Apr 4th, 4:30 PM - 4:45 PM

**Waterbird monitoring and habitat association modeling to inform tidal marsh restoration in an urbanized estuary**

Susan De La Cruz  
_U.S. Geological Survey, United States_, sdelacruz@usgs.gov

Lacy M. Smith  
_Utah State Univ., United States_, lacymsmith@gmail.com

Stacy Moskal  
_U.S. Geological Survey, United States_, smoskal@usgs.gov

Cheryl Strong  
_U.S. Fish and Wildlife Service, United States_, cheryl_strong@fws.gov

John Krause  
_California Dept. of Fish and Wildlife, United States_, John.Krause@wildlife.ca.gov

See next page for additional authors

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Speaker
Susan De La Cruz, Lacy M. Smith, Stacy Moskal, Cheryl Strong, John Krause, Yiwei Wang, and John Yutaka Takekawa

This event is available at Western CEDAR: https://cedar.wwu.edu/ssec/2018ssec/allsessions/111
Monitoring Waterbird Response to Wetland Management and Restoration in Pacific Coast Estuaries

Susan E. W. De La Cruz, Isa Woo, Melanie Davis, Lacy Smith, Tanya Graham
Connectivity among Pacific Coast Estuaries

Birds rely on networks of interconnected coastal sites to build stores during migration
(Western Sandpiper - Williams et al. 2007)

Species may show high site fidelity to wintering and stopover sites, reusing them year after year
(Surf Scoters - De La Cruz et al. 2009; Red Knots – Buchanan et al. 2012)

Need a common way to evaluate habitat change and avian response among linked estuaries
Landscape Scale Change in Coastal Estuaries

Coastal Development
- Worldwide loss of intertidal flats associated with declining waterbird populations
  (Zöckler et al. 2003, Boere and Piersma 2012, Iwamura et al. 2013)

Climate Change
- SLR, storm events, altered freshwater and sediment inputs may affect characteristics of intertidal areas
  (e.g. Galbraith et al. 2002)

Tidal Restorations
- Opportunities to restore tidal flow to large areas to benefit native endangered species
- Balancing the needs of migratory birds

Thorne et al.
Measuring Avian Response to Tidal Restorations

Goals

• Compare function and values of restoring and managed areas
• Inform adaptive management to optimize restoration design for waterbird habitat
• Evaluate how well restoration is meeting targets
Developing a Common Monitoring Framework

Benefits of using similar methods within a region, across estuaries
  – Ask same questions among sites, regions, estuaries
  – Commonalities and differences in use among sites
  – Importance of key resources among sites

Challenges
  – Not all restorations are created equal
    • Elevation
    • Hydrology
    • Sediment availability
    • Accessibility
  – Difficult to measure in the same way across sites
Spatially Explicit, Scalable Approach
Grid-based Area Counts

**Scales**

- **Grid**
- **Single Site**
- **Regional**

**Variables Measured and Frequency**

**1 X /Infrequently:** Site area, Distances to key features (Bay edge, urban, creek slough), area and location of key features (islands, levees), public access

**Yearly/Seasonally:** Bathymetry/elevations, vegetation density and distribution, prey density and distribution

**Each survey:** Water depth, bird species/sex/number and behavior, predator numbers

**Continuously:** Water quality
Avian Guilds

Drawing adapted from Warnock 2004
Pacific Coast Estuary Studies

Nisqually NWR
Assessing effects of restoration on capacity for salmon and waterbirds

SFB
North and South Bay Salt Pond Restoration
North and South Bay Salt Pond Restoration

**North Bay**
- 3,828 ha, 14 impoundments
- 2006 - present: Phased Restorations
  - 61% Pond Area breached
- 1999 – Present: Avian Surveys

**South Bay**
- 6,110 ha, 53 impoundments
- 2004 - 2013: Phased Management and Restoration
  - 13% Pond Area Breached
- 2002 – Present: Avian Surveys

Goal: Restore a mosaic of habitats ranging from tidal marsh to open ponds that balance needs of marsh species with migratory shorebird and waterfowl populations.
Nisqually Delta Restoration

- 360 ha
- 2006 - 2009: Phased Restorations
  - Complete tidal flow restored, freshwater unit maintained
- 2009 – 2015: Avian Surveys
Scalable Research Questions

Across Regions
• How do waterbird abundances compare across regions?

Within Regions
• How do waterbirds use restoring vs managed wetlands?
• What meso and macro habitat features that drive waterbird densities?

Site
• How does spatial distribution of waterbirds within a site shift across tidal cycle and seasons?
• How do prey resources influence waterbird densities?
Across Regions: How Do Abundance Trends Compare?

Small Shorebirds

South Bay

North Bay

Medium Shorebirds
Within Region: How do Waterbirds Use Restoring vs Managed Wetland Areas?

The bar chart shows the density of birds (birds/ha) in managed and breached areas during winter, spring, and fall. The data indicates higher density in managed areas compared to breached areas across all seasons.
Breached at High Tide vs Low Tide
Medium Shorebirds

Density (birds/ha)

<table>
<thead>
<tr>
<th></th>
<th>Foraging</th>
<th>Roosting</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Tide Category: Low</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Pond Area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Season: Spring</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Season: Winter</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Days Since Breached</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

HT: High Tide, LT: Low Tide
Wtr: Winter, Spr: Spring, Fall: Fall
Within Region: How Do Small Shorebird Distributions Change with Restoration Actions?
Within Region: Small Shorebird Distributions
**Within Region: What Habitat Features Drive Waterbird Densities?**

**Data collection:** Monthly grid-based HT counts at 53 ponds and associated habitat features data

**Time period:** Oct to Apr 2003-2015

**Analyses:**
1) Generalized Linear Mixed Models (GLMM) to identify important predictor variables
2) Generalized Additive Models (GAMs) to identify values of predictor variables where abundance was maximized

**Response variables:** Foraging and roosting abundance of several species and guilds

**Predictor variables:** Pond area, water depth, topography, mean salinity, distance to SF Bay, distance to urban area, distance to creek, pond management (breached or not), island presence, hunting access, public access

**Grid Scale**

**Pond Scale**

**Scales:**
Within Region: What Habitat Features Drive Waterbird Densities?

Grid Topography

Model-averaged results from General Linear Mixed Models (GLMM) to identify important predictor variables.
Within Region: What Habitat Features Drive Waterbird Densities?

Generalized Additive Models (GAMs) to identify values of predictor variables where abundance is maximized.
# Pond Scale: Optimized Habitat Values

## Foraging

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Dabbling Ducks</th>
<th>Diving Ducks</th>
<th>Medium Shorebirds</th>
<th>Small Shorebirds</th>
<th>Gulls</th>
<th>Piscivores</th>
<th>Terns</th>
<th>Waders</th>
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<tbody>
<tr>
<td>Depth (m)</td>
<td>--</td>
<td>0.75</td>
<td>0.13</td>
<td>0</td>
<td>1.48</td>
<td>&gt;0.4</td>
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<tr>
<td>Salinity (ppt)</td>
<td>6</td>
<td>&lt;17</td>
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<td>--</td>
<td>124</td>
<td>4</td>
<td>15</td>
<td>17</td>
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<tr>
<td>Pond Area (km2)</td>
<td>--</td>
<td>1.25</td>
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<td>--</td>
<td>&gt;0</td>
<td>&gt;0</td>
<td>&gt;0.75</td>
<td>&gt;0</td>
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<td>Distance to Bay (km)</td>
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<td>1.1</td>
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<td>&gt;0.9</td>
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<td>Distance to Urban (km)</td>
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<td>Islands (Presence)</td>
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<tr>
<td>Levee Open Hunting (%)</td>
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<td>--</td>
<td>&gt;78</td>
<td>25</td>
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<tr>
<td>Topography (m)</td>
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<tr>
<td>Breached</td>
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<tr>
<td>Levee Open Public (%)</td>
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<td>--</td>
<td>0 &amp; 70</td>
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<tr>
<td>Distance to Landfill (km)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
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## Roosting

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<th>Gulls</th>
<th>Piscivores</th>
<th>Terns</th>
<th>Waders</th>
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<td>1.5</td>
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<td>0.3</td>
<td>&gt;1.25</td>
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<tr>
<td>Salinity (ppt)</td>
<td>6</td>
<td>&lt;5</td>
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<td>4</td>
<td>15</td>
<td>17</td>
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<tr>
<td>Pond Area (km2)</td>
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<td>1.25</td>
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<td>&gt;1.75</td>
<td>&gt;0.5</td>
<td>&gt;1.5</td>
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<tr>
<td>Distance to Bay (km)</td>
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<td>1.1</td>
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<td>&gt;0</td>
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<tr>
<td>Distance to Urban (km)</td>
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<tr>
<td>Levee Open Hunting (%)</td>
<td>&lt;77</td>
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<td>--</td>
<td>100</td>
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<tr>
<td>Topography (m)</td>
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<td>Breached</td>
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<tr>
<td>Levee Open Public (%)</td>
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<td>46</td>
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<tr>
<td>Distance to Landfill (km)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>2.8</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Site Scale: What is the Seasonal Density and Distribution of Nisqually Small Shorebirds?

High Tide

Spring | Summer | Fall | Winter

Low Tide
Site: How do Prey Resources Influence Waterbird Densities?

Restored Refuge

Survey Area:
- Boardwalk Transects
- Benthic Invertebrates: Spring, Summer, Fall 2012 (at starred grids)
- Birds: Weekly, March 2012 - January 2013
Benthic invertebrate prey densities and biomass were 79-150% greater during the fall than in spring or summer.

Highest prey densities were observed at lower elevations that were more frequently inundated ($R^2 = 0.12$, $p = 0.002$)
Prey Availability in Restoring Wetlands

- Prey Availability:
  - Oct, Jan, Mar
  - Sampling locations stratified random
  - Balanced number of cores each in:
    - Borrow ditches, natural channels, pannes
Conclusion

- Grid-based area counts provide a scalable methodology to link response of waterbirds to biotic and abiotic changes at restoration site
  - Common currency enabling comparison across sites and regions
  - Enables meso and macro-scale habitat association modeling
  - Informs adaptive management and restoration design

- Pre and post breach/dike removal data ideal to capture avian response to site evolution

- Accessibility, staffing, funding may limit effort. Random sampling of grids allows for modeling, but may limit ability to evaluate fine scale spatial distributions

- Restorations may benefit multiple species at different times in their trajectories. Important to evaluate use by all waterbird species to have multiple indicators of restoration benefits
  - Co-benefits for fish and birds – shared prey resources
Acknowledgements

Project Design & Data Management:
John Takekawa, Nicole Athearn, L. Arriana Brand

Field Crews:

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Collaborators: Nisqually Tribe, SFBBO, PRBO, Ducks Unlimited, Moss Landing Marine Labs, San Jose State University, San Francisco State University
Within Region: What Habitat Features Drive Waterbird Densities?

Pond Salinity

Model-averaged results from General Linear Mixed Models (GLMM) to identify important predictor variables.