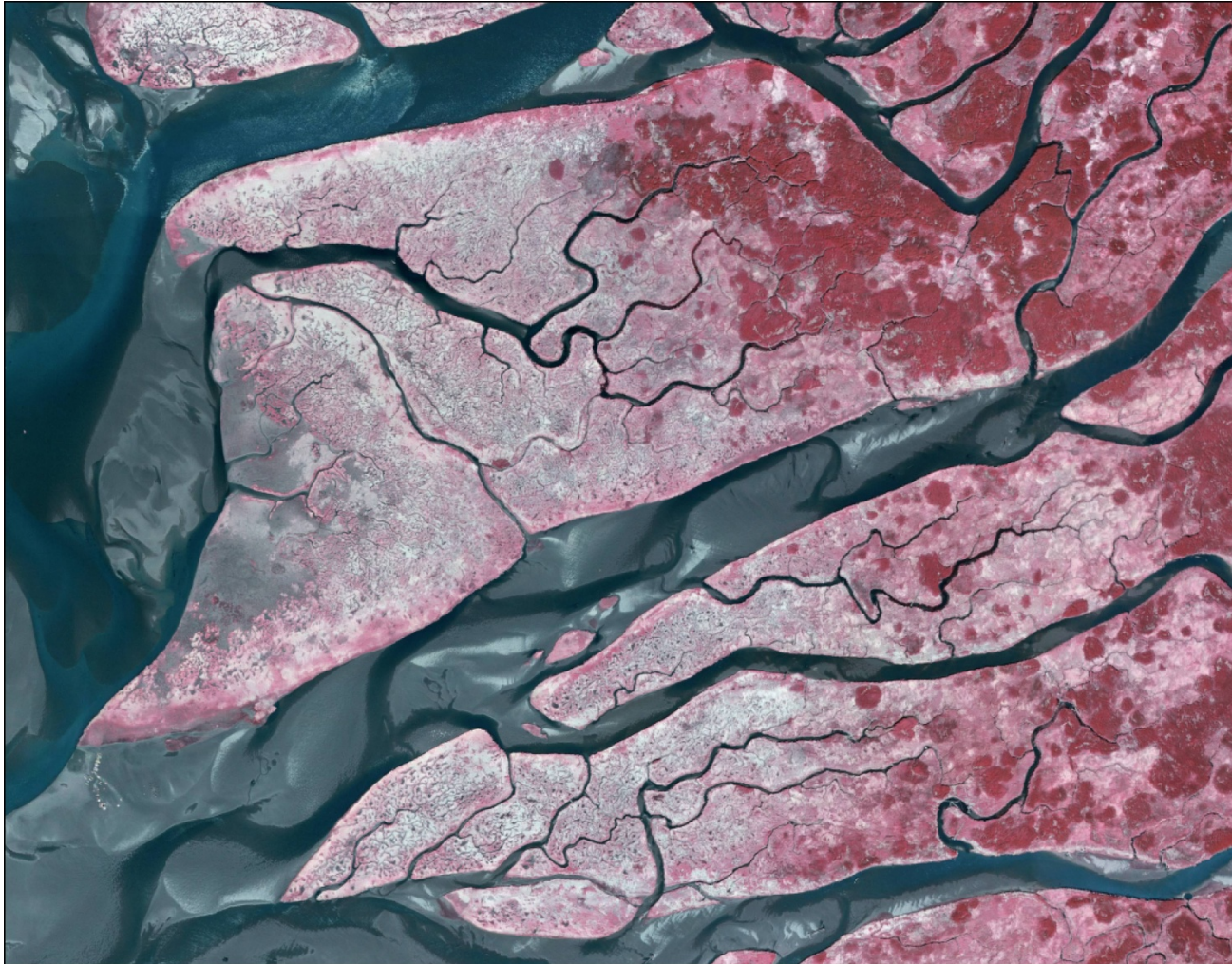


Geographic Variation in Puget Sound Tidal Channel Geometry

Developing a Tool for Restoration Planning, Design, and Monitoring



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Skagit River System Cooperative

1. Methods and Theoretical Background

Channel Hydraulic Geometry

$$Q = aP^b$$

Q = tidal prism

P = channel depth, width or
cross-sectional area

Problems with traditional approach

- Drainage basins may be poorly defined
- Tidal prism often difficult to define—sheet flow vs. channel flow
- Vegetation type may affect flow velocity and direction, thus basin size



Solution: Finesse the problem

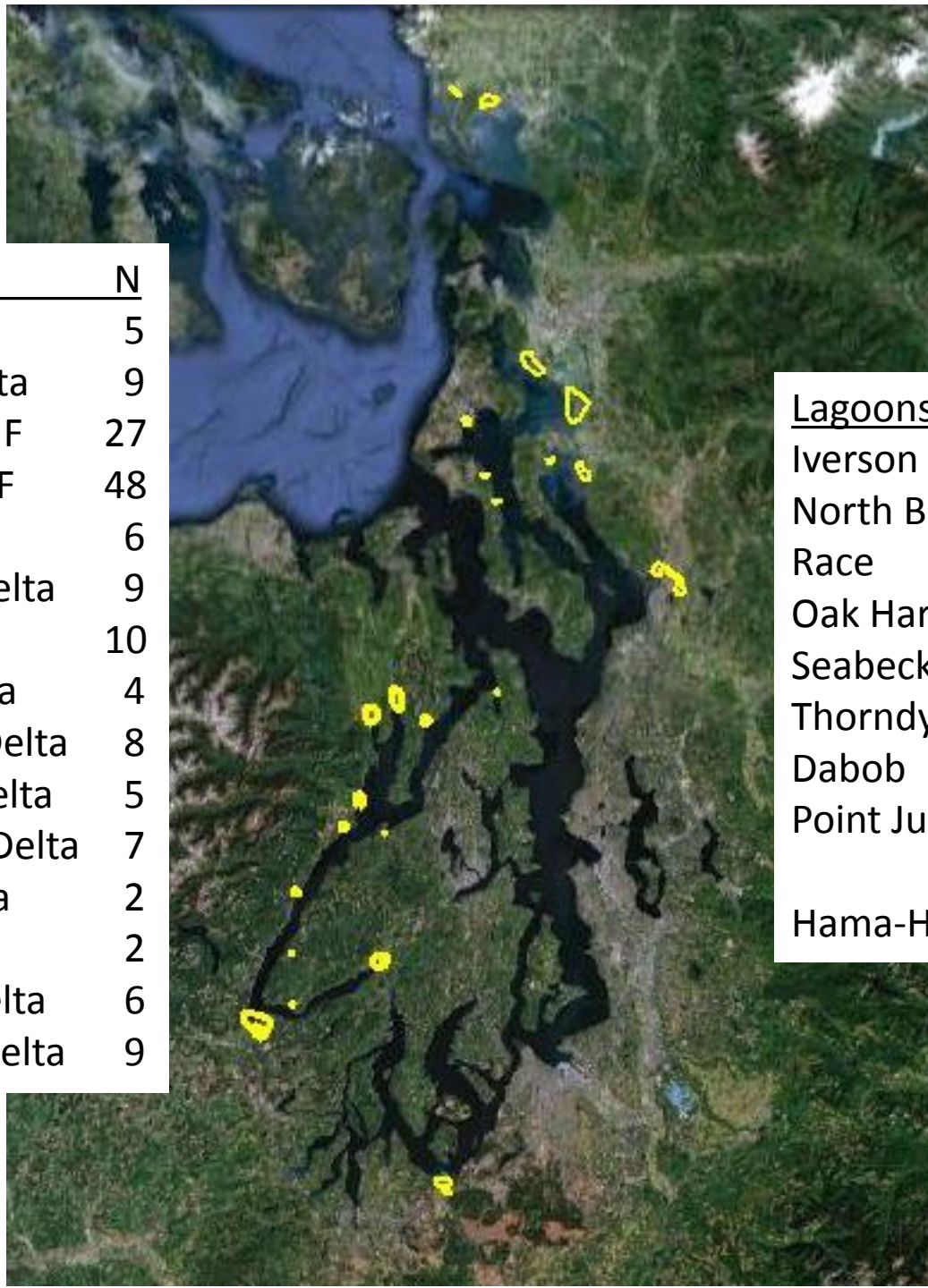
Allometry of marsh islands and channel geometry

Landscapes are fractal, i.e., scaling relationships exist between different landscape elements, e.g., marsh islands and tidal channels.

Note: scaling relationships are power functions that can be linearized by log transformation,

$$Q = aP^b \rightarrow \log(Q) = \log(a) + b \log(P)$$

Benefit: Prediction of a suite of useful channel geometries not typical of hydraulic geometry.

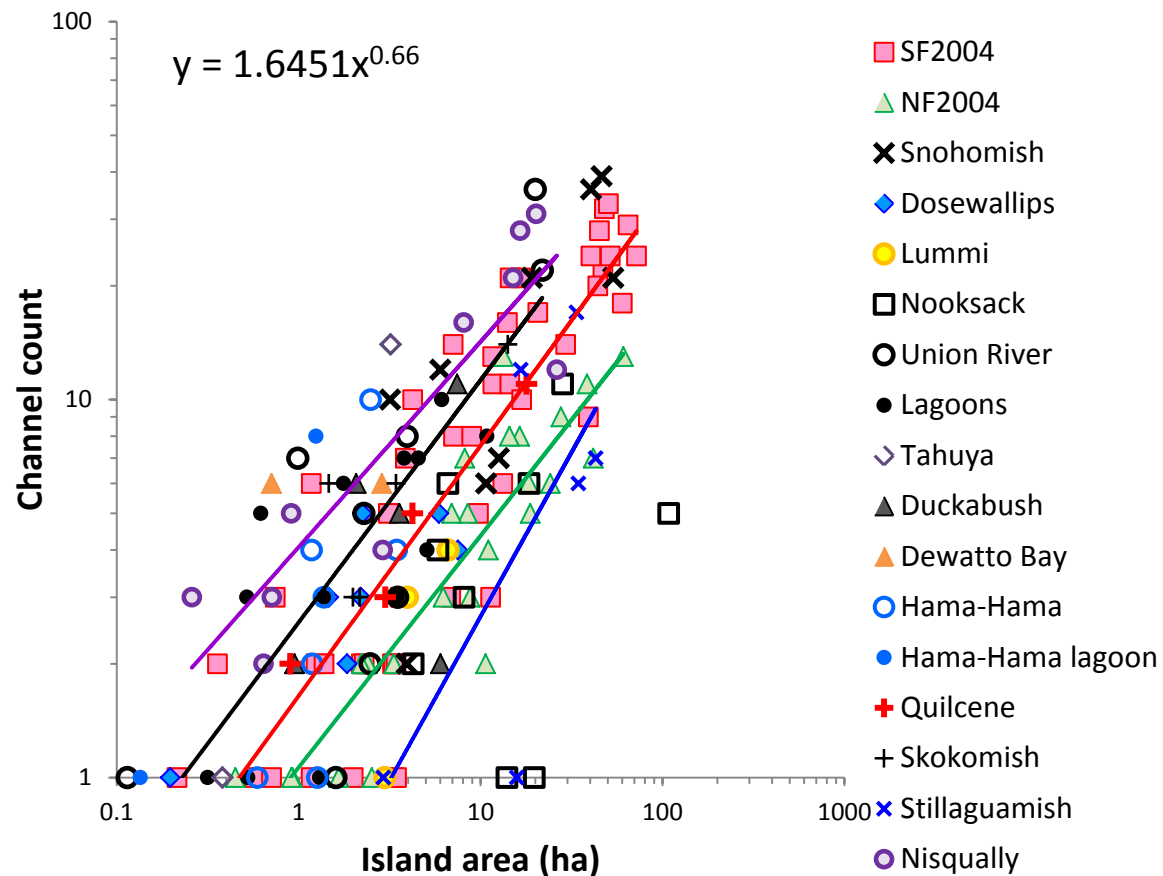


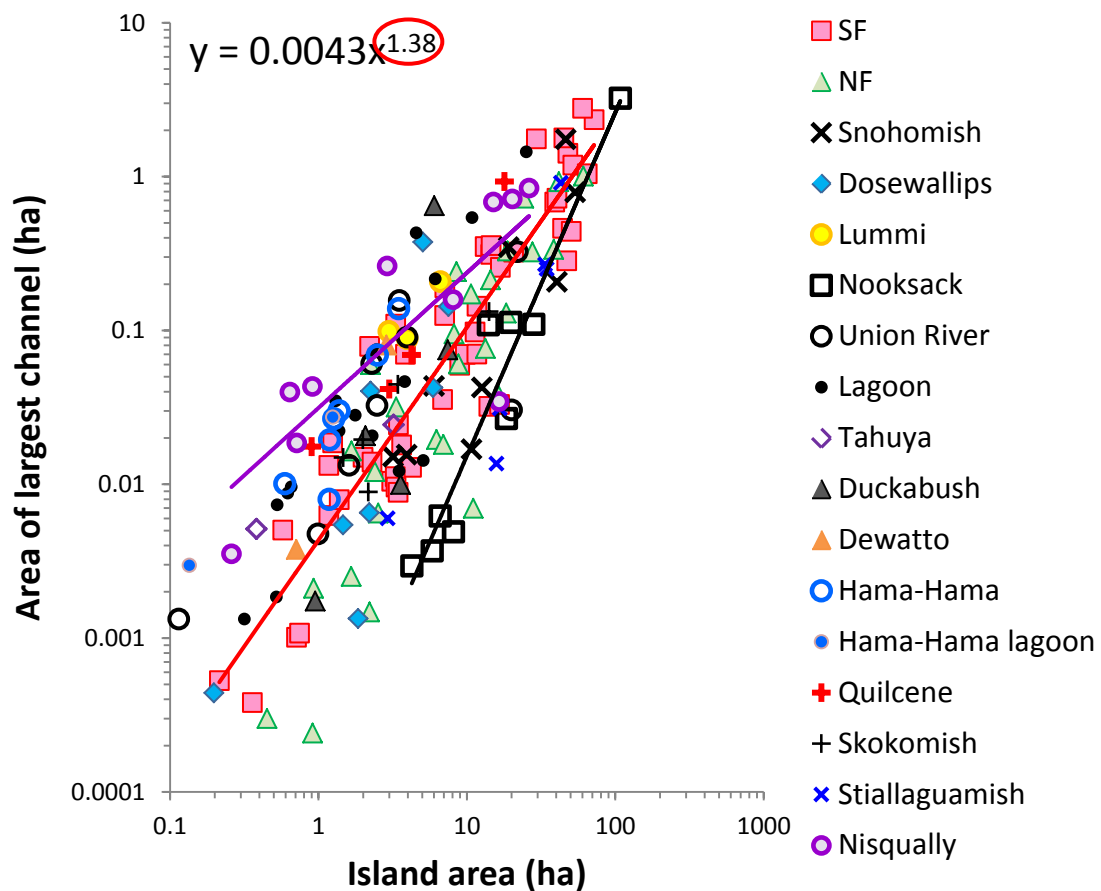
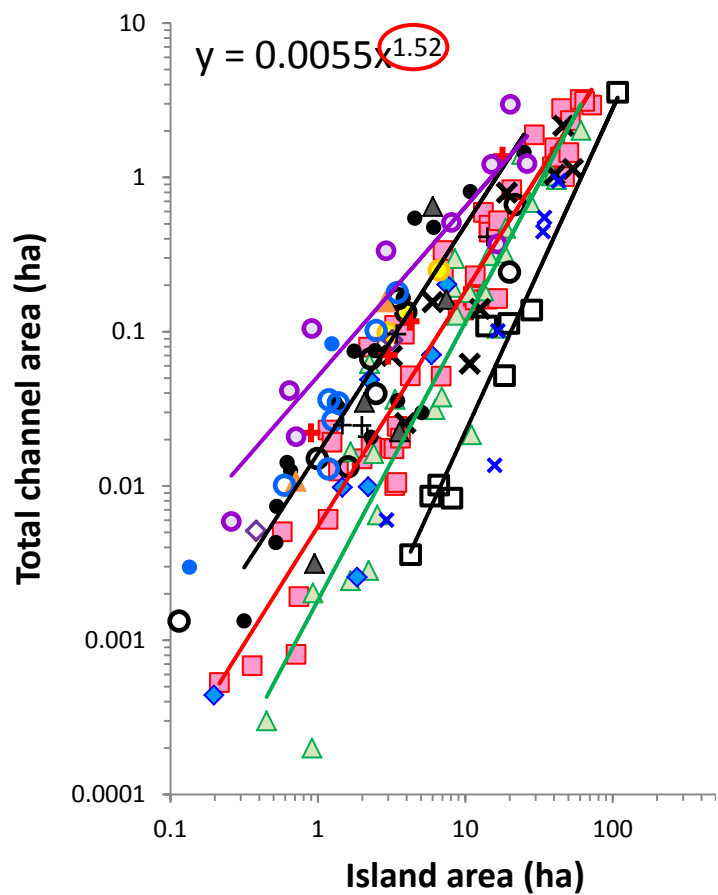
<u>Deltas</u>	<u>N</u>
Lummi	5
Nooksack Delta	9
Skagit Delta NF	27
Skagit Delta SF	48
Stillaguamish	6
Snohomish Delta	9
Nisqually	10
Quilcene Delta	4
Dosewallips Delta	8
Duckabush Delta	5
Hama-Hama Delta	7
Dewatto Delta	2
Tahuya Delta	2
Skokomish Delta	6
Union River Delta	9

<u>Lagoons</u>	<u>N</u>
Iverson	1
North Bluff	1
Race	1
Oak Harbor	2
Seabeck	2
Thorndyke	3
Dabob	6
Point Julia	1
Hama-Hama	2

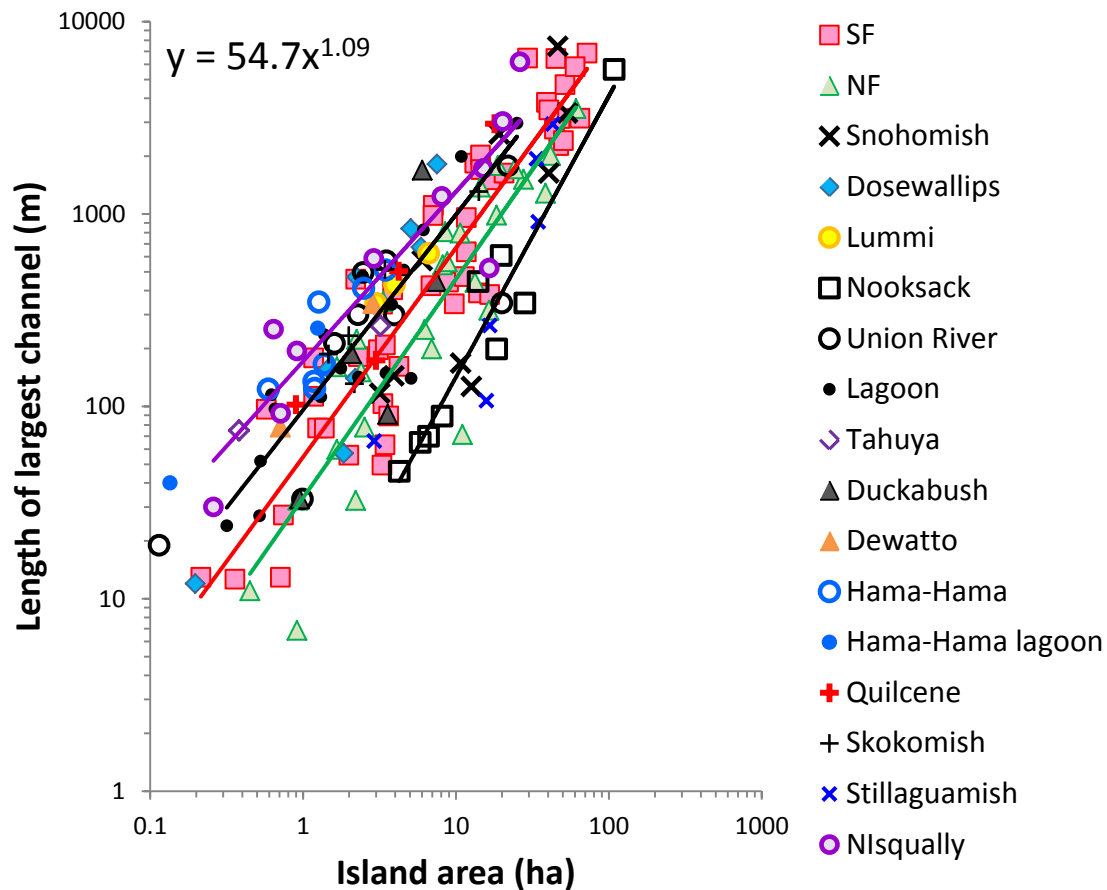
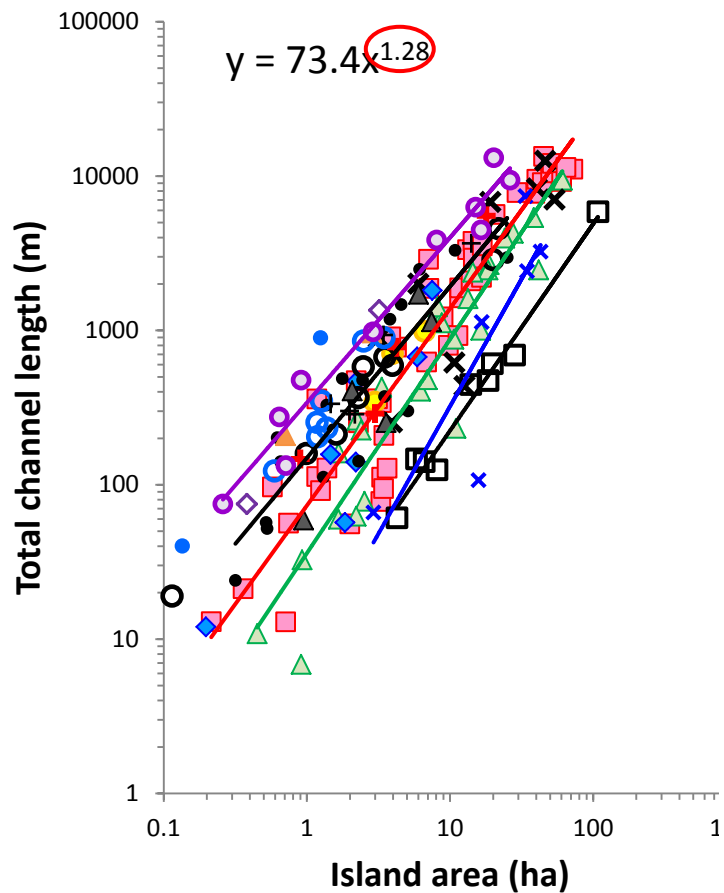
2. Results

- Similar scaling functions between marsh island area and a suite of channel planform metric for tidal marshes throughout Puget Sound
- Non-linear cumulative effects are evident for total channel length, total channel surface area, and the surface area of the largest channel draining a marsh island (i.e., allometric exponents > 1.0)
- Regression elevations (y-intercepts) are related to tidal range and wave energy: TIDE +, WAVE -

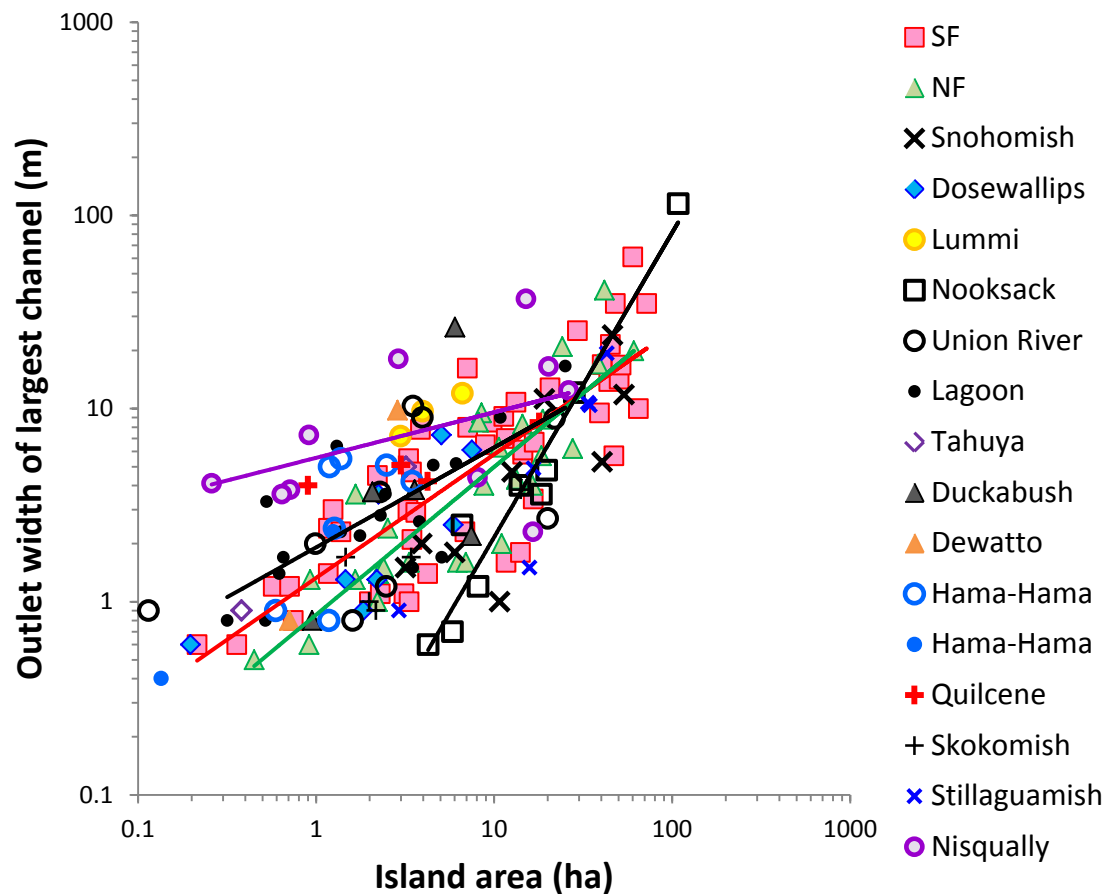
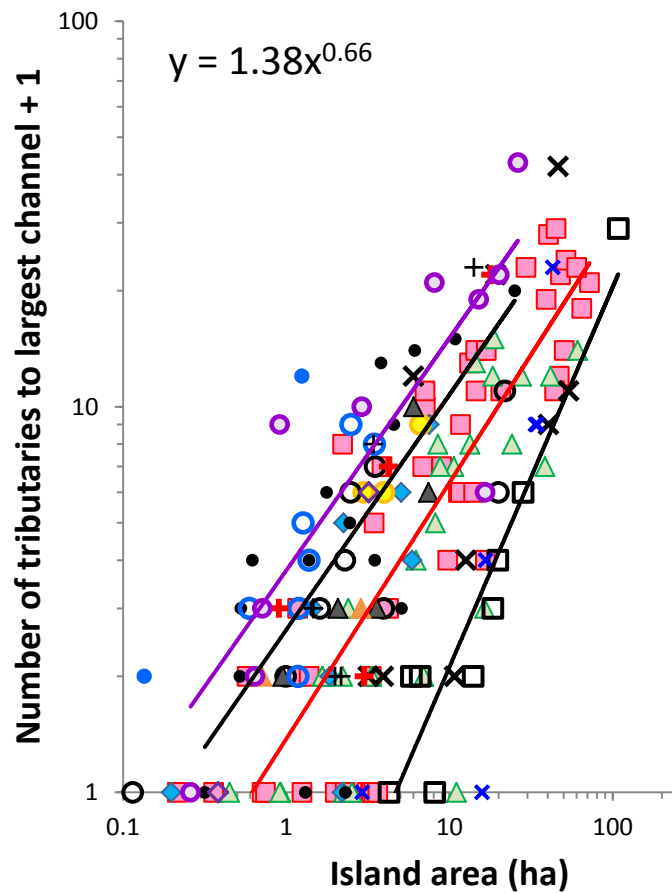




- SF
- NF
- Snohomish
- Dosewallips
- Lummi
- Nooksack
- Union River
- Lagoon
- Tahuya
- Duckabush
- Dewatto
- Hama-Hama
- Hama-Hama lagoon
- Quilcene
- Skokomish
- Stiallaguamish
- Nisqually



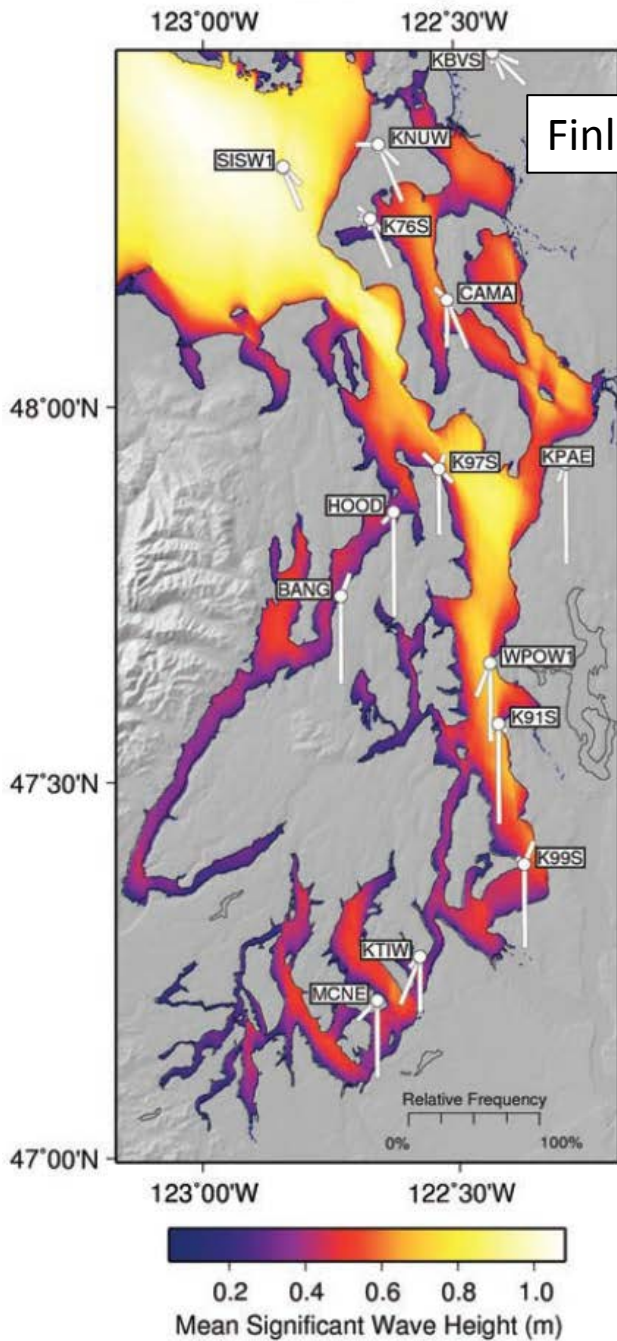
- SF
- △ NF
- × Snohomish
- ◆ Dosewallips
- Lummi
- Nooksack
- Union River
- Lagoon
- ◇ Tahuya
- ▲ Duckabush
- ▲ Dewatto
- Hama-Hama
- Hama-Hama lagoon
- ✚ Quilcene
- + Skokomish
- × Stillaguamish
- Nisqually



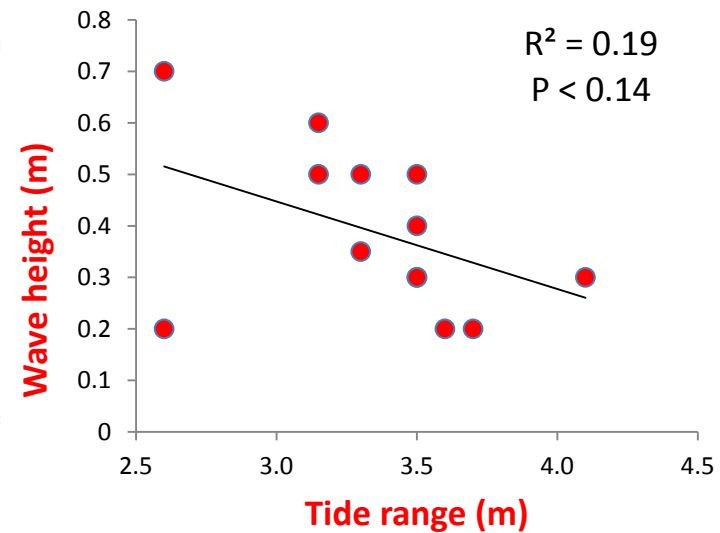
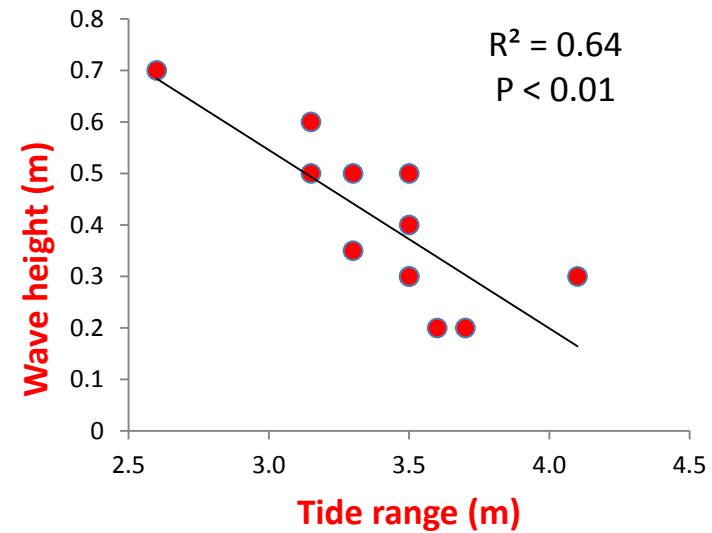
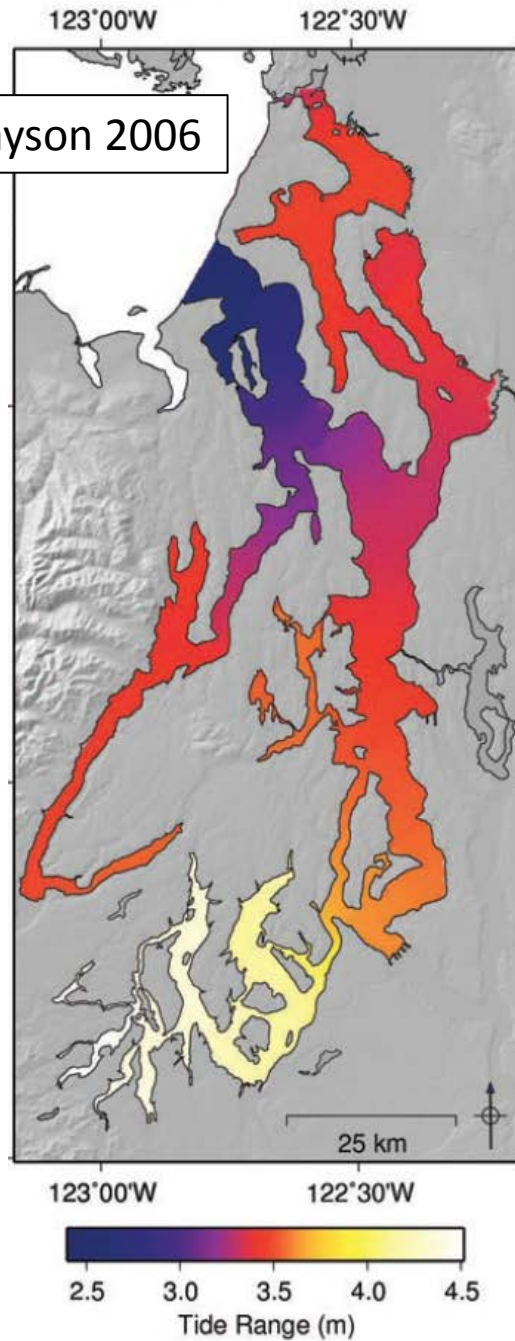
- SF
- △ NF
- × Snohomish
- ◇ Dosewallips
- Lummi
- Nooksack
- Union River
- Lagoon
- ◇ Tahuya
- ▲ Duckabush
- ▲ Dewatto
- Hama-Hama
- Hama-Hama
- + Quilcene
- + Skokomish
- × Stillaguamish
- Nisqually

3. Examining regression intercepts

Wave Height



Tide Range



Stepwise multiple regression of ANCOVA elevations (y-intercepts) with wave height (Finlayson 2006), drainage basin area (Czuba et al. 2011), and tide range (NOAA).

Without Lummi Delta

Parameter	Predictor	P-value	R ²
Channel count	Tide range, wave height	< 0.002	0.77
Total channel area	Tide range	<0.0005	0.72
Total channel length	Tide range, wave height	<0.0007	0.81
Total magnitude	Tide range	<0.0004	0.74
Area of largest channel	Tide range	<0.002	0.65
Length of largest channel	Tide range	<0.001	0.68
Magnitude of largest channel	Tide range	<0.0005	0.73
Tributary count of largest channel	Tide range	<0.0006	0.71

TIDE +, WAVE -

Stepwise multiple regression of ANCOVA elevations (y-intercepts) with wave height (Finlayson 2006), drainage basin area (Czuba et al. 2011), and tide range (NOAA).

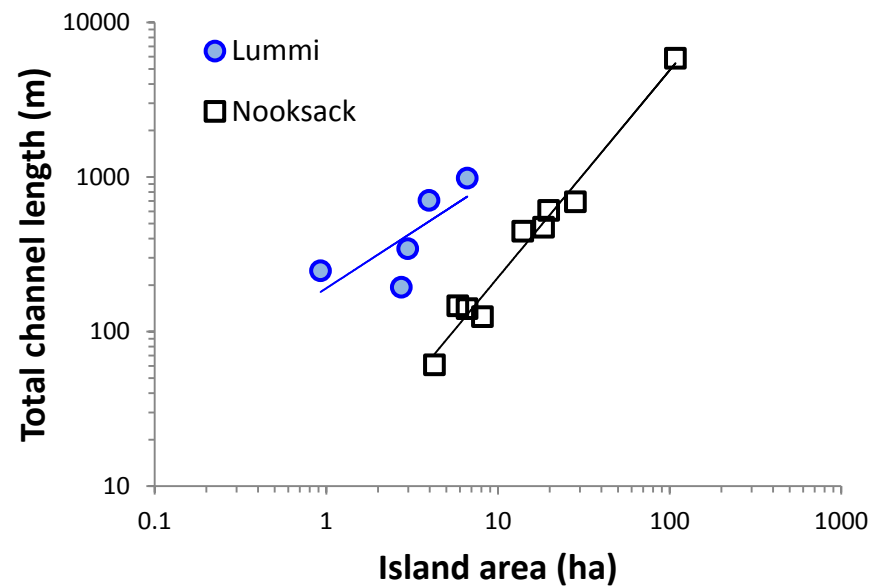
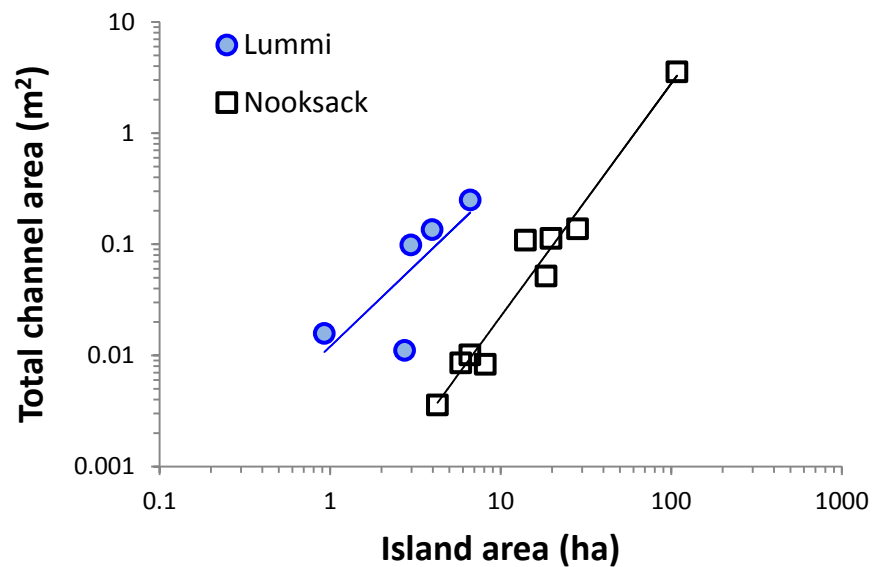
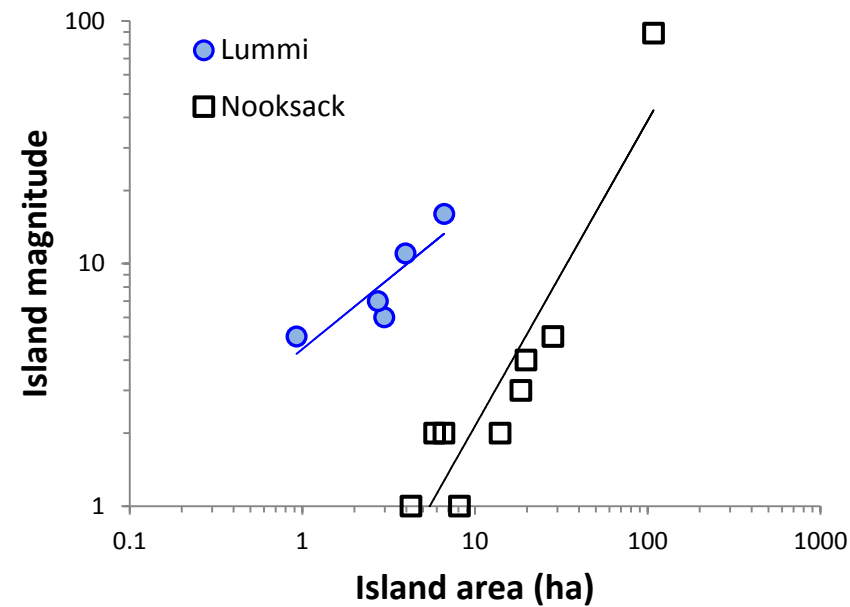
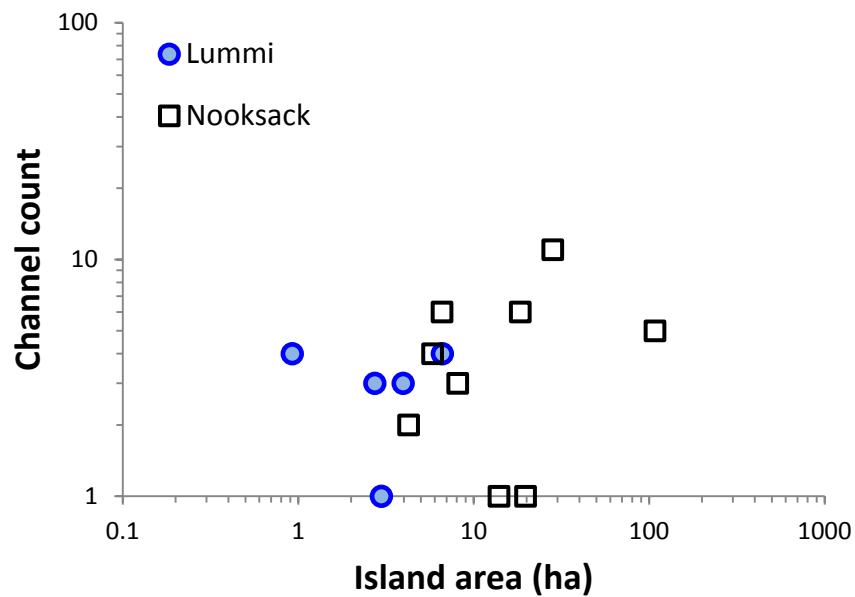
With Lummi Delta

Parameter	Predictor	P-value	R ²
Channel count	Tide range, wave height	< 0.0007	0.77
Total channel area	Wave height, tide range	<0.002	0.72
Total channel length	Wave height, tide range	<0.0005	0.79
Total magnitude	Wave height, tide range	<0.002	0.84
Area of largest channel	Wave height	<0.004	0.56
Length of largest channel	Wave height, tide range	<0.002	0.72
Magnitude of largest channel	Wave height, tide range	<0.004	0.82
Tributary count of largest channel	Wave height, tide range	<0.003	0.71

TIDE +, WAVE -

Nooksack Delta vs. Lummi Delta

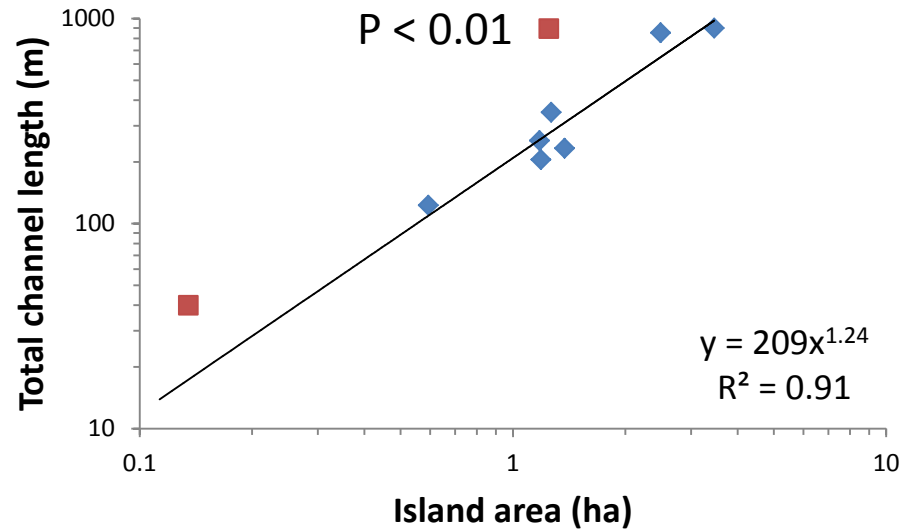
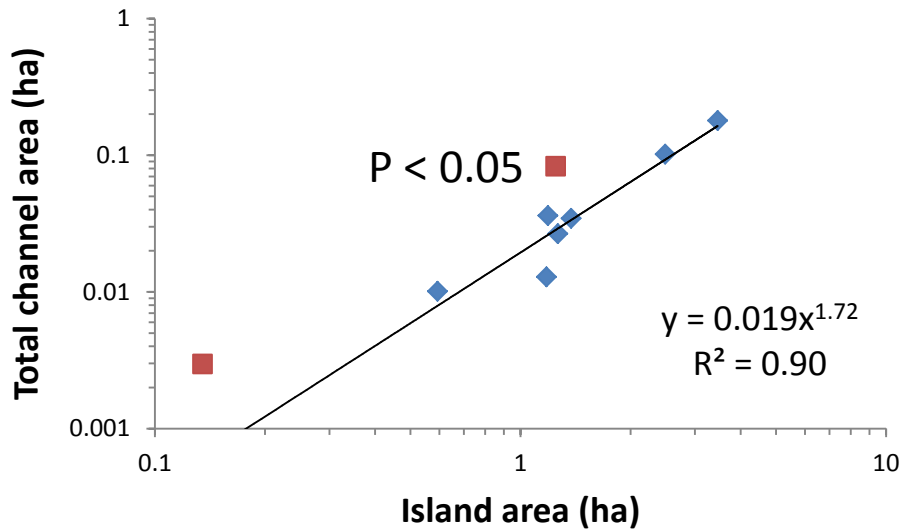
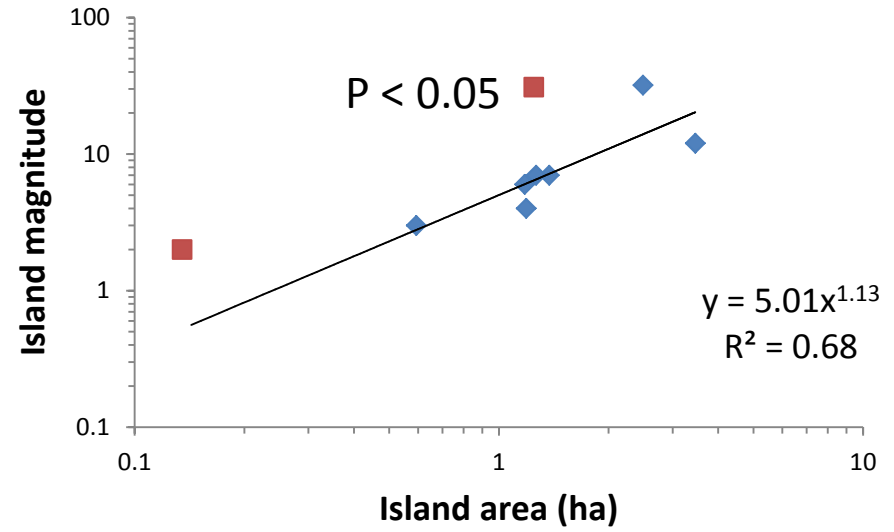
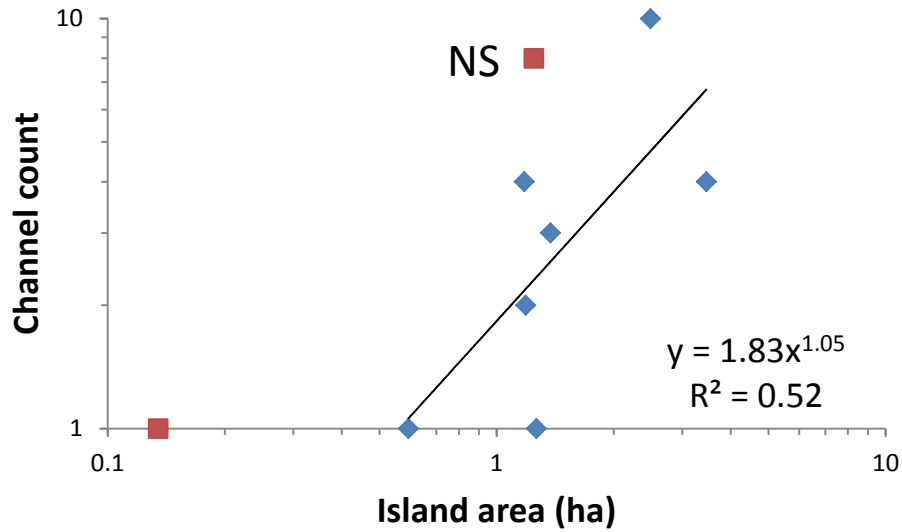




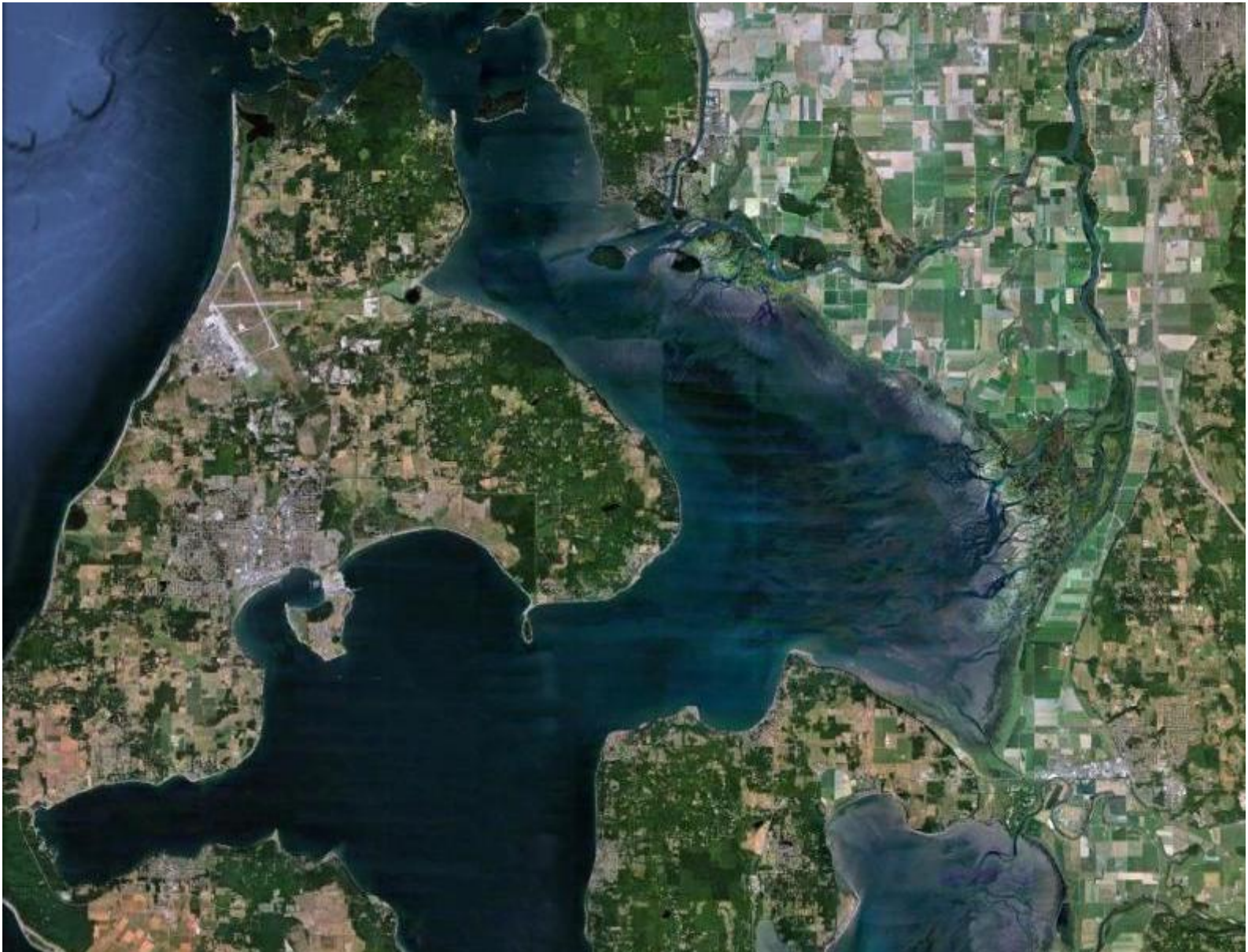
Hama-Hama Delta vs. Lagoons

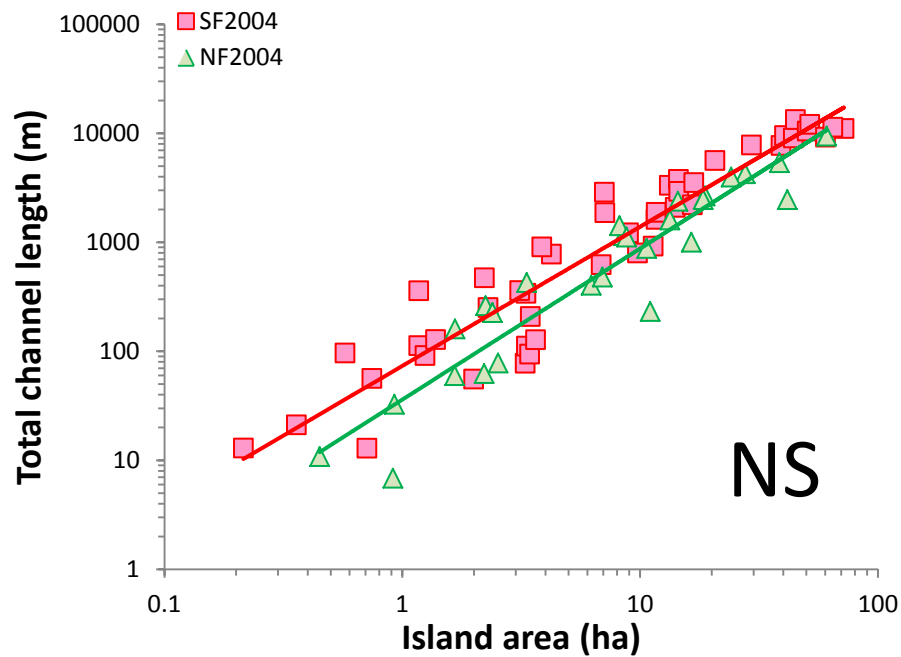
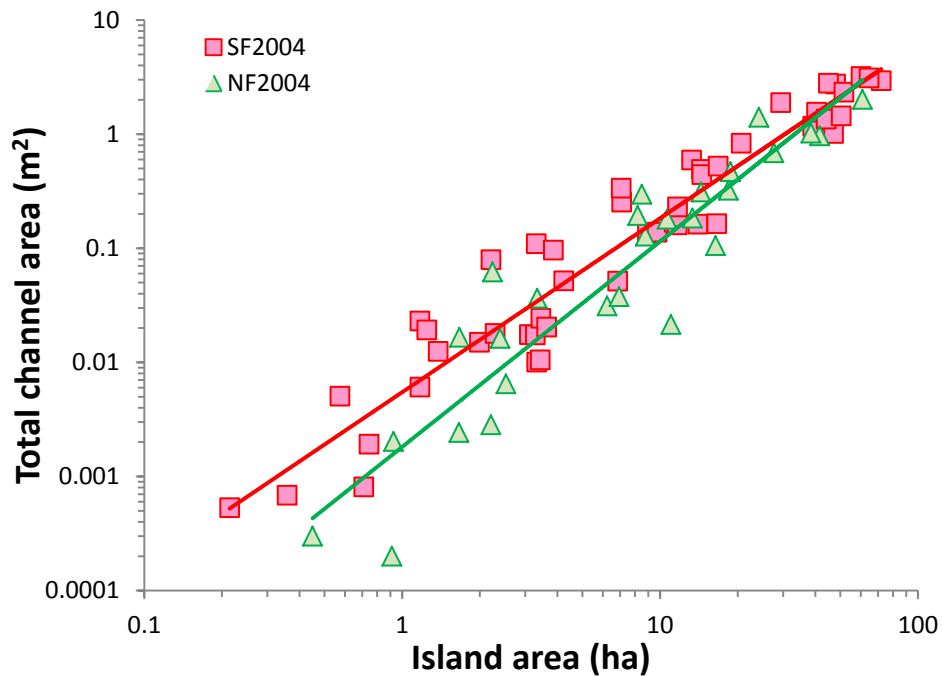
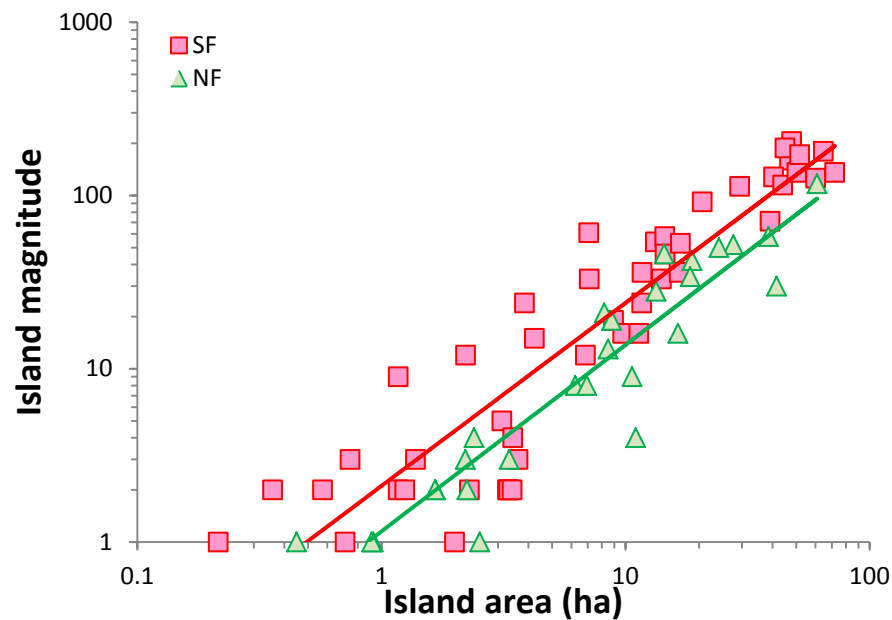
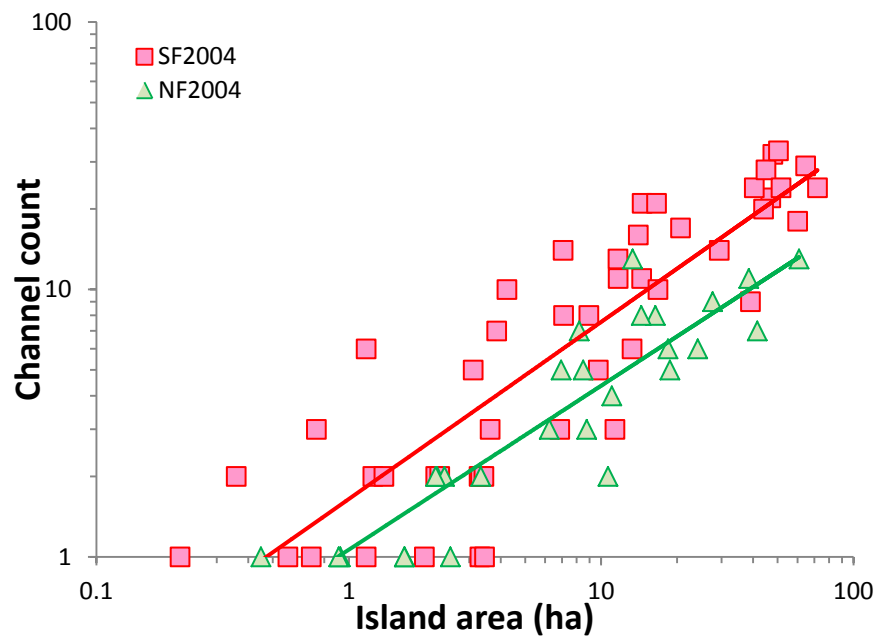


Hama-Hama Delta vs. Lagoons



North Fork Skagit Delta vs. South Fork Skagit Delta





4. Application to Restoration Design and Planning

Smith Island Conceptual Design vs. Model Predictions

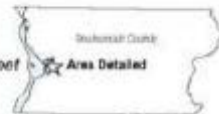
	Predicted (95%/80% CL)	Planned
Channel Count	46 (14//22)	8
Total Length	47,522 (11,170//18,700)	14,021
Largest chan. L	14,121 (3,250//5,480)	9,060
Largest chan. Tribs	41 (10//17)	23
Total Area	13.1 (56.5//33.6)	14.1
Largest chan. A	5.0 (29.4//15.6)	10.0



Key to Features:

- Proposed Dike Alignment
- Tidal Channels
- Estuarine Intertidal Shrub
- Estuarine Intertidal Emergent
- Estuarine Intertidal Nudflat

0 500 1,000 Feet



NOTE: This depiction of conceptual post-project habitat and channel conditions is only an artistic representation of what the restoration area may look like at some point following dike removal. The actual appearance will have similar conditions, but will certainly differ compared to the conceptualization. Additionally, site conditions will not be static, but will continue to adjust and evolve over time as is expected and desired.



Non-linear Cumulative Effects

Total channel area (slope = 1.58), total channel length (slope = 1.26), and area of the largest channel draining an island (slope = 1.45) all exhibit non-linear cumulative effects, which has significant implications for restoration planning, e.g., “splitting the baby” negotiations, SLOSS decisions, mitigation for loss.

E.g.,	Site size	Total Channel Area	Total Channel Length
	100 ha	5.81 ha	24,173 m
	50 ha	2.03 ha	10,093 m
	65 ha		14,080 m
	75 ha	3.78 ha	
	2 x 57.7 ha (115.4 ha)		12,086 m
	2 x 63.5 ha (127 ha)	2.90 ha	
	3 x 41.8 ha (125.4 ha)		8,058 m
	3 x 48.6 ha (145.8 ha)	1.94 ha	

Summary

1. Similar scaling throughout Puget Sound/Hood Canal, except... tidal range is directly and wave energy is inversely related to the amount of tidal channel area, length, etc. Sheltered lagoons in particular have comparatively large channel networks. Drainage basin area and sediment load were not significant predictors of regression elevations.
2. Results can be applied to planning, design, and monitoring of tidal marsh restoration.
3. Still need to examine the effects of marsh plain elevation relative to the tidal frame.

