Delta Landscape Metrics

Creating a Spatial Framework to Inform Restoration Planning

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The Delta Landscapes Project

Management Tools
for Landscape-Scale Restoration

Funded by the Ecosystem Restoration Program
A Delta TRANSFORMED
ecological functions, spatial metrics, and landscape change
in the Sacramento-San Joaquin Delta

San Francisco Estuary Institute
Aquatic Science Center SFEI ASC
How do we create ecologically functional, resilient *landscapes*? (not just nice projects)
1. Provide a framework that helps individual projects add up to a larger functional landscape (pieces of the puzzle)

2. Provide guidance for what kinds of projects make sense where (avoid one-size-fits-all)

3. Reduce conflicts and mistakes (shared understanding of priorities and current science)

4. Make better use of long-term physical/climatic trajectories (work with processes, not against them)

5. Meet landscape-scale species needs (connectivity, migration for multiple species)
Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process

- Funded by Ecosystem Restoration Program (CDFG, NOAA, US FWS)
- Collaboration with KQED QUEST and Stanford’s Bill Lane Center for the American West: [science.kqed.org.quest/delta-map/](http://science.kqed.org.quest/delta-map/)
1. Define target ecological functions

2. Identify associated system attributes (spatial metrics)

3. Quantify landscape change metrics

4. Describe subregional potential (physical drivers, opportunities)

5. Create conceptual Operational Landscape Units (e.g. “archetypes”)

6. Produce restoration guidelines and potential performance metrics
Landscape Interpretation Team (LIT)

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Ted Sommer  (DWR)
<table>
<thead>
<tr>
<th>Level</th>
<th>Theme</th>
<th>Function</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Inundation extent, duration, timing, and frequency</td>
<td>Marsh to open water ratio</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marsh area by patch size (patch size distribution)</td>
<td>Marsh area by nearest neighbor distance</td>
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<td></td>
<td></td>
<td>Ponded area in summer by depth and duration</td>
<td>Wetted area by type in winter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Riparian habitat area by patch size</td>
<td>Riparian habitat length by width class</td>
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<tr>
<td></td>
<td></td>
<td>Length of marsh-terrestrial transition zone by terrestrial habitat type</td>
<td>To be addressed with qualitative conceptual models in Task 4.</td>
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<tr>
<td></td>
<td></td>
<td>Maintains adaptation potential within wildlife populations</td>
<td>Expected to be addressed with a related project.</td>
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<tr>
<td></td>
<td></td>
<td>Maintains food supplies and nutrient cycling to support robust food webs</td>
<td>Maintains biodiversity by supporting diverse natural communities</td>
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</table>

**POPULATION**

- Provides habitat and connectivity for fish
- Provides habitat and connectivity for marsh wildlife
- Provides habitat and connectivity for waterbirds
- Provides habitat and connectivity for riparian wildlife
- Provides habitat and connectivity for marsh-terrestrial transition zone wildlife

**COMMUNITY**

- Adaptation potential
- Food webs
- Biodiversity

**FUNCTION**

- Life history support

**METRICS**

- Adjacency of marsh to open water by length and marsh patch size
- Marsh core area ratio
- Ratio of looped to dendritic channels (by length and adjacent habitat type)
- Marsh fragmentation index
<table>
<thead>
<tr>
<th>Ecological Functions list (Task 3)</th>
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<tbody>
<tr>
<td><strong>Habitat and connectivity</strong></td>
</tr>
<tr>
<td>for pelagic fish</td>
</tr>
<tr>
<td>for resident mammals</td>
</tr>
<tr>
<td>for native plants</td>
</tr>
<tr>
<td>for demersal fish</td>
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<tr>
<td>for marsh birds</td>
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<tr>
<td>for anadromous fish</td>
</tr>
<tr>
<td>for littoral fish</td>
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<tr>
<td>for riparian birds</td>
</tr>
<tr>
<td>for migratory waterfowl</td>
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<tr>
<td>Maintain genetic/phenotypic diversity</td>
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<tr>
<td>Nutrient movement and recycling</td>
</tr>
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<td>Maintain connectivity</td>
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<tr>
<td>for fragmented populations</td>
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<tr>
<td>Maintain diverse native communities</td>
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<tr>
<td>Net food supply</td>
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# Landscape Metrics List (Task 3)

<table>
<thead>
<tr>
<th>Landscape Metric Family</th>
<th>Associated Ecological Functions</th>
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<tbody>
<tr>
<td></td>
<td>- Sinuosity</td>
</tr>
<tr>
<td></td>
<td>- Density (by depth class)</td>
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<tr>
<td></td>
<td>- Total length (by width class and depth class)</td>
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<tr>
<td></td>
<td>- Total area (by depth class and season)</td>
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<tr>
<td></td>
<td>- Ratio of flow-through to blind channels</td>
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<tr>
<td></td>
<td>- Total riparian forest area</td>
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<td></td>
<td>- Number of riparian forest patches</td>
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<tr>
<td></td>
<td>- Riparian forest patch length (by type and width class)</td>
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<tr>
<td></td>
<td>- Gap-absence</td>
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<tr>
<td></td>
<td>- Linear extent adjacent to wetlands (by type)</td>
</tr>
<tr>
<td></td>
<td>- Total length of wetland/upland or wetland/riparian edge</td>
</tr>
<tr>
<td></td>
<td>- Patch size distribution (for select habitat types)</td>
</tr>
<tr>
<td></td>
<td>- Edge to area ratio (for select habitat types)</td>
</tr>
<tr>
<td></td>
<td>- Nearest neighbor distance (for select habitat types)</td>
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<tr>
<td></td>
<td>- Patch adjacency diversity</td>
</tr>
<tr>
<td></td>
<td>- Patch type richness</td>
</tr>
<tr>
<td></td>
<td>- Area of wetland habitat (by depth class and season)</td>
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<tr>
<td></td>
<td>- Ponded area in summer (by depth class and duration)</td>
</tr>
<tr>
<td></td>
<td>- Wetted area in winter (by type)</td>
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<tr>
<td></td>
<td>- Estimated annual primary production (by habitat)</td>
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<td></td>
<td>- Volumes of net auto- vs. net hetero-trophic habitat</td>
</tr>
<tr>
<td></td>
<td>- Area of marsh (by type)</td>
</tr>
</tbody>
</table>
There has been a 73-fold reversal in the ratio between marsh and open water in the Delta, affecting the character and quality of aquatic habitats.
historical

modern

support for native fish

historical modern

open water

16,300 ha

26,600 ha

+ 63%
historical: 193,200 ha
modern: 4,300 ha

74x decrease in marsh to open water ratio

-98% decrease

support for native fish

historical: 100 : 1,182
modern: 100 : 16
Support for native fish

<table>
<thead>
<tr>
<th></th>
<th>Historical</th>
<th>Modern</th>
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<tbody>
<tr>
<td>Open Water</td>
<td>16,300 ha</td>
<td>26,600 ha</td>
</tr>
<tr>
<td>Marsh</td>
<td>193,200 ha</td>
<td>4,300 ha</td>
</tr>
</tbody>
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100 : 1,182 100 : 16

74x decrease in marsh to open water ratio

“channels in marsh” → “marsh in channels”
historical modern

support for native fish

open water

16,300 ha

26,600 ha

marsh

193,200 ha

4,300 ha

100 : 1,182

100 : 16

74x decrease in marsh to open water ratio

“channels in marsh” → “marsh in channels”
There is twice as much shallow-water habitat (<2m) in the Delta today as there was historically.

Historical DEM co-developed with UCDavis CWS (Fleenor, Whipple, Bell, et al.)
Complex dendritic channel networks likely provided high productivity habitat for fish.

Most dendritic channels are now gone, especially in the central Delta

As Delta marshes were diked, connections were severed to the channel networks that wove through them. These dendritic lower-order tidal channels (also known as "dead-end" or "blind channels") that terminated within the wetland were once the capillary exchange system between the wetland and aquatic areas, promoting both food web productivity and spatial complexity in habitat conditions. They provided native fish species with a range of gradients (e.g., temperature, turbidity, and water velocity) at both large and small scales. Dendritic channel networks offered channel complexity and higher turbidities, which provided refuge for certain species. Channels that branched through the marsh may have been particularly important for salmonids because they provided access to and export of invertebrates from the marsh plain, physical cover and turbidity for refuge, and slow moving water for energetic refugia. The larger, looped channels that characterize the Delta today allow water to move through and mix more quickly, with less diversity in residence time and less heterogeneity in channel habitat.

The lack of large wetlands connected to channels means that there is little exchange of organic matter, organisms, or sediment between these ecosystems.

Comparing the historical (right) and modern (far right) landscape, while the skeletal framework of looped mainstem channels remains largely similar (red), the branching networks of dendritic channels (green and yellow) are mostly gone.

Methods: Classifying channel types
Channel reaches were manually classified using the following definitions:
- Dendritic tidal channel reaches connected to the tidal source by only one non-overlapping path
- Loop: tidal channel reaches connected to the tidal source (the Delta mouth) by two independent and non-overlapping paths
- Fluvial: channel reaches connected to the tidal source, but upstream of the approximate limit of bidirectional tidal flows (during spring tides in times of low river stage) AND tidal reaches between upstream perennial fluvial reaches and downstream flow through reaches
- Detached: channel reaches without a direct connection to the tidal source (through the larger channel network)
- Dendritic channels (segmented at 100 m intervals) were classified into those adjacent to marsh and those non-adjacent to marsh based on the habitat type.

Historically, the complex structure of Delta channels established gradients in residence time, a pattern heavily altered in the modern Delta (after Chris Enright, Delta Science Program). Historically, small low-order tidal creeks had high residence times, which allowed phytoplankton to accumulate and created net autotrophic conditions. Deeper sloughs, by contrast, had shorter residence times which created net heterotrophic conditions. The increased connectivity of modern channels in the Delta has led to homogenization of residence time across channel networks, increasing the reach of tidal excursion within channel networks and decreasing the occurrence of small channels with high residence time. The relationship between residence time and primary productivity in the modern Delta has been additionally
Most of the temporarily flooded habitat available to fish in the Delta has been lost.
historical modern

support for native fish

PONDS, LAKES, CHANNELS, FLOODED ISLANDS

Mostly perennial open water features
• variable depth
**PONDS, LAKES, CHANNELS, FLOODED ISLANDS**

*Mostly perennial open water features*
- variable depth

**TIDAL INUNDATION**

*Diurnal overflow of tidal sloughs into marshes*
- high recurrence (2x daily to monthly)
- low duration (< 6 hrs per event)
- low depth (“wetted” up to .5 m)
**PONDS, LAKES, CHANNELS, FLOODED ISLANDS**

*Mostly perennial open water features*

- variable depth

**TIDAL INUNDATION**

*Diurnal overflow of tidal sloughs into marshes*

- high recurrence (2x daily to monthly)
- low duration (< 6 hrs per event)
- low depth (“wetted” up to 0.5 m)

**SEASONAL LONG DURATION FLOODING**

*Prolonged inundation from river overflow into flood basins*

- low recurrence (~1 event per year)
- high duration (persists up to 6 months)
- generally deeper than ‘seasonal short-term flooding’

**SEASONAL SHORT-TERM FLOODING**

*Short-term fluvial inundation*

- can be multiple events per year
- low duration (days-weeks per event)
- generally shallower than ‘seasonal long duration flooding’
Juvenile salmon reared in ephemeral floodplain habitats of the Cosumnes River have been found to grow significantly larger than juvenile salmon reared only within the Cosumnes River (Jeffres et al. 2008).
Native fish are adapted to a complex, variable landscape with extensive aquatic resources throughout the year.
There are a number of additional elements to a complete Delta ecosystem.
Majority of riparian habitat today is of "unsuitable" width to support yellow billed cuckoos (Laymon & Halterman 1989). Length of forest of "optimal" width has decreased by 91%.
Marsh in patches large enough to fully support rails (based on Liu et al. 2012, Spautz & Nur 2002):

Historical: 192,000 ha
Modern: 1,000 ha
The historical marsh-terrestrial transition zone was continuous and gradual today's marsh-terrestrial transition zones are fragmented.

The transition zone between marsh and terrestrial habitats supported many wildlife species and ecological functions. Animals, organic matter, sediment, and water moved across this wide, complex, and heterogeneous area that supported a broad moisture gradient. Continuous transition zones bordered the Delta periphery and major riparian corridors. Most transition zones were wide and gradual, yet some were short and steep. This continuity and variability allowed diverse terrestrial wildlife to access wetland habitat, and was critical for the movement and dispersal of transition-zone obligates. The transition zone may have been particularly important to the endemic giant garter snake, which used aquatic habitats dominated by emergent vegetation from early spring to mid-fall, and drier, higher-elevation habitats during winter dormancy. Foraging birds and bats may have used seasonal wetlands at different times of the year depending on inundation and food production. In the modern Delta, the terrestrial edge is fragmented and narrow, providing less foraging access, cover, and movement corridors.

Marsh-terrestrial transition zones in the historical (right) and modern (far right) Delta, represented by pink lines. Historically, much of the marsh gradually transitioned to seasonal wetland, vernal pool, alkali wetland, or riparian forest. In contrast, the modern transition zone is discontinuous and rapidly shifts to mostly grassland. Modern grasslands are heavily altered habitats, and modern transition zones are often steep leves.

**Methods: Marsh-terrestrial transition zone (F-zone)**

- "marsh" includes both tidal and non-tidal freshwater emergent wetland
- the "marsh-terrestrial transition zone" was mapped wherever marsh polygons and terrestrial habitat type polygons were adjacent to one another
- "terrestrial habitat types" include oak woodlands, seasonal wetlands, and riparian habitat zones; among others, rice is included

Most transition zone types are greatly reduced. A few types have expanded in quantity, but these tend to be relatively fragmented and disturbed. For example, although the extent of grassland has increased, modern grasslands are dominated by non-native annual grasses, which has changed the timing and availability of resources for wildlife.

The longest continuous unleved marsh-terrestrial transition zone left in the Delta is along Lindsey Slough (above). This
THANKS

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DSP: Peter Goodwin, Chris Enright, Anke Mueller-Solger, Cliff Dahm

Cache Slough Team: Bruce Orr, Noah Hume (Stillwater); Stuart Siegel (ESA)
Lower Yolo Team: Curt Schmutte, Val Connor
TNC MWT: Leo Winternitz, Rodd Kelsey

The LIT
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http://sfei.li/deltametrics