the Napa Plant Site (North, Central, and South Units) at low tide from Dec. 2010 through Dec. 2011.

	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Dabbling Ducks	**246**	**1115**	**1071**	**166**	**249**	**208**	**326**	**75**	**34**	**7847**	**5198**	**6775**	**5360**	**28670**	**2205.4**	**844.5**
American Coot	165	259	213	125	16	0	0	0	0	89	1032	4683	3131	9713	747.2	422.5
American Green-winged Teal	10	150	81	4	0	0	0	0	0	40	65	12	300	662	50.9	25.2
American Wigeon	4	113	8	0	0	0	0	0	0	0	18	648	608	1399	107.6	67.3
Cinnamon Teal	0	0	0	0	0	0	0	0	0	0	0	9	0	9	0.7	0.7
Gadwall	58	501	311	2	75	104	16	33	0	440	127	949	892	3508	269.8	96.0
Mallard	9	10	13	18	44	103	310	42	34	1202	90	126	96	2097	161.3	93.2
Northern Pintail	0	0	0	0	0	0	0	0	0	6068	3850	211	197	10326	794.3	549.8
Northern Shoveler	0	82	445	17	114	1	0	0	0	8	16	137	136	956	73.5	35.9
Diving Ducks	**1420**	**1140**	**684**	**1346**	**220**	**11**	**3**	**0**	**0**	**0**	**370**	**2431**	**2238**	**9863**	**758.7**	**253.0**
Bufflehead	30	28	3	4	0	0	0	0	0	0	0	87	15	167	12.8	7.1
Canvasback	99	517	1	32	0	0	0	0	0	0	0	92	62	803	61.8	40.9
Common Goldeneye	0	18	1	3	1	0	1	0	0	0	0	4	3	31	2.4	1.4
Ruddy Duck	1291	577	678	55	23	1	0	0	0	0	370	2248	2158	7401	569.3	237.1
Greater and Lesser Scaup	0	0	1	1252	196	10	2	0	0	0	0	0	0	1461	112.4	100.1
Eared Grebes	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**5**	**0.4**	**0.2**
Fish-Eaters	**5**	**7**	**8**	**7**	**1**	**6**	**5**	**25**	**101**	**149**	**37**	**47**	**21**	**419**	**32.2**	**12.9**
American White Pelican	0	0	1	0	0	0	2	23	60	93	23	0	0	202	15.5	8.4
Clark's Grebe	3	0	1	0	0	1	1	0	0	0	0	0	1	7	0.5	0.3
Double-crested Cormorant	0	1	1	6	1	2	2	2	41	56	14	37	8	171	13.2	5.4
Pied-billed Grebe	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0.4	0.4
Western Grebe	2	6	5	1	0	1	0	0	0	0	0	7	7	29	2.2	0.8
Western or Clark's Grebe	0	0	0	0	0	2	0	0	0	0	0	3	0	5	0.4	0.3

Table 5.2. Continued.

	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Geese	**0**	**0**	**8**	**10**	**7**	**42**	**35**	**26**	**212**	**1**	**83**	**40**	**1**	**465**	**35.8**	**16.8**
Canada Goose	0	0	8	10	7	42	35	26	212	1	76	15	0	432	33.2	16.8
Greater White-fronted Goose	0	0	0	0	0	0	0	0	0	0	0	12	0	12	0.9	1.0
Mute Swan	0	0	0	0	0	0	0	0	0	0	7	13	1	21	1.6	1.1
Gulls	**286**	**420**	**190**	**136**	**4**	**1**	**7**	**15**	**92**	**337**	**377**	**211**	**188**	**2264**	**174.2**	**42.7**
California Gull	51	43	31	55	1	1	1	8	2	7	107	1	9	317	24.4	9.3
Glaucous Gull	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0.2	0.2
Glaucous-winged Gull	0	0	0	10	0	0	0	0	0	0	0	0	0	10	0.8	0.8
Herring Gull	39	211	68	12	0	0	0	0	0	44	58	84	16	532	40.9	17.0
Mew Gull	0	57	19	0	0	0	0	0	11	0	0	1	0	88	6.8	4.7
Ring-billed Gull	25	46	31	6	3	0	0	3	71	250	137	105	149	826	63.5	22.2
Western Gull	171	60	41	53	0	0	6	4	8	36	75	20	14	488	37.5	13.6
Herons	**5**	**10**	**3**	**3**	**3**	**3**	**11**	**4**	**32**	**31**	**17**	**12**	**11**	**145**	**11.2**	**2.9**
Great Blue Heron	0	1	0	0	0	0	2	3	6	1	1	3	3	20	1.5	0.5
Great Egret	1	8	2	0	1	1	7	1	17	14	7	2	6	67	5.2	1.6
Snowy Egret	4	1	1	3	2	2	2	0	9	16	9	7	2	58	4.5	1.3
Medium Shorebirds	**2076**	**1147**	**1627**	**424**	**328**	**127**	**273**	**217**	**715**	**1121**	**1317**	**1230**	**2110**	**12712**	**977.8**	**199.6**
American Avocet	1255	552	1324	161	4	14	8	0	106	76	410	609	1172	5691	437.8	146.7
Black-bellied Plover	339	351	122	20	16	3	4	2	73	265	341	232	441	2209	169.9	47.0
Black-necked Stilt	14	0	0	0	0	3	0	0	0	0	0	3	1	21	1.6	1.1
Greater Yellowlegs	0	2	2	3	0	0	0	0	3	4	8	7	1	30	2.3	0.8
Killdeer	0	1	5	1	0	1	7	4	4	6	13	5	10	57	4.4	1.1
Lesser Yellowlegs	0	0	0	0	0	0	0	0	2	6	0	0	2	10	0.8	0.5
Long-billed Curlew	77	34	42	19	23	4	9	54	22	10	47	7	10	358	27.5	6.4
Marbled Godwit	328	171	128	98	202	84	152	101	314	338	227	99	153	2395	184.2	26.4
Whimbrel	0	4	1	0	0	0	0	0	0	2	2	1	2	12	0.9	0.4
Willet	63	32	3	122	83	18	93	56	191	414	269	267	318	1929	148.4	37.8

Table 5.2. Continued.

	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Phalaropes	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**0.2**	**0.1**
Red-necked Phalarope	0	0	0	0	0	0	1	1	0	0	0	0	0	2	0.2	0.1
Raptors	**4**	**3**	**3**	**6**	**1**	**3**	**1**	**1**	**7**	**4**	**1**	**2**	**3**	**39**	**3.0**	**0.6**
Burrowing Owl	1	1	1	0	0	0	0	0	0	0	0	0	0	3	0.2	0.1
Northern Harrier	1	0	1	1	1	0	0	0	0	2	1	0	1	8	0.6	0.2
Osprey	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1	0.1
Peregrine Falcon	2	2	0	0	0	0	0	0	0	0	0	1	1	6	0.5	0.2
Red-tailed Hawk	0	0	1	2	0	0	0	1	0	0	0	0	1	5	0.4	0.2
Turkey Vulture	0	0	0	1	0	3	0	0	7	2	0	0	0	13	1.0	0.6
White-tailed Kite	0	0	0	2	0	0	0	0	0	0	0	1	0	3	0.2	0.2
Small Shorebirds	**4727**	**816**	**1023**	**252**	**5260**	**0**	**0**	**7076**	**4085**	**5380**	**10996**	**20125**	**21506**	**81246**	**6249.7**	**2088.6**
Long- and Short-billed Dowitcher	3	0	0	4	0	0	0	0	0	9	2	158	420	596	45.8	34.8
Dunlin	454	369	3	17	2079	0	0	0	0	70	2229	4026	7124	16371	1259.3	623.5
Least Sandpiper	2092	208	150	21	100	0	0	7076	949	172	2634	2529	2037	17968	1382.2	578.0
Semipalmated Plover	60	42	0	0	91	0	0	0	8	52	144	76	72	545	41.9	13.2
Western Sandpiper	2118	197	870	210	2990	0	0	0	3128	5077	5987	13336	11853	45766	3520.5	1298.8
Terns	**1**	**36**	**2**	**0**	**5**	**8**	**4**	**3**	**3**	**0**	**0**	**3**	**0**	**65**	**5.0**	**2.8**
Caspian Tern	0	0	0	0	5	3	0	0	1	0	0	0	0	9	0.7	0.4
Forster's Tern	1	36	2	0	0	0	0	0	0	0	0	3	0	42	3.2	2.9
Least Tern	0	0	0	0	0	5	4	3	2	0	0	0	0	14	1.1	0.5
Total	**8770**	**4658**	**4617**	**2351**	**6073**	**401**	**662**	**7440**	**5278**	**14870**	**18396**	**30875**	**31439**	**135830**	**10448.5**	**3037.0**

Table 5.3. Total number of birds detected by guild in each unit of the Napa Plant Site at high tide from Dec. 2010 through Dec. 2011.

	2010 Dec	**2011 Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Average Monthly**	**SE**
North Unit	**1853**	**1923**	**595**	**387**	**166**	**109**	**191**	**149**	**272**	**1665**	**2318**	**1230**	**2150**	**13008**	**1000.6**	**241.2**
Dabbling Ducks	1572	552	193	206	113	82	171	2	9	1395	2131	1141	1694	9261	712.4	211.3
Diving Ducks	212	860	83	57	0	2	0	0	0	0	0	24	435	1673	128.7	70.2
Eared Grebes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Fish-Eaters	0	0	1	3	2	0	0	4	4	11	1	0	0	26	2.0	0.9
Geese	0	13	0	7	6	22	17	10	187	2	2	0	0	266	20.5	14.0
Gulls	2	8	3	0	5	0	2	78	2	27	4	11	7	149	11.5	5.9
Herons	1	1	1	0	1	0	1	2	2	6	1	0	1	17	1.3	0.4
Medium Shorebirds	65	489	314	114	38	2	0	52	62	220	178	54	13	1601	123.2	39.9
Phalaropes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Raptors	1	0	0	0	1	1	0	1	5	2	0	0	0	11	0.8	0.4
Small Shorebirds	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.1	0.1
Terns	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.1	0.1
Central Unit	**77**	**166**	**183**	**962**	**1513**	**9**	**35**	**13**	**285**	**325**	**444**	**938**	**824**	**5774**	**444.2**	**130.6**
Dabbling Ducks	43	69	118	120	57	6	32	0	0	73	97	808	697	2120	163.1	73.7
Diving Ducks	32	63	64	0	0	0	0	0	0	0	0	1	26	186	14.3	6.7
Eared Grebes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Fish-Eaters	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0.2	0.2
Geese	0	16	0	0	0	2	0	0	12	0	0	0	0	30	2.3	1.5
Gulls	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0.2	0.2
Herons	2	0	1	1	0	1	1	4	2	1	1	0	0	14	1.1	0.3
Medium Shorebirds	0	18	0	838	77	0	0	0	271	191	157	123	101	1776	136.6	63.3
Phalaropes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Raptors	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0.2	0.2
Small Shorebirds	0	0	0	0	1377	0	0	9	0	60	189	6	0	1641	126.2	105.3
Terns	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.1	0.1

Table 5.3. Continued.

	2010 Dec	**2011 Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Average Monthly**	**SE**
South Unit	**5036**	**1324**	**4213**	**5228**	**3573**	**196**	**659**	**310**	**2096**	**7602**	**8122**	**10053**	**10613**	**59025**	**4540.4**	**1010.8**
Dabbling Ducks	237	705	922	1223	181	68	122	6	5	5505	6802	6848	6312	28936	2225.8	808.0
Diving Ducks	1211	102	304	730	674	11	2	0	2	21	654	2153	2740	8604	661.8	245.9
Eared Grebes	1	1	0	0	0	0	0	0	0	0	1	0	0	3	0.2	0.1
Fish-Eaters	1	8	6	6	10	7	59	8	2	188	62	51	31	439	33.8	14.3
Geese	0	5	0	6	9	30	45	120	8	30	0	116	1	370	28.5	11.7
Gulls	30	90	32	18	34	0	3	58	42	88	29	184	25	633	48.7	13.6
Herons	6	0	1	1	1	2	3	2	6	15	11	8	4	60	4.6	1.2
Medium Shorebirds	659	329	500	2119	28	74	14	2	213	407	469	622	673	6109	469.9	153.8
Phalaropes	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0.2	0.2
Raptors	1	3	1	1	1	0	3	2	2	8	0	1	1	24	1.8	0.6
Small Shorebirds	2890	81	2447	1123	2625	0	405	110	1815	1340	92	70	826	13824	1063.4	297.0
Terns	0	0	0	0	9	2	3	2	1	0	0	0	0	17	1.3	0.7
Total	**6966**	**3413**	**4991**	**6577**	**5252**	**314**	**885**	**472**	**2653**	**9592**	**10884**	**12221**	**13587**	**77807**	**5985.2**	**1247.6**

Table 5.4. Total number of birds detected by guild in each unit of the Napa Plant Site at low tide from Dec. 2010 through Dec. 2011.

	2010 Dec	**2011 Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Average Monthly**	**SE**
North Unit	**2995**	**2237**	**1325**	**311**	**1449**	**156**	**86**	**2684**	**3177**	**3314**	**4281**	**3594**	**4666**	**30275**	**2328.8**	**429.3**
Dabbling Ducks	122	416	266	14	59	87	75	36	9	938	818	1314	1067	5221	401.6	129.0
Diving Ducks	215	756	24	27	0	0	0	0	0	0	0	109	692	1823	140.2	74.0
Eared Grebes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Fish-Eaters	0	1	1	4	0	1	0	2	0	3	1	2	0	15	1.2	0.4
Geese	0	0	2	4	5	19	0	23	146	1	42	0	0	242	18.6	11.2
Gulls	65	32	20	3	1	0	1	6	19	25	48	8	22	250	19.2	5.5
Herons	4	1	2	3	1	1	4	1	3	2	2	1	1	26	2.0	0.3
Medium Shorebirds	312	721	760	139	222	44	6	163	276	439	681	194	621	4578	352.2	73.2
Phalaropes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Raptors	0	0	0	2	0	0	0	0	1	2	1	0	1	7	0.5	0.2
Small Shorebirds	2277	310	250	115	1161	0	0	2450	2723	1904	2688	1966	2262	18106	1392.8	307.4
Terns	0	0	0	0	0	4	0	3	0	0	0	0	0	7	0.5	0.4
Central Unit	**2811**	**666**	**1592**	**524**	**2429**	**89**	**148**	**1973**	**258**	**1777**	**2958**	**4092**	**4373**	**23690**	**1822.3**	**405.5**
Dabbling Ducks	96	36	62	144	4	12	53	2	0	570	58	744	655	2436	187.4	75.6
Diving Ducks	66	90	0	12	0	0	0	0	0	0	0	0	0	168	12.9	8.2
Eared Grebes	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.1	0.1
Fish-Eaters	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.1	0.1
Geese	0	0	0	0	0	2	0	0	21	0	0	13	0	36	2.8	1.8
Gulls	18	16	7	1	0	0	0	0	11	2	3	2	1	61	4.7	1.8
Herons	0	0	0	0	0	1	4	0	2	0	0	0	0	7	0.5	0.3
Medium Shorebirds	1142	424	749	250	89	72	90	47	203	131	147	285	563	4192	322.5	89.8
Phalaropes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Raptors	3	0	1	0	0	0	0	0	0	1	0	0	0	5	0.4	0.2
Small Shorebirds	1486	100	773	116	2336	0	0	1924	21	1073	2750	3047	3154	16780	1290.8	342.3
Terns	0	0	0	0	0	2	1	0	0	0	0	0	0	3	0.2	0.2

Table 5.4. Continued

	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
South Unit	**2965**	**1791**	**1704**	**1516**	**2201**	**165**	**432**	**2786**	**1846**	**9779**	**11158**	**23192**	**22402**	**81937**	**6302.8**	**2231.5**
Dabbling Ducks	28	663	743	8	186	109	198	37	25	6339	4322	4717	3638	21013	1616.4	627.7
Diving Ducks	1139	294	660	1307	220	11	3	0	0	0	370	2322	1546	7872	605.5	207.7
Eared Grebes	1	0	0	0	0	0	0	0	0	0	0	2	1	4	0.3	0.2
Fish-Eaters	5	6	7	3	1	5	5	23	101	146	36	44	21	403	31.0	12.2
Geese	0	0	6	6	2	21	35	3	45	0	41	27	1	187	14.4	4.7
Gulls	203	372	163	132	3	1	6	9	62	310	326	201	165	1953	150.2	36.2
Herons	1	9	1	0	2	1	3	3	27	29	15	11	10	112	8.6	2.7
Medium Shorebirds	622	2	118	35	17	11	177	7	236	551	489	751	926	3942	303.2	89.8
Phalaropes	0	0	0	0	0	0	1	1	0	0	0	0	0	2	0.2	0.1
Raptors	1	3	2	4	1	3	1	1	6	1	0	2	2	27	2.1	0.4
Small Shorebirds	964	406	0	21	1763	0	0	2702	1341	2403	5558	15112	16090	46360	3566.2	1544.0
Terns	1	36	2	0	5	2	3	0	3	0	0	3	0	55	4.2	2.7
Total	**8771**	**4694**	**4621**	**2351**	**6079**	**410**	**666**	**7443**	**5281**	**14870**	**18397**	**30878**	**31441**	**135902**	**10454.0**	**2917.2**

Figure 1.1. Completed bathymetric transects of the North, Central, and South Units at the Napa Plant Site during 2011.

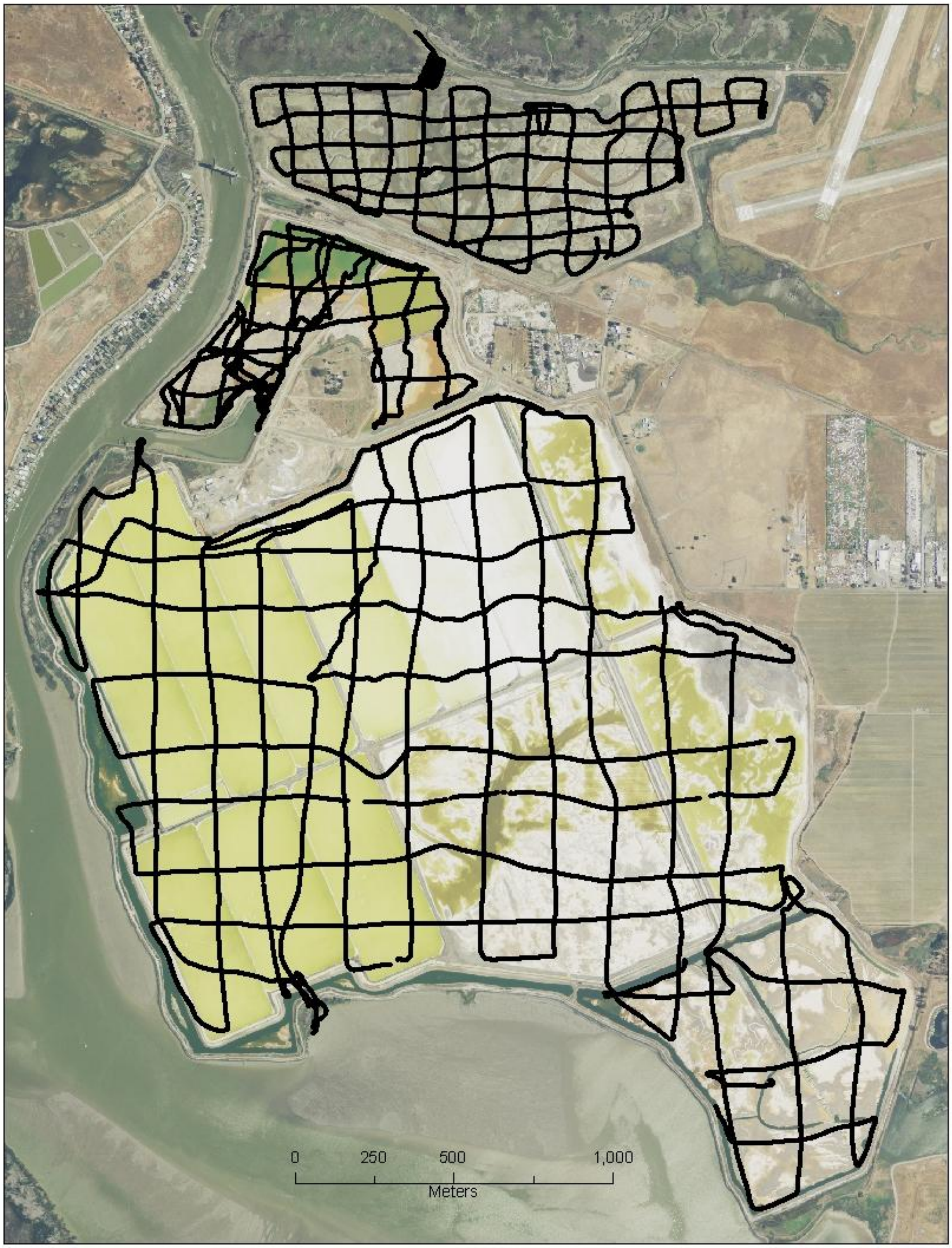


Figure 1.2. Bathymetric map of elevation (meters NAVD88) of the North Unit, Fall 2010 (A), Fall 2011 (B), and the change between years (C).

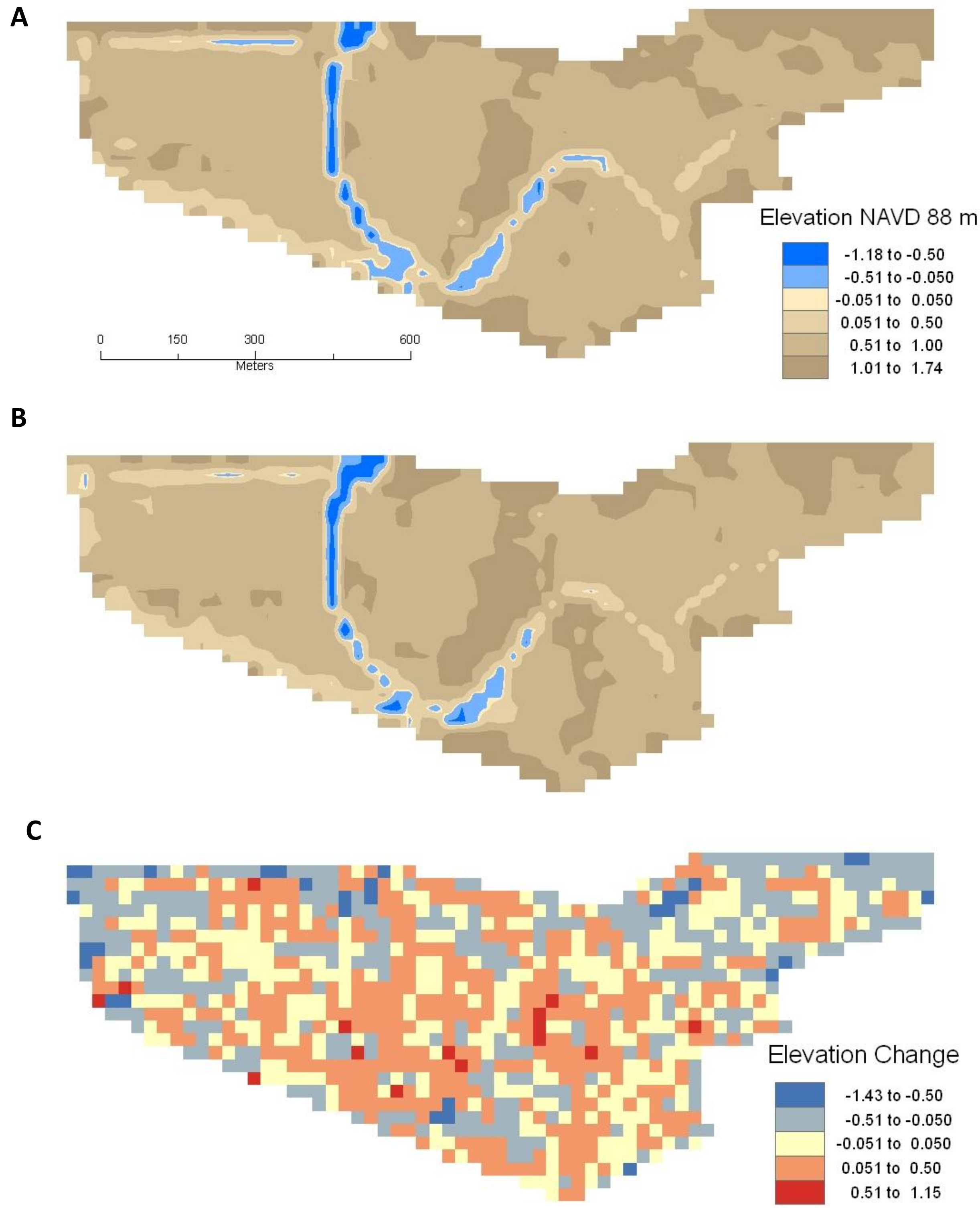
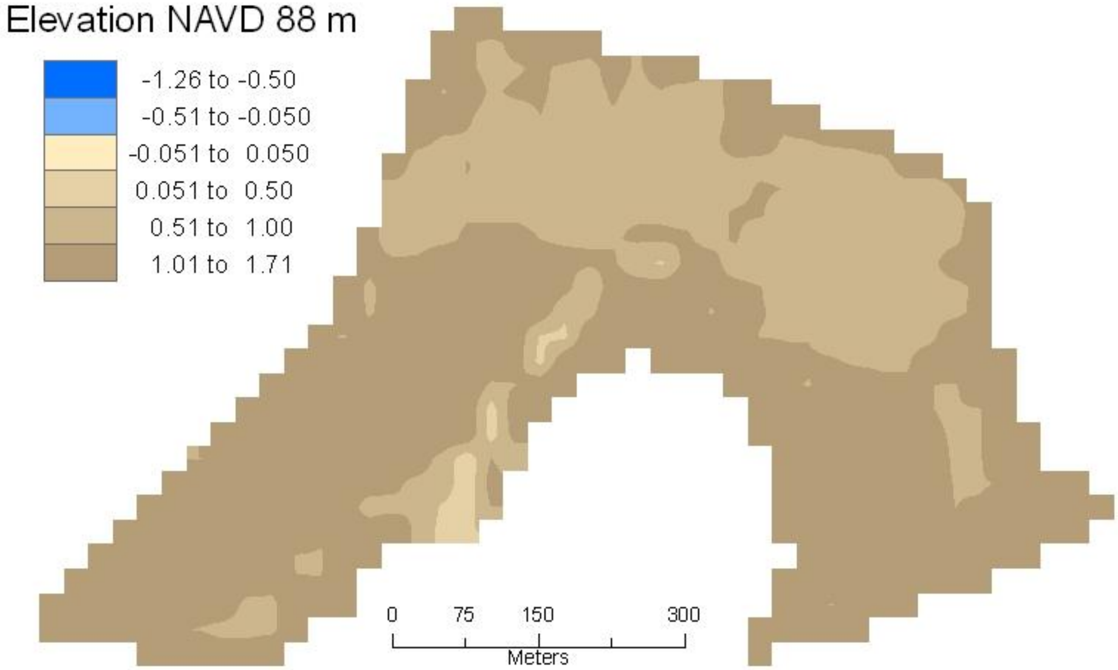


Figure 1.3. Bathymetric map of elevation (meters NAVD88) of the Central Unit, Fall 2010 (A) and Fall 2011 (B).

A



B

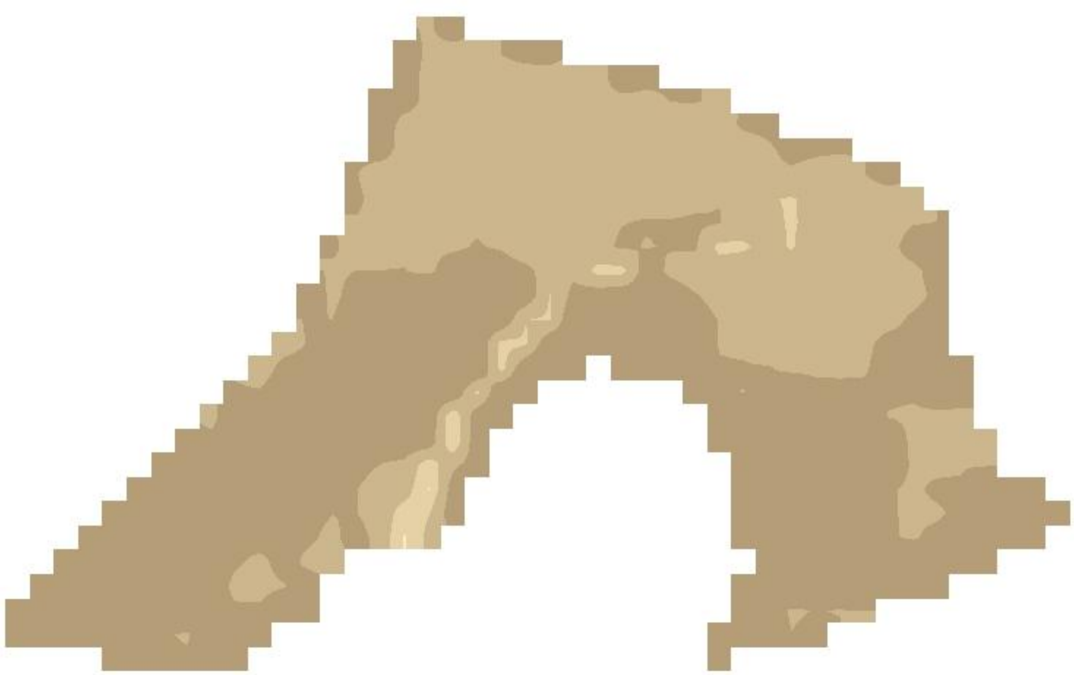


Figure 1.4. Bathymetric map of elevation change (meters NAVD88) of the Central Unit between Fall 2010 and Fall 2011.

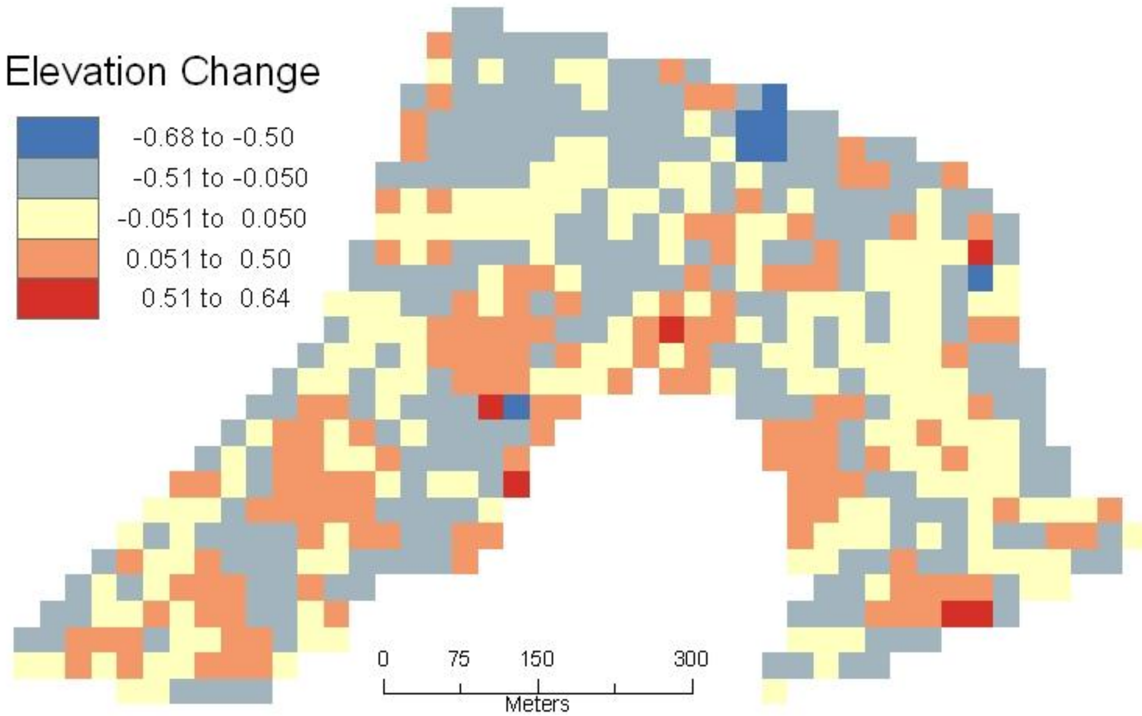


Figure 1.5. Bathymetric map of elevation (meters NAVD 88) of the South Unit, Fall 2010 (A) and Fall 2011 (B). White grid cells indicate no data where islands are present.

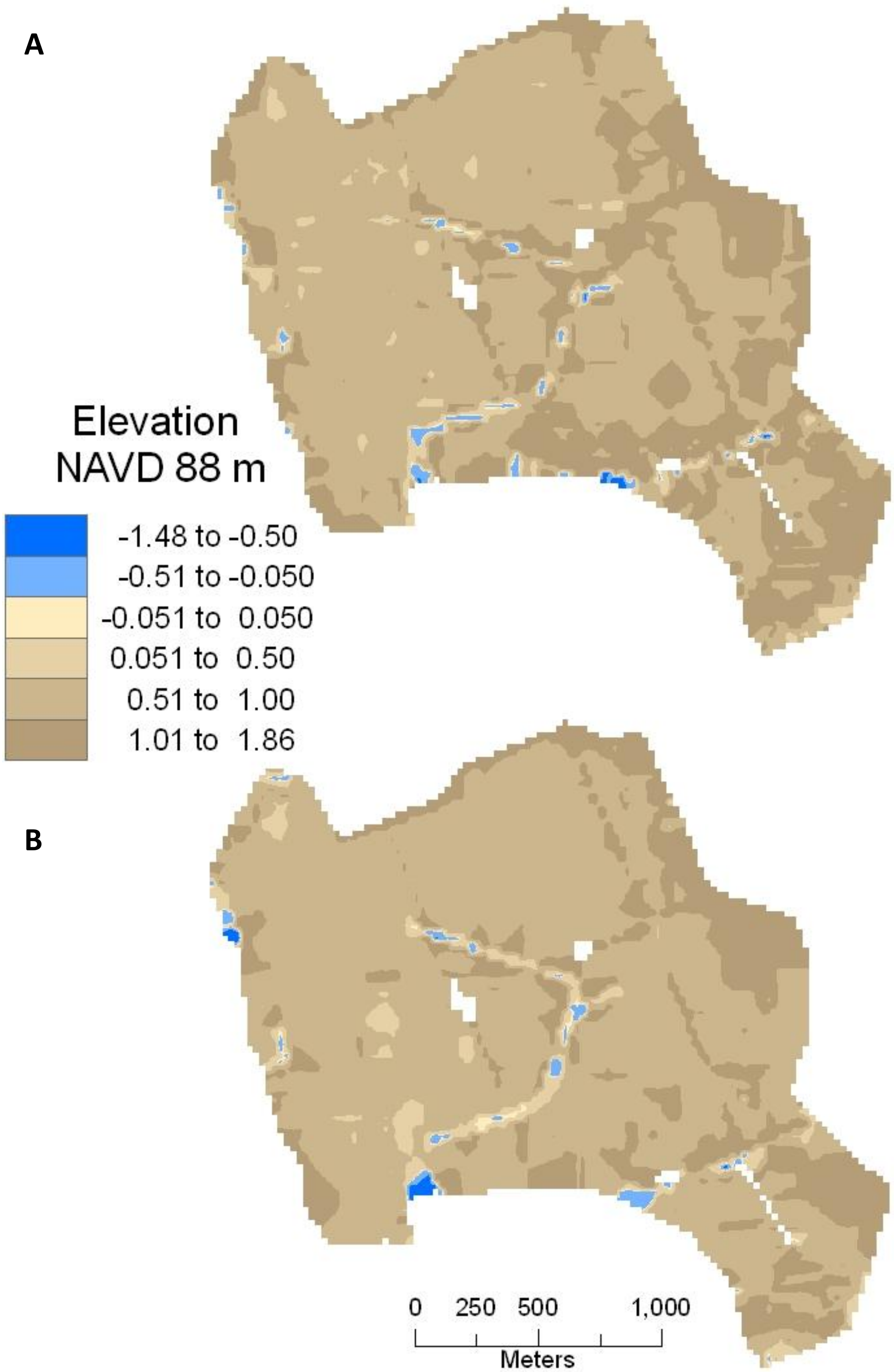


Figure 1.6. Bathymetric map of elevation change (meters NAVD88) of the South Unit between Fall 2010 and Fall 2011. White grid cells indicate no data where islands are present.

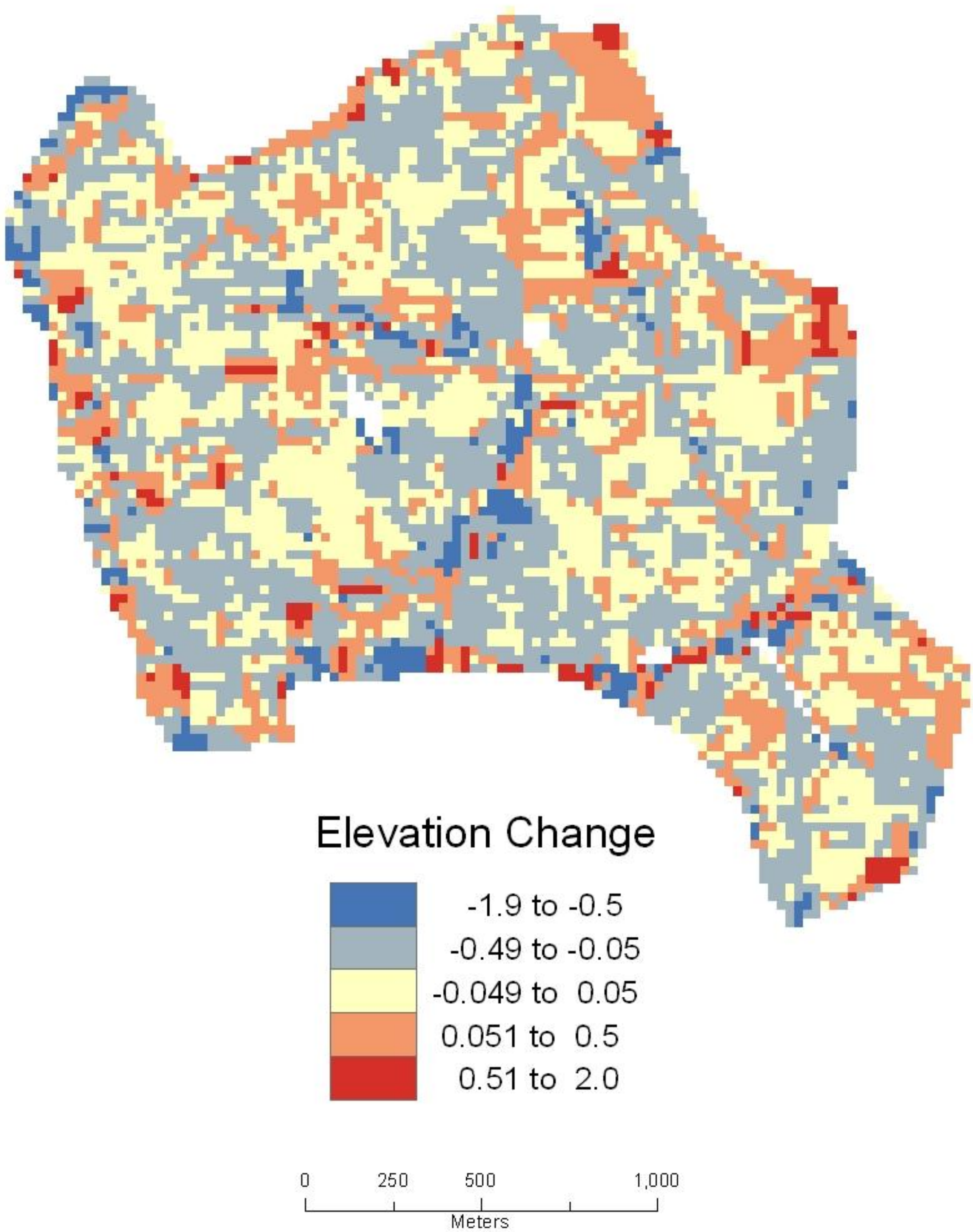


Figure 1.7. Bathymetric maps of elevation (meters NAVD88) of the North Unit breach in 2010 (A), 2011 (B), and the elevation change between years (C).

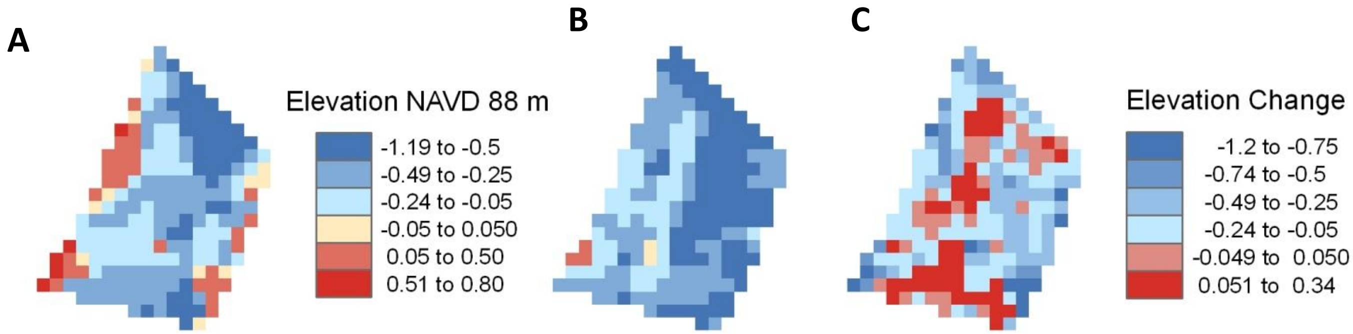


Figure 1.8. Bathymetric maps of elevation (meters NAVD88) of the Central Unit pond breach in 2010 (A), 2011 (B), and the elevation change between years (C).

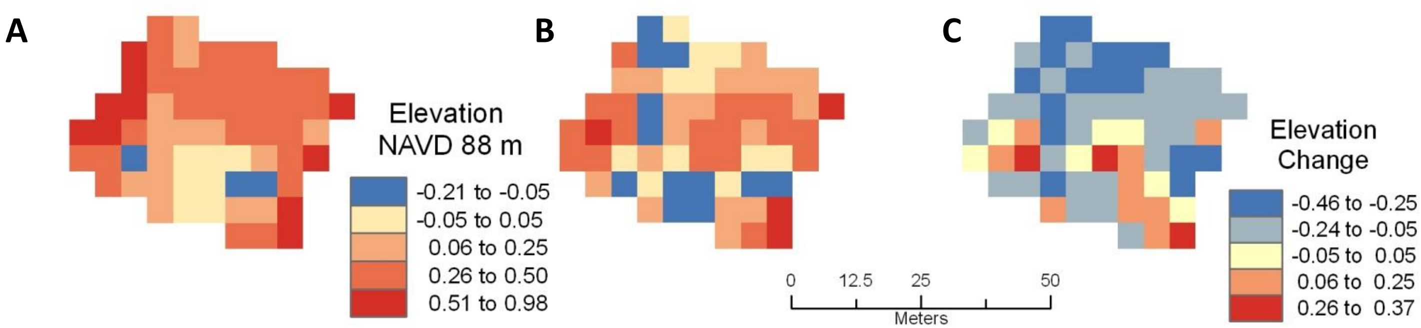


Figure 1.9. Bathymetric maps of elevation (meters NAVD88) of the South Unit salinity reduction breach in 2010 (A), 2011(B), and the elevation change between years (C).

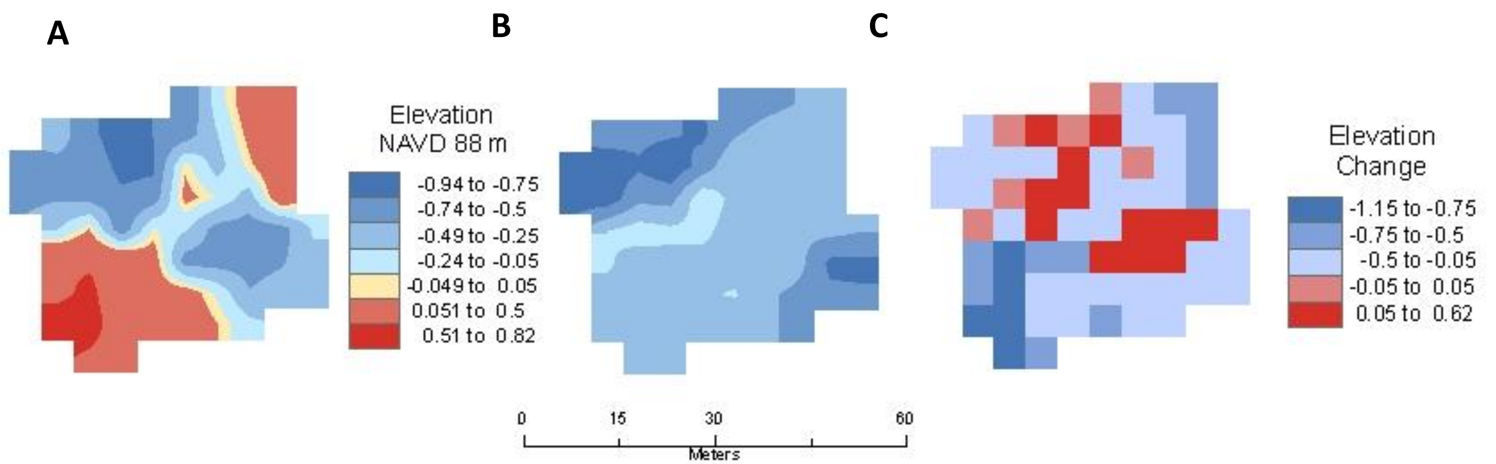


Figure 1.10. Bathymetric maps of elevation (meters NAVD88) of the South Unit northern pond breach in 2011.

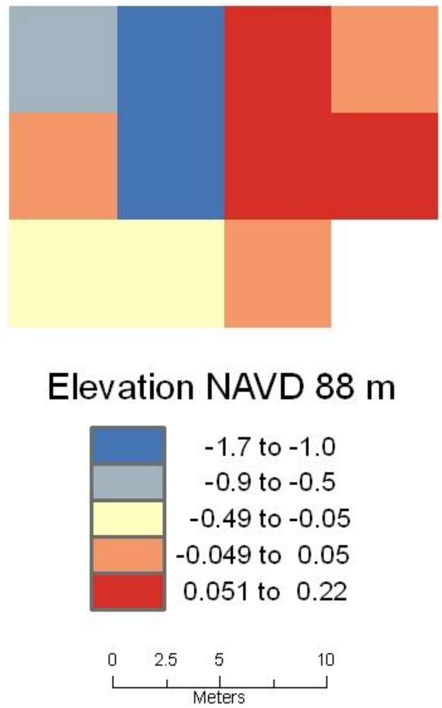


Figure 2.1. Fagan Slough cross sections for slough comparison between 2008 and 2011.

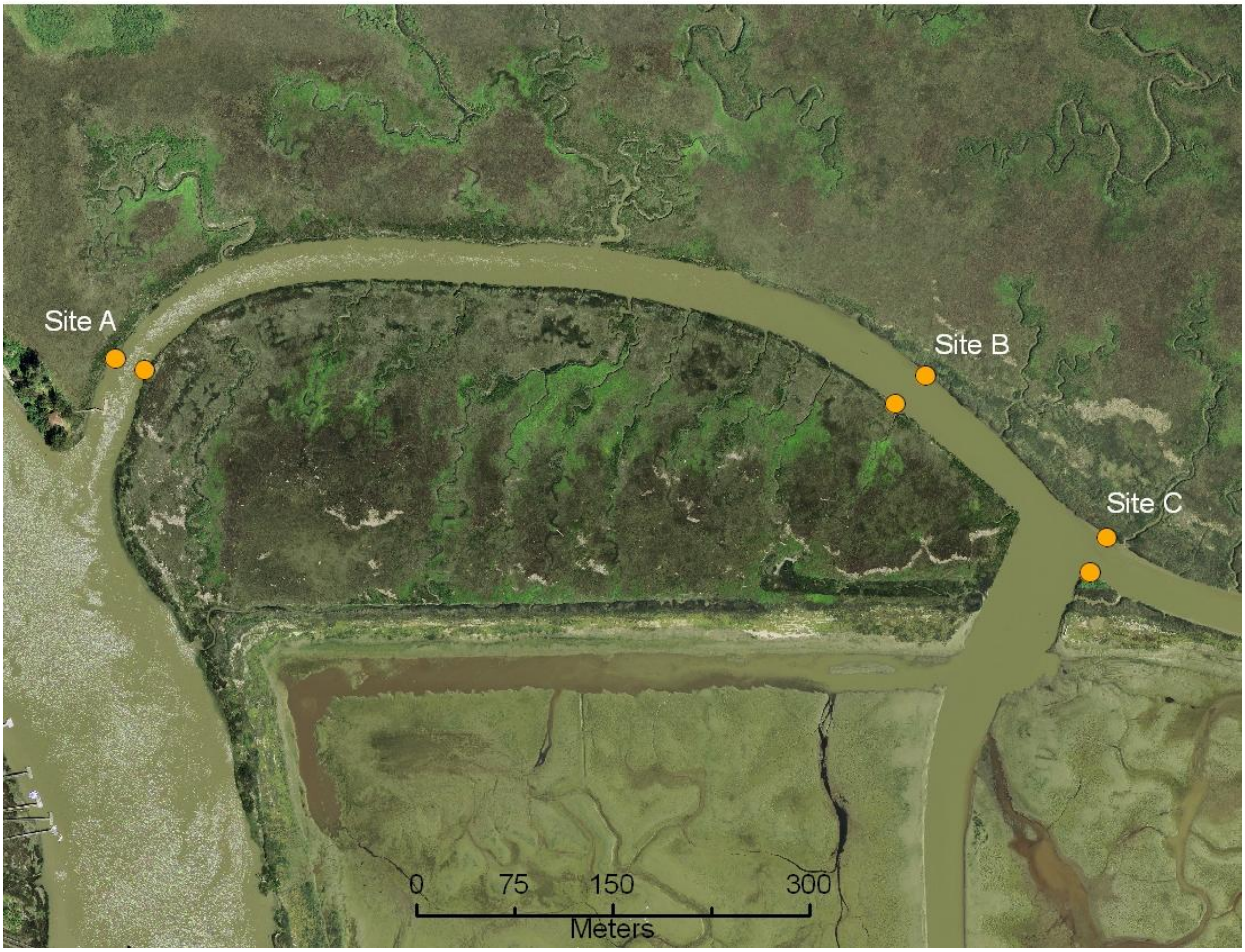


Figure 2.2. Side view of erosion at two locations on the northern bank of Fagan Slough between the Napa River and North Unit breach observed at a low tide during 2010 (a) and high tide during 2011 (b).

Figure 2.3. Top view of erosion on the northern bank of Fagan Slough between the Napa River and North Unit breach observed at a low tide during 2010.

Figure 2.4. Top view of the northern bank of Fagan Slough between the Napa River and North Unit breach observed at a high tide during 2011.

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Figure 3.1. Map of benthic invertebrate sampling locations in the Napa River (NR1, NR2), Fagan Slough (FS1, FS2), and North Unit (NU1 - NU10). Yellow points processed monthly from Dec 2008-Oct 2011; Green points processed Dec 2008, Jan 2009, Nov 2009, Sep 2010, Nov 2010.

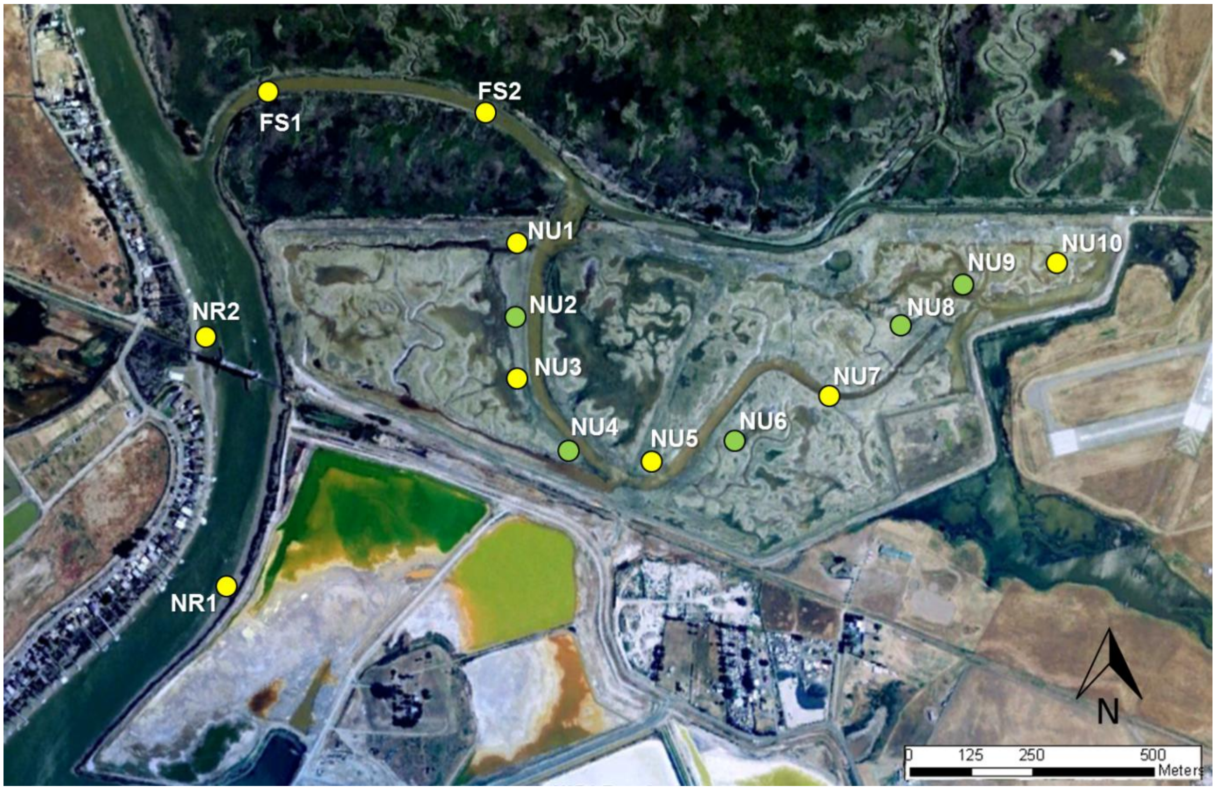


Figure 3.2. Common taxa found throughout the sampling area (Cumacea (I), Amphipoda (II), Polychaeta (III), and Tanaidacea (IV). Nematoda picture was not included due to its small size. Photos by San Francisco Bay Estuary Field Station Invertebrate Laboratory.

Figure 3.3. Field technicians processing a sediment core in the coring table during high tide.

Figure 3.4. Field technicians sampling during a low tide with a light plastic boat.

Figure 3.5. Benthic samples being sieved at San Francisco Bay Estuary Field Station.

Figure 3.6. Variation in sample matrix size and processing times. i. Sample on the left fit easily into one 8 oz. jar. Sample on the right required four 12 oz. jars. ii. Variation in sample matrix debris types (salt crystals, vegetation, and clay).

Figure 3.7. Mean invertebrate abundance (individuals/m²) by taxa and month in the Napa River.

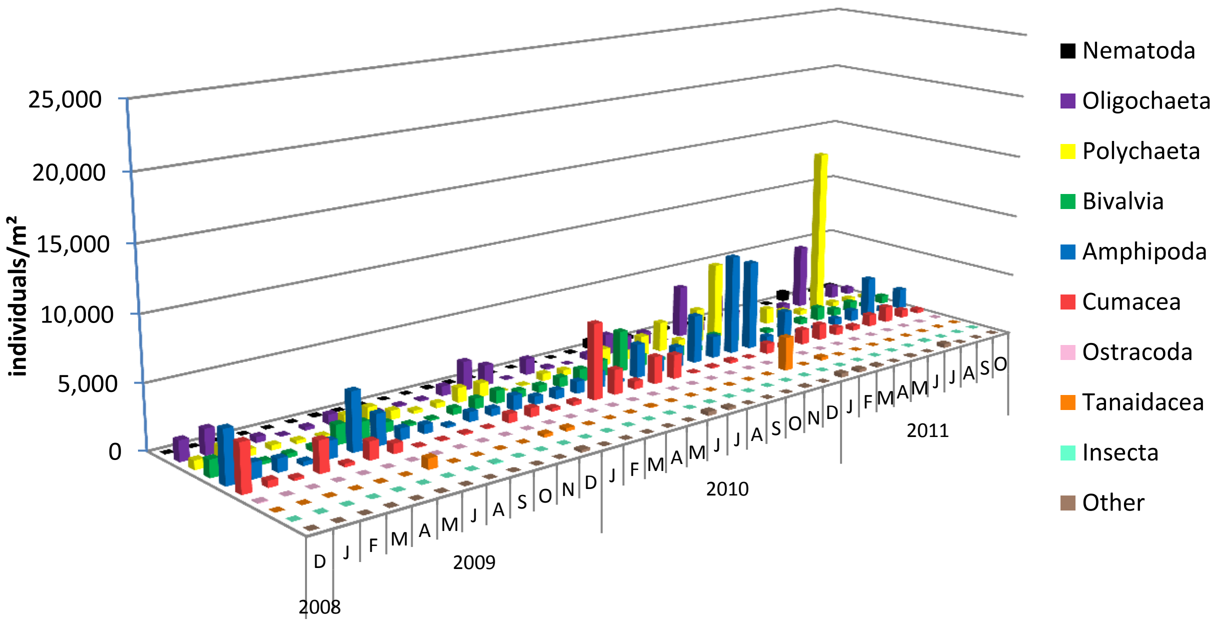


Figure 3.8. Mean invertebrate abundance (individuals/m²) by taxa and month in Fagan Slough.

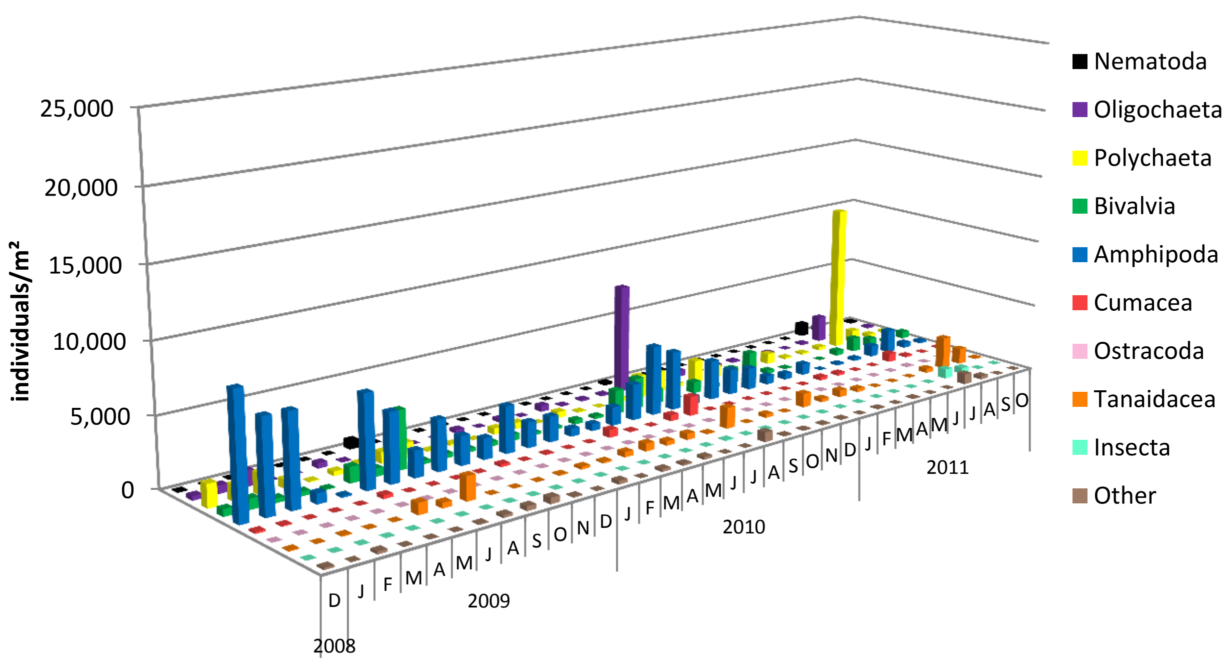


Figure 3.9. Mean invertebrate abundance (individuals/m²) by taxa and month in the North Unit.

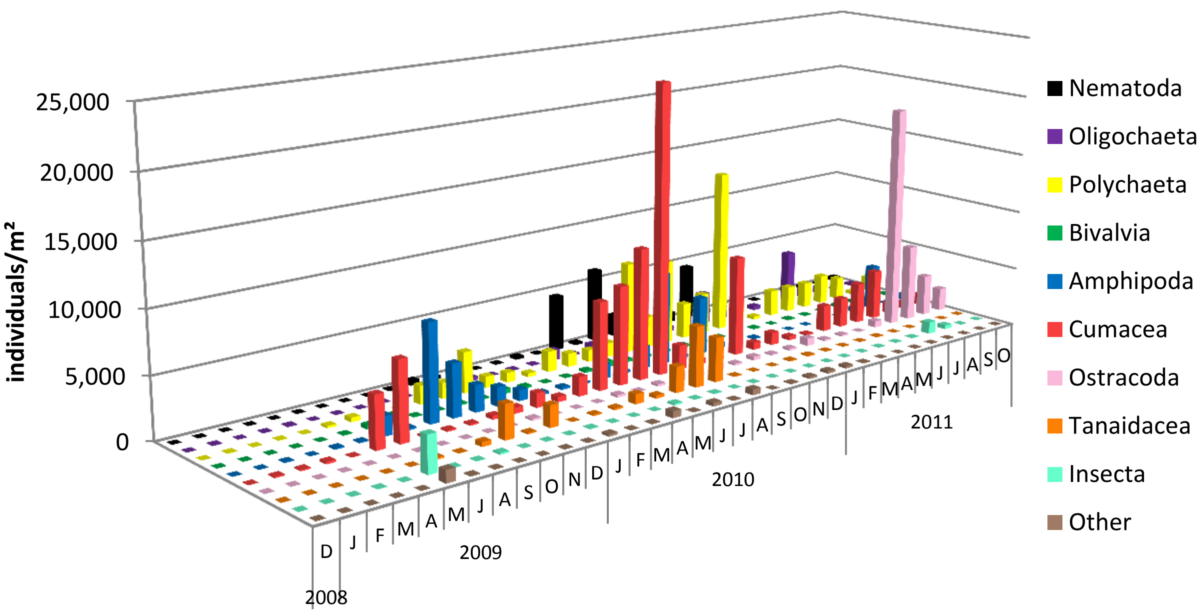


Figure 3.10. Cumacea density (individuals/m²) trends within Napa River (NR1, NR2), Fagan Slough (FS1, FS2) and North Unit (NU1-10).

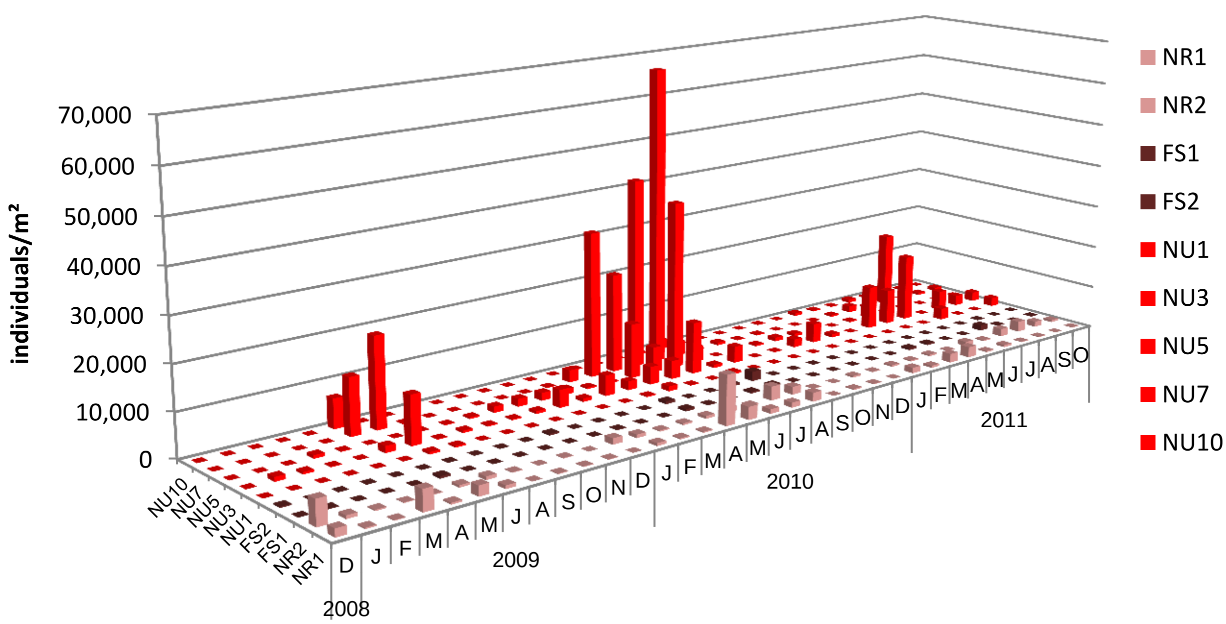


Figure 3.11. Amphipoda density (individuals/m²) trends within Napa River (NR1, NR2), Fagan Slough (FS1, FS2) and North Unit (NU1, NU3, NU5, NU7, NU10).

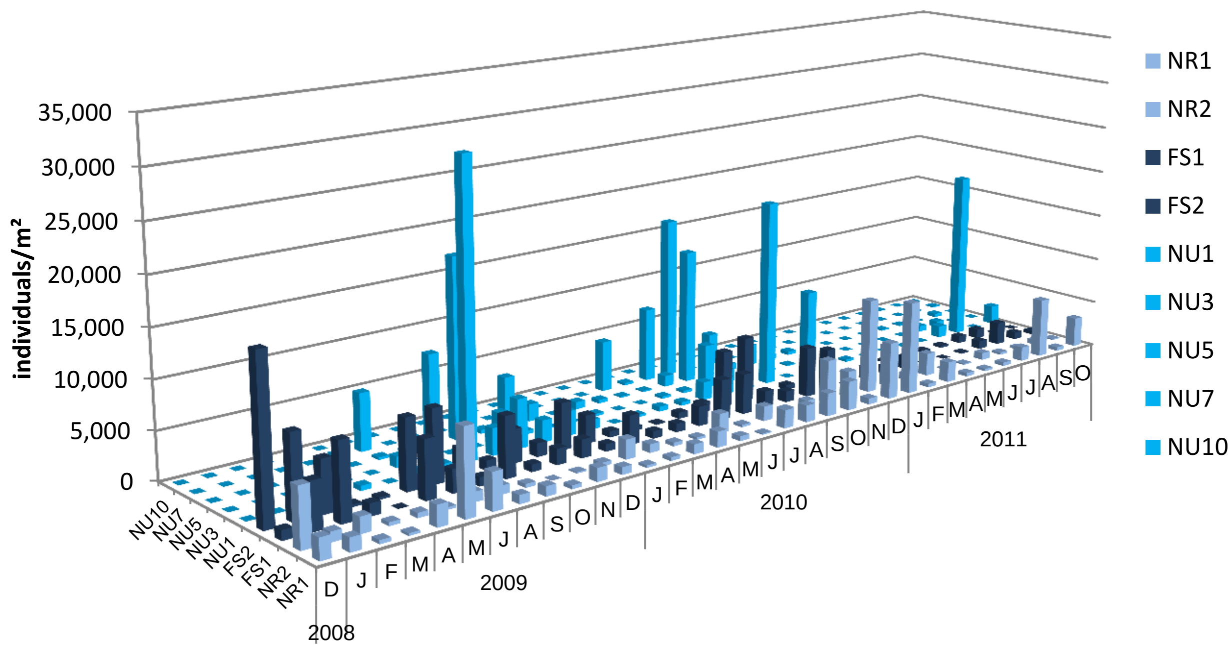


Figure 3.12. Polychaeta density (individuals/m²) trends within Napa River (NR1, NR2), Fagan Slough (FS1, FS2) and North Unit (NU1, NU3, NU5, NU7, NU10).

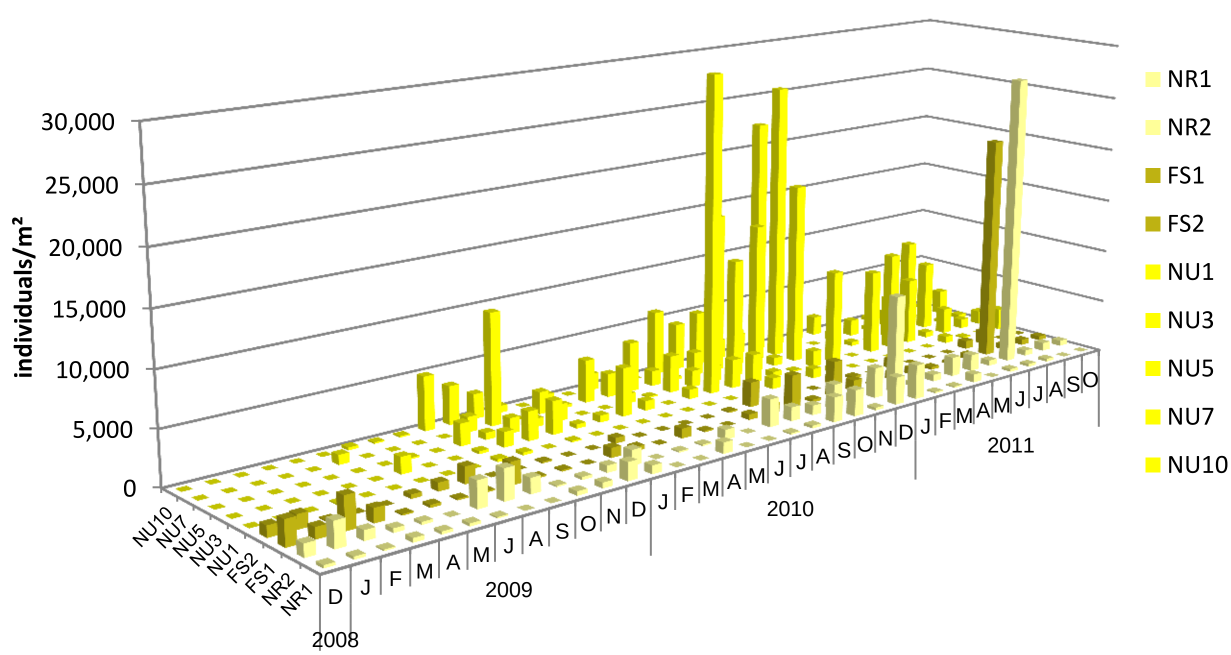


Figure 3.13. Tanaidacea density (individuals/m²) trends within Napa River (NR1, NR2), Fagan Slough (FS1, FS2) and North Unit (NU1, NU3, NU5, NU7, NU10).

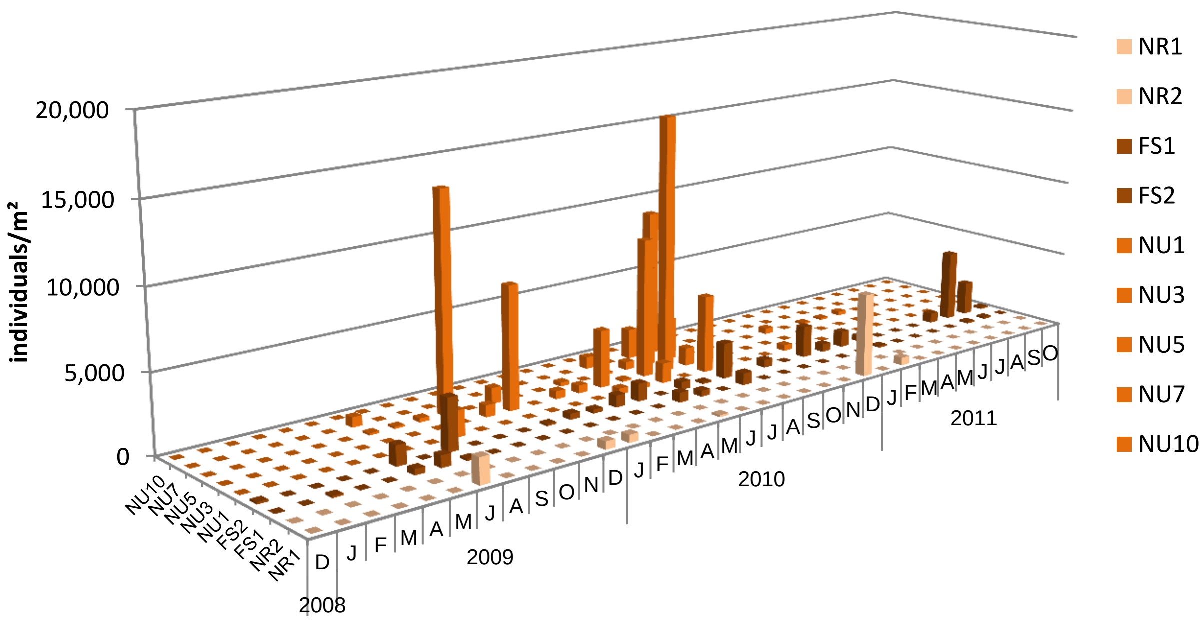


Figure 3.14. Ostracoda density (individuals/m²) trends within Napa River (NR1, NR2), Fagan Slough (FS1, FS2) and North Unit (NU1, NU3, NU5, NU7, NU10).

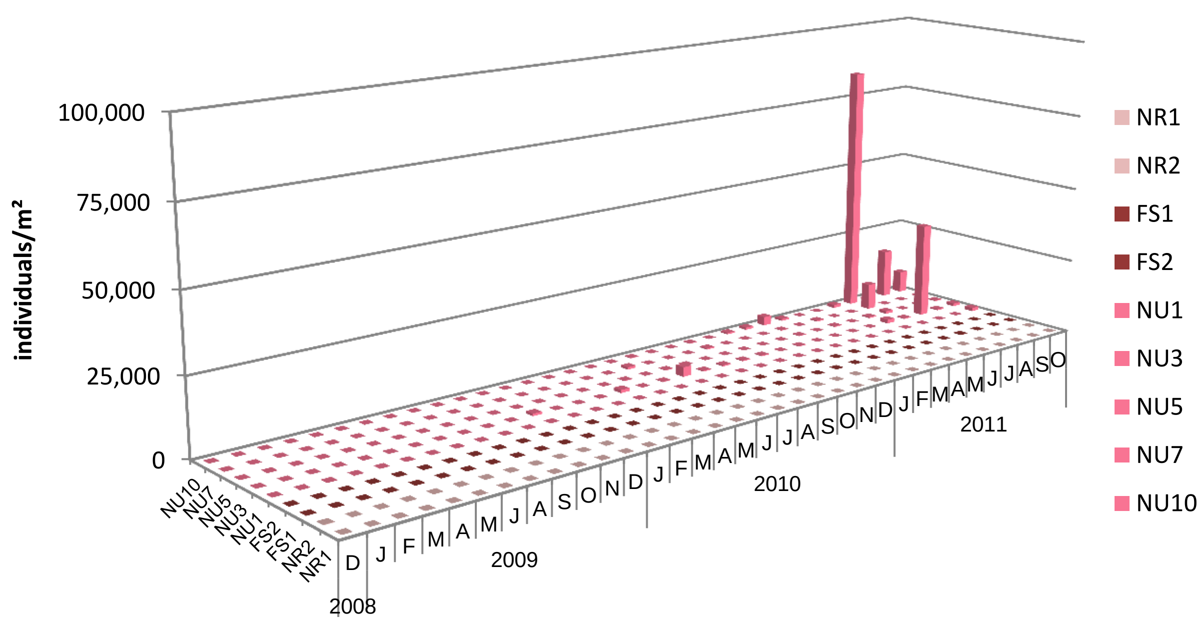


Figure 3.15. Bivalve species average density (individuals/m²) by coring location from December, 2008 through October, 2011.

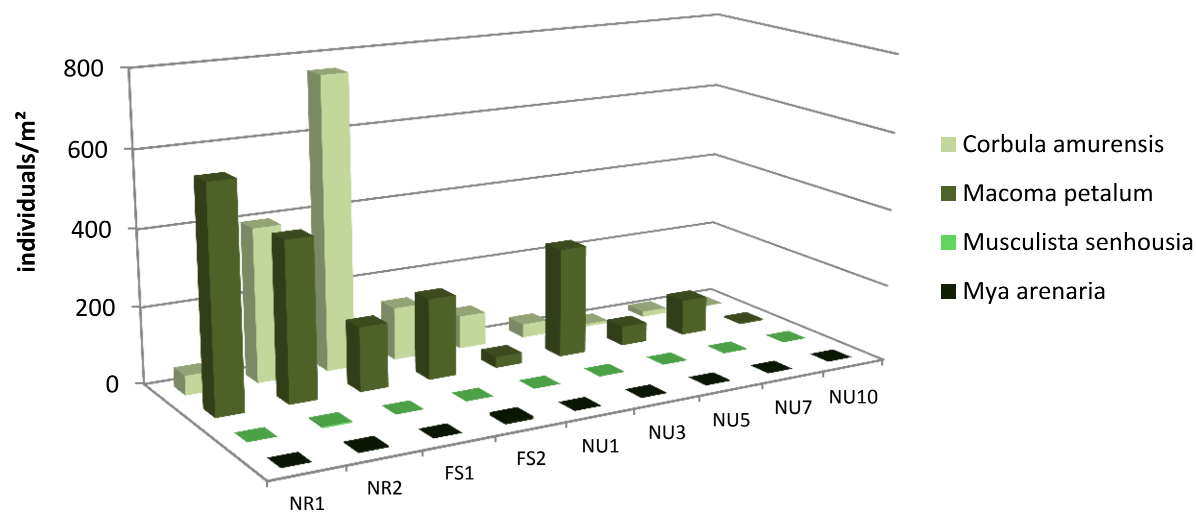


Figure 3.16. Bivalve species average biomass (mg dry weight/m²) by coring location from December, 2008 through October, 2011.

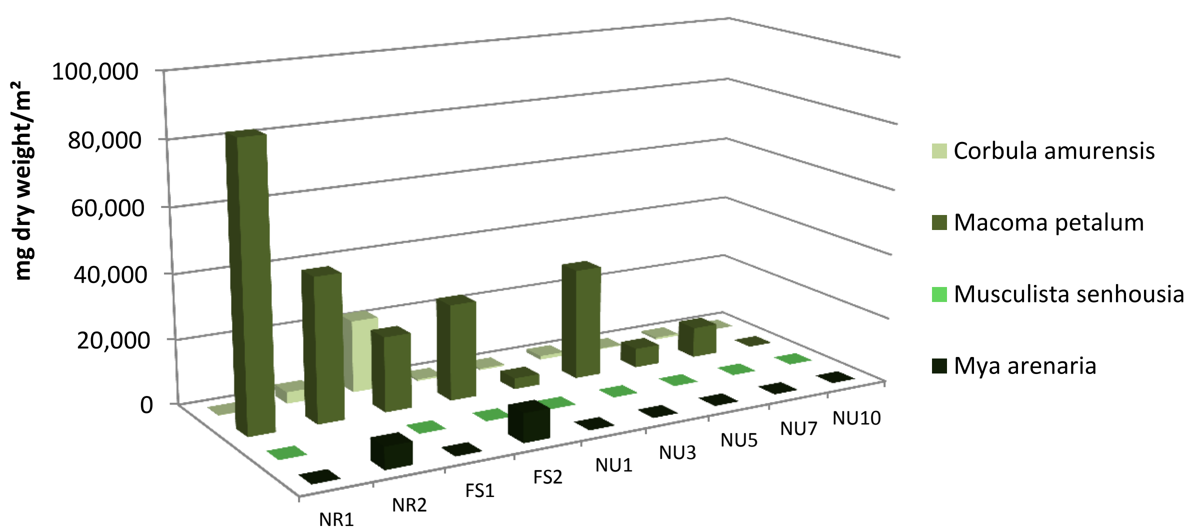


Figure 3.17. *Macoma petalum* density (individuals/m²) trends within Napa River (NR1, NR2), Fagan Slough (FS1, FS2) and North Unit (NU1, NU3, NU5, NU7, NU10).

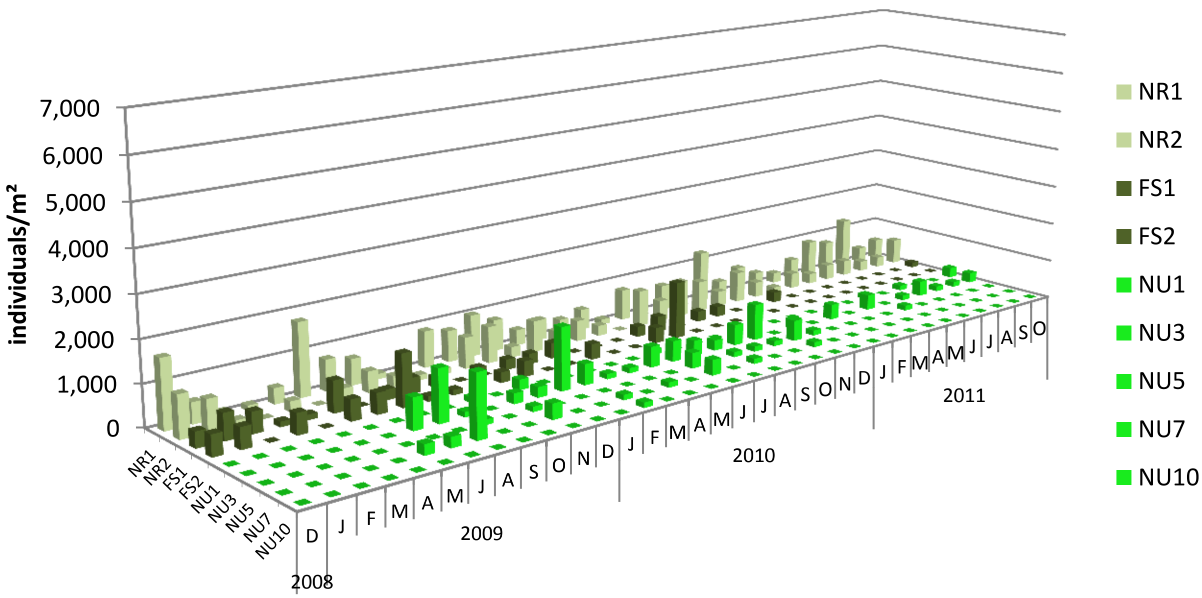


Figure 3.18. *Macoma petalum* biomass (mg dry weight/m²) trends within Napa River (NR1, NR2), Fagan Slough (FS1, FS2), and North Unit (NU1, NU3, NU5, NU7, NU10).

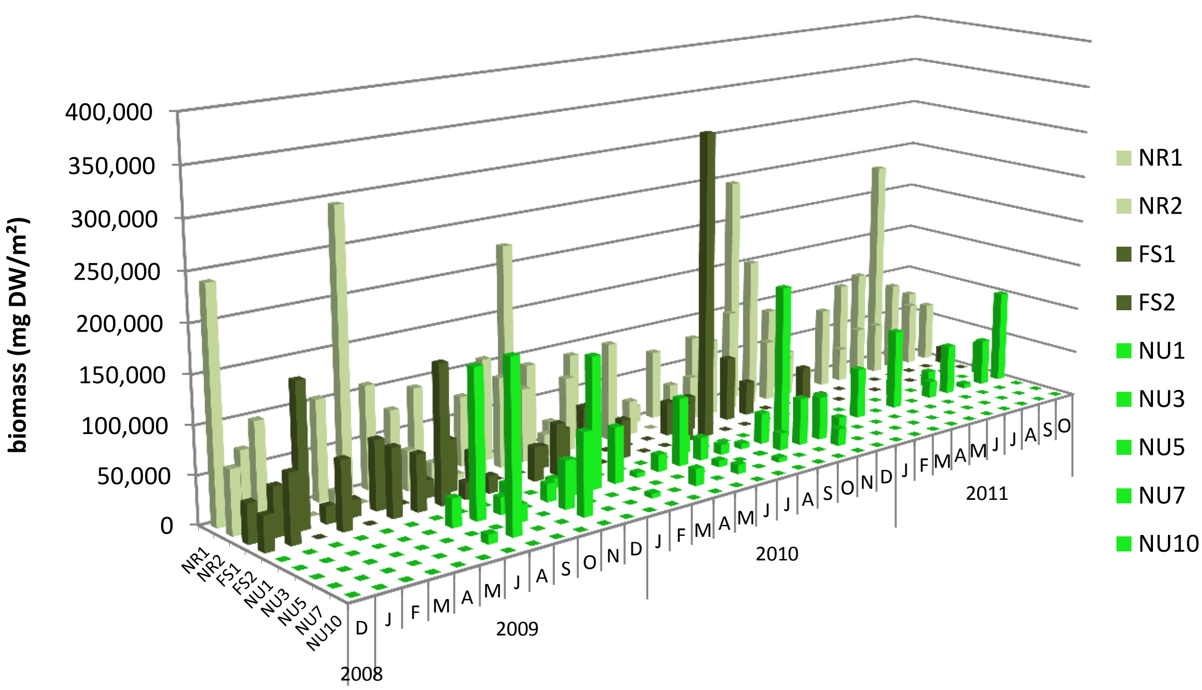


Figure 3.19. *Corbula amurensis* density (individuals/m²) trends within Napa River (NR1, NR2), Fagan Slough (FS1, FS2) and North Unit (NU1, NU3, NU5, NU7, NU10).

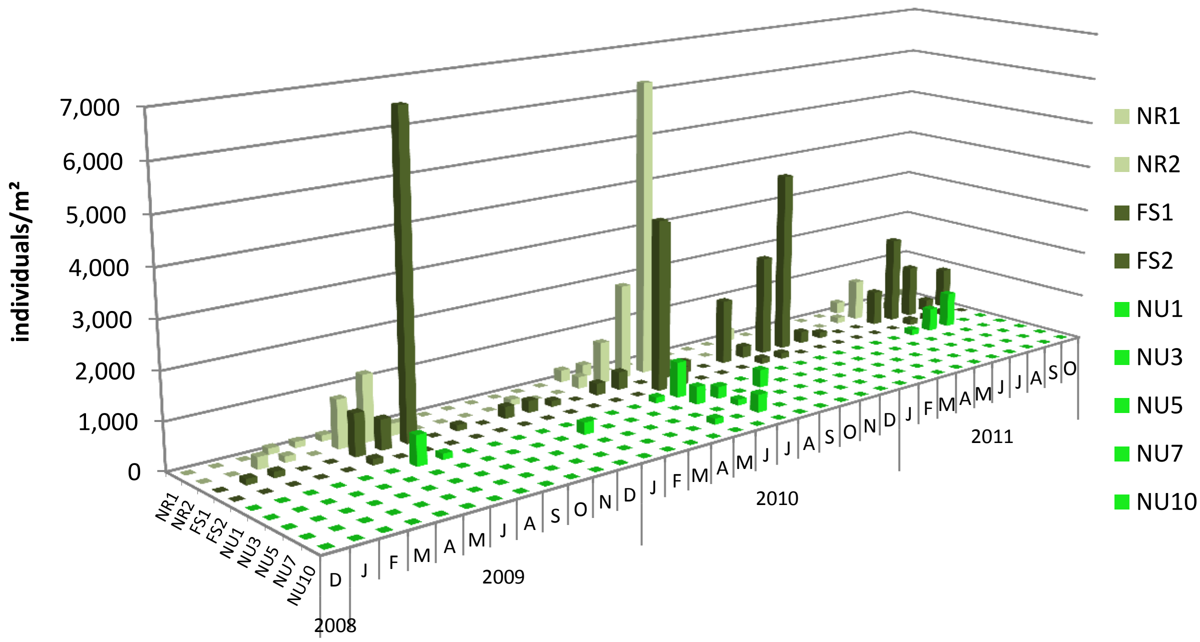


Figure 3.20. *Corbula amurensis* biomass (mg dry weight/m²) trends within Napa River (NR1, NR2), Fagan Slough (FS1, FS2), and North Unit (NU1, NU3, NU5, NU7, NU10).

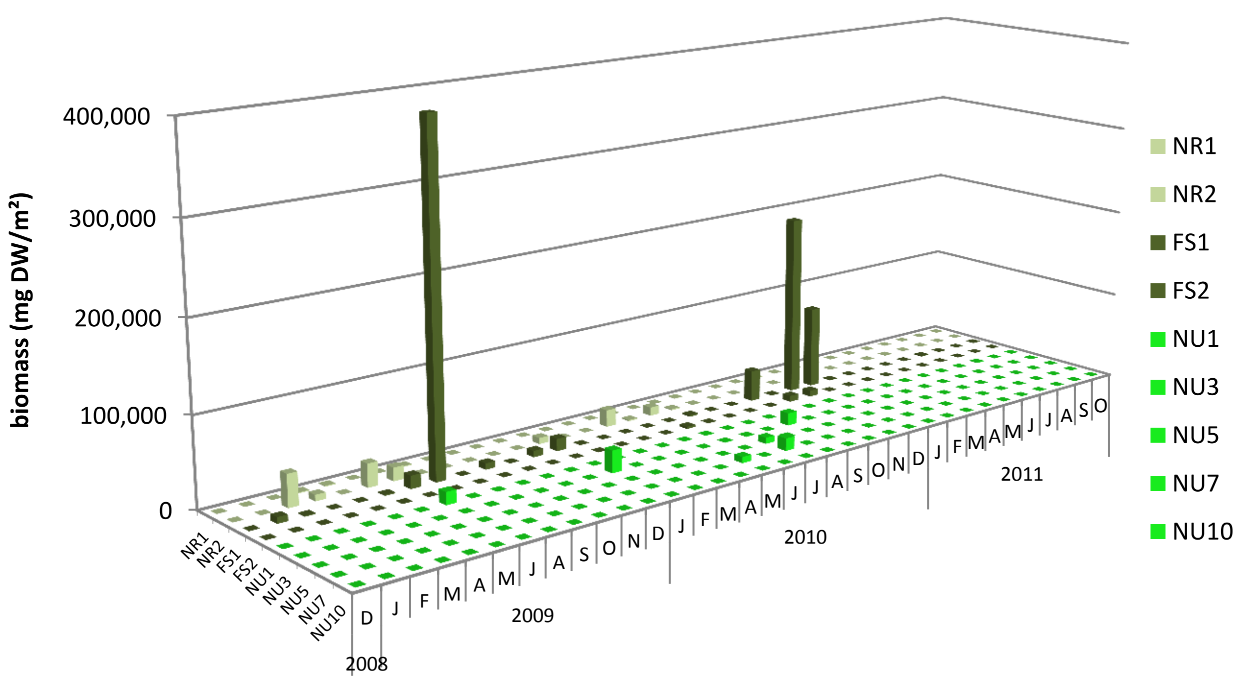


Figure 3.21. Overall invertebrate abundance (individuals/m²) in Napa River, Fagan Slough and North Unit from December 2008 – October 2011.

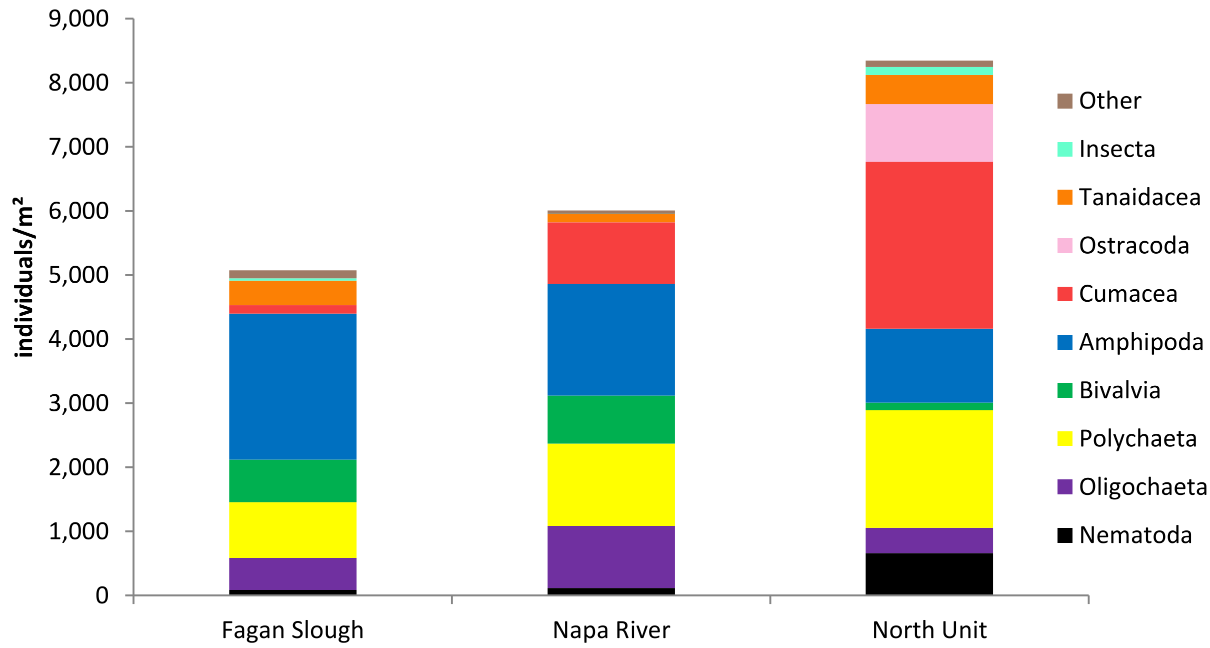


Figure 3.22. Invertebrate composition and abundance (individuals/m²) in core NU1 over time.

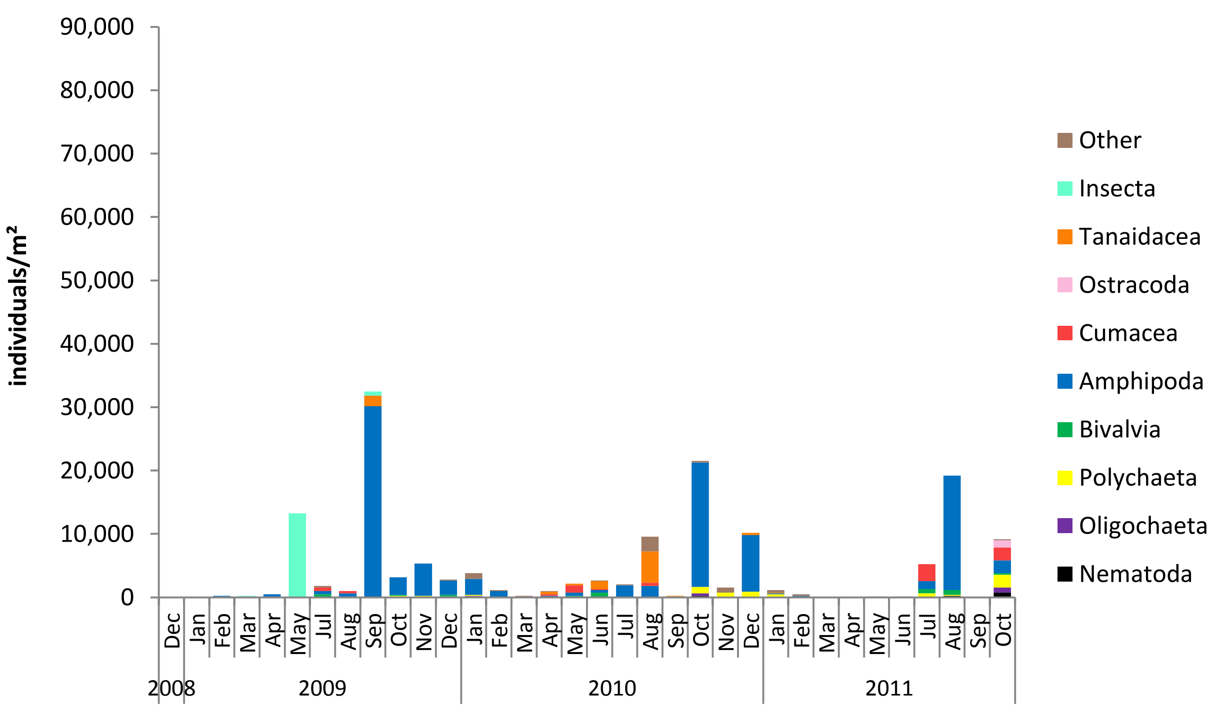


Figure 3.23. Invertebrate composition and abundance (individuals/m²) in core NU3 over time.

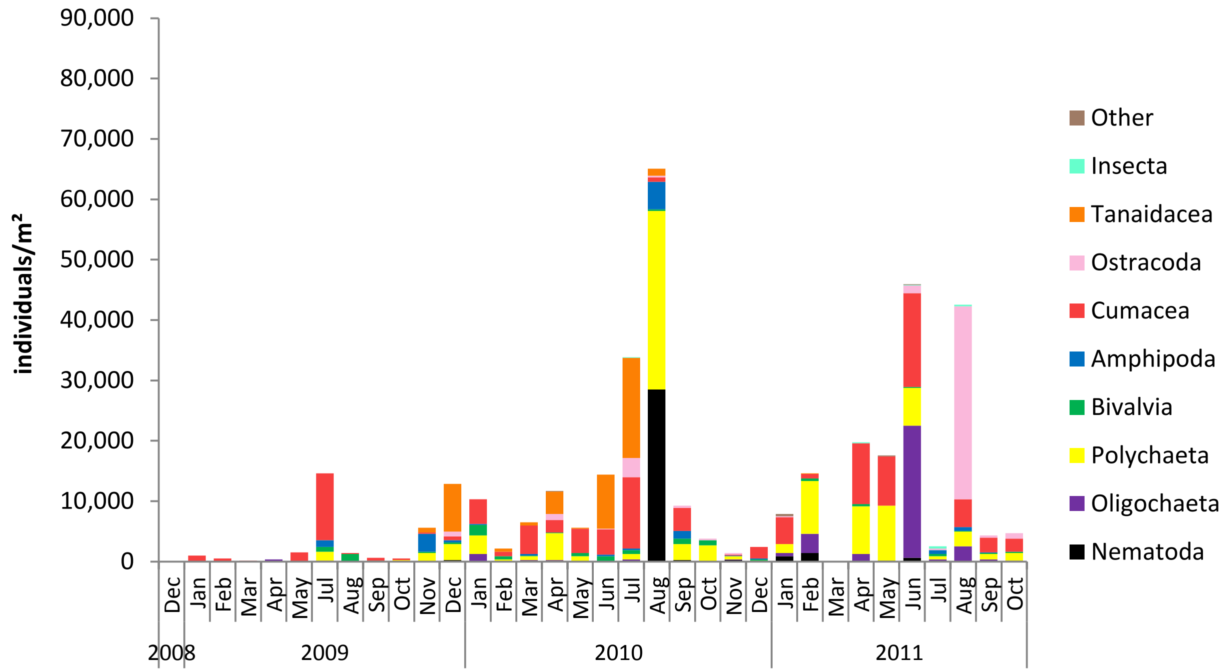


Figure 3.24. Invertebrate composition and abundance (individuals/m²) in core NU5 over time.

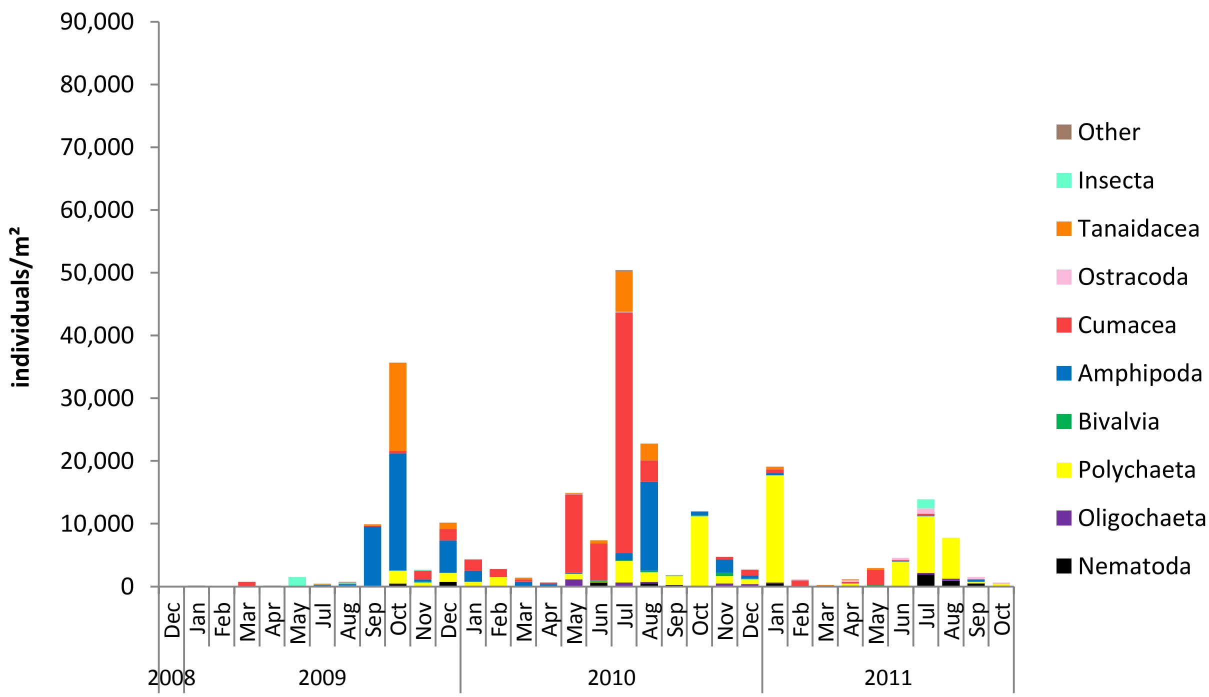


Figure 3.25. Invertebrate composition and abundance (individuals/m²) in core NU7 over time.

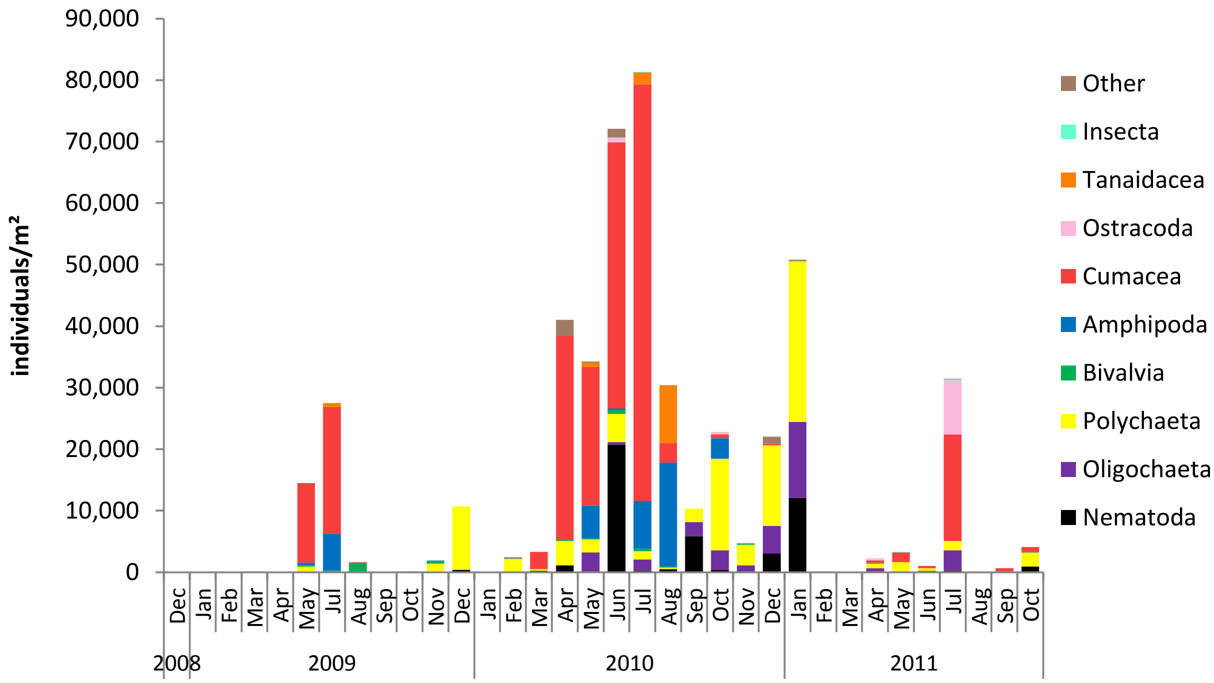


Figure 3.26. Invertebrate composition and abundance (individuals/m²) in core NU10 over time.

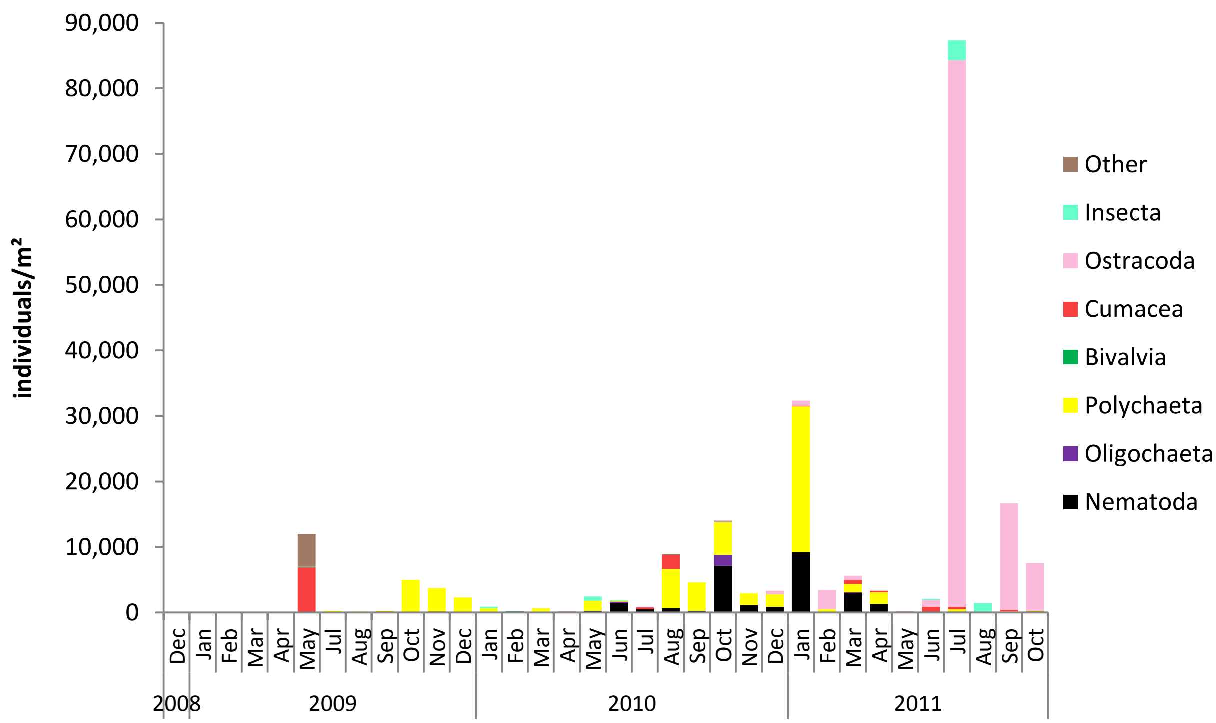


Figure 3.27. Mean invertebrate distribution and abundance (individuals/m²) across Napa River (NR1, NR2), Fagan Slough (FS1, FS2) and North Unit (NU1 – NU10) in A) Dec 2008, B) Jan 2009, C) Nov 2009, D) Sep 2010, E) Nov 2010.

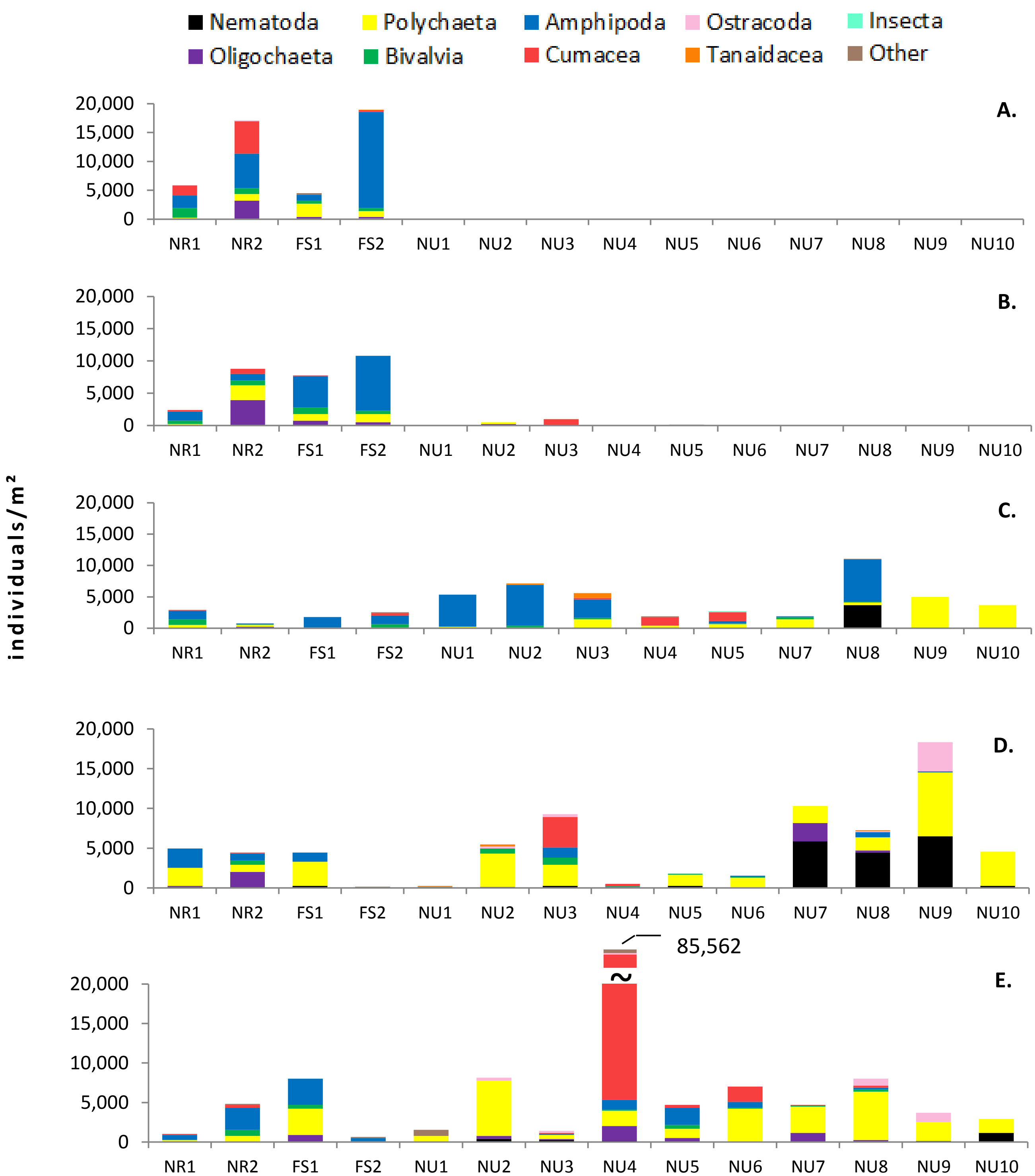


Figure 4.1. Small mammal trapping sites in Fagan Marsh: A) Northern Marsh; B) Southern Marsh

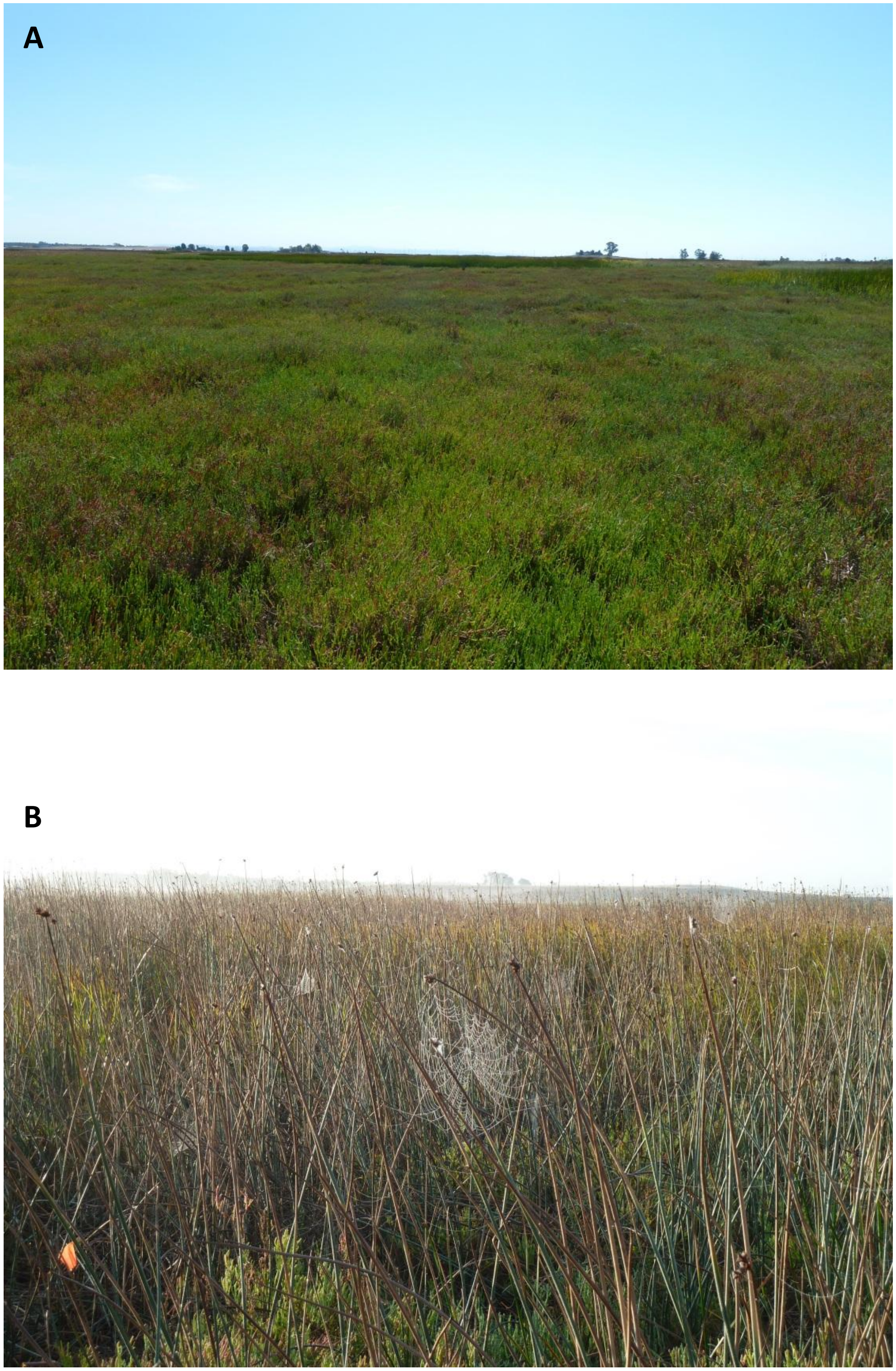


Figure 4.2. Small mammal processing includes species identification, sex, and age, and measurements of mass, length, and marking with non-permanent paint pens and fur clips. Additional tail and venter metrics were taken for *Reithrodontomys* spp.

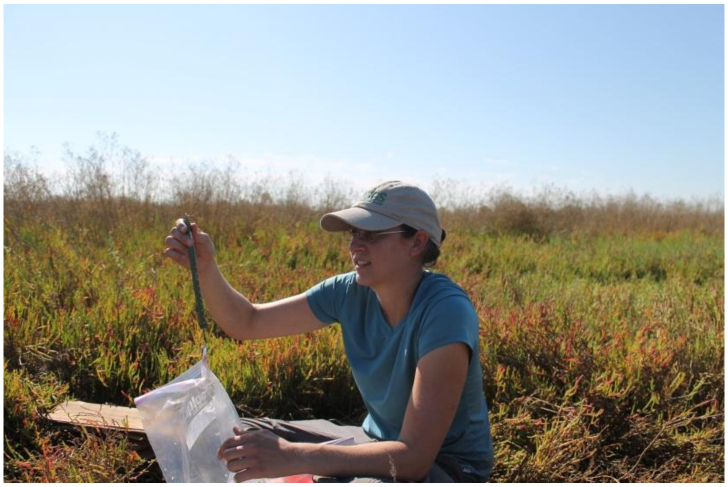


Figure 4.3. Number of new and recaptured small mammal individuals by species: the native California vole (*Microtus californicus;*MICA), the endangered salt marsh harvest mouse (*Reithrodontomys raviventris*, RERA), the non-native house mouse (*Mus musculus*; MUMU) and the native shrew (*Sorex ornatus*, subspecies unknown, SOOR).

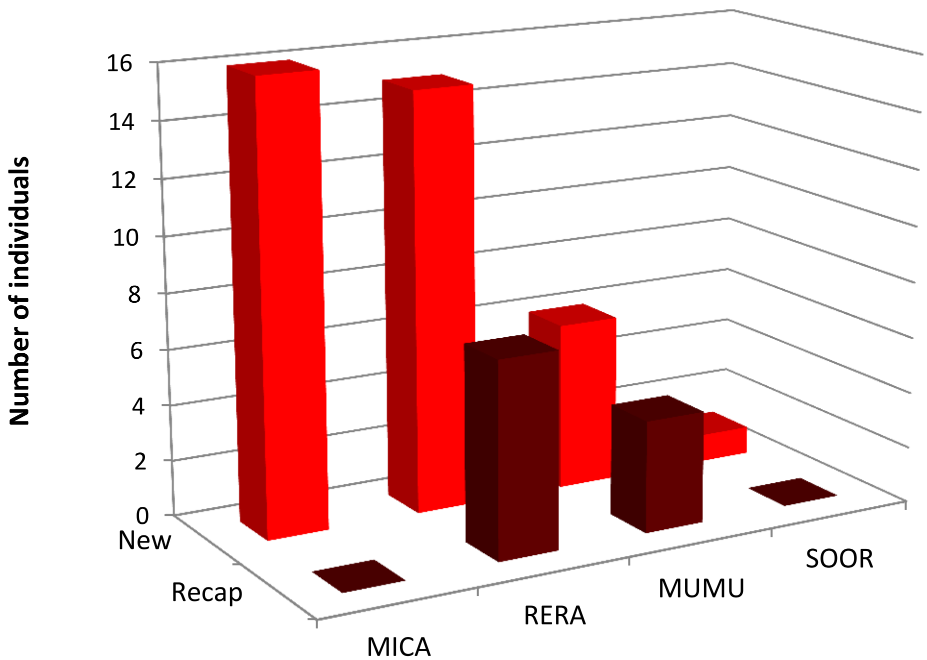
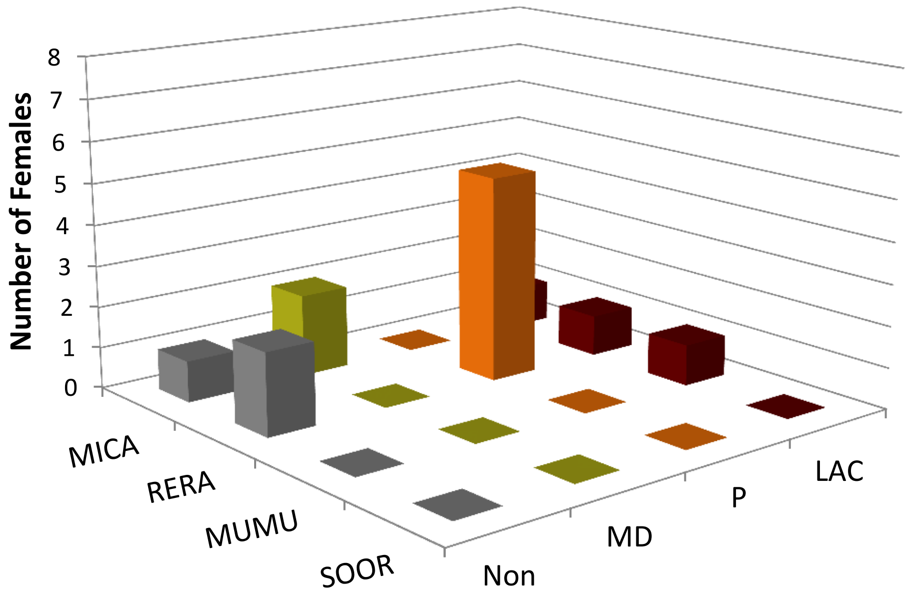


Figure 4.4. Reproductive status for females (A) and males (B) by species. For females: Non = non-reproductive, MD = developed mammaries, P = pregnant, LAC = lactating. For males: Non = non-reproductive, Scr = Scrotal.

A



B

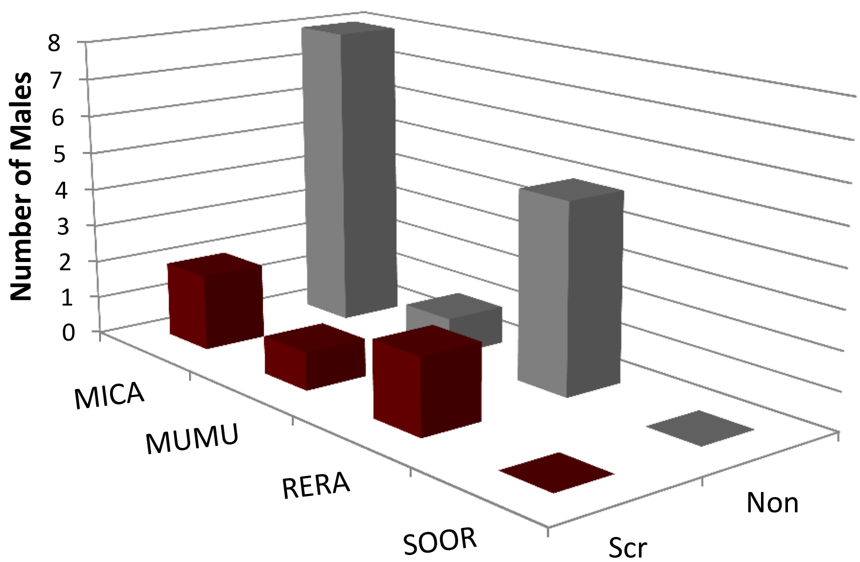
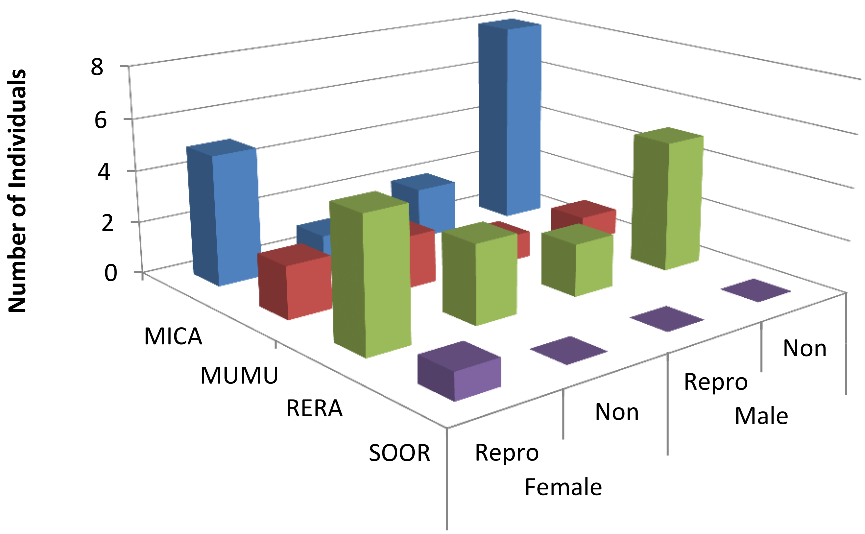


Figure 4.5. Southern Marsh (A) had greater numbers overall than Northern Marsh (B).

A



B

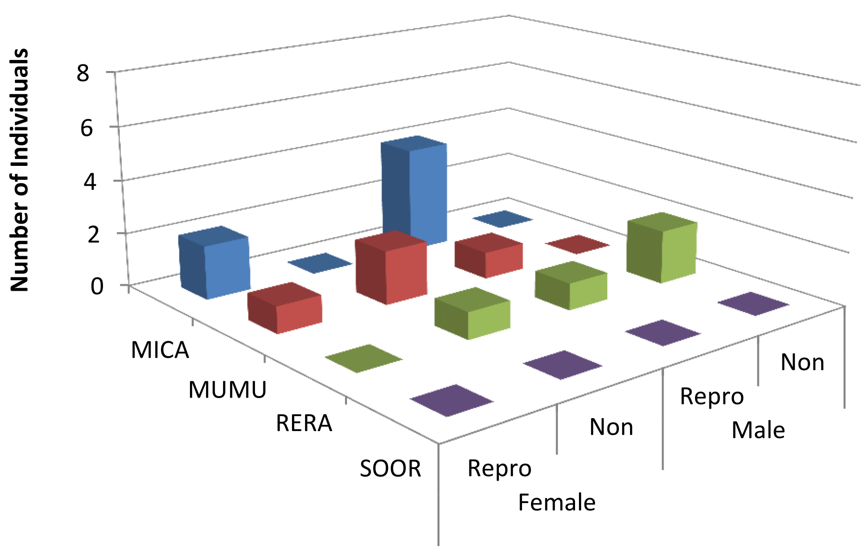


Figure 4.6. Overall capture index by species across sites (A) and capture index by species at Northern Marsh compared to Southern Marsh (B).

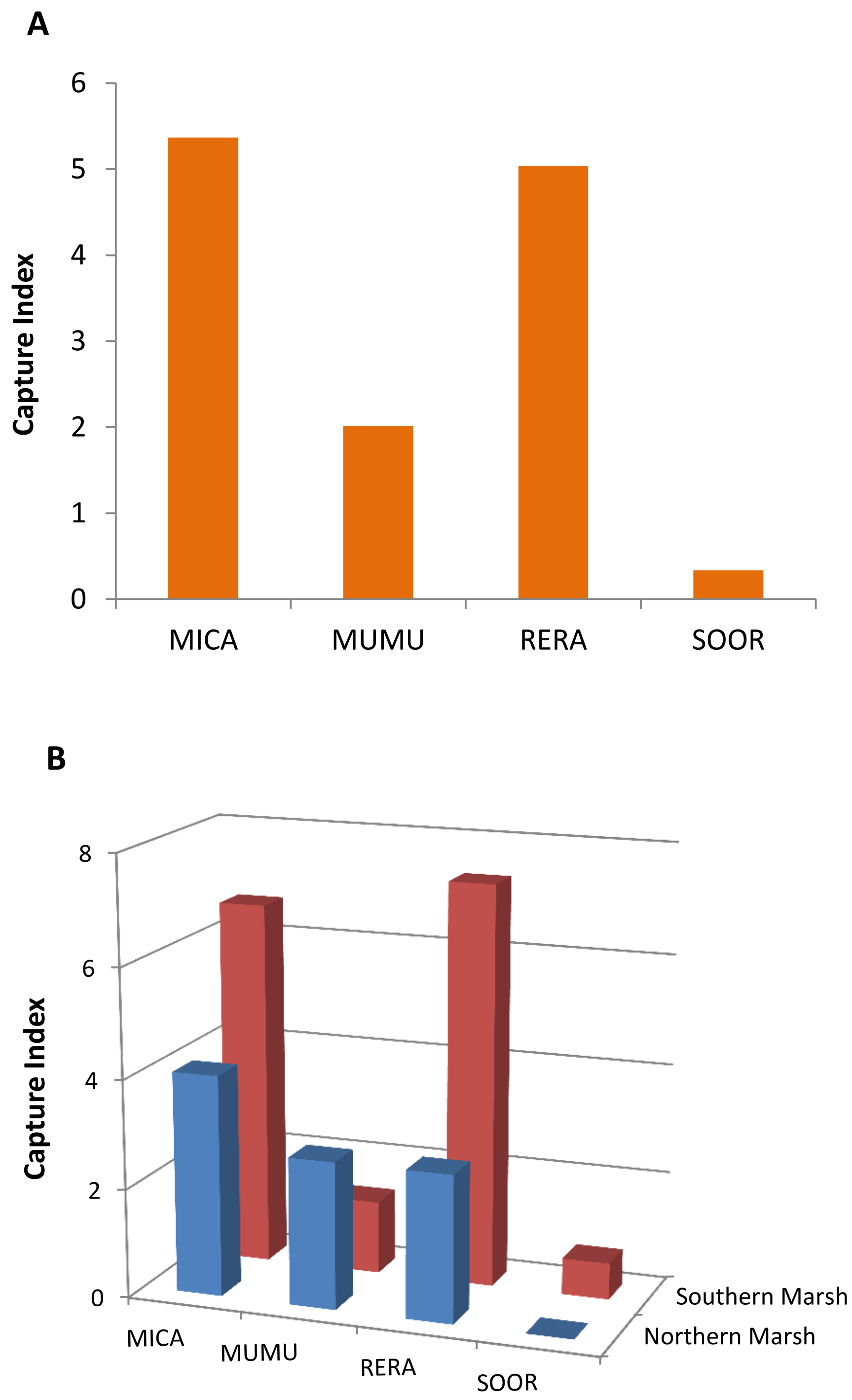


Figure 5.1. Seasonal average number (spring, n = 3; winter 2012, n = 1; all other winter, n = 3) of small shorebirds observed on the Central (pale orange), North (orange), or South Unit (burnt orange) at high (HT) or low tide (LT). Note the change in y-axis of winter LT.

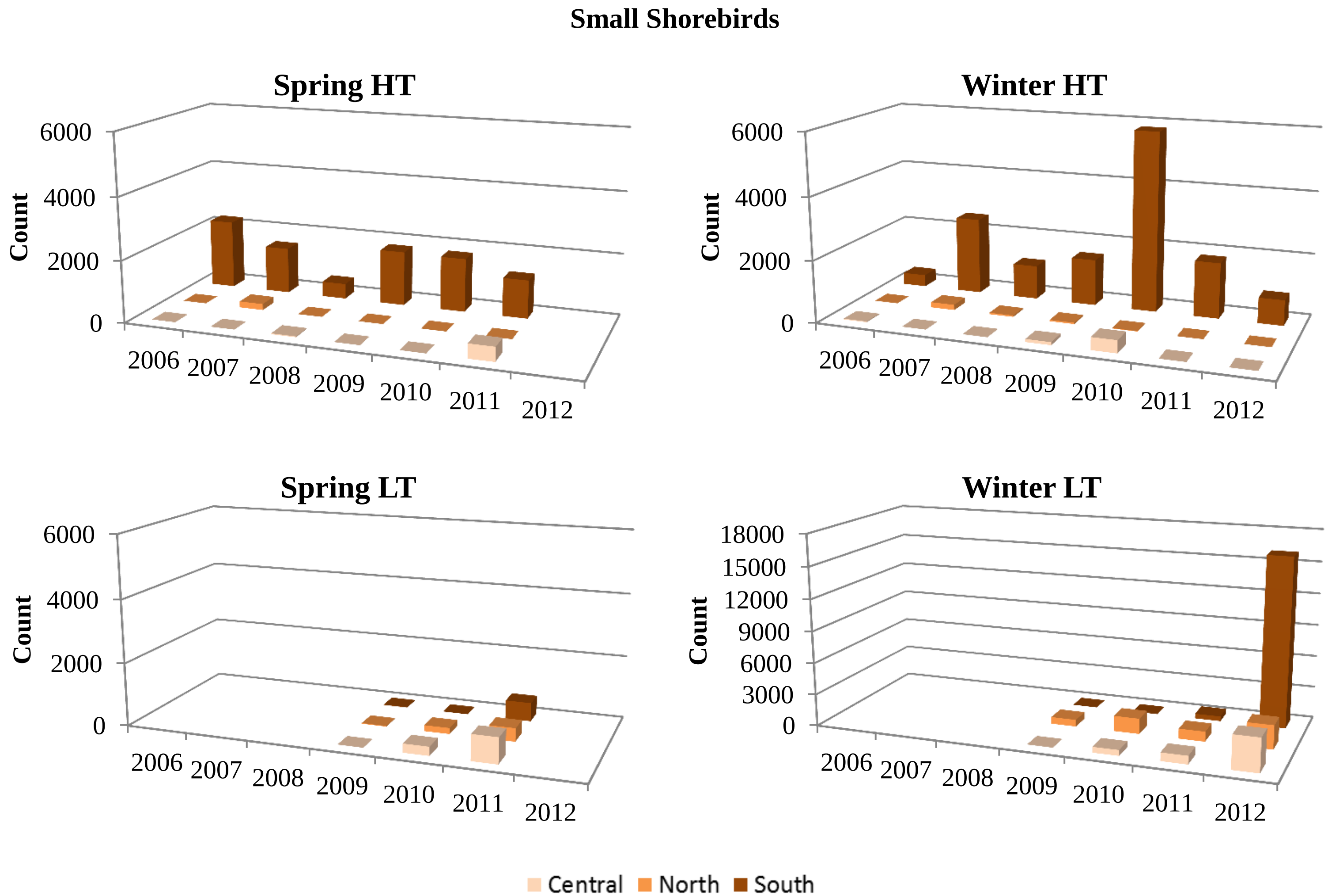


Figure 5.2. Seasonal average number (spring, n = 3; winter 2012, n = 1; all other winter, n = 3) of medium shorebirds observed on the Central (pale orange), North (orange), or South Unit (burnt orange) at high (HT) or low tide (LT).

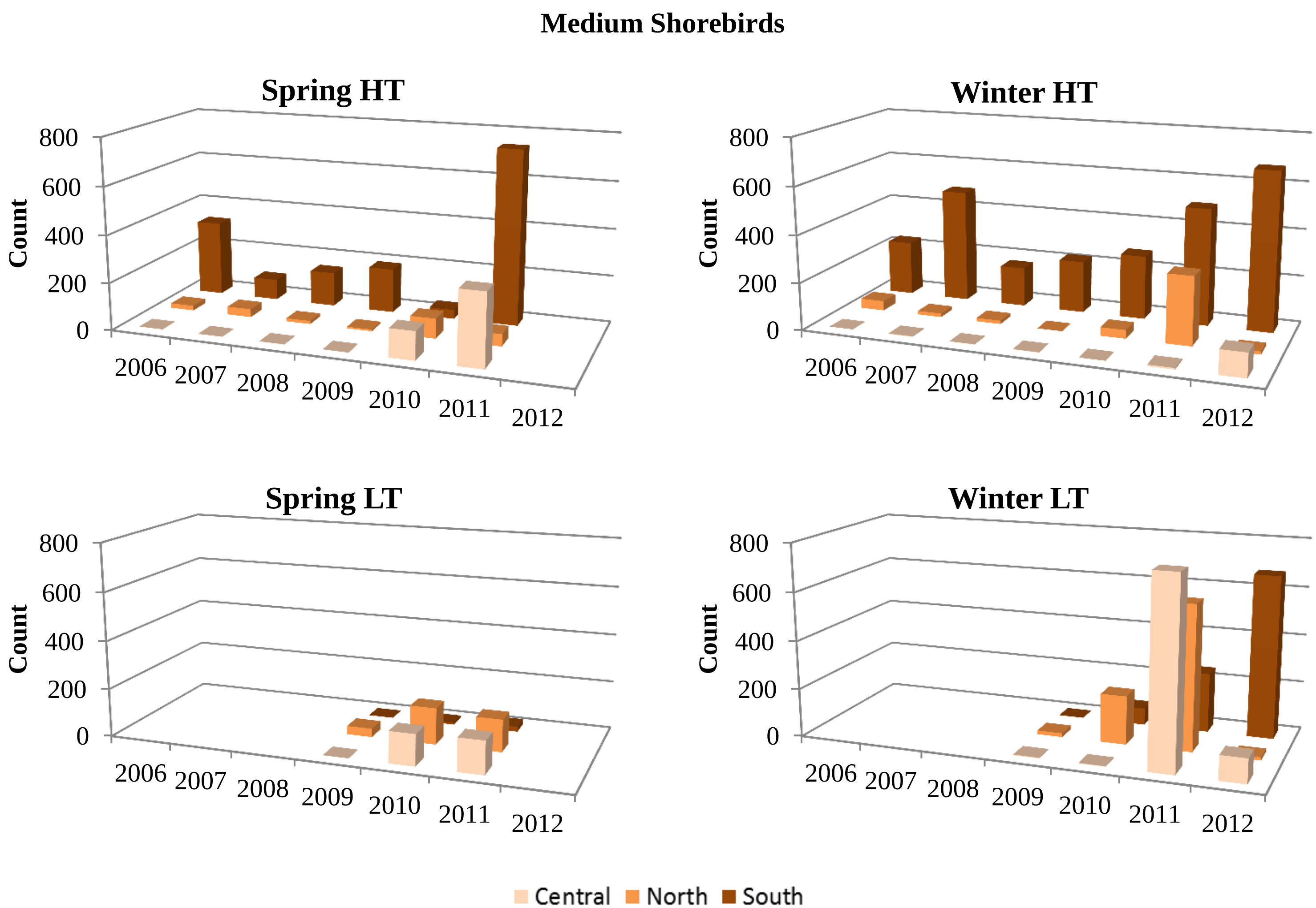


Figure 5.3. Seasonal average number (spring, n = 3; winter 2012, n = 1; all other winter, n = 3) of dabbling ducks observed on the Central (pale orange), North (orange), or South Unit (burnt orange) at high (HT) or low tide (LT).

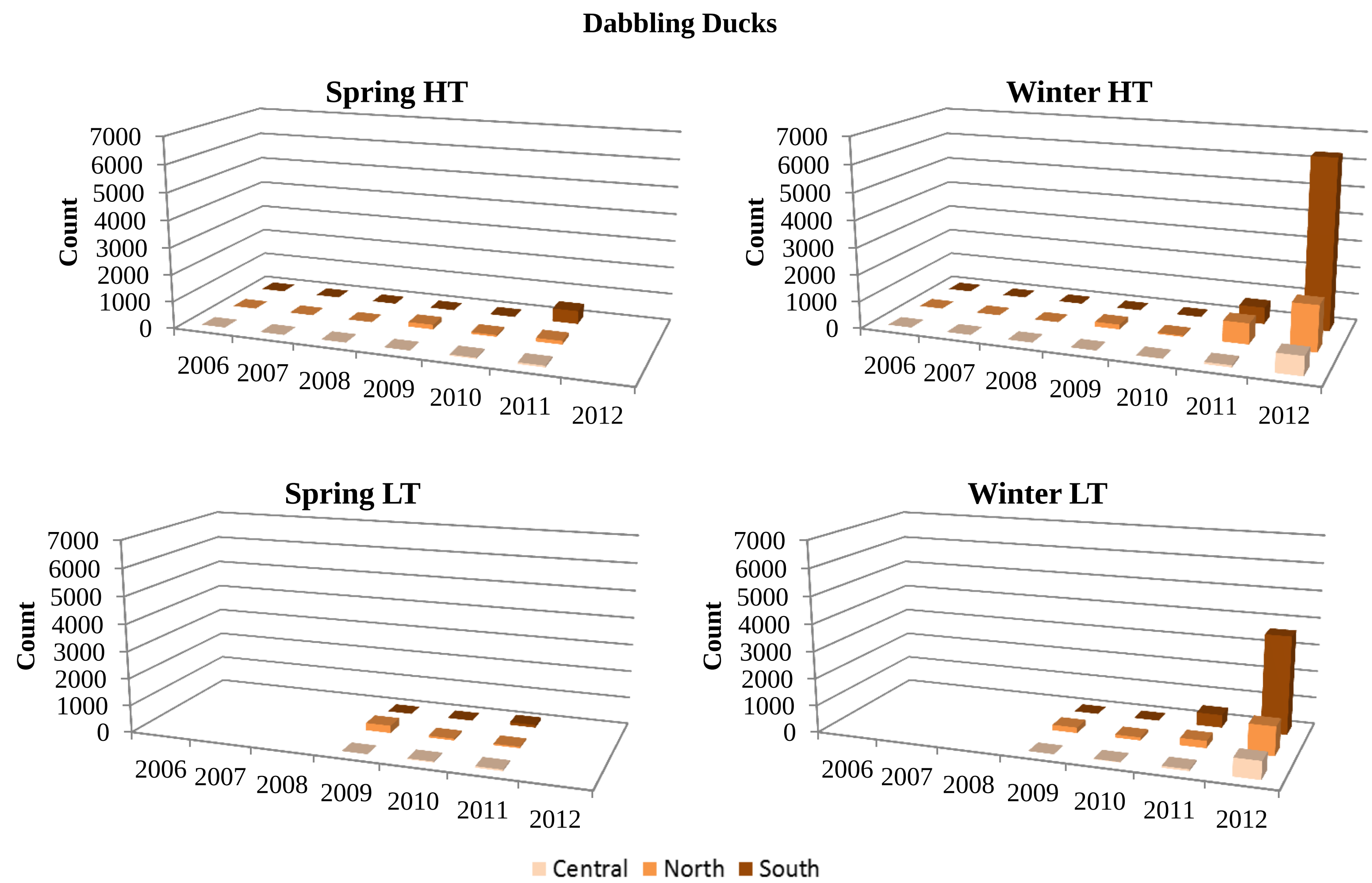


Figure 5.4. Seasonal average number (spring, n = 3; winter 2012, n = 1; all other winter, n = 3) of diving ducks observed on the Central (pale orange), North (orange), or South Unit (burnt orange) at high (HT) or low tide (LT).

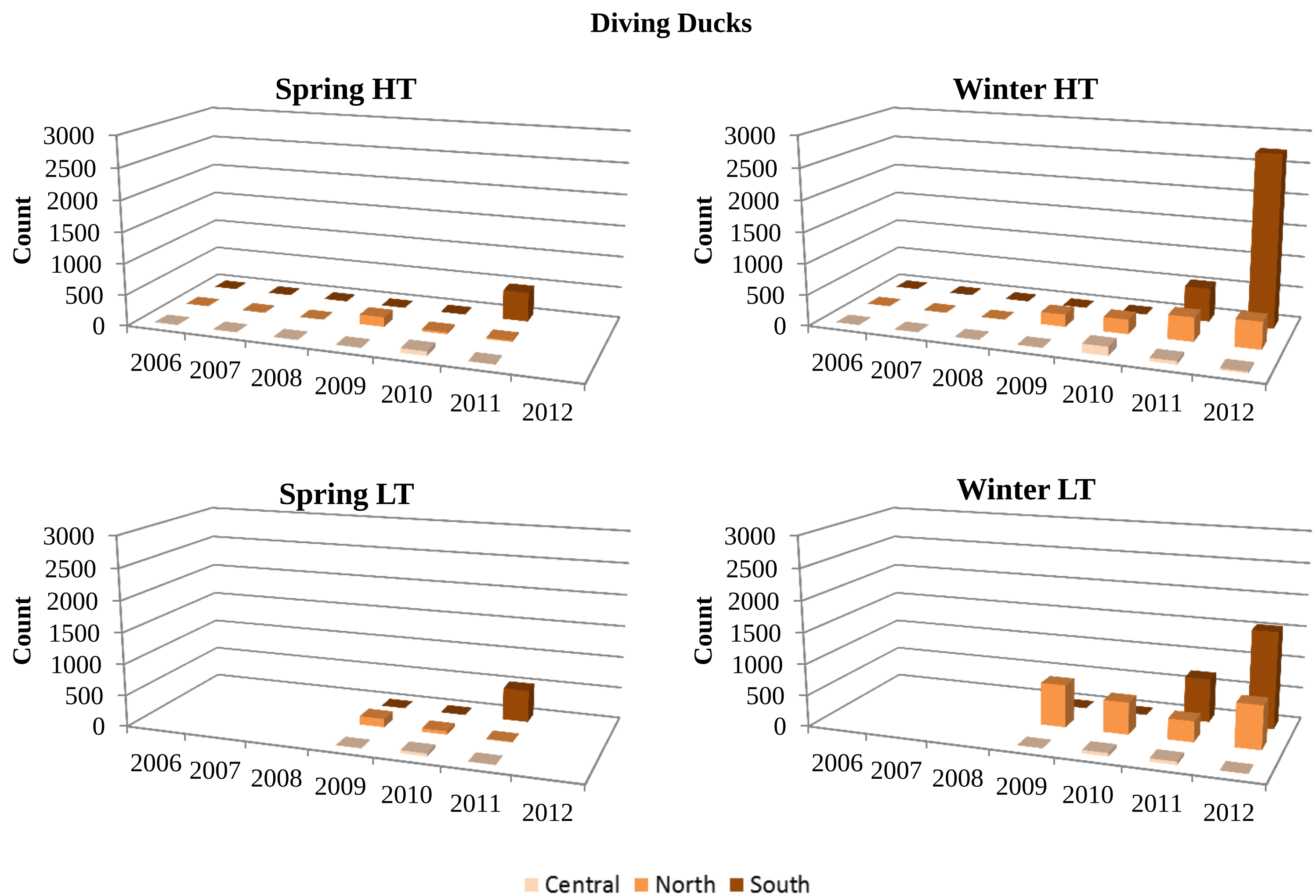


Figure 5.5. Average seasonal abundance of waterbirds by guilds that comprise > 95% of total avian abundance during winter (Dec – Feb) at high (HT) or low tide (LT) on the North Unit from winter 2006 through winter 2012 (Dec. 2011). Vertical dashed line represents the breach event. winter 2012, n = 1; all other winter, n = 3.

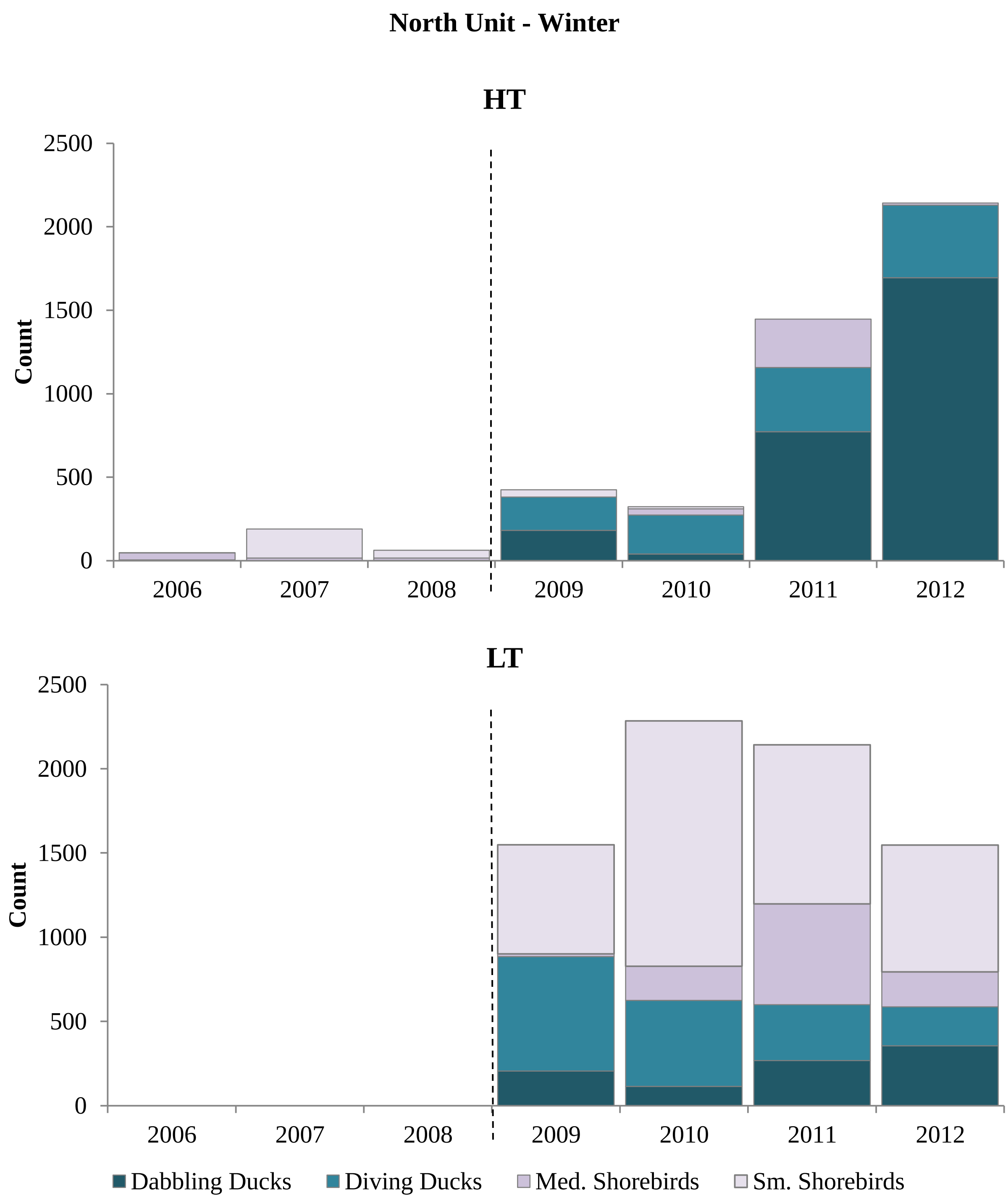


Figure 5.6. Average seasonal abundance of waterbirds by guilds that comprise > 95% of total avian abundance during winter (Dec – Feb) at high (HT) or low tide (LT) on the Central Unit from winter 2006 through winter 2012 (Dec. 2011). Vertical dashed line represents the breach event. winter 2012, n = 1; all other winter, n = 3.

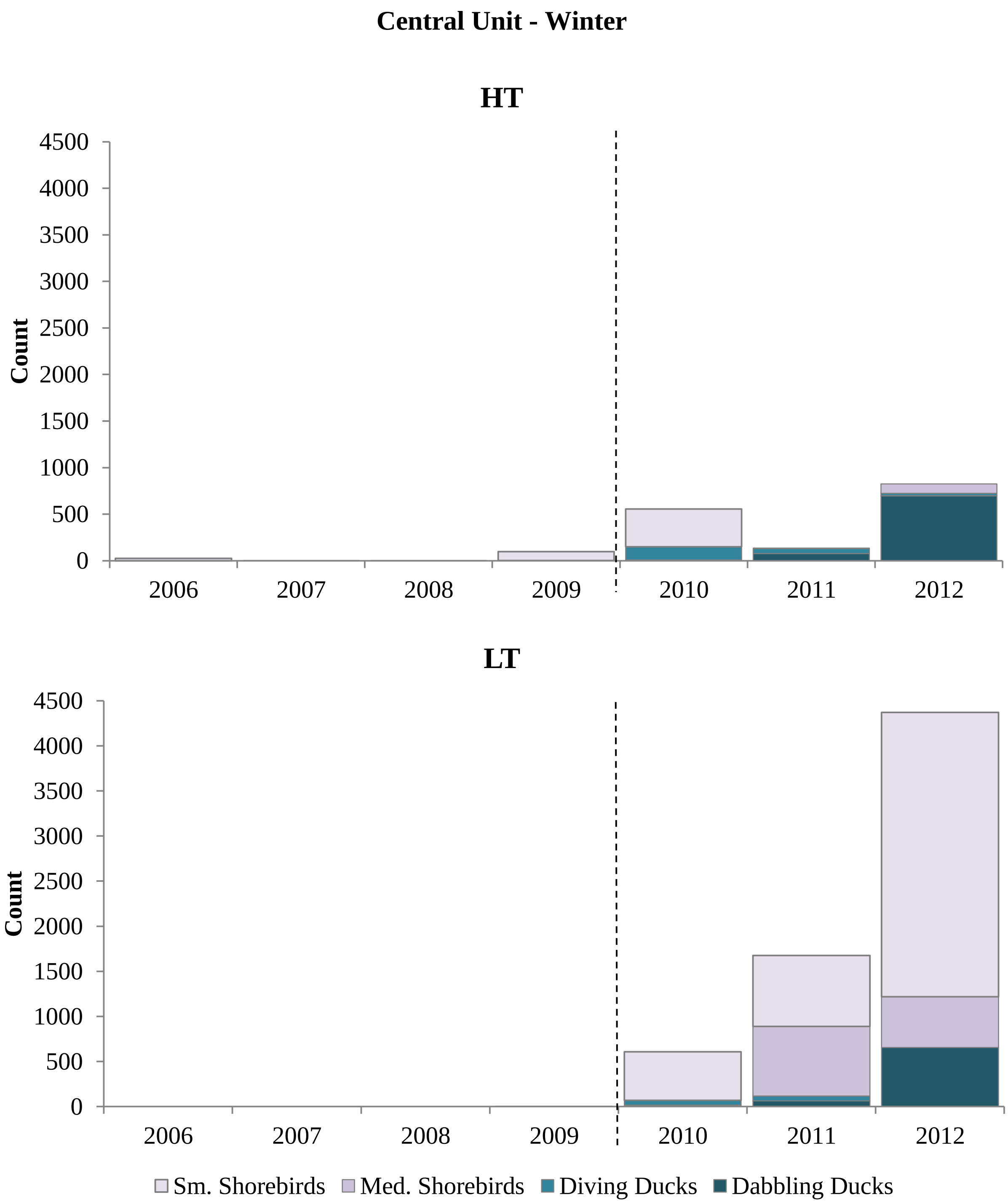


Figure 5.7. Average seasonal abundance of waterbirds by guilds that comprise > 95% of total avian abundance during winter (Dec – Feb) at high (HT) or low tide (LT) on the South Unit from winter 2006 through winter 2012 (Dec. 2011). Vertical dashed line represents the breach event. winter 2012, n = 1; all other winter, n = 3.

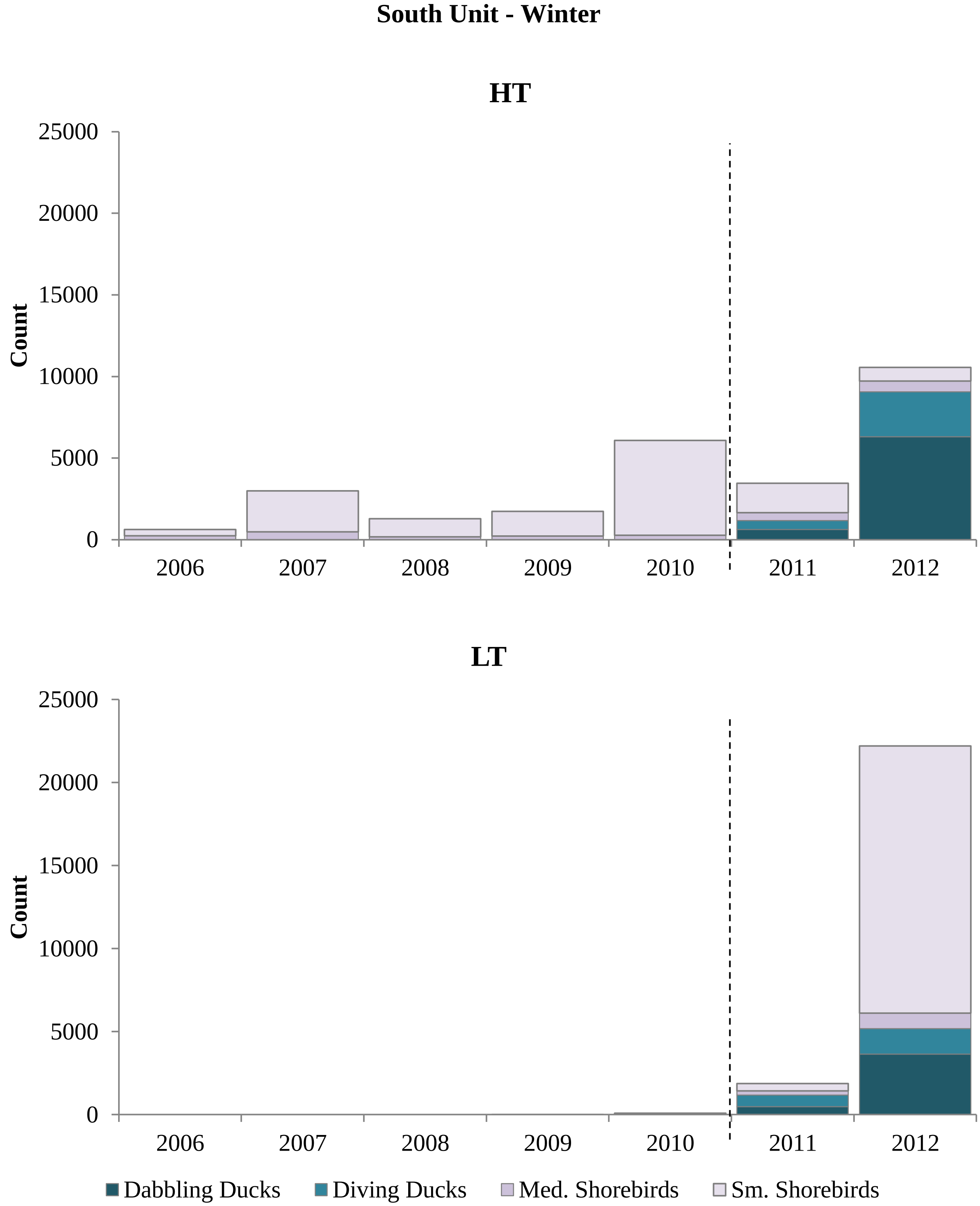


Figure 5.8. Proportional abundance of foraging (blue) and roosting (pink) medium or small shorebirds at Napa Plant Site from Sep. 2009 through Dec. 2011 (post- breach of the South Unit) at high (HT) or low (LT) tide by season (n = 3, except winter 2012, n = 1).

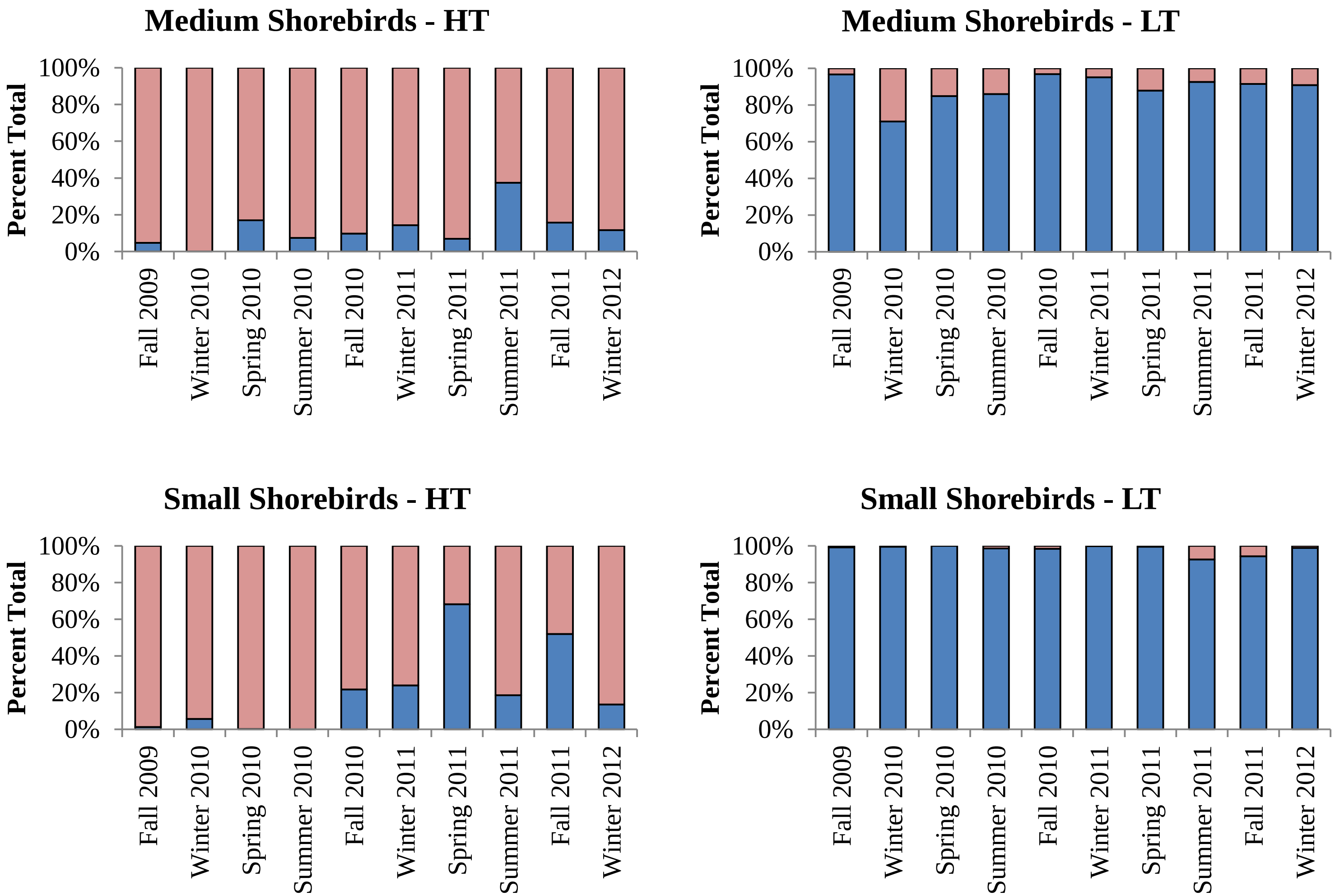


Figure 5.9. Proportional abundance of foraging (blue) and roosting (pink) dabbling or diving ducks at the Napa Plant Site from Sep. 2009 through Dec. 2011 (post- breach of the South Unit) at high (HT) or low (LT) tide by season (n = 3, except winter 2012, n = 1).

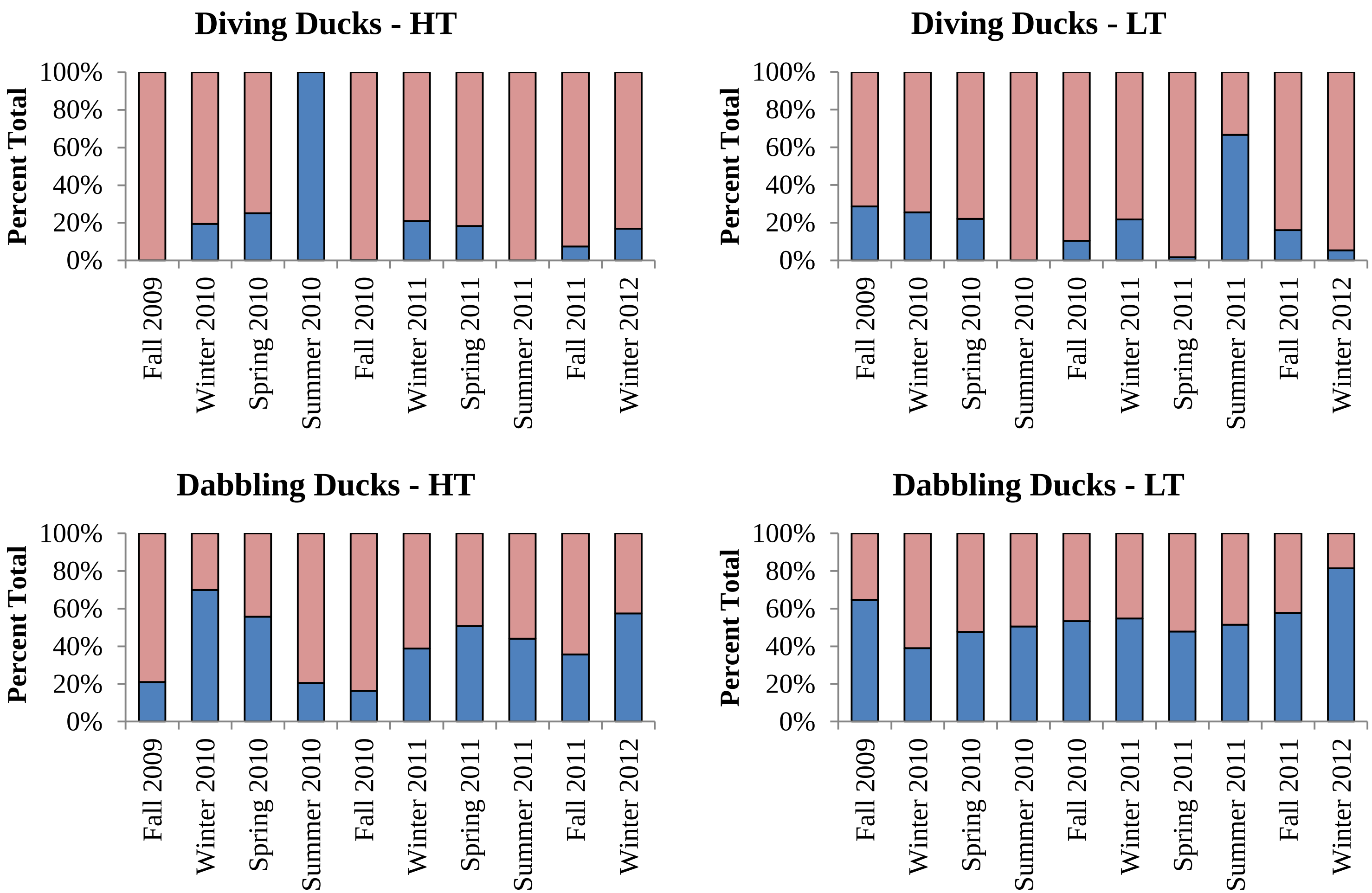


Figure 5.10. Monthly average count of foraging (blue) versus roosting (pink) waterbirds by guild at the Napa Plant Site observed during high or low tide surveys from Sep. 2009 through Dec. 2011 (post- breach of the South Unit; n = 28).

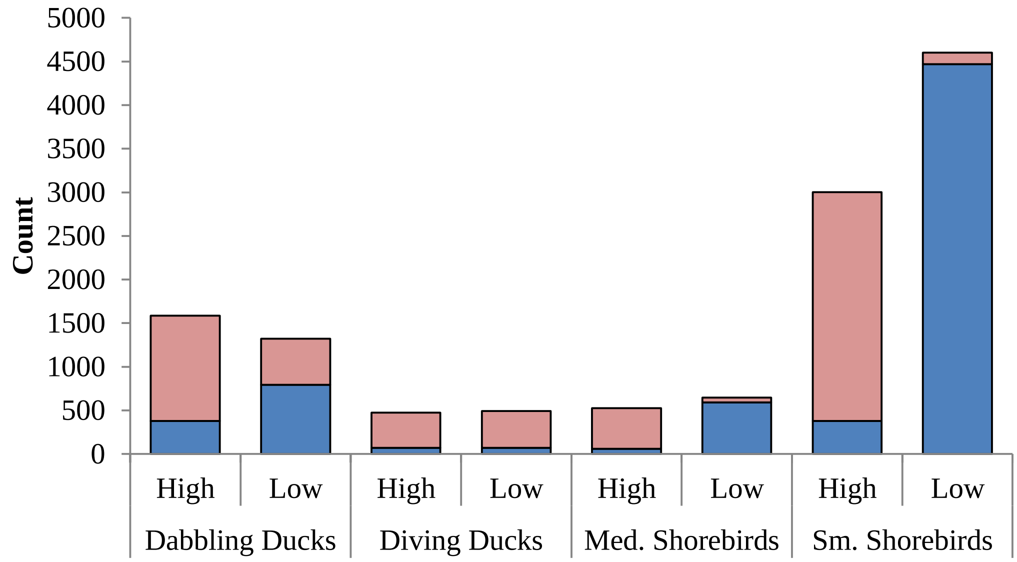


Figure 6.1. Water quality parameters from monthly minisonde sampling of the North Unit. No samples were taken in August or December 2011 due to failure of the minisonde.

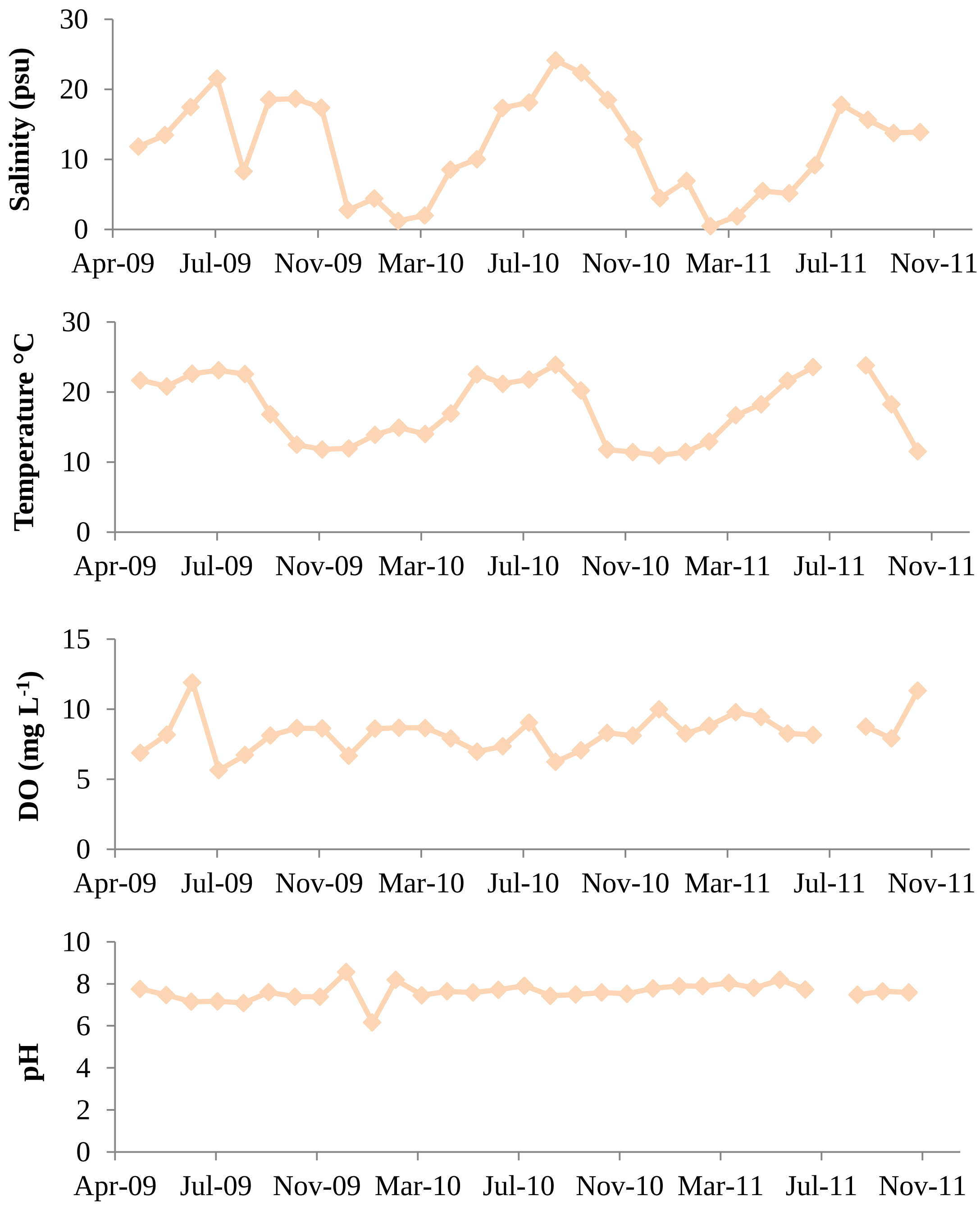


Figure 6.2. Water quality parameters from monthly minisonde sampling of the Central Unit. No samples were taken in August or December 2011 due to failure of the minisonde.

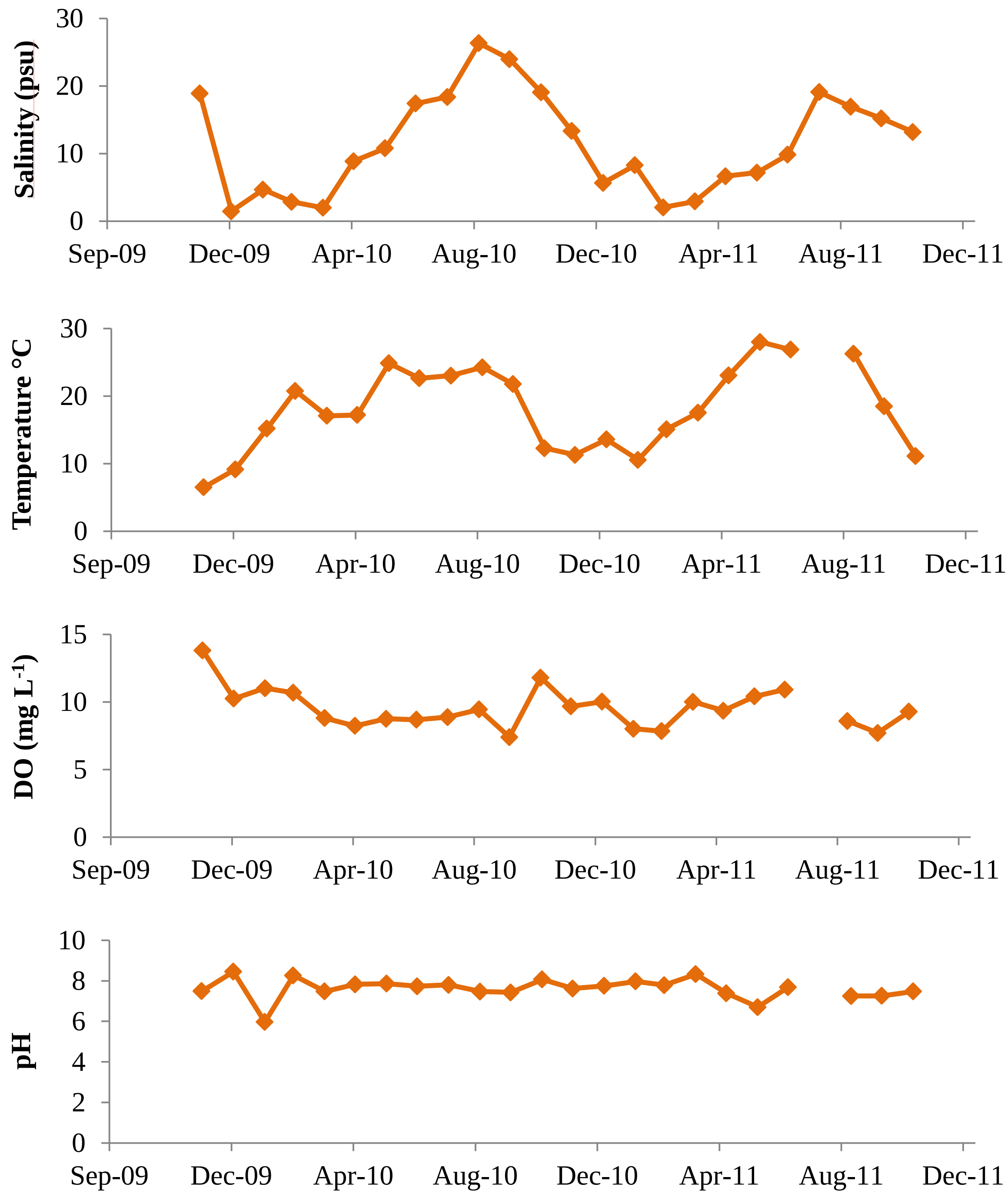
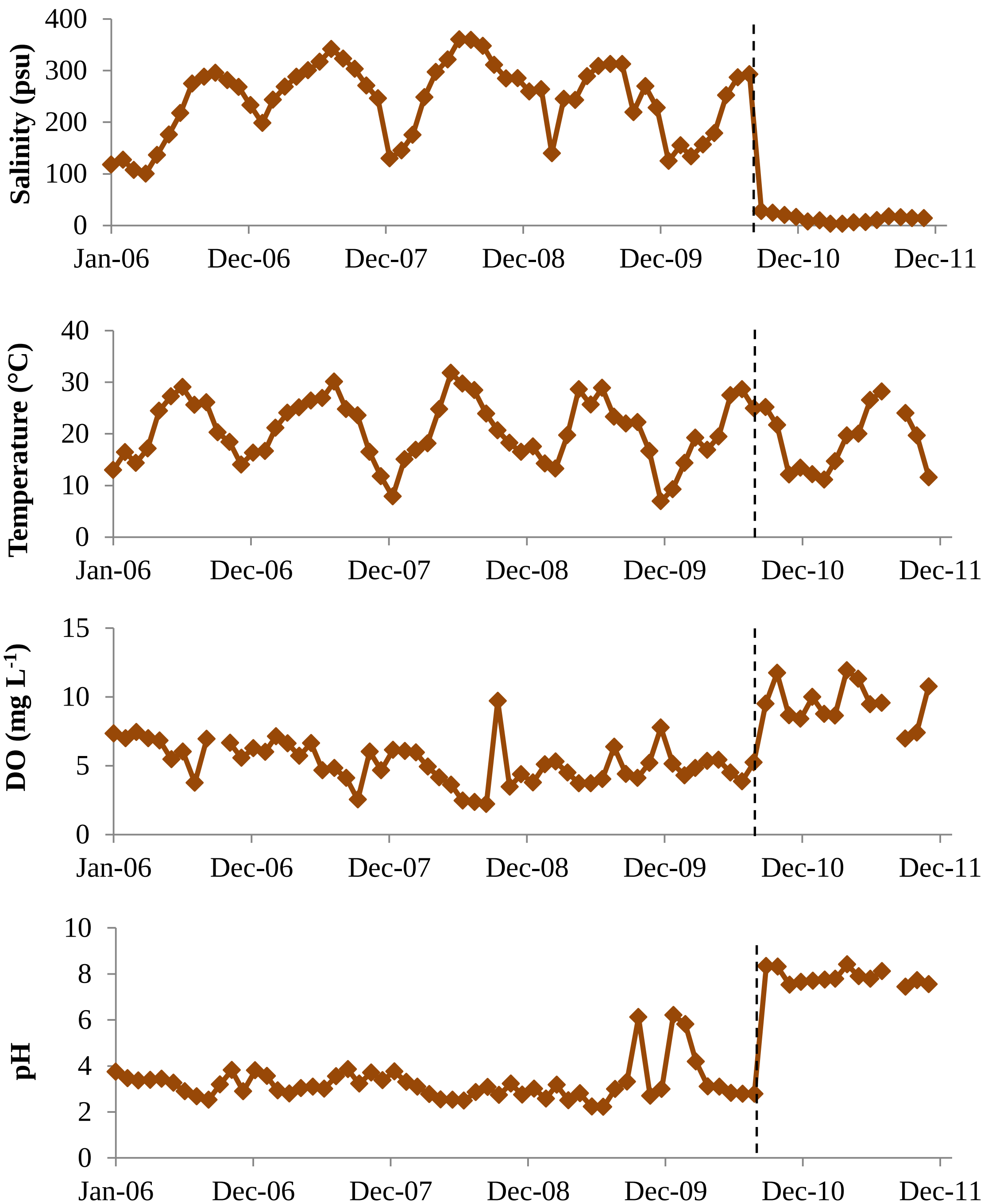


Figure 6.3. Water quality parameters from monthly minisonde sampling of the South Unit. Vertical dashed line indicates initial breach event. No samples were taken in August or December 2011 due to failure of the minisonde.



Appendix A. Total number of birds detected at the North Unit during low tide surveys from Dec. 2010 through Dec. 2011.

	2010	2011													Average	
North Unit	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Monthly**	**SE**
Dabbling Ducks	**122**	**416**	**266**	**14**	**59**	**87**	**75**	**36**	**9**	**938**	**818**	**1314**	**1067**	**5221**	**401.6**	**129.0**
American Green-winged Teal	10	127	69	4	0	0	0	0	0	40	22	6	41	319	24.5	10.4
American Coot	71	110	40	0	0	0	0	0	0	60	653	668	263	1865	143.5	66.8
American Wigeon	4	97	0	0	0	0	0	0	0	0	16	229	326	672	51.7	29.3
Gadwall	35	61	132	2	48	60	7	0	0	436	119	374	356	1630	125.4	43.5
Mallard	2	4	0	8	7	26	68	36	9	171	0	12	1	344	26.5	13.2
Northern Pintail	0	0	0	0	0	0	0	0	0	224	3	2	29	258	19.8	17.2
Northern Shoveler	0	17	25	0	4	1	0	0	0	7	5	23	51	133	10.2	4.2
Diving Ducks	**215**	**756**	**24**	**27**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**109**	**692**	**1823**	**140.2**	**74.0**
Bufflehead	0	1	0	2	0	0	0	0	0	0	0	0	1	4	0.3	0.2
Canvasback	34	448	0	11	0	0	0	0	0	0	0	12	41	546	42.0	34.1
Common Goldeneye	0	4	0	0	0	0	0	0	0	0	0	0	0	4	0.3	0.3
Ruddy Duck	181	303	23	2	0	0	0	0	0	0	0	97	650	1256	96.6	52.8
Greater or Lesser Scaup	0	0	1	12	0	0	0	0	0	0	0	0	0	13	1.0	0.9
Fish-Eaters	**0**	**1**	**1**	**4**	**0**	**1**	**0**	**2**	**0**	**3**	**1**	**2**	**0**	**15**	**1.2**	**0.4**
American White Pelican	0	0	0	0	0	0	0	2	0	2	0	0	0	4	0.3	0.2
Double-crested Cormorant	0	1	1	4	0	1	0	0	0	1	1	2	0	11	0.8	0.3
Geese	**0**	**0**	**2**	**4**	**5**	**19**	**0**	**23**	**146**	**1**	**42**	**0**	**0**	**242**	**18.6**	**11.2**
Canada Goose	0	0	2	4	5	19	0	23	146	1	42	0	0	242	18.6	11.2
Gulls	**65**	**32**	**20**	**3**	**1**	**0**	**1**	**6**	**19**	**25**	**48**	**8**	**22**	**250**	**19.2**	**5.5**
California Gull	29	0	1	2	1	0	0	5	0	5	4	1	6	54	4.2	2.2
Herring Gull	16	2	13	0	0	0	0	0	0	1	1	4	6	43	3.3	1.5
Mew Gull	0	15	3	0	0	0	0	0	1	0	0	0	0	19	1.5	1.2
Ring-billed Gull	10	13	0	1	0	0	0	1	18	13	0	2	0	58	4.5	1.8
Western Gull	10	2	3	0	0	0	1	0	0	6	43	1	10	76	5.8	3.3

Appendix A. Continued.

North Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Herons	**4**	**1**	**2**	**3**	**1**	**1**	**4**	**1**	**3**	**2**	**2**	**1**	**1**	**26**	**2.0**	**0.3**
Great Blue Heron	0	0	0	0	0	0	1	1	0	0	0	1	0	3	0.2	0.1
Great Egret	1	1	1	0	0	0	3	0	2	1	0	0	1	10	0.8	0.3
Snowy Egret	3	0	1	3	1	1	0	0	1	1	2	0	0	13	1.0	0.3
Medium Shorebirds	**312**	**721**	**760**	**139**	**222**	**44**	**6**	**163**	**276**	**439**	**681**	**194**	**621**	**4578**	**352.2**	**73.2**
American Avocet	60	395	610	21	1	11	0	0	3	0	56	116	432	1705	131.2	57.3
Black-bellied Plover	47	222	91	5	5	0	0	2	4	192	328	26	117	1039	79.9	29.5
Black-necked Stilt	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0.2	0.2
Greater Yellowlegs	0	0	1	0	0	0	0	0	0	0	3	1	0	5	0.4	0.2
Killdeer	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.1	0.1
Long-billed Curlew	15	9	17	11	23	0	6	43	16	4	37	4	5	190	14.6	3.6
Marbled Godwit	157	80	40	40	179	29	0	84	233	150	171	21	25	1209	93.0	21.0
Whimbrel	0	0	1	0	0	0	0	0	0	1	1	0	2	5	0.4	0.2
Willet	33	15	0	62	14	1	0	34	20	92	84	26	40	421	32.4	8.4
Raptors	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**1**	**2**	**1**	**0**	**1**	**7**	**0.5**	**0.2**
Northern Harrier	0	0	0	1	0	0	0	0	0	1	1	0	1	4	0.3	0.1
Turkey Vulture	0	0	0	0	0	0	0	0	1	1	0	0	0	2	0.2	0.1
White-tailed Kite	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.1	0.1
Small Shorebirds	**2277**	**310**	**250**	**115**	**1161**	**0**	**0**	**2450**	**2723**	**1904**	**2688**	**1966**	**2262**	**18106**	**1392.8**	**307.4**
Long- and Short-billed Dowitcher	3	0	0	0	0	0	0	0	0	9	2	120	0	134	10.3	9.2
Dunlin	110	104	0	3	172	**0**	0	0	0	34	405	369	1004	2201	169.3	79.6
Least Sandpiper	1506	66	30	0	25	0	0	2450	5	145	203	125	63	4618	355.2	207.5
Semipalmated Plover	12	0	0	0	4	**0**	0	0	0	0	0	2	1	19	1.5	0.9
Western Sandpiper	646	140	220	112	960	0	0	0	2718	1716	2078	1350	1194	11134	856.5	250.4
Terns	**0**	**0**	**0**	**0**	**0**	**4**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**7**	**0.5**	**0.4**
Caspian Tern	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0.2	0.2
Least Tern	0	0	0	0	0	2	0	3	0	0	0	0	0	5	0.4	0.3

Appendix B. Total number of birds detected at the Central Unit during low tide surveys from Dec. 2010 through Dec. 2011.

Central Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Dabbling Ducks	**96**	**36**	**62**	**144**	**4**	**12**	**53**	**2**	**0**	**570**	**58**	**744**	**655**	**2436**	**187.4**	**75.6**
American Coot	94	0	0	125	0	0	0	0	0	0	0	640	383	1242	95.5	54.4
American Wigeon	0	2	0	0	0	0	0	0	0	0	0	0	7	9	0.7	0.5
Gadwall	2	23	37	0	2	8	3	0	0	0	4	85	234	398	30.6	18.2
Mallard	0	0	0	2	2	4	50	2	0	263	0	5	4	332	25.5	20.1
Northern Pintail	0	0	0	0	0	0	0	0	0	307	54	0	0	361	27.8	23.6
Northern Shoveler	0	11	25	17	0	0	0	0	0	0	0	14	27	94	7.2	2.9
Diving Ducks	**66**	**90**	**0**	**12**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**168**	**12.9**	**8.2**
Bufflehead	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1	0.1
Canvasback	65	69	0	8	0	0	0	0	0	0	0	0	0	142	10.9	6.9
Ruddy Duck	0	21	0	4	0	0	0	0	0	0	0	0	0	25	1.9	1.6
Eared Grebes	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0.1**	**0.1**
Fish-Eaters	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0.1**	**0.1**
Double-crested Cormorant	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.1	0.1
Geese	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**21**	**0**	**0**	**13**	**0**	**36**	**2.8**	**1.8**
Canada Goose	0	0	0	0	0	2	0	0	21	0	0	13	0	36	2.8	1.8
Gulls	**18**	**16**	**7**	**1**	**0**	**0**	**0**	**0**	**11**	**2**	**3**	**2**	**1**	**61**	**4.7**	**1.8**
California Gull	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.1	0.1
Herring Gull	3	1	1	0	0	0	0	0	0	1	1	1	1	9	0.7	0.2
Mew Gull	0	5	0	0	0	0	0	0	10	0	0	1	0	16	1.2	0.8
Ring-billed Gull	13	10	6	0	0	0	0	0	1	0	1	0	0	31	2.4	1.2
Western Gull	2	0	0	1	0	0	0	0	0	1	0	0	0	4	0.3	0.2
Herons	**0**	**0**	**0**	**0**	**0**	**1**	**4**	**0**	**2**	**0**	**0**	**0**	**0**	**7**	**0.5**	**0.3**
Great Blue Heron	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.1	0.1
Great Egret	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0.2	0.2
Snowy Egret	0	0	0	0	0	1	2	0	1	0	0	0	0	4	0.3	0.2

Appendix B. Continued.

Central Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Medium Shorebirds	**1142**	**424**	**749**	**250**	**89**	**72**	**90**	**47**	**203**	**131**	**147**	**285**	**563**	**4192**	**322.5**	**89.8**
American Avocet	623	157	606	131	3	0	2	0	103	26	9	69	356	2085	160.4	62.3
Black-bellied Plover	291	129	29	0	0	3	0	0	0	3	9	145	133	742	57.1	25.1
Black-necked Stilt	2	0	0	0	0	0	0	0	0	0	0	3	1	6	0.5	0.3
Greater Yellowlegs	0	1	0	0	0	0	0	0	1	4	4	5	0	15	1.2	0.5
Killdeer	0	0	0	0	0	0	0	0	0	6	6	4	5	21	1.6	0.7
Long-billed Curlew	54	25	25	8	0	4	3	11	6	5	9	1	2	153	11.8	4.2
Lesser Yellowlegs	0	0	0	0	0	0	0	0	2	6	0	0	0	8	0.6	0.5
Marbled Godwit	142	91	88	58	23	55	37	17	29	15	35	18	11	619	47.6	10.7
Whimbrel	0	4	0	0	0	0	0	0	0	0	0	0	0	4	0.3	0.3
Willet	30	17	1	53	63	10	48	19	62	66	75	40	55	539	41.5	6.6
Raptors	**3**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**5**	**0.4**	**0.2**
Northern Harrier	1	0	1	0	0	0	0	0	0	0	0	0	0	2	0.2	0.1
Peregrine Falcon	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0.2	0.2
Turkey Vulture	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0.1	0.1
Small Shorebirds	**1486**	**100**	**773**	**116**	**2336**	**0**	**0**	**1924**	**21**	**1073**	**2750**	**3047**	**3154**	**16780**	**1290.8**	**342.3**
Long- and Short-billed Dowitcher	0	0	0	4	0	0	0	0	0	0	0	36	399	439	33.8	30.6
Dunlin	60	5	3	14	530	0	0	0	0	34	792	598	865	2901	223.2	93.8
Least Sandpiper	506	71	120	0	75	0	0	1924	14	0	1362	828	565	5465	420.4	170.7
Semipalmated Plover	0	0	0	0	26	0	0	0	1	9	39	45	10	130	10.0	4.5
Western Sandpiper	920	24	650	98	1705	0	0	0	6	1030	557	1540	1315	7845	603.5	177.7
Terns	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0.2**	**0.2**
Caspian Tern	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.1	0.1
Least Tern	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0.2	0.1

Appendix C. Total number of birds detected at the South Unit during low tide surveys from Dec. 2010 through Dec. 2011.

South Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Dabbling Ducks	**28**	**663**	**743**	**8**	**186**	**109**	**198**	**37**	**25**	**6339**	**4322**	**4717**	**3638**	**21013**	**1616.4**	**627.7**
American Green-winged Teal	0	23	12	0	0	0	0	0	0	0	43	6	259	343	26.4	19.7
American Coot	0	149	173	0	16	0	0	0	0	29	379	3375	2485	6606	508.2	303.9
American Wigeon	0	14	8	0	0	0	0	0	0	0	2	419	275	718	55.2	36.8
Cinnamon Teal	0	0	0	0	0	0	0	0	0	0	0	9	0	9	0.7	0.7
Gadwall	21	417	142	0	25	36	6	33	0	4	4	490	302	1480	113.8	48.1
Mallard	7	6	13	8	35	73	192	4	25	768	90	109	91	1421	109.3	57.0
Northern Pintail	0	0	0	0	0	0	0	0	0	5537	3793	209	168	9707	746.7	492.7
Northern Shoveler	0	54	395	0	110	0	0	0	0	1	11	100	58	729	56.1	30.3
Diving Ducks	**1139**	**294**	**660**	**1307**	**220**	**11**	**3**	**0**	**0**	**0**	**370**	**2322**	**1546**	**7872**	**605.5**	**207.7**
Bufflehead	29	27	3	2	0	0	0	0	0	0	0	87	14	162	12.5	6.9
Canvasback	0	0	1	13	0	0	0	0	0	0	0	80	21	115	8.8	6.2
Common Goldeneye	0	14	1	3	1	0	1	0	0	0	0	4	3	27	2.1	1.1
Ruddy Duck	1110	253	655	49	23	1	0	0	0	0	370	2151	1508	6120	470.8	194.2
Greater or Lesser Scaup	0	0	0	1240	196	10	2	0	0	0	0	0	0	1448	111.4	95.2
Eared Grebes	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**4**	**0.3**	**0.2**
Fish-Eaters	**5**	**6**	**7**	**3**	**1**	**5**	**5**	**23**	**101**	**146**	**36**	**44**	**21**	**403**	**31.0**	**12.2**
American White Pelican	0	0	1	0	0	0	2	21	60	91	23	0	0	198	15.2	7.9
Clark's Grebe	3	0	1	0	0	1	1	0	0	0	0	0	1	7	0.5	0.2
Double-crested Cormorant	0	0	0	2	1	1	2	2	41	55	13	34	8	159	12.2	5.2
Pied-billed Grebe	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0.4	0.4
Western Grebe	2	6	5	1	0	1	0	0	0	0	0	7	7	29	2.2	0.8
Western or Clark's Grebe	0	0	0	0	0	2	0	0	0	0	0	3	0	5	0.4	0.3
Geese	**0**	**0**	**6**	**6**	**2**	**21**	**35**	**3**	**45**	**0**	**41**	**27**	**1**	**187**	**14.4**	**4.7**
Canada Goose	0	0	6	6	2	21	35	3	45	0	34	2	0	154	11.8	4.5
Greater White-fronted Goose	0	0	0	0	0	0	0	0	0	0	0	12	0	12	0.9	0.9
Mute Swan	0	0	0	0	0	0	0	0	0	0	7	13	1	21	1.6	1.1

Appendix C. Continued.

South Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Gulls	**203**	**372**	**163**	**132**	**3**	**1**	**6**	**9**	**62**	**310**	**326**	**201**	**165**	**1953**	**150.2**	**36.2**
California Gull	22	43	30	53	0	1	1	3	2	2	102	0	3	262	20.2	8.5
Glaucous Gull	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0.2	0.2
Glaucous-winged Gull	0	0	0	10	0	0	0	0	0	0	0	0	0	10	0.8	0.8
Herring Gull	20	208	54	12	0	0	0	0	0	42	56	79	9	480	36.9	16.1
Mew Gull	0	37	16	0	0	0	0	0	0	0	0	0	0	53	4.1	3.0
Ring-billed Gull	2	23	25	5	3	0	0	2	52	237	136	103	149	737	56.7	21.1
Western Gull	159	58	38	52	0	0	5	4	8	29	32	19	4	408	31.4	12.0
Herons	**1**	**9**	**1**	**0**	**2**	**1**	**3**	**3**	**27**	**29**	**15**	**11**	**10**	**112**	**8.6**	**2.7**
Great Blue Heron	0	1	0	0	0	0	1	2	5	1	1	2	3	16	1.2	0.4
Great Egret	0	7	1	0	1	1	2	1	15	13	7	2	5	55	4.2	1.4
Snowy Egret	1	1	0	0	1	0	0	0	7	15	7	7	2	41	3.2	1.3
Medium Shorebirds	**622**	**2**	**118**	**35**	**17**	**11**	**177**	**7**	**236**	**551**	**489**	**751**	**926**	**3942**	**303.2**	**89.8**
American Avocet	572	0	108	9	0	3	6	0	0	50	345	424	384	1901	146.2	57.2
Black-bellied Plover	1	0	2	15	11	0	4	0	69	70	4	61	191	428	32.9	15.2
Black-necked Stilt	12	0	0	0	0	0	0	0	0	0	0	0	0	12	0.9	0.9
Greater Yellowlegs	0	1	1	3	0	0	0	0	2	0	1	1	1	10	0.8	0.3
Killdeer	0	1	5	1	0	1	7	4	4	0	6	1	5	35	2.7	0.7
Long-billed Curlew	8	0	0	0	0	0	0	0	0	1	1	2	3	15	1.2	0.6
Lesser Yellowlegs	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0.2	0.2
Marbled Godwit	29	0	0	0	0	0	115	0	52	173	21	60	117	567	43.6	16.0
Whimbrel	0	0	0	0	0	0	0	0	0	1	1	1	0	3	0.2	0.1
Willet	0	0	2	7	6	7	45	3	109	256	110	201	223	969	74.5	26.5
Phalaropes	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**0.2**	**0.1**
Red-necked Phalarope	0	0	0	0	**0**	0	1	1	0	0	0	0	0	2	0.2	0.1

Appendix C. Continued.

South Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Raptors	**1**	**3**	**2**	**4**	**1**	**3**	**1**	**1**	**6**	**1**	**0**	**2**	**2**	**27**	**2.1**	**0.4**
Burrowing Owl	1	1	1	0	0	0	0	0	0	0	0	0	0	3	0.2	0.1
Northern Harrier	0	0	0	0	1	0	0	0	0	1	0	0	0	2	0.2	0.1
Osprey	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1	0.1
Peregrine Falcon	0	2	0	0	0	0	0	0	0	0	0	1	1	4	0.3	0.2
Red-tailed Hawk	0	0	1	2	0	0	0	1	0	0	0	0	1	5	0.4	0.2
Turkey Vulture	0	0	0	1	0	3	0	0	6	0	0	0	0	10	0.8	0.5
White-tailed Kite	0	0	0	1	0	0	0	0	0	0	0	1	0	2	0.2	0.1
Small Shorebirds	**964**	**406**	**0**	**21**	**1763**	**0**	**0**	**2702**	**1341**	**2403**	**5558**	**15112**	**16090**	**46360**	**3566.2**	**1544.0**
Long- and Short-billed Dowitcher	0	0	0	0	0	0	0	0	0	0	0	2	21	23	1.8	1.6
Dunlin	284	260	0	0	1377	0	0	0	0	2	1032	3059	5255	11269	866.8	440.8
Least Sandpiper	80	71	0	21	0	0	0	2702	930	27	1069	1576	1409	7885	606.5	240.3
Semipalmated Plover	48	42	0	0	61	0	0	0	7	43	105	29	61	396	30.5	9.2
Western Sandpiper	552	33	0	0	325	0	0	0	404	2331	3352	10446	9344	26787	2060.5	1007.9
Terns	**1**	**36**	**2**	**0**	**5**	**2**	**3**	**0**	**3**	**0**	**0**	**3**	**0**	**55**	**4.2**	**2.7**
Caspian Tern	0	0	0	0	5	0	0	0	1	0	0	0	0	6	0.5	0.4
Forster's Tern	1	36	2	0	0	0	0	0	0	0	0	3	0	42	3.2	2.7
Least Tern	0	0	0	0	0	2	3	0	2	0	0	0	0	7	0.5	0.3

Appendix D. Total number of birds detected at the North Unit during high tide surveys from Dec. 2010 through Dec. 2011.

North Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Dabbling Ducks	**1572**	**552**	**193**	**206**	**113**	**82**	**171**	**2**	**9**	**1395**	**2131**	**1141**	**1694**	**9261**	**712.4**	**211.3**
American Coot	323	48	32	0	0	0	0	0	0	7	1074	291	325	2100	161.5	84.4
American Green-winged Teal	81	34	0	118	16	0	0	0	0	0	8	135	16	408	31.4	13.3
American Wigeon	732	81	97	2	16	0	0	0	0	2	17	108	1004	2059	158.4	89.4
Gadwall	327	343	60	62	58	70	119	2	7	817	699	543	136	3243	249.5	76.6
Mallard	81	25	4	8	21	10	52	0	2	258	109	32	4	606	46.6	19.9
Northern Pintail	0	0	0	0	2	0	0	0	0	210	0	4	209	425	32.7	21.8
Northern Shoveler	28	21	0	16	0	2	0	0	0	101	224	28	0	420	32.3	17.7
Diving Ducks	**212**	**860**	**83**	**57**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**24**	**435**	**1673**	**128.7**	**70.2**
Bufflehead	0	0	1	0	0	0	0	0	0	0	0	0	3	4	0.3	0.2
Canvasback	76	620	8	47	0	0	0	0	0	0	0	5	64	820	63.1	47.0
Common Goldeneye	1	3	3	0	0	0	0	0	0	0	0	0	0	7	0.5	0.3
Redhead	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0.2	0.2
Ruddy Duck	133	237	71	10	0	0	0	0	0	0	0	19	362	832	64.0	31.7
Greater or Lesser Scaup	0	0	0	0	0	2	0	0	0	0	0	0	6	8	0.6	0.5
Fish-Eaters	**0**	**0**	**1**	**3**	**2**	**0**	**0**	**4**	**4**	**11**	**1**	**0**	**0**	**26**	**2.0**	**0.9**
American White Pelican	0	0	0	0	0	0	0	4	3	9	0	0	0	16	1.2	0.7
Clark's Grebe	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0.1	0.1
Double-crested Cormorant	0	0	0	3	0	0	0	0	1	2	1	0	0	7	0.5	0.3
Western Grebe	0	0	1	0	1	0	0	0	0	0	0	0	0	2	0.2	0.1
Geese	**0**	**13**	**0**	**7**	**6**	**22**	**17**	**10**	**187**	**2**	**2**	**0**	**0**	**266**	**20.5**	**14.0**
Canada Goose	0	13	0	7	6	22	17	10	187	2	2	0	0	266	20.5	14.0

Appendix D. Continued.

North Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Gulls	**2**	**8**	**3**	**0**	**5**	**0**	**2**	**78**	**2**	**27**	**4**	**11**	**7**	**149**	**11.5**	**5.9**
California Gull	0	0	0	0	1	0	2	0	0	18	0	0	4	25	1.9	1.4
Herring Gull	2	0	0	0	0	0	0	0	0	0	0	11	0	13	1.0	0.8
Ring-billed Gull	0	1	3	0	4	0	0	76	1	8	3	0	0	96	7.4	5.8
Western Gull	0	7	0	0	0	0	0	2	1	1	1	0	3	15	1.2	0.6
Herons	**1**	**1**	**1**	**0**	**1**	**0**	**1**	**2**	**2**	**6**	**1**	**0**	**1**	**17**	**1.3**	**0.4**
Great Blue Heron	1	0	0	0	0	0	0	0	1	1	0	0	1	4	0.3	0.1
Great Egret	0	1	1	0	1	0	1	2	1	4	0	0	0	11	0.8	0.3
Snowy Egret	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0.2	0.1
Medium Shorebirds	**65**	**489**	**314**	**114**	**38**	**2**	**0**	**52**	**62**	**220**	**178**	**54**	**13**	**1601**	**123.2**	**39.9**
American Avocet	0	0	0	71	1	2	0	0	0	0	82	0	0	156	12.0	8.0
Black-bellied Plover	65	0	85	0	0	0	0	0	0	23	42	0	0	215	16.5	8.1
Killdeer	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.1	0.1
Long-billed Curlew	0	1	0	6	0	0	0	0	0	2	0	0	0	9	0.7	0.5
Marbled Godwit	0	458	179	26	23	0	0	26	22	46	19	20	0	819	63.0	35.4
Willet	0	30	50	10	14	0	0	26	40	149	35	34	13	401	30.8	10.8
Raptors	**1**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**5**	**2**	**0**	**0**	**0**	**11**	**0.8**	**0.4**
Northern Harrier	1	0	0	0	1	0	0	1	1	0	0	0	0	4	0.3	0.1
Red-tailed Hawk	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.1	0.1
Turkey Vulture	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0.2	0.2
White-tailed Kite	0	0	0	0	0	0	0	0	2	2	0	0	0	4	0.3	0.2
Small Shorebirds	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**0.1**	**0.1**
Dunlin	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.1	0.1
Terns	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0.1**	**0.1**
Caspian Tern	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.1	0.1

Appendix E. Total number of birds detected at the Central Unit during high tide surveys from Dec. 2010 through Dec. 2011.

Central Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Dabbling Ducks	**43**	**69**	**118**	**120**	**57**	**6**	**32**	**0**	**0**	**73**	**97**	**808**	**697**	**2120**	**163.1**	**73.7**
American Coot	2	0	0	0	0	0	0	0	0	0	0	701	460	1163	89.5	62.0
American Green-winged Teal	31	3	0	0	0	0	0	0	0	0	0	0	51	85	6.5	4.4
American Wigeon	0	0	2	0	0	0	0	0	0	0	0	9	4	15	1.2	0.7
Cinnamon Teal	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0.2	0.2
Gadwall	10	61	106	87	4	4	2	0	0	6	17	73	153	523	40.2	14.0
Mallard	0	2	10	0	26	2	30	0	0	60	6	7	2	145	11.2	4.9
Northern Pintail	0	0	0	0	1	0	0	0	0	5	68	0	0	74	5.7	5.2
Northern Shoveler	0	3	0	33	26	0	0	0	0	2	6	18	24	112	8.6	3.3
Diving Ducks	**32**	**63**	**64**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**26**	**186**	**14.3**	**6.7**
Bufflehead	4	3	0	0	0	0	0	0	0	0	0	1	0	8	0.6	0.4
Canvasback	0	47	21	0	0	0	0	0	0	0	0	0	0	68	5.2	3.8
Common Goldeneye	1	0	8	0	0	0	0	0	0	0	0	0	0	9	0.7	0.6
Redhead	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.1	0.1
Ruddy Duck	27	13	33	0	0	0	0	0	0	0	0	0	25	98	7.5	3.5
Greater or Lesser Scaup	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0.2	0.2
Fish-Eaters	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0.2**	**0.2**
Western Grebe	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0.2	0.2
Geese	**0**	**16**	**0**	**0**	**0**	**2**	**0**	**0**	**12**	**0**	**0**	**0**	**0**	**30**	**2.3**	**1.5**
Canada Goose	0	16	0	0	0	2	0	0	12	0	0	0	0	30	2.3	1.5
Gulls	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0.2**	**0.2**
Herring Gull	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.1	0.1
Ring-billed Gull	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.1	0.1
Herons	**2**	**0**	**1**	**1**	**0**	**1**	**1**	**4**	**2**	**1**	**1**	**0**	**0**	**14**	**1.1**	**0.3**
Great Blue Heron	1	0	0	0	0	1	0	1	2	1	1	0	0	7	0.5	0.2
Great Egret	1	0	1	1	0	0	0	3	0	0	0	0	0	6	0.5	0.2
Snowy Egret	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1	0.1

Appendix E. Continued.

Central Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Medium Shorebirds	**0**	**18**	**0**	**838**	**77**	**0**	**0**	**0**	**271**	**191**	**157**	**123**	**101**	**1776**	**136.6**	**63.3**
American Avocet	0	0	0	648	2	0	0	0	188	57	2	39	0	936	72.0	50.2
Black-bellied Plover	0	0	0	1	8	0	0	0	0	5	23	0	1	38	2.9	1.8
Greater Yellowlegs	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.1	0.1
Killdeer	0	0	0	0	0	0	0	0	0	13	3	0	0	16	1.2	1.0
Long-billed Curlew	0	0	0	1	10	0	0	0	2	0	1	0	3	17	1.3	0.8
Marbled Godwit	0	0	0	163	19	0	0	0	59	44	56	18	11	370	28.5	12.8
Willet	0	18	0	24	38	0	0	0	22	72	72	66	86	398	30.6	9.0
Raptors	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0.2**	**0.2**
Red-tailed Hawk	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1	0.1
Turkey Vulture	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1	0.1
Small Shorebirds	**0**	**0**	**0**	**0**	**1377**	**0**	**0**	**9**	**0**	**60**	**189**	**6**	**0**	**1641**	**126.2**	**105.3**
Long- and Short-billed Dowitcher	0	0	0	0	0	0	0	0	0	0	0	6	0	6	0.5	0.5
Dunlin	0	0	0	0	230	0	0	0	0	0	41	0	0	271	20.8	17.7
Least Sandpiper	0	0	0	0	935	0	0	9	0	0	11	0	0	955	73.5	71.8
Semipalmated Plover	0	0	0	0	12	0	0	0	0	1	2	0	0	15	1.2	0.9
Western Sandpiper	0	0	0	0	200	0	0	0	0	59	135	0	0	394	30.3	17.9
Terns	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0.1**	**0.1**
Least Tern	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.1	0.1

Appendix F. Total number of birds detected at the South Unit during high tide surveys from Dec. 2010 through Dec. 2011.

South Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Dabbling Ducks	**237**	**705**	**922**	**1223**	**181**	**68**	**122**	**6**	**5**	**5505**	**6802**	**6848**	**6312**	**28936**	**2225.8**	**808.0**
American Coot	12	153	481	290	43	0	0	0	0	12	2152	5580	5374	14097	1084.4	564.4
American Green-winged Teal	0	0	4	0	0	0	0	0	0	0	264	47	170	485	37.3	23.0
American Wigeon	3	115	190	14	29	0	0	0	0	0	1032	581	449	2413	185.6	87.9
Cinnamon Teal	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.1	0.1
Gadwall	184	321	199	76	0	45	5	0	0	107	192	614	227	1970	151.5	48.2
Mallard	34	28	2	6	67	16	117	6	5	39	56	8	43	427	32.8	9.1
Northern Pintail	4	19	0	0	0	0	0	0	0	5344	2986	16	24	8393	645.6	453.3
Northern Shoveler	0	69	46	837	42	7	0	0	0	3	120	2	24	1150	88.5	63.2
Diving Ducks	**1211**	**102**	**304**	**730**	**674**	**11**	**2**	**0**	**2**	**21**	**654**	**2153**	**2740**	**8604**	**661.8**	**245.9**
Bufflehead	3	12	7	6	0	0	0	0	0	0	0	20	115	163	12.5	8.7
Canvasback	0	3	0	60	0	0	0	0	0	0	0	28	370	461	35.5	28.3
Common Goldeneye	0	0	0	6	1	0	0	0	0	0	1	9	5	22	1.7	0.8
Ruddy Duck	1208	87	286	495	149	5	0	0	0	21	653	2093	2240	7237	556.7	220.9
Greater or Lesser Scaup	0	0	11	163	524	6	2	0	2	0	0	3	10	721	55.5	40.9
Eared Grebes	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**3**	**0.2**	**0.1**
Fish-Eaters	**1**	**8**	**6**	**6**	**10**	**7**	**59**	**8**	**2**	**188**	**62**	**51**	**31**	**439**	**33.8**	**14.3**
American White Pelican	0	0	0	0	0	0	54	3	0	24	27	1	0	109	8.4	4.6
Clark's Grebe	0	0	0	3	1	0	0	0	0	0	0	0	2	6	0.5	0.3
Double-crested Cormorant	1	0	1	1	1	1	2	2	2	164	35	16	10	236	18.2	12.5
Pied-billed Grebe	0	0	0	0	0	0	0	0	0	0	0	24	1	25	1.9	1.8
Red-breasted Merganser	0	0	0	0	0	0	0	0	0	0	0	1	2	3	0.2	0.2
Western Grebe	0	8	4	2	8	6	2	3	0	0	0	9	14	56	4.3	1.2
Western or Clark's Grebe	0	0	1	0	0	0	1	0	0	0	0	0	2	4	0.3	0.2
Geese	**0**	**5**	**0**	**6**	**9**	**30**	**45**	**120**	**8**	**30**	**0**	**116**	**1**	**370**	**28.5**	**11.7**
Canada Goose	0	5	0	6	9	30	45	120	8	30	0	116	1	370	28.5	11.7

Appendix F. Continued.

South Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Gulls	**30**	**90**	**32**	**18**	**34**	**0**	**3**	**58**	**42**	**88**	**29**	**184**	**25**	**633**	**48.7**	**13.6**
California Gull	0	26	0	3	20	0	2	10	9	64	0	43	1	178	13.7	5.5
Glaucous-winged Gull	0	0	0	4	0	0	0	0	0	0	0	0	0	4	0.3	0.3
Herring Gull	14	27	9	7	0	0	0	0	0	7	24	123	21	232	17.8	9.2
Ring-billed Gull	2	0	1	0	5	0	1	48	9	12	3	1	2	84	6.5	3.6
Western Gull	5	37	22	4	9	0	0	0	24	5	2	17	1	126	9.7	3.3
Unidentified Gull	9	0	0	0	0	0	0	0	0	0	0	0	0	9	0.7	0.7
Herons	**6**	**0**	**1**	**1**	**1**	**2**	**3**	**2**	**6**	**15**	**11**	**8**	**4**	**60**	**4.6**	**1.2**
Great Blue Heron	2	0	1	0	0	0	0	2	1	4	6	2	1	19	1.5	0.5
Great Egret	0	0	0	1	0	1	1	0	3	6	3	1	1	17	1.3	0.5
Snowy Egret	4	0	0	0	1	1	2	0	2	5	2	5	2	24	1.8	0.5
Medium Shorebirds	**659**	**329**	**500**	**2119**	**28**	**74**	**14**	**2**	**213**	**407**	**469**	**622**	**673**	**6109**	**469.9**	**153.8**
American Avocet	502	0	0	1552	0	2	14	0	0	20	9	0	5	2104	161.8	122.0
Black-bellied Plover	138	77	500	296	15	4	0	0	168	73	195	229	467	2162	166.3	47.1
Black-necked Stilt	7	0	0	0	0	0	0	0	0	0	0	0	0	7	0.5	0.5
Greater Yellowlegs	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1	0.1
Killdeer	11	2	0	0	0	1	0	2	4	0	0	2	1	23	1.8	0.8
Long-billed Curlew	0	0	0	31	1	0	0	0	3	0	0	0	3	38	2.9	2.4
Lesser Yellowlegs	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0.2	0.2
Marbled Godwit	0	0	0	150	0	4	0	0	18	181	155	113	60	681	52.4	19.7
Willet	0	250	0	90	12	63	0	0	20	133	110	275	137	1090	83.8	26.3
Phalaropes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**2**	**0.2**	**0.2**
Red-necked Phalarope	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0.2	0.2

Appendix F. Continued.

South Unit	2010 Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Monthly	SE
Raptors	**1**	**3**	**1**	**1**	**1**	**0**	**3**	**2**	**2**	**8**	**0**	**1**	**1**	**24**	**1.8**	**0.6**
American Kestrel	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1	0.1
Osprey	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0.1	0.1
Peregrine Falcon	1	0	1	1	0	0	0	0	0	0	0	1	0	4	0.3	0.1
Red-tailed Hawk	0	3	0	0	0	0	0	1	0	1	0	0	1	6	0.5	0.2
Turkey Vulture	0	0	0	0	0	0	2	1	2	7	0	0	0	12	0.9	0.5
Small Shorebirds	**2890**	**81**	**2447**	**1123**	**2625**	**0**	**405**	**110**	**1815**	**1340**	**92**	**70**	**826**	**13824**	**1063.4**	**297.0**
Long- and Short-billed Dowitcher	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0.2	0.2
Dunlin	7	0	2400	288	1208	0	0	0	0	1	92	20	517	4533	348.7	196.1
Least Sandpiper	2375	0	12	200	1044	0	0	90	501	6	0	0	2	4230	325.4	190.4
Semipalmated Plover	382	0	0	0	13	0	0	0	11	75	0	0	0	481	37.0	29.3
Western Sandpiper	126	81	35	635	358	0	405	20	1303	1258	0	50	307	4578	352.2	126.2
Terns	**0**	**0**	**0**	**0**	**9**	**2**	**3**	**2**	**1**	**0**	**0**	**0**	**0**	**17**	**1.3**	**0.7**
Caspian Tern	0	0	0	0	9	0	2	1	0	0	0	0	0	12	0.9	0.7
Least Tern	0	0	0	0	0	2	1	1	1	0	0	0	0	5	0.4	0.2