State of the Estuary Report 2015

Summary

WILDLIFE – Wintering Waterfowl

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State of the Estuary 2015: Wildlife

Wintering Waterfowl Population Indicator

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1. Brief description of indicator and benchmark; background

The indicator is based on indices of population abundance for two principal groups of waterfowl, dabbling and diving ducks, calculated for three regions of the Estuary: North Bay, Central San Francisco Bay and South San Francisco Bay. The indices here were determined for 1989-2014 based on data from the Midwinter Waterfowl Survey (MWS) conducted in January of each year, an annual survey conducted in the United States since 1955. For more detailed information on the MWS in the San Francisco Bay region, see Richmond et al. (2014).

For dabbling ducks, we used the six most commonly observed species in the dataset: American wigeon, gadwall, green-winged teal, mallard, northern pintail, and northern shoveler. For diving ducks, we used the six most commonly observed "species": bufflehead, canvasback, goldeneye (both Barrow's and common goldeneye), ruddy duck, scoter (black, white-winged, and surf scoter), and scaup (lesser and greater scaup). Henceforth we will refer to the six diving duck taxa as "species." Based on previous studies (Accurso 1992), birds coded as "goldeneye" were assumed to be predominantly common goldeneye, and birds coded as "scoters" were assumed to be predominantly surf scoters. For each group (dabbling ducks, diving ducks), the indicator developed synthesizes population change among all six "species," rather than species by species.

We used the historic period, 1989-1993, as the reference baseline from which we developed our benchmark. The reference period constituted the first five years of the time series available for analysis, and aligned with the published objectives of the San Francisco Bay Joint Venture. The most recent 5-year period (2010-2014) was compared to the reference baseline period. Abundance exceeding the reference value was scored "Good." Abundance 40% or more below the reference baseline was scored "Poor." Thus, Fair was 60% to 100% of the reference value. In addition, we calculated linear and quadratic trends for each group, in each region, during the entire period and also for the last 10 years.

Background:

Because of the long-recognized importance of waterfowl to the mission of the U. S. Fish and Wildlife Service, the MWS has been conducted by this agency, throughout the United States since 1955, in cooperation with state and other federal agencies. The indicator used here for the

San Francisco Estuary draws on a localized subset of the data, gathered as part of a long-standing nation-wide effort. The survey attempts to enumerate all waterfowl, by species, for "high concentration areas" of the estuary. Survey efforts in the San Francisco Estuary target two main habitat types: open bay and salt production/managed ponds. The MWS complements breeding waterfowl surveys (see, in particular, Wildlife: Breeding Waterfowl Index for the Delta and Suisun). Because the MWS has been conducted intermittently in Suisun open bay, here we only present results for North San Francisco Bay ("North Bay"), Central San Francisco Bay ("Central Bay"), and South San Francisco Bay ("South Bay"). Note that North Bay is largely coincident with San Pablo Bay.

Note that most waterfowl wintering in the San Francisco Estuary breed elsewhere in the Pacific or Central Flyways (including Alaska, Canada, the Intermountain-West, as well as additional areas inside and outside of California).

2. Summary of Indicator status and trend measurements

Indicator status was determined for dabbling ducks and for diving ducks, for each of the three regions of the San Francisco Estuary (Table 1). Comparing the recent period with the reference period, the abundance index for dabblers in North Bay increased by 631% and was scored "Good." Results are displayed in Figure 1A; the index itself is natural log-transformed, but to summarize changes in abundance for the purposes of the Table, index results were back-transformed, providing estimates of percentage change. The abundance index for North Bay divers decreased by 59% and was scored "Poor" (Table 1, Figure 1A).

The abundance index for Central Bay dabblers increased by 274% and was scored "Good" (Table 1, Figure 1B). The abundance index for Central Bay divers decreased by 71% and was scored "Poor." The abundance index for South Bay dabblers increased by 157% and was scored "Good" (Table 1, Figure 1C). The abundance index for South Bay divers increased by 21%. Because the increase was not statistically significant, we scored this group as "Fair." Thus, the four "Good" results were all significantly greater than the reference value ($P < 0.01$ or better; Table 1); the two "Poor" results were more than 40% below the reference value and each was significantly different from the baseline (Table 1). The "Fair" result was only 21% higher than the reference value and was not significantly different from the reference value.

Table 1. Summary of Wintering Waterfowl Indicator Results for San Francisco Bay. Percent change in wintering waterfowl abundance index for recent (2010-2014) vs. historic reference (1989-1993) periods for dabbling ducks and diving ducks, by region. Values shown are percent differences in the count index for the two time periods. P values for t tests on the differences between the two time periods are shown as well as the Status Score (see text and Technical Appendix for details).

	Dabbling Ducks			Diving Ducks		
	Percent change	P-value	Status	Percent change	P-value	Status
North Bay	631%	P < 0.001	Good	-59%	P = 0.001	Poor
Central SF Bay	274%	P = 0.009	Good	-71%	P < 0.001	Poor
South SF Bay	157%	P < 0.001	Good	21%	P > 0.2	Fair

Long-term linear trends were assessed over the entire time period, 1989-2014. North Bay and South Bay dabblers demonstrated significantly increasing trends (P < 0.001 in both cases; Table 2; Figure 1A, 1C); the trend for Central Bay dabblers was an increase of borderline significance (P = 0.052 for the test of the slope differing from zero; Table 2, Figure 1B). North Bay and Central Bay divers exhibited significantly decreasing long-term linear trends (P < 0.001 in both cases; Table 2); South Bay divers demonstrated an overall trend that was near zero (<1% change per year), and did not differ significantly from zero (P > 0.4).

The long-term linear trend results were predominantly concordant with the benchmark determinations. The only difference was that for Central Bay dabblers, the recent years had a significantly higher abundance than the reference period (P < 0.001), but the linear trend was only of borderline significance (P = 0.052). The discrepancy was due to the increase for this group only being manifest in the more recent years, rather than during the entire period (Figure 1B).

In addition, non-linear trends were assessed, as were short-term trends; for these, see “Trend Results” below.

3. Brief write-up of scientific results and interpretation

a. What is this indicator?

The indicator is an index of abundance calculated for two groups of ducks (dabbling ducks and diving ducks) during the winter, as determined by the MWS for the period 1989-2014 (Richmond et al. 2014). The index is calculated for each of three regions: North San Francisco Bay, henceforth "North Bay" (which includes San Pablo Bay and adjacent managed ponds), Central Bay, and South Bay (which includes adjacent salt production and managed ponds). Surveys were not conducted in Suisun Bay in many years, hence Suisun Bay surveys have not been analyzed here. Total counts of birds were summed for each region and year, separately for each species. Counts are not adjusted for incomplete coverage of survey areas (for example, open bay transects are spaced more widely than salt production/managed pond transects) nor for imperfect detection. However, the same routes are generally flown year-to-year, allowing for comparisons across years. Further details on the survey methodology are provided by Accurso (1992) and Richmond et al. (2014).

b. Why is it important?

Waterfowl are an important component of the ecosystem of the San Francisco Estuary, and of the aquatic foodweb more specifically. They represent significant energy flow and biomass, consuming both plants and invertebrates. In addition, duck hunting is an important economic and recreational activity.

San Francisco Estuary provides some of the most important wintering habitat for waterfowl, particularly for diving ducks, in the Pacific Flyway (Goals Project 2000, Steere & Schaefer 2001). For some diving duck species, the San Francisco Estuary hosts nearly half of the birds counted on the MWS in the lower Pacific Flyway, which is made up of major waterfowl concentration areas in Washington, Oregon, California, Arizona, Utah and Idaho and portions of New Mexico, Colorado, Montana and Wyoming (Steere & Schaefer 2001). This is in addition to the estuary's value to waterfowl during the breeding season (especially in the Suisun Bay region) and during the spring and fall migratory periods. More than 30 species of waterfowl are commonly observed in the San Francisco Bay region (Goals Project 2000).

The importance of the estuary for waterfowl has long been recognized. The San Francisco Bay region is identified as a waterfowl habitat area of major concern in the North American Waterfowl Management Plan (NAWMP 2004). The San Francisco Bay Joint Venture has made waterfowl conservation in the Bay area a priority and we follow their population targets (Steere and Schaefer 2001). Waterfowl conservation has also been a prime objective as part of significant restoration projects in the San Francisco Bay Area. There is the potential for waterfowl to be adversely impacted by restoration that converts former salt ponds into tidal marsh (Stralberg et al. 2009). Thus, tracking waterfowl population changes is one important component of assessing overall response to restoration, as well as to management intended to reduce or eliminate adverse impacts.

This indicator tracks two important groups of waterfowl: **dabbling ducks**, which feed at the surface or in shallow water, and **diving ducks**, which forage in the benthos at deeper depths. Under diving ducks we include bay (*Aythya* spp.), sea (Tribe *Mergini)*, and stiff tail (*Oxyura* spp.) duck species.

c. What is the benchmark? How was it selected?

The reference value used to determine the benchmark is the mean MWS abundance index in the period 1989-1993, the first five years of the available time series for which the current survey methodology was used; the San Francisco Bay Joint Venture has chosen a similar time period for setting population goals in the San Francisco Bay region. The most recent 5-year period (2010-2014) was compared to the reference period. All statistical analyses were carried out on natural log-transformed values to stabilize the variance in counts with respect to species and years as is widely recommended (Nur et al. 1999).

Abundance values exceeding the reference were scored "Good," provided that the difference was statistically significant. Abundance 40% or more below the reference was scored "Poor," assuming that the difference was statistically significant. We maintain that a 40% decline over c. 20 years, which represents an average decline of 2.5% per year, is of sufficient magnitude to elicit serious management concerns, and, possibly, management action. In addition, where the difference between current and reference values was not significant, this was scored as Fair.

d. Indicator Results, Status and Trends

i. Calculation of index values and statistical analysis.

Methods are described briefly here and in greater detail in the Technical Appendix. Counts by species were summed for each region and log-transformed in each year. For each region and for each guild (dabblers, divers), we first fit a linear model, with species and year as factors, i.e., categorical variables. We obtained model-predicted values for each year for that region-guild. To obtain these results we used two different approaches: we either weighted each species equally or we weighted each species by overall abundance in that region. Results were similar using the two approaches, but here we present only results weighted by species-specific abundance, since we consider that result to be more meaningful at the ecosystem level. We then estimated the difference between the two time periods (i.e., comparison of the five reference years with the five current years) using a comparable linear model, with model results weighted by species-specific abundance, and tested if the difference between the two time periods was significantly different from zero. Finally, we fit linear and quadratic trends to the data, again controlling for species as a factor. If the quadratic trend was statistically significant, we display that trend; if not, we graph the linear trend. We report both short-term (last 10 years) and long-term (1989-2014) linear trends, whether or not the quadratic trend was significant, to facilitate comparison among guild-by-regions. Note that a linear trend on log-transformed values provides an estimate of a constant proportional change over the period being analyzed (Nur et al. 1999).

ii. Index results and Scores

Annual variation in the natural-log-transformed waterfowl abundance index is depicted in Figures 1A, 1B, and 1C for each region of the San Francisco Bay estuary. In addition, in the Figures we depict the trend over the entire period, either linear or quadratic, choosing the trend of best fit. We depict a linear trend unless a quadratic trend provided statistically significantly better fit than a linear trend.

Comparison of the current period (last 5 years) with the reference period is summarized in Table 1. Dabbling ducks had sizeable and significant increases in all three regions; therefore all regions are scored "Good." Diving ducks had strong, significant declines in the North Bay and Central Bay; therefore these are scored Poor. South Bay diving ducks had a modest, non-significant increase comparing current to reference periods; they are scored as Fair.

iii. Trend Results

Trends were analyzed for each region-guild, both long-term (entire time series) and short-term (last 10 years). Linear trend results are shown in Table 2. Quadratic trend results are summarized in the text and in Figure 1, but only where they provide superior model fit compared to a linear trend (i.e., the quadratic coefficient was significantly different from zero). Dabbling ducks had increasing trends in all three bay regions, both short- and long-term. For this guild, all trends were significant except North Bay short-term trend ($P > 0.6$) and long-term trend for Central Bay, which was marginally significant ($P = 0.052$). For Central Bay and South Bay dabblers, the quadratic trend was significant, and up-turned (accelerating; Figures 1B, 1C). In the North Bay, there was no significant quadratic curvature.

Diving ducks had long-term significant declines in the North Bay, but not in the short-term (Table 1). In the Central Bay, both long-term and short-term declines were significant. In the South Bay, there were weak, positive but not significant ($P > 0.1$ or greater) increases both long- and short-term.

Central Bay diving ducks had significant downward curvature (i.e., accelerating decline; Figure 1B). North Bay and South Bay diving ducks evidenced no significant curvature.

Table 2. Trends in the San Francisco Estuary Wintering Waterfowl Population Indicator (midwinter waterfowl surveys, USFWS). Long-term (1989 - 2014) and short-term (2005 - 2014) linear trends in the abundance index for two groups of waterfowl. Shown are estimated annual, constant percent changes per year in the abundance index for the two time periods. P values shown for t test of whether slope is different from zero. Analyses control for species-specific differences, weighted by abundance of each species (see text).

	Number of years	Dabbling Ducks Ann Pct Change	P-value	Diving Ducks Ann Pct Change	P-value
North Bay					
Long-term	23	10.2%	P < 0.001	-4.0%	P < 0.001
Short-term	10	1.6%	P > 0.6	-0.3%	P > 0.1
Central SF Bay					
Long-term	24	4.6%	P = 0.052	-5.6%	P < 0.001
Short-term	10	21.2%	P = 0.010	-10.9%	P < 0.001
South SF Bay					
Long-term	24	5.1%	P < 0.001	0.6%	P > 0.4
Short-term	10	7.3%	P < 0.001	2.7%	P > 0.1

Figure 1A. Abundance Index for dabblers and divers, North Bay. Note reference values (mean, 1989-1993) = 6.49 (dabbler); 9.81 (diver). The best fit was a linear trend for both groups, shown. Model-fitted index values (ln-transformed counts) for each year, weighted by species abundance, are shown.

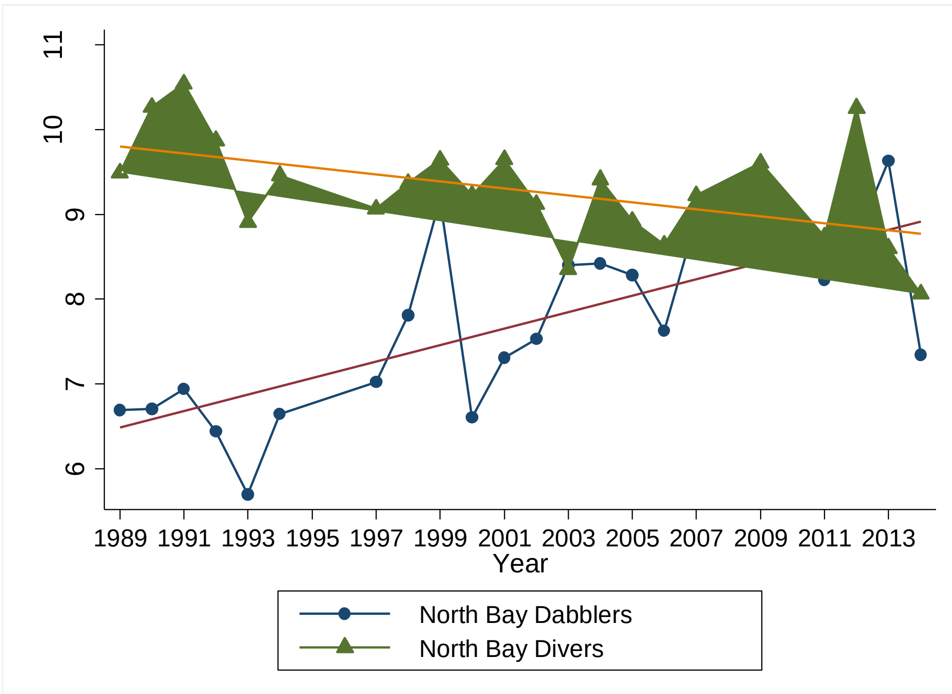


Figure 1 B. Abundance Index for dabblers and divers, Central Bay. Note reference values (mean, 1989-1993) = 2.76 (dabblers); 4.08 (divers). The best fit was a quadratic trend for both groups, shown. Model-fitted index values (ln-transformed counts) for each year, weighted by species abundance, are shown.

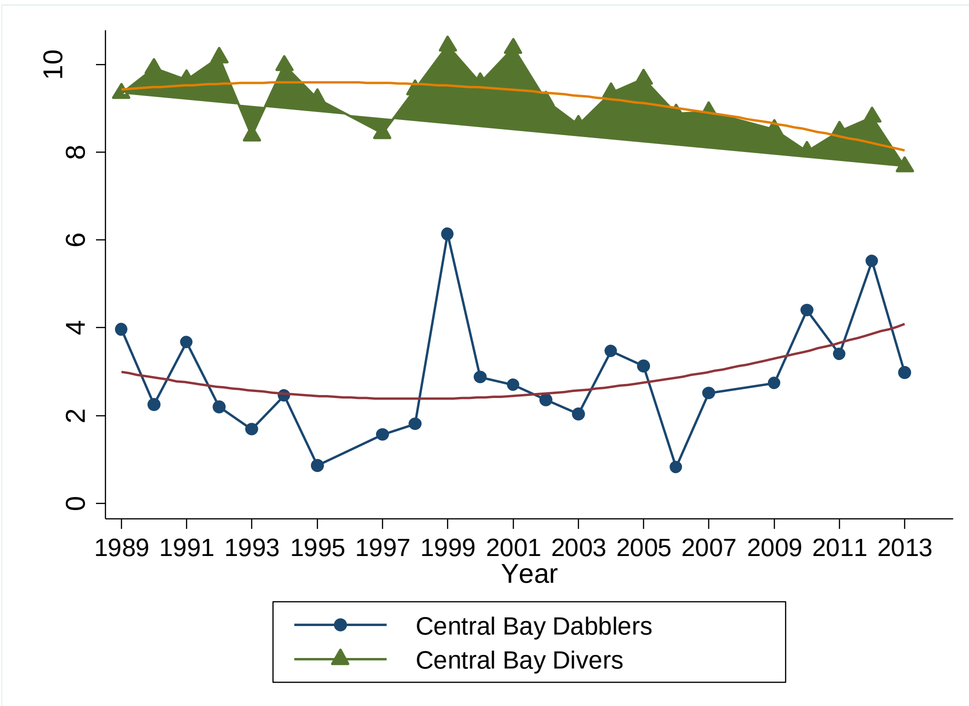
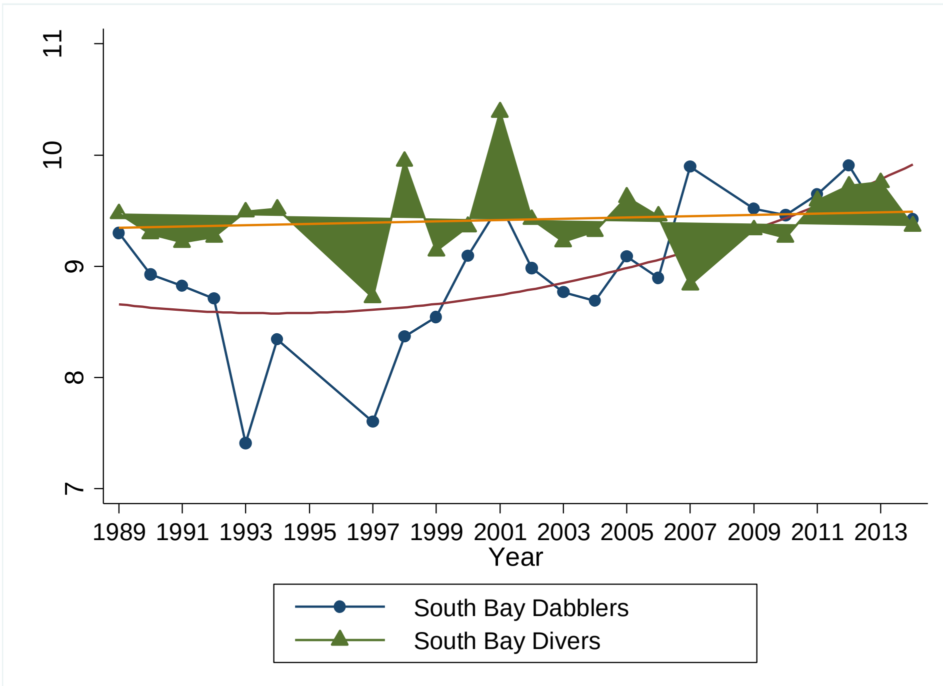


Figure 1C. Abundance Index for dabblers and divers, South Bay. Note reference values (mean, 1989-1993) = 8.63 (dabblers); 9.35 (divers). The best fit was a linear trend for divers and a quadratic trend for dabblers, shown. Model-fitted index values (ln-transformed counts) for each year, weighted by species abundance, are shown.



d. What does it mean?

The dabbler guild demonstrated sharply increasing trends in abundance in the North Bay and South Bay. In fact, species by species, all six dabbler species showed increasing trends in the North Bay, while in the South Bay, five of the six species showed an increasing trend, with only gadwall displaying a non-significant decreasing trend (see Technical Appendix for individual species results). In the Central Bay, dabbler trends were less evident, with no species demonstrating a significant trend, though four out of five were positive; only northern pintail showed a non-significant declining trend (no green-winged teal were present in the Central Bay). Nevertheless, in the Central Bay, recent trends for dabblers were significantly positive, and as a result the comparison of the current period to the reference period was scored as Good, reflecting a 274% increase ($P = 0.009$).

For **the diving duck guild**, the picture differed depending on bay region. In the North Bay and in the Central Bay, divers demonstrated significant declining trends. Scaup, scoter, and goldeneye all declined significantly in the North Bay; the other three species were weakly positive (ruddy duck) or weakly negative (bufflehead, canvasback). In the Central Bay, scaup and scoter also declined significantly, while bufflehead increased significantly. The other three species either displayed non-significant declines (canvasback, gadwall) or non-significant increases (ruddy duck).

In the South Bay, there was an overall weak, increasing trend for divers, at about 0.6% per year, over the long-term, but 2.7% increase per year in recent years. These trends were not significant ($P > 0.1$ or greater). Here, results differed most markedly among species. Scaup demonstrated a significant, strong declining trend, whereas ruddy duck, goldeneye and canvasback demonstrated significant positive trends. The other species had non-significant trends either positive (bufflehead) or negative (scoter). Thus, the score of Fair for South Bay divers reflects a mixed picture, i.e., a combination of strong declines for scaup, significant increases for three species, and intermediate, non-significant trends for the other two species.

In summary, dabbling ducks have demonstrated increases (and are scored Good) in all three regions while diving ducks have either declined strongly and significantly (in the North Bay and Central Bay) or demonstrated a mixed picture (in the South Bay) reflecting species-specific differences. In the latter case, the modest overall increase in the diving duck index (compared to reference) is tempered by the strong, significant decline for scaup.

The strong decline in diving ducks is potentially of great concern. However, a better understanding is needed of how wintering distributions of diving ducks are shifting over time in response to climate change and other factors. An open question is whether the diver declines observed in the San Francisco Estuary represent true population declines or shifts in wintering distribution to other areas. A comparison with diver trends for the entire Pacific Flyway provides some insight into this question (see Richmond et al. 2014 for an analysis of trends from 1981-2012), however the MWS does not include the west coast of Canada nor Alaska due to weather restrictions. Thus, the MWS Flyway data may not be adequate for detecting northward shifts in wintering distributions. The difference in outlook for diving versus dabbling ducks likely reflects, in part, differences in food availability, reflecting prey or plant species, as well as availability of foraging locations (dabbling ducks can forage in shallower water; Goals Project 2000, Stralberg et al. 2009). However, a second important factor is the status of breeding populations outside of the San Francisco Estuary, since most wintering waterfowl breed elsewhere. Since Pacific Flyway populations are characterized by declining populations of scaup (Austin et al. 2000; Afton and Anderson 2001; Austin et al. 2006; USFWS 2009) and scoter (Agler et al. 1999) and increasing populations of dabbling ducks (USFWS 2009), such as mallard, it is not surprising that San Francisco Estuary MWS results show a similar picture.

The widely observed increase in dabbling ducks must be considered a positive result. Such a result is consistent with favorable environmental conditions in the San Francisco Estuary during the winter, but it may reflect changes in the wintering distribution of these species. In addition, favorable conditions on the breeding grounds for dabbling ducks, far removed from the San Francisco Estuary, may be contributing to the observed increase. If changes in wintering distribution are leading to reduced abundance of diving ducks, we must consider what may be the underlying causes for such shifts. Possibilities include drought, range contraction due to climate effects, increased development that leads to habitat loss or alteration, and long-term changes in prey resources. For both dabblers and divers, ongoing restoration is of potential concern, since conversion of managed ponds to tidal marsh will likely impact both groups of ducks, but especially diving ducks, because they depend on deeper water to forage, and thus have little opportunity to forage in tidal marsh habitat (Stralberg et al. 2009).

4. Figures. Figures have been inserted into the text above.

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Technical Appendix

WILDLIFE – Wintering Waterfowl

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Technical Appendix.

Background and Rationale

This is described in more detail in section 1, above. The indicator is a multi-species indicator, calculated separately for diving ducks and dabbling ducks and separately for each region of the San Francisco Bay Estuary. For each of the two groups of ducks we analyzed data from the six most abundant species. Two approaches were explored for combining results among species: weighting each species equally or weighting each species in proportion to its overall abundance in the dataset. Note that "combining species" refers to analyzing multiple species in a single model, where waterfowl counts were first natural log-transformed before analysis.

Benchmark

The benchmark chosen was the average index value for the first five years of the time series analyzed, 1989-1993. Note that the MWS began in 1955, but only since 1989 have data been collected in a standardized manner sufficient to allow analysis. The period we have chosen is similar to the period chosen by the San Francisco Bay Joint Venture for their baseline comparisons, 1988 to 1990.

Data Sources and Methods

Data collection for the San Francisco Bay Midwinter Waterfowl Surveys is described in Richmond et al. (2014). The results compiled and analyzed here were collected on surveys led by USFWS in San Francisco Bay, with many collaborators including San Francisco Bay Bird Observatory and USGS. In brief, surveys are conducted on a single day per survey area per year; often several areas are surveyed in a single day. Surveys are conducted from fixed-wing aircraft, as well as from the ground. Open bay and salt ponds are the targeted habitats.

Surveys are not standardized with respect to tide. Weather and other physical conditions during the survey period are noted but analyses do not statistically adjust for weather conditions (Richmond et al. 2014). Survey effort may be noted, but counts are not adjusted by effort. In theory, one could convert counts into densities by dividing by the area surveyed, but this has not been implemented.

The statistical approach used was to tally the number of individuals counted in each region, by species, separately for each habitat type (open bay or salt pond). Survey numbers are summarized by bay region: North Bay (San Pablo Bay and the northern portion of San Francisco Bay), Central San Francisco Bay, and South San Francisco Bay. For each species in each region, counts were then either summed over the two habitat types (results presented in the main section, above) or analyzed separately (results presented here in the Technical Appendix). The next step was to natural-log-transform all the counts. All analyses were conducted on ln-transformed counts and results presented in the Figures use this index.

The index values were analyzed in a linear model that included species main effects, separately for dabbling and diving ducks and by region. Each analysis included six species of dabbling ducks (American wigeon, gadwall, green-winged teal, mallard, northern pintail, and northern shoveler) and six species of diving ducks (bufflehead, canvasback, goldeneye, ruddy duck, scaup, and scoter). The result was an overall estimate of change over time for each waterfowl group (dabblers and divers). For estimating year to year differences in the index value for each analysis, we used the `margins` command in STATA 13.1 (Stata Corp.). For trend estimation, we estimated the "common slope" across species.

We used three methods to evaluate change over time: (1) long-term trends over time, for the period 1989 to 2014, (2) short-term trends over time, for the most recent 10 yr period (2005-2014), and (3) comparison of the period 2010-2014 with the 5-year reference period, 1989 to 1993. For all analyses, we either weighted each species equally or weighted each species by its mean abundance. Given the large variation in abundance among the twelve species, we chose to present results weighting by abundance.

Assumptions and uncertainties: The number of waterfowl counted during the survey period may be affected by weather conditions and the ability of observers to enumerate and identify individuals to species. In addition survey effort may vary. In some cases transects may be widely spaced and in other cases more tightly spaced. These influences are not incorporated into current analyses.

A second problem is that a comprehensive, systematic, probabilistic sampling frame is not used. Thus, there may be biases in deriving the annual index value because some areas are more likely to be included than others. Tidal marsh habitat, for example, is not sampled. In addition, shallow areas of open bay are less likely to be included. These deficiencies are well known for the MWS and summarized in Richmond et al. (2014). As a result plans are underway to modify the design and analysis of MWS data.

Additional Details Regarding Results

The wintering waterfowl indicator combines data across species for each guild. We maintain that assessing the condition of waterfowl is best accomplished through combining data among multiple species; that said, it is nevertheless also informative to examine species-specific results. Table A1 provides trend results for each species, by bay region. The analysis method is the same as that presented in Table 2 above, except that each species was analyzed separately.

For North Bay dabblers, all species demonstrated increasing trends, and for five of the six species, the trend was significant. In fact, all North Bay dabbler species increased at rates of at least 5% per year.

Central Bay dabblers showed non-significant increasing trends for three species, and a non-significant declining trend for northern pintail. Green-winged teal were not observed in the Central Bay.

South Bay dabblers showed significant increasing trends for two species (American wigeon and Green-winged teal) and marginally significant increasing trends for two species (northern pintail and northern shoveler). The remaining two species displayed non-significant trends, either positive (mallard) or negative (gadwall). Thus, five of six dabblers in the South Bay showed increasing trends, but only two were statistically significant.

For North Bay divers, five out of six species demonstrated declining trends (as did the group overall, Table 2, above). Only the ruddy duck showed an increase among divers, and it did so in all three regions though trends were not significant in the North Bay or Central Bay. Three of the six species showed significant declining trends in the North Bay (all at $P < 0.01$): goldeneye, scaup and scoter. Scoter was the only species (diver or dabbler) to show significant declining trends in all three regions, in all cases exceeding 7% decline per year.

For Central Bay divers the pattern was mixed. Bufflehead increased significantly, but scaup and scoter decreased significantly. The decline in canvasback was estimated to be 10% per year but was borderline significant ($P = 0.050$). The trends for two species were not significant ($P > 0.4$): goldeneye (increasing) and ruddy duck (decreasing).

Among South Bay divers, results were split. Four of the six species had increasing trends; three of these were significant (canvasback, goldeneye, and ruddy duck); bufflehead increased but not significantly. Scoter declined significantly while the decline in scaup was less than 1% per year and not significant. Thus, in the North Bay and Central Bay, either four or five (respectively) of the six species declined, but, in the South Bay, four of six species increased.

Appendix, Table A1: San Francisco Estuary Waterfowl (winter waterfowl surveys, USFWS)

Long-term (1989 to 2014) linear trends for individual species, for two groups of waterfowl

Shown are estimated annual percent changes per year in population index, for open bay and salt ponds combined.

	North Bay			Central Bay			South Bay		
	Coeff	Ann Pct	P-value	Coeff	Ann Pct	P-value	Coeff	Ann Pct	P-value
Dabblers									
American Wigeon	0.1049	11.1%	P < 0.001	0.0606	6.2%	P > 0.15	0.0985	10.4%	P < 0.001
Gadwall	0.1321	14.1%	P < 0.001	0.0128	1.3%	P > 0.7	-0.0124	-1.2%	P > 0.5
Green-winged Teal	0.0560	5.8%	P > 0.2	no observations			0.1094	11.6%	P = 0.019
Mallard	0.1195	12.7%	P = 0.002	0.0617	6.4%	P > 0.2	0.0363	3.7%	P > 0.15
Northern Pintail	0.0787	8.2%	P = 0.024	-0.0111	-1.1%	P > 0.8	0.0478	4.9%	P = 0.052
Northern Shoveler	0.0893	9.3%	P = 0.001	0.0596	6.1%	P > 0.3	0.0317	3.2%	P = 0.10
Divers									
Bufflehead	-0.0232	-2.3%	P > 0.2	0.0794	8.3%	P = 0.008	0.0269	2.7%	P > 0.1
Canvasback	-0.0069	-0.7%	P > 0.7	-0.1054	-10.0%	P = 0.050	0.0228	2.3%	P = 0.027
Goldeneye	-0.1277	-12.0%	P = 0.001	-0.0063	-0.6%	P > 0.9	0.1058	11.2%	P = 0.011
Ruddy Duck	0.0295	3.0%	P > 0.2	0.0262	2.7%	P > 0.4	0.0565	5.8%	P = 0.001
Scaup	-0.0500	-4.9%	P = 0.008	-0.0549	-5.3%	P = 0.003	-0.0076	-0.8%	P > 0.5
Scoter	-0.1042	-9.9%	P = 0.001	-0.0806	-7.7%	P = 0.002	-0.0864	-8.3%	P < 0.001

The wintering waterfowl indicator also combined data across two important habitat types: open bay and salt ponds. For each guild, Table A2 separates trends for open bay from those for salt ponds for the North Bay and South Bay regions (no salt ponds are found in the Central Bay). Table A2 demonstrates that in the North Bay trends differed for dabblers in the salt ponds (significant increase at 12.4% year), compared to the same species in the open bay (non-significant increase of 2.5% per year). However, trends were similar and not statistically distinguishable for divers in the North Bay: divers declined significantly in both habitat types.

Appendix Table A2: San Francisco Estuary Waterfowl (winter waterfowl surveys, USFWS)
Long-term (1989 to 2014) linear trends by habitat, for two groups of waterfowl
Shown are estimated annual percent changes per year in population index

	Dabbling Ducks			**Diving Ducks**		
	Coeff	Ann Pct	P-value	Coeff	Ann Pct	P-value
North Bay						
Open Bay	0.0245	2.5%	P > 0.2	-0.0428	-4.2%	P = 0.002
Salt Ponds	0.1167	12.4%	P < 0.001	-0.0292	-2.9%	P = 0.039
South SF Bay						
Open Bay	0.0610	6.3%	P = 0.006	-0.0208	-2.1%	P > 0.15
Salt Ponds	0.0555	5.7%	P < 0.001	0.0899	9.4%	P < 0.001

The complementary pattern was observed in the South Bay. Here the trend for dabblers was similar in open bay and in the salt ponds (significant increase of about 6% per year). However, for divers trends differed in the two habitats: diving ducks increased significantly in salt ponds but showed non-significant declining trends in open bay habitat in the South Bay.

To summarize, trends for dabbling and diving ducks in some cases differed in salt ponds as compared to open bay, and in other cases did not differ. Habitat-specific trends differed most strongly among North Bay dabblers and South Bay divers.

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