Introduction
The San Francisco Bay and the Sacramento-San Joaquin Delta are often studied and managed as distinct systems. However, the Bay and Delta function as a united and complex system which crosses several ecologically significant gradients (i.e. tidal influence, salinity, and vegetation). These gradients are important when planning for restoration of wildlife corridors and interconnected habitats. While current regional management and restoration efforts emphasize a landscape-scale approach to restoration, the tools available from larger, more extensive habitat restoration projects need to be adapted for the Estuary as a whole.

To inform these efforts, the San Francisco Estuary Institute used newly developed datasets to perform multiple landscape ecology analyses of marsh in the Bay and Delta. These analyses— including marsh patch size, nearest large neighbor distance, and core area ratio—were performed on high-resolution and contemporary datasets of the Estuary’s aquatic resources. Landscape metrics were designed to help quantify landscape patterns in a manner that is relevant to a particular organism or process by quantifying habitat extent, distribution, quantity and connectivity for marsh habitat. In literature search was conducted to identify ecologically-relevant thresholds for Clapper rails (Rhina renjana) and black rails (Zoothera libellula), which were then used to parameterize landscape metrics.

Ultimately, landscape metrics allowed us to characterize historical marsh habitat for key species. Illustrate the current configuration of marsh habitat across the Estuary, and analyze net changes between 1850 and 2008. This work has the potential to inform ongoing assessment of the regional progress towards targets established by the Bay-Delta Conservation Plan (BDCP) and the Bay Delta Stewardship Council Plan and is notable for both its synthesis of complementary regional datasets and its application across the whole San Francisco Estuary.

Methods
Datasets:
• Core area ratios were computed from the Ecocad Historical Aquatic Resources layer (a synthesis of 12 regional historical ecology studies carried out by SFEI since 1996, SRMCD 2011) by selecting polygons classified as “Tidal Salt Marsh” or “Wetland (non tidal marsh) and clipping to the extent of modern SFEI Historical Baylands (1996) and Delta Historical Ecology (SFEI et al. 2012) studies. Modern marsh polygons were taken from 2009/2010 data (modified for the BayDelta Ecosystem Habitat Goals Update (BDHGU) and from an unpublished Tier 2 study of BDCP vegetation.
• Marsh polygons were clipped to the extent of modern HAMR data (2009/2010). This is the primary dataset for the analysis as it has the highest resolution and is the most recent data available. The primary data used were from the Ecoatlas Historical Aquatic Resources layer which has been further refined and updated by SFEI-ASC, Richmond, CA.
• Browse data used for this study came from multiple sources. Historical marsh polygons were extracted from the Ecocad Historical Aquatic Resources layer, and contemporary marsh polygons were performed on SFEI’s Delta Marsh GIS database. Future marsh polygons were derived from the Delta Marsh GIS database and the Sacramento-San Joaquin River Delta.

Patch size:
• Marsh patch size was determined by calculating the total area covered by each patch and then weighting the mean area of a patch by its area. The mean area-weighted patch size is a measure of the mean area of a patch and is expressed as a percentage of the total area.
• Nearest large neighbor was calculated for each patch by subtracting the area of the patch from the area of the nearest patch greater than 100 ha. The distance to the nearest 100 ha marsh and (2) the work of Liu et al. (2012), which showed a significant negative correlation between Black Rail presence and distance to the nearest marsh, was used as a measure of connectivity.

Results
Patch size:
• Marsh patch size across all marsh types in the Mod Hist and Hist Mod periods is lower than in the Bay and Delta periods. This can be attributed to the increased area of the Delta and the lower number of large marsh patches in the Mod Hist and Hist Mod periods.

Core area ratio:
• Core area ratios were calculated for each patch by determining the area of the patch that is at least 50 m from the nearest patch of at least 100 ha. The core area ratio is a measure of the degree of isolation of a patch and is expressed as a percentage of the total area.

Conclusions
- There has been dramatic net loss and fragmentation of the Estuary’s marsh habitat over the last 150 years. Continuous marsh habitat no longer lines the Estuary and is more fragmented.

- Estuary-wide decreases in average marsh patch size and total area are more pronounced in the Delta than the Bay. Large marshes are more likely to provide cover from predators, and to have a well-developed channel network (all factors that are important for rails). These gradients are important when planning for restoration of wildlife habitat, the presence of large marshes is expected to translate to decreased connectivity between resident metapopulations. The high rates of predation in edge habitat, this configuration increases the probability of habitat loss and the decreased connectivity between marsh patches.

- A reverse move in the relative proportion of marsh in the Bay vs. Delta. The extensive historical freshwater marsh of the Delta would have differed from the tidal and fresh marshes in tidal influence, the timing of habitat inundation, and the species characteristic of the upstream marsh complex. This is consistent with the hypothesis that the Delta will become more saline, and the Bay will become more freshwater.

- This landscape-scale analysis highlights the need for reestablishing marsh habitat connectivity to provide protected areas where rail species can thrive. This is particularly important as we work to design sustainable marsh networks that allow natural species to persist with anthropogenic climate change.

Works cited
SFEI-ASC (Central Delta Water Quality Project) (2010). Delta Marsh Landscape Connectivity. San Francisco Estuary Institute, Richmond, CA.
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