Quantifying Habitat Connectivity in the Lower Columbia River and Estuary

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Acknowledgements

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Need

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Columbia Estuary Ecosystem Restoration Program (CEERP) primary strategy for ecosystem restoration is to reconnect tidal wetlands to the main stem estuary.

Questions:

- Quantitatively, how has habitat connectivity for juvenile salmon changed since 2000 due to reconnection restoration actions?
- How much is CEERP improving habitat connectivity by estuary zone?
- How much more potential is there for tidal hydrologic reconnection by estuary zone?

Objective: to index habitat connectivity estuary wide and by zone for 2000 (baseline), 2010 (intermediate), and 2016 (current conditions).

Spatial Scale

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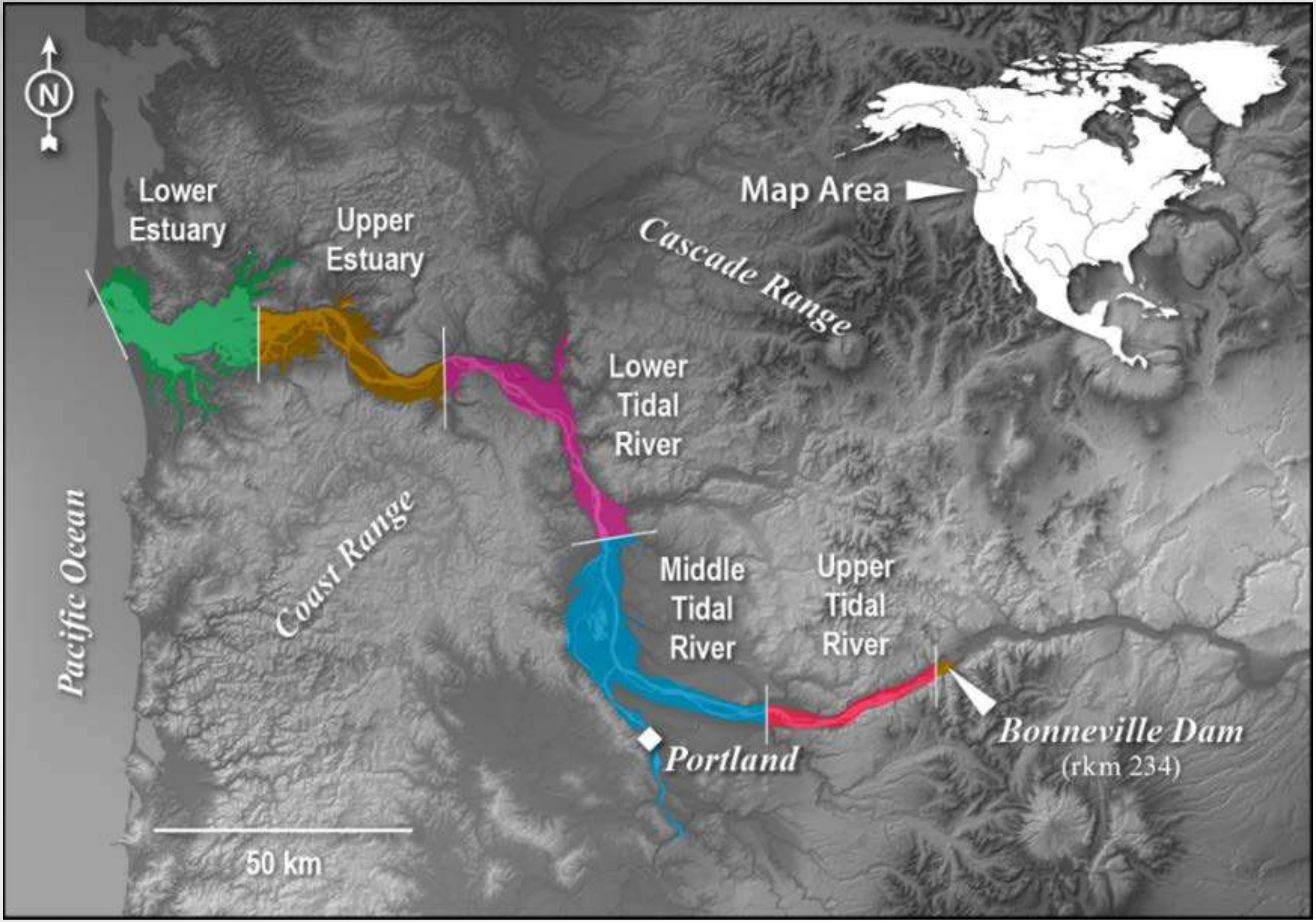
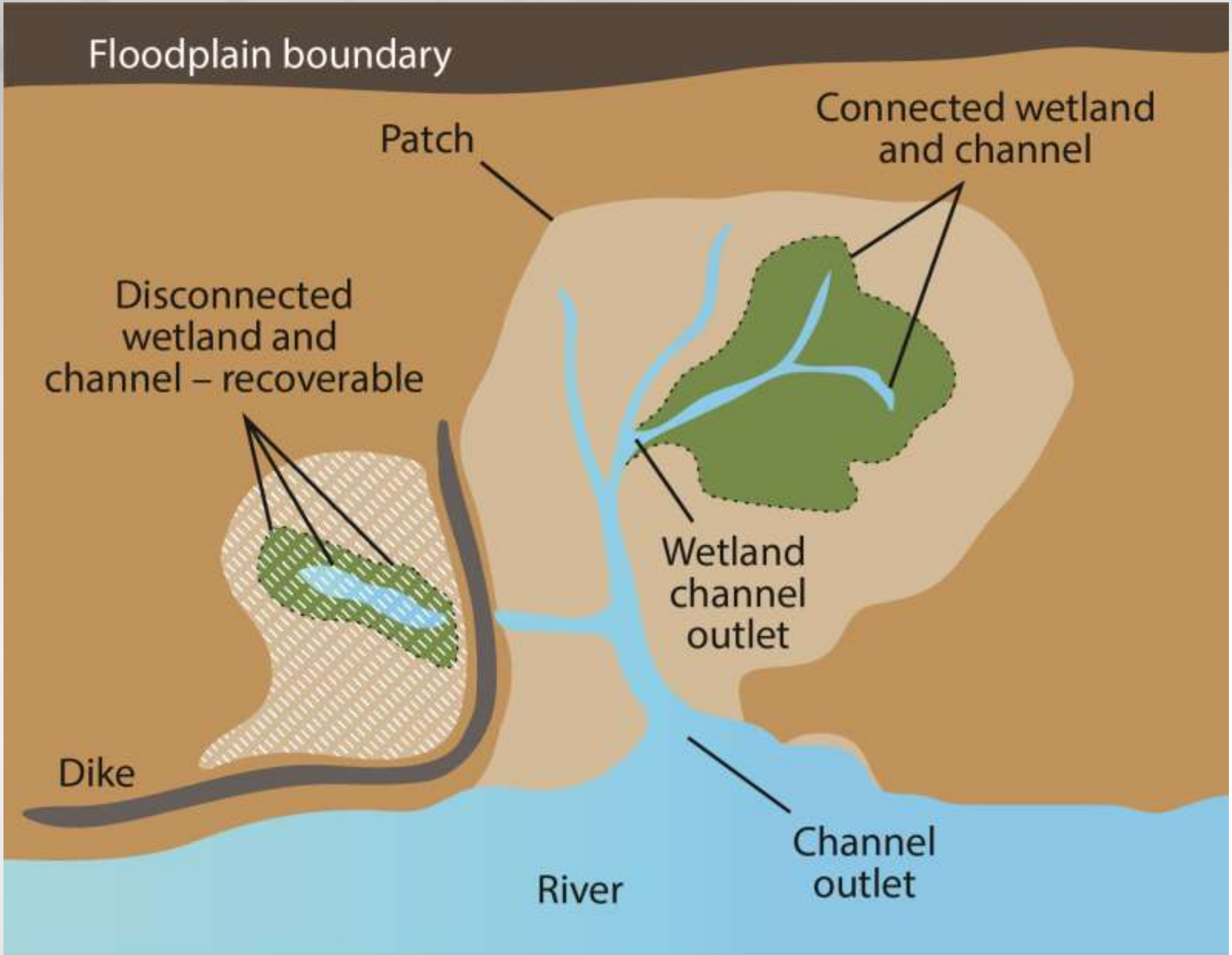


Defining Connectivity



Defining Connectivity

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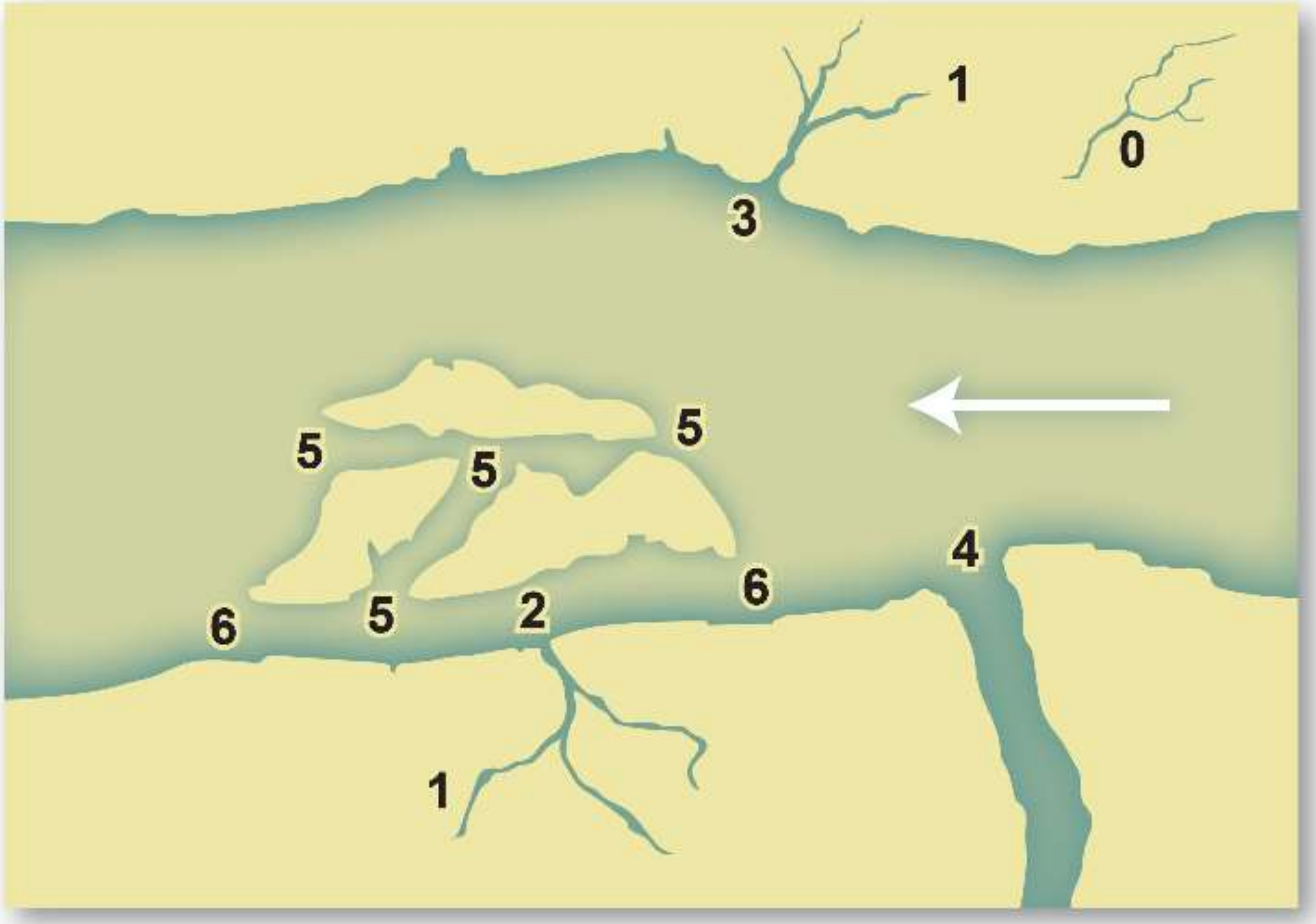
Hydrologic Connectivity



Based on Lasne et al. 2007. Rank connectivity of river floodplain habitats. *Biological Conservation* 139.

Approach

- Utilize existing estuary-wide spatial datasets
- Modify as needed to create connectivity-related datasets
- Quantify the metrics of connectivity
- Calculate an Index of Connectivity
- Calculate change in Index over time with restoration

Data Sources and Metrics

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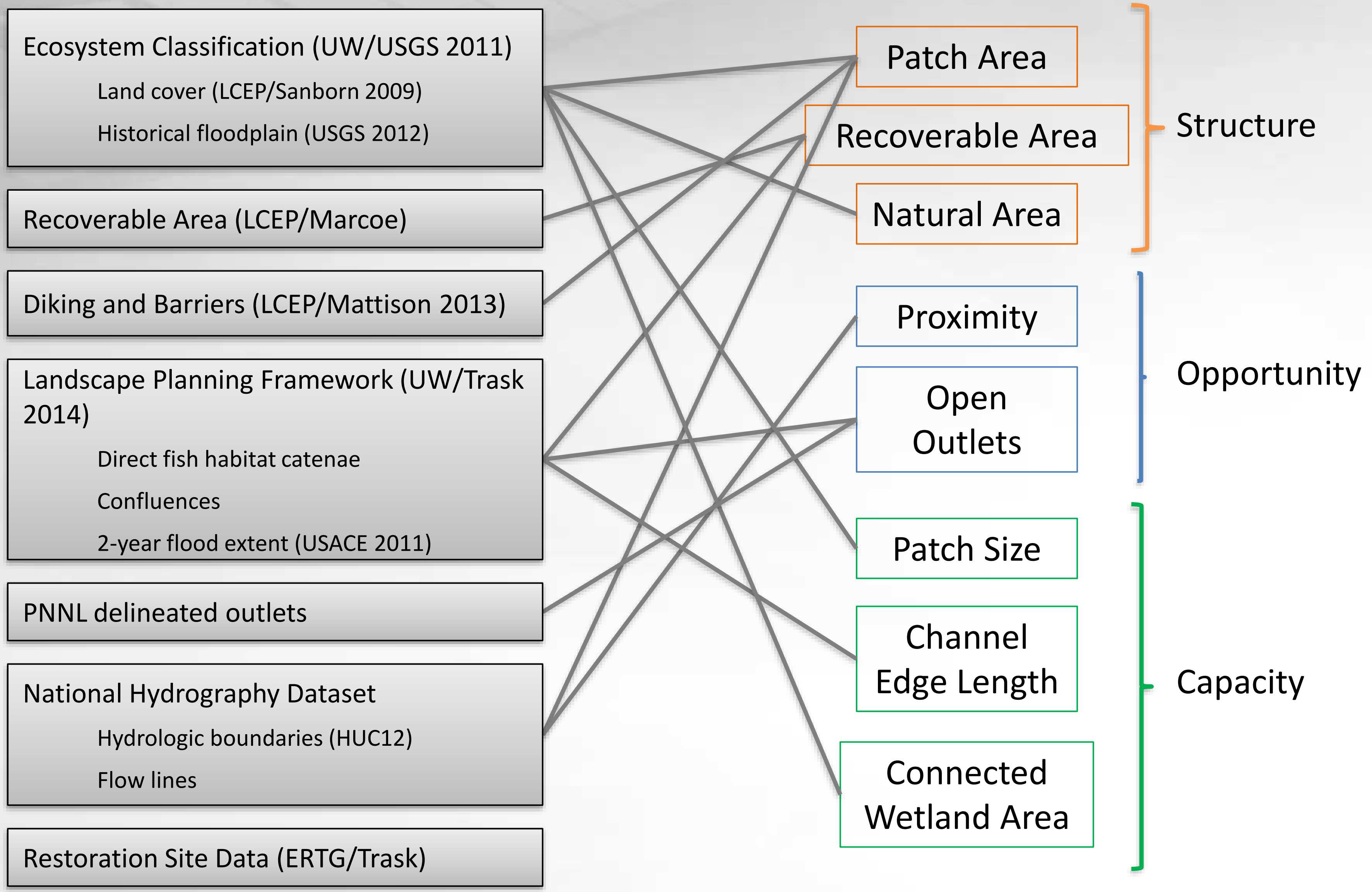


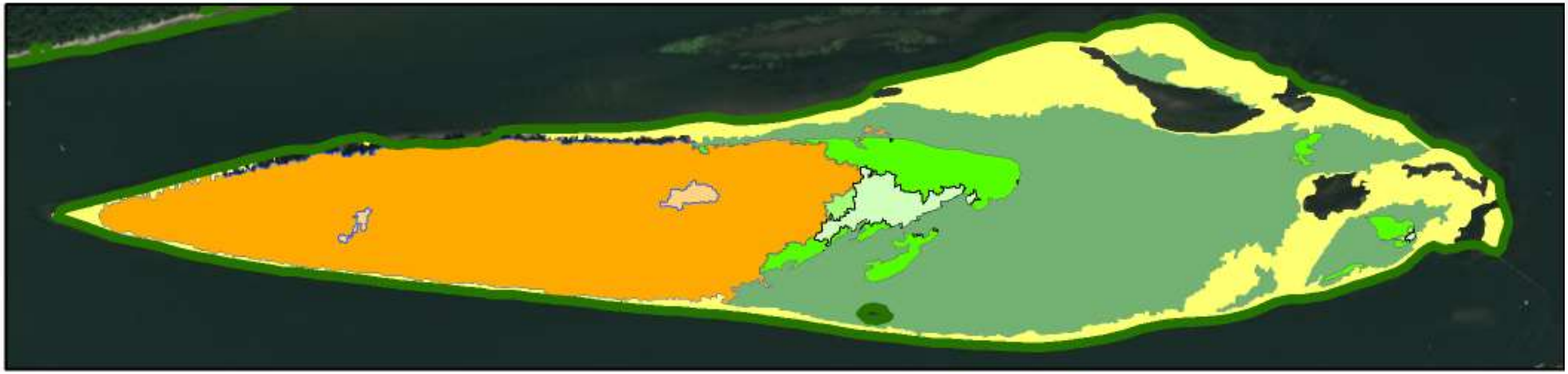
What is a Patch??

- A *Patch* includes the following:
  - Tidally influenced wetland area
  - Contiguous upland or non-tidal wetland area
  - Within a hydrologic boundary

Why is it important??

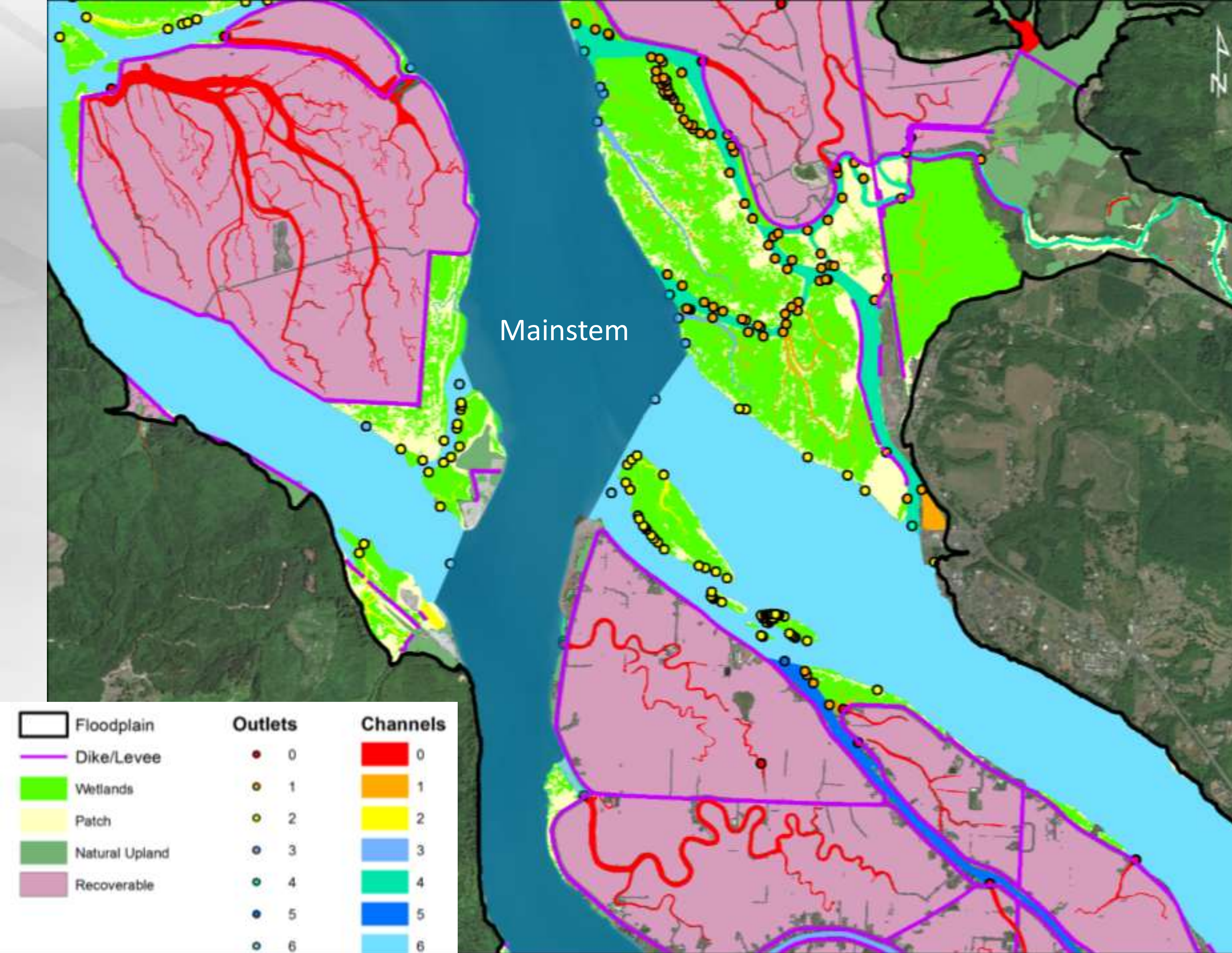
- The relatively undisturbed, natural area surrounding tidal wetlands provides the following:
  - Buffer for disturbance
  - Source of allochthonous material
  - Increased resiliency by allowing potential for wetland migration

Delineation of a Patch



Landcover classification

- Sand
- Tidal wetland
- Non-tidal wetland, deciduous forest
- Non-tidal wetland, shrub-scrub
- Non-tidal wetland, herbaceous
- Upland deciduous forest
- Upland shrub-scrub
- Upland herbaceous


Mainstem
Floodplain
Dike/Levee
Wetlands
Patch
Natural Upland
Recoverable
Outlets
0
1
2
3
4
5
6
Channels
0
1
2
3
4
5
6

Habitat Connectivity Variables

Variable	Description	Equation
Structural – A measure of patch area connected hydrologically to the mainstem, expressed as the proportion of connected patch area out of all non-developed area at time *t*		
A	Proportion of connected patch area to all non-developed area	$A = \frac{L}{L+R+M}$
L	Total area of less-disturbed connected patches (ha)	
R	Total recoverable area, i.e., not currently connected but potentially could be in the future (ha)	
M	Total area of remaining natural habitats that are not wetland nor connected (ha)	
Functional – Measures of the opportunity for juvenile salmon to access habitats and the capacity of those habitats to provide ecological advantages for juvenile salmon		
Opportunity, involves three elements: proximity, open outlets, and open outlets weighted by channel class		
D_t	Proximity is the average normalized distance from wetland outlets to the main stem river for time *t*	$D_t = (1-\bar{d}_t)$
$\bar{d}_t$	mean normalized outlet distance to main stem for time *t*	$\bar{d}_t = \frac{\sum_{i=1}^{P_t}\sum_{j=1}^{J_i}\left(\frac{d_{ij}-d_{min}}{d_{max}-d_{min}}\right)}{n_t}$
d_{ij}	distance of the j[th] outlet in the i[th] wetland to main stem	
d_{min}	the minimum distance of a wetland outlet to the main stem over all times	
d_{max}	the maximum distance of a wetland outlet to the main stem over all times	
J_i	the total number of outlets in the i[th] patch	
P_t	the total number of patches for time *t*	

Variable	Description	Equation
n_t	total number of outlets for all patches combined for time *t*	
O	Proportion of open outlets	$O = \frac{o}{o+c}$
o	total number of open channel outlets	
c	total number of closed channel outlets	
K	proportion of open channel outlets weight by class of outlet (1 = 0-4)	$K = \frac{\sum_{l=1}^{4}(l * o_l)}{o*4}$
o	total number of open channel outlets	
$l*o$	weighted outlets	
Capacity, involves four elements: patch size, channel class 5 edge length, channel class 0-4 edge length, and connected wetland area.		
$\bar{S}_t$	mean normalized patch size for time *t*	$\bar{S}_t = \frac{\sum_{i=1}^{P_t}\left(\frac{S_i - S_{min}}{S_{max}-S_{min}}\right)}{P_t}$
S_i	size of the i[th] patch	
S_{min}	minimum patch size over all times (ha)	
S_{max}	maximum patch size over all times (ha)	
P_t	total number of patches for time *t*	
F	proportion of total class 5 channel edge length adjacent to or within patches; these are off channels and may be outside the patch	$F = \frac{f_a}{f_a + f_n}$
f_a	class 5 channel edge length adjacent to patches (m)	
f_n	class 5 channel edge length not adjacent to patches (m)	
E	proportion of total classes 0-4 channel edge length in patches	$E = \frac{e_a}{e_a + e_n}$
e_a	edge length of channel classes 0-4 (m)	
e_n	edge length of channels class 99 (altered) (m)	
X	proportion of wetland area connected to the mainstem	$X = \frac{\sum_{i=1}^{P}\sum_{k=1}^{K_i} x_{ik}}{Z}$
x_{ik}	area of the kth wetland in the i[th] patch (ha)	
K_i	total number of wetlands in the i[th] patch	
P	total number of patches	
Z	total area of historical floodplain not including developed areas (ha) (Z=L+R+M)	
Habitat Connectivity		
HConI	habitat connectivity index	$HabConI = \frac{\sum_{v=1}^{V}(Y_v * 100 * w_v)}{V}$
Y_v	value of the *v*th variable (*A, D, O, K, S, F, E, X*)	
w_v	weighting factor for the v[th] variable (= 1 for all variables)	
V	total number of variables	

Restoration

- 2004-2009 7 sites

Lord - Walker Islands
Crims Island
Deep River, Svensen's Landing
Lewis & Clark River Dike Breaches
Fort Clatsop/South Slough
Walluski River North, Elliot #1
Vancouver Water Resources Center

- 2010-2016 31 sites

Haven Island
Fort Columbia
Fort Columbia Patch 8 (outside)
Mill Road
Colewort Creek (Nutel Landing)
Gnat Creek #1
Gnat Creek #2
Otter Point
South Tongue Point (Liberty Lane)
Dibblee Point
Honeyman Creek
Kandoll Farm #2
LA (Louisiana) Swamp
North Unit (Ruby Lake) Phase 1
Sandy River Dam Removal

Fee-Simon
Karlson Island
Multnomah Channel Metro
North Unit (Widgeon/Deep/Millionaire) Phase 2
Steamboat Slough
Thousand Acres
Batwater Station
Buckmire Slough
Elochoman Slough Thomas
LaCenter Wetlands
North Unit (Three Fingered Jack) Phase 3
Crane Slough-Domeyer
Kerry Island
Trestle Bay
Wallacut River
Westport Slough USFWS #1

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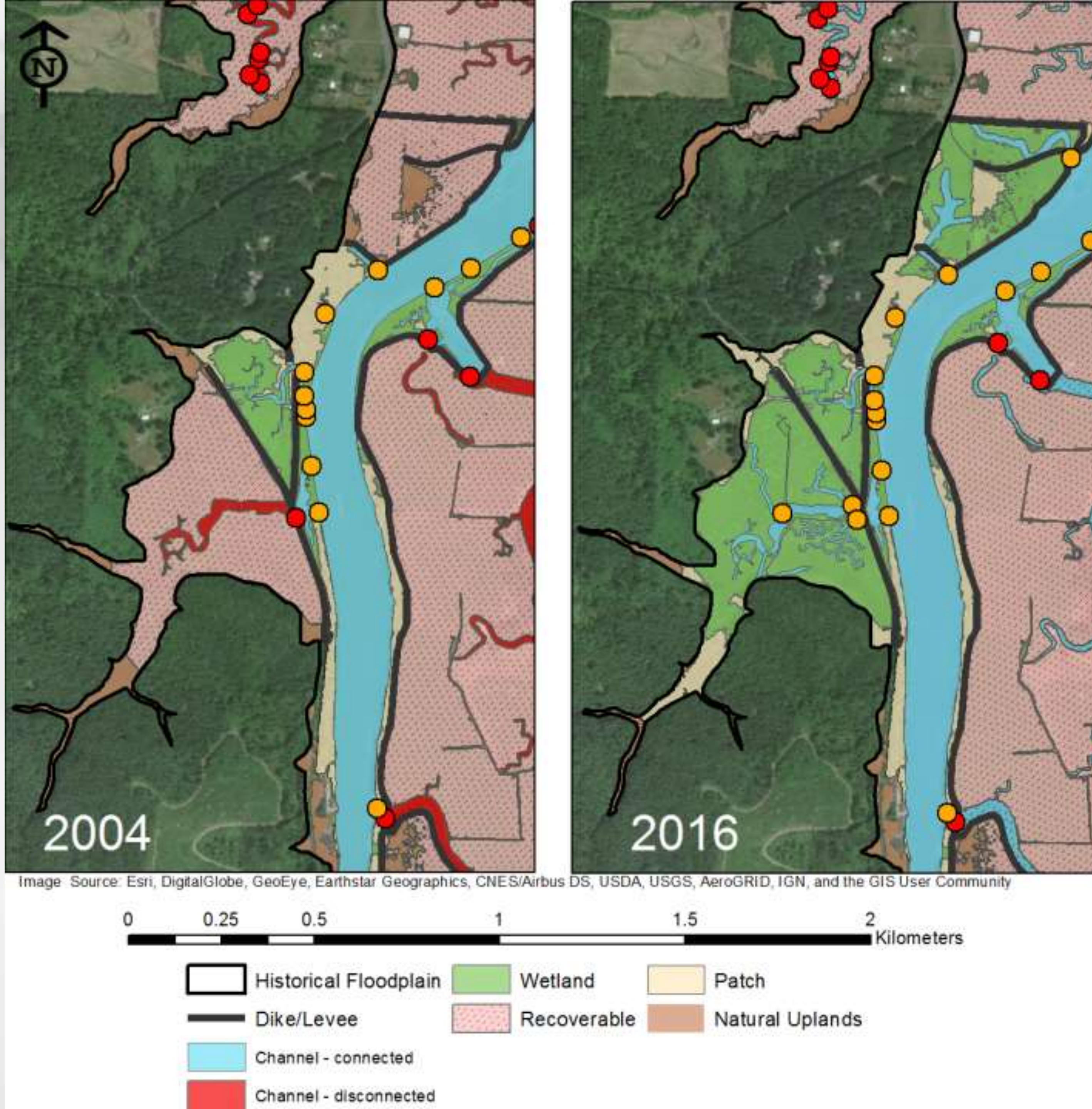
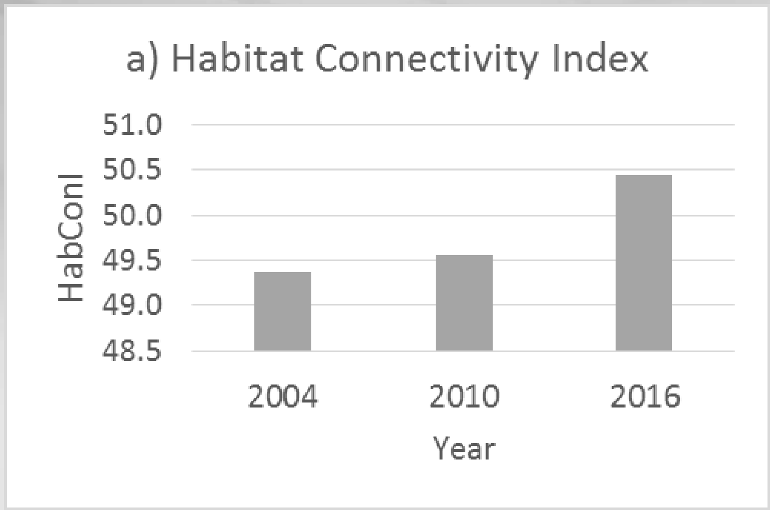


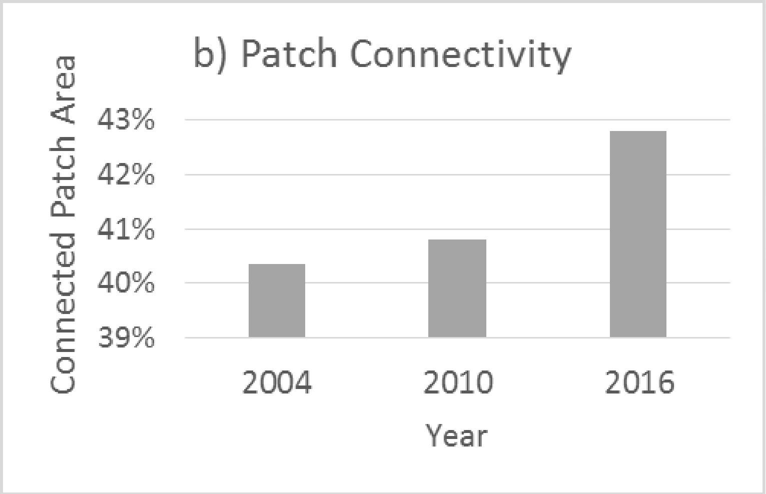
Image Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

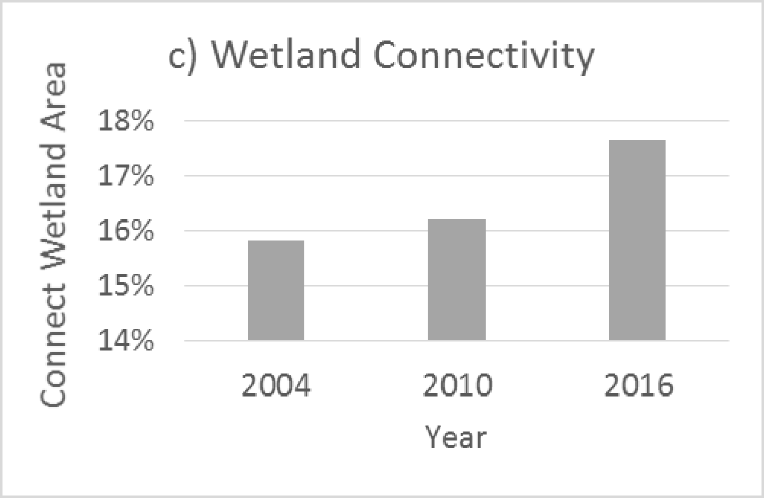
Summary Results

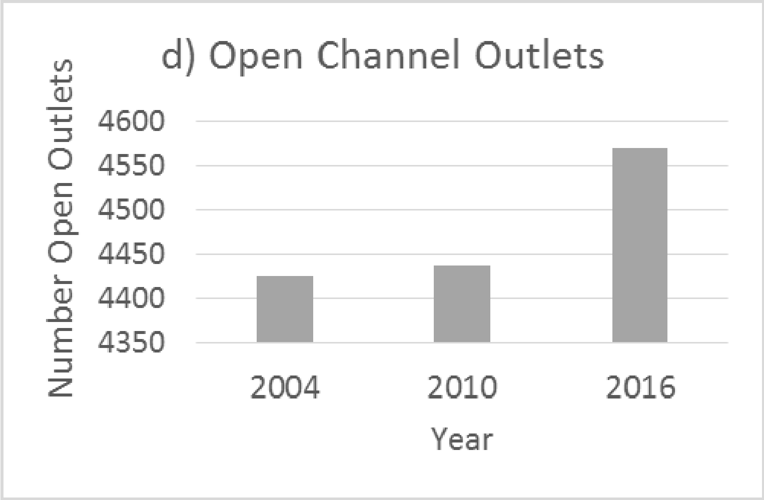
		2004	2010	2016
P	number of patches	326	323	327
L	total area of patches (ha)	22723	23002	24126
R	total area of recoverable area (ha)	21942	21725	21014
M	total area of remaining natural (ha)	11647	11617	11236
Sum x	Connected tidal wetlands in patches (ha)	8909	9120	9943
X	proportion of connected wetland area	0.29	0.30	0.32
O	Proportion of open outlets	0.84	0.85	0.86
o	total number of open channel outlets	4425	4437	4569
c	total number of closed channel outlets	818	810	739
F	Proportion class 6 edge connected to patch	0.73	0.73	0.74
E	Proportion class 1-5 edge connected to patch	0.63	0.63	0.65

Calculated for 3 time periods









Calculated for 5 Zones

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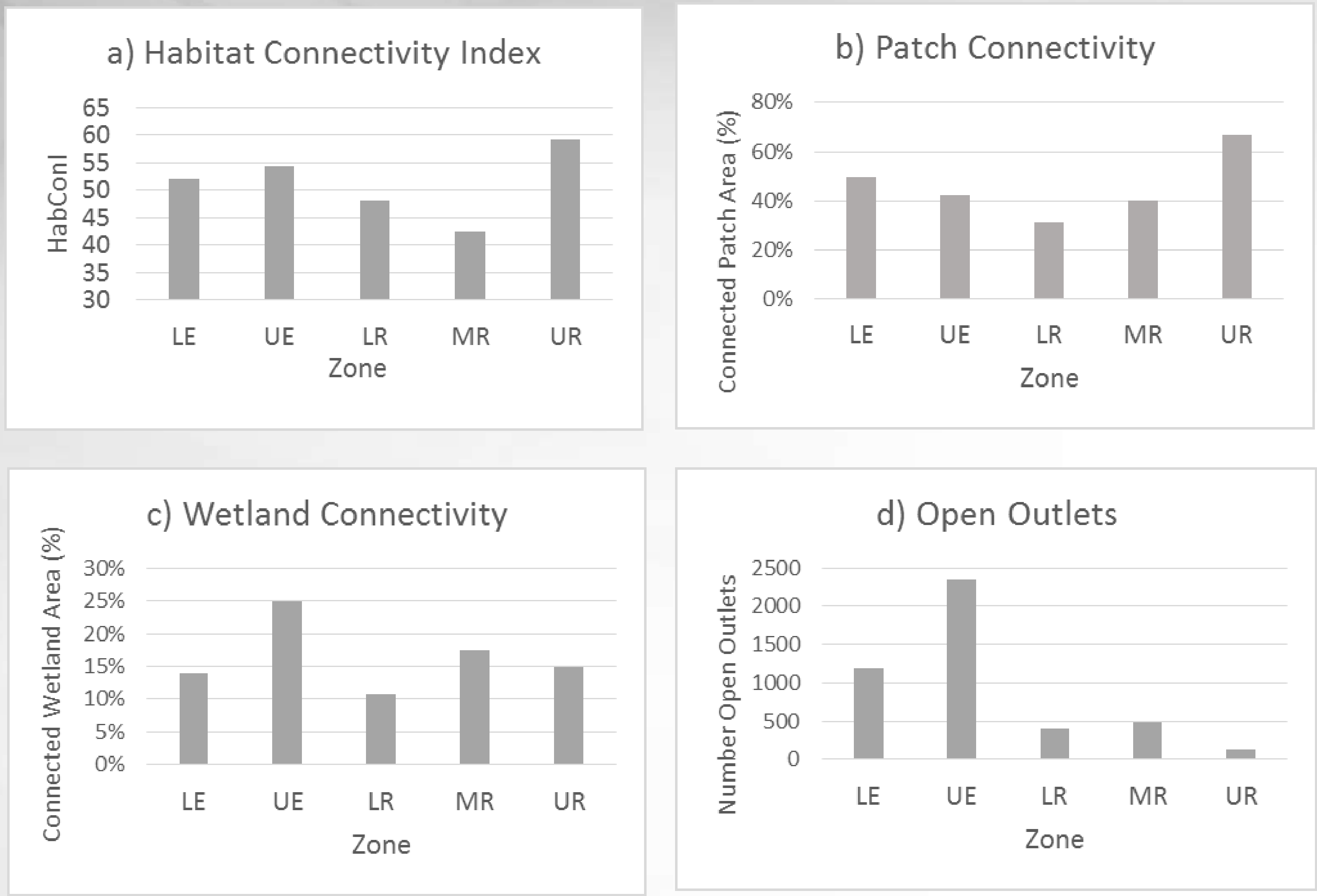

Summary and Implications

- ~ 1/3 of the *potential* tidally connected wetland area is currently connected
- ~ 1000 ha of wetland habitat were restored as of 2016 as part of CEERP; an 11.4% increase
- ~ 2500 ha of habitat patches were reconnected
- ~ 2/3 – 3/4 of tidal channels are within patches
- A high proportion (~ 85%) of channel outlets were delineated as "open" however outlets of "closed" channels were not necessarily delineated similarly

- While much has been accomplished in the CEERP program, there is more to do
- This method is viable for quantifying habitat connectivity
- The framework is established so that updating the Index in future years will be straight-forward

Future Actions

Results are presented in CEERP 2018 Synthesis Memo

Comments welcome

Update every 5 years

Columbia Estuary Ecosystem Restoration Program

2018 SYNTHESIS MEMORANDUM

90% DRAFT

Edited by:
Gary E. Johnson, Pacific Northwest National Laboratory
Kurt L. Fresh, National Marine Fisheries Service (retired)

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