Assessing Historic Change and Relative Vulnerability of Southern California Coastal Wetlands to Sea Level Rise

Eric D. Stein
Southern California Coastal Water Research Project
Approach for Developing the Regional Strategy

Past: Historical Ecology

Present: Monitoring & Research

Future: Climate Change Predictions

Ecosystem functions and services, resilient and dynamic landscapes, landscape trajectory goals, watershed context

Regional Strategy = Quantifiable Objectives + Regional Monitoring Program + Decision-support Tool

Site Specific Restoration Projects

Regional Management
**Key Historical Documents**

- Spanish explorers' journals
- Mexican disenos
- US Coast Survey
- USCGS and USGS
- Landscape photographs by Alice Hare
- USDA aerial photography

**Contemporary and Prior Land Use**

- 1750
- 1800
- 1850
- 1900
- 1950
- 2000

- Native management
- Capacity-level grazing
- Ditching of valley floor; extension of discontinuous stream channels
- Tidal marsh reclamation
- Intensive agriculture
- Land surface subsidence due to groundwater pumping
Historically (19,560 ha)

- 40% vegetated wetlands (e.g. salt marsh)
- 25% was unvegetated wetlands (e.g. salt flat and mudflat)
- 35% was subtidal water.

Since ca. 1850, overall loss of 48% of historical estuarine habitat

- Estuarine vegetated wetlands – 75% loss
- Estuarine unvegetated – 78% loss
- Subtidal water now is 71% of total area
Type Conversion
“Reestablish a mosaic of full functioning wetland systems with a diversity of habitat types and connections, which preserves and recovers self-sustaining populations of species.”

FUNDING
- Total restoration funds: $631,324,722
- Total acquisition funds: $301,984,228
- Total planning funds: $300,384,477
- Other funds: $28,956,017

200 projects over 15 years

as identifying new projects that align with the WRP’s Regional Strategy.
Future Challenges

Fig. 1.5 Time changes an undisturbed ecosystem, making targets from the past hard to determine.

Harris and Van Diggelen 2006
Assessing Vulnerability

• What is the relative vulnerability of coastal wetlands to effects of sea level rise?
• How does vulnerability vary by wetland type or location?
• How can management actions affect vulnerability?

Comprehensive = can apply to all systems
Consistent application across all systems
Accommodate varying data availability
Clear and easy to communicate
Transparent documentation of uncertainty
Conducive to evaluating management options
Provides a starting point for more in depth study
Conceptual Approach to Vulnerability Assessment

All sites/systems will be assessed for vulnerability → aggregate to subregion and regional scales
Accretion Rates

Summary of Empirical Observation

Warrick et al 2004
Mouth Dynamics

BERM FORMATION (swell conditions)

OVERTOPPING (storm conditions)

OVERWASHING (storm and surge)

OVERWASHING WITH CREST LOWERING (storm and surge with depleted beach)
Estimating Mouth Closure Rate

- Estimate increase in closure rate based on SLR
- Estimate additional inundation based on new closure rate

Based on Behrens et al. 2015
## Estimated Additional Inundation Based on Mouth Closure

<table>
<thead>
<tr>
<th>Archetype</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Δ Likelihood of Closure (%)</td>
<td>Δ Lagoonal water level (m)</td>
</tr>
<tr>
<td>Small Creek</td>
<td>+13%</td>
<td>0.43</td>
</tr>
<tr>
<td>Small Lagoon</td>
<td>+8%</td>
<td>0.43</td>
</tr>
<tr>
<td>Intermittently Open Estuary</td>
<td>+3%</td>
<td>0.42</td>
</tr>
<tr>
<td>Large Perennially-Open Lagoon</td>
<td>+7%</td>
<td>0.42</td>
</tr>
<tr>
<td>Large River Valley Estuary</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>Fragmented River Valley Estuary</td>
<td>No Data</td>
<td>No Data</td>
</tr>
<tr>
<td>Open Bay/Harbor</td>
<td>No Data</td>
<td>No Data</td>
</tr>
</tbody>
</table>

Changes calculated using 2016 as the baseline.
Estimating Area Available for Transgression

- 1.5 m SLR Extent
- NERR Visitor Center and Parking Lot
- Residential
- Airport
- Agricultural Lands
- Upland Open Space
Estimating Habitat Change Using Hypsometric Curves

- Sea level rise
- Low and high marsh accretion
- Changes to mouth dynamics
- Opportunities for transgression

Tijuana Estuary

\[ z^* = (z - \text{MSL/MHHW-MSL}) \]
Habitat Elevation Inundation Relationships
Overall Regional Vulnerability

<table>
<thead>
<tr>
<th>Marsh Zone</th>
<th>Current</th>
<th>2050</th>
<th>Δ Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtinal</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Intertidal Mudflat</td>
<td>0.0%</td>
<td>0.8%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Low</td>
<td>0.0%</td>
<td>77.5%</td>
<td>77.5%</td>
</tr>
<tr>
<td>Mid</td>
<td>80.0%</td>
<td>18.0%</td>
<td>61.9%</td>
</tr>
<tr>
<td>High</td>
<td>20.0%</td>
<td>3.7%</td>
<td>16.4%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>156.6%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \frac{(157\%_{\text{Total}})}{197\%_{\text{Max}}} \times 10 = 7.9_{2050} \]
Inform development of regional (or site specific) restoration objectives
A continuing emphasis on historical knowledge has the benefit of curbing overly ambitious and potentially destructive management and restoration efforts that emphasize human interests at the expense of ecosystems

Higgs et al. 2014
EXTRA SLIDES
Predicted Habitat Changes

Figure 30. Projected changes in habitat composition under the NRC’s high SLR scenario (142 cm for Mad River; 166 cm for all other sites) from 2010 to 2110.

Source: USGS, draft
Final Thoughts

• Promoting resilient landscapes begins now

• Flexible & adaptable goals

• Today’s unthinkable might be tomorrow’s feasible

• Explore options and plan for the long-term

• It’s never too soon to begin long-term monitoring

• Improved modeling of potential effects
mean sea level + events

Maximum Potential Inundation Elevation (!)

Episodic Risk Factors
- + Extreme High Tide
- + Extreme Storm Wave setup + runup
- + ENSO + PDO

Long-Term Risk Factors

Sea Level Today

California Today

California in 2100+

slide adapted by Giddings from Bill O'Reilly and Reinhard Flick

Sarah N Giddings, SIO
# Regional Archetypes

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>General Description</th>
<th>Associated Habitats</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small Creek</td>
<td>Small creek systems; minimal subtidal habitat area; generally higher gradient</td>
<td>Intertidal (Cowardin), Riparian marsh and meadow (calveg)</td>
</tr>
<tr>
<td>2</td>
<td>Small Lagoon</td>
<td>Small coastal lagoon without an associated creek</td>
<td>Intertidal and subtidal habitats. May have fringing riparian marsh</td>
</tr>
<tr>
<td>3</td>
<td>Intermittently Open Estuary</td>
<td>Intermittently closing river mouth estuaries</td>
<td>Intertidal (Cowardin), Riparian marsh and meadow (calveg)</td>
</tr>
<tr>
<td>4</td>
<td>Large Perennially-Open Lagoon</td>
<td>Open basin, extensive subtidal habitat, fringing intertidal;</td>
<td>Intertidal emergent, pickleweed and/or cordgrass habitats (calveg)</td>
</tr>
<tr>
<td>5</td>
<td>Large River Valley Estuary</td>
<td>Large, depositional river valleys, fringing marsh; high dynamic ratio</td>
<td>Intertidal emergent, pickleweed and/or cordgrass habitats (calveg), moderate subtidal area (Cowardin)</td>
</tr>
<tr>
<td>6</td>
<td>Fragmented River Valley Estuary</td>
<td>Currently fragmented large depositional river valley; opportunities for reconnection</td>
<td>Intertidal emergent, pickleweed and/or cordgrass habitats (calveg), moderate subtidal area (Cowardin)</td>
</tr>
<tr>
<td>7</td>
<td>Open Bay/Harbor</td>
<td>Open water harbors, bays, lagoons; large area, wide &amp; low-lying mouth</td>
<td>Dominated by subtidal habitat</td>
</tr>
</tbody>
</table>
Archetype Distribution

Distribution of area by subregion

- Gaviota Coast
- Ventura Coast
- Santa Monica Bay
- San Pedro Bay
- San Diego Coast

Legend:
- Fragmented river valley estuary
- Intermittently open estuary
- Large perenially-open lagoon
- Large river valley estuary
- Open bay/harbor
- Small creek
- Small lagoon
## Accretion Rates by Archetype

<table>
<thead>
<tr>
<th>Archetype</th>
<th>Zone</th>
<th>By Zone</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Creeks</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Lagoons</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermittently Open Estuary</td>
<td>3</td>
<td>Low</td>
<td>3.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.63</td>
</tr>
<tr>
<td>Large Perennially-Open Lagoon</td>
<td>4</td>
<td>Mid</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>21.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.55 ± 9.40</td>
</tr>
<tr>
<td>Large River Valley Estuary</td>
<td>5</td>
<td>Low</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mid</td>
<td>4.83 ± 5.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.68 ± 2.94</td>
</tr>
<tr>
<td>Fragmented River Valley Estuary</td>
<td>6</td>
<td>Low</td>
<td>1.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mid</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.2 ± 0.65</td>
</tr>
<tr>
<td>Open Bay/ Harbor</td>
<td>7</td>
<td>Low</td>
<td>2.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mid</td>
<td>3.24 ± 2.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>7.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.84 ± 2.32</td>
</tr>
</tbody>
</table>
Evaluate Potential SLR Management Response

Next Steps

- Allow or facilitate passive marsh migration
- Grade areas adjacent to wetlands to increase opportunity for migration
- Construct “passive” levees to facilitate marsh realignment
- Alter structure and/or management of “mouth” of lagoons
- Thin layer sediment augmentation or facilitated sediment deposition
- Active pumping or tide gates to control water elevations
- Allow wetland to “convert” to deep water habitat
- Reconnecting currently fragmented systems to improve water flow
- Relocation or abandon adjacent infrastructure or development

Inform development of regional (or site specific) restoration objectives
Loss and Type Conversion

Change to non-wetland
8,368 ha

Change to different estuarine wetland type
3,684 ha

No change in estuarine wetland type
6,604 ha

Change to Non-tidal wetland
880 ha

* Change to Ocean or Beach 57 ha