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San Francisco Estuary Midwinter Waterfowl Survey: 2012 Survey Results and Trend Analysis (1981-2012)

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Executive Summary

Aerial and ground surveys of waterfowl and coots were conducted January 2-14, 2012, in San Francisco Bay, Suisun Bay and selected coastal sites in Marin and Sonoma counties (hereafter 'SF Estuary') as part of the annual nationwide Midwinter Waterfowl Survey (hereafter 'MWS') organized by state and federal agencies. The purpose of the MWS is to assess the distribution of wintering waterfowl and to provide a long-term dataset for assessing wintering population trends. In the Pacific Flyway, the MWS covers major waterfowl concentration areas south of the Canadian border, including parts of Washington, Oregon, California, Arizona, New Mexico, Utah, Colorado, Idaho, Montana and Wyoming (hereafter 'Lower Pacific Flyway'). The SF Estuary survey area included open bays, salt production ponds, ponds managed for waterbird species (managed ponds), sloughs, marshes, inlets, coastal lagoons and other near-coastal waters. A new GPS-enabled aerial survey methodology was piloted in the SF Estuary in 2012 to improve data quality and utility.

The SF Estuary had a large proportion of the Lower Pacific Flyway count for diving ducks (tribes Aythyini, Mergini and Oxyurini): 60% for greater and lesser scaup, 54% for scoter spp., 51% for canvasback, 36% for ruddy duck and 32% for bufflehead. The Estuary is currently a relatively minor wintering area for dabbling ducks (tribe Anatini) and American coots in the Lower Pacific Flyway. The North Bay and South Bay salt production ponds and managed ponds (hereafter 'North Bay Ponds' and 'South Bay Ponds', respectively) had 55% of the waterfowl and coots counted in the SF Estuary in 2012, while the North Bay Open Bay accounted for 28%. Aside from the open bay areas, Don Edwards San Francisco Bay National Wildlife Refuge (NWR) had the highest count of waterfowl/coots observed in the Estuary, followed by Napa-Sonoma Marshes Wildlife Management Area and San Pablo Bay National Wildlife Refuge.

The MWS count for scoter spp. and mallard showed significant negative trends from 1981-2012 for the Lower Pacific Flyway and the SF Estuary. MWS counts for northern pintail, canvasback and scaup spp. exceeded San Francisco Bay Joint Venture (SFBJV) targets in 2012; however, the count for scoter spp. was substantially below the target (target: 41,481 vs. observed: 17,978). The long-term decline in the scoter spp. count from 1981-2012 for the Lower Pacific Flyway and SF Estuary, in addition to the 2012 count being substantially below the SFBJV target, highlights them as a potential species of concern for the Lower Pacific Flyway and the Estuary. Continued monitoring is needed to determine how waterfowl and coots will respond to ongoing tidal marsh restoration projects and threats such as environmental contaminants, human disturbance and climate change in the SF Estuary. The results of this report should be interpreted carefully due to a number of factors that can potentially introduce error into the dataset, including sampling design bias, imperfect detection, inter-observer differences in experience, variation in protocols (e.g., aerial vs. ground surveys) and variation in effort from year to year. In addition, the MWS for the Pacific Flyway does not include western Canada and Alaska, where substantial numbers of waterfowl, particularly diving ducks, are known to overwinter. Recommendations include re-evaluating the SF Estuary sampling design, standardizing the transect width, using correction

factors to account for ground-air differences in detection probability, periodically estimating variation in detection probability between observers, and considering the use of Unmanned Aircraft Systems (UASs) or aerial photography to reduce costs, improve data quality and alleviate safety concerns.

Key Words aerial transect survey, coots, dabbling ducks, diving ducks, geese, managed ponds, midwinter waterfowl survey, salt ponds, San Francisco Estuary, San Pablo Bay, sea ducks, stiff-tailed ducks, Suisun Bay, waterfowl

Introduction

The 2012 SF Estuary MWS was conducted January 2-14, 2012. At a national level, the MWS provides information on the distribution of wintering waterfowl and a long-term dataset for assessing population trends across the four major flyways. For the SF Estuary, the MWS is the primary source of information used to assess the effects of environmental threats (e.g., development, ferry routes, oil spills) and conservation actions such as restoration projects (e.g., tidal marsh restoration) on wintering waterfowl and coots. Prior to 2012, the survey methods used in the SF Estuary did not capture precise spatial locations of individual birds or flocks, which limited the ability to relate waterfowl distribution to environmental variables or management units. This report documents the implementation of an improved survey methodology that included a GPS-enabled data collection system. In addition, the report examines recent trends in waterfowl and coot counts for selected species and provides recommendations for making future improvements to the survey design and methodology.

National Context

The MWS is the oldest operational survey conducted by the U.S. Fish and Wildlife Service (USFWS). Focusing on waterfowl in major wintering concentration areas, this nationwide annual survey was first flown in 1935, but not in the SF Estuary until 1954. Breeding season waterfowl surveys, initiated in 1955, have largely replaced the MWS as the primary source of information for developing waterfowl hunting regulations and evaluating progress toward meeting continental population objectives established by the North American Waterfowl Management Plan (North American Waterfowl Management Plan Committee 2012). However, the MWS remains the primary source of data on the wintering distribution and relative abundance of waterfowl/coots and is still used for setting hunting regulations for some species that breed in remote Arctic locations that are difficult to survey using traditional methods (e.g., tundra swan and brant).

The overall design of the MWS has been criticized because different methods and sampling designs are used in different locations, and the survey is largely based on judgment or representative sampling rather than probability sampling (Eggeman and Johnson 1989, Heusmann 1999). MWS counts are total counts of waterfowl observed in known areas with high waterfowl concentrations. Because low-density areas are typically not surveyed and imperfect

detection probability is not considered, MWS counts should not be used to make inferences about abundance outside of sampled areas nor estimate total waterfowl abundance within a given area. Annual total counts of the same areas can provide an index to temporal changes in populations if it is assumed that: (1) surveyed areas collectively contain a similar proportion of all waterfowl present each year and (2) detection probability remains relatively constant across years. As these assumptions are not usually tested, trends derived from MWS data should be interpreted with caution.

In 2011, the FWS undertook a comprehensive review of the MWS in all four Flyways. The review focused on three issues: (1) assessing the current utility of the data; (2) evaluating survey methodology; and (3) evaluating safety risks and training standards. The draft report from the review found that the most common uses of MWS data in the Pacific Flyway include documenting wintering waterfowl status and distribution, providing public outreach, and obtaining information for winter waterfowl habitat conservation (U.S. Fish and Wildlife Service 2012). Respondents in the Pacific Flyway were mostly in favor of retaining the MWS and viewed it as a medium to high priority compared to other waterfowl monitoring efforts, and a medium priority compared to all wildlife monitoring in their agencies. The draft review identified several important areas of improvement for the MWS, including increased emphasis on statistical design, standardization of methods, improved training, and greater availability of qualified observers and aircraft (U.S. Fish and Wildlife Service 2012).

Regional Context

The SF Estuary is among the most significant coastal wintering and migratory stopover areas along the Pacific Flyway for waterfowl and other waterbirds (San Francisco Bay Joint Venture 2000, North American Waterfowl Management Plan Committee 2012, Cordell 2013). Over twenty species of waterfowl use a variety of habitat types, including tidal marsh, tidal flat, salt production pond, managed and/or breached pond, open bay, tidal slough, lagoon, coastal bay and freshwater marsh, pond and creek. The SF Estuary is a particularly important wintering area for diving ducks (tribes Mergini, Aythyini and Oxyurini; see Appendix A for taxonomic information) and provides habitat for a variety of dabbling ducks (tribe Anatini; see Appendix A). Notwithstanding the large numbers of waterfowl that utilize it, the SF Estuary has been heavily impacted by human activities such as urbanization, pollution, sedimentation and water diversion. Over 80 percent of the tidal marshes and 40 percent of the mudflats that once occupied two-thirds of the Bay's shores have been destroyed or degraded (San Francisco Bay Joint Venture 2000). Furthermore, sea level rise threatens to inundate intertidal ecosystems (Knowles 2010), and there is substantial uncertainty about the level of resilience of tidal marshes and other shoreline ecosystems to this threat.

To address the historical loss and degradation of wetland habitats in the SF Estuary, large wetland restoration projects are underway that have resulted in about 10,000 acres of restored tidal marsh over the last decade (San Francisco Estuary Partnership 2011). This has been accomplished mainly through the conversion of salt production and other managed ponds to tidal

marsh, and there are ambitious plans to restore an additional 50,000 acres of tidal marsh by 2100 (San Francisco Estuary Partnership 2011). Tidal marsh restoration could reduce existing pond acreage by up to 40%, which is expected to negatively impact diving ducks and alter the species composition of waterfowl populations in the estuary (San Francisco Bay Joint Venture 2000). Given the extensive amount of restoration occurring throughout the SF Estuary, its importance to wintering waterfowl and the uncertainties presented by climate change and other environmental threats, long-term monitoring will be critical for evaluating how waterfowl populations respond to environmental changes and for assessing the effectiveness of management interventions aimed at maintaining desired waterfowl populations over time.

SF Estuary MWS data is used for a variety of purposes, including:

1) Assessing the effects of restoration/management activities on waterfowl
   - Evaluating diving duck management objectives identified in the South Bay Salt Pond Restoration Project Adaptive Management Plan (Trulio et al. 2007)
   - Assessing the effects of restoration at Don Edwards San Francisco Bay National Wildlife Refuge (NWR) and San Pablo Bay NWR (C. Strong and M. Marriott pers. comm.)
2) Evaluating impacts of development projects and other human disturbances on waterfowl
   - Assessing impacts of airport runway expansions at San Francisco and Oakland International Airports (J. Takekawa, pers. comm.)
   - Assessing impacts of dredge disposal and channel dredging, new ferry terminal options and ferry routes, America's Cup routes, San Francisco Bay Area Water Trail additions and oil spills on waterfowl (J. Takekawa, pers. comm.)
3) Setting population objectives for conservation plans
   - Establishing San Francisco Bay Joint Venture waterfowl population objectives (see Appendix B; San Francisco Bay Joint Venture 2000, SFBJV Science-subcommittee 2011)
4) Identifying habitat conservation priorities and gaps for waterfowl
   - Identifying habitat conservation priorities for waterfowl across California (Stralberg et al. 2010)
5) Informing harvest regulations for select species
   - Setting harvest regulations for Pacific brant (Pacific Flyway Council 2002)
6) Evaluating long-term trends in the distribution and abundance of waterfowl in response to climate change and other environmental changes
   - Assessing trends in waterfowl abundance for State of the Estuary reports (San Francisco Estuary Partnership 2011)
   - Examining differences in waterfowl community composition between salt production ponds and other bayland habitats (Takekawa et al. 2001)
   - Identifying declines in waterfowl populations in the SF Estuary (Austin et al. 2000)

In 2011, the Region 8 I&M Initiative recognized a need for improvements to the MWS methodology for the SF Estuary. Aerial observers had traditionally used Olympus WS-110 Digital Voice Recorders to record observations of individual birds or flocks by species. The survey unit (pond, marsh, slough, bay, lagoon or transect for open bay units) code or name was recorded by the observer immediately prior to recording a string of waterfowl observations, and the data were later transcribed and entered into an Access database maintained by refuge staff at Don Edwards San Francisco Bay National Wildlife Refuge. The old system had four main problems: (1) errors in the survey unit were difficult to identify without a spatial reference for each data point; (2) missing data for the survey unit were very difficult to correct without a spatial reference; (3) distributions of waterfowl in the open bay were recorded at a very coarse scale because they were only identified to transect, some of which are miles long; and (4) observations of individual birds and flocks lacked precise time stamps, which precluded the ability to examine the effects of time of day or tidal stage on bird distributions. In 2012, the Region 8 I&M Initiative improved the survey methodology by implementing a GPS-enabled data recording system and provided additional observer training with the goal of improving the quality and utility of the data collected. Further details on the new methodology and its benefits are provided in the Methods section below.

Methods

In 2012, the SF Estuary MWS was coordinated by the USFWS (coordinator Cheryl Strong of the San Francisco Bay National Wildlife Refuge Complex) and the California Department of Fish and Wildlife (CDFW; coordinator Melanie Weaver). USFWS coordinated aerial surveys for San Francisco Bay, Suisun Bay (open bay only, excluding Suisun Marsh and Grizzly Island) and the Outer Coast estuaries in Marin and Sonoma counties. The San Francisco Bay Bird Observatory (SFBBO) and the U.S. Geological Survey (USGS) contributed ground count data for 67 South Bay salt production and managed ponds (hereafter ‘ponds’). Thus, these ponds were not surveyed by air. CDFW coordinated aerial surveys of Suisun Marsh, Grizzly Island and the Delta; count data from Suisun Marsh and Grizzly Island are included in the analysis of long-term MWS trends, but not in the detailed results and maps for the SF Estuary in 2012 (see below). Count data from the Delta are not included in any sections of this report.

The MWS is typically scheduled for the first or second week of January in each year by the Pacific Flyway Study Committee. The actual dates of the aerial and ground portions of the survey in the SF Estuary vary year to year due to weather conditions and logistical constraints. In 2012, the survey was conducted January 2-14 in the SF Estuary.

Survey Area

The SF Estuary was divided into three survey regions: the Outer Coast, San Francisco Bay and Suisun Bay (Figure 1). These regions were then subdivided into 12 zones (Table 1 and Figure 1). The Outer Coast region includes Abbotts Lagoon, Bodega Bay, Drakes Estero, Rodeo Lagoon

and Tomales Bay zones. The Suisun Bay region and zone includes the open waters of Suisun Bay but excludes Grizzly Island, Ryer Island and Roe Island. The North Bay Open Bay zone encompasses the open waters of San Pablo Bay. Its boundary with the upstream Suisun Bay region is the Carquinez Bridge. Downstream it abuts the Central Bay Open Bay zone on the western shore at Point San Pedro and on the eastern shore at Point San Pablo. The Central Bay Open Bay zone includes the main body of San Francisco Bay and extends along the western shore from Point San Pedro to the San Mateo Bridge, and along the eastern shore from Point San Pablo to the San Mateo Bridge. The South Bay Open Bay zone includes the southern-most portion of San Francisco Bay. It abuts the Central Bay zone on the western and eastern sides at the San Mateo Bridge. The North Bay Pond and South Bay Pond zones encompass salt production ponds, other managed ponds, sloughs, rivers and marshes (Figure 1).

The Outer Coast and Suisun Bay regions were surveyed using only aerial surveys. The San Francisco Bay region was surveyed using aerial surveys except for 67 ponds in the South Bay Ponds zone where ground count data were used from an ongoing monitoring project conducted by USGS and SFBBO (Figure 1). Ground count data were used because this reduced the required flight time, and ground count data are considered to be more accurate than aerial count data (Pollock and Kendall 1987).

Due to unpredictable weather conditions, not every region or zone is surveyed in each year. Within a zone, aerial transects are not always completed in their entirety due to air traffic restrictions near airports (San Francisco International Airport, Oakland International Airport, Palo Alto Airport, Hayward Executive Airport and Napa County Airport), dense concentrations of gulls near landfills, weather or other hazards. Suitable weather conditions in 2012 allowed for all regions and zones to be surveyed.

Tidal stage

The MWS can be conducted only when weather conditions permit, which is often a narrow temporal window due to winter fog conditions; thus, the survey is not timed to coincide with a particular tidal stage. Prior to 2012, the protocol for the MWS in the SF Estuary did not require surveyors to record the time of each observation of a bird or flock of birds along a transect or within a pond. The new protocol used in 2012 incorporates a time stamp for each observation (see Aerial Surveys below), allowing for time-dependent covariates (i.e., tidal stage and time of day) to be considered in future analyses.

Aerial surveys

Preparation

In preparation for the aerial surveys, a training program was developed to reduce observer variability, improve species identification, increase the accuracy of waterfowl counts and provide training in the use of the new GPS-enabled data collection system. All aerial observers (Table 2) received a pictorial guide to identifying waterfowl from the air and were tested on their ability to

identify San Francisco Bay waterfowl species using a PowerPoint quiz. Observers practiced estimating large numbers of objects using the customized software package 'Wildlife Counts' (Lucid Reverie, LLC, Juneau, AK). The software package generates random single-species flocks of generic ducks, geese or dots but does not include simulations of mixed-species flocks. Observers were trained in the use of the GPS-enabled data collection system by car. All observers participated in at least one of nine training flights that were offered over the course of three days in December 2011. During these training flights, observers practiced identifying waterfowl and estimating flock sizes while experienced observers (Mike Wolder, Chris Nicolai and Joy Albertson, all with USFWS) provided feedback.

Sampling Scheme

We used transects in the open bay zones and North Bay Ponds that had been established in 1987-1988 by Accurso (1992; Figures 1, 2 and 3). The overall layout of the transects in the open bay areas was designed to maximize coverage of the shallower regions of the bay believed to hold most of the estuary's wintering waterfowl (Accurso 1992). Transects in the North Bay Open Bay (17 transects; N2 to N16, N3.5, N4.5) and South Bay Open Bay (41 transects; A00, A1-A19, B00, B1-B20) zones are oriented in an east-west direction and are spaced at approximately 1-km intervals (Figure 2). Transects in Suisun Bay (19 transects; S01-S19) are oriented in a north-south direction and are spaced at approximately 1 km intervals (Figure 3). Two non-linear shoreline transects oriented in a generally north-south direction in the North Bay Open Bay and Central Bay Open Bay, one on the east shore and one on the west shore, were established approximately 0.5 km from the edge of the Bay's intertidal shoreline (Figure 3). Transects in the North Bay Ponds (26 transects; P-01-P26) are spaced at approximately 0.5-km intervals and are oriented in an east-west direction (Figure 2). Transects P3-P9 were extended in 2012 in order to encompass the newly restored Napa Plant Site along the Napa River. Selected ponds, sloughs, marshes, lagoons and bays in the North Bay Ponds, South Bay Ponds and Outer Coast are surveyed by air without fixed transects; these locations are indicated as short, unlabeled transects in Figure 2 and data is collected by site name rather than associated with a transect.

The following locations were not surveyed in 2012: (1) transect B5 was cut short by two tenths of a mile, transect B6 was not surveyed and transect B7 was cut short one mile in the South Bay Open Bay due to San Francisco International Airport traffic; (2) Inner Bair Island was dry and was not surveyed; (3) the southwest edge of Middle Bair Island was dry and was not surveyed; (4) Cooley Landing Restoration was not surveyed; and (5) Baumberg Duck Club was not surveyed. Note: differences in the survey area covered from year to year were not accounted for in the analysis of temporal trends in waterfowl and coot counts presented in the Results section.

Aircraft

A Partenavia twin-engine high-wing six-seat plane was flown by Barry Hansen (Aspen Helicopters, Inc., 2899 West Fifth Street, Oxnard, CA 93030; Phone: 805-985 5416; http://www.aspenhelo.com/) for aerial surveys in the North Bay Open Bay, North Bay Ponds, Central Bay Open Bay, South Bay Open Bay and South Bay Ponds. A fixed-wing single-engine

Cessna 182R was flown by Bob Van Wagenen (Ecoscan Resource Data, 143 Browns Valley Road, Watsonville, CA 95076; Phone: 831-728-5900) for aerial surveys of the Outer Coast region. During surveys, both planes flew at altitudes of approximately 60 m (200 ft) at speeds of approximately 90 knots. Two aerial observers were used for each survey and sat in the second row of seats (behind the pilot). A navigator sat in the front right seat next to the pilot for flights in the San Francisco and Suisun Bay regions (but not the Outer Coast region) to assist with navigation and detecting hazards using detailed paper maps of the survey routes. The navigators played a critical role by keeping the pilot on course and keeping the observers informed of the plane's location, especially in the more complex pond regions. The dates, observers, zones covered and plane type for the 2012 surveys are provided in Table 3.

Waterfowl counts

Waterfowl numbers were determined with direct counts for smaller flocks or by estimation for larger flocks. We assumed that individual birds were not double counted or missed, although this assumption is likely violated to some degree because counts are spaced out over several days; in addition, the transects in the North Bay Ponds zone are quite close together (0.5 km), which could lead to double counting. No adjustments for detection probability or observer bias were made to count values. Counts were also not adjusted to account for birds present in unsampled parts of the SF Estuary.

Species identification

A list of the potential waterfowl and coot species found in the SF Estuary, including common and scientific names, families, sub-families and tribes, are provided in Appendix A. Waterfowl and coots were identified to species except for goldeneye, mergansers, scaup and scoter. Goldeneye were assumed to be predominantly common goldeneye, though Accurso (1992) found up to 1% Barrow's goldeneye. Mergansers included common merganser and red-breasted merganser. Scaup included greater and lesser scaup. Scoters were assumed to be predominantly surf scoters, though Accurso (1992) found up to 1% black and/or white-winged scoters. Waterfowl that could not be identified were recorded as unidentified (e.g., unidentified dabbler, unidentified diver, or unidentified duck). Grebes were not consistently recorded by all observers in 2012, so the counts should be interpreted with caution. When counted, grebes that could not be distinguished, e.g., western and Clark's grebes, were lumped.

Data collection and transcription

In 2012, aerial observers recorded all waterfowl seen from the aircraft using a GPS-enabled data recording system developed by John I. Hodges, U.S. Fish and Wildlife Service, Migratory Bird Management, 3000 Vintage Blvd., Suite 240, Juneau, AK 99801-7100. Each aerial observer had a Dell Latitude D620 laptop running a software package called "Survey Programs" written by Hodges. Bird observations were verbally recorded using a Phillips SpeechMike USB dictation microphone connected to each laptop via a USB cable. Each laptop concurrently received position and temporal data from a Garmin GPSMAP 76 GPS receiver placed on the plane's dashboard. The GPS units and laptops were supplied with power via a DC to AC power inverter

connected to the aircraft's electrical system. Voice recordings were saved to sound files (.wav format) that were linked to a position file containing location, date and time.

After the flights, each observer transcribed their data by playing back the sound files and entering species codes and counts for each observation using a custom transcription program written by Hodges. The transcription program produced an ASCII text file, each line of which contained the species code, count, geographic coordinates, date, time (in seconds since midnight), observer code, observer position in aircraft and survey unit identifier. The system also recorded a "track file" consisting of a list of the aircraft's geographic coordinates every five seconds during flight. The data files were then imported into the MWS Access database maintained by Don Edwards San Francisco Bay National Wildlife Refuge staff (current database manager Cheryl Strong). Access queries were used to extract desired data for the production of maps, tables and other data products developed for this report.

Ground counts

SFBBO and USGS conducted ground counts at a total of 67 ponds in the South Bay Pond zone in January 2012 (Figure 1). During each survey, birds were counted by trained observers using spotting scopes and binoculars from the nearest drivable levee. A list of the observers and their years of experience is provided in Table 2. The location of individual birds and flocks of birds in each pond was recorded using an aerial map superimposed with 250 m^2 individually labeled grids. Birds were identified at the species level whenever possible, with the exception of greater and lesser scaup, which were identified as scaup. When species identification was not possible, birds were identified to genus or foraging guild (e.g., diver vs. dabbler). Ground surveys were conducted exclusively during high tide, defined as a tide of 4.0 feet or greater at the Alameda Creek Tide Sub-Station (37° 35.7' 122°). Ground counts were summed by species for each pond for use in further analyses.

Data analysis

Data collected during aerial surveys in 2012 included date, observer, region, zone, survey unit (pond, slough, marsh, lagoon, bay ID or transect ID), species, count, location (X-Y coordinates) and time. Data collected during ground counts in 2012 included the same information, except bird counts were grouped by pond.

Annual MWS data from 1981-2012 were obtained from Steve Olson, Wildlife Biologist for the Pacific Flyway, Division of Migratory Bird Management, USFWS, 911 NE 11th Ave., Portland, OR 97232; Office (503) 231-6163 FAX (503) 231-6228; Steve_Olson@fws.gov. The Lower Pacific Flyway data for Suisun Bay included Suisun Marsh and Grizzly Island, surveyed by CDFW, in addition to the open bay portion of Suisun Bay, surveyed by USFWS. As the counts from Suisun Marsh and Grizzly Island could not be separated from the rest of Suisun Bay for this historical Flyway dataset, they were included in the analyses of long-term trends but not in the more detailed analyses of 2012 counts and distribution. The Pacific Flyway dataset also combines counts from the Delta in the San Francisco Bay "strata," but we were able to remove

the Delta counts prior to the analysis. Waterfowl distribution maps were created in ArcMap 10 (Environmental Systems Research Institute 2009), and summaries and statistical analyses were conducted using R version 2.12.0 (R Development Core Team 2009).

In this report, MWS counts are considered to be an imperfect index of waterfowl/coot abundance and were used to evaluate the contribution of the SF Estuary to Lower Pacific Flyway total counts. For analysis of trends from 1981-2012, waterfowl count data were analyzed for the Lower Pacific Flyway, the SF Estuary as a whole, and by region (San Francisco Bay, Suisun Bay and Outer Coast). Analyses of long-term trends were limited to eleven species or species groups with adequate data, including five dabbling duck species (American wigeon, gadwall, mallard, northern pintail and northern shoveler), five diving duck species (bufflehead, canvasback, ruddy duck, scaup spp. and scoter spp.) and American coots. Trends in total dabbling and diving duck counts were also analyzed. The species included in the dabbling duck and diving duck guilds are provided in Appendix A. Descriptive statistics such as total counts and percentages were used to summarize waterfowl use over time and by region. Kendall's tau nonparametric test was used to determine whether time-series trends in count data were statistically significant at a p-value of 0.05 (Kendall and Gibbons 1990, Chandler and Scott 2011). Note that Kendall's tau statistic is a test of monotonic trends (singular direction with time), thus smaller-scale shifts in abundance within the period of record might result in signal noise that precludes accurate detection of trends over longer time periods. A nonparametric regression technique called locally weighted scatterplot smoothing (Loess) was used to help visualize trends in abundance (Chandler and Scott 2011). Distribution maps were generated for the 2012 data using X-Y coordinates of individual birds or flocks for the aerial data and X-Y coordinates of pond centroids for ground count data, where counts for each species were summed for each pond.

Results

2012 Summary

A total of 381,301 waterfowl and coots were counted in the SF Estuary during the MWS in 2012, excluding Suisun Marsh, Grizzly Island and the Delta, comprising eighteen species and four species groups (Table 4). Of these, 104,137 were dabbling ducks, 228,581 were diving ducks, 1,046 were geese and swans, 7,924 were grebes and 35,477 were American coots (Table 4). The three zones with the highest counts of waterfowl and coots in the SF Estuary were the South Bay Ponds (153,196 or 40.2%), North Bay Open Bay (108,325 or 28.4%) and North Bay Ponds (57,954 or 15.2%; Table 4).

Dabbling ducks

Total counts for dabbling ducks included the sum of counts for American wigeon, cinnamon teal, gadwall, green-winged teal, mallard, northern pintail, northern shoveler and unidentified dabbling ducks. There was no evidence for trends in total January dabbling duck counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.09; p-value=0.49) or the SF

Estuary (Mann-Kendall test; τ= -0.20; p-value=0.12; Figure 9A). Among the Estuary's regions from 1981-2012, dabbling ducks were usually most abundant in Suisun Bay and occasionally more abundant in San Francisco Bay (Figure 9B). A total of 104,137 dabbling ducks were counted in the SF Estuary in January 2012, excluding Suisun Marsh, Grizzly Island and the Delta (Table 4), representing 2% of the dabbling ducks counted in the Lower Pacific Flyway and 27% of the waterfowl/coots counted in the SF Estuary. In 2012, dabbling ducks were distributed primarily in the North and South Bay ponds (Figure 9C). Detailed results are presented below for the five most abundant dabbling ducks: American wigeon, gadwall, mallard, northern pintail and northern shoveler.

American wigeon

There was no evidence of a trend in January American wigeon counts from 1981-2012 for either the Lower Pacific Flyway (Mann-Kendall test; τ=0.21; p-value=0.09) or the SF Estuary (Mann-Kendall test; τ=0.12; p-value=0.36; Figure 4A). Among the Estuary's regions, American wigeon were most abundant in San Francisco Bay in the early 1980s, Suisun Bay through the late 1990s and San Francisco Bay for most of the 2000s (Figure 4B). A total of 19,988 American wigeon were counted in the SF Estuary in January 2012 (Table 4; 25,440 including Suisun Marsh and Grizzly Island), representing 3% of the American Wigeon counted in the Lower Pacific Flyway and 5% of the waterfowl/coots counted in the SF Estuary. In 2012, American wigeon were distributed throughout the North and South Bay ponds and on the Outer Coast (Figure 4C). The largest concentrations were in the South Bay Ponds (12,720 or 64%; Table 4 and Figure 17A).

Gadwall

There were significant positive trends in January gadwall counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.60; p-value<0.001) and the SF Estuary (Mann-Kendall test; τ=0.34; p-value=0.01; Figure 5A). Among the Estuary's regions from 1981-2012, gadwall were more abundant in San Francisco Bay and Suisun Bay than in the Outer Coast (Figure 5B). A total of 2,661 gadwall were counted in the SF Estuary in January 2012 (Table 4; 5,758 including Suisun Marsh and Grizzly Island), representing 2% of the gadwall counted in the Lower Pacific Flyway and <1% of the waterfowl/coots counted in the SF Estuary. In 2012, gadwall were distributed mainly in the North and South Bay ponds (Figure 4C). Their largest concentrations were in the North Bay Ponds (1,405 or 53%; Table 4 and Figure 17A).

Mallard

There were significant negative trends in January mallard counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ= -0.54; p-value<0.001) and the SF Estuary (Mann-Kendall test; τ= -0.19; p-value=0.013; Figure 6A). Among the Estuary's regions from 1981-2012, mallards were usually most abundant in Suisun Bay (Figure 6B). A total of 1,672 mallards were counted in the SF Estuary in January 2012 (Table 4; 4,646 including Suisun Marsh and Grizzly Island), representing <1% of the mallards counted in the Lower Pacific Flyway and <1% of the waterfowl/coots counted in the SF Estuary. In 2012, mallards were distributed mainly in the

North and South Bay ponds and on the western and northern edges of the North Bay Open Bay (Figure 6C). The largest concentrations were in the North Bay Open Bay (905 or 54%; Table 4 and Figure 17A).

Northern pintail

There was a significant positive trend in January northern pintail counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.25; p-value=0.05) and a negative trend for the SF Estuary (Mann-Kendall test; τ= -0.36; p-value<0.001; Figure 7A). Among the Estuary's regions from 1981-2012, northern pintails were usually most abundant in Suisun Bay (Figure 7B). A total of 21,964 northern pintail were counted in the SF Estuary in January 2012 (Table 4; 24,046 including Suisun Marsh and Grizzly Island), representing 1% of the northern pintail counted in the Lower Pacific Flyway and 6% of the wintering waterfowl/coots counted in the SF Estuary. In 2012, northern pintail were distributed mainly in the North and South Bay salt ponds and in the North Bay Open Bay region (Figure 7C). The largest concentrations were in the South Bay Ponds (11,848 or 54%) and North Bay Open Bay (5,059 or 23%; Table 4 and Figure 17A).

Northern shoveler

There was a significant positive trend in January northern shoveler counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.54; p-value<0.001) and no significant trend for the SF Estuary (Mann-Kendall test; τ= -0.07; p-value=0.59; Figure 8A). Among the Estuary's regions from 1981-2012, northern shovelers were most abundant in Suisun Bay and San Francisco Bay (Figure 8B). A total of 54,082 northern shovelers were counted in the SF Estuary in January 2012 (Table 4; 63,386 including Suisun Marsh and Grizzly Island), representing 7% of the northern shovelers counted in the Lower Pacific Flyway and 14% of the waterfowl/coots counted in the SF Estuary. In 2012, northern shovelers were distributed almost exclusively in the North and South Bay ponds (Figure 8C). The largest concentrations were in the South Bay Ponds (37,812 or 70%; Table 4 and Figure 17A).

Diving ducks

Total counts for diving ducks included the sum of counts for bufflehead, canvasback, goldeneye spp., merganser spp., redhead, ruddy duck, scaup spp., scoter spp. and unidentified diver. There was a significant positive trend in total January diving duck counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.52; p-value<0.001) and no evidence of a trend for the SF Estuary (Mann-Kendall test; τ= -0.06; p-value=0.66; Figure 15A). Among the Estuary's regions from 1981-2012, diving ducks were consistently most abundant in San Francisco Bay (Figure 15B). A total of 228,581 diving ducks were counted in the SF Estuary in January 2012, excluding Suisun Marsh and Grizzly Island (Table 4), representing 44% of the divers counted in the Lower Pacific Flyway and 60% of the waterfowl/coots counted in the SF Estuary. In 2012, diving ducks were distributed throughout all regions of the SF Estuary (Figure 15C). Detailed results are presented below for the five most abundant diving ducks: bufflehead, canvasback, ruddy duck, scaup spp. and scoter spp.

Bufflehead

There was a significant positive trend in January bufflehead counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.36; p-value<0.001) and no significant trend for the SF Estuary (Mann-Kendall test; τ=0.08; p-value=0.53; Figure 10A). Among the Estuary's regions from 1981-2012, bufflehead tended to be most abundant either in the Outer Coast or San Francisco Bay (Figure 10B). A total of 15,862 bufflehead were counted in the SF Estuary in January 2012 (Table 4; 15,967 including Suisun Marsh and Grizzly Island), representing 32% of the bufflehead counted in the Lower Pacific Flyway and 4% of the waterfowl/coots counted in the SF Estuary. In 2012, bufflehead were distributed widely across the North and South Bay salt ponds, Central, North and South open bays and the Outer Coast (Figure 10C). The largest concentrations were in the Outer Coast (6,691 or 42%), Central Bay Open Bay (3,751 or 24%) and South Bay Open Bay (2,464 or 16%); Table 4 and Figure 17A).

Canvasback

There was a significant positive trend in January canvasback counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.31; p-value=0.01) and no significant trend for the SF Estuary (Mann-Kendall test; τ=0.12; p-value=0.36; Figure 11A). Among the Estuary's regions from 1981-2012, canvasback were consistently most abundant in San Francisco Bay (Figure 11B). A total of 34,356 canvasback were counted in the SF Estuary in January 2012 (Table 4; 35,906 including Suisun Marsh and Grizzly Island), representing 51% of the canvasback counted in the Lower Pacific Flyway and 9% of the waterfowl/coots counted in the SF Estuary. In 2012, canvasback were distributed mainly in the North and South Bay salt ponds and in the North Bay Open Bay (Figure 11C). The largest concentrations were in the North Bay Open Bay (13,864 or 40%) and North Bay Ponds (11,198 or 33%; Table 4 and Figure 17A).

Ruddy duck

There was no evidence of trends in January ruddy duck counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.22; p-value=0.08) or SF Estuary (Mann-Kendall test; τ=0.11; p-value=0.37; Figure 12A). Among the Estuary's regions from 1981-2012, ruddy ducks were consistently most abundant in San Francisco Bay (Figure 12B). A total of 38,818 ruddy ducks were counted in the SF Estuary in January 2012 (Table 4; 40,393 including Suisun Marsh and Grizzly Island), representing 36% of the ruddy ducks counted in the Lower Pacific Flyway and 10% of the wintering waterfowl/coots in the SF Estuary. In 2012, ruddy ducks were distributed mainly in the North and South Bay salt ponds (Figure 12C). The largest concentrations were in the South Bay Ponds (29,892 or 77%; Table 4 and Figure 17A).

Scaup spp.

There was a significant positive trend in January scaup spp. counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.27; p-value=0.03) and no evidence of a trend for the SF Estuary (Mann-Kendall test; τ=0.04; p-value=0.73; Figure 13A). Among the Estuary's regions from 1981-2012, scaup spp. were consistently most abundant in San Francisco Bay

(Figure 13B). A total of 119,082 scaup spp. were counted in the SF Estuary in January 2012 (Table 4; 119,517 including Suisun Marsh and Grizzly Island), representing 60% of the scaup counted in the Lower Pacific Flyway and 31% of the waterfowl/coots counted in the SF Estuary. In 2012, scaup were distributed mainly in the open bay areas of the Central, North and South bays and in the South Bay Ponds (Figure 13C). The largest concentrations were in the North Bay Open Bay (74,949 or 63%) and South Bay Ponds (20,589 or 17%; Table 4 and Figure 17A).

Scoter spp.

There was a significant negative trend in January scoter spp. counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ= -0.53; p-value<0.001) and a significant negative trend for the SF Estuary (Mann-Kendall test; τ= -0.24; p-value=0.05; Figure 14A). Among the Estuary's regions from 1981-2012, scoter spp. were consistently most abundant in San Francisco Bay (Figure 14B). A total of 17,978 scoter spp. were counted in the SF Estuary in January 2012 (Table 4; 17,978 including Suisun Marsh and Grizzly Island), representing 54% of the scoter spp. counted in the Lower Pacific Flyway and 5% of the waterfowl/coots counted in the SF Estuary. In 2012, scoter spp. were distributed mainly in Central, North and South open bays (Figure 14C). The largest concentrations were in the North Bay Open Bay (8,204 or 46%) and Central Bay Open Bay (4,853 or 27%; Table 4 and Figure 17A).

American coot

There was a significant positive trend in January American coot counts from 1981-2012 for the Lower Pacific Flyway (Mann-Kendall test; τ=0.71; p-value<0.001) and a significant positive trend for the SF Estuary (Mann-Kendall test; τ=0.23; p-value=0.06; Figure 16A). Among the Estuary's regions from 1981-2012, American coots were most abundant in either San Francisco Bay or Suisan Bay in all years (Figure 16B). A total of 35,477 American coots were counted in the SF Estuary in January 2012 (Table 4; 50,454 including Suisun Marsh and Grizzly Island), representing 6% of the American coots counted in the Lower Pacific Flyway and 9% of the waterfowl/coots counted in the SF Estuary. In 2012, American coots were distributed almost exclusively in the North and South Bay salt ponds (Figure 16C). The largest concentrations were in the South Bay Ponds (21,142 or 60%) and North Bay Ponds (13,173 or 37%; Table 4 and Figure 17A).

Geese and swans

A total of 1,046 geese and swans were counted in the SF Estuary in January 2012 (Table 4), excluding Suisun Marsh, Grizzly Island and the Delta, representing <1% of the waterfowl/coots counted in the SF Estuary. All of the brant were counted in the Outer Coast and most of the Canada geese were counted in the South Bay Ponds.

Grebes

A total of 7,924 grebes were counted in the SF Estuary in January 2012 (Table 4), excluding Suisun Marsh, Grizzly Island and the Delta, representing 2% of the waterfowl/coots counted in the SF Estuary. The highest numbers of grebes were counted in the South Bay Ponds (Table 4).

Species counts and composition by region

By region, the South Bay Ponds had the highest total waterfowl and coot counts in 2012 (153,196 or 40%), followed by the North Bay Open Bay (108,325 or 28%), North Bay Ponds (57,954 or 15%), Central Bay Open Bay (23,077 or 6%), Outer Coast (15,981 or 4%), South Bay Open Bay (13,503 or 4%) and Suisun Bay (9,265 or 2%; Table 4). The North and South Bay ponds had fairly mixed species compositions with high representation of both diving and dabbling ducks, while the North, Central, South and Suisun open bays had less diverse species compositions more heavily weighted towards diving ducks (Figure 17B).

Species counts and composition by land ownership/status

The areas surveyed during the MWS are owned by a variety of public and private entities (Figure 19). The California State Lands Commission has jurisdiction and management control over land underlying the State's navigable and tidal waterways. Known as sovereign lands, these lands include the beds of California's navigable rivers, lakes and streams, as well as the state's tide and submerged lands along the State's more than 1,100 miles of coastline and offshore islands from the mean high tide line to three nautical miles offshore. In the San Francisco Estuary, the California State Lands Commission has jurisdiction over the Central, North and South open bays, the Napa River and other navigable rivers and sloughs, Suisun Bay, and the Outer Coast (excluding Bolinas Lagoon, which is owned by the Marin County Open Space District, and Abbotts Lagoon, which is owned by the National Park Service). A portion of the North Bay Open Bay is owned by the California State Lands Commission but leased and managed by the USFWS as part of San Pablo Bay National Wildlife Refuge; count data from this area was included with San Pablo Bay NWR totals. Areas managed by the California State Lands Commission had the largest total count of waterfowl and coots (138,118 or 36.2% of the total count), followed by USFWS (133,908, or 35.1%), CDFW (66,412 or 17.4%), private lands (26,495 or 6.9%) and other (16,368 or 4.3%; Table 5). Among protected areas, Don Edwards San Francisco Bay NWR had the largest total count of waterfowl and coots (101,899 or 26.7% of the total count), followed by Napa-Sonoma Marshes Wildlife Management Area (53,069 or 13.9%), San Pablo Bay NWR (32,009 or 8.4%) and Eden Landing Ecological Reserve (13,343 or 3.5%; Table 5 and Figure 18).

Discussion

Based on long-term MWS counts at major waterfowl concentration areas in the Lower Pacific Flyway, the SF Estuary has continued to be a major waterfowl wintering area, particularly for diving ducks, since at least the 1980s. This is consistent with Accurso's findings (1992). In

January 2012, the SF Estuary had large proportions of the scaup spp., scoter spp., canvasback, ruddy duck and bufflehead counted in the Lower Pacific Flyway. In contrast, the SF Estuary had much smaller proportions of the dabbling ducks counted.

The long-term decline in MWS counts of scoter spp. from 1981-2012 for the Lower Pacific Flyway and SF Estuary, in addition to their low counts relative to the SFBJV target, highlights them as a potential species of concern for the Flyway and the Estuary. Other studies in the Pacific Flyway have documented scoter declines. For example, from 1957-94, breeding season scoter spp. counts declined by 40% in Alaska (Hodges et al. 1996). Scoter declines in the Pacific Flyway have been associated with environmental contaminants, climatic regime shifts and declining fish stocks (Henny et al. 1995, Agler et al. 1999, Barjaktarovic et al. 2002). Based on Accurso's (1992) findings, we assumed that most of the scoter spp. observed in 2012 were surf scoters. However, the species composition of this group should be periodically reassessed, along with the species compositions of goldeneye spp. and scaup spp. Given their concentrations primarily in the open bay and outer coast regions, management actions are more limited for scoter spp. than for waterfowl that commonly utilize state- and federally-managed ponds. A recent study documented a greater contribution of soft-bodied prey to surf scoter diets than had previously been recognized implying that standing stocks of bivalves should not be the only consideration when prioritizing critical foraging sites for conservation efforts (Anderson et al. 2008).

While scaup spp. counts showed a significant positive trend for the the Lower Pacific Flyway from 1981-2012 and no significant trend for the SF Estuary over this period, counts from 2000-2012 appear to be declining in the Estuary (Figure 13A). The North American continental population of lesser scaup went through a period of decline during the 1980s, possibly due to lower recruitment of juvenile scaup into the fall population (Austin et al. 2000, Afton and Anderson 2001). This highlights greater and lesser scaup as potential species of concern for the SF Estuary.

Public lands and waters had the largest numbers of wintering waterfowl and coots in January 2012. The North Bay Open Bay, Don Edwards San Francisco Bay NWR, Napa-Sonoma Marshes Wildlife Management Area and San Pablo Bay NWR were particularly important sites for wintering waterfowl, highlighting the importance of public lands and waters to wintering waterfowl. Continued monitoring is needed to assess the benefits and impacts of tidal marsh restoration and environmental threats on the distribution and abundance of waterfowl, especially in light of the importance of managed and salt production ponds to waterfowl.

The SF Estuary MWS survey methods were greatly improved in 2012. The new GPS-enabled data collection system allowed fine-scaled spatial data with time stamps to be collected. This dataset can be used in the future to examine fine-scaled shifts in waterfowl distribution and waterfowl-habitat relationships. Additional aerial survey training conducted in December 2011 allowed experienced observers to gain a refresher and new observers to be trained, thus reducing

observer bias. This type of dedicated training time should be conducted on a regular basis (i.e., no less frequently than every 3 years).

The following improvements are recommended for the MWS training program:

1) Better aerial photographs and/or videos are needed of all waterfowl species at the MWS altitude (approximately 60 m);
2) A threshold level of accuracy should be established for flock size estimation; and
3) An annual test should be developed for all observers that combines species identification and flock size estimation using photographs and/or videos.

Despite improvements to the SF Estuary survey methods in 2012, MWS count data for the SF Estuary and the Lower Pacific Flyway should be interpreted carefully for several reasons. First, the MWS does not include western Canada or Alaska where some waterfowl, particularly sea ducks, overwinter in substantial numbers (Kraege and Hodges 2011). Thus, apparent declines in sea duck (i.e., scoter) counts in the SF Estuary could be caused by population declines or by more birds overwintering further to the north. Furthermore, within the states covered by the Lower Pacific Flyway MWS, the surveyed locations were selected using judgment or convenience sampling rather than probabilistic sampling, potentially biasing results. Analyses of MWS data typically don't take detection probability into account, even though detectability during aerial counts is known to be lower, on average, than during ground counts (Smith 1995). MWS counts are likely to have high inter-observer variability due to differences in experience, training and ability to accurately estimate large flock sizes among observers. Finally, survey effort varies from year to year depending on funding, adding noise to the data and potentially skewing trend estimates. Thus, any management decisions made using data from this report should be made in consultation with local USFWS personnel who have knowledge of the specific limitations of this dataset.

Specific issues with the current SF Estuary sampling design and methods include:

1) The current sampling design of the SF Estuary MWS provides reasonable coverage of ponds, shallow regions of the open bay and selected locations on the outer coast—areas believed to hold most of the estuary's wintering waterfowl (Accurso 1992). Nevertheless, the sampled areas in the Outer Coast region and South Bay Pond zones were selected using judgment sampling, a nonrandom approach based on expert opinion, which can introduce bias in abundance and trends estimates. Open Bay transects were established using systematic sampling. However, without coverage of deeper regions of the open bay, inferences cannot be drawn about abundance in these areas. While deeper areas may have few or no waterfowl now, it is still important to determine average densities for low-density areas and maintain the ability to detect shifts in bird use due to climate change, restoration, etc. into the future. North Bay Pond transects were also established using systematic sampling, but the transects are spaced at 0.5 km vs. 1.0 km for Open Bay

transects. This difference in transect spacing is not accounted for when total counts are reported.

2) Aerial observers are not given consistent guidance about the transect width, thus bird densities cannot reliably be estimated and there is a risk of double counting; e.g., transects in the North Bay Salt Pond zone are spaced 500 m apart, and observers could be double counting birds if they include flocks farther than 250 m from the plane.
3) Selected areas in the North Bay Ponds, South Bay Ponds and Outer Coast are not sampled consistently from year to year due to a lack of fixed aerial transects.
4) Some regions (particularly Suisun Bay and the Outer Coast), transects or portions of transects are not surveyed every year due to fluctuating budgets, poor weather, air traffic constraints, etc. yet counts are not adjusted for survey effort.
5) Counts are not adjusted to account for different survey methodologies (e.g., ground vs. air) or observer experience.
6) There is no established procedure for altering the sampling scheme in response to changes in pond/slough/marsh configuration from several large-scale restoration projects that are underway (e.g., South Bay Salt Pond Restoration Project).

In summary, the current sampling design is a mixture of judgment and systematic sampling where the systemic portion of the survey suffers from a lack of standardization of transect width and spacing. As a result, it is difficult to extrapolate from the sampled areas to arrive at total estimates for the entire Estuary, and, as a result, only raw counts are currently reported. These raw counts are surely underestimates of the real abundances. Several improvements could be made to the current survey design and methods to improve efficiency and enable the survey to provide a reliable estimate of waterfowl abundance. The following improvements to the sampling design and survey methods are recommended:

1) A working group should be established to reevaluate the SF Estuary sampling design. The new design should avoid judgment sampling in favor of systematic sampling. Areas expected to have high and low densities of waterfowl should be delineated and sampling should be stratified within these areas. Historical data should be analyzed to determine if less intensive sampling designs are feasible while still meeting objectives for population and distribution monitoring and while minimizing risks to pilots and aerial observers. Areas expected to have lower densities of waterfowl could be sampled at a lower intensity than areas expected to have high densities of waterfowl. Additional analysis and optimization is necessary to ensure that the new sampling scheme would meet the needs of local applications (e.g., refuge-scale information needs). The sampling design should include a procedure for adapting to changes in pond/slough/marsh configuration over time. Clear procedures should be developed for extrapolating Estuary-wide abundance estimates (with standard errors) based on the sampled regions. This revision of the sampling design should be carried out in coordination with the Pacific Flyway study committee, CDFW and the San Francisco Bay and Central Valley Joint Ventures.

2) A standard transect width should be established and the aircraft windows should be marked to ensure that observers are counting flocks out to the same distance. We recommend a strip transect width of 400 m (200 m from each side of the plane) to reduce the probability of double counting. This is the transect width used during waterfowl breeding population surveys (Smith 1995). In future years, guiding marks should be used on the planes' wings to help observers with this distance estimate.
3) A correction factor should be used to account for different survey methodologies (aerial surveys vs. ground counts). Aerial counts should be adjusted to reflect the lower detection probability expected from this survey method. A ground-air correction factor was developed as part of a recent study comparing simultaneous ground and aerial waterfowl counts in South Bay Ponds (Burns et al. 2013).
4) Double-observer surveys should be periodically conducted to estimate variation in detection probability between observers.
5) The high cost of coordinating and implementing the survey and the safety risks inherent to manned aerial surveys remain a significant challenge. The use of aerial photography/videography and Unmanned Aircraft Systems (UAS) should be investigated as alternative survey methods.

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Tables

Table 1. Regions and zones for the San Francisco Estuary Midwinter Waterfowl Survey.

Region	Zone
Outer Coast	Abbotts Lagoon
	Bodega Bay
	Bolinas Lagoon
	Drakes Estero
	Rodeo Lagoon
	Tomales Bay
San Francisco Bay	Central Bay Open Bay
	North Bay Open Bay
	North Bay Ponds
	South Bay Open Bay
	South Bay Ponds
Suisun Bay	Suisun Bay

Table 2. Observers who participated in the 2012 Midwinter Waterfowl Survey (name, affiliation, survey type and number of years of previous experience conducting aerial or ground waterfowl counts).

Observer name	Affiliation	Survey type	Previous experience (# of years)
Christina Sloop	SFBJV	Aerial	0
Diane Kodama	USFWS	Aerial	12
Joy Albertson	USFWS	Aerial	19
Len Liu	PRBO Conservation Science	Aerial	0
Orien Richmond	USFWS	Aerial	0
Susan De La Cruz	USGS	Aerial	10
Annie Schultz	USGS	Ground	8
Josh Scullen	SFBBO	Ground	3
Katharine Lovett	USGS	Ground	2.5
Laurel Ann Curry	USGS	Ground	1.5
Sara Pottier	USGS	Ground	5
Sharon Dulava	USFWS	Ground	0
Stacy Moskal	USGS	Ground	7
Tanya Graham	USGS	Ground	4
Vivian Bui	USGS	Ground	1

Table 3. Survey type, date, observer, zone and plane type for the 2012 San Francisco Estuary Midwinter Waterfowl Survey.

Survey type	Dates	Observers	Zones	Plane type
Aerial	1/2/2012	Len Liu Christina Sloop	Abbotts Lagoon, Bodega Bay, Bolinas Lagoon, Drakes Estero, Rodeo Lagoon, Tomales Bay	Single-engine Cessna
Aerial	1/4/2012	Diane Kodama Susan De La Cruz	Central Bay Open Bay, North Bay Open Bay, South Bay Open Bay	Partenavia
Aerial	1/5/2012	Joy Albertson Orien Richmond	North Bay Ponds, South Bay Ponds, Suisun	Partenavia
Ground	1/3/2012	Josh Scullen	South Bay Ponds	n/a
Ground	1/4/2012	Stacy Moskal Sara Pottier Josh Scullen Tanya Graham	South Bay Ponds	n/a
Ground	1/5/2012	Sarah Pottier Annie Schultz Vivian Bui Laurel Ann Curry Katharine Lovett Josh Scullen	South Bay Ponds	n/a
Ground	1/6/2012	Sharon Dulava Annie Schultz Vivian Bui Stacy Moskal Sara Pottier Katharine Lovett Laurel Ann Curry Josh Scullen	South Bay Ponds	n/a
Ground	1/9/2012	Katharine Lovett Josh Scullen	South Bay Ponds	n/a
Ground	1/12/2012	Josh Scullen	South Bay Ponds	n/a
Ground	1/14/2012	Stacy Moskal	South Bay Ponds	n/a

Table 4. Number of waterfowl and coots counted by area in the San Francisco Estuary Midwinter Waterfowl Survey in January 2012.

Species/species group	Outer Coast	Central Bay Open Bay	North Bay Open Bay	North Bay Ponds	South Bay Open Bay	South Bay Ponds	Suisun Bay Open Bay	Total	%
Dabbling ducks									
American wigeon	2358	390	600	3635	84	12720	201	**19988**	5.2
Cinnamon teal	0	0	0	45	0	0	0	**45**	0.0
Gadwall	25	153	438	1405	218	422	0	**2661**	0.7
Green-winged teal	50	0	0	770	0	1234	0	**2054**	0.5
Mallard	65	80	905	141	31	450	0	**1672**	0.4
Northern pintail	208	100	5059	4425	324	11848	0	**21964**	5.8
Northern shoveler	555	396	157	14478	679	37812	5	**54082**	14.2
Unidentified dabbling duck	30	50	1570	0	21	0	0	**1671**	0.4
Total dabbling ducks	***3291***	***1169***	***8729***	***24899***	***1357***	***64486***	***206***	***104137***	***27.3***
Diving ducks									
Bufflehead	6691	3751	1092	280	2464	1205	379	**15862**	4.2
Canvasback	77	83	13864	11198	269	8260	605	**34356**	9.0
Goldeneye spp.[1]	11	351	47	0	117	807	1	**1334**	0.3
Merganser spp.[2]	0	2	0	0	0	95	0	**97**	0.0
Redhead	0	0	0	385	0	433	0	**818**	0.2
Ruddy duck	285	1317	544	5355	726	29892	699	**38818**	10.2
Scaup spp.[3]	1283	9592	74949	62	5793	20589	6814	**119082**	31.2
Scoter spp.[4]	2748	4853	8204	0	2147	26	0	**17978**	4.7
Unidentified diving duck	0	125	100	0	0	11	0	**236**	0.1
Total diving ducks	***11095***	***20074***	***98800***	***17280***	***11516***	***61318***	***8498***	***228581***	***59.9***
Unidentified ducks	***150***	***31***	***84***	***2250***	***41***	***1460***	***120***	***4136***	***1.1***
Total ducks	***14536***	***21274***	***107613***	***44429***	***12914***	***127264***	***8824***	***336854***	***88.3***

[1] Assumed to be predominantly common goldeneye; Accurso (1992) found <1% Barrow's goldeneye
[2] Includes common merganser and red-breasted merganser
[3] Includes greater and lesser scaup
[4] Assumed to be predominantly surf scoter; Accurso (1992) found <1% white-winged scoter and/or black scoter

Species/species group	Outer Coast	Central Bay Open Bay	North Bay Open Bay	North Bay Ponds	South Bay Open Bay	South Bay Ponds	Suisun Bay Open Bay	Total	%
Geese and swans									
Brant	560	0	0	0	0	0	0	**560**	0.1
Canada goose spp.	0	0	0	90	0	368	25	**483**	0.1
Swan spp.	0	0	0	3	0	0	0	**3**	0.0
Total geese and swans	***560***	***0***	***0***	***93***	***0***	***368***	***25***	***1046***	***0.3***
Grebes									
Eared grebe	0	25	0	0	0	3895	0	**3920**	1.0
Pied-billed grebe	0	0	0	0	0	241	0	**241**	0.1
Unidentified grebe	95	73	19	0	0	42	0	**229**	0.1
Western/Clark's grebe	0	1655	668	259	589	244	119	**3534**	0.9
Total grebes	***95***	***1753***	***687***	***259***	***589***	***4422***	***119***	***7924***	***2.1***
Total waterfowl	***15191***	***23027***	***108300***	***44781***	***13503***	***132054***	***8968***	***345824***	***90.7***
Coots									
American coot	790	50	25	13173	0	21142	297	**35477**	9.3
Total waterfowl and coots	***15981***	***23077***	***108325***	***57954***	***13503***	***153196***	***9265***	***381301***	***100.0***
%	4.2	6.1	28.4	15.2	3.5	40.2	2.4	**100.0**	

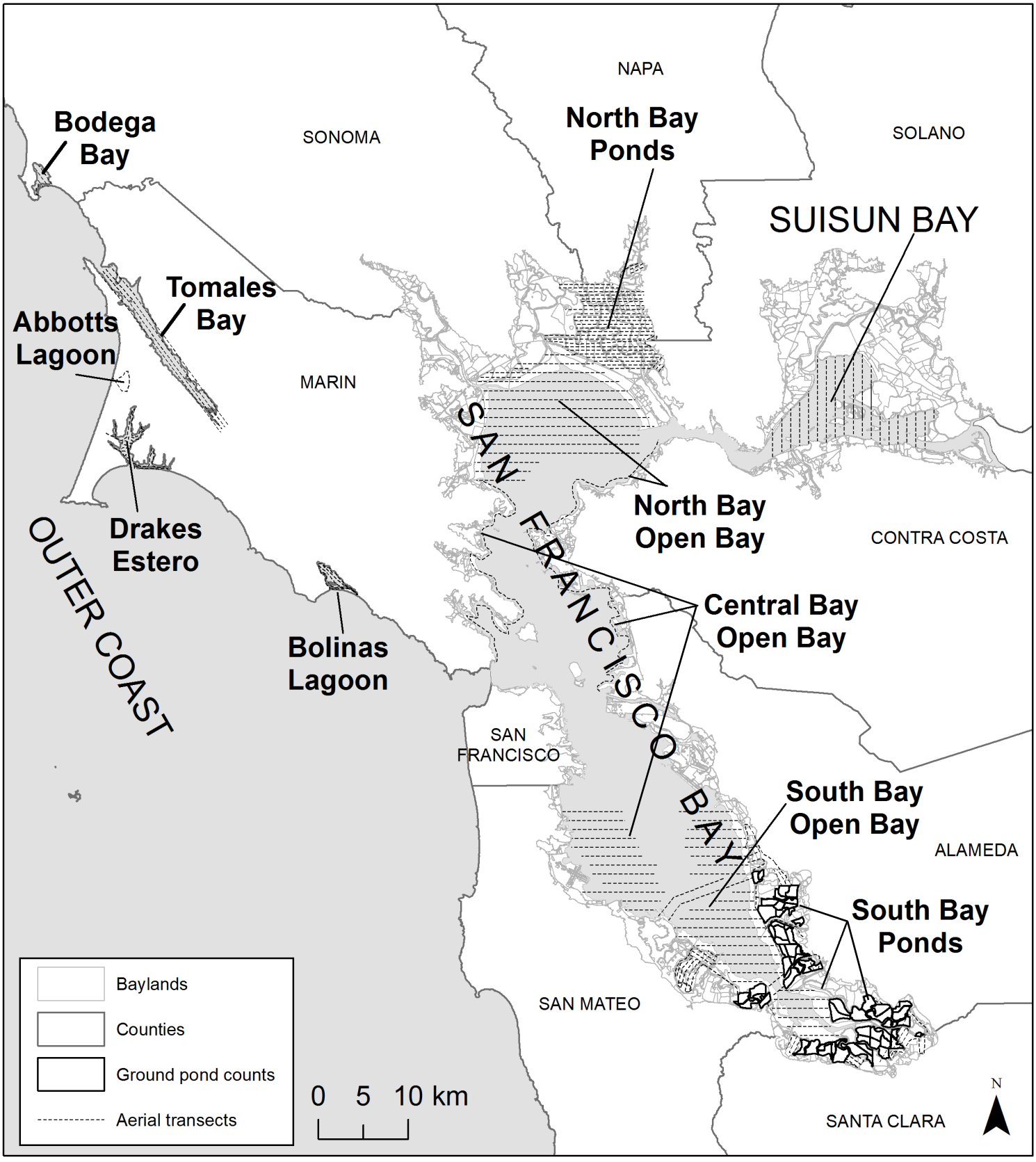
Table 5. Number of waterfowl and coots counted by land ownership/status in the SF Estuary Midwinter Waterfowl Survey in January 2012.

Species/species group	CA State Lands Commission	Don Edwards SF Bay NWR	Eden Landing Ecol. Res.	Napa-Sonoma Marshes WA	Private	San Pablo Bay NWR	Other	Total FWS	Total CDFW	Total	%
Dabbling Ducks											
American wigeon	2898	5890	1309	3659	2540	307	3385	6197	4968	**19988**	5.2
Cinnamon teal	0	0	0	5	0	0	40	0	5	**45**	0.0
Gadwall	396	342	65	1242	0	433	183	775	1307	**2661**	0.7
Green-winged teal	50	1195	34	770	0	0	5	1195	804	**2054**	0.5
Mallard	433	259	25	51	0	646	258	905	76	**1672**	0.4
Northern pintail	1838	8924	549	4405	1600	3815	833	12739	4954	**21964**	5.8
Northern shoveler	1702	11227	3944	13678	18566	33	4932	11260	17622	**54082**	14.2
Unidentified dabbling duck	111	0	0	0	0	1560	0	1560	0	**1671**	0.4
Total dabbling ducks	***7428***	***27837***	***5926***	***23810***	***22706***	***6794***	***9636***	***34631***	***29736***	***104137***	***27.3***
Diving Ducks											
Bufflehead	13823	820	109	179	200	228	503	1048	288	**15862**	4.2
Canvasback	10596	4893	275	10258	1630	4352	2352	9245	10533	**34356**	9.0
Goldeneye spp.[5]	527	677	122	0	0	0	8	677	122	**1334**	0.3
Merganser spp.[6]	2	91	4	0	0	0	0	91	4	**97**	0.0
Redhead	0	368	65	385	0	0	0	368	450	**818**	0.2
Ruddy duck	3834	23511	6151	4590	50	292	390	23803	10741	**38818**	10.2
Scaup spp.[7]	78190	20244	319	62	2	20201	64	40445	381	**119082**	31.2
Scoter spp.[8]	17940	26	0	0	0	12	7	38	0	**17978**	4.7
Unidentified diving duck	125	11	0	0	0	100	0	111	0	**236**	0.1
Total diving ducks	***125030***	***50641***	***7045***	***15474***	***1882***	***25185***	***3324***	***75826***	***22519***	***228581***	***59.9***
Unidentified duck	440	220	0	1955	500	6	1015	226	1955	**4136**	1.1
Total ducks	***132898***	***78698***	***12971***	***41239***	***25088***	***31985***	***13975***	***110683***	***54210***	***336854***	***88.3***

[5] Assumed to be predominantly common goldeneye; Accurso (1992) found <1% Barrow's goldeneye
[6] Includes common merganser and red-breasted merganser
[7] Includes greater and lesser scaup
[8] Assumed to be predominantly surf scoter; Accurso (1992) found <1% white-winged scoter and/or black scoter

Species/species group	CA State Lands Commission	Don Edwards SF Bay NWR	Eden Landing Ecol. Res.	Napa-Sonoma Marshes WA	Private	San Pablo Bay NWR	Other	Total FWS	Total CDFW	Total	%
Geese and Swans											
Brant	510	0	0	0	0	0	50	0	0	**560**	0.1
Canada Goose	25	16	132	10	0	0	300	16	142	**483**	0.1
Tundra swan	0	0	0	2	0	0	1	0	2	**3**	0.0
Total geese and swans	***535***	***16***	***132***	***12***	***0***	***0***	***351***	***16***	***144***	***1046***	***0.3***
Grebes											
Clark's/western grebe	3205	218	25	63	0	22	1	240	88	**3534**	0.9
Eared Grebe	25	3867	28	0	0	0	0	3867	28	**3920**	1.0
Pied-billed Grebe	0	229	12	0	0	0	0	229	12	**241**	0.1
Unknown grebe	187	42	0	0	0	0	0	42	0	**229**	0.1
Total grebes	***3417***	***4356***	***65***	***63***	***0***	***22***	***1***	***4378***	***128***	***7924***	***2.1***
Total waterfowl	***136850***	***83070***	***13168***	***41314***	***25088***	***32007***	***14327***	***115077***	***54482***	***345824***	***90.7***
Coots											
American coot	1268	18829	175	11755	1407	2	2041	18831	11930	**35477**	9.3
Total waterfowl and coots	***138118***	***101899***	***13343***	***53069***	***26495***	***32009***	***16368***	***133908***	***66412***	***381301***	***100.0***
%	36.2	26.7	3.5	13.9	6.9	8.4	4.3	35.1	17.4	**100.0**	

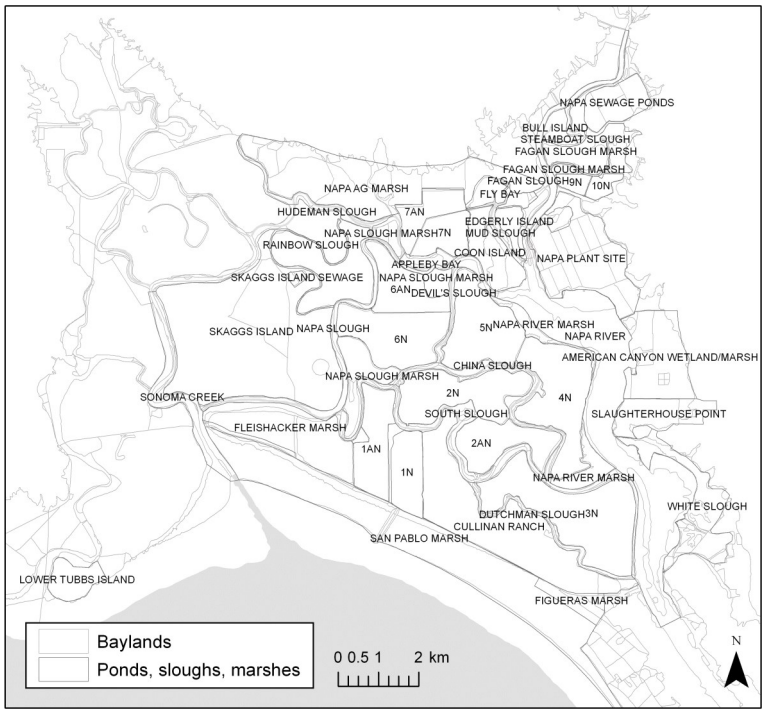
Fig 1. Map of San Francisco Estuary Midwinter Waterfowl Survey regions and zones, including aerial transects and ponds that were surveyed by ground in 2012.



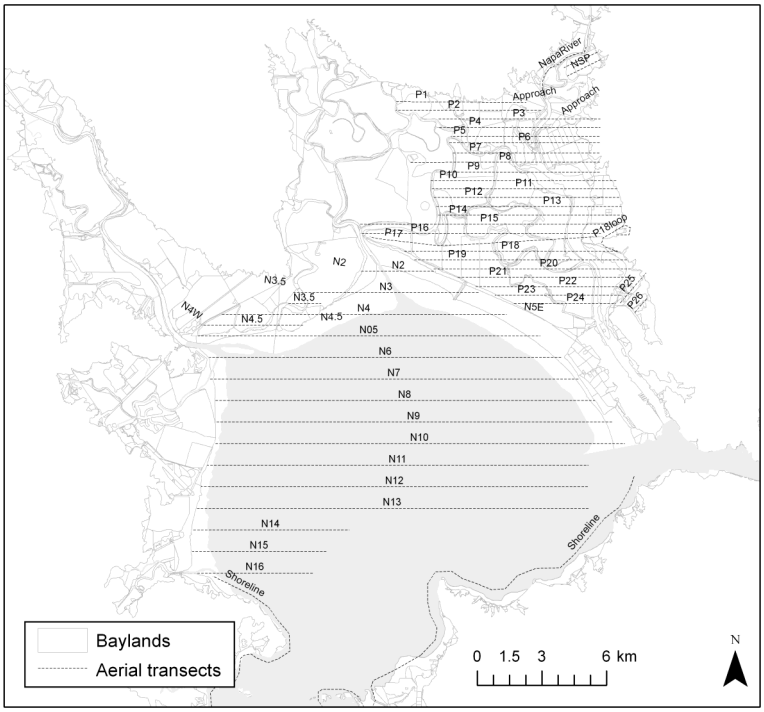
Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 2. Survey units (ponds, sloughs and marshes) and aerial transects in North and South San Francisco Bay.

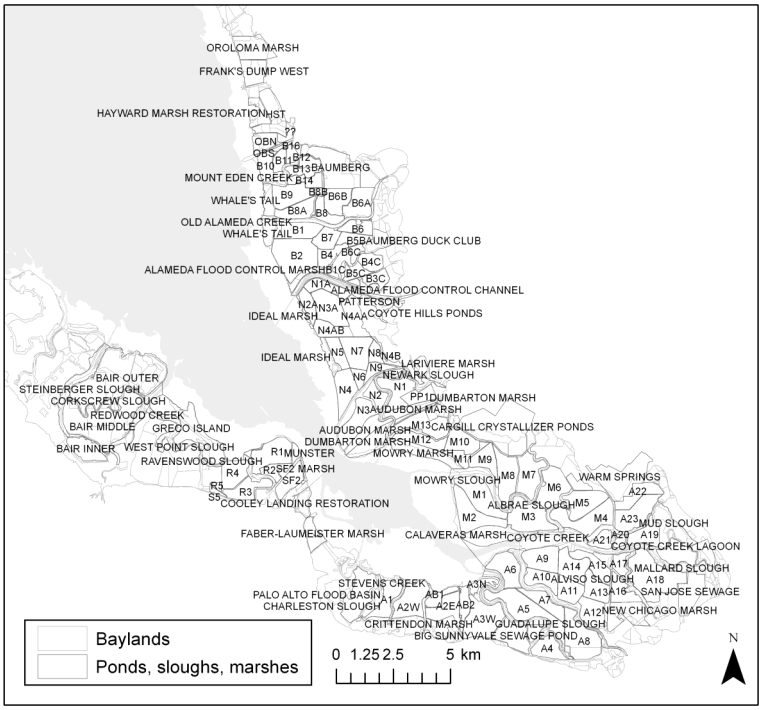
A. North Bay ponds, sloughs and marshes.



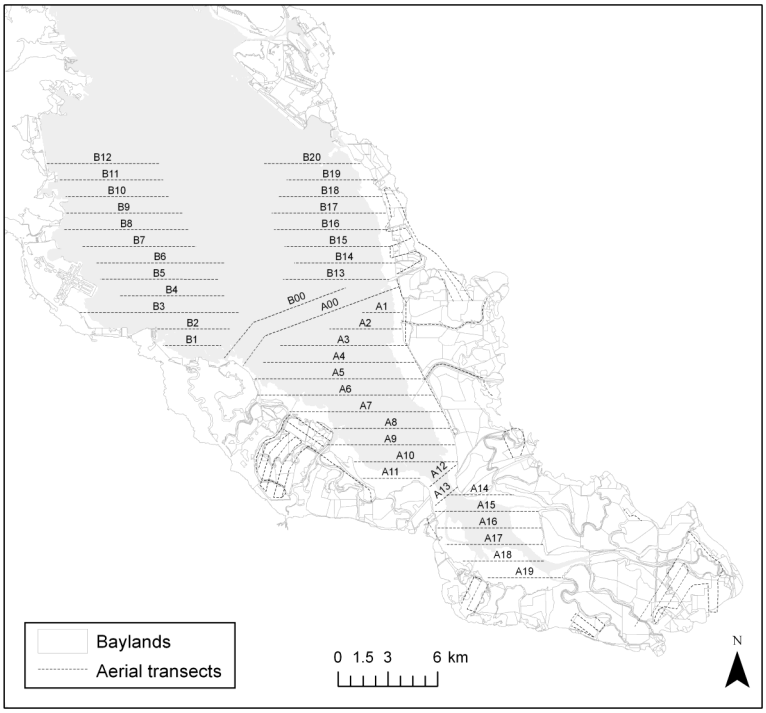
B. North Bay aerial transects.



C. South Bay ponds, sloughs and marshes.



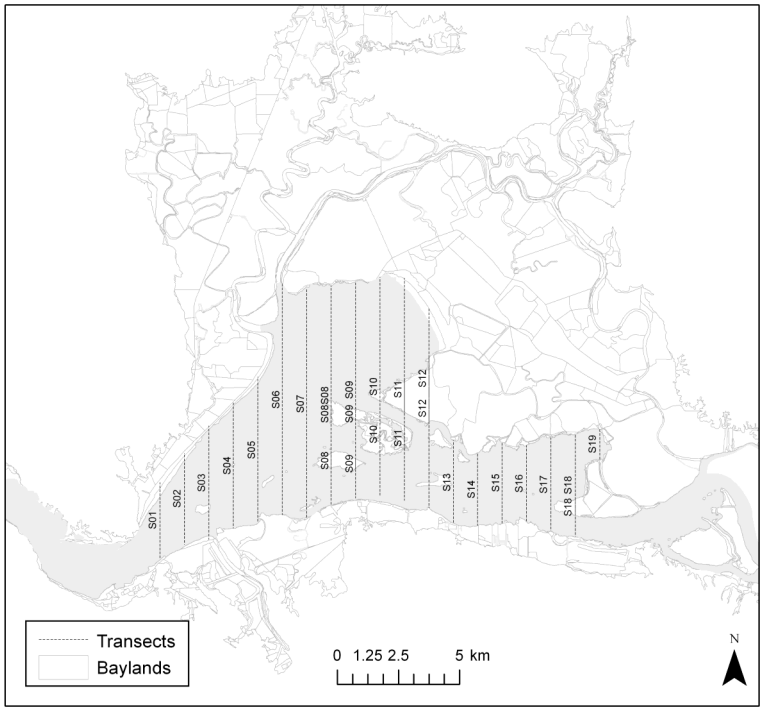
D. South Bay aerial transects.



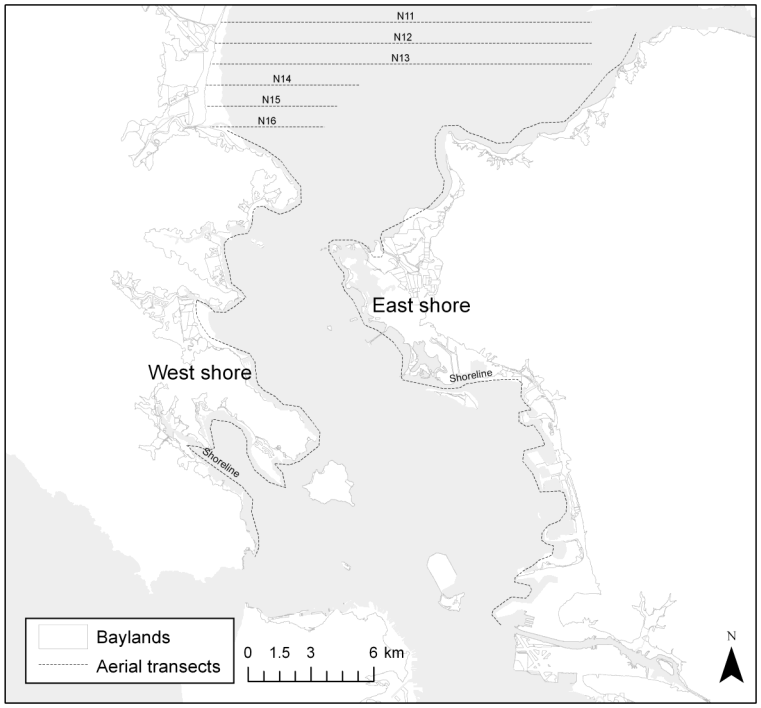
Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: November 1, 2012; Source Data: Transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig. 3. Aerial transects in Suisun Bay and Central San Francisco Bay.

A. Suisun Bay aerial transects.

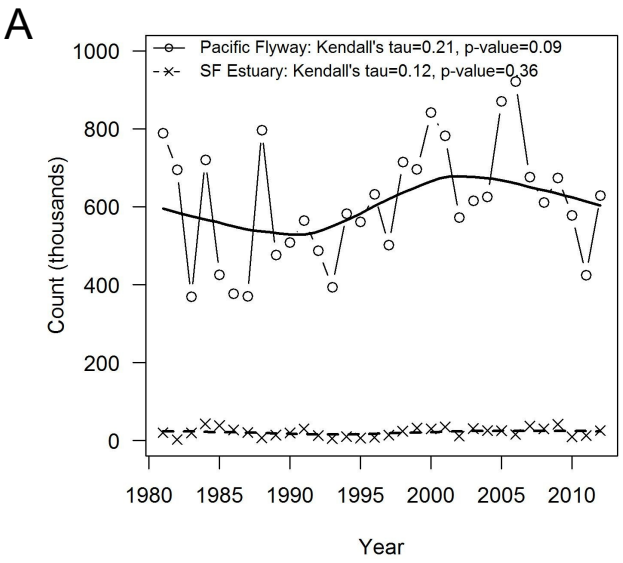


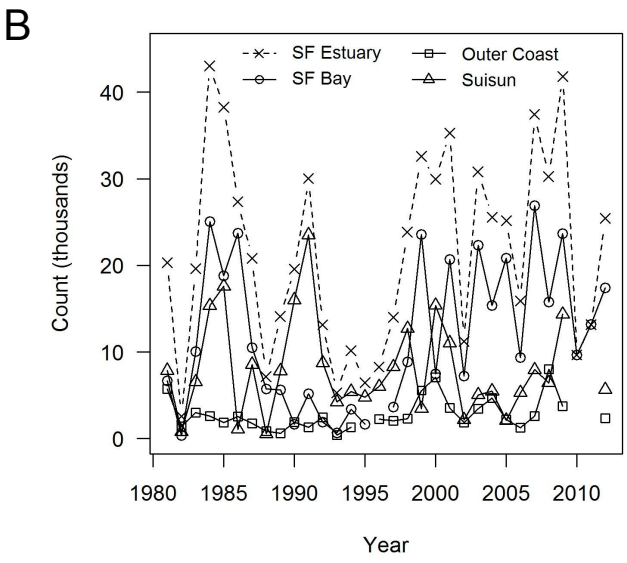
B. Central San Francisco Bay shoreline transects.

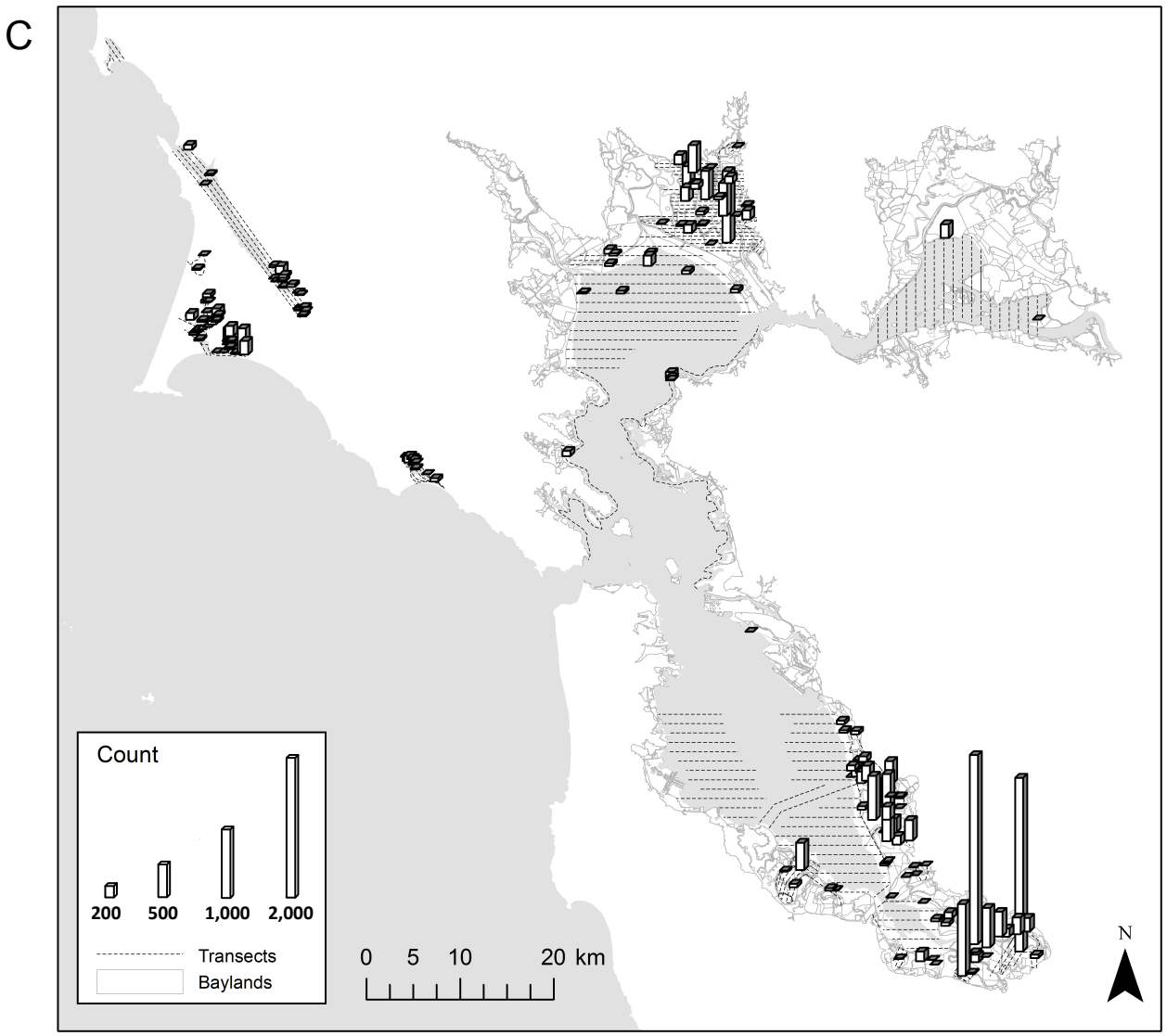


Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 31, 2012; Source Data: Transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 4(A) American Wigeon January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) American Wigeon January count in the San Francisco Estuary by region 1981-2012; and (C) American Wigeon distribution and count in Jan 2012.

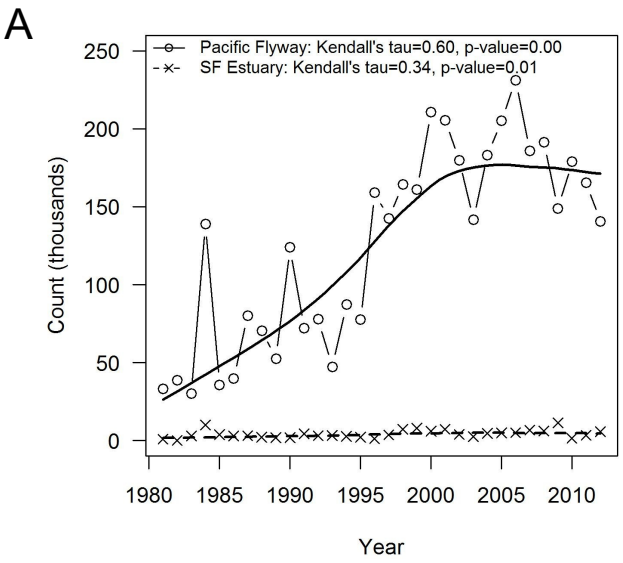


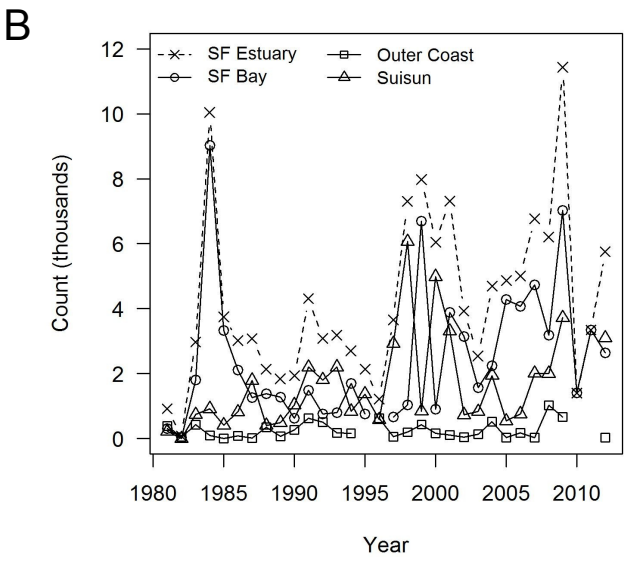


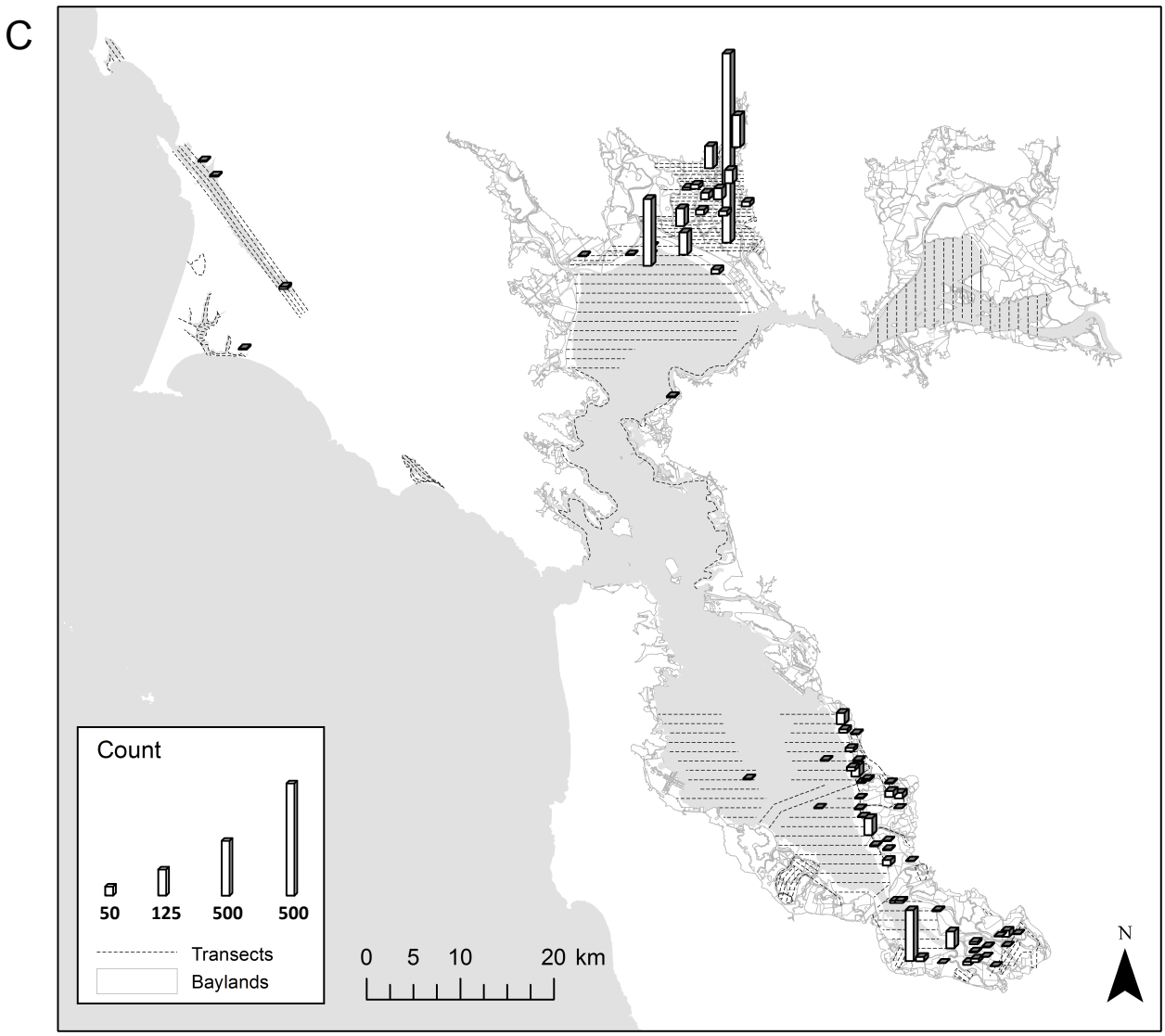


Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 5(A) Gadwall January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) Gadwall January count in the San Francisco Estuary by region 1981-2012; and (C) Gadwall distribution and count in Jan 2012.

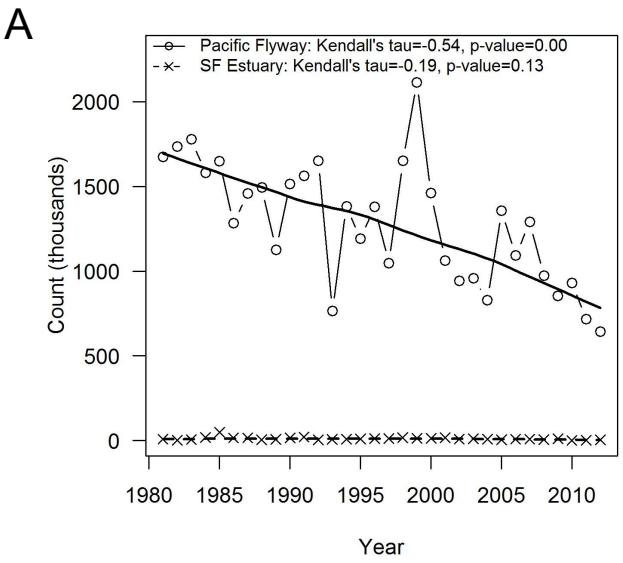


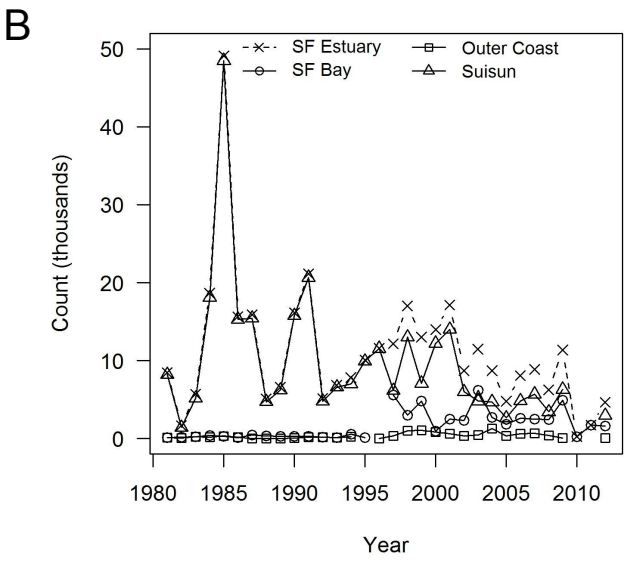


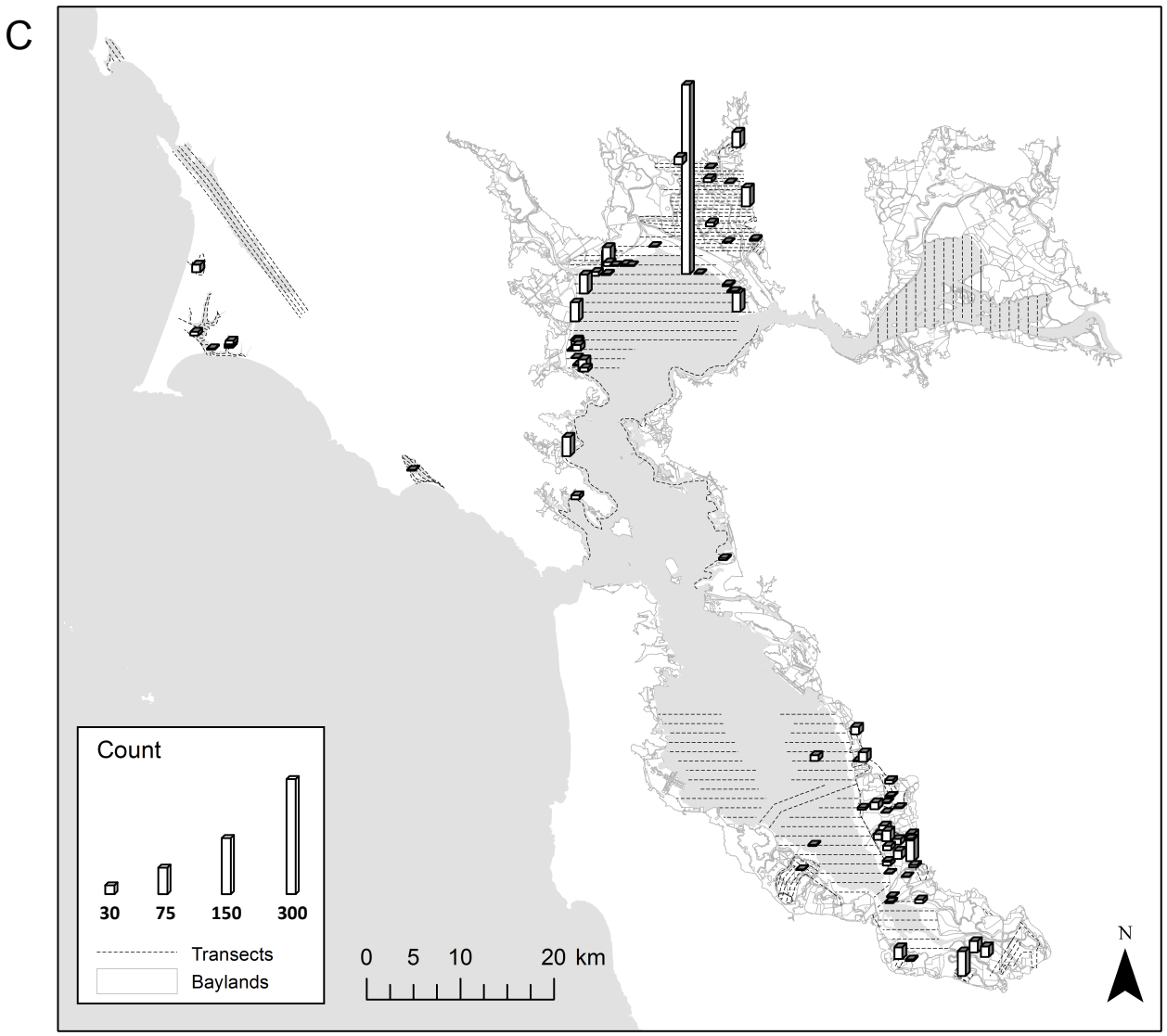


Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 6(A) Mallard January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) Mallard January count in the San Francisco Estuary by region 1981-2012; and (C) Mallard distribution and count in Jan 2012.

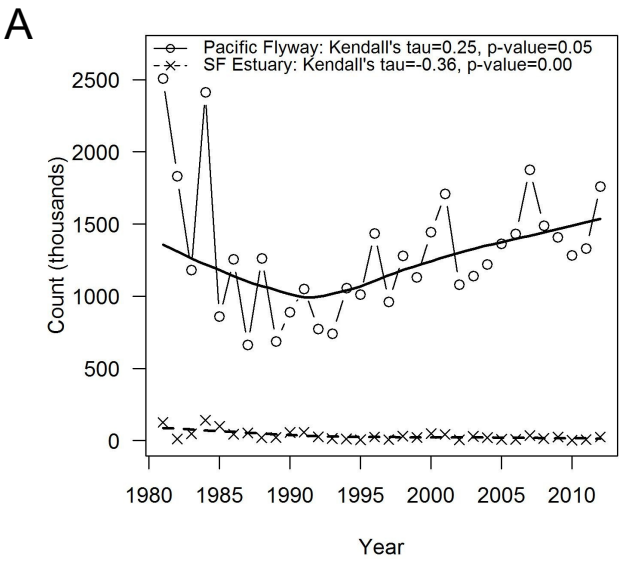


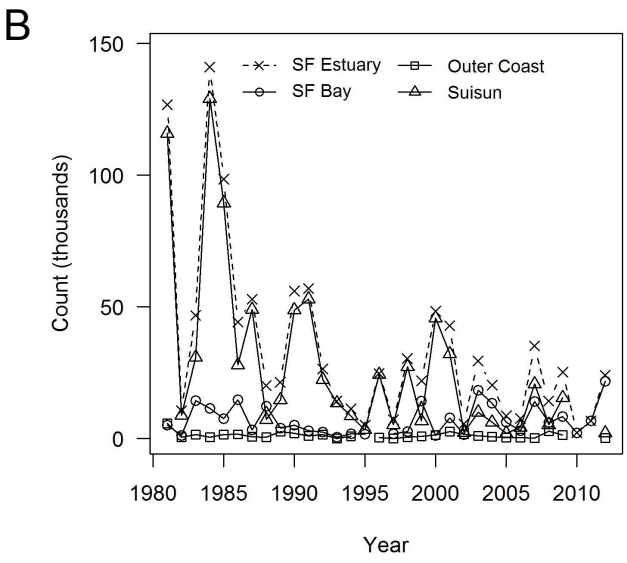


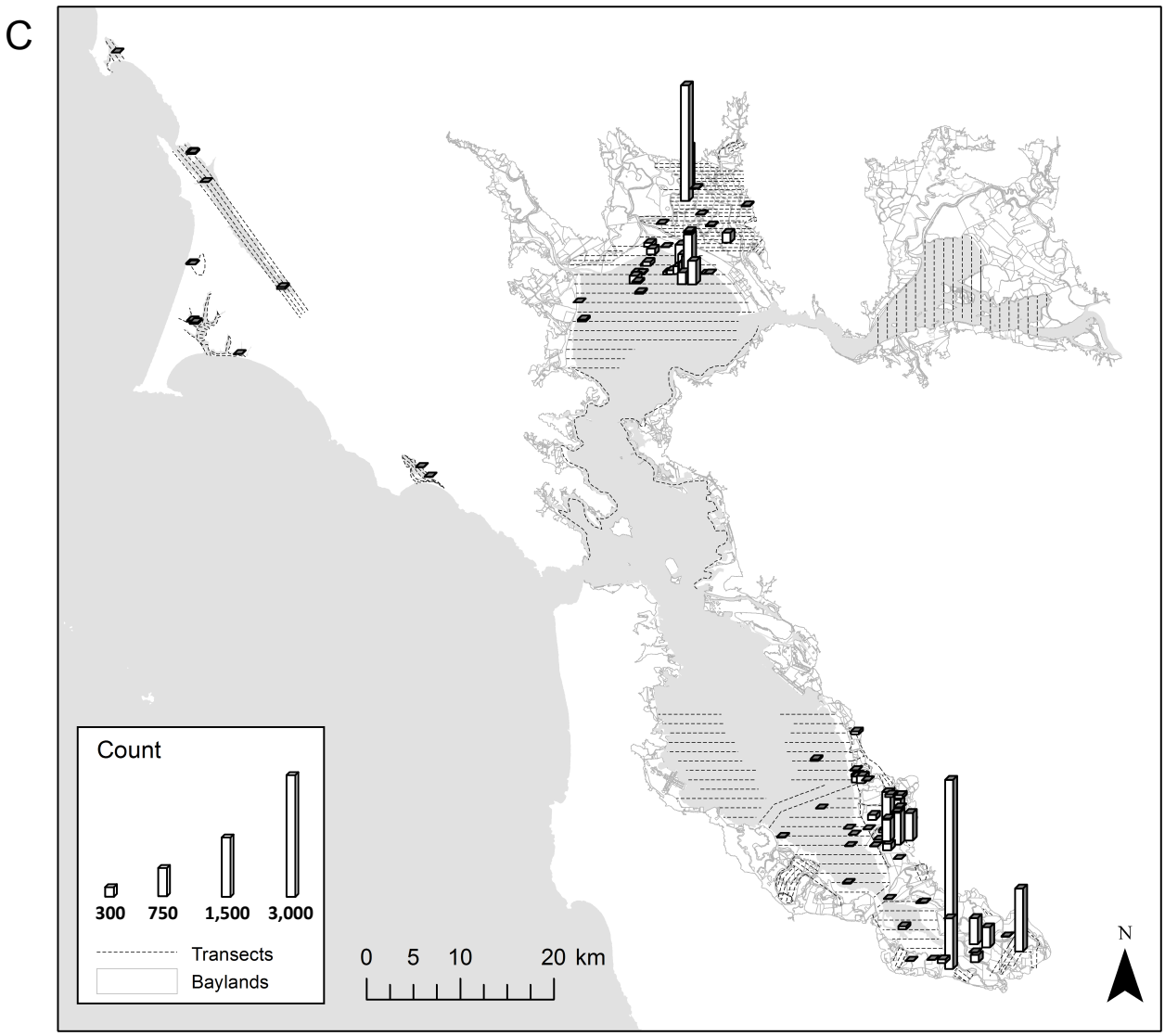


Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 7(A) Northern Pintail January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) Northern Pintail January count the San Francisco Estuary by region 1981-2012; and (C) Northern Pintail distribution and count in Jan 2012.

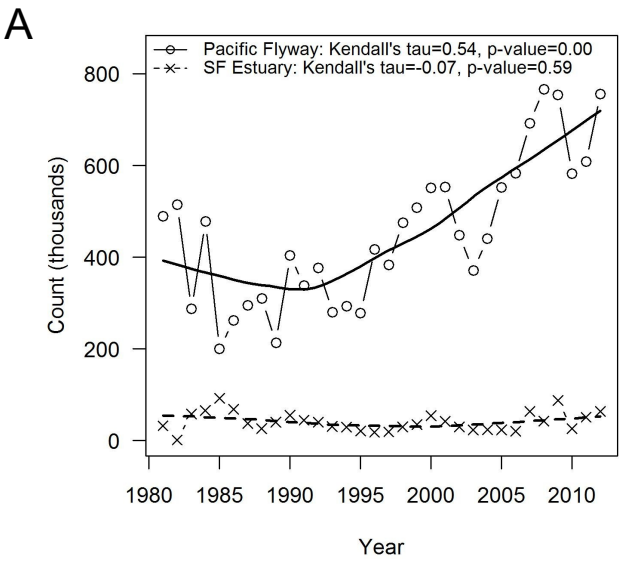


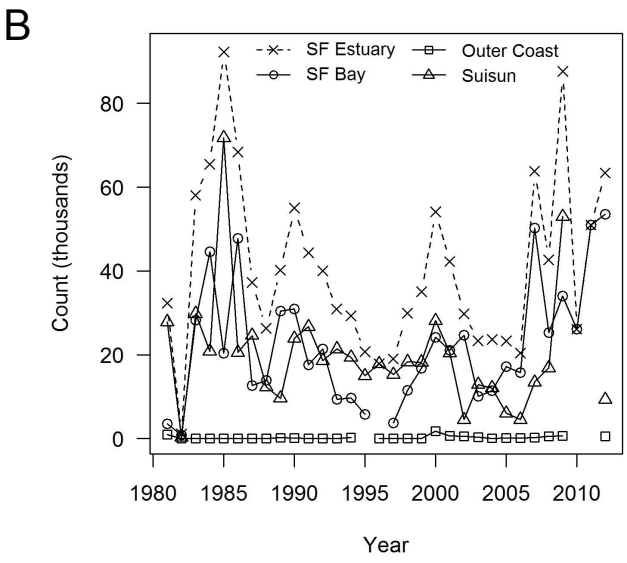


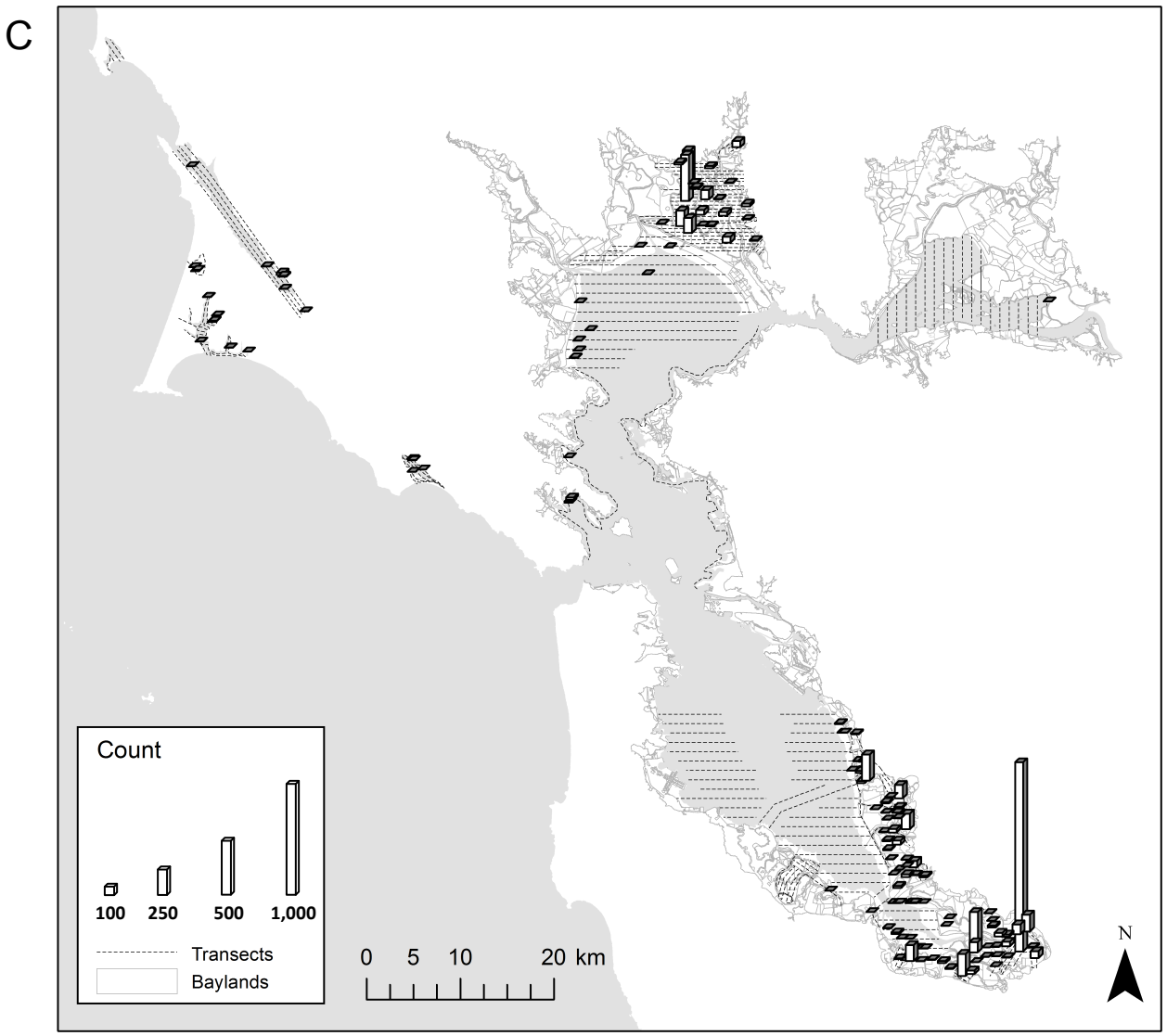


Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 8(A) Northern Shoveler January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) Northern Shoveler January count in the San Francisco Estuary by region 1981-2012; and (C) Northern Shoveler distribution and count in Jan 2012.

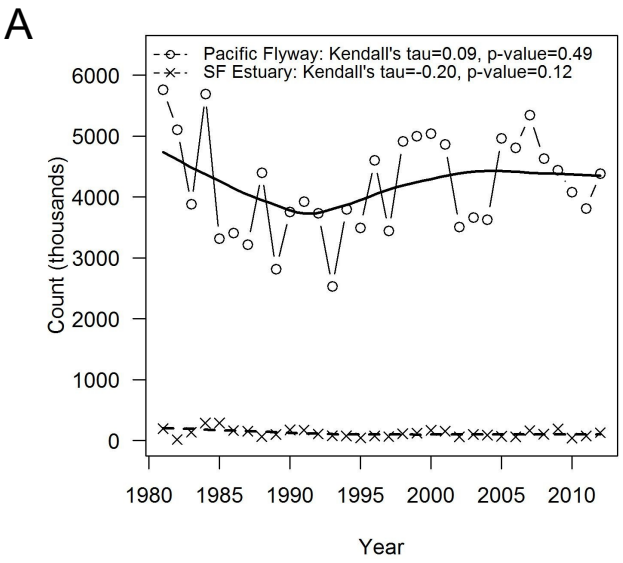


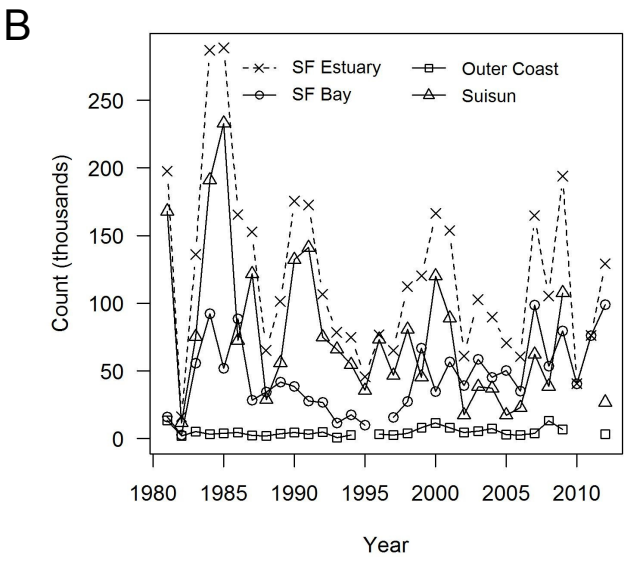


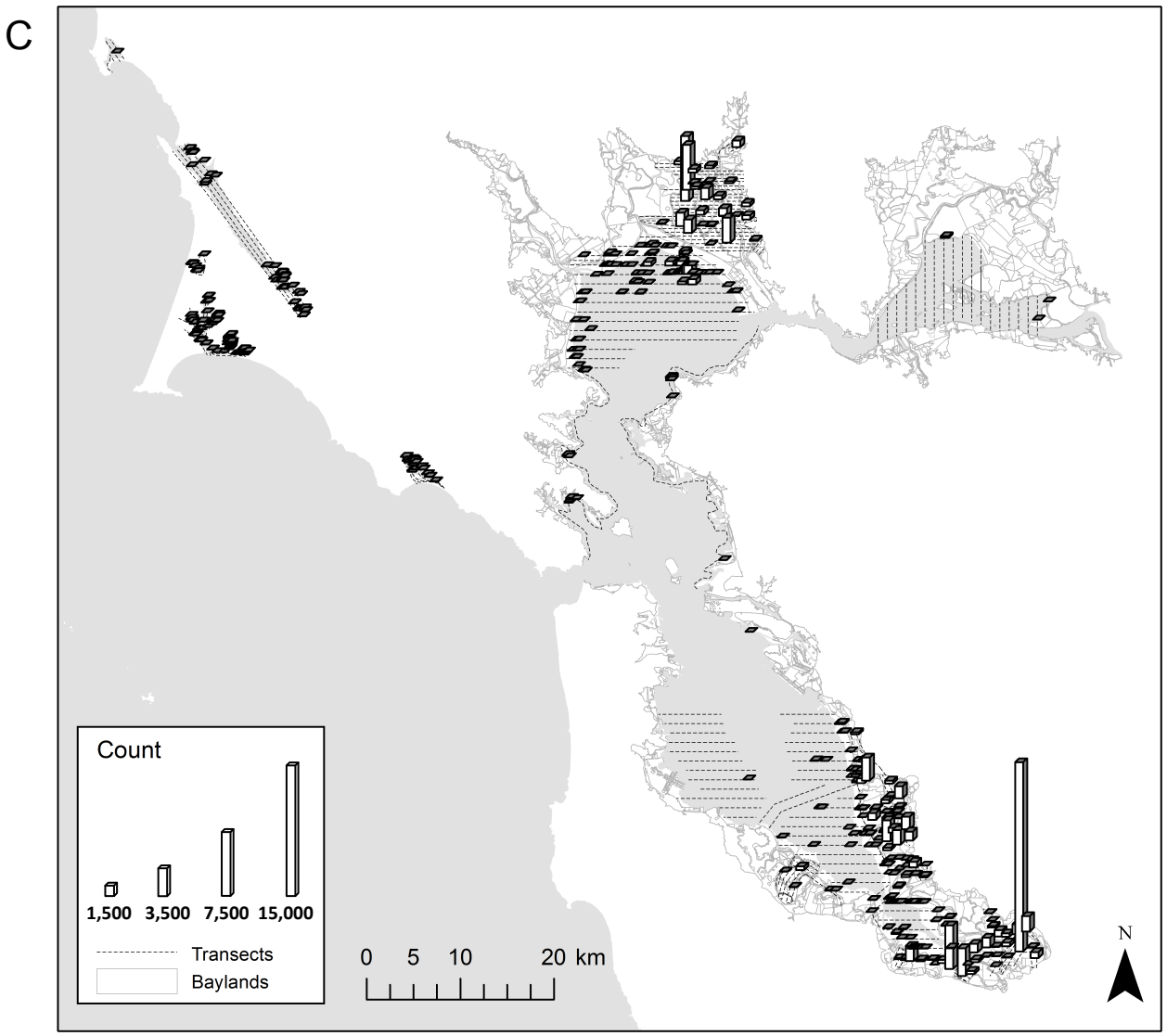


Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 9(A) Total dabbler January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) dabbler January count in the San Francisco Estuary by region 1981-2012; and (C) dabbler distribution and count in Jan 2012.

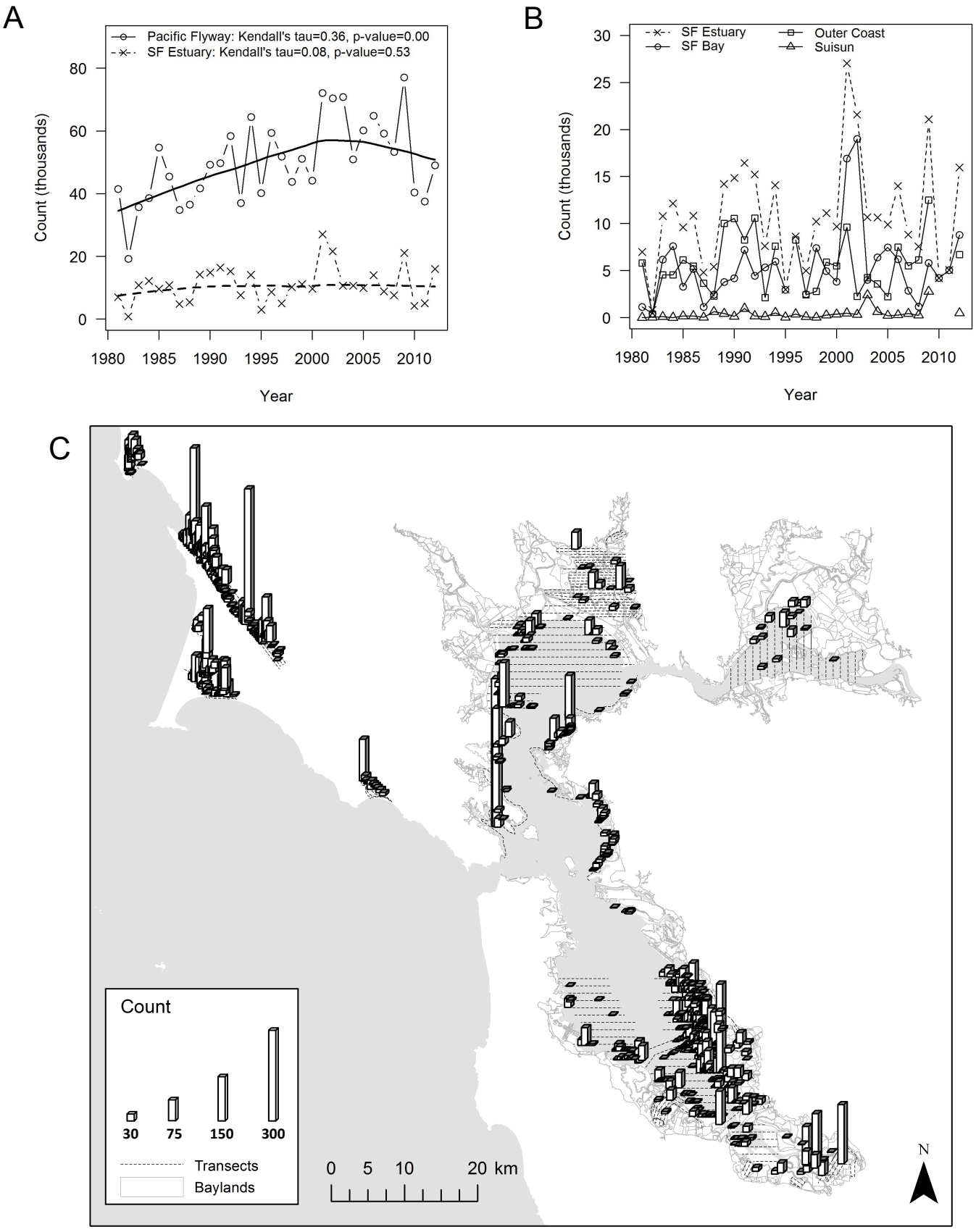






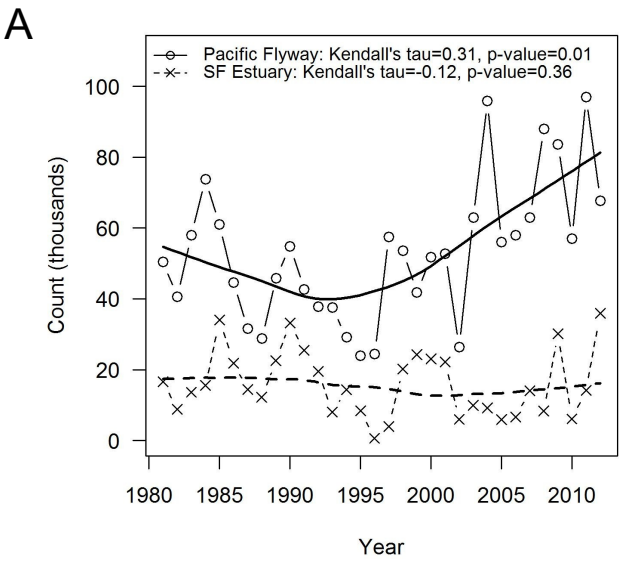
Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

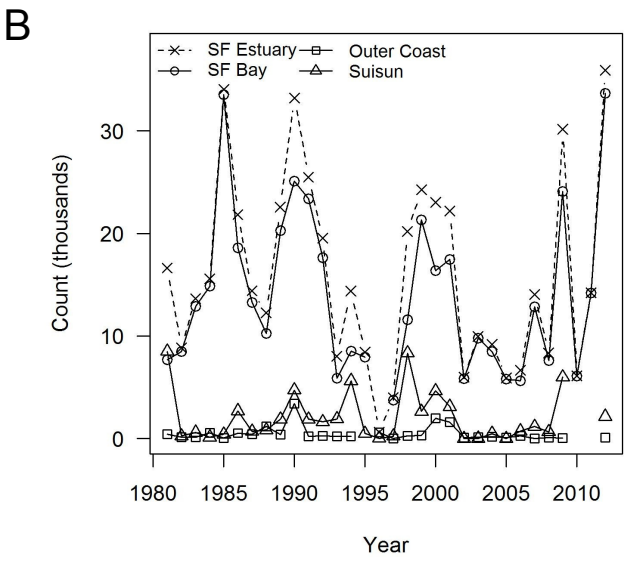
Fig 10(A) Bufflehead January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) Bufflehead January count in the San Francisco Estuary by region 1981-2012; and (C) Bufflehead distribution and count in Jan 2012.

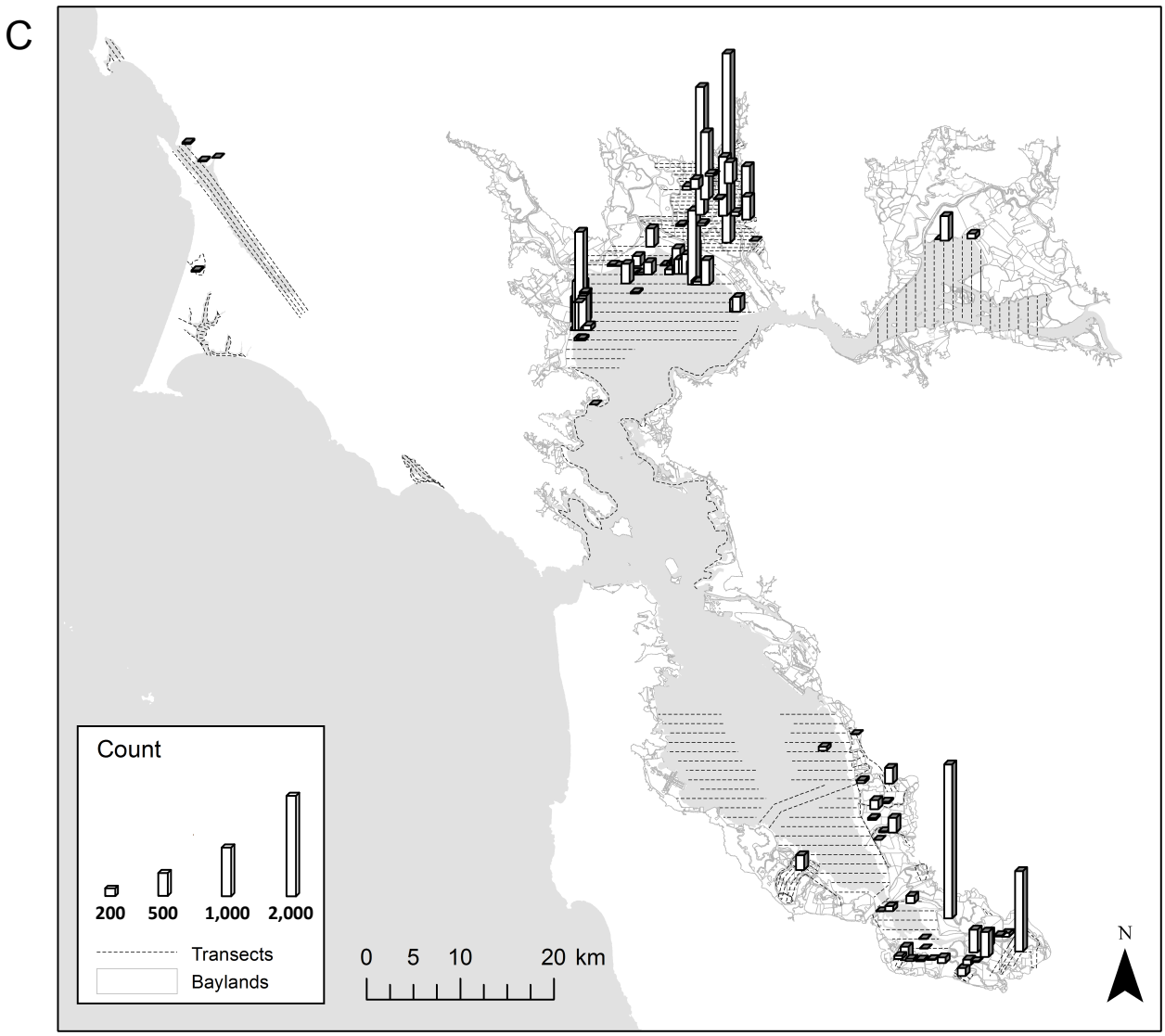


Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 11(A) Canvasback January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) Canvasback January count in the San Francisco Estuary by region 1981-2012; and (C) Canvasback distribution and count in Jan 2012.

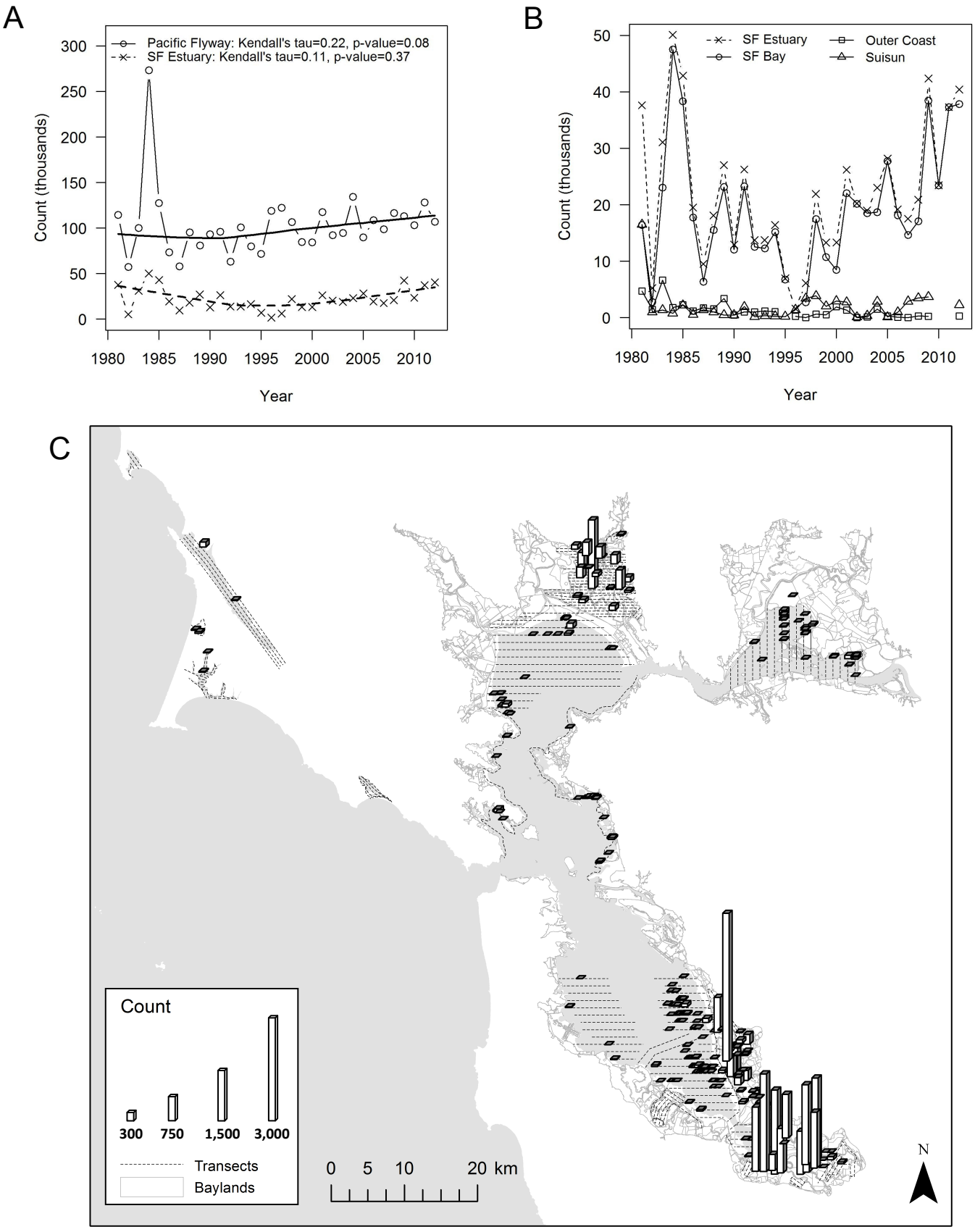






Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

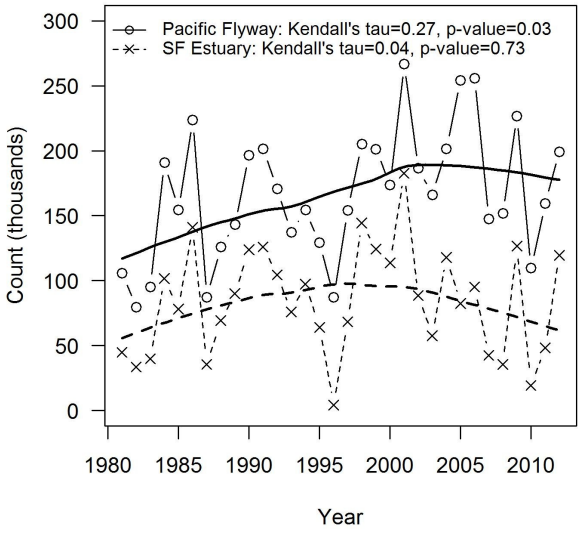
Fig 12(A) Ruddy Duck January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) Ruddy Duck January count in the San Francisco Estuary by region 1981-2012; and (C) Ruddy Duck distribution and count in Jan 2012.



Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 13(A) Scaup (Greater and Lesser) January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) Scaup January count in the San Francisco Estuary by region 1981-2012; and (C) Scaup distribution and count in Jan 2012.

A



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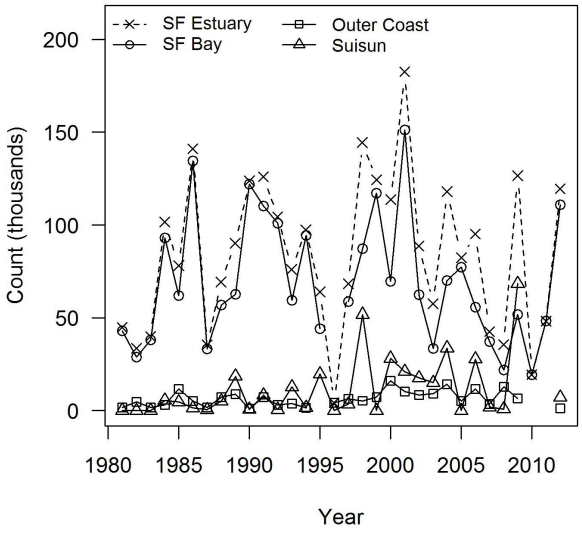

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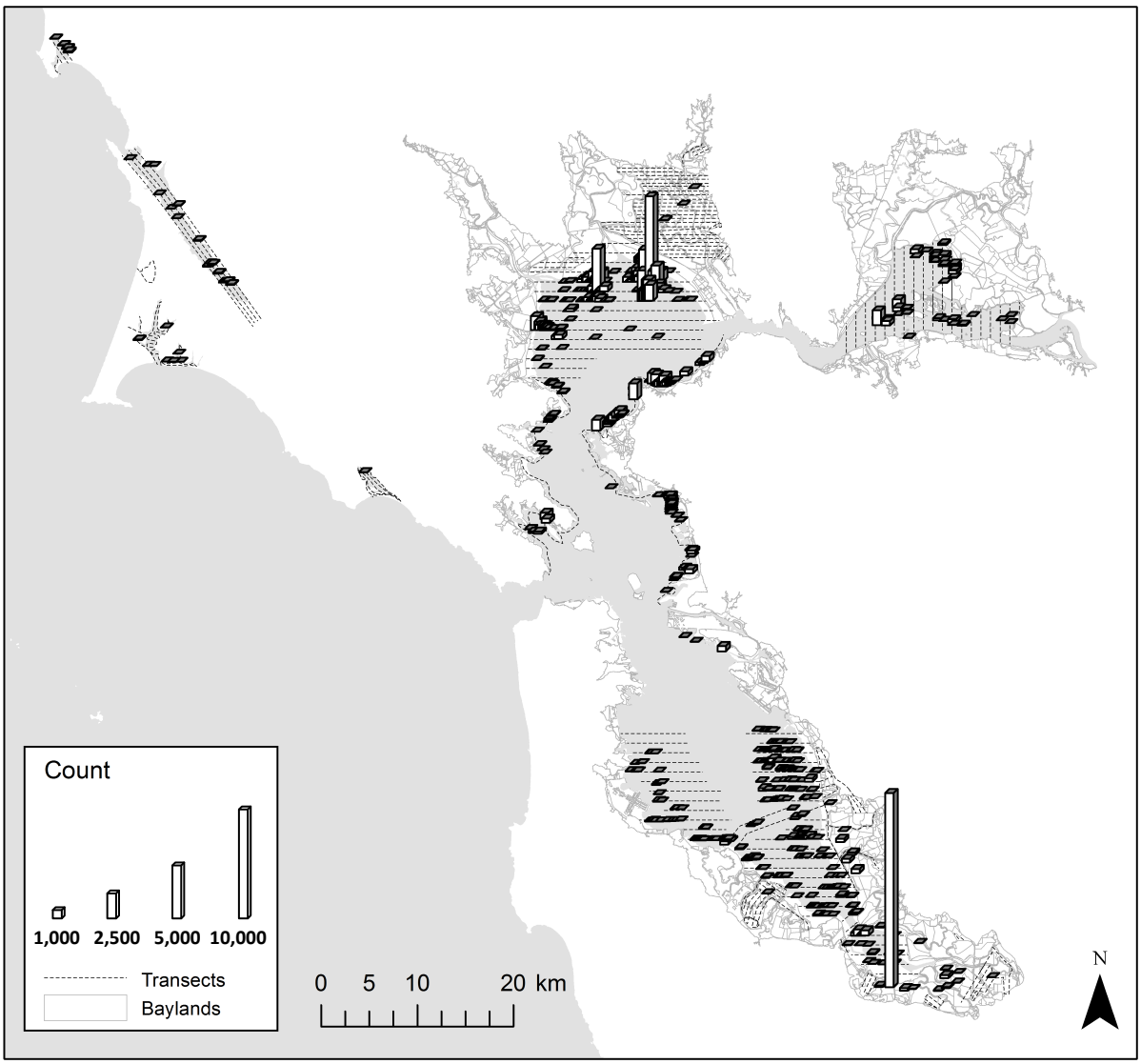
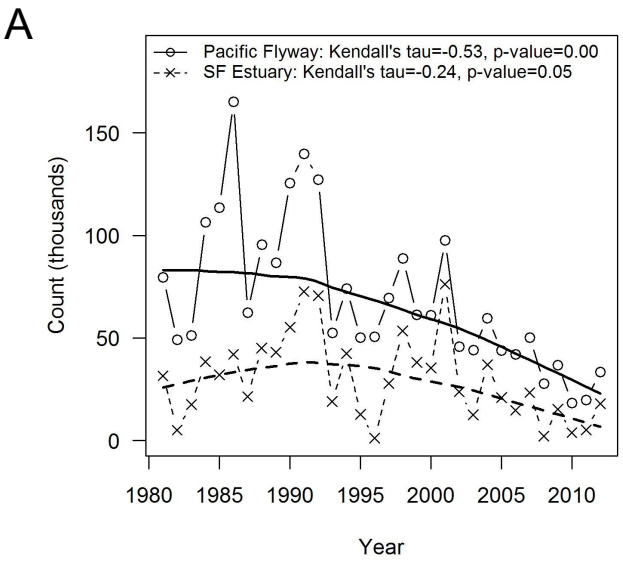
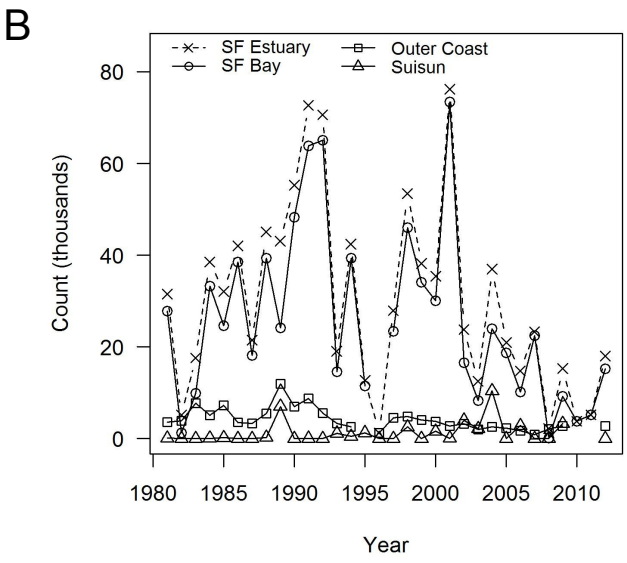
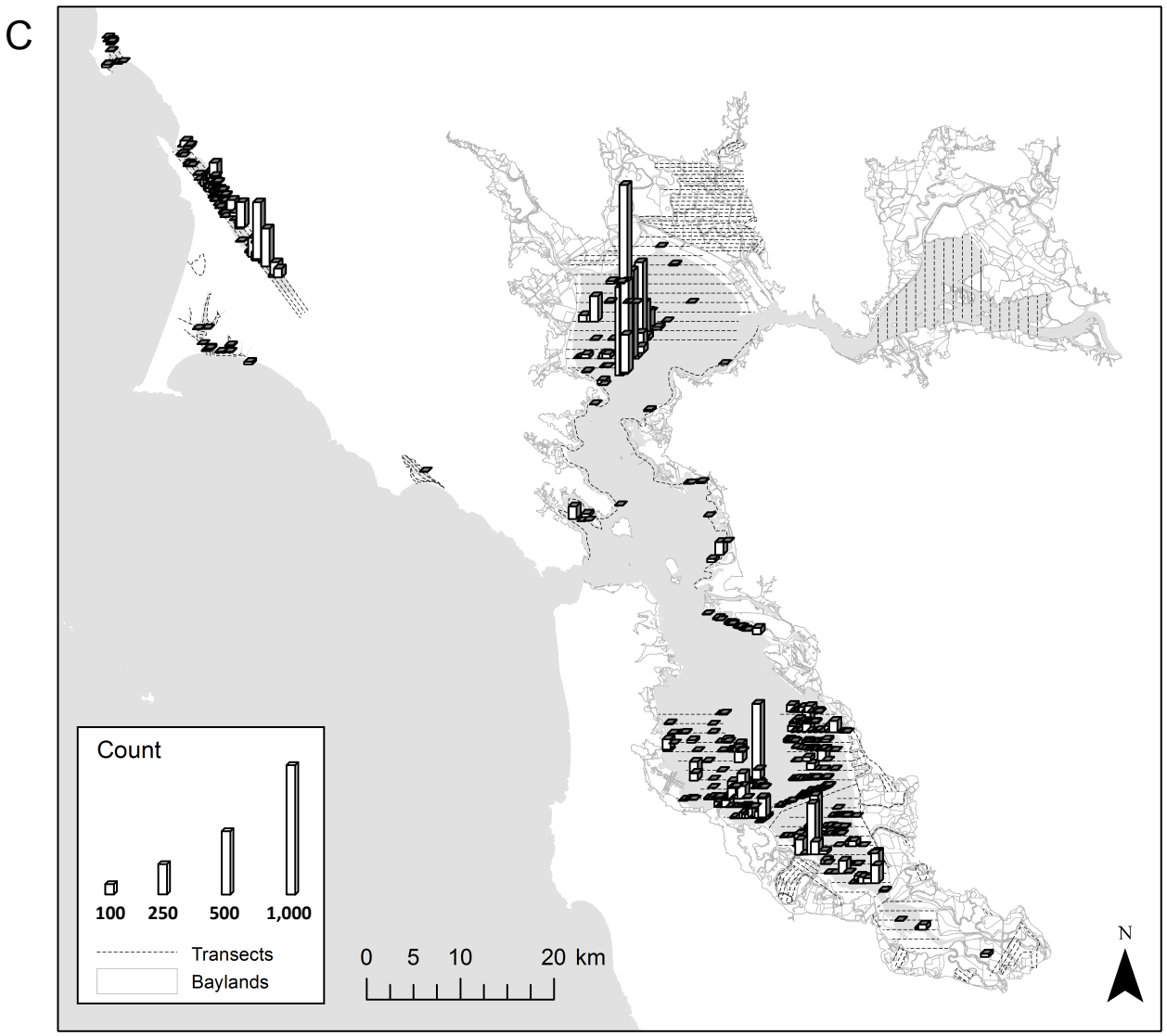


Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 14(A) Scoter (Surf, Black and White-winged) January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) Scoter January count in the San Francisco Estuary by region 1981-2012; and (C) Scoter distribution and count in Jan 2012.



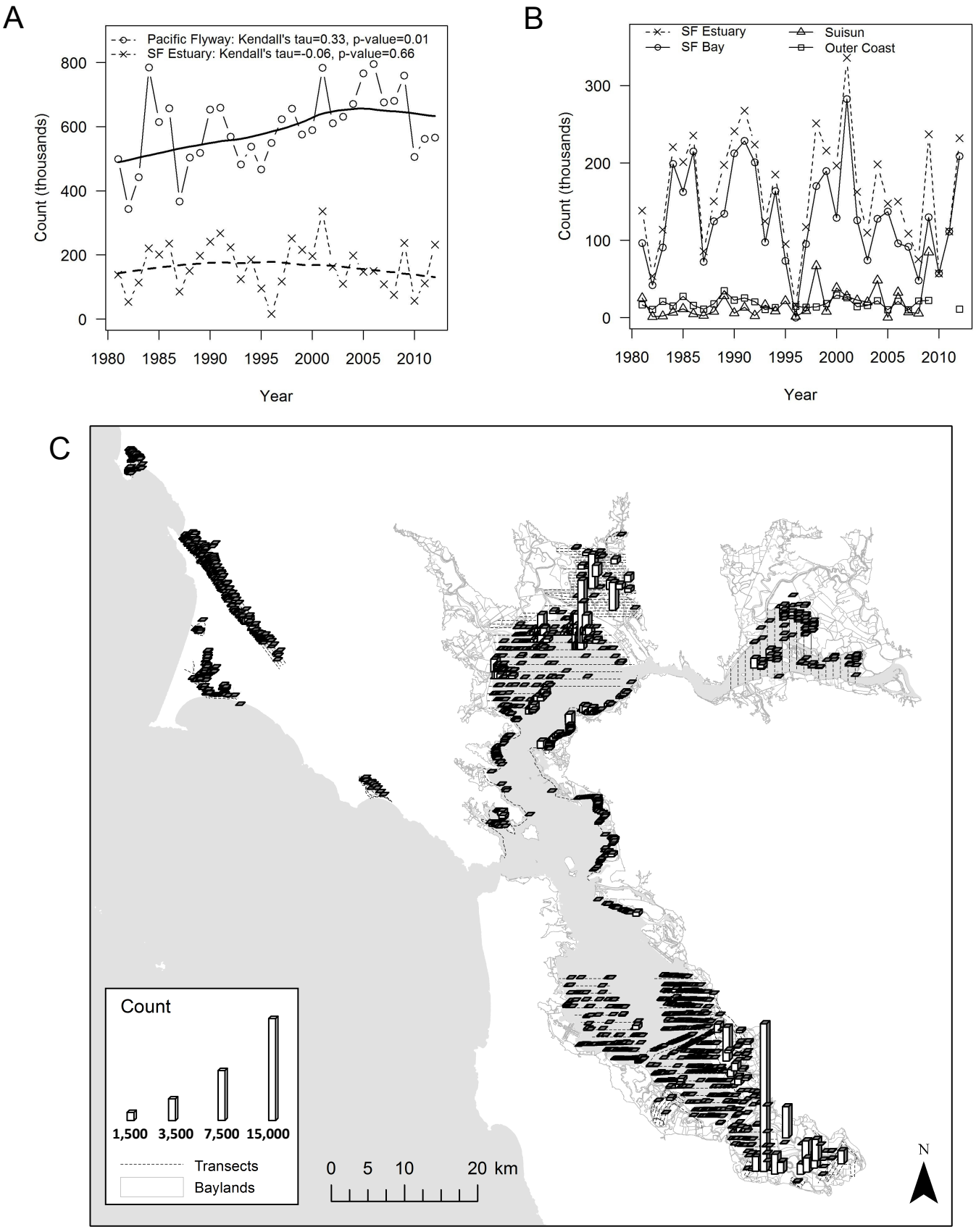




Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

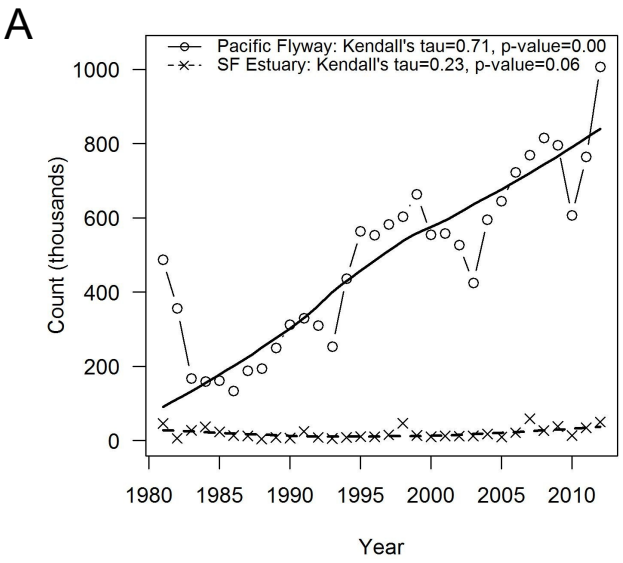
Fig 15(A) Total diver* January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) diver January count in the San Francisco Estuary by region 1981-2012; and (C) diver distribution and count in Jan 2012.

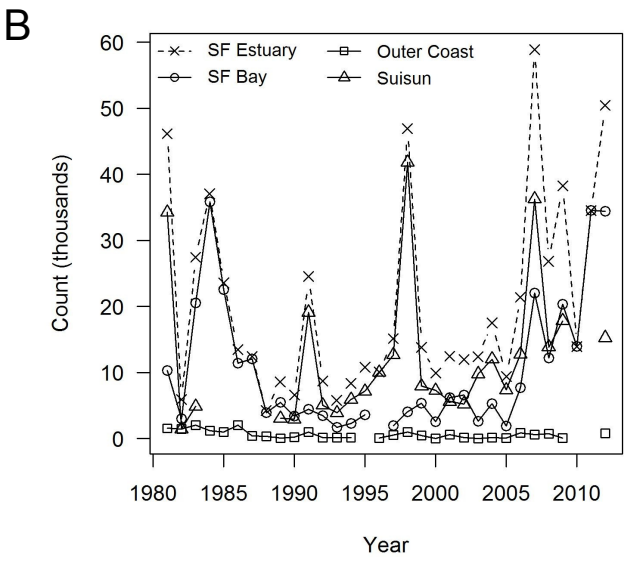
*Including sea ducks and stiff-tailed ducks

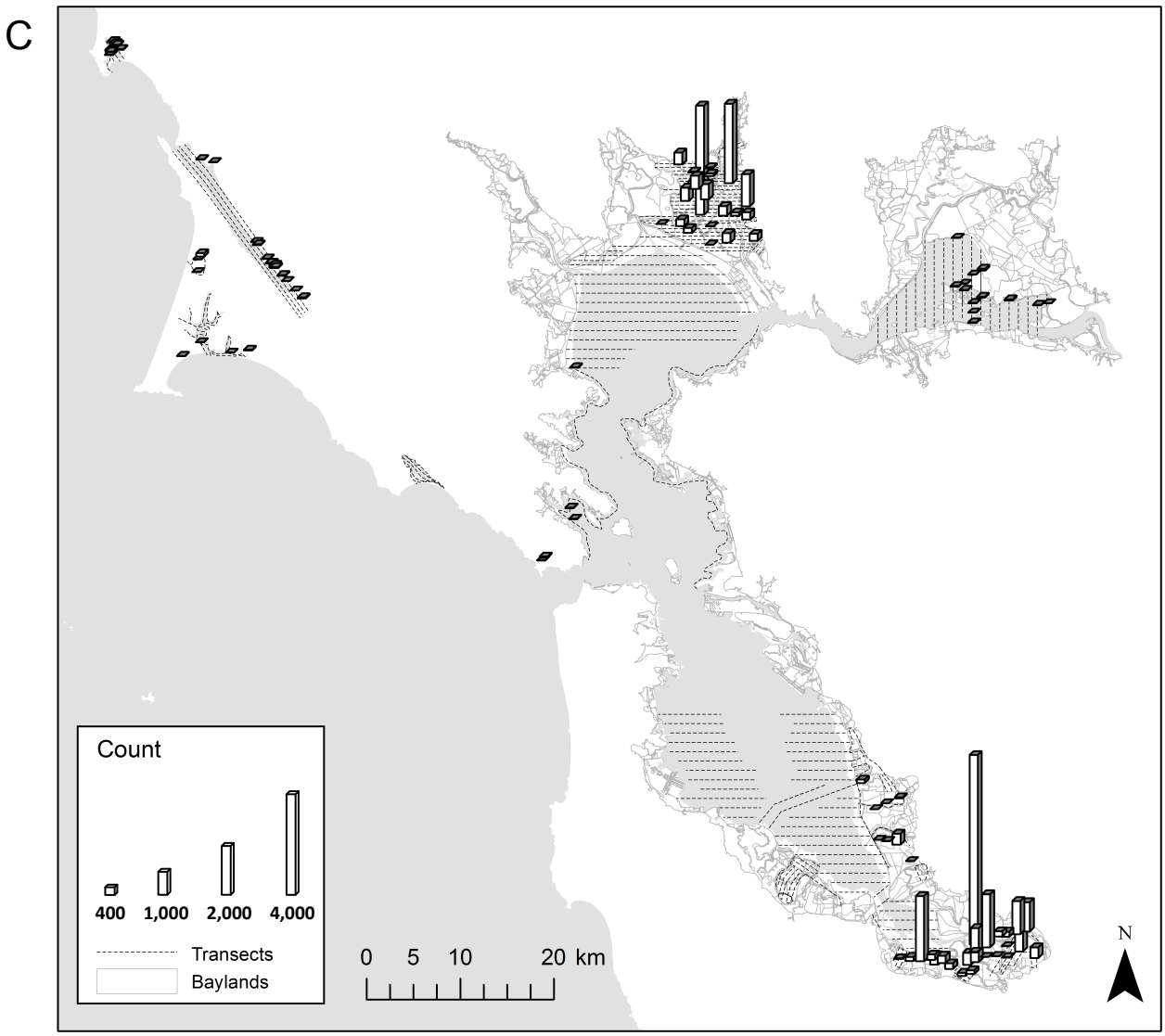


Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 16(A) American Coot January count in the Pacific Flyway and San Francisco Estuary 1981-2012 with Loess curves; (B) American Coot January count in the San Francisco Estuary by region 1981-2012; and (C) American Coot distribution and count in Jan 2012.



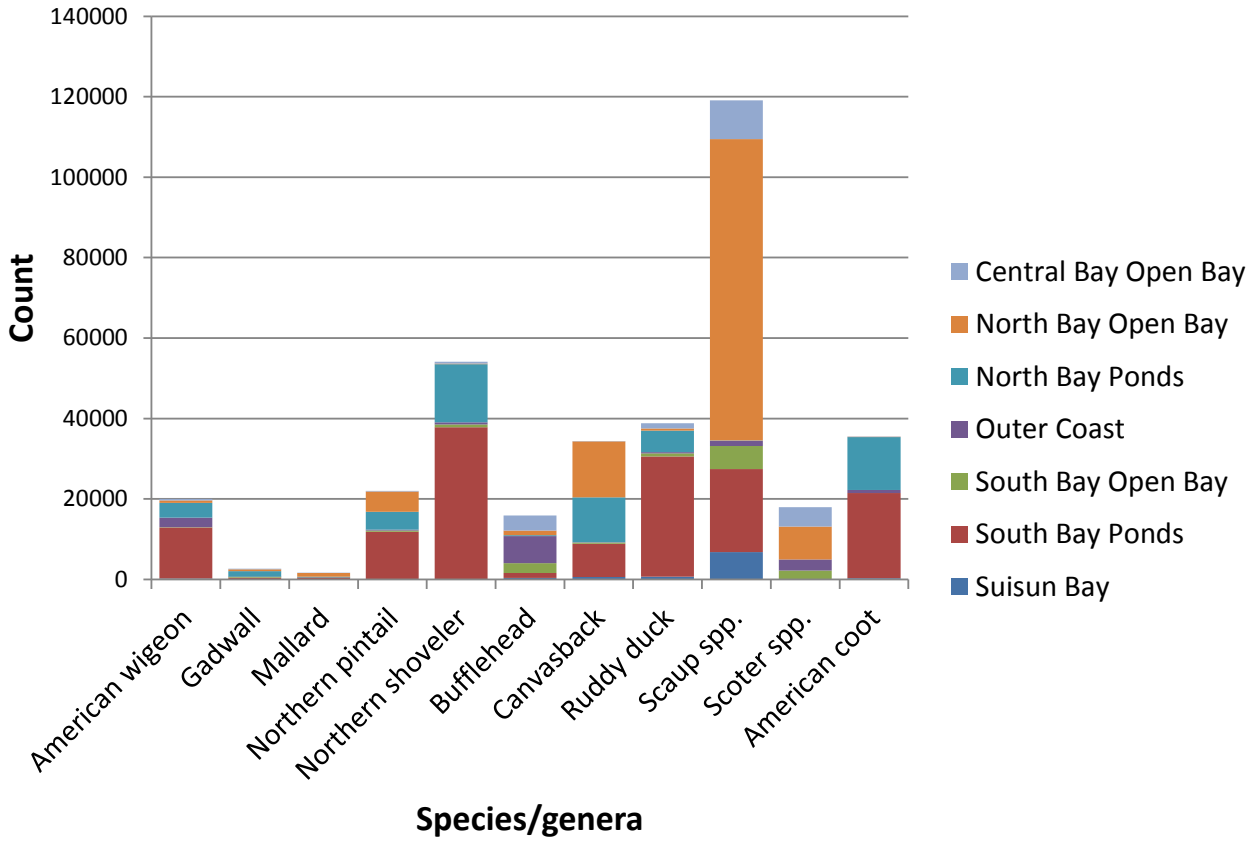




Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: October 22, 2013; Source Data: Waterfowl count data and transects from Don Edwards San Francisco Bay National Wildlife Refuge, March 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Fig 17(A) Regional distribution of ten waterfowl species and American coots in the San Francisco Estuary in January 2012; (B) Waterfowl species composition for seven regions and zones of the San Francisco Estuary in January 2012.

A



B

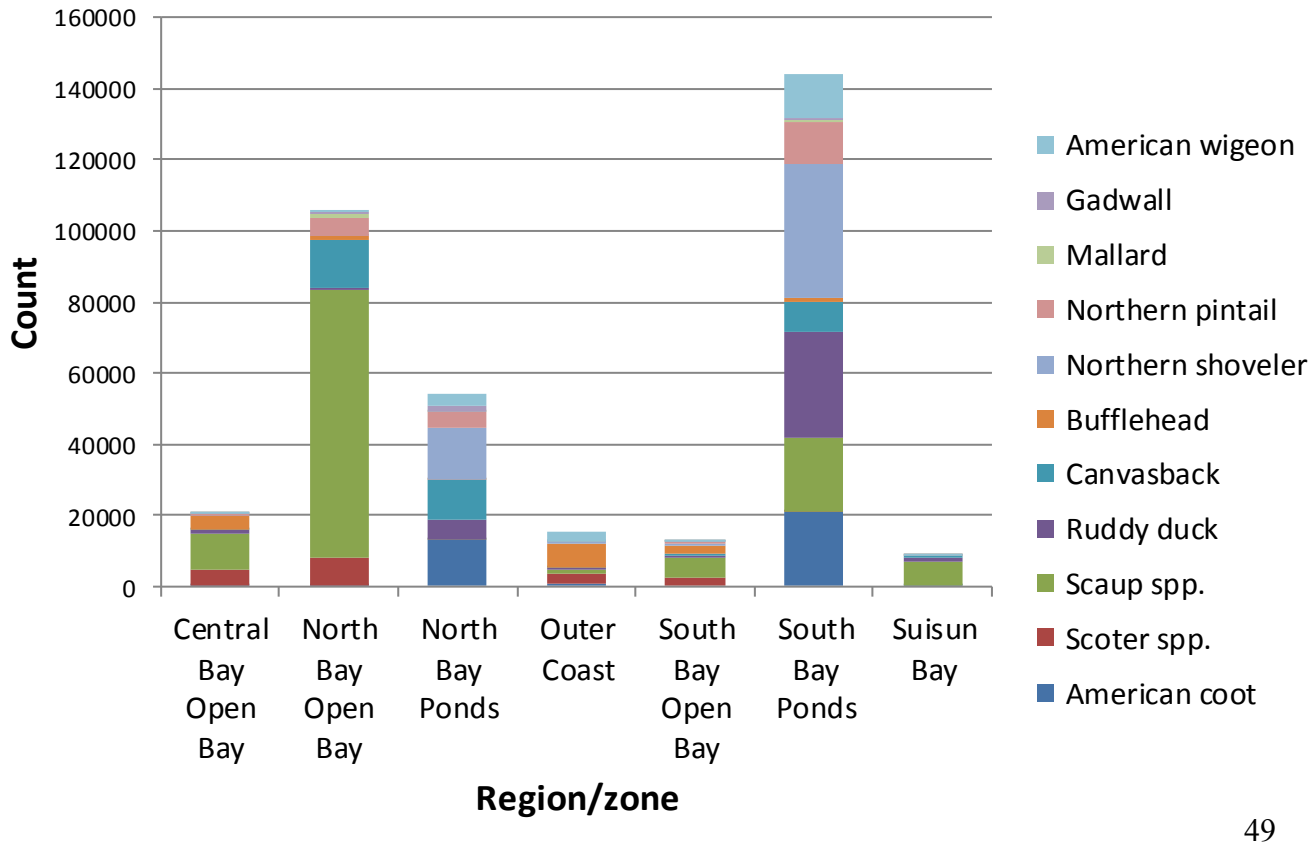


Fig 18. Species composition and abundance of waterfowl by land ownership/status in the San Francisco Estuary in January 2012. National Wildlife Refuge lands included fee title, leased, easement and other lands where the U.S. Fish and Wildlife Service has management responsibility.

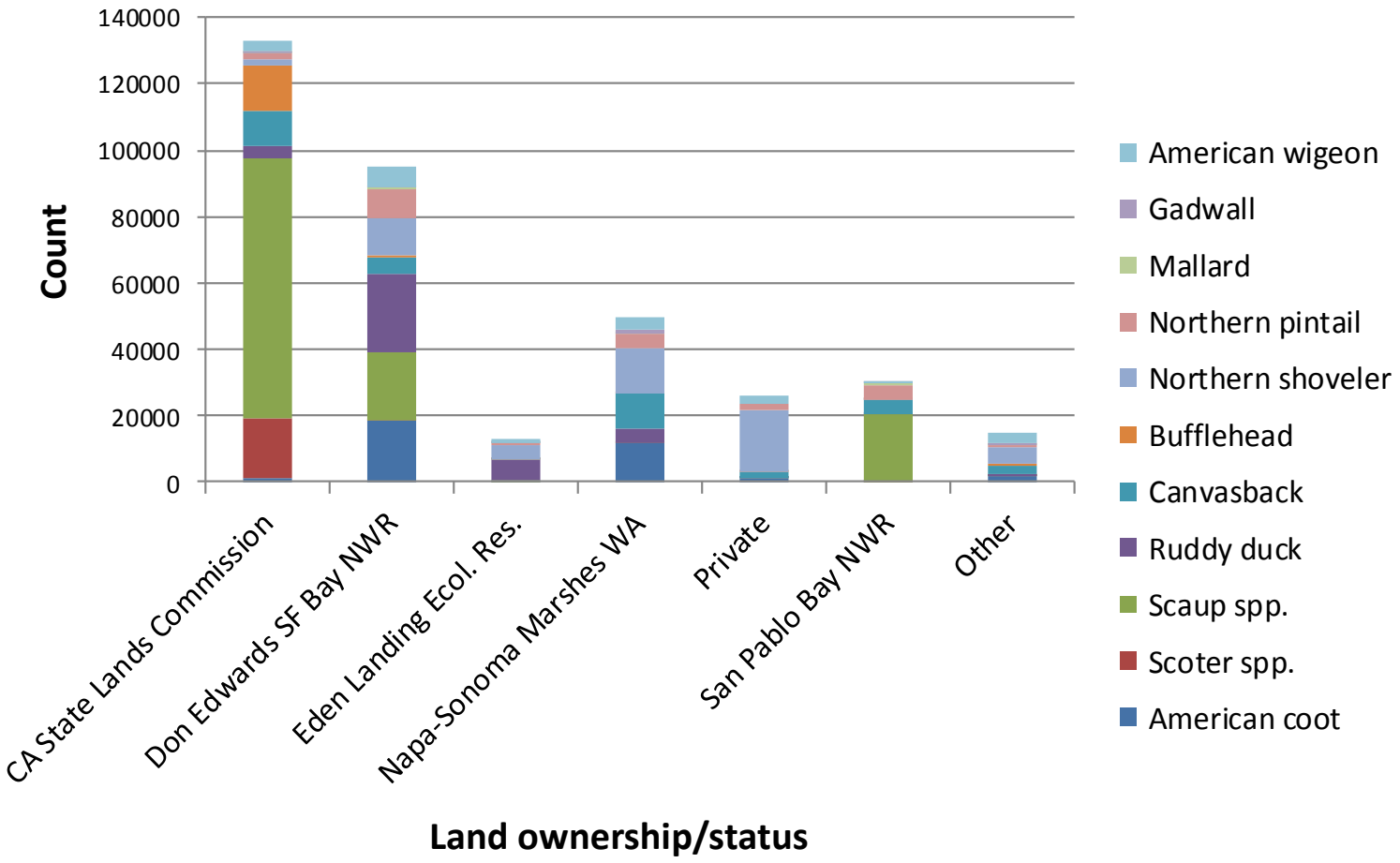
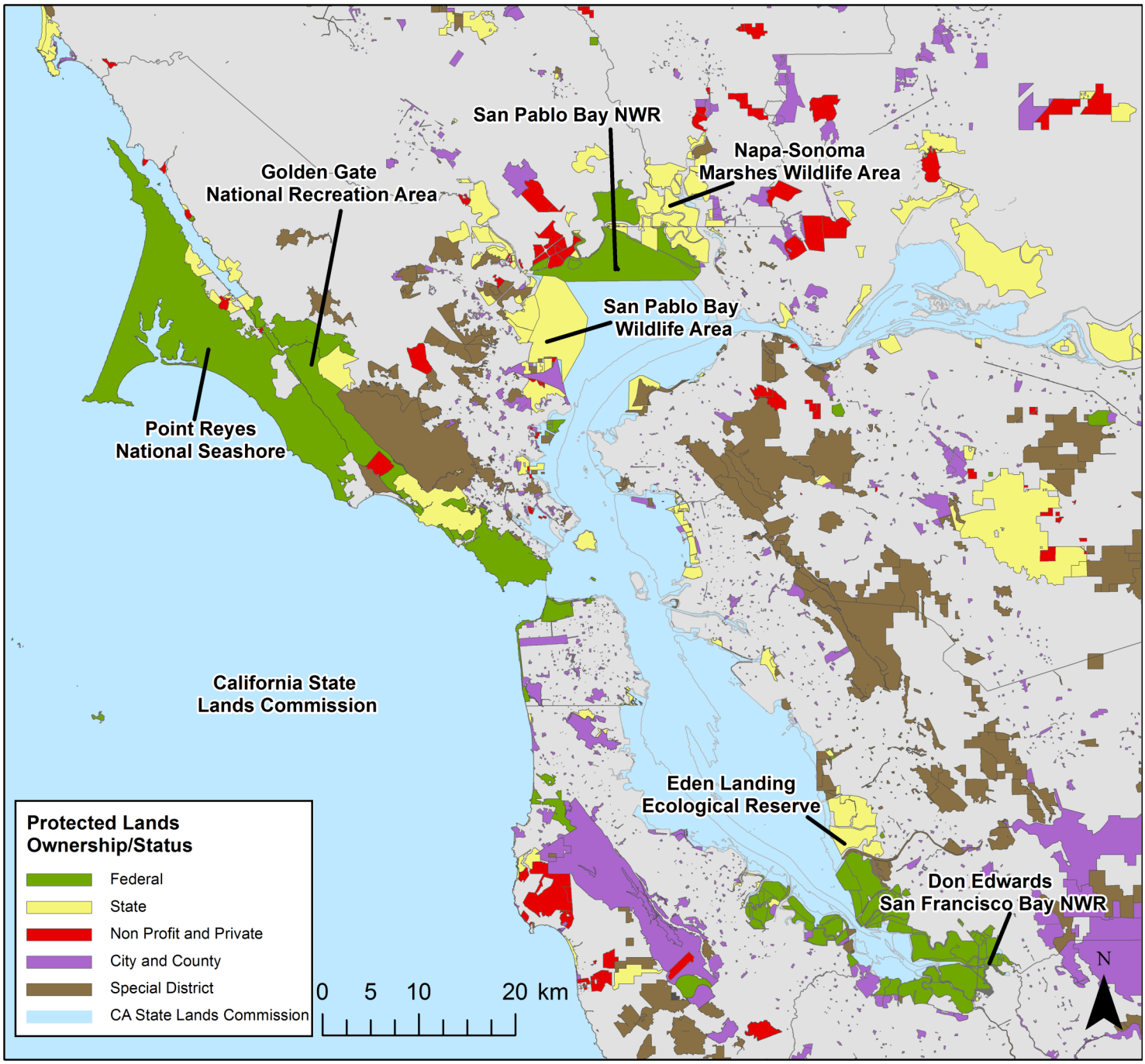


Fig 19. Map of 2012 protected land ownership/status in the San Francisco Estuary.



Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: November 26, 2013; Source Data: Non-federal lands from California Protected Areas Database (CPAD) 2012; federal lands from U.S. Fish and Wildlife Service Region 8 Realty Office November 2012; Modern Baylands from San Francisco Estuary Institute EcoAtlas, August 2012.

Appendices

Appendix A. Potential waterfowl and coot species present in the San Francisco Estuary, including common name, scientific name, name used in the SF Estuary Midwinter Waterfowl Survey, guild, family, subfamily and tribe[9,10].

Common name	Scientific name	Name used in MWS	Guild	Family	Subfamily	Tribe
American coot	*Fulica americana*	American coot	Coot	Rallidae		
American wigeon	*Anas americana*	American wigeon	Dabbler	Anatidae	Anatinae	Anatini
Barrow's goldeneye	***Bucephala islandica***	**Goldeneye**	**Diver**	**Anatidae**	**Anatinae**	**Mergini**
Black scoter	***Melanitta americana***	**Scoter**	**Diver**	**Anatidae**	**Anatinae**	**Mergini**
Blue-winged teal	*Anas discors*	Blue-winged teal	Dabbler	Anatidae	Anatinae	Anatini
Brant	*Branta bernicla*	Brant	Goose	Anatidae	Anserinae	Anserini
Bufflehead	*Bucephala albeola*	Bufflehead	Diver	Anatidae	Anatinae	Mergini
Cackling goose	*Branta hutchinsii*	Cackling goose	Goose	Anatidae	Anserinae	Anserini
Canada goose	*Branta canadensis*	Canada goose	Goose	Anatidae	Anserinae	Anserini
Canvasback	*Aythya valisineria*	Canvasback	Diver	Anatidae	Anatinae	Aythyini
Cinnamon teal	*Anas cyanoptera*	Cinnamon teal	Dabbler	Anatidae	Anatinae	Anatini
Clark's grebe	***Aechmophorus clarkii***	**Clark's/western grebe**	**Grebe**	**Podicipedidae**		
Common goldeneye	***Bucephala clangula***	**Goldeneye**	**Diver**	Anatidae	**Anatinae**	**Mergini**
Common merganser	***Mergus merganser***	**Merganser**	**Diver**	**Anatidae**	**Anatinae**	**Mergini**
Eared grebe	*Podiceps nigricollis*	Eared grebe	Grebe	Podicipedidae		
Gadwall	*Anas strepera*	Gadwall	Dabbler	Anatidae	Anatinae	Anatini
Greater scaup	***Aythya marila***	**Scaup**	**Diver**	**Anatidae**	**Anatinae**	**Aythyini**
Greater white-fronted goose	*Anser albifrons*	Greater white-fronted goose	Goose	Anatidae	Anserinae	Anserini
Green-winged teal	*Anas crecca*	Green-winged teal	Dabbler	Anatidae	Anatinae	Anatini

[9] Rows in bold indicate taxa that are not identified to the species level during the Midwinter Waterfowl Survey.
[10] Taxonomy follows Gill and Donsker (2013).

Common name	Scientific name	Name used in MWS	Guild	Family	Subfamily	Tribe
Harlequin duck	*Histrionicus histrionicus*	Harlequin duck	Diver	Anatidae	Anatinae	Mergini
Lesser scaup	***Aythya affinis***	**Scaup**	**Diver**	**Anatidae**	**Anatinae**	**Aythyini**
Long-tailed duck	*Clangula hyemalis*	Long-tailed duck	Diver	Anatidae	Anatinae	Mergini
Mallard	*Anas platyrhynchos*	Mallard	Dabbler	Anatidae	Anatinae	Anatini
Red-breasted merganser	***Mergus serrator***	**Merganser**	**Diver**	**Anatidae**	**Anatinae**	**Mergini**
Northern pintail	*Anas acuta*	Northern pintail	Dabbler	Anatidae	Anatinae	Anatini
Northern shoveler	*Anas clypeata*	Northern shoveler	Dabbler	Anatidae	Anatinae	Anatini
Pied-billed grebe	*Podilymbus podiceps*	Pied-billed grebe	Grebe	Podicipedidae		
Redhead	*Aythya americana*	Redhead	Diver	Anatidae	Anatinae	Aythyini
Ring-necked duck	*Aythya collaris*	Ring-necked duck	Diver	Anatidae	Anatinae	Aythyini
Ross's goose	*Chen rossii*	Ross's goose	Goose	Anatidae	Anserinae	Anserini
Ruddy duck	*Oxyura jamaicensis*	Ruddy duck	Diver	Anatidae	Anserinae	Oxyurini
Snow goose	*Chen caerulescens*	Snow goose	Goose	Anatidae	Anserinae	Anserini
Surf scoter	***Melanitta perspicillata***	**Scoter**	**Diver**	**Anatidae**	**Anatinae**	**Mergini**
Tundra swan	*Cygnus columbianus*	Tundra swan	Swan	Anatidae	Anserinae	Anserini
White-winged scoter	***Melanitta deglandi***	**Scoter**	**Diver**	**Anatidae**	**Anatinae**	**Mergini**
Western grebe	***Aechmophorus occidentalis***	**Clark's/western grebe**	**Grebe**	**Podicipedidae**		
Wood duck	*Aix sponsa*	Wood duck	Perching duck	Anatidae	Anatinae	Cairinini

Appendix B. San Francisco Bay Joint Venture population targets for focal waterfowl species.

Table B1. San Francisco Bay Joint Venture population targets for focal waterfowl species based on peak population levels recorded from 1988-1990 by Accurso (1999) and the corresponding Midwinter Waterfowl Survey count equivalent[11].

Species	Population targets	Corresponding MWS count equivalent
Dabbling ducks		
Mallard	702	
Northern pintail	8771	6538
Northern shoveler	48079	
Diving ducks		
Canvasback	29818	20540
Ruddy duck	24073	
Scaup spp.	139214	86824
Scoter spp.	61248	41481

Table B2. Conversion factors for determining annual peak waterfowl counts from Midwinter Waterfowl Survey data based on peak population levels recorded from 1988-1990 by Accurso (1999).

Species	Conversion factor
Northern pintail	1.341622
Canvasback	1.451713
Scaup	1.603405
Scoter	1.476519

[11] The SFBJV established population targets for focal waterfowl species in the San Francisco Estuary based on peak abundance estimates from a series of thorough surveys conducted from October-April 1988-1990 (Accurso 1992). The SFBJV's primary waterfowl goal is to provide enough high-quality wetland habitat to consistently support wintering populations of canvasback, greater and lesser scaup and scoters at peak population levels recorded in 1989–90. A secondary goal of the SFBJV is to provide enough habitat to consistently support wintering populations of mallard, northern pintail, northern shoveler, and ruddy duck at peak population levels recorded in 1989–90 (San Francisco Bay Joint Venture 2000, SFBJV Science-subcommittee 2011). As the timing of peak abundance varies by species, the MWS tends to underestimate the actual peak abundance (San Francisco Bay Joint Venture 2000). To account for this, Accurso's data from the 1988-90 period was used to derive species-specific correction factors (Table 2) that convert MWS abundance estimates to annual peak estimates. The conversion factors are based on data from the three years of fall/winter/spring surveys conducted by Accurso (1992). To obtain the annual peak estimate, the MWS abundance estimate is multiplied by the corresponding conversion factor (San Francisco Bay Joint Venture 2000, SFBJV Science-subcommittee 2011).