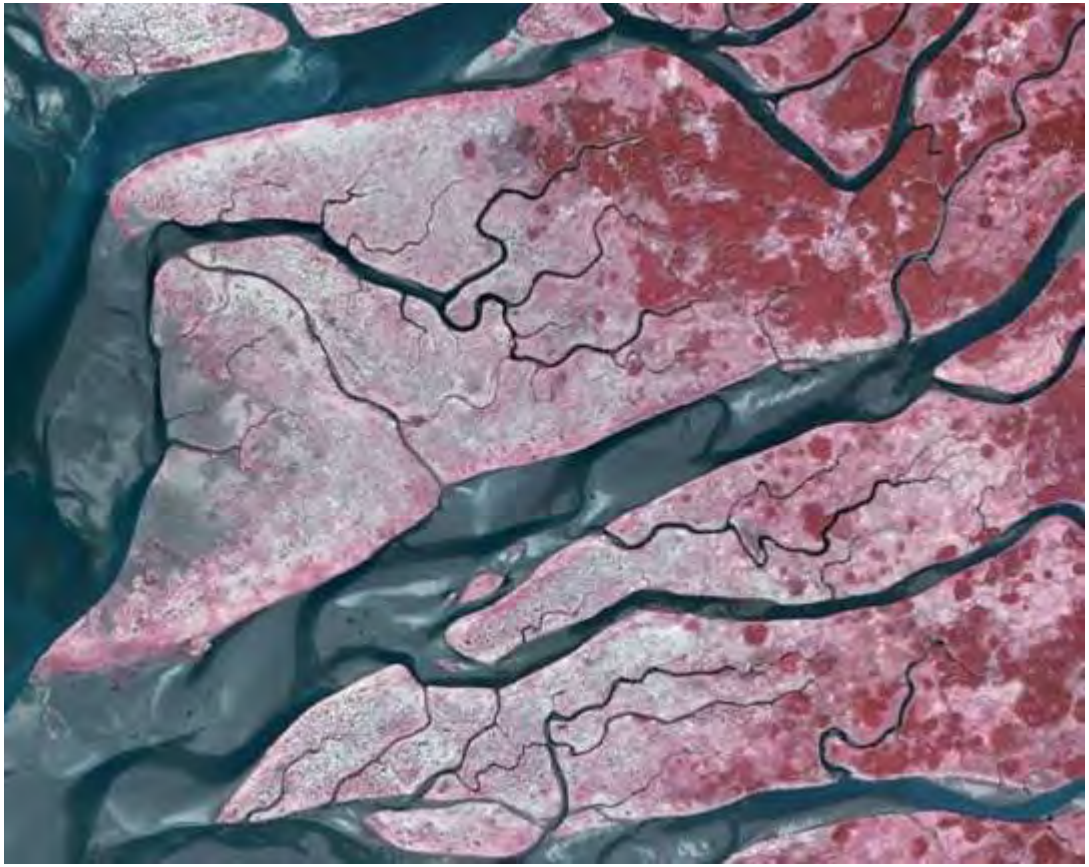
Predicting Rates of Tidal Channel Development

W. Gregory Hood
Skagit River System Cooperative



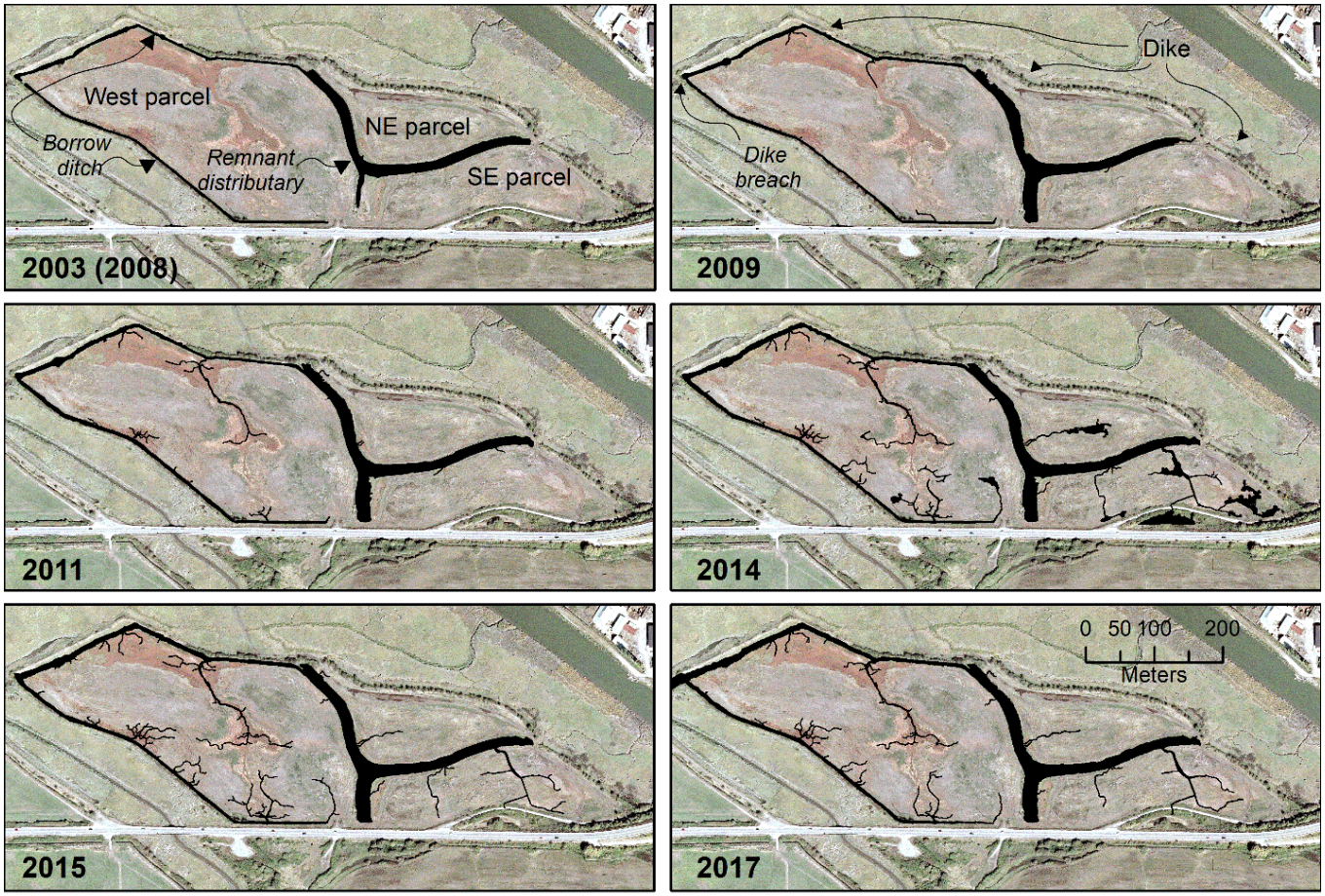
Funding provided by ESRP

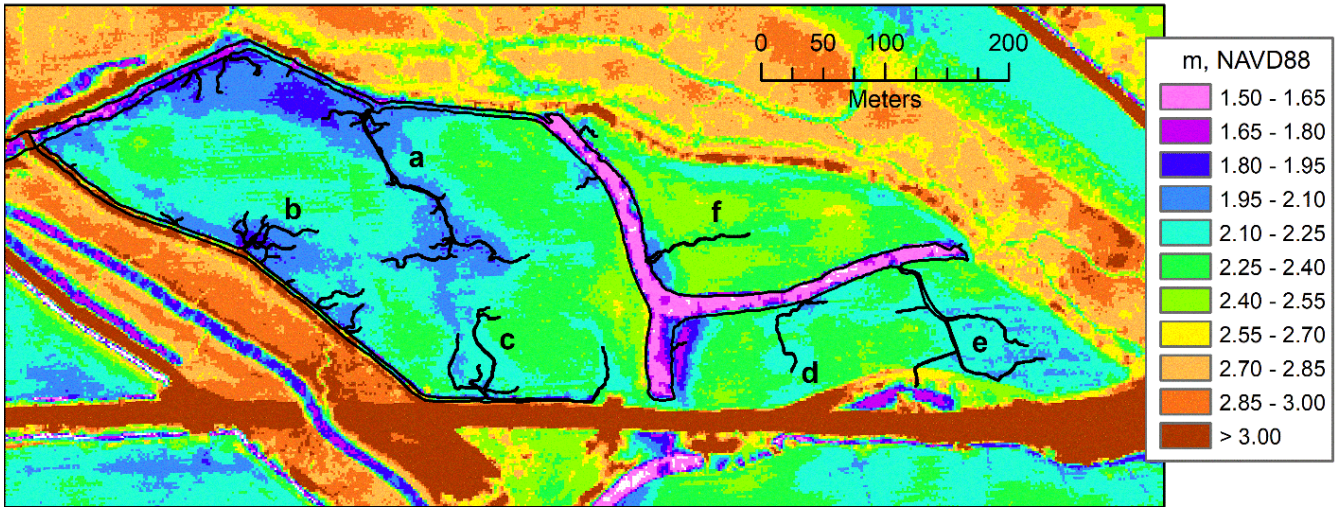
Principal Project Questions

1. How fast do channel networks develop in restored tidal marshes?
   - Related to how quickly restoration benefits accrue to juvenile salmon and other channel-dwelling species.
   - Improved restoration/mitigation planning.

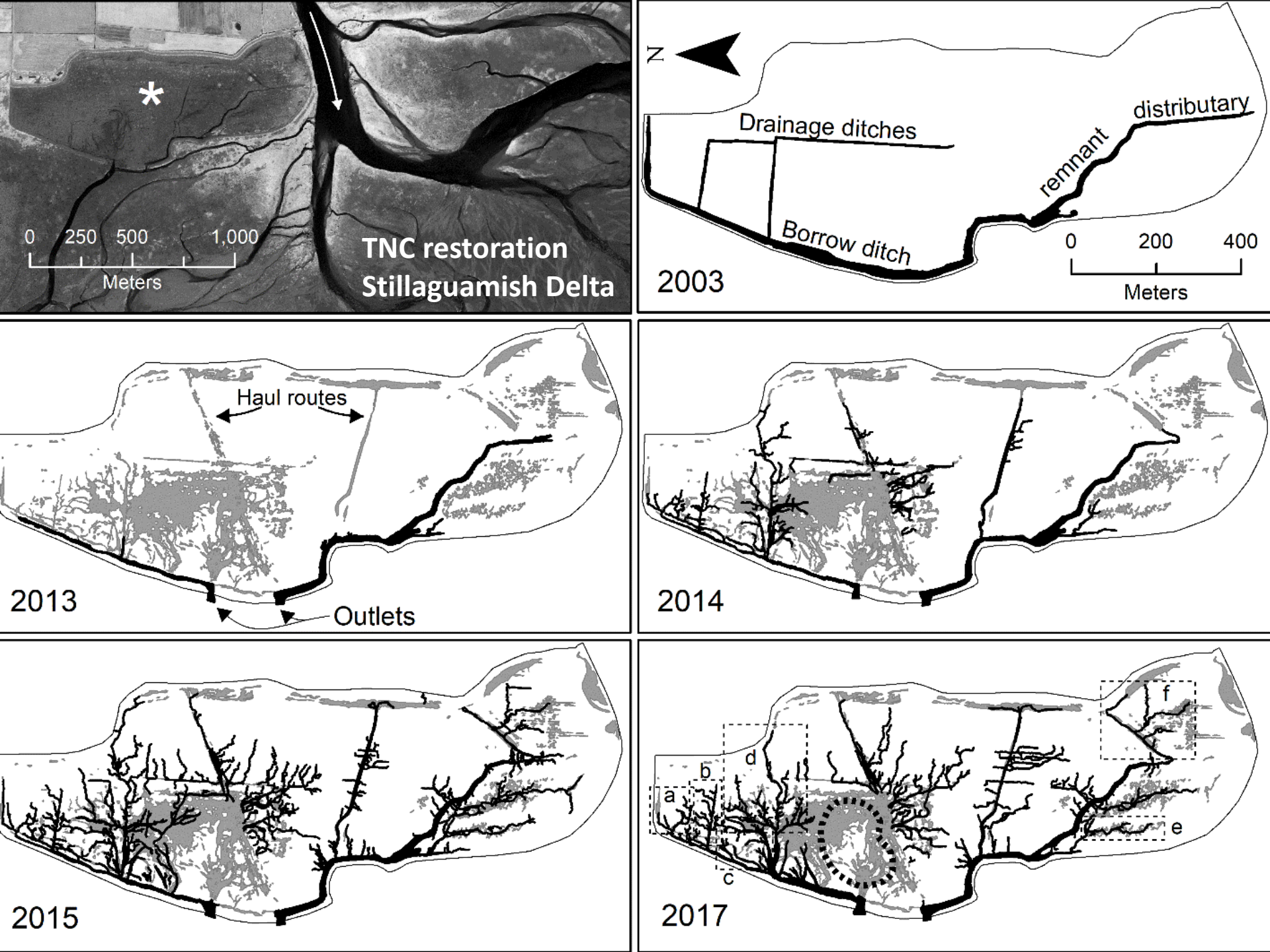
2. Should tidal channels be excavated as part of tidal marsh restoration?
   + accelerate site development
   + increase/accelerate fish production
   - greater cost of restoration

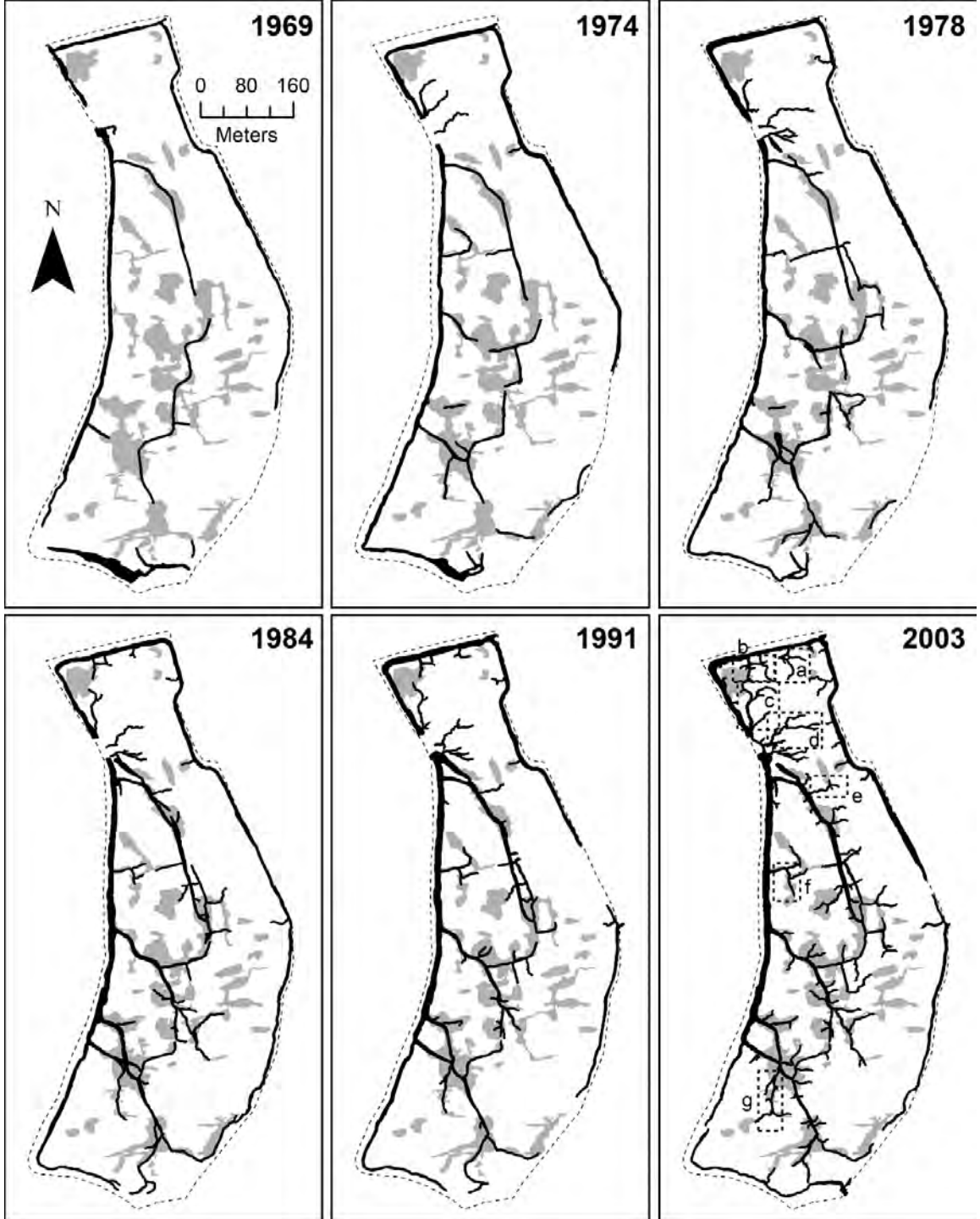
3. Are channel network development rates constant between sites or do they depend on site size (all other things being equal)?



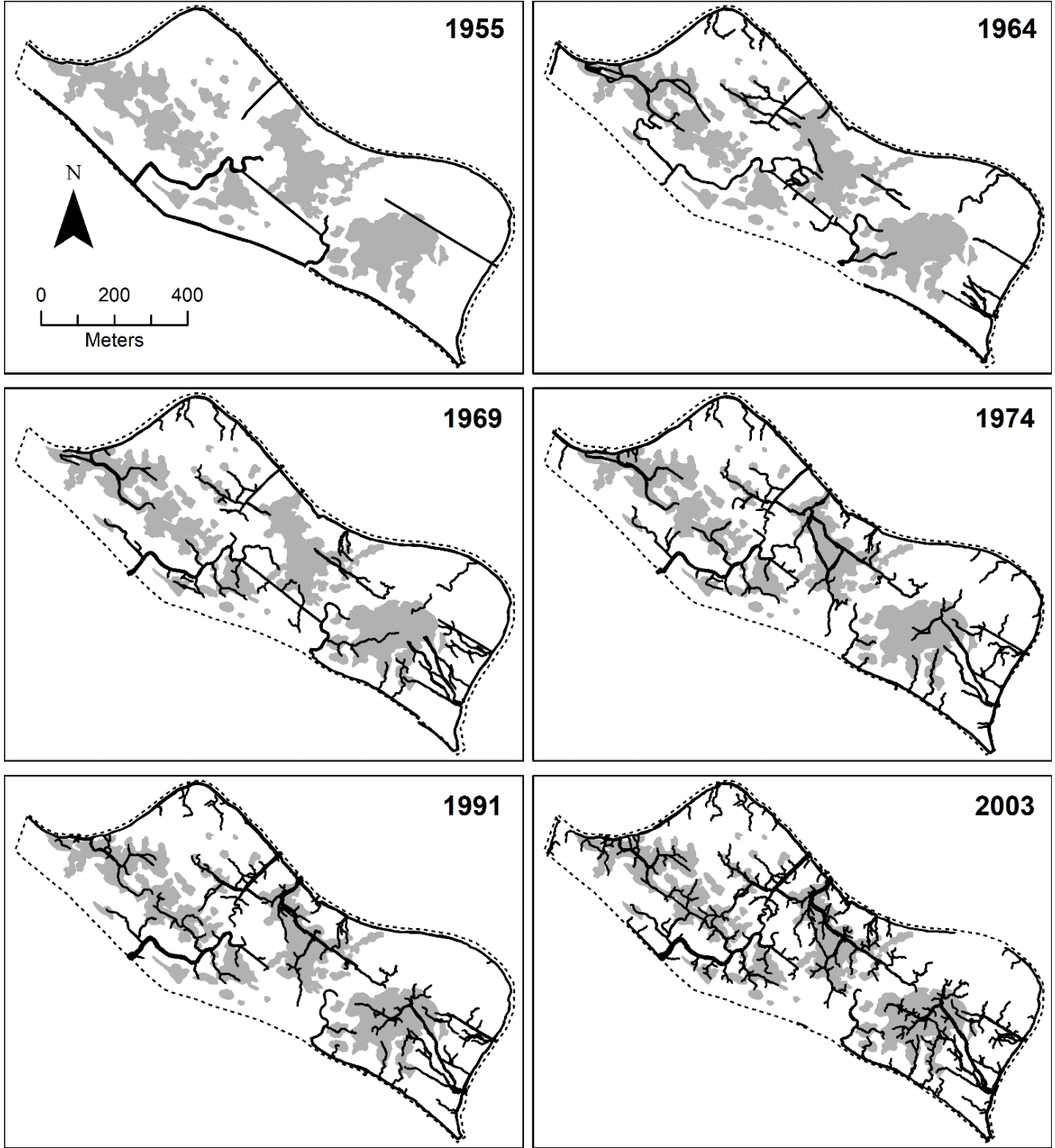


North Leque
Skagit/Stillaguamish

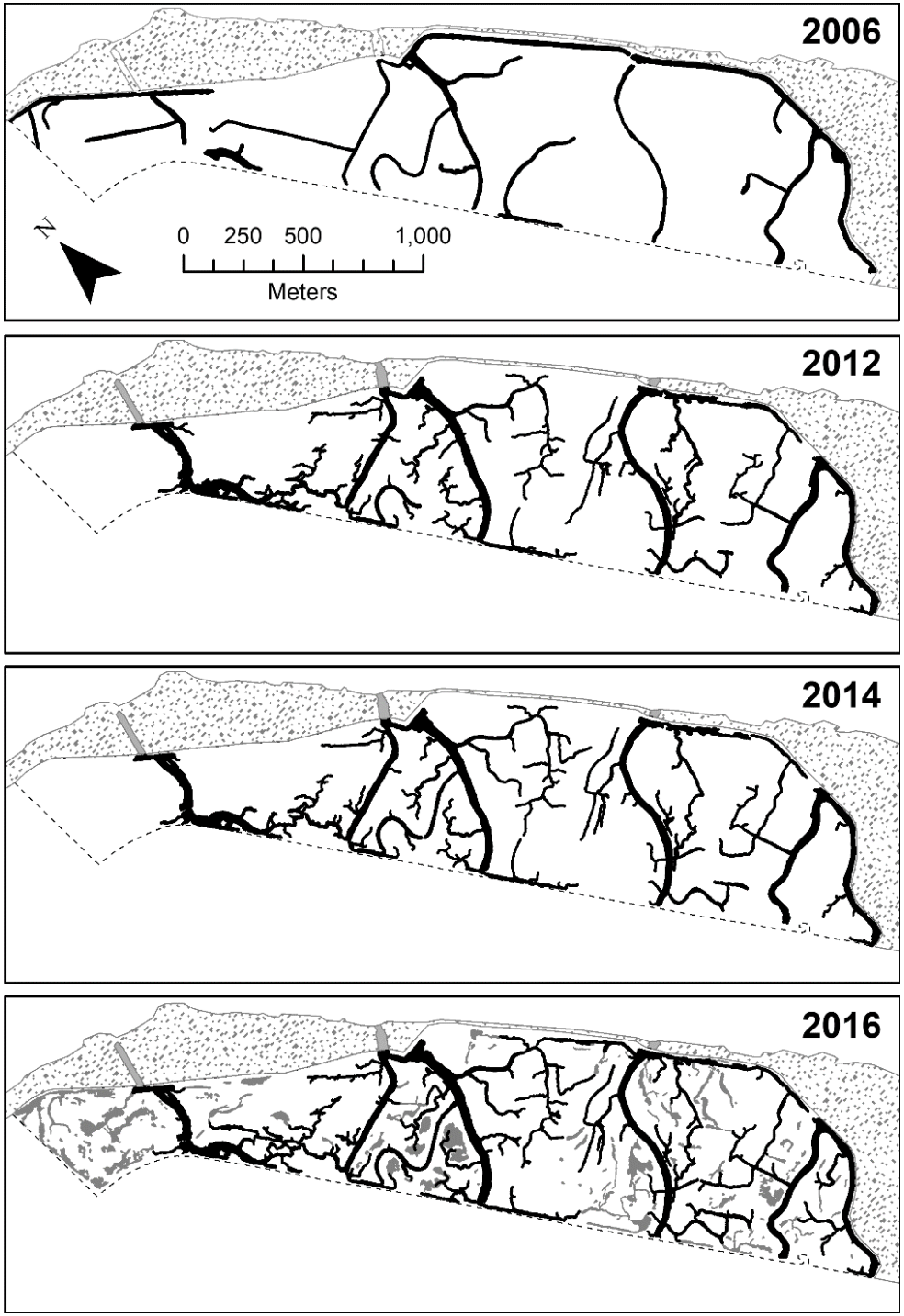

0 250 500 1,000
Meters
TNC restoration
Stillaguamish Delta
N
Drainage ditches
distributary
remnant
Borrow ditch
0 200 400
Meters
2003
Haul routes
Outlets
2013
2014
2015
a
b
c
d
e
f
2017



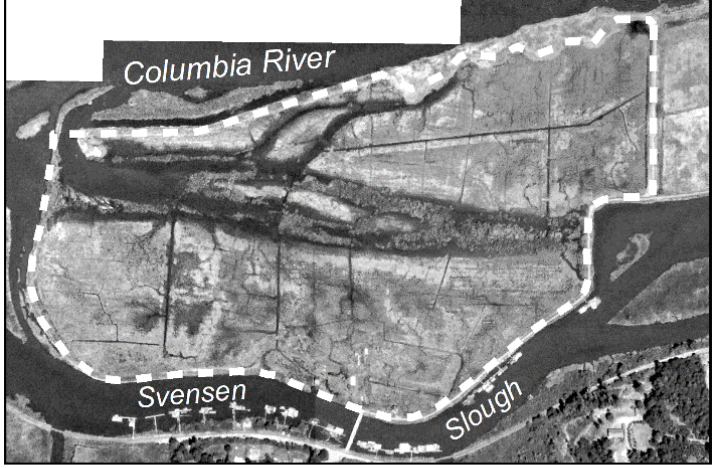
Mid-Spencer Island
Snohomish Delta



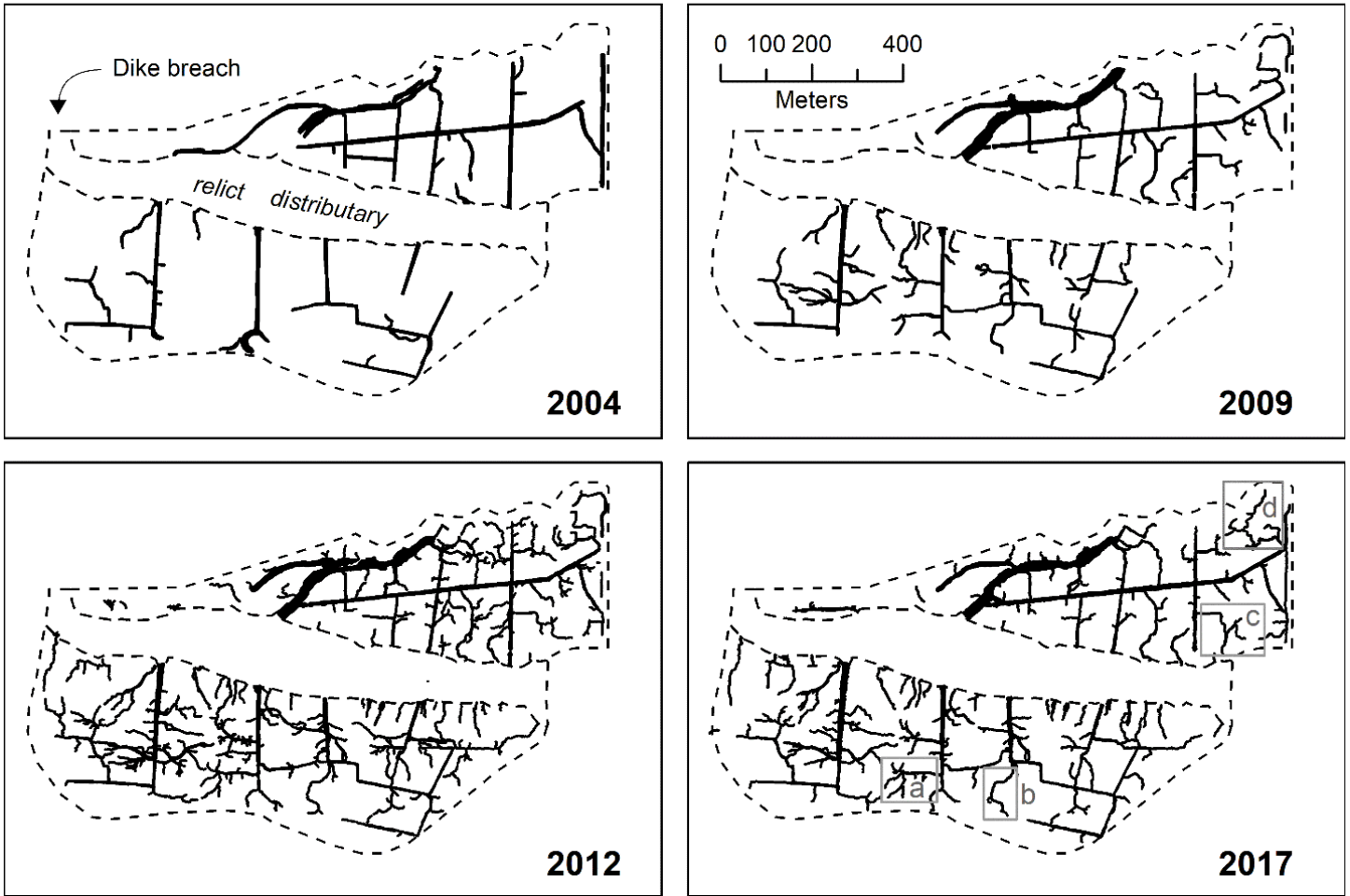
Cattail Island
Snohomish Delta



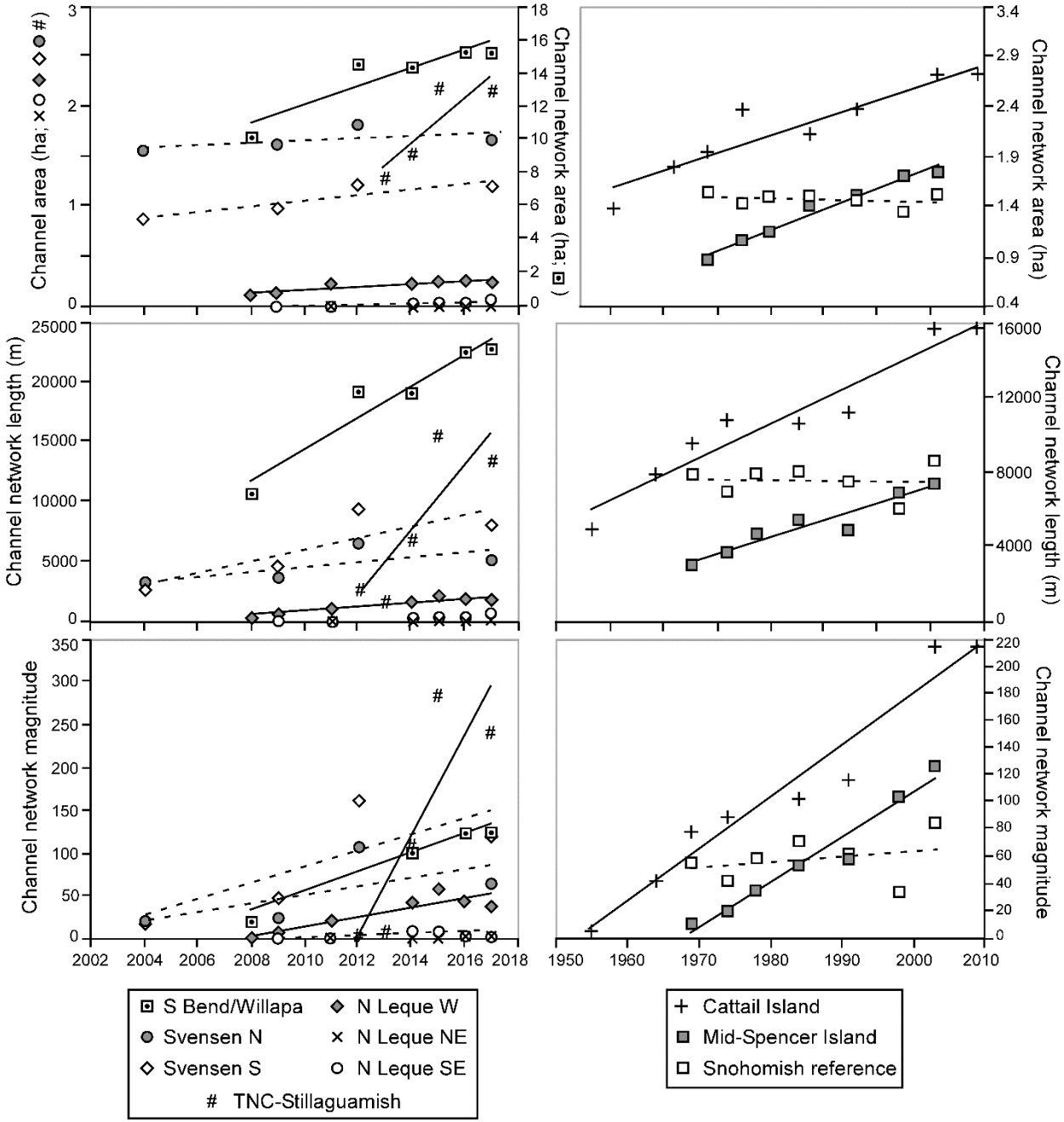
South Bend restoration
Willapa River/Bay

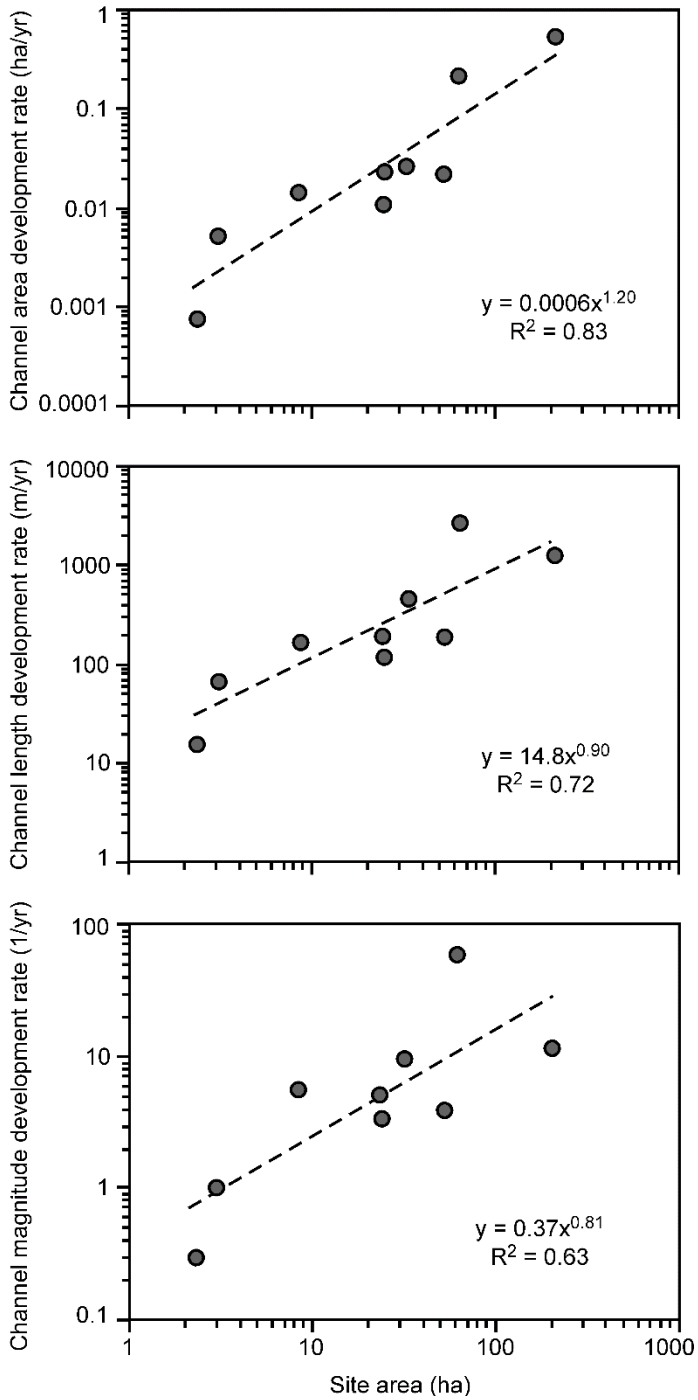


Svensen Island
Columbia River Estuary
(near Astoria)



Channel network development rates




Channel area development rate (ha/yr)
1
0.1
0.01
0.001
0.0001
y = 0.0006x^1.20
R^2 = 0.83
Channel length development rate (m/yr)
10000
1000
100
10
1
y = 14.8x^0.90
R^2 = 0.72
Channel magnitude development rate (1/yr)
100
10
1
0.1
y = 0.37x^0.81
R^2 = 0.63
1
10
100
1000
Site area (ha)

How long does it take for channels to fully develop?

$T_e = P/R_P$,

where

T_e = time to equilibrium state (yrs),
P = a channel network parameter (e.g., total surface area, total length, magnitude),
R_P = rate of development for a channel network parameter.

Using SF Skagit equations in the numerator,
with Puget Sound estimates of common slope,
where x = site area (ha).

$A = 0.0055x^{1.52}$	$L = 79.616x^{1.24}$	$M = 2.350x^{1.00}$
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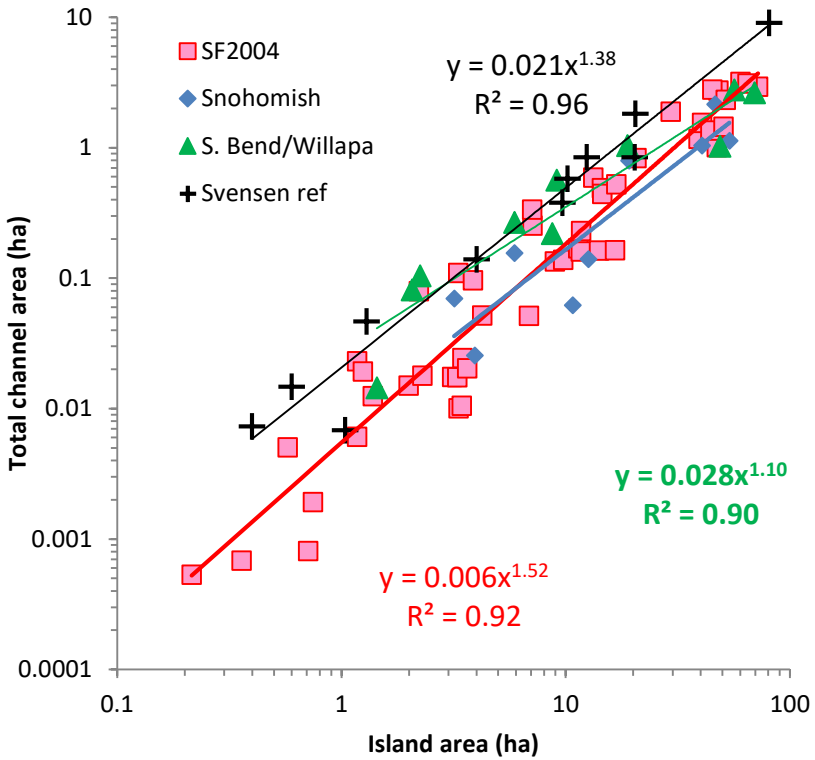
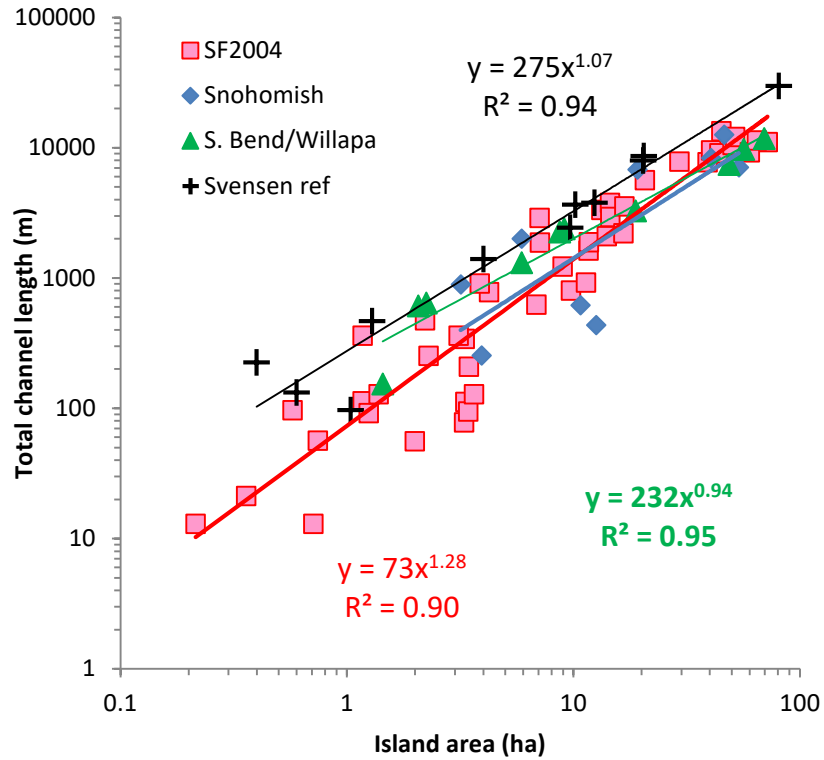
$R_A = 0.0006x^{1.20}$	$R_L = 14.824x^{0.90}$	$R_M = 0.372x^{0.81}$
$T_{e,A} = 9.2x^{0.32}$	$T_{e,L} = 5.4x^{0.34}$	$T_{e,M} = 6.3x^{0.19}$

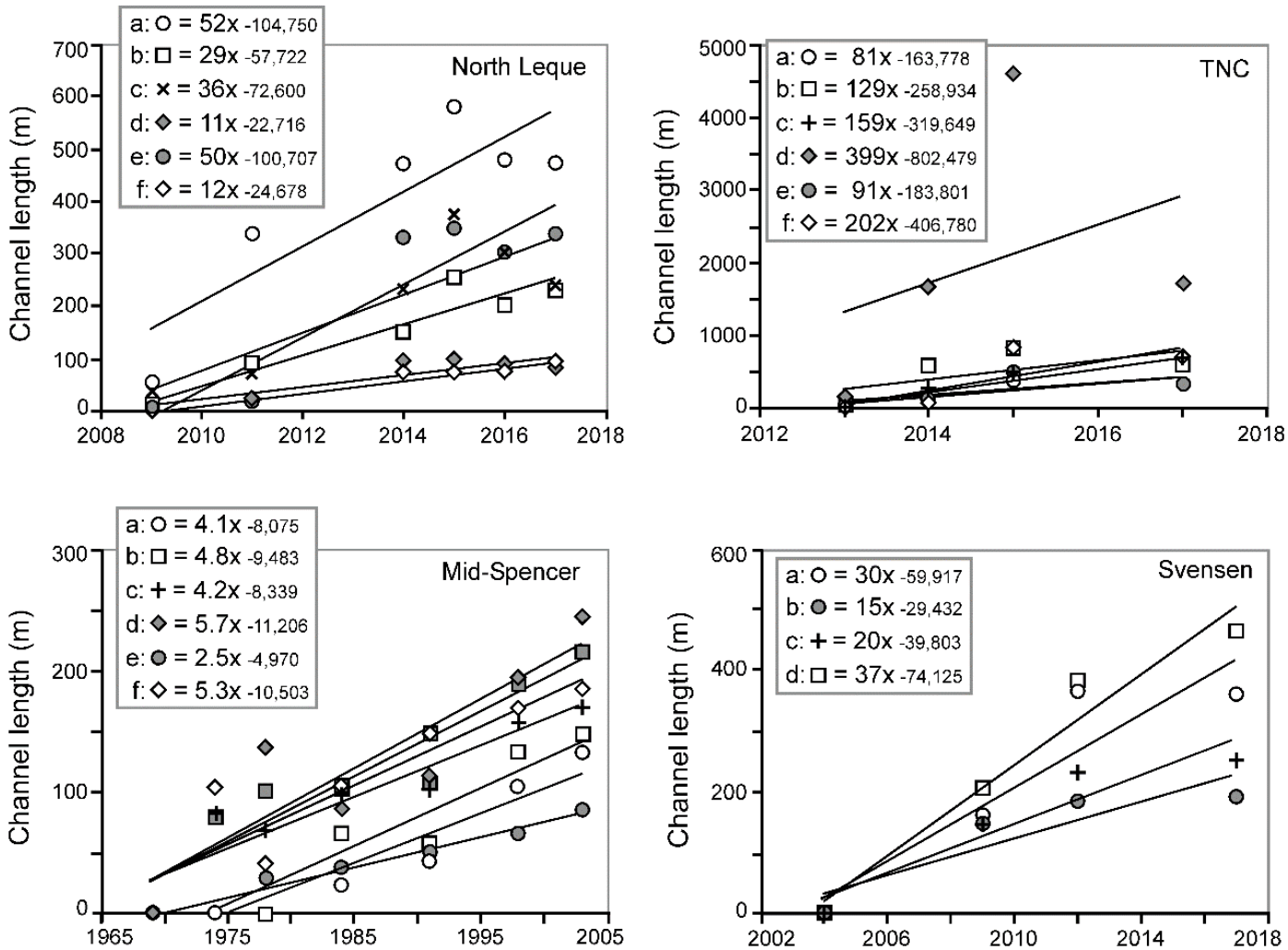

SF2004
Snohomish
S. Bend/Willapa
Svensen ref
y = 0.021x^1.38
R² = 0.96
y = 0.028x^1.10
R² = 0.90
y = 0.006x^1.52
R² = 0.92
Total channel area (ha)
Island area (ha)
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100


SF2004
Snohomish
S. Bend/Willapa
Svensen ref
y = 275x^1.07
R² = 0.94
y = 232x^0.94
R² = 0.95
y = 73x^1.28
R² = 0.90
Total channel length (m)
Island area (ha)
100000
10000
1000
100
10
1
0.1
1
10
100

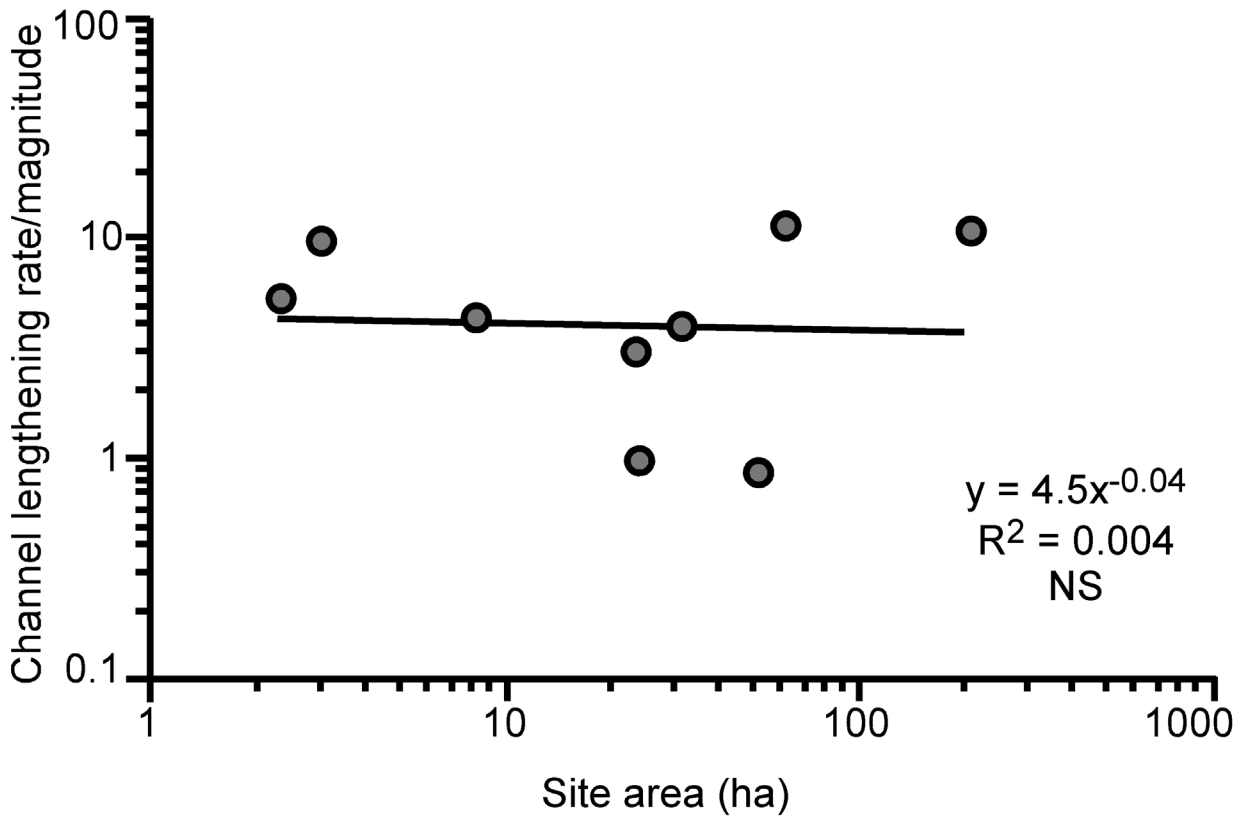
Estimated time to equilibrium (T_e) compared to site age and predicted versus latest observed channel network surface area, length, and magnitude. Sites are listed in order from those most underperforming reference marsh allometric predictions to those most exceeding predictions.

Site	Site area (ha)	$T_{e,A}$ (yrs)	$T_{e,L}$ (yrs)	Site age (yrs)	Predicted area (ha)	Observed area (ha)	Predicted length (m)	Observed length (m)	Predicted magnitude	Observed magnitude
Svensen S	32	53	29	14	2.19	1.21 (-)	10,580	8,093 (-)	197	122 (-)
N Leque NE	2.3	12	7	9	0.020	0.007 (-)	224	133 (-)	5	3 (-)
Svensen N	23.6	48	26	14	1.45	1.68 (+)	7,670	5,250 (-)	145	66 (-)
South Bend	206	51	33	9	9.87	15.36 (+)	34,170	22,800 (-)	158	123 (-)
TNC	61.8	9	7	4	2.93	2.17 (-)	13,240	13,467 (=)	145	242 (+)
N Leque SE	3.0	13	8	9	0.029	0.040 (+)	310	455 (+)	7	7 (=)
Cattail	52.1	33	21	43	2.26	2.71 (+)	10,710	15,725 (+)	122	215 (+)
N Leque W	8.3	18	11	9	0.14	0.24 (+)	1,100	1,812 (+)	20	40 (+)
Mid-Spencer	24.0	25	16	34	0.70	1.74 (+)	4,100	7,433 (+)	56	126 (+)

Within- and between-site variation in channel development rates



Big channels grow quickly; small channels grow slowly



Channel network development rates, standardized by network magnitude, are comparable to literature reports for single-thread channel head-cutting.

Principal Project Questions

1. *How fast do channel networks develop in restored tidal marshes?*
   - *Related to how quickly restoration benefits accrue to juvenile salmon and other channel-dwelling species.*
   - *Improved restoration/mitigation planning.*

- 1 to 5 decades, depending on site size, reference marsh allometry, and site conditions
- Site conditions: clay inclusions, goldilocks elevation
  - Check for clay inclusions and excavate in those areas
  - Very low elevations might be filled to allow vegetation colonization and more rapid channel development, or channels might be excavated in these areas with spoils side cast to mimic natural levees
- Channel excavation has potential to significantly shorten time to maturity for channel networks
- Excavation should focus on locally low topography, as long as it is not too low for vegetation development

Principal Project Questions

2. *Should tidal channels be excavated as part of tidal marsh restoration?*
   + *accelerate site development*
   + *increase/accelerate fish production*
   - *greater cost of restoration*

YES, as much as possible given economic, logistical, and political constraints, but good design is important!

3. *Are channel erosion rates constant between sites or do they depend on site size (all other things being equal)?*

Erosion rates, standardized by channel network magnitude, are constant relative to site size, but network development rates scale with site size.

Additional Lessons Learned

The locations of future tidal channel networks can be roughly predicted from topography, either from lidar or observed ponding.

Hypothesis: rules-based selection of low topographies for siting of tidal channel excavation may be as effective as numerical modeling of morphodynamics.