Evaluating Cumulative Ecosystem Response of the Columbia River Estuary Ecosystem to Past and Current Restoration Efforts

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Cumulative Effects in Restoration

(modified from Leibowitz et al. 1992)

- *Cumulative restoration impacts* are the net sum of all changes in selected habitat metrics of all restoration projects occurring over time and space, including those in the foreseeable future.
- *Cumulative restoration effects* are the net change in ecosystem-wide metrics and ecosystem state resulting from cumulative restoration impacts.

Managers Want Answers to…

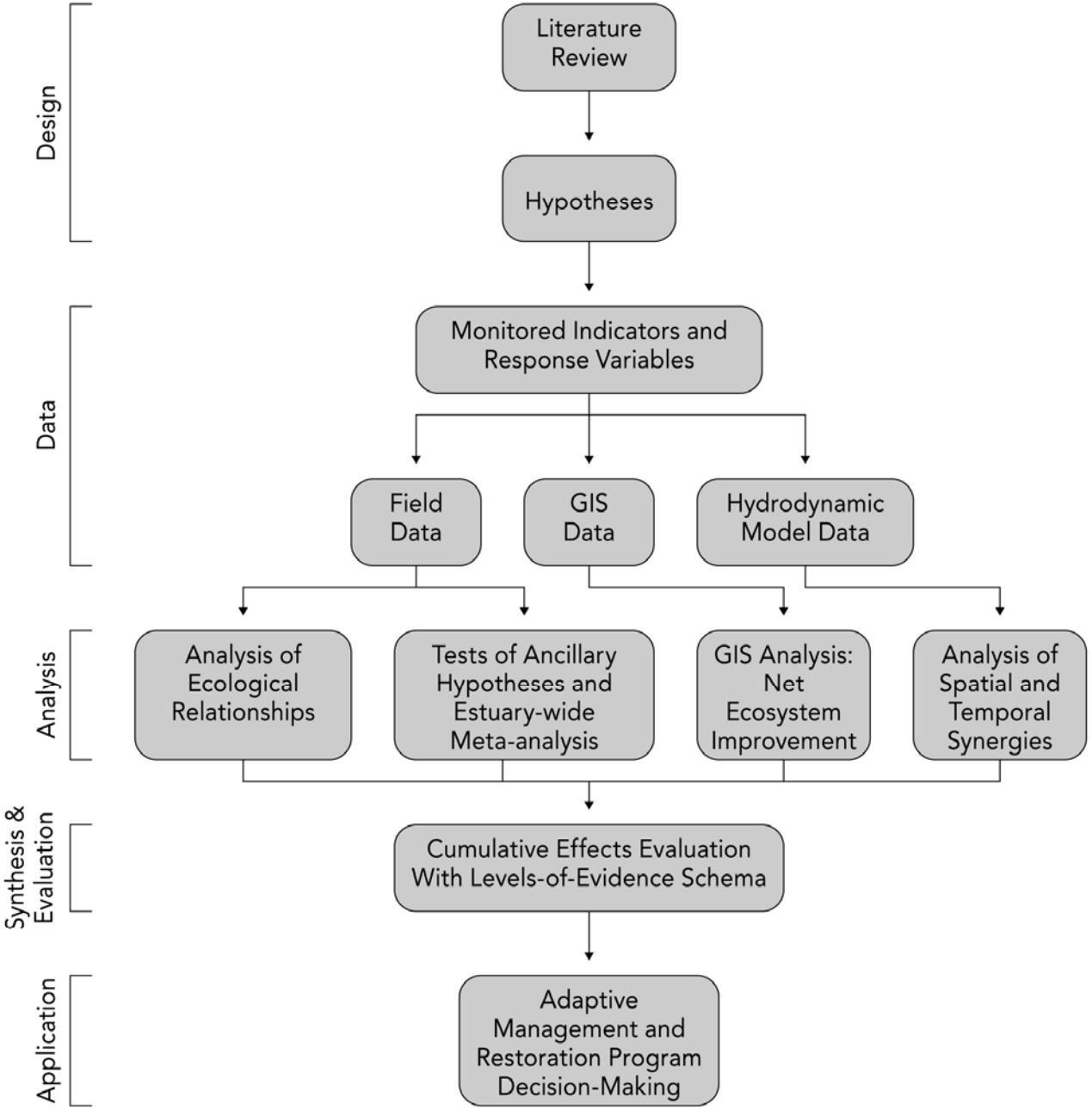
- Are protection and restoration resulting in continued loss, no net loss, or net ecosystem improvement in the context of continuing land conversion?
- What suite of projects results in an increase in habitat opportunity and capacity for juvenile salmon?
- What suite of projects produces increased habitat connectivity, maximum flood attenuation, sediment trapping, nutrient processing, return of marsh macrodetritis, and other ecosystem functions?
- What are the survival benefits to juvenile salmonids from CRE habitat restoration actions?

Topics

- Purpose
- Approach
- Metrics
  - Hydrology
  - Water quality
  - Topography
  - Vegetation
  - Fish
  - Habitat Size
  - Material Exchange
  - Fish usage
- Meta-analysis
- Modeling
- Summary and recommendations

There Are Four Overall Objectives of a Multi-Year (2004-2010) Study Funded by the Portland District and Implemented by a Collaboration of CREST, NMFS, PNNL, UW

- Develop standard effectiveness monitoring protocols.
- **Develop the empirical basis for a cumulative assessment methodology.**
- Design and implement field evaluations of the cumulative effects methodologies.
- Develop an adaptive management framework that coordinates and compares the diverse restoration efforts in the Columbia River estuary.



Gary Johnson, PNNL
Management

John Skalski, UW
Statistical Design

Curtis Roegner, NOAA
Mikah Russell, CREST
Fish Studies

Helda Diefenderfer, PNNL
Modeling

Ron Thom, PNNL
Scaling

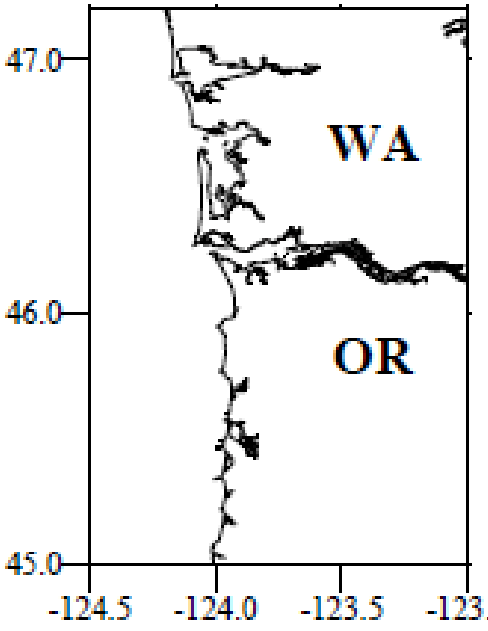
Catherine Corbett, LCREP
Meta Analysis

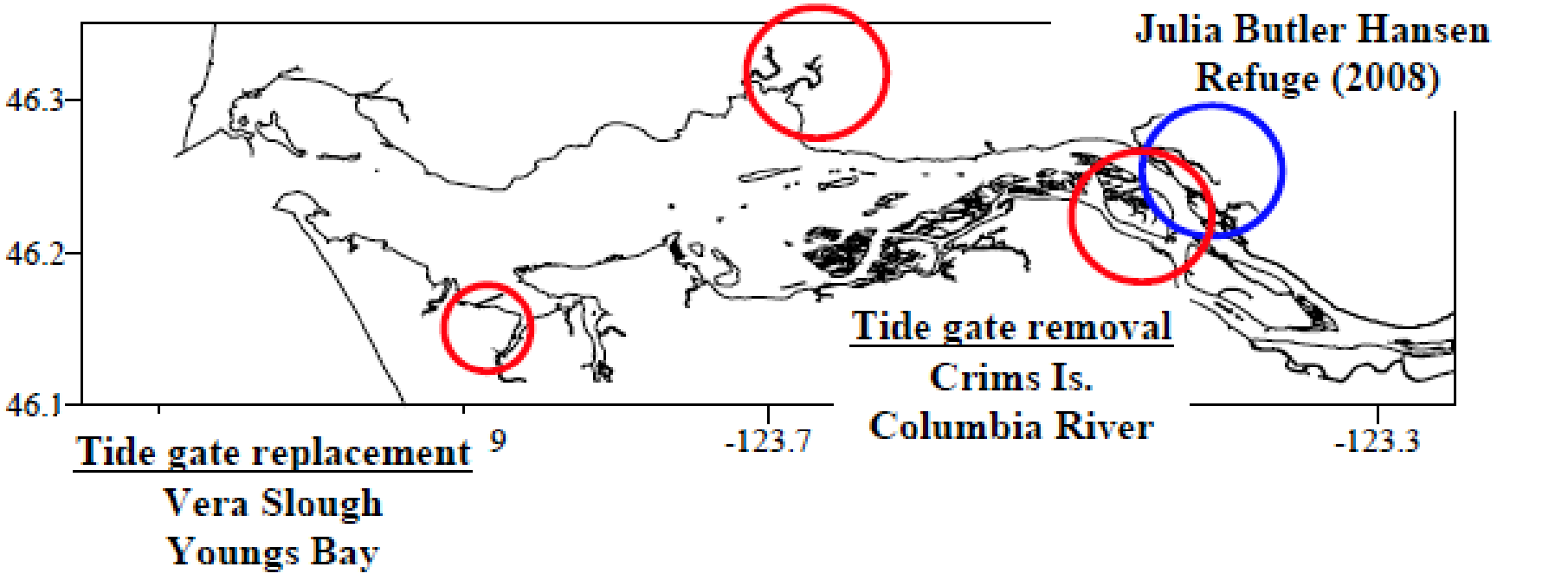
Blaine Ebberts, COE
Adaptive Management

Hypotheses

- **Working H_1** = Habitat restoration activities in the estuary will have a cumulative beneficial effect on salmon
- **Landscape-scale H_1** = …will produce an increasing number of hectares and connectivity of floodplain wetlands trending toward historical levels prior to land conversion…
- **Ancillary H_1** = Monitored indicators will trend toward reference conditions
  - Hydrology – area time inundation index
  - Water quality – temperature
  - Topography/bathymetry – land elevation, sedimentation rate
  - Vegetation – percent cover by species
  - Fish – presence, abundance, res. time, diet, growth rate, fitness
  - Exchange – plant biomass, TOC, nutrients, chlorophyll, macro-invertebrates

Field Sites for CE Study





Basic Model


Impact
Controlling Factors
Habitat Structure
Habitat Processes
Ecological Functions

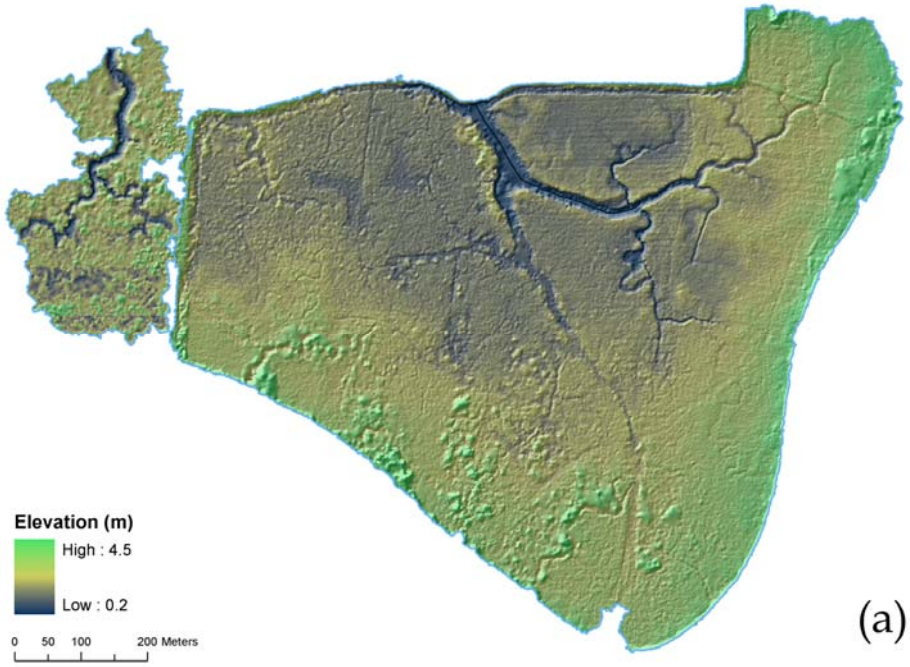
Indicators of Effectiveness

Category	Indicator
Core Indicators – Ecosystem Controlling Factors and Structures	
Hydrology	Water surface elevation, catchment area, tidal exchange volume, wetland delineation
Water quality	Temperature, salinity, dissolved oxygen
Topography/ bathymetry	Elevation, sediment accretion rate, channel cross-sectional area
Landscape	Photo points, aerial photos
Vegetation	Percent cover by species, plant community composition
Fish	Presence, abundance, species composition, size structure
Higher Order Indicators – Ecosystem Processes and Realized Functions	
Habitat Size	Area-time inundation, wetted-channel edge length, floodplain wetted area
Material Flux	Flux rates for nutrients, chlorophyll, dissolved organic matter, plant biomass, total organic carbon, macro-invertebrates
Fish Usage	Residence time, diet, growth rate, fitness, prey availability, stock


Grays River
Deep River
Rosburg
Image © 2009 DigitalGlobe
© 2009 Tele Atlas
©2009 Google
Imagery Date: Jul 21, 2004
46°18'55.67" N 123°39'28.23" W elev 12 m
Eye alt 9.80 km

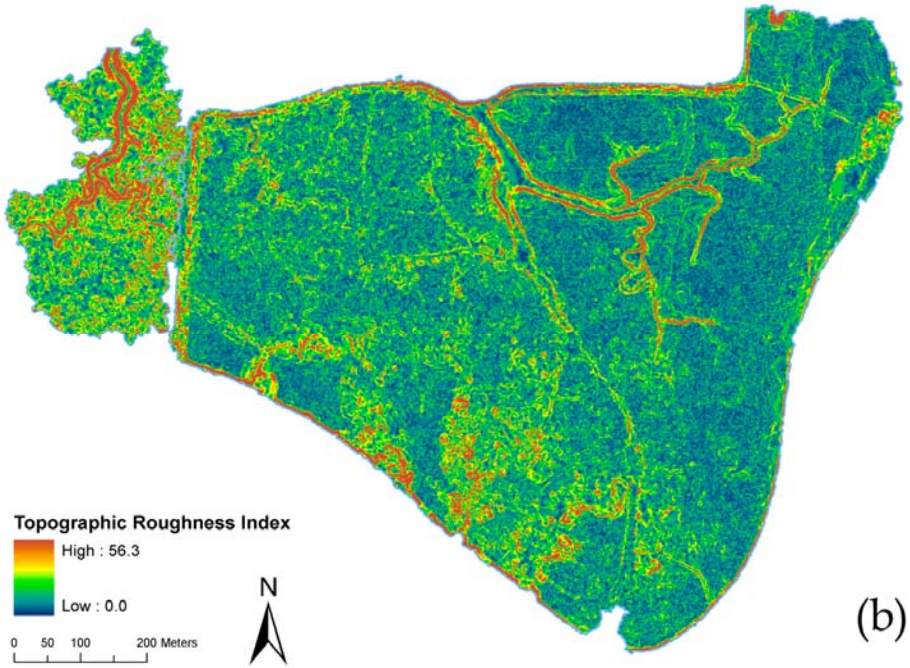

Image State of Oregon
© 2009 Tele Atlas
Image © 2009 DigitalGlobe
©2009 Google
Imagery Dates: Jul 21, 2004 - Jun 29, 2005
46°19'33.51" N 123°39'39.06" W elev 5 m
Eye alt 2.17 km


HITACHI



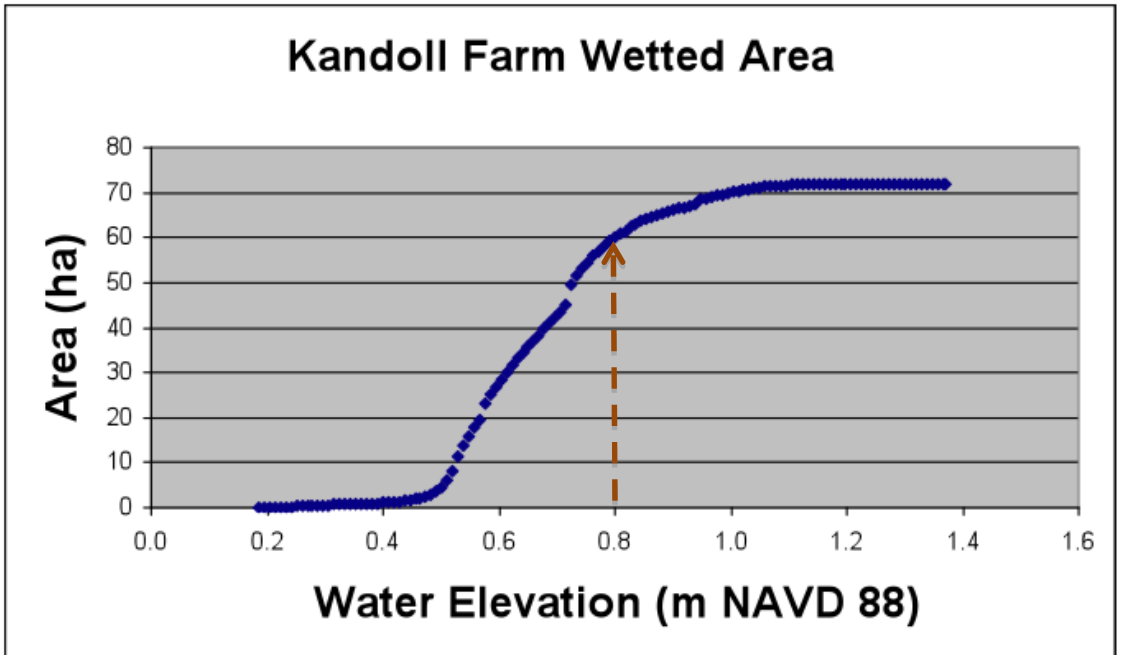
(a)

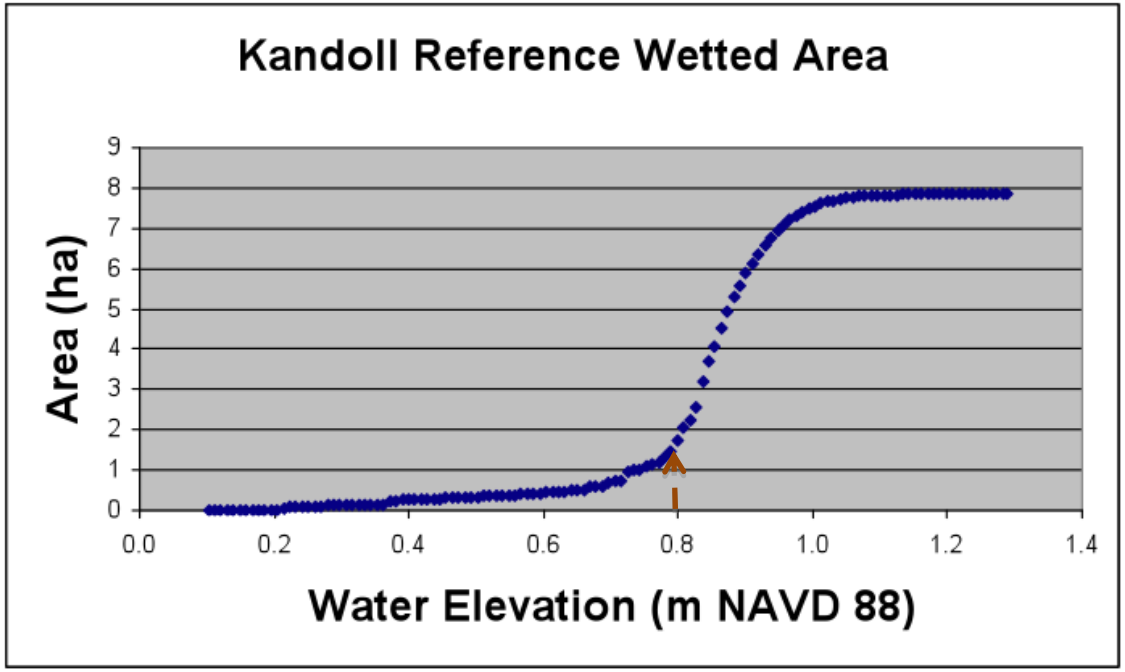
Wetted Area at Kandoll Farm



(b)

Roughness Index

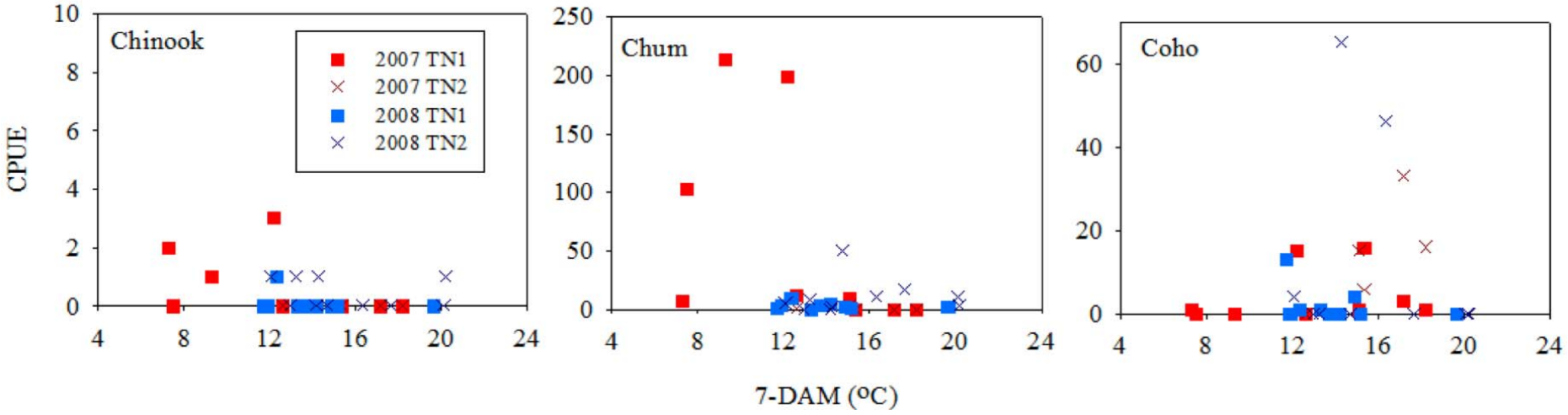

Kandoll Farm Wetted Area
Area (ha)
0
10
20
30
40
50
60
70
80
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Water Elevation (m NAVD 88)


Kandoll Reference Wetted Area
Area (ha)
0
1
2
3
4
5
6
7
8
9
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Water Elevation (m NAVD 88)

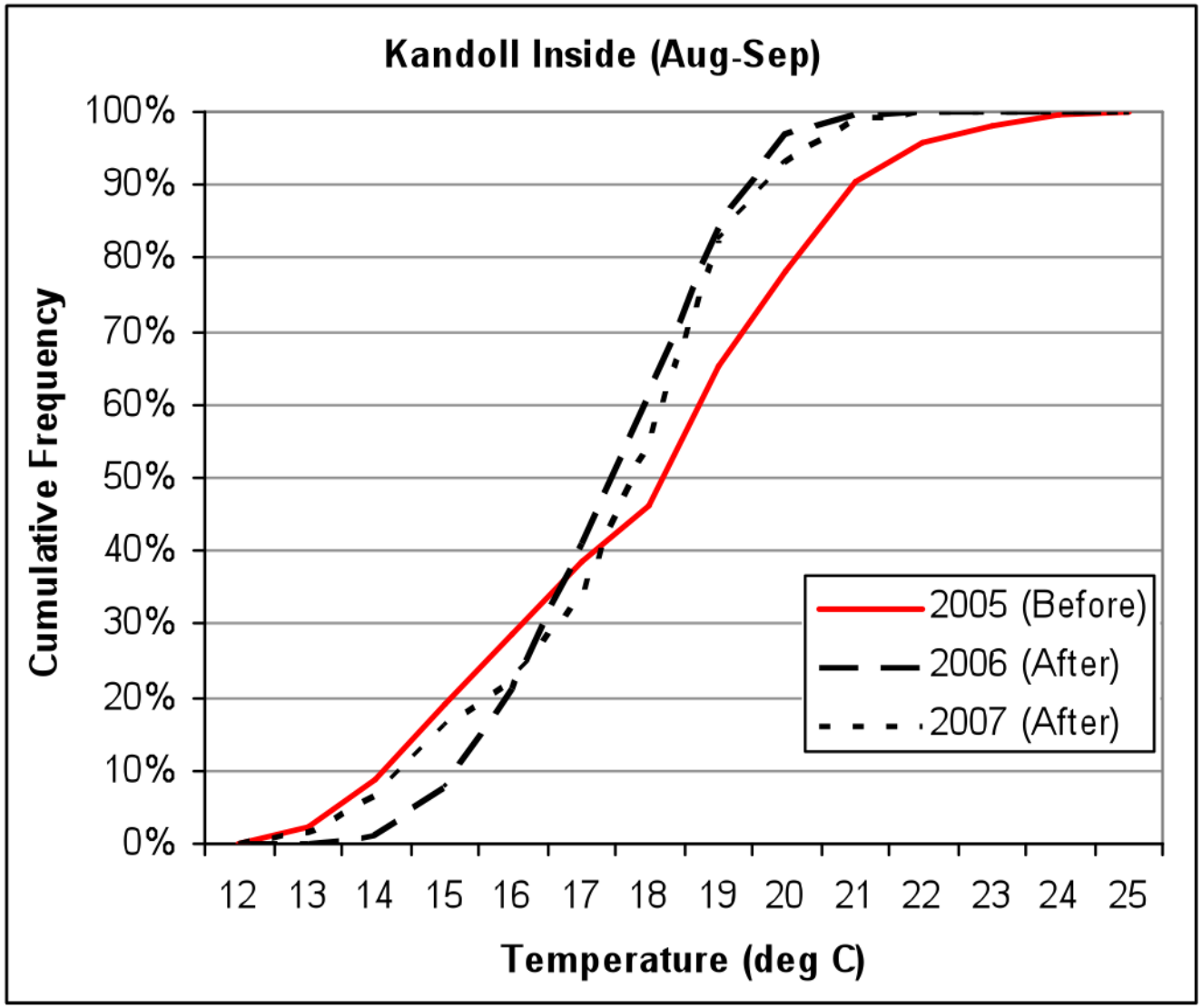
Diefenderfer and Montgomery (2008)

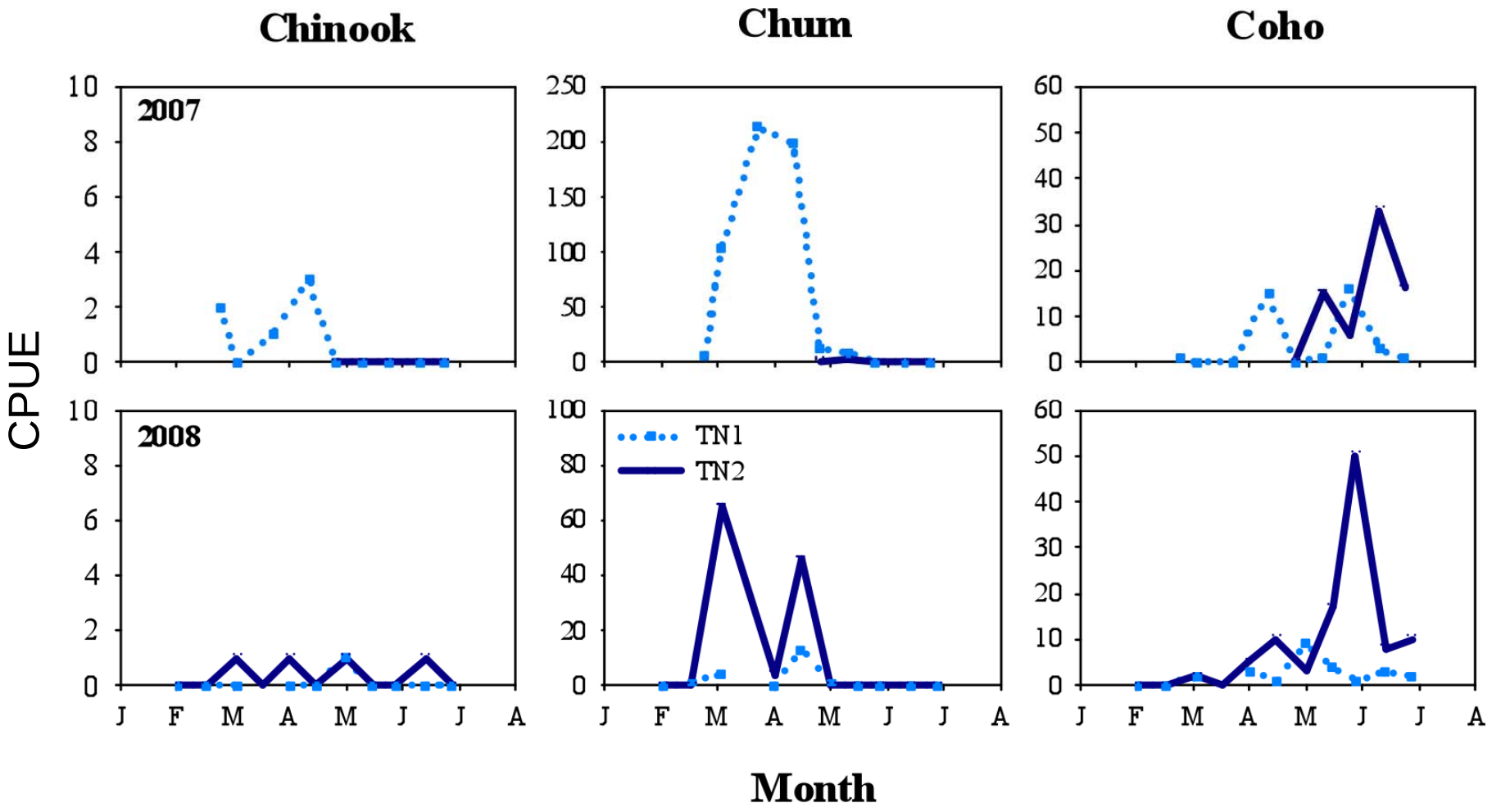

Accretion Rate ~2-3 cm y-1

Juvenile Salmon Catch vs Temperature at Kandoll Restoration Site



Pre and Post-Restoration Water Temperatures at Kandoll Farm




Chinook
Chum
Coho
2007
2008
CPUE
TN1
TN2
J F M A M J J A
Month


MANUFACTURING

Marsh Macro-detritus Organic Matter Export

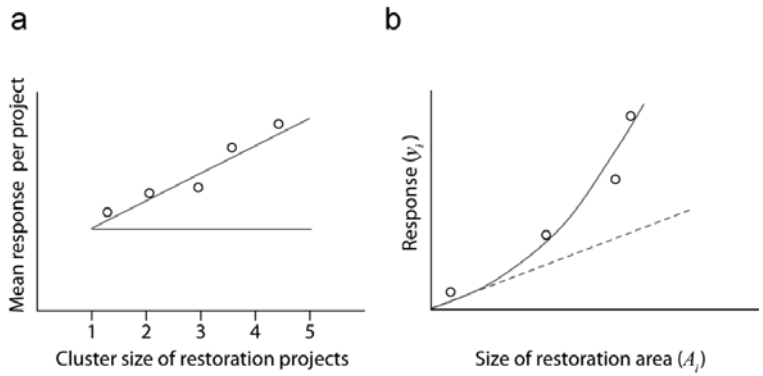
- Loss of marsh macrodetritus could have dampened the life history diversity in the CRE (Bottom et al. 2005)
- Vascular plant detritus and hatchery food are the dominant sources of OM to subyearling Chinook (Maier and Simenstad 2009)
- CE Findings –
  - 96 ha (237 acres) of restoring sites in Grays River could be exporting 391 metric tons (dry wt) (~431 tons) of marsh macro-detritus each year
  - The macro-detritus drift contains insects
  - Inference is that the restored wetland in contributing OM and salmon prey
  - Will model particle pathway this fall

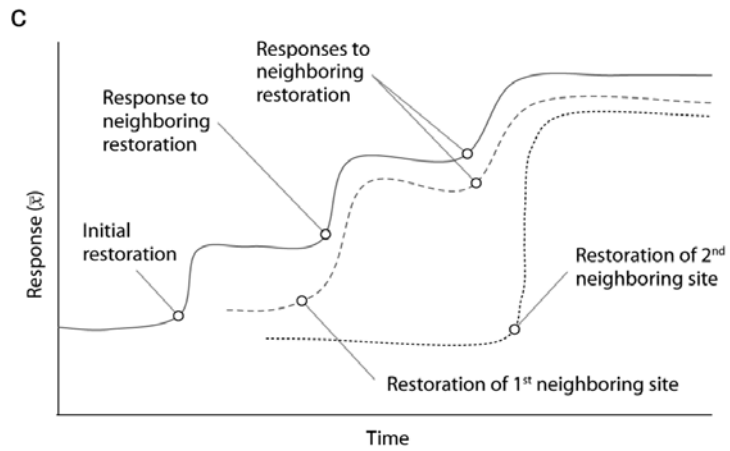
Summary Meta-Analysis Table

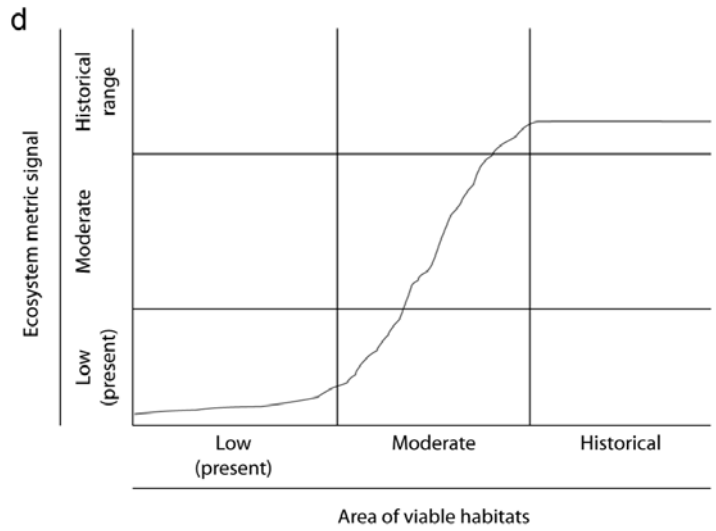
Is the response variable trending in the desired direction?

	Photo Point	Water Temperature	Sediment Accretion Rate	Juvenile Salmon Presence
Crims Is.	Yes	--	Yes	Yes
Ft. Clatsop	--	Cooler in Summer	--	Yes
Johnson Property	Yes	--	--	Yes
Kandoll Farm	Yes	Cooler in Summer	Yes	Yes
Vera Slough	Yes	--	--	No

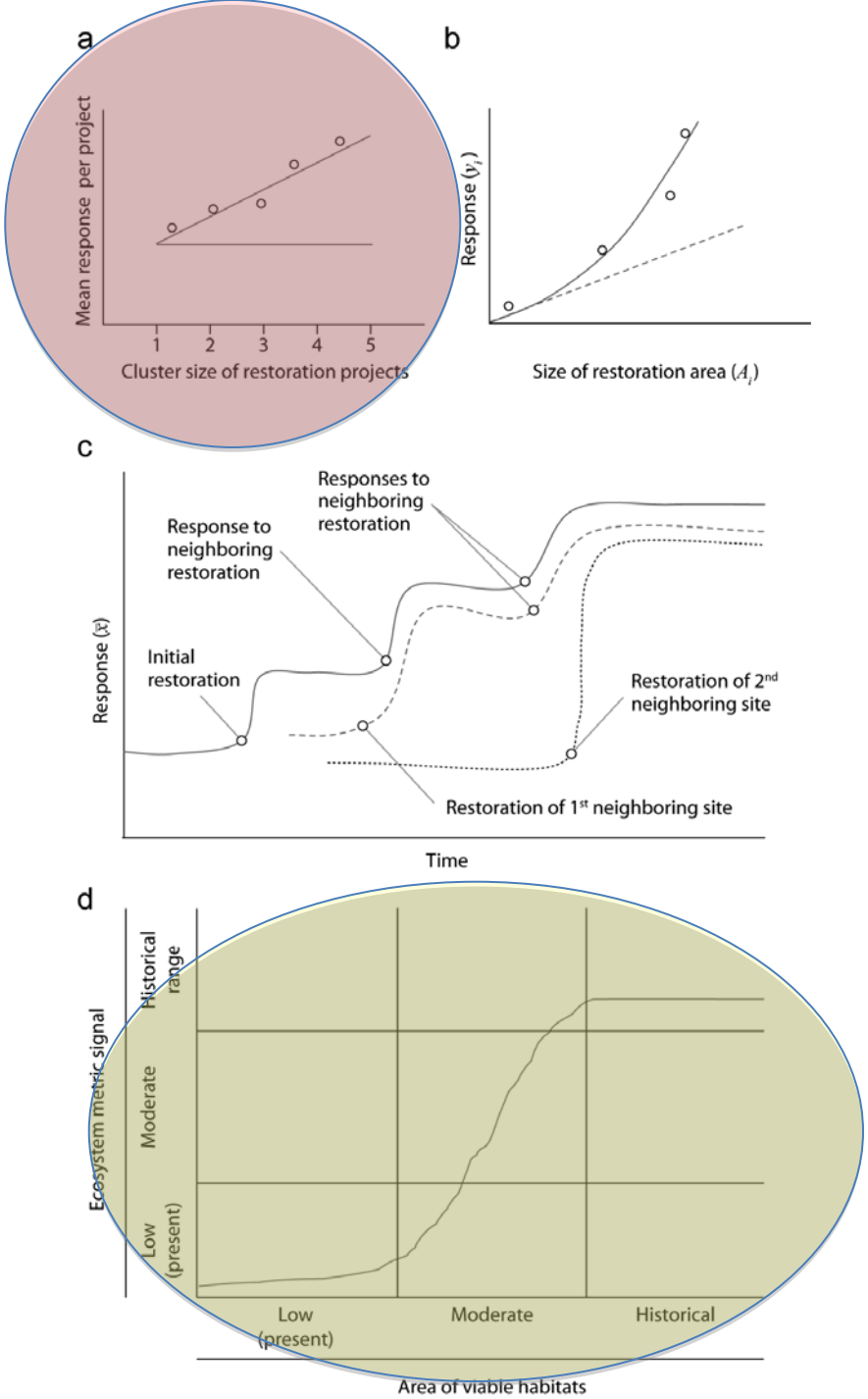
Cumulative Effects Theory







Cumulative Effects Theory



Scaling Ecological Influence

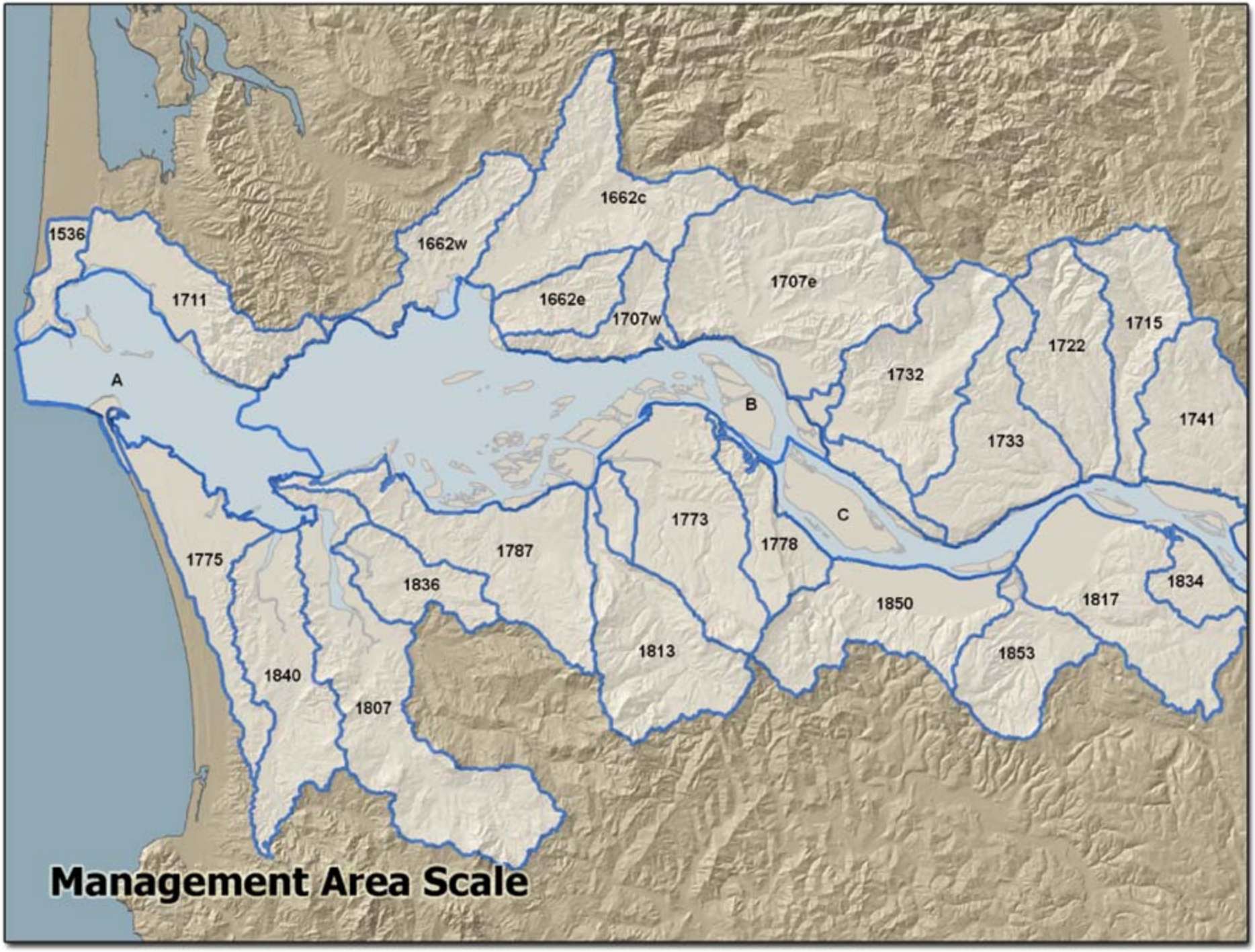
- Empirical data – Exchange studies
- Linear model – NEI and CNEI calculation at various scales in GIS
- Wetted area hydrodynamic model
- Predictions based on empirical data using linear model and hydrodynamic model

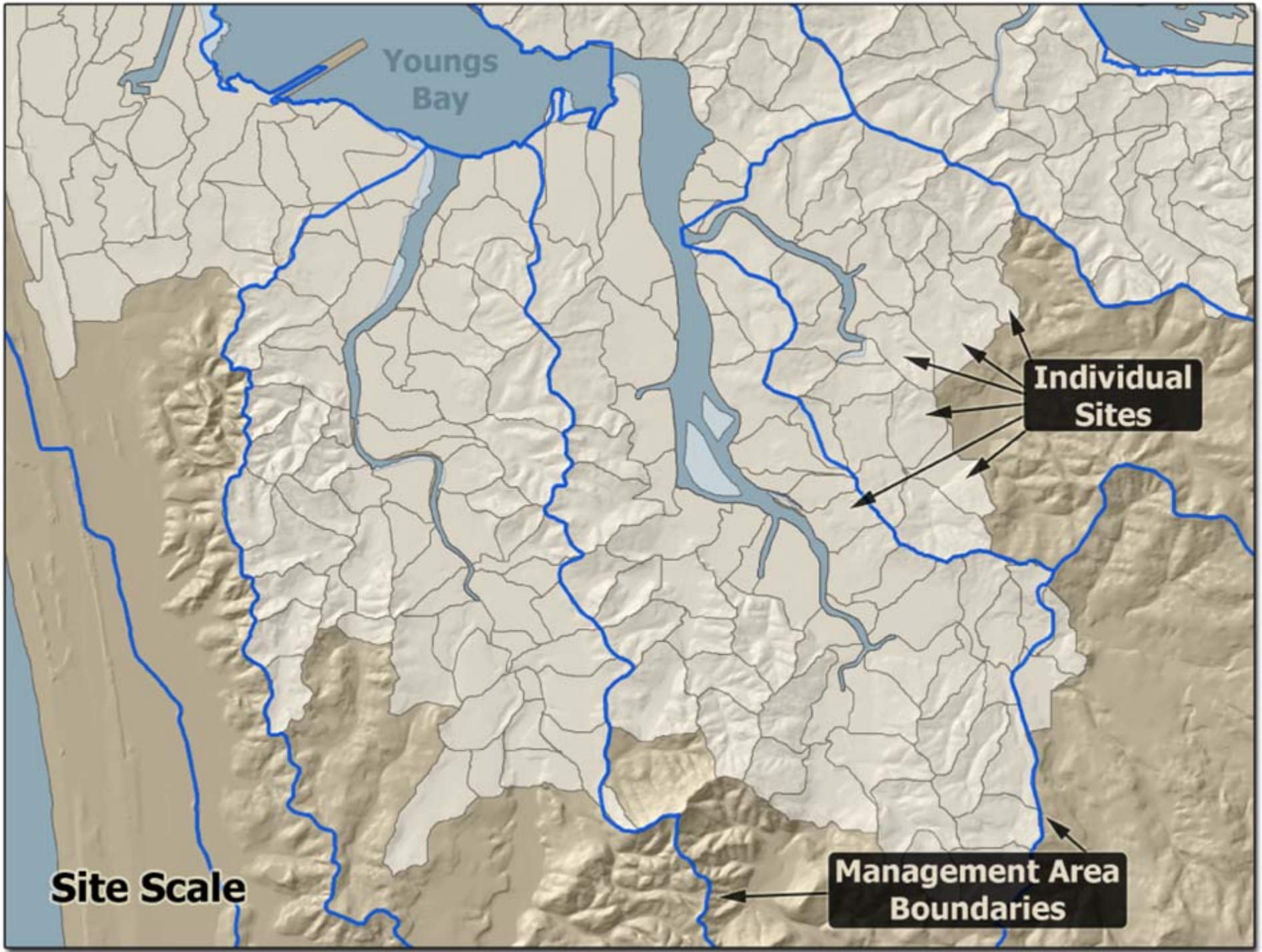
Organizing Model
Ecosystem Kaizen

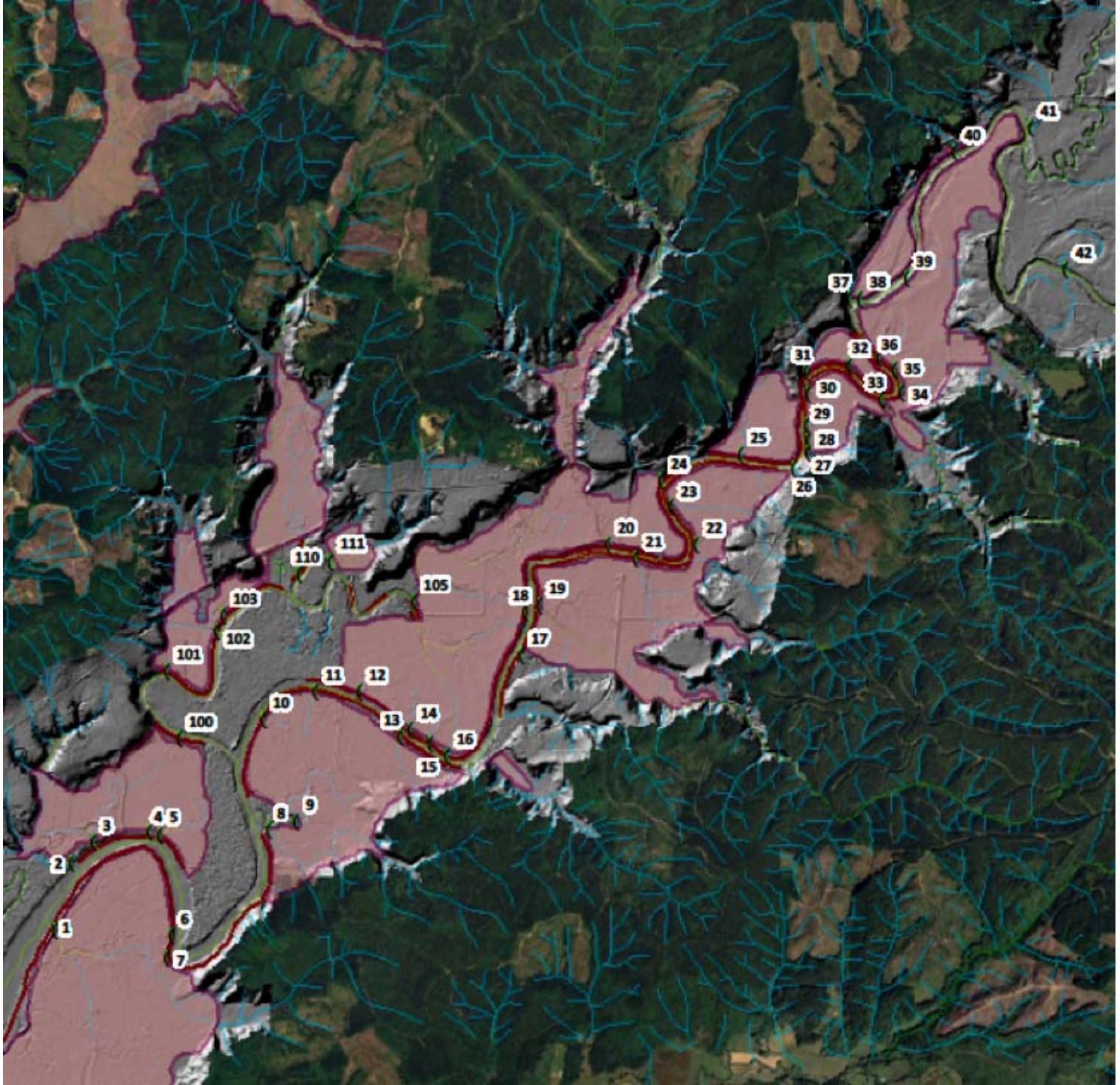
Net Ecosystem Improvement (NEI) *"…following development, there is an increase in the size and natural functions of an ecosystem or natural components of the ecosystem."* (Thom et al. 2005)

$$NEI = f(\Delta function, \Delta size, probability)$$

$$CNEI = \Sigma\ NEI \text{ across sites}$$


1536
1711
1662w
1662c
1662e
1707w
1707e
1715
1722
1732
1741
1733
A
B
C
1773
1778
1775
1787
1836
1850
1834
1817
1813
1853
1840
1807
Management Area Scale


Youngs Bay
Individual Sites
Site Scale
Management Area Boundaries


41
40
42
39
37
38
31
32
36
35
30
33
34
29
25
28
24
27
23
26
20
21
22
111
110
105
18
19
103
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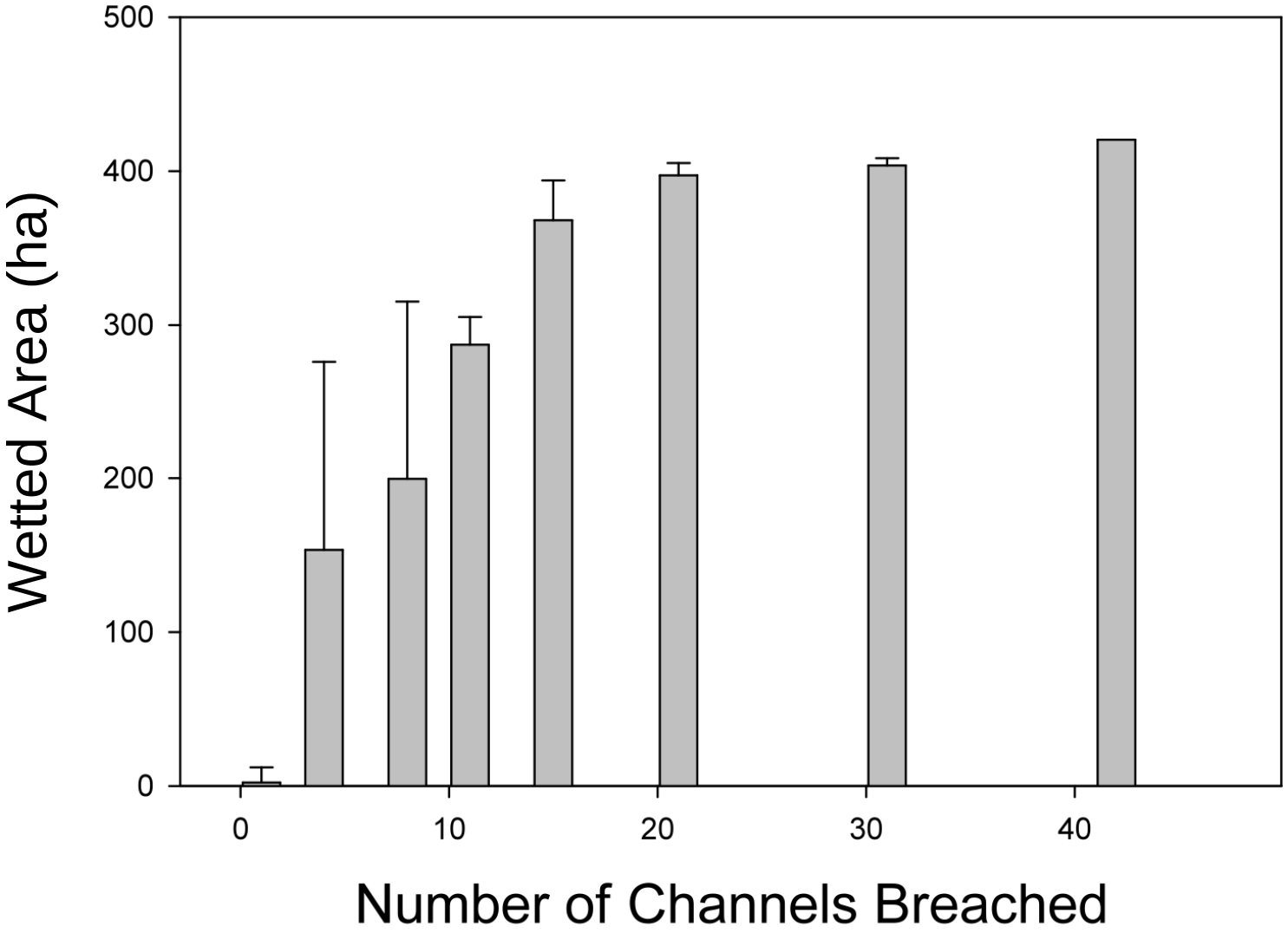
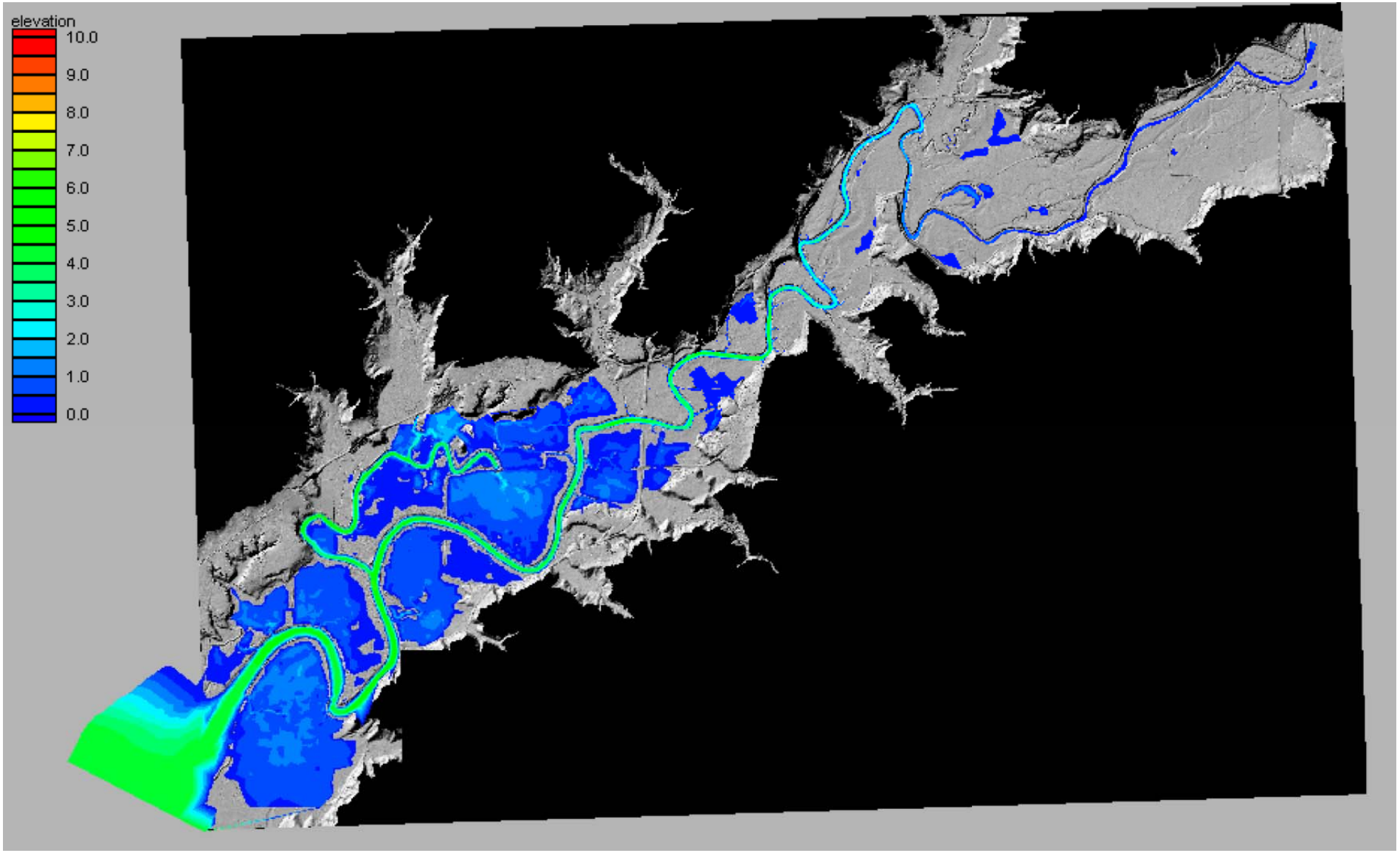
15
9
8
3
4
5
2
1
6
7


Wetted Area (ha)
500
400
300
200
100
0
0
10
20
30
40
Number of Channels Breached


elevation
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

Some Empirical Studies Linking Estuarine Habitat to Juvenile Salmon Survival Benefits

- Shreffler et al. (residence and growth in Gog-le-hi-te)
- Miller (residence and growth in Chehalis River)
- Levings and others (experimental releases and returns in Campbell River; diet and behavior in Fraser R.)
- Beamer et al. (Skagit River delta use)
- Bottom et al. (Salmon river estuary use and returns)
- Bottom et al. (Salmon at Rivers' End)
- Maier and Simenstad (diet sources in LCRE)
- Shreffler et al. (returns in Jimmy-Come-Lately Creek)
- Roegner et al. (opportunity and diet in restored LCRE sites)
- Fresh and many others (genetics research on origins and estuarine use)
- Simenstad and Cordell (opportunity + capacity = realized function)

Findings and Products from the CE Research

- Estuary-wide habitat monitoring protocol and report card
- Proof of frequent and prolonged salmon use of restored sites
- Proof of prey production and use in restored systems
- Evidence of improved WQ conditions for salmon
- Initial quantification of export of macro-detritus to ecosystem
- Evidence of initiation of sediment accretion, channel formation, nutrient processing and OM export
- Evidence of initial rate of recovery
- Evidence that the greater the tidal reconnection the faster the recovery
- Development of a method to accumulate effects on ecological processes supporting salmon and predict cumulative effects
- Evidence of potential synergism and optimization of projects
- Development of an AM plan to accumulate learning and improve results

Recommendations

- H_0: Restoring historical, and conserving existing, shallow water habitat and landscapes will result in the increased fitness and survival of young salmon and thus increase salmon populations
- Needs-
  - More concentrated and coordinated effectiveness monitoring of restored sites
  - Quantification of the 'realized function' of these sites to young salmon
  - Monitoring of adult returns in a strategic manner to link actions to the goal
  - Ecosystem Restoration Plan – comprehensive and system wide
  - …that includes a focused, feasible AM to validate and improve predictive models and thus maximize the effectiveness of future efforts

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Dana Woodruff (PNNL)

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