State of San Francisco Bay 2011
Appendix I

ECOLOGICAL PROCESSES – Food Web
Technical Appendix

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Heron and Egret Brood Size

Background and Rationale:
Audubon Canyon Ranch has monitored brood size, prior to fledging, in Great Blue Heron and Great Egret nests across all known nesting colonies (40-50 sites) in the northern San Francisco Estuary, annually, since 1991. The number of young produced in successful heron and egret nests depends on the number of young hatched in the nest and the extent of subsequent brood reduction (i.e., mortality of nestlings during the brood-rearing period). Both parameters (young hatched per nest and survival of those young), reflect the amount of suitable foraging habitat and/or supply or availability of prey, in surrounding wetlands, especially that which is needed to provision nestlings with food (Frederick 2002, Kushlan and Hancock 2005). The Heron and Egret Brood Size Indicator is sensitive to changes in the extent and quality of foraging habitat, and is likely to be influenced by changes in land-use, hydrology (especially water circulation and depth), geomorphology, environmental contamination, vegetation characteristics, and the availability of suitable prey (Kushlan 2000). The two target species reflect differences in feeding habitat preference: Great Egrets preferentially forage in small ponds in emergent wetlands and 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). Previous work in the northern San Francisco Estuary demonstrated that prefledging brood size in herons and egrets is influenced by the extent of wetland habitat types as far as 10 km from nest sites (Kelly et al. 2008). Thus, this indicator reflects wetland condition over large spatial scales. The conspicuousness of heron and egret nesting colonies and the visibility of nests and broods—especially when nestlings are too young to leave the nests but old enough to have survived the period when most brood size reduction occurs—facilitates the use of brood size as an effective index of breeding productivity.

Data Source:
The Heron and Egret Brood Size Indicator was calculated using data from ongoing regional heron and egret studies by Audubon Canyon Ranch (Kelly et al. 1993, 2007). The data, which reflect brood size in successful nests at all known colony sites, provide an effective index of regional and subregional heron and egret productivity.

Methods and Calculations:
The Heron and Egret Brood Size Indicator includes metrics calculated for Great Egrets and Great Blue Herons. It is based on the number of young in completely visible nests when Great Blue Heron nestlings are known to be 5-8 weeks old and Great Egrets are known to be 5-7 weeks old (Pratt 1970, Pratt and Winkler 1985). The indicator measures changes or differences in brood size prior to fledging among nests that successfully fledge one or more young. Brood size counts are sampled in approximate proportion to colony size and averaged annually (1991-2008) among nests within and across the three major subregions of northern San Francisco Bay (Central San Francisco Bay, San Pablo Bay, and Suisun Bay). Brood size estimates are based on observations at most of the 40-50 colony sites within foraging range (i.e., 10 km) of the historic tidal wetland boundary (ca.1770–1820; San Francisco Estuary Institute 1999; Figure H1). The Brood Size Indicator is calculated by first determining for each species and each region the proportional change between the year in question and the benchmark value (five-year reference period) for that species. Then the geometric mean across species was calculated and, finally, this was

converted to percent change. The species-specific benchmark value was derived from the 1991-1995 data (Great Blue Heron: 2.01±0.088 young; Great Egret: 2.26±0.107 young, weighted equally across years).

Goals, Targets and Reference Conditions:
CCMP goals to "restore" and "enhance" the ecological productivity and habitat values of wetlands are non-quantitative. However, the use of time series back to 1991 allows the specification of appropriate quantitative reference conditions. Differences or trends in nest density can be quantified and used for assessment.

Maintenance of current resource levels

- Target: current 3-year mean (2006-2008) ≥ 5-year reference mean (1991-1995).

Enhancement of resources with wetland restoration

- Target: current 3-year mean (2006-2008) ≥ highest 5-year *subregional* reference mean (1991-1995)

Results:

Results of the Heron and Egret Brood Size Indicator are shown in Figure H4.

Current brood sizes (2006-2008) declined from reference levels (1991-1995).
Brood sizes in the northern San Francisco Estuary were significantly lower in 2006-2008, relative to 1991-1995 reference levels ($t_{745} = -9.9$, $P < 0.001$; Figure H4), with 8.4% and 17.1% fewer young produced in successful Great Blue Heron and Great Egret nests, respectively. Therefore, the proposed target associated with overall resource enhancement was also not achieved: regional productivity per nest was significantly less ($t_{570} = 5.1$, $P < 0.001$) than the highest subregional 1991-1995 level (Suisun Bay, 4.6% above regional reference value).

Changes in brood size differ among subregions.
During the 1991-1995 reference period, brood sizes were significantly smaller in San Pablo Bay than in other subregions (multiple comparisons, $P < 0.001$). In recent years (2006-2008), the Brood Size Indicator revealed significantly smaller broods in Suisun Bay than in other subregions ($P < 0.02$), suggesting a shift in relative per capita productivity among subregions (Figure H4). In addition, brood sizes in Suisun Bay in 2006-2008 were significantly smaller than the regional 1991-1995 average ($t_{353} = -8.3$, $P < 0.001$), with nests producing 14% fewer Great Blue Heron young and 19% fewer Great Egret young. The productivity of nests in San Pablo Bay in the recent years was also significantly lower than in the reference period ($t_{273} = -3.7$, $P < 0.001$), with average declines of 5.2% in Great Blue Herons and 10.5% in Great Egrets. In the Central Bay, the productivity of Great Egret nests declined by 13.8% ($t_{56} = 3.8$, $P < 0.001$) relative to reference levels, but the productivity in Great Blue Heron nests in recent years was similar to brood size during the reference period ($P > 0.05$).

Based on brood size estimates for Great Blue Heron and Great Egret, CCMP goals of restoring or enhancing wetland productivity and associated wetland habitat values have not been met in the region or within any subregion.
Recent productivity in successful nests of both species declined by 8-17% relative to the 1991-1995 reference period, with declines generally observed across the subregions. Subregional

differences in productivity suggest opportunities for habitat restoration or enhancement, especially in Suisun Bay.

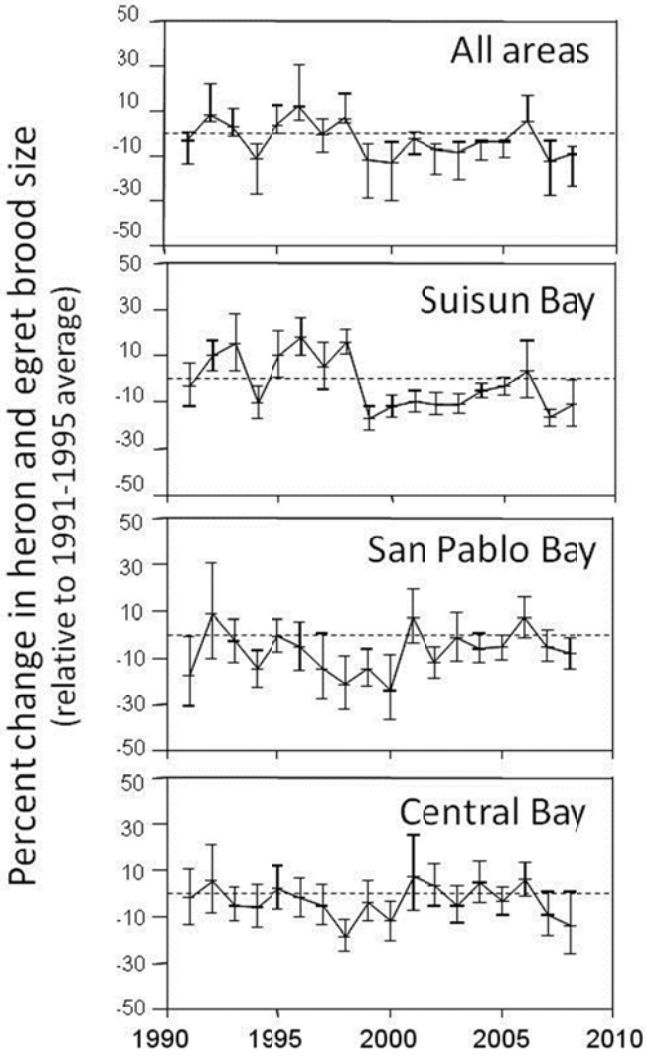

Figure H4. Annual percent change in heron and egret brood size, 1991-2008, relative to the average brood size (dashed line) for the reference period, 1991-1995, in the northern San Francisco Estuary, by bay region and for all 3 regions combined.

Peer Review: The above indicator was evaluated using methods and analysis described in Kelly *et al*. (2007).

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