State of the Estuary Report 2015

Summary

WILDLIFE – Herons and Egrets

Prepared by

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State of the San Francisco Estuary 2015
Wildlife – Heron and Egret Nest Density and Nest Survival Indicators

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What are the indicators?

As top wetland predators that operate over large areas of the San Francisco Estuary, herons and egrets depend on extensive tidal marshes, seasonal wetlands, and associated freshwater systems. The State of the Estuary Report uses two indicators based on the status of nesting herons and egrets to assess ecological conditions across broad wetland landscapes. The Heron and Egret Nest Density Indicator provides an index of regional heron and egret population sizes. The Heron and Egret Nest Success Indicator is based on nest survival through the breeding cycle (not on the productivity of successful nests) and is used to assess the dynamics of nest-predator populations, human disturbance, and changes in human land use that can affect the size and distribution heron and egrets nesting colonies. The chapter on "Processes-Feeding Chicks," in the 2015 State of the Estuary Report, summarizes the Heron and Egret Brood Size Indicator, which uses the number of young produced in successful nests to index conditions that affect the availability of food, the productivity of estuarine food webs, and the quality of wetland feeding areas. For details, see State of the Estuary 2015: Processes – Heron and Egret Brood Size Indicator document.

Attribute	Indicator	Benchmark
Wildlife: Birds	Great Blue Heron/Great Egret Nest Density	The benchmark for nest density is the average nest density observed from 1991-2000, for each region: Central San Francisco Bay, San Pablo Bay, and Suisun Bay, and all three areas combined.
	Great Blue Heron/Great Egret Nest Survival	The benchmark for nest success is the average nest survival from 1994-2000, for each region: Central San Francisco Bay, San Pablo Bay, and Suisun Bay, and all three areas combined.

How are the current indicator conditions measured?

Heron and Egret Nest Density Indicator
The Heron and Egret Nest Density Indicator was calculated using data from ongoing regional heron and egret studies by Audubon Canyon Ranch (Kelly et al. 1993, 2007, 2008; Kelly and Condeso 2014). The data, which reflect repeated annual nest counts at all known colony sites, provide intensive and extensive measurements of nest abundance and an index of regional breeding population sizes. Results

are provided for each year (1991-2014), for all known nesting colonies in each of three northern subregions (Central San Francisco Bay, San Pablo Bay, Suisun Bay, and the combined area of all three subregions.

The Nest Density Indicator is calculated as the geometric mean of annual nest densities for two species, Great Blue Heron (*Ardea herodias*) and Great Egret (*Ardea alba*). The Heron and Egret Nest Density Indicator was also calculated separately for Great Egrets and Great Blue Herons (see Technical Appendix). Nest density estimates are based the peak number of active nests at each of 40-50 active colony sites each year, summed within and across subregions, based on four (monthly) visits per year to each site within foraging range (10 km) of the historic tidal wetland boundary (ca.1770–1820; San Francisco Estuary Institute 1999). Density is calculated as the number of nests per 100 km^2, within the region or subregion, excluding the extensive open water areas of the San Francisco Estuary.

For analysis, we calculated the percent change in the mean indicator values during recent years, 2009-2014, relative to the ten-year baseline period, 1991-2000. In addition, patterns of proportional change over time were modeled as linear or quadratic trends over the 24 years of monitoring, 1991-2014. The trends were estimated using quadratic models, with increasing or decreasing slopes, *if and only if* the quadratic term was significant ($P<0.05$); otherwise changes over time were estimated as linear trends.

Heron and Egret Nest Survival Indicator

Audubon Canyon Ranch has monitored the survival of focal Great Blue Heron and Great Egret nests (proportion of nest attempts that fledge at least one young) across nesting colonies throughout the northern San Francisco Estuary, annually, since 1994 (Kelly et al. 2007, Kelly and Condeso 2014).

The Heron and Egret Nest Survival Indicator, calculated as the annual, arithmetic mean of apparent nest success, between species, for Great Egret and Great Blue Heron, is calculated within and across the three major subregions of northern San Francisco Bay (Central San Francisco Bay, San Pablo Bay, and Suisun Bay; Indicator values were also calculated separately for Great Egrets and Great Blue Herons; see Technical Appendix). Great Egret and Great Blue Heron nests are considered successful if at least one young survives to minimum fledging age of seven or eight weeks, respectively (Pratt 1970, Pratt and Winkler 1985). Nest are sampled in approximate proportion to colony size. In colonies with fewer than 15 active nests, all nests initiated before the colony reaches peak nest abundance are treated as focal nests. At larger colonies, random samples of at least 10-15 focal nests are selected.

For analysis, we calculated the percent change in the mean Nest Survival Indicator between recent years, 2009-2014, and the seven-year baseline period, 1994-2000. In addition, changes over time were estimated using linear or quadratic models over 21 years, 1994-2014. As with the Nest Density Indicator, above, changes were modeled as quadratic trends *if and only if* the quadratic term was significant ($P<0.05$); otherwise they were estimated as linear trends. We converted estimates of proportional change to percent annual change over the entire monitoring period, or before/after years with minimum/maximum values.

What are the benchmarks for these indicators, and how were they selected?

Heron and Egret Nest Density Indicator

The benchmark for the Heron and Egret Nest Density Indicator is the geometric mean indicator value (back-transformed, $\log_e$ mean) during the first ten years of regional monitoring, 1991-2000. This period was selected because it reflected a period of relatively lower annual variation in nest density for both of the two study species, relative to subsequent years.

Heron and Egret Nest Survival Indicator

The benchmark for the Heron and Egret Nest Survival Indicator is mean annual proportional nest survival during the first seven years of regional monitoring, 1994-2000. This period was selected to be consistent with the benchmark selected for the Heron and Egret Nest Density Indicator but reduced in length because of nest survival data were not available for 1991-1993.

What is the status and trend of each indicator in each area?

Heron and Egret Nest Density

Heron and Egret Nest Density (Figure 1, Table 1) increased by 1.1% annually across all areas ($\log_e$ density increase: 0.012 ±0.005 [SE] per year; P=0.046). In recent years, 2009-2014, Heron and Egret Nest Density

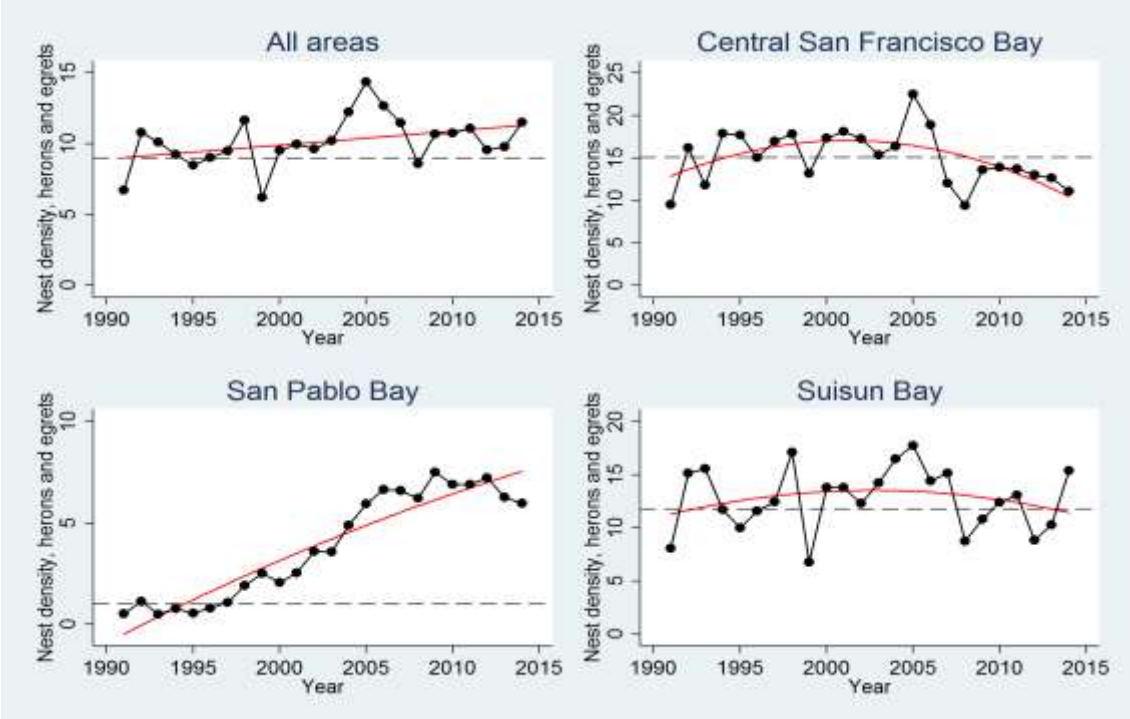

Figure 1. Annual Heron and Egret Nest Density Indicator and trends in Central San Francisco Bay, San Pablo Bay, and Suisun Bay, and all areas combined, 1991-2014. Red lines indicate the linear or quadratic trends, 1991-2014; dashed lines indicate the mean values (benchmarks) for the reference period 1991-2000.

was 17% greater, on average, than during the baseline period of 1991-2000 ($F_{1,14}$=3.6, P<0.07), although the difference was only marginally significant (Table 1).

Heron and Egret Nest Density in Central San Francisco Bay exhibited an increasing, quadratic trend that leveled off in 2001 ($F_{2,21}$=5.82, P<0.01) at 17.4 nests per 100 km^2, 13% above the baseline. After 2001, nest density declined, on average, by 3.5% annually ($\log_e$ decline: 0.04±0.01; P=0.01). Heron and egret nest density appeared to be 14% lower in 2009-2014 than during the baseline period, although the significance was marginal ($F_{1,14}$= 2.71, P=0.12; Table 1).

In San Pablo Bay, the Heron and Egret Nest Density Index increased by 13.5% annually since 1991 ($\log_e$ increase: 0.126±0.012 per year, P<0.001), but leveled off after 2010. Heron and Egret Nest Density was 570% greater in San Pablo Bay, on average, in 2009-2014 than during the baseline period ($F_{1,14}$=59.3, P<0.001; Table 1). In Suisun Bay, Heron and Egret Nest Density was dynamic across years but

showed no significant trend ($F_{2,21}$=0.66, P=0.53) or difference between recent years and the baseline period, 1991-2000 ($F_{1,14}$=0.01, P=0.91; Table 1).

Table 1. Heron and Egret Nest Density Indicator (species combined) results including current and baseline means (nests/100 km^2), 95% confidence intervals (CI), and percent change comparing the "current" period of recent years, 2009-2014, relative to the baseline period, 1991-2000, the mean percent change between current and baseline periods, and the *F*-value and significance (*P*) of the change; all results are back-transformed from natural-log values.

Area	Current (2009-2014)	95% CI	Baseline (1991-2000)	95% CI	Percent change	$F_{1, 14}$	*P*
All areas combined	10.6	9.8 - 11.4	9.0	7.9 - 10.3	**17.0**	**3.6**	**0.07**
Central San Francisco Bay	12.9	11.8 - 14.1	15.1	12.9 - 17.5	-14.1	2.7	0.12
San Pablo Bay	6.8	6.2 - 7.4	1.0	0.7 - 1.7	**570.0**	**59.3**	**<0.001**
Suisun Bay	11.6	9.5- 14.3	11.8	9.5 - 14.5	-1.4	0.1	0.91

Heron and Egret Nest Survival

Mean Heron and Egret Nest Survival (Figure 2, Table 2) across northern San Francisco Bay was dynamic but stable, exhibiting no significant trend ($F_{2,18}$=.80, P=0.46) and no significant difference between recent years (2009-2014) and the baseline period (1994-2000; $F_{1,14}$=0.9, P=0.35; Table 2). However,

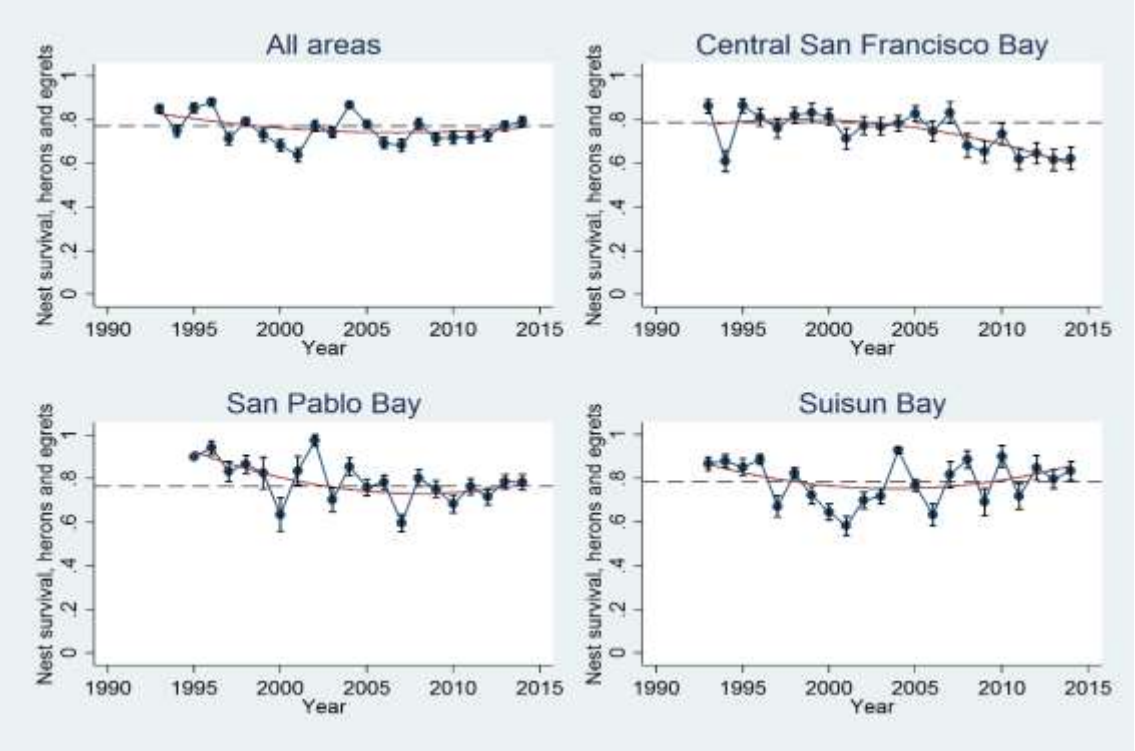

Figure 2. Annual Heron and Egret Nest Survival Indicator and trends in Central San Francisco Bay, San Pablo Bay, and Suisun Bay, and all areas combined, 1991-2014. Error bars represent standard errors; red lines indicate the linear or quadratic trends, 1991-2014; dashed lines indicate the mean values (benchmarks) for the reference period 1994-2000.

within Central San Francisco Bay, nest survival began to decline in 1998, at an average rate of 1.8% per year ($\log_e$ rate: -0.018±0.0003; $F_{1,15}$=35.2, P<0.001), dropping from 78% nest survival in 1994-2000 to 65% in 2009-2014 ($F_{1,14}$=13.1, P=0.004). In San Pablo Bay, Heron and egret nest survival declined by 1.46% per year from 1995 to 2008, then leveled out through 2014 ($F_{2,17}$=3.78, P=0.04). Mean nest survival was relatively stable in Suisun Bay ($F_{2,18}$=0.89, P=0.42).

Table 2. Heron and Egret Nest Survival Indicator (species combined) results, including the mean and standard error (SE) of annual percent nest survival, weighted equally among years, l during the "current" period of recent years, 2009-2014, and the baseline period, 1994-2000, the mean percent change between current and baseline periods, and the *F*-value and significance (*P*) of the change relative to variation among years.

Area	Current (2009-2014)	SE	Baseline (1994-2000)	SE	Percent change	$F_{1, 11}$	*P*
All areas combined	74.3	2.44	77.5	2.22	-4.1	0.9	0.35

Central San Francisco Bay	64.7	2.91	78.8	2.59	**-17.9**	**13.1**	**0.004**
San Pablo Bay	75.0	4.21	76.3	6.29	-1.7	0.03	0.87
Suisun Bay	79.3	5.19	78.7	3.04	0.7	0.01	0.93

In general, what do the results mean and why are they important?

Heron and Egret Nest Density

The nesting densities of herons and egrets are stable or increasing in the northern San Francisco Bay region. This suggests improvements in wetland condition associated with the extent or quality of suitable foraging or nesting areas, or with the supply or availability of fish or other suitable prey. In San Pablo Bay, substantial increases in heron and egret nesting density may be associated with wetland restoration efforts; the apparent, recent leveling off of nest densities in San Pablo Bay suggests that regional heron and egret distributions have stabilized after the colonization of new wetland feeding areas. A relatively steep, declining trend in nest density in Central San Francisco Bay may be of some concern, with regard to the management of several islands used for nesting, including the potential disturbance by ravens or other nest predators.

Heron and Egret Nest Survival

Heron and Egret nest survival is stable when measured across all areas of northern San Francisco Bay. This is consistentwith the localized scale of disturbance to heronries that accounts for most of the variation in nest survival (Kelly et al. 2007). The declining trend in nest survival in Central San Francisco Bay is consistent with the parallel decline in nest density. This suggests that localized disturbances by nest predators or humans, which typically account for most heron and egret nest failures, could be reducing the number of nesting herons and egrets in Central San Francisco Bay.

How do the indicators relate to the ecological health of the estuary?

Heron and Egret Nest Density Indicator

Heron and egret nest abundance is recognized as a valuable metric for assessing biotic condition in estuarine and wetland ecosystems (Parnell et al. 1988, Kushlan 1993, Fasola et al. 2010, Kushlan and Hancock 2005, Kelly et al. 2008, Erwin and Custer 2000). Energetic limits on the foraging ranges of these species are associated with interannual shifts among nesting colony sites that in turn lead to dynamic variation in nest density which reflects suitability of surrounding feeding areas (Gibbs 1991, Wittenberger and Hunt 1985, Kelly et al. 2008). The two target species are used to indicate population responses to different habitat conditions: Great Egrets preferentially forage in small ponds in emergent wetlands and in areas with shallow, fluctuating water depths for foraging. In contrast, Great Blue Herons forage along the edges of larger bodies of water and creeks and are less sensitive to water depth (Custer and Galli 2002, Gawlik 2002). This indicator is sensitive to changes in land-use, hydrology (especially water circulation and depth), geomorphology, environmental contamination, vegetation characteristics, and the availability of suitable prey (Kushlan 2000).

Differences in breeding abundance reflect responses to habitat conditions within 30-300 km^2 (Custer et al. 2004, Kelly et al. 2008) and can be used to evaluate differences in habitat use between or across years at multiple spatial scales (colony sites, major wetland subregions, region-wide). Linkage between nest abundance and the landscape distribution of wetland habitat types is well-documented

in the San Francisco Estuary (Kelly et al 2008) and in the Sacramento Valley (Elphick 2008). At the local scale of colony sites and adjacent marshes, changes in heron and egret nest abundance reflect variation in other factors, such as disease, nest predation, especially by human commensal species such as raccoons or ravens, and direct human disturbance to colony sites (Kelly et al. 2007).

Heron and Egret Nest Survival Indicator

This indicator is sensitive to nest predation and colony disturbance by native and introduced nest predators (especially by human commensal species such as raccoons and ravens), land development and human activity near heronries, and severe weather (Pratt and Winkler 1985, Frederick and Spalding 1994, Kelly et al. 2005 and 2007, Rothenbach and Kelly 2012). Such ecological processes can vary over space and time in response to landscape patterns of habitat change, dynamics of predator populations, and changes in human land use (Kelly et al. 2008), and are therefore likely to differentially affect nesting colonies of herons and egrets. Nest survival is not a strong indicator of food availability; processes affecting food web conditions are more clearly monitored by the Heron and Egret Brood Size Indicator (see chapter on Processes).

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Technical Appendix

WILDLIFE – Herons and Egrets

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Technical Appendix

Great Blue Heron Nest Density.

The evaluation of Great Blue Heron nest density (Figure 3, Table 3) across all areas revealed an increasing, quadratic trend that peaked in 2005 ($F_{2,21}$=3025 P=0.058), with an estimated maximum density of 6.3, 17.2% above the baseline average. After 2005, nest density declined, although non-significantly, by 2.2% per year ($F_{1,7}$=2.0, P=0.20). Mean Great Blue heron nest density in 2009-2014 did not differ from the baseline period ($F_{1,14}$=1.58, P=0.23; Table 3).

In Central San Francisco Bay, Great Blue Heron nest density increased by 4.1% annually ($\log_e$ trend: 0.040±0.006 [SE], P<0.001), until 2011 reaching a an estimated maximum density of 12.9 birds per 100 km^2, 67.8% above the baseline average ($F_{2,21}$=37.52 P<0.001). In 2009-2014, Great Blue Heron nest density in Central San Francisco Bay was 66.2% greater, on average, than during the baseline period ($F_{1,24}$=24.1; P<0.001; Table 3).

Great Blue Heron nest density in San Pablo Bay exhibited a marginally significant linear increase of 1.3% ($\log_e$ increase of .013±007 per year; P=0.08), leading in 2009-2014 to nest density 25.9% greater, on average, than during the baseline period ($F_{1,14}$=5.0; P=0.04; Table 3).

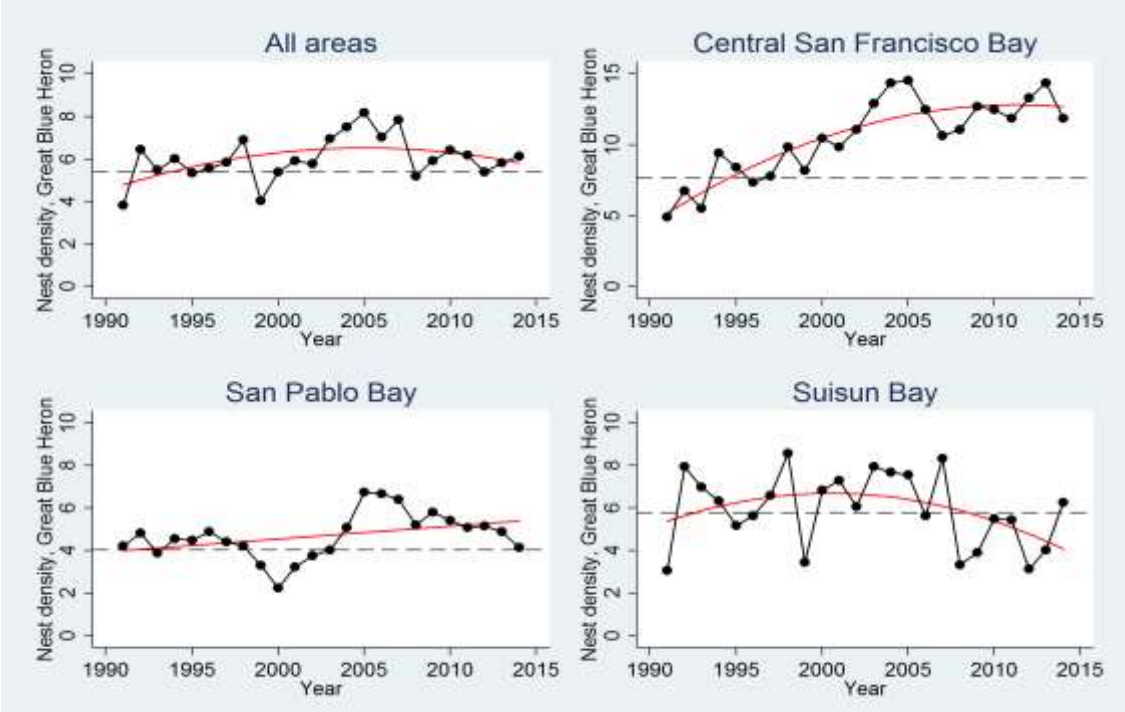

Figure 3. Annual Great Blue Heron nest density and trends in Central San Francisco Bay, San Pablo Bay, and Suisun Bay, and all areas combined, 1991-2014. Red lines indicate the linear or quadratic trends, 1991-2014; dashed lines indicate the mean values (benchmarks) for the reference period 1991-2000.

Table 3. Great Blue Heron Nest Density Indicator results, including current and baseline means (nests/100 km2), 95% confidence intervals (CI), and percent change during the "current" period of recent years, 2009-2014, relative to the baseline period, 1991-2000, the mean percent change between current and baseline periods, and the F-value and significance (*P*) of the change; all results are back-transformed from natural-log values.

Area	Current (2009-2014)	95% CI	Baseline (1991-2000)	95% CI	Percent change	$F_{1, 14}$	*P*
All areas combined	6.0	5.6 - 6.4	5.4	4.7 - 6.2	10.5	1.6	0.23
Central San Francisco Bay	12.8	11.8 - 13.8	7.7	6.4 - 9.1	**62.2**	**24.1**	**<0.001**
San Pablo Bay	5.1	4.5 - 5.7	4.0	3.4 - 4.8	**25.9**	**5.0**	**0.04**
Suisun Bay	4.6	3.5 - 6.1	5.8	4.6 - 7.4	-20.8	2.3	0.15

In Suisun Bay, Great Blue Heron nest density exhibited a quadratic trend with a peak density of 15.7% above the baseline in 2003, but the strength of the quadratic coefficient (b = -0.015±0.008, P<0.07) and the overall trend was marginal ($F_{2,21}$=2.43 P=0.11). Mean Great Blue Heron nest density, in Suisun Bay, 2009-2014, was 20.8% below the baseline period, suggesting a decline in Suisun Bay, but the difference was not significant ($F_{1,14}$=2.1, P=0.17; Table 3).

Great Egret Nest Density

Great Egret nest density (Figure 4, Table 4) increased by 1.3% annually across all areas ($\log_e$ increase: 0.013±0.006 per year; P=0.03). Great Egret nest density was 24.6% greater, on average, in 2009-2014 than during the baseline period ($F_{1,14}$=5.1, P=0.04).

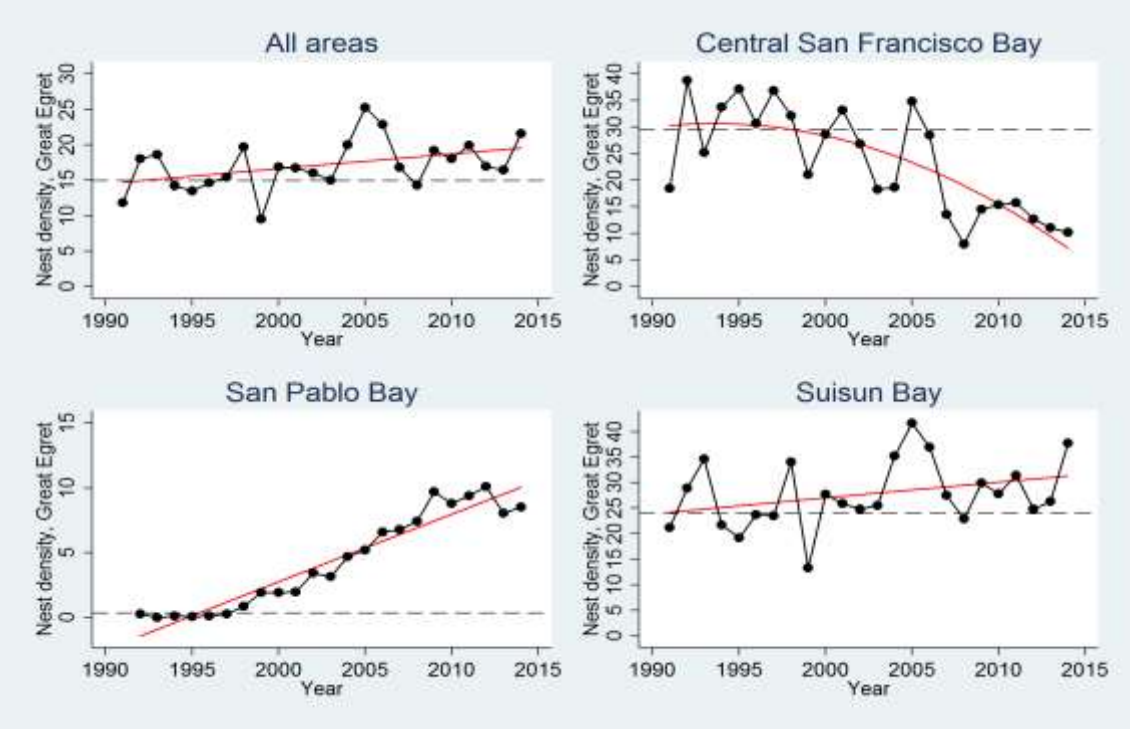

Figure 4. Annual Great Egret nest density and trends in Central San Francisco Bay, San Pablo Bay, and Suisun Bay, and all areas combined, 1991-2014. Red lines indicate the linear or quadratic trends, 1991-2014; dashed lines indicate the mean values (benchmarks) for the reference period 1991-2000.

In Central San Francisco Bay, an accelerating decline in Great Egret nest density began in 1995 ($F_{2,21}$=15.1 P<0.001), by 5.6% annually ($\log_e$ decline: -.0638573±0.009, P<0.001), leading to nest densities in 2009-2014 that were 55.5% lower, on average, than in 1991-2000 ($F_{1,14}$=47.7; P<0.001; Table 4).

In San Pablo Bay, Great Egret nest density increased by 13.5% annually since 1991($\log_e$ increase: 0.224±0.024; P<0.001) and, by 2009-2014, Greg Egret nest densities were 2452% greater than the low average only 0.36 nests per 100 km^2 in 1991-2000 ($\log_e$ mean: -1.03±0.45; $F_{1,14}$=37.7, P<0.001; Table 4).

Great Egret nest densities in Suisun Bay suggested a marginally significant linear trend, increasing by 1.2% annually ($\log_e$ increase: 0.012±0.007, P=0.10). However, the 22.7% increase in mean nest densities in 2009-2014 over the 1991-2000 baseline period was not significant ($F_{1,14}$=2.6, P=0.13; Table 4).

Table 4. Great Egret Nest Density Indicator results, including current and baseline means (nests/100 km2), 95% confidence intervals (CI), and percent change during the "current" period of recent years, 2009-2014, relative to the baseline period, 1991-2000, the mean percent change between current and baseline periods, and the F-value and significance (P) of the change; all results are back-transformed from natural-log values.

Area	Current (2009-2014)	95% CI	Baseline (1991-2000)	95% CI	Percent change	$F_{1, 14}$	P
All areas combined	18.6	16.7 - 20.7	14.9	12.7 - 17.5	**24.6**	**5.1**	**0.04**

Central San Francisco Bay	13.1	10.9 - 15.8	29.5	24.7 - 35.3	**-55.5**	**47.7**	**<0.001**
San Pablo Bay	9.1	8.3 - 9.9	0.4	0.1 - 1.0	**2452.0**	**37.7**	**<0.001**
Suisun Bay	29.4	25.2 - 34.4	24.0	19.5 - 19.4	22.7	2.6	0.13

Great Blue Heron Nest Survival

Mean annual Great Blue Heron nest survival (Figure 5, Table 5) was relatively stable, with no long-term trends in the Central Bay, San Pablo Bay, Suisun Bay, or all areas combined, and no significant differences in annual nest survival between recent years (2009-2014) and the 1994-2000 baseline period (P>0.05).

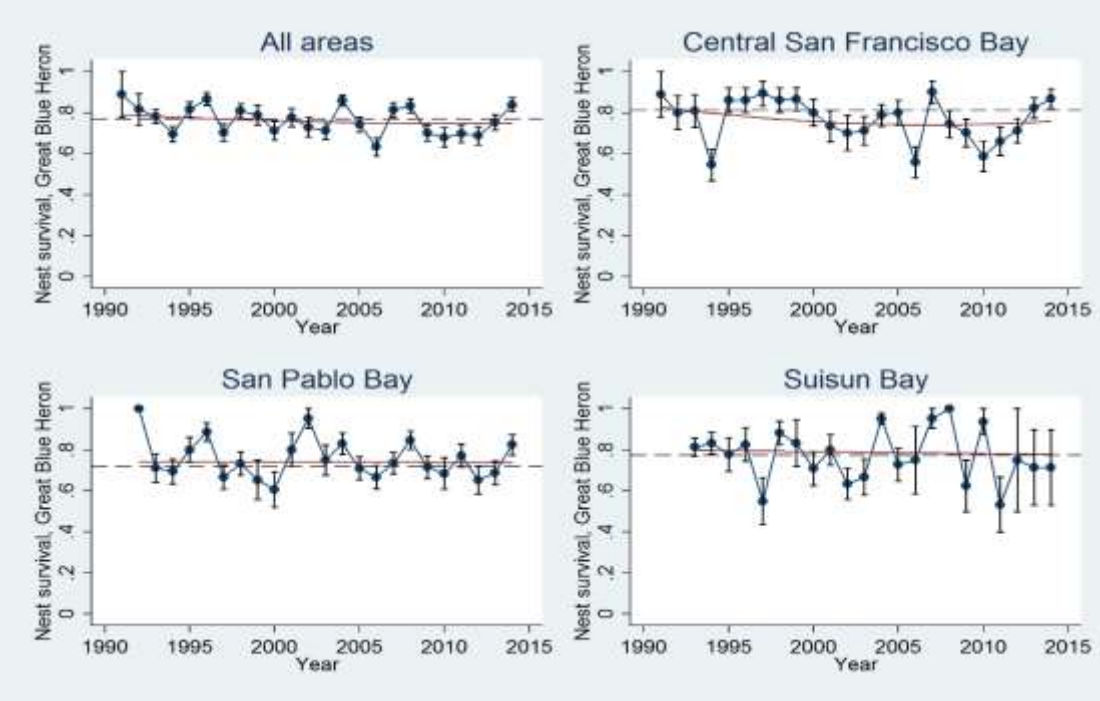

Figure 5. Annual Great Blue Heron nest survival and trends in Central San Francisco Bay, San Pablo Bay, and Suisun Bay, and all areas combined, 1991-2014. Error bars represent standard errors; red lines indicate the linear or quadratic trends, 1991-2014; dashed lines indicate the mean values (benchmarks) for the reference period 1994-2000.

Table 5. Great Blue Heron Nest Survival Indicator results, including the mean and standard error (SE) of annual percent nest survival, weighted equally among years, during the "current" period of recent years, 2009-2014, and the baseline period, 1994-2000, the mean percent change between current and baseline periods, and the *t*-value and significance (*P*) of the change.

Area	Current (2009-2014)	SE	Baseline (1994-2000)	SE	Percent change	$F_{1, 11}$	*P*
All areas combined	72.8	2.65	77.3	2.41	-5.7	1.5	0.24
Central San Francisco Bay	72.8	4.74	81.0	4.22	-10.1	1.7	0.22
San Pablo Bay	72.2	2.47	72.6	3.69	-0.6	0.0	0.93
Suisun Bay	69.8	5.92	79.2	3.46	-11.8	1.8	0.20

Great Egret Nest Survival

Great Egret Nest Survival (Figure 6, Table 6) exhibited no significant trends when evaluated across all subregions combined ($F_{2,19}$=1.2, P=0.31). However, in Central San Francisco Bay, a significantly negative trend began in 1999 ($F_{2,19}$=8.7, P=0.002), with nest survival declining by 3.9% per year, on average,

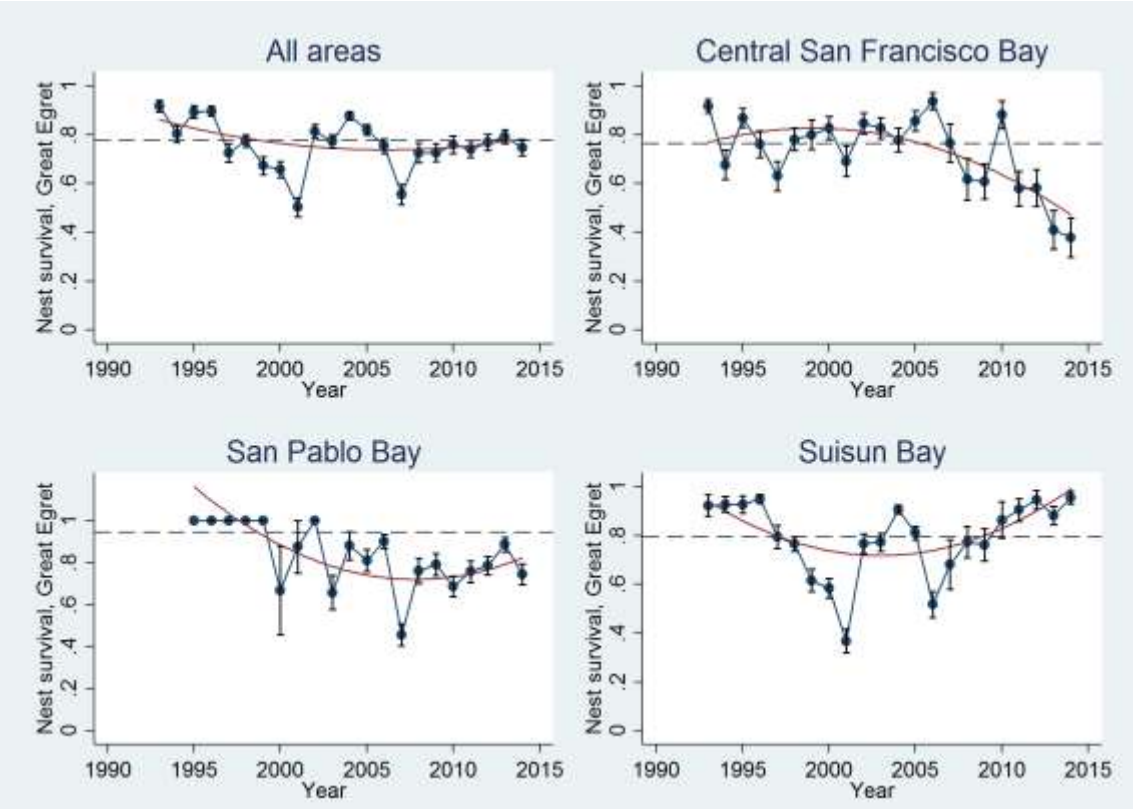

Figure 6. Annual Great Egret nest survival and trends in Central San Francisco Bay, San Pablo Bay, and Suisun Bay, and all areas combined, 1991-2014. Error bars represent standard errors; red lines indicate the linear or quadratic trends, 1991-2014; dashed lines indicate the mean values (benchmarks) for the reference period 1994-2000.

through 2014. As a result, average nest survival in recent years (2009-2014) was significantly lower than during the reference period, averaging 57.3±7.34% survival compared to a baseline of 76.4±3.16% ($F_{1,12}$=9.0, P=0.01; Table 6).

In San Pablo Bay, Great Egret nest survival declined from a relatively high average of 94.4±5.6% during 1995-2000 (based on relatively small samples of only 15.6±4.9 nests per year) to a low of 72.0% survival in 2008, followed by an apparent recovery to near baseline levels by 2014; however, survival rates varied substantially and the trend was not statistically significant ($F_{2,17}$=1.43, P=0.27). In addition, recent nest survival in 2009-2014, averaging 77.5±2.71%, did not differ significantly from the baseline level ($F_{1,10}$=0.27, P=0.61).

In Suisun Bay, a marginally significant (quadratic) trend in Great Egret nest survival suggested a decline survival in the late 1990s, followed by a recovery through 2014 ($F_{2,18}$=2.7, P=0.09). In recent years (2009-2014), average nest survival (88.6±2.87%) did not differ, on average, from the baseline period ($F_{1,12}$=0.02, P=0.90).

Table 6. Great Egret Nest Survival Indicator results, including the mean and standard error (SE) of annual percent nest survival, weighted equally among years, during the "current" period of recent years, 2009-2014, and the baseline period, 1994-2000, the mean percent change between current and baseline periods, and the *t*-value and significance (*P*) of the change.

Area	Current (2009-2014)	SE	Baseline (1994-2000)	SE	Percent change	$F_{1, 11}$	*P*
All areas combined	75.7	2.99	77.6	2.71	-2.5	0.2	0.64
Central San Francisco Bay	56.5	5.39	76.6	4.80	**-26.2**	**7.7**	**0.02**
San Pablo Bay	77.8	7.67	80.0	11.47	-2.8	0.0	0.88
Suisun Bay	88.7	7.43	78.2	4.35	13.3	1.5	0.25

What are the historical uses of these indicators and current programs to evaluate them?

Audubon Canyon Ranch (ACR) has monitored Great Blue Heron and Great Egret nest abundance at all known nesting colonies (40-50 sites) in the northern San Francisco Estuary, annually, since 1991. ACR continues to sustain this effort on an ongoing basis, and to produce regular reports based on this information (e.g., Kelly et al. 1993, 2005, 2006, 2007, 2008; Kelly and Rothenbach 2012; Kelly and Condeso 2014).

What is the suitability of the reference conditions and targets?

Heron and Egret Indicators are suitable targets for monitoring wetland conditions at landscape scales (Kelly et al. 2008). Nest densities during 1991-2000 represent a relatively stable period. Inter-year variation in water levels, weather and climate may challenge identification of reference conditions and targets. Nest densities may be affected by inter-year movements of individuals to or from the Central Valley.

What are the data sources?

The Heron and Egret Nest Density Indicator was calculated using data from ongoing regional heron and egret studies by Audubon Canyon Ranch (Kelly et al. 1993, 2007, 2008; Kelly and Condeso 2014). The data, which reflect repeated annual nest counts at all known colony sites, provide intensive and extensive measurements of nest abundance and an effective index of regional breeding population sizes. Additional data on nest abundances in the southern San Francisco Bay (not presented here) are available from partners at the San Francisco Bay Bird Observatory.

What assumptions and uncertainties are involved?

Heron and Egret Nest Density Indicator

The Nest Density Indicator assumes that most or all of the colony sites are known and monitored, that hidden, concealed nests are rare, and that the intraseasonal peak nest abundance is documented

accurately. The conspicuousness of heron and egret colonies and nests facilitates the successful use of this indicator.

Heron and Egret Nest Survival Indicator

The Nest Survival Indicator assumes (1) that nestling ages in successful nests are accurately estimated, based on repeated nest monitoring and physical and behavior correlates of nestling development, and (2) that nestlings do not fledge before they are 7 weeks old, post-hatch (Great Egret) or 8 weeks old (Great Blue Heron). Uncertainties are related to early failures during incubation, unobserved nest failures followed by and renesting between observations. The conspicuousness of heron and egret nests facilitates the successful use of this indicator.

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