Exploring the Ecosystem and Salmon Habitat Functions of Large-River Floodplain Marshes with Altered Disturbance Regimes

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Inception of the Research Idea at CREC 2012

Fort Stevens at the Mouth of the Columbia

Photo: Oregon State Parks

Inception of the Research Idea at CREC 2012

Mouth of the Columbia-Jetties

Inception of the Research Idea at CREC 2012

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Land Use Legacies: Logging, Diking, Grazing

Inception of the Research Idea at CREC 2012

Keywords: Disturbance Ecology, Legacies

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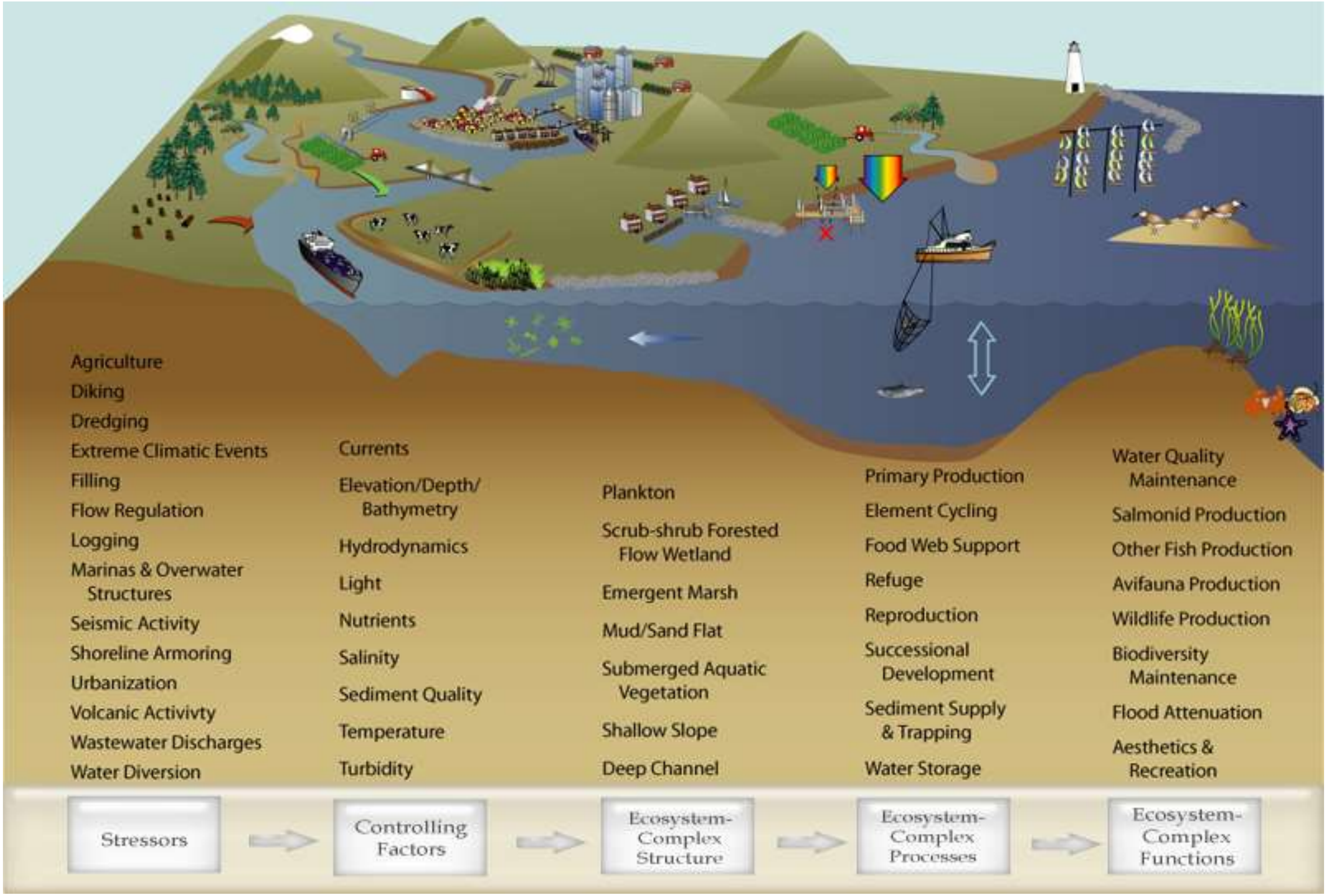
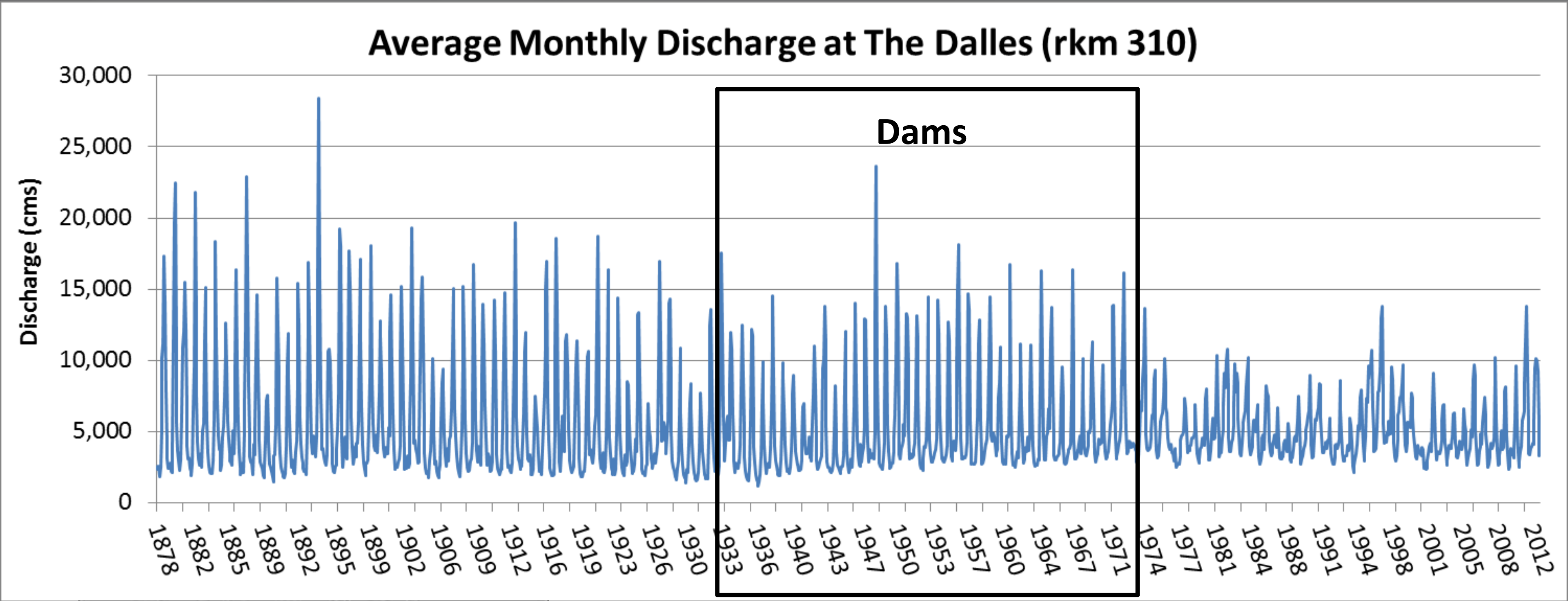
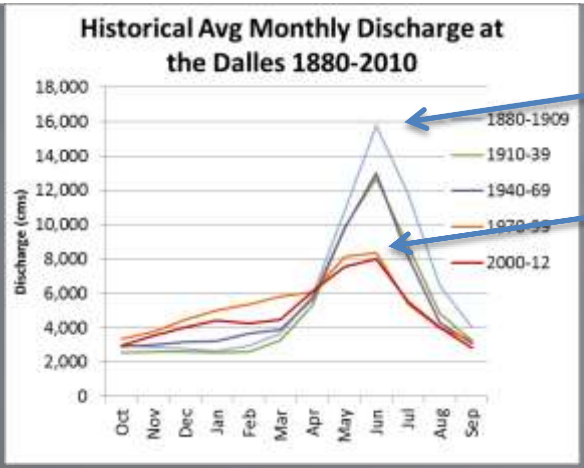
- Disturbance Ecology examines effects of stressors on **ecosystems**; effects of magnitude, duration and frequency of events (often physical processes); questions like alternative stable states; land use legacies; etc.
- Rich History of this ecological research in the PNW
  - Fire Ecology (Jim Agee, many others)
  - Mt. St. Helens (Jerry Franklin, many others)
  - “Discovery” of “Large Woody Debris” Legacies (Mark Harmon, many others)
  - Riparian Interfaces (Bob Naiman, many others)
  - Etcetera…….

Early Conceptual Models for the Columbia Estuary Ecosystem Restoration Program



Tidal Wetlands Assumed Affected by Changes to the Hydrograph





Flow Trends 1878-2012: Decrease and Interannual Variability

http://nwis.waterdata.usgs.gov/nwis

But effects of physical processes differ by zone and distance from main stem

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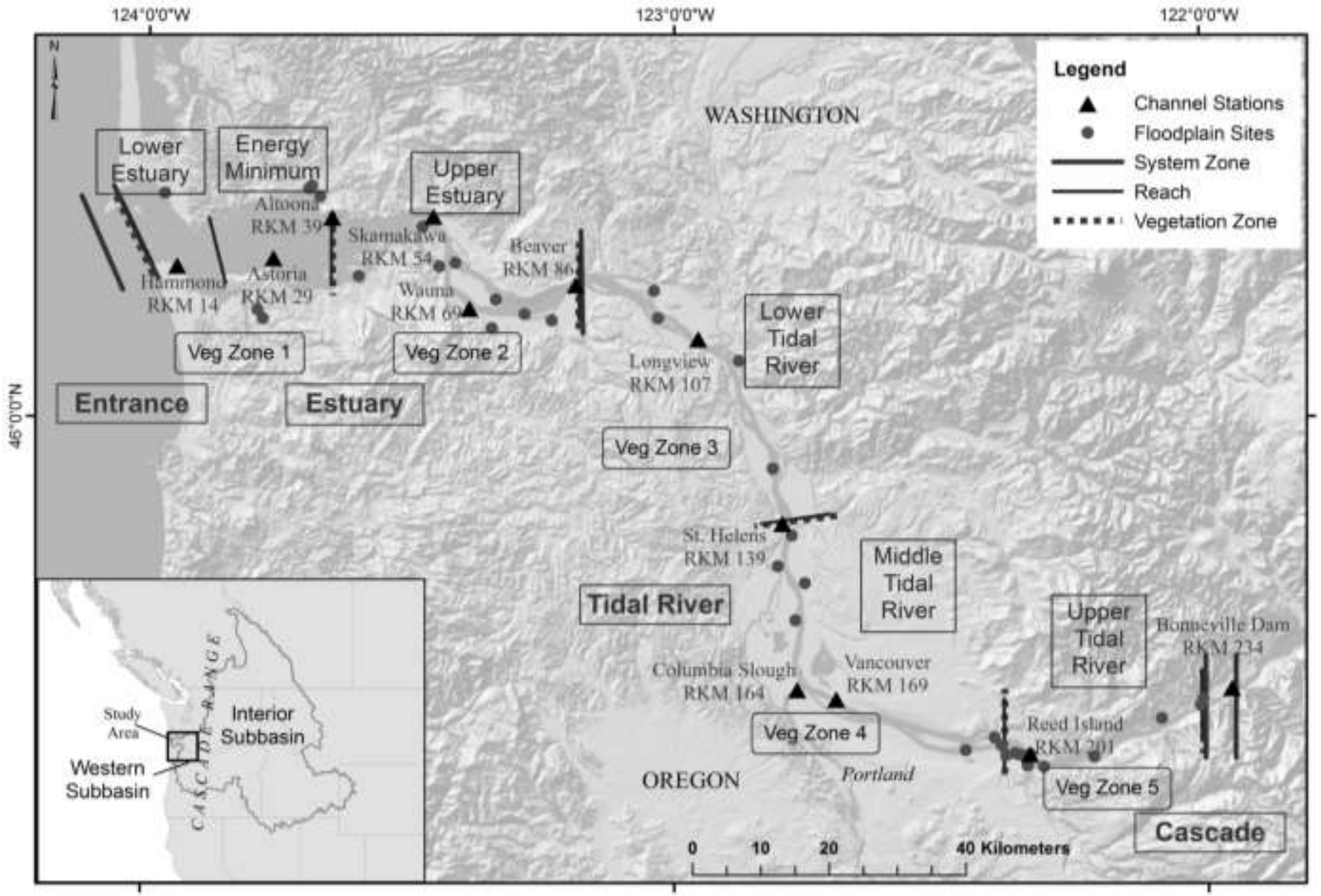

Jay, D. A., K. Leffler, H. Diefenderfer, and A. Borde. In press. Tidal-fluvial and estuarine processes in the Lower Columbia River: Part I and Part II. *Estuaries and Coasts*.

Tidal Wetland Study Sites (47 Reference Sites and 3 Recently Restored Sites)

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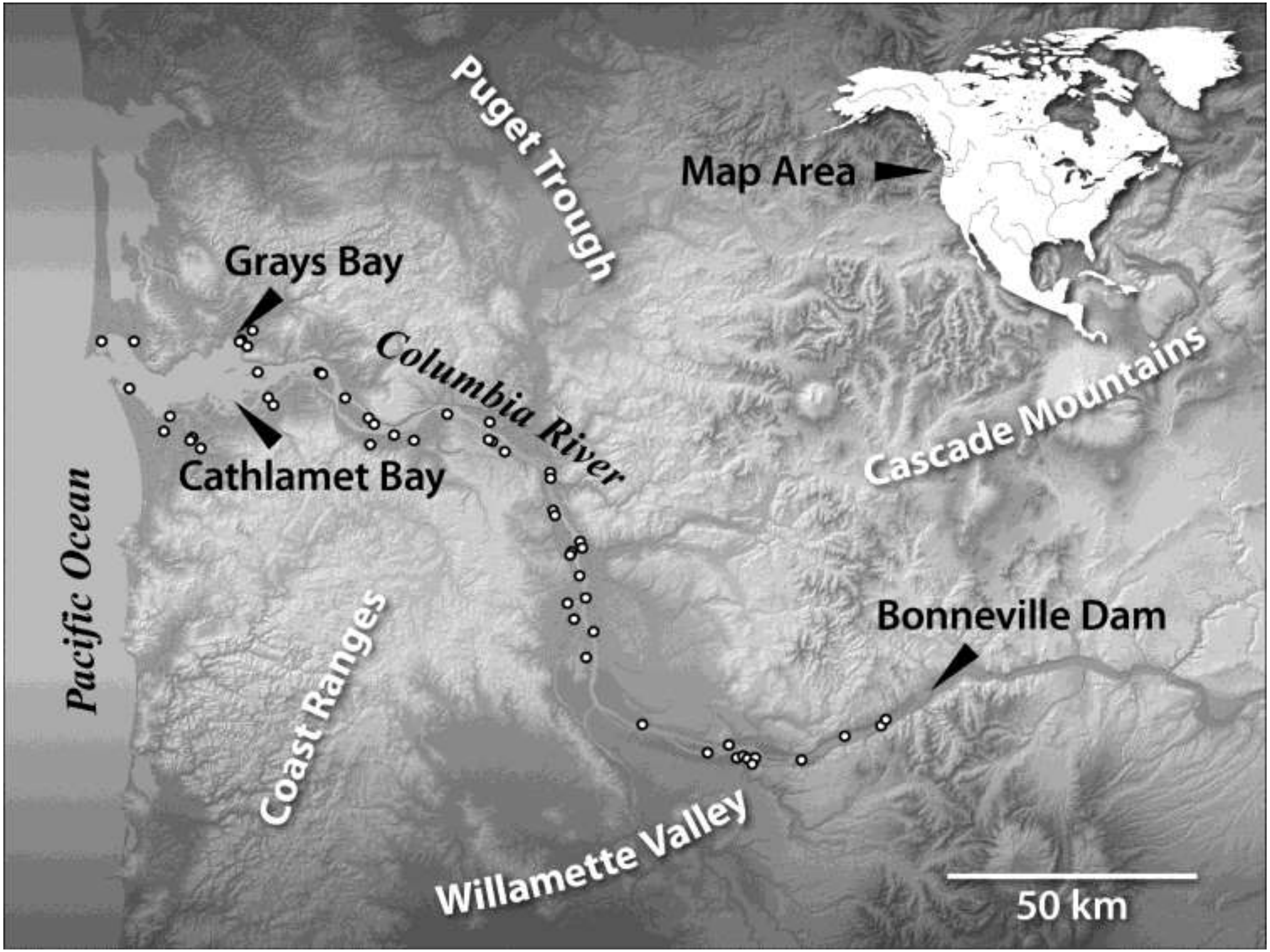

Can we assign marshes dates of origin? Reference Sites Change Analysis Methods

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- Comprehensive aerial photo record has large gaps
- Compared 47 current tidal wetland reference sites in the late 1800s and today using two polygon datasets:

  1) digitized representation of historically mapped land cover from the late 1800s (Burke 2010);

  2) digital representation of current land cover developed in 2011 (Keith Marcoe, LCREP, pers. comm., 2012).
- Merged the cover classes into similar categories to compare
- Clipped these datasets to the *study area* scale, which included the larger area surrounding the sampling sites, and the *vegetation survey* scale.
- Calculated the areas of resulting land cover polygons

Marsh Progradation: Change Analysis at Existing Wetlands

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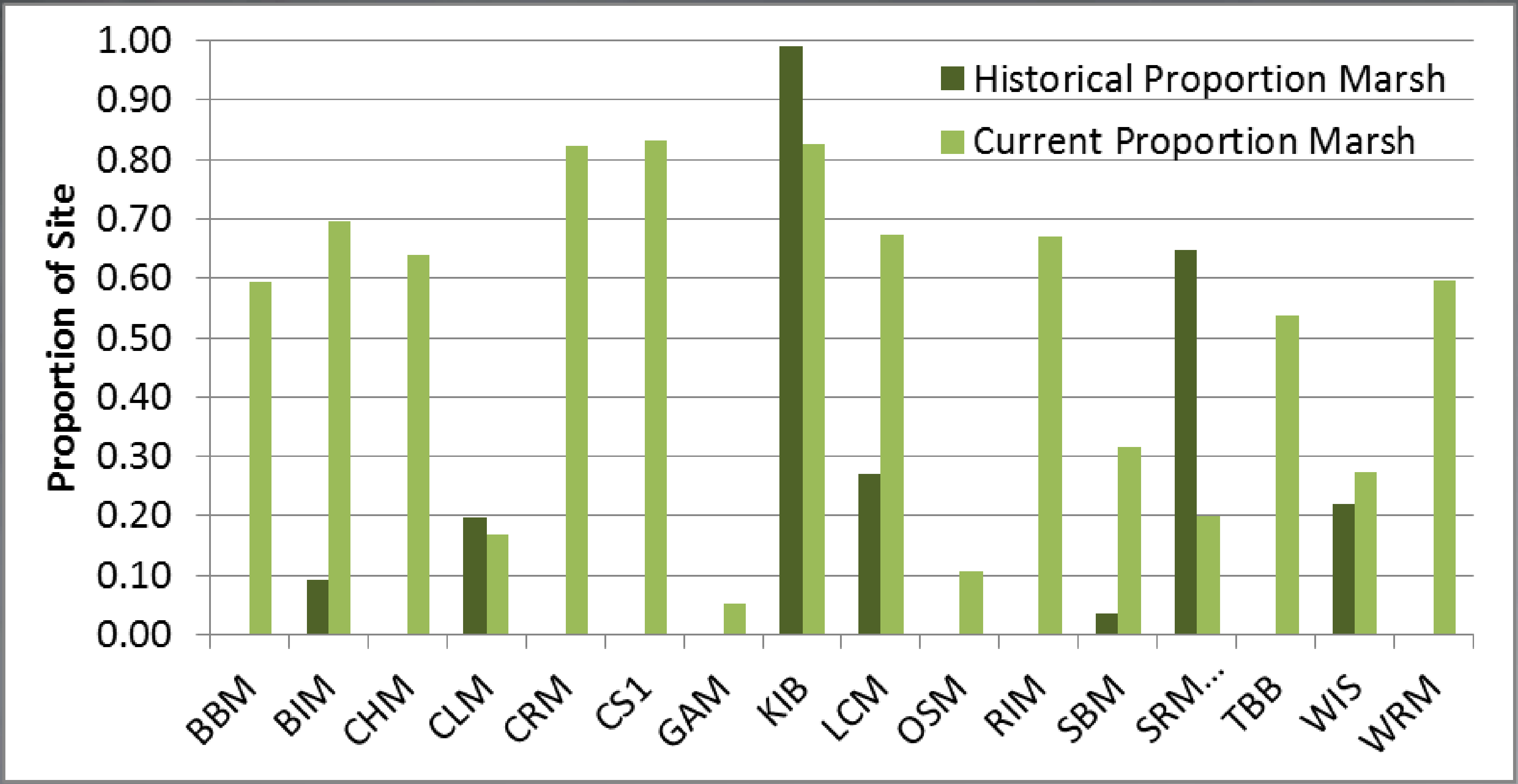
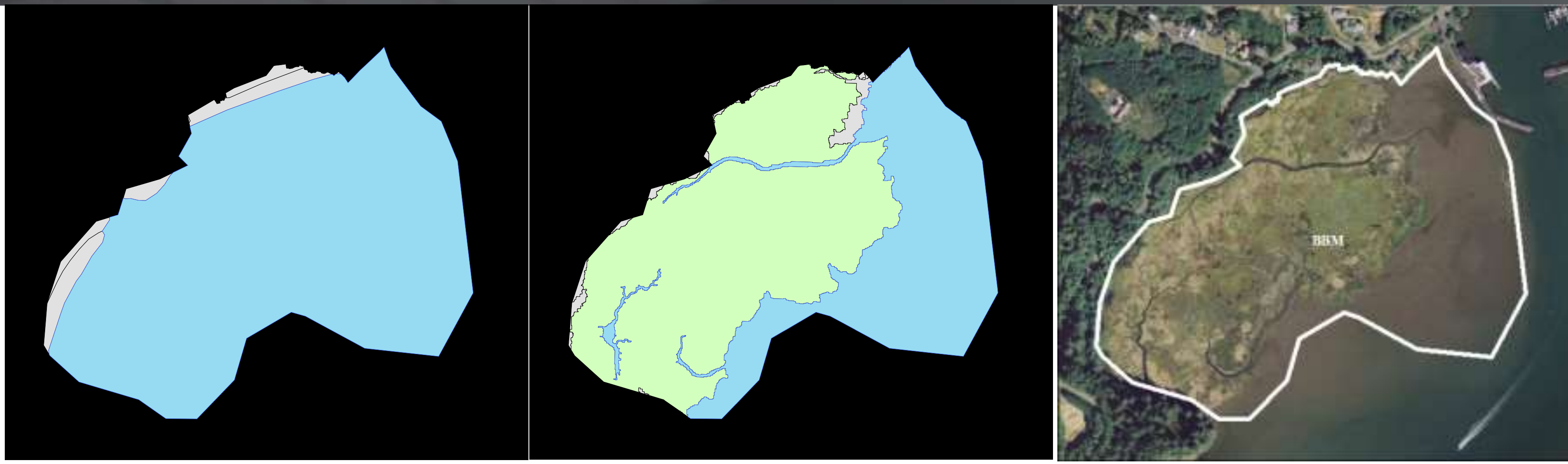


Reference Sites Change Analysis Examples



Progradation at Baker Bay Marsh Reference Site (above); Dredged Material Placement at Deer Island and Goat Island (right)

Habitat Change Analysis

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Take Home Message: Newly developed wetlands make up 30-40% of what exists today

Normalized Land Cover Class	Historic Data (ha)	Current Data (ha)	**Overall Change (ha)**	% of Overall Area (Historic)	% of Overall Area (Current)
Herbaceous Tidal Wetland	14353	4606	**-9747**	8.8	2.8
Wooded Tidal Wetland	15960	4973	**-10987**	9.8	3.1

	Tidal flats to Tidal Wetland (ha)	Water to Tidal Wetland (ha)	**Total Gain (ha)**
Herbaceous Tidal Wetland	537	1370	**1907**
Wooded Tidal Wetland	175	1432	**1607**

Simple summation of relevant data reported by Keith Marcoe and Steve Pilson. 2011. *Habitat change in the Lower Columbia River and Estuary, 1870 – 2010.* Lower Columbia Estuary Partnership, Portland, Oregon.

Implications of Reference Sites Change Analysis for Disturbance History Analysis

- Only 2 of the marsh areas sampled in the LCRE/CEERP reference sites network were present in the late 1800's, and 5 were partially vegetated
- Age of wetland establishment could only be assigned to a minority of sites using existing historical data; a limitation on analytical methods
- Evidence of prior dredged material placement at 20 reference wetlands, but exact dates and number of instances unknown; again, limiting "time" or "age" considerations in analysis

Development of Tidal Wetland Disturbance Classification Scheme; 3 Scales of Influence

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- **Least disturbed**, same land cover present in 1870
- **Landscape disturbance only,** e.g., hydrologic and sedimentary processes affected by landscape-scale alterations, but no known local disturbance
- **Local disturbance** in the vicinity, e.g. trestles, jetties, pile dikes
- **Site disturbance:** previously diked; historically breached
- **Site disturbance:** recently reconnected
- **Site disturbance:** dredged material placement

- Hypothesis: the variability of any given attribute of a tidal-fluvial wetland in the LCRE is within the same range regardless of disturbance history or distance from the main-stem river

(won’t be discussing the *distance* results today)

40 Variables Analyzed by Disturbance Category (22 Sites with both Fish and Wetland Data)

- **Sediment Characteristics**: Sediment Accretion Rate (cm/yr), Floodplain TOC (%), Channel TOC (%), Floodplain Sand (%), Channel Sand (%), Floodplain Fines (%), Channel Fines (%)
- **Channel Morphology & Floodplain Topography**: Bank Elevation (m, CRD), Thalweg Elevation (m, CRD), Channel Depth (m), Cross Section Area (m2), Channel Width (m), Width:Depth Ratio, Proportion Low Marsh, Average Site Elevation (m, CRD), Distance to Main Channel (km)
- **Surface Water**: Water Temperature, Inundation (Channel/Overbank)
- **Plant Community**: Average Total Vegetative Cover (%), No. Species, No. Native Species, Average No. Species/Quadrat, Proportion Quadrats w' Non-native Species, Average Native Species Cover (%), Average Non-native Species Cover (%), Relative and Absolute Cover of PHAR (%), Ratio of PHAR to Non-native Cover
- **Fish Community**: No. Species, Species Diversity, % Salmon in Total Catch, % Salmon (without stickleback), % Non-native Fish in Total Catch, Chinook density (Fish/m^2), Salmon density (Fish/m^2), % Fry (Chinook), % Marked (Chinook), Mean Length (Chinook)

12 Significant Metrics Univariate Analysis, with Direction from Median by Disturbance Category

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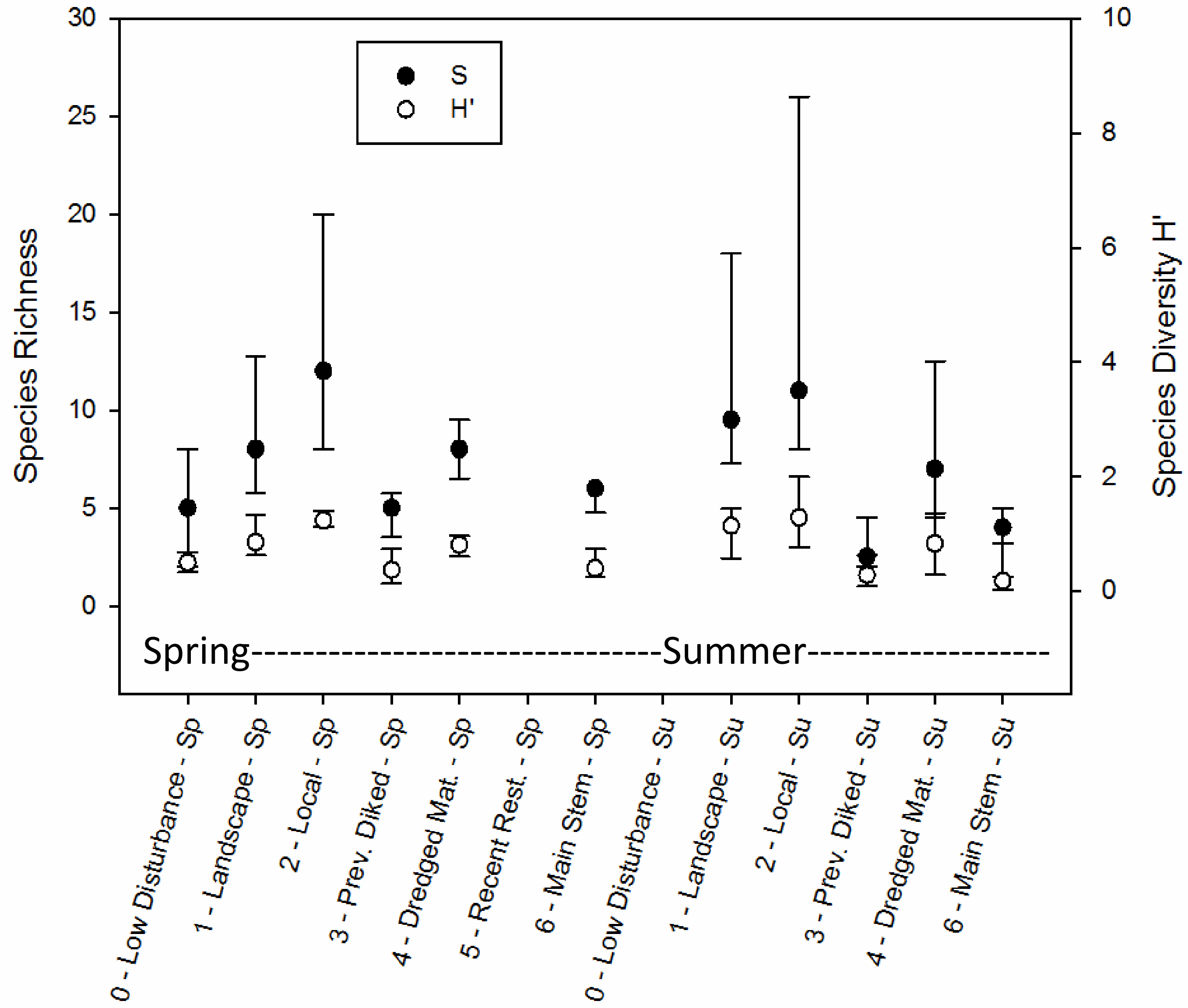
Significant Kruskal-Wallis Test at at α=0.05

0=least disturbed
1=landscape
2=local
3=site previously diked
4=site dredged material
5=recently reconnected
6=main stem channel

	+	-	
Floodplain soil TOC (%)		4	physical
Thalweg Elevation (m, CRD)	2	5	physical
Channel Depth (m)	3,5	4	physical
Cross Section Area (m^2)	3,5		physical
Width:Depth Ratio	4	2	physical
Proportion Low Marsh	2	4	physical
Channel Inundation	3	2	physical
Over-Bank Inundation		3	physical
Proportion Quadrats Non-Native	2	1	biological
Average Native Species Cover		2	biological
Fish Species Richness (Spring; summer)	2;1	3;3,6	biological
Fish Species Diversity (Spring; summer)	2;2		biological

Significant Fish Metrics: Species Richness and Diversity



Discriminant Model Using Channel & Floodplain Features

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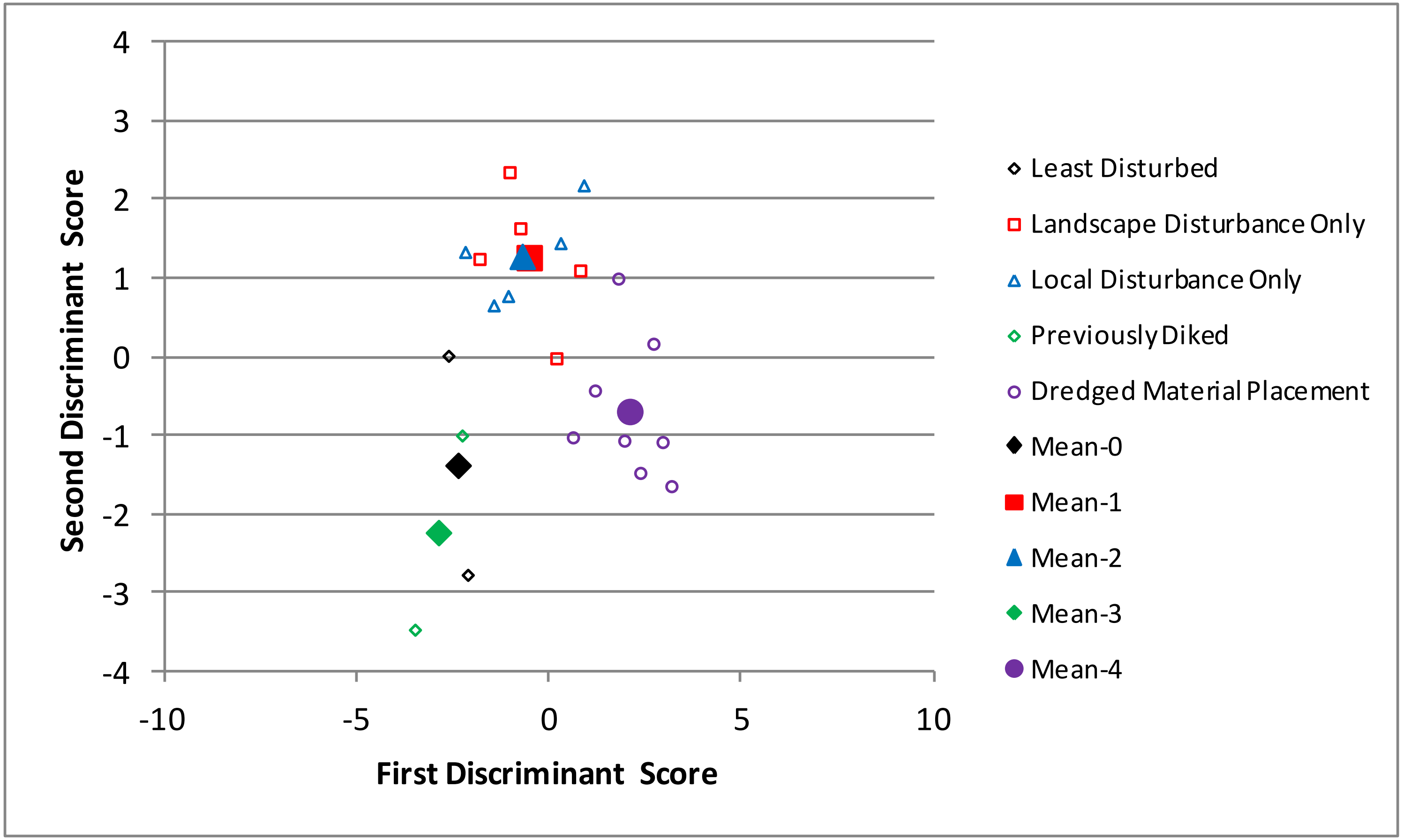

correctly classified 20/22 sites (91%) that had no missing values in the modeled variables (Wilks' lambda 0.02)

Two functions explain 80% of variability; third root separates least disturbed and previously diked sites.

After stepwise analysis, variables in the Model: average floodplain TOC (%), cross-sectional area (m^2), channel width (m), bank elevation (m), average yearly accretion/erosion rate (cm), average channel fines (%), and average marsh fines (%).

Descriptive Findings by Disturbance Category: Dredged Material Placement

- low elevations (site & channel bank)
- high sediment accretion rates
- high proportions of low marsh
- high channel width:depth ratios
- shallow channel depths ($\bar{x}$ = 0.68m)
- low TOC% in floodplain and channel
- locations near the main channel CR

Descriptive Findings by Disturbance Category: Dike Breaches 10-60 yrs Old

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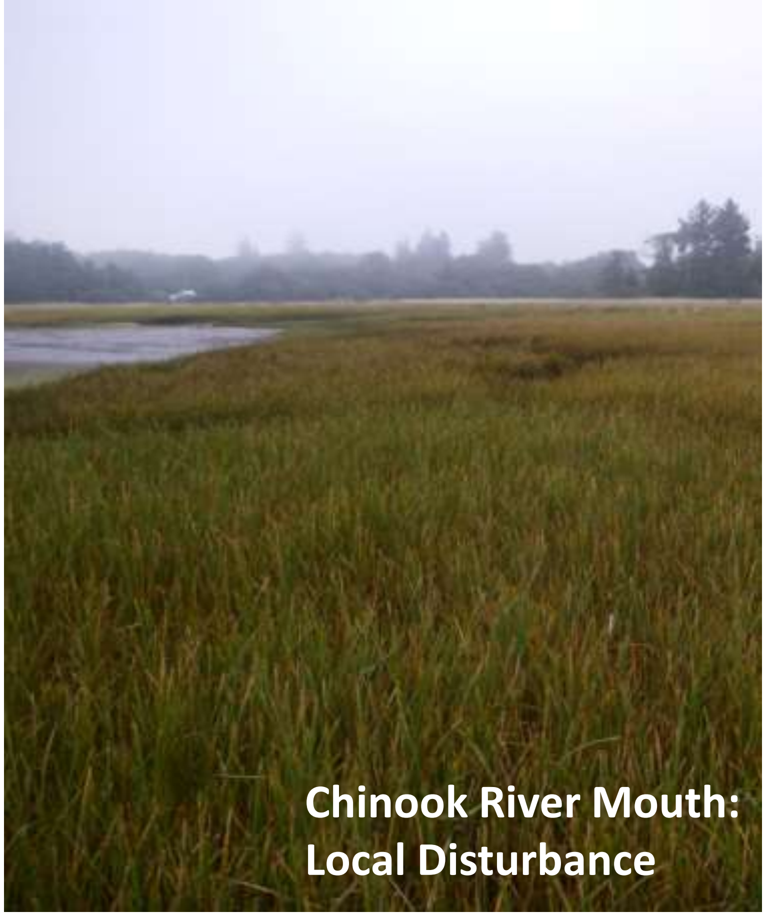
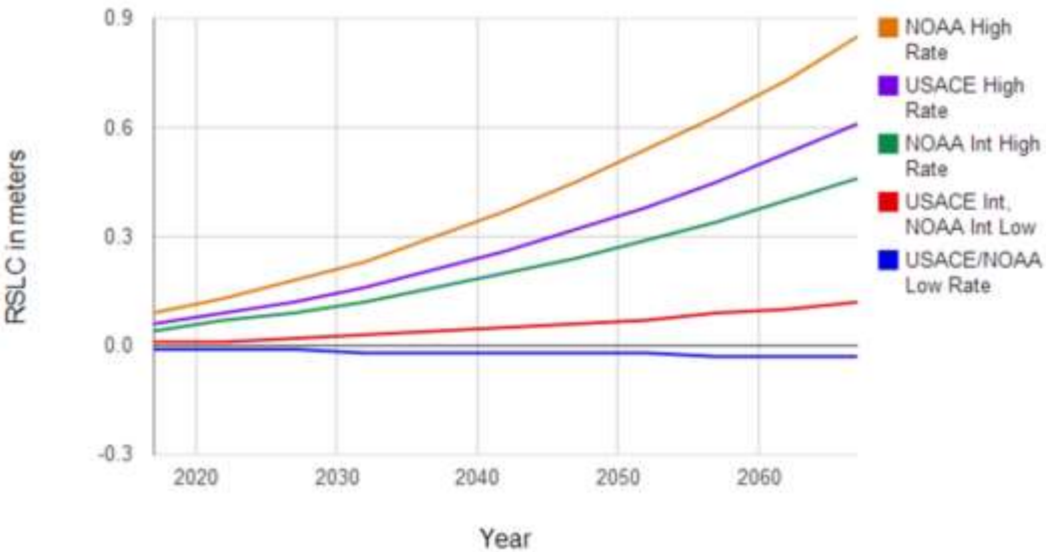
- most frequently inundated channels/least frequently inundated overbank
- deep channels and large cross-sectional areas (also applies to wetlands with recent dike breaches)

Descriptive Findings by Disturbance Category: Local v. Landscape Disturbance

- Landscape scale disturbance: low proportion of observations with non-native plant species, high fish species richness in summer.
- Locally disturbed sites: higher elevations, least frequently inundated channels, higher proportion observations with non-native plant species, lower average native plant cover, lower proportions of low marsh, high fish species richness in spring, high fish species diversity in spring and summer.



Other Processes: East Sand Island RSLR Example



Scenarios for a 50-yr project life, 2017-2067, using the online tool developed by the Corps and NOAA. Scenarios are tied to IPCC. http://www.corpsclimate.us/ccaceslcurves.cfm

Mud flat extent is white line (shorebird habitat); tan is potential emergent vegetation:

In Restoring a Site…Consider Processes and Disturbances at Site and Landscape Scales

Chinook River Estuary and Fort Columbia Restoration Projects

Photo: USACE

Conclusions

- Sediment deposition and marsh progradation processes in the LCRE are active. (Thomas 1983)
- Because site selection focused on proximity to channels for comparability to restoration sites, most of the CEERP Reference Marshes are relatively young (< 100 yrs)
- Few older marsh ecosystems in the LCRE have been studied (see Elliot, C. 2004. *Tidal emergent plant communities, Russian Island, Columbia River Estuary.* MS, UW, Seattle, WA)
- In these young marshes, channel morphology and floodplain characteristics discriminate by disturbance categories but plant community and salmon metrics mostly don't.
- Position in the river is a better predictor of ecological structure and function than disturbance history. However, a limitation of the reference marsh dataset is that we do not have examples of all disturbance histories in all zones of the LCRE.

Research and Management Implications

- Juvenile salmon are found in tidal wetlands regardless of historical status and disturbance history. (We didn't consider function.)
- Strong relationship between water temperature and salmon abundance and temperature did not differ by disturbance.
- Marsh plant communities can develop regardless of historical status and disturbance history.
- Marsh plant communities develop rather quickly in response to changed sediment availability…at least in terms of progradation. The reverse—i.e. ability to migrate up the elevation gradient in response to SLR is indicated by response to 1700 earthquake.
- Morphology/topography affected by disturbance e.g. dredged material placement sites not similar to naturally formed channels
- Data from reference sites suitable for long-term marsh development (>50 years) are not available for most parts of the LCRE; consider this in paired restoration/reference trajectory analyses!
- May want to include disturbance history in multivariate analyses

Acknowledgements

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  - Implemented by U.S. Army Corps of Engineers Portland District and Bonneville Power Administration with partner organizations.

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