Predicting the response of salmon habitat to changing hydrologic regimes in southeast Alaska

Matt Sloat, Gordon Reeves,
Kelly Christiansen

Wild Salmon Center

USFSPNW Research Station

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Gordon and Betty MOORE FOUNDATION

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Objectives:

- Determine the vulnerability of southeast Alaska watersheds to potential impacts of climate change.

- Focus on changes in flood disturbance in response to trends for a warmer, wetter climate.

- Determine the impact of increases in mean annual flooding on spawning habitat for Pacific salmon.

Pacific salmon prefer to spawn in particular geomorphic settings

Species	Habitat quality	Gradient (%)	Bankfull width (m)	Bankfull depth (m)	Confinement	D_{50} (mm)
coho salmon						
	high	<2.0	>2.0	>0.5	unconfined	10 - 50
	moderate	<4.5	>2.0	>0.5	confined	10 - 50

Paustian et al. 1992

High quality: small to large floodplain reaches

Moderate quality: moderate gradient, small to large confined reaches

Pacific salmon prefer to spawn in particular geomorphic settings

Species	Habitat quality	Gradient (%)	Bankfull width (m)	Bankfull depth (m)	Confinement	D_{50} (mm)
pink salmon						
	high	<2.0	>10.0	>0.5	unconfined	5 - 25
	high	≤1.0	>2.0	>0.5	unconfined	5 - 25
	moderate	<4.5	>10.0	>0.5	confined	5 - 25

Paustian et al. 1992

High quality: medium to large estuarine and floodplain reaches
High quality: small estuarine reaches

Moderate quality: moderate gradient, medium to large confined reaches

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chum salmon						
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	high	≤1.0	>2.0	>0.5	unconfined	5 - 50
	moderate	<4.5	>10.0	>0.5	confined	5 - 50

Paustian et al. 1992

High quality: medium to large estuarine and floodplain reaches
High quality: small estuarine reaches

Moderate quality: moderate gradient, medium to large confined reaches

- Where do these habitats occur on the landscape?
- What is their exposure to climate-induced hydrologic change?
- What is their sensitivity to hydrologic change?

- Where do these habitats occur on the landscape?

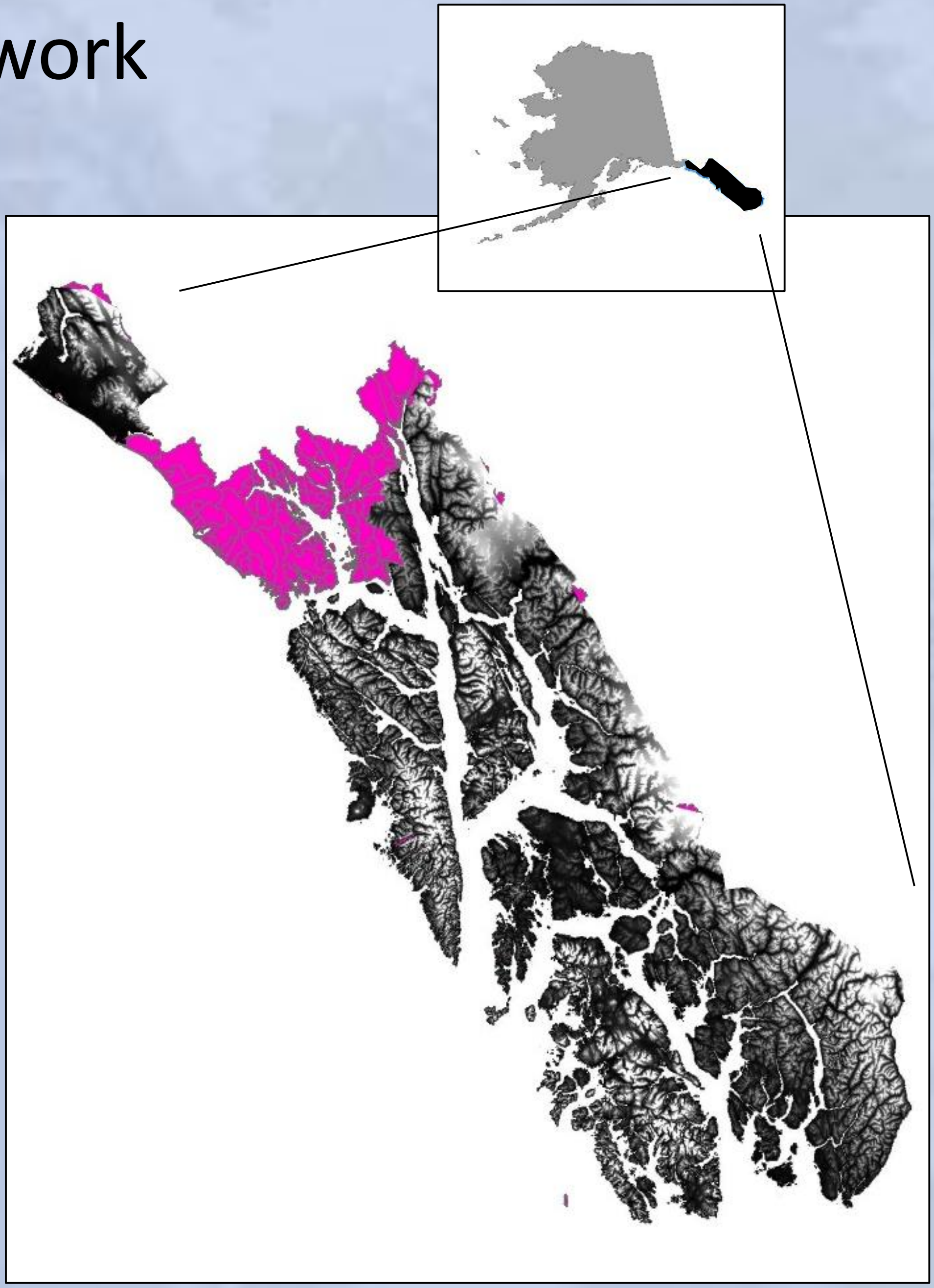
  Use synthetic stream network generated from 20m DEM (Netmap).

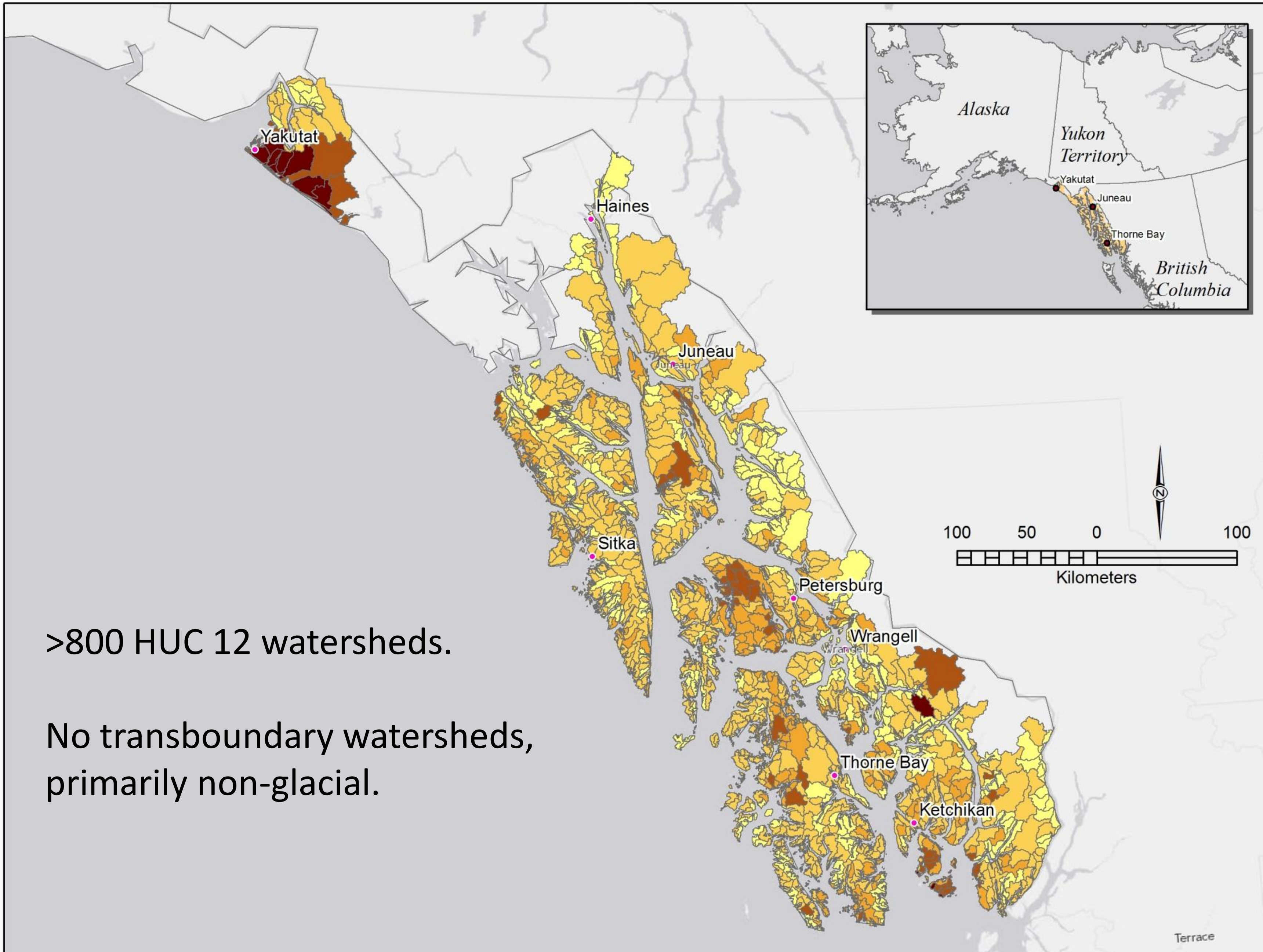
  Parameterize stream reaches (e.g., width, depth, substrate size) using field measurements and numerical models.

Netmap stream network

>800 HUC 12 watersheds.

No transboundary watersheds, primarily non-glacial.





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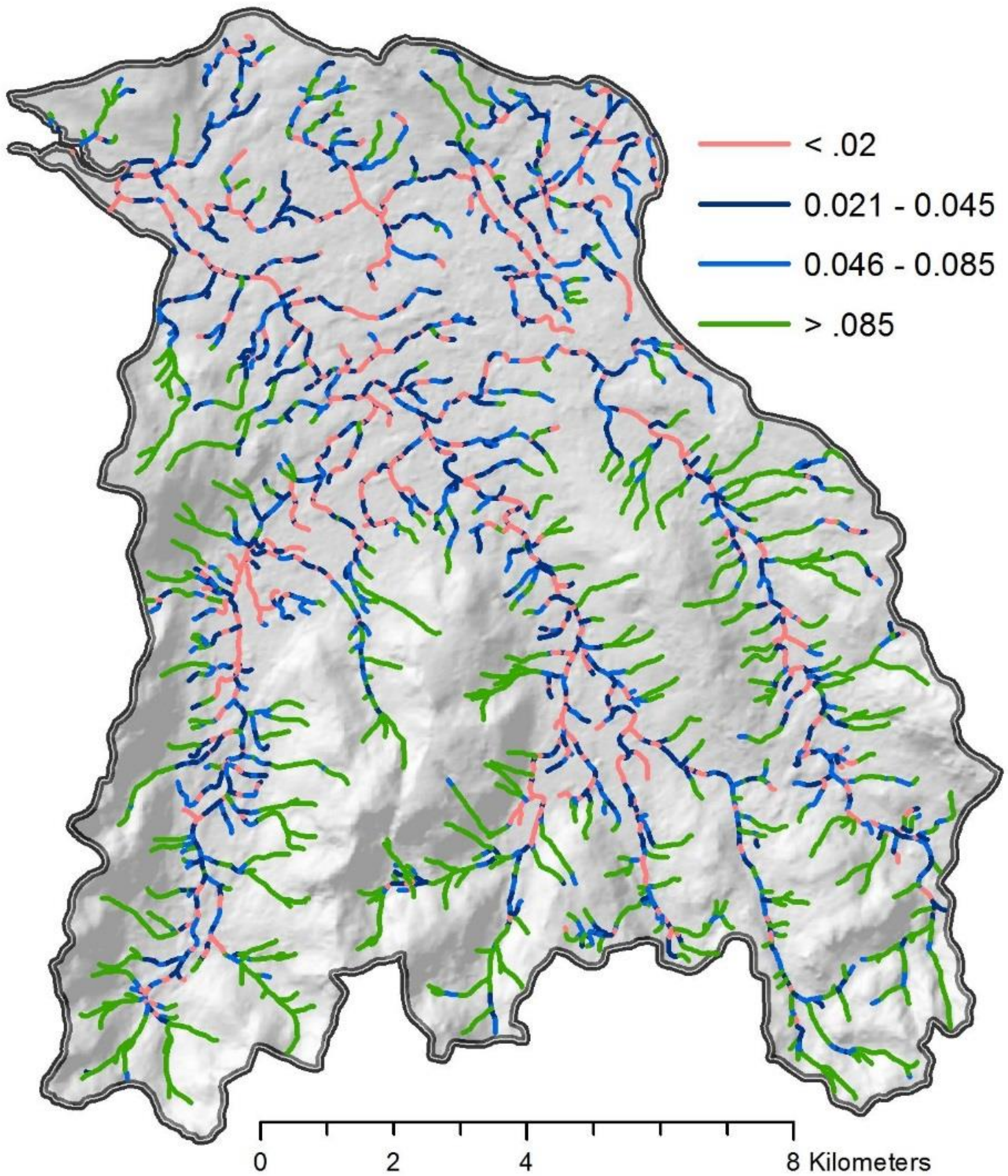
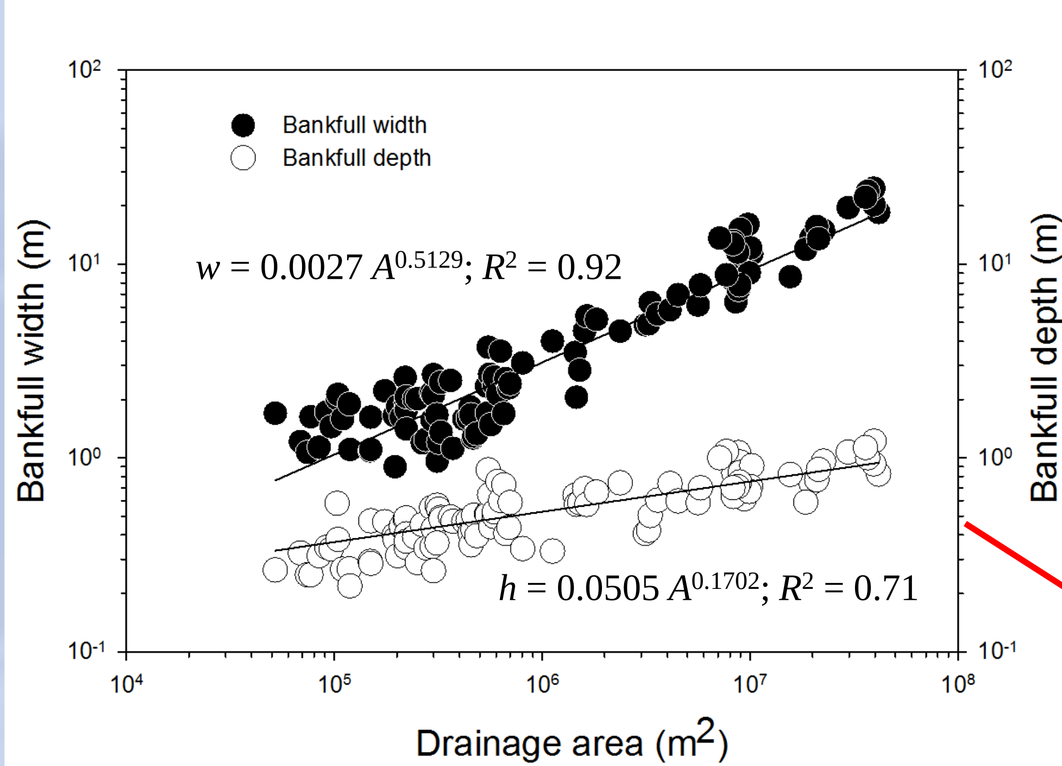
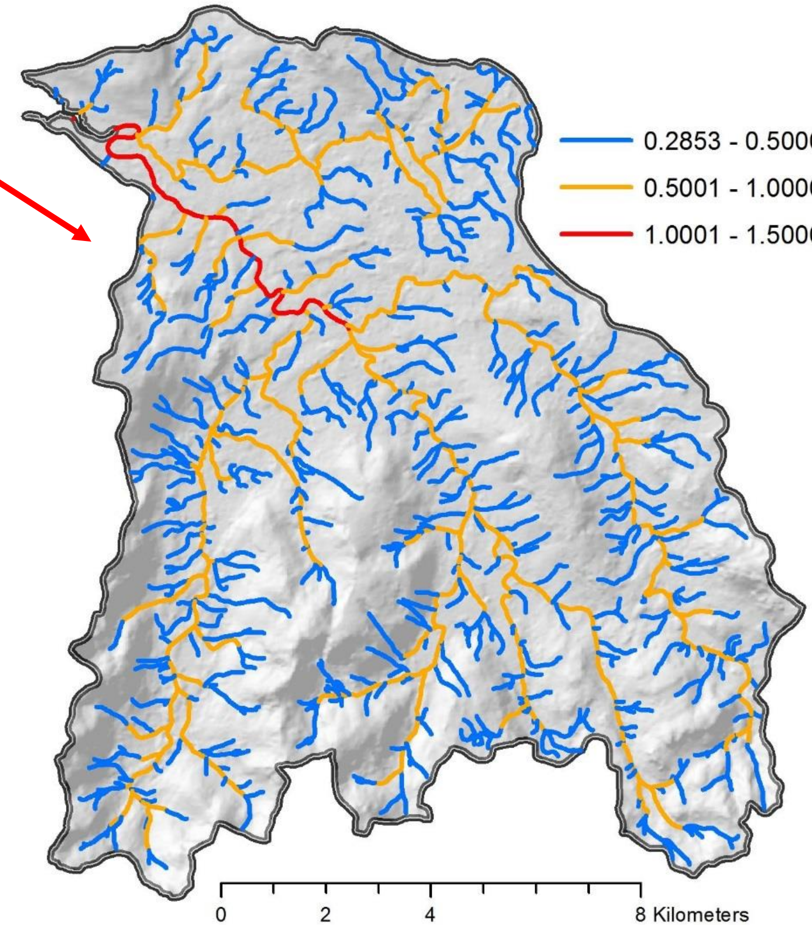
No transboundary watersheds, primarily non-glacial.

DEM-derived channel slope





Bank-full channel depth (h_{bf})



Zynda, T. (2005) Unpublished Master's Thesis, Michigan State University, Lansing MI.

Wood-Smith RD, Buffington JM (1996) Earth Surface Processes and Landforms, 21, 377-393.

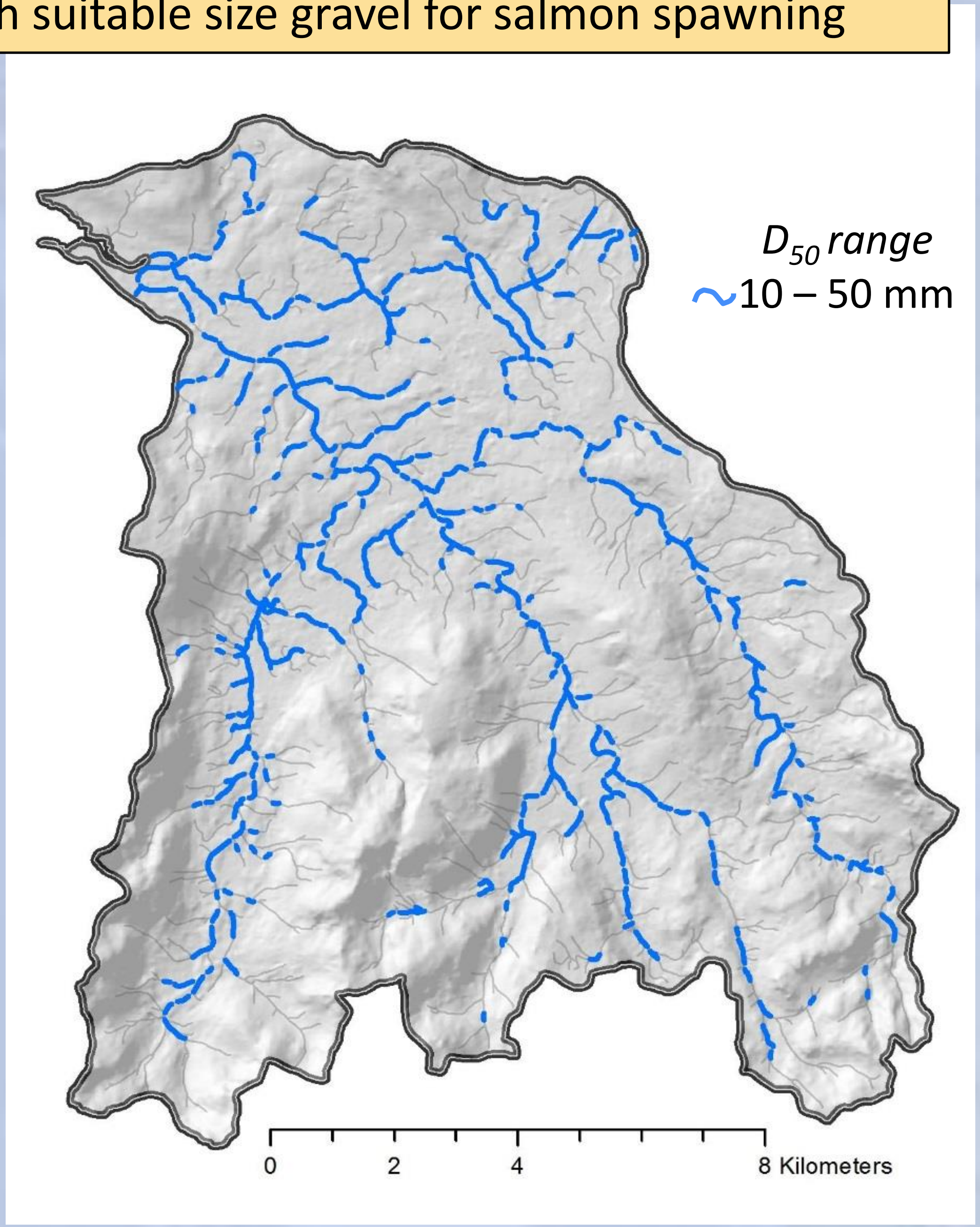
Spatially explicit prediction of median gravel size is used to assess the extent of reaches with suitable size gravel for salmon spawning

Substrate Size Models

Buffington et al. (2004) CJFAS, 61, 2085-2096.

Surface substrate size characterized by median grain size (D_{50}) and predicted by :

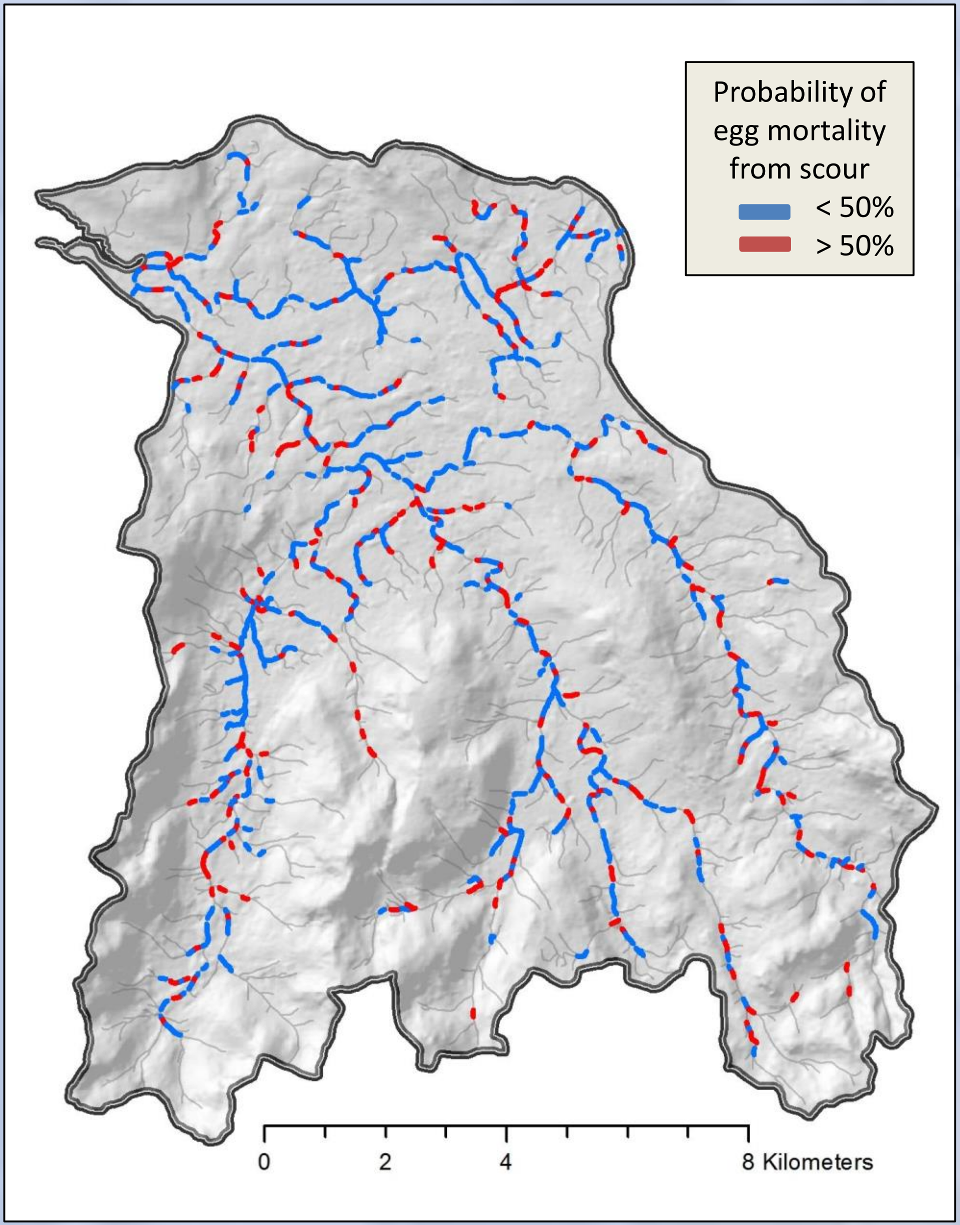
$D_{50} = (\rho h S)^{1-n}/(\rho_s-\rho)kg^n$



Gravel Scour Potential Models

Haschenburger (1999)
Water Resources Research,35, 2857–2869.

Goode et al. (2013)
Hydrologic Processes, 27, 750-765.



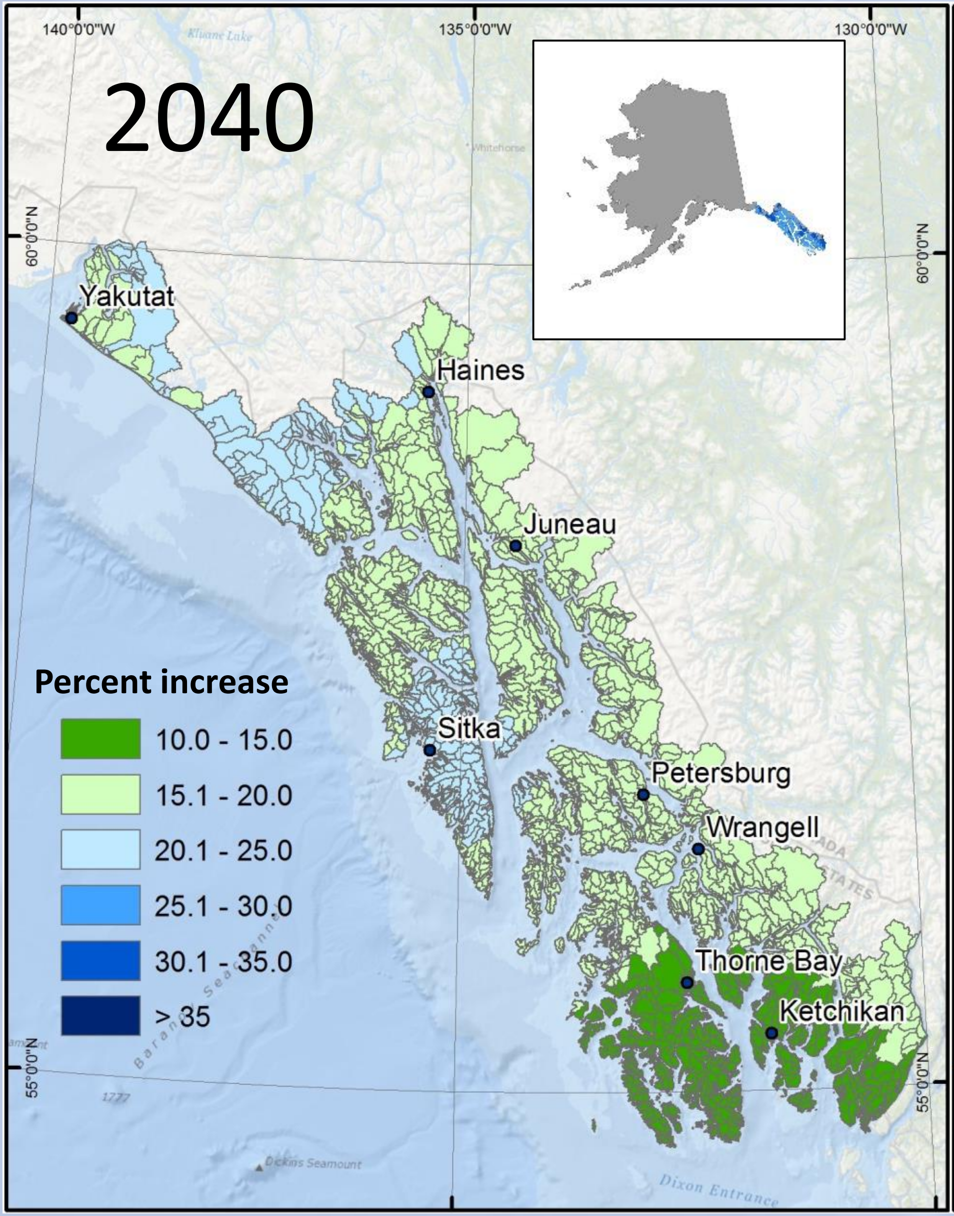
- What is their exposure to climate-induced hydrologic change?

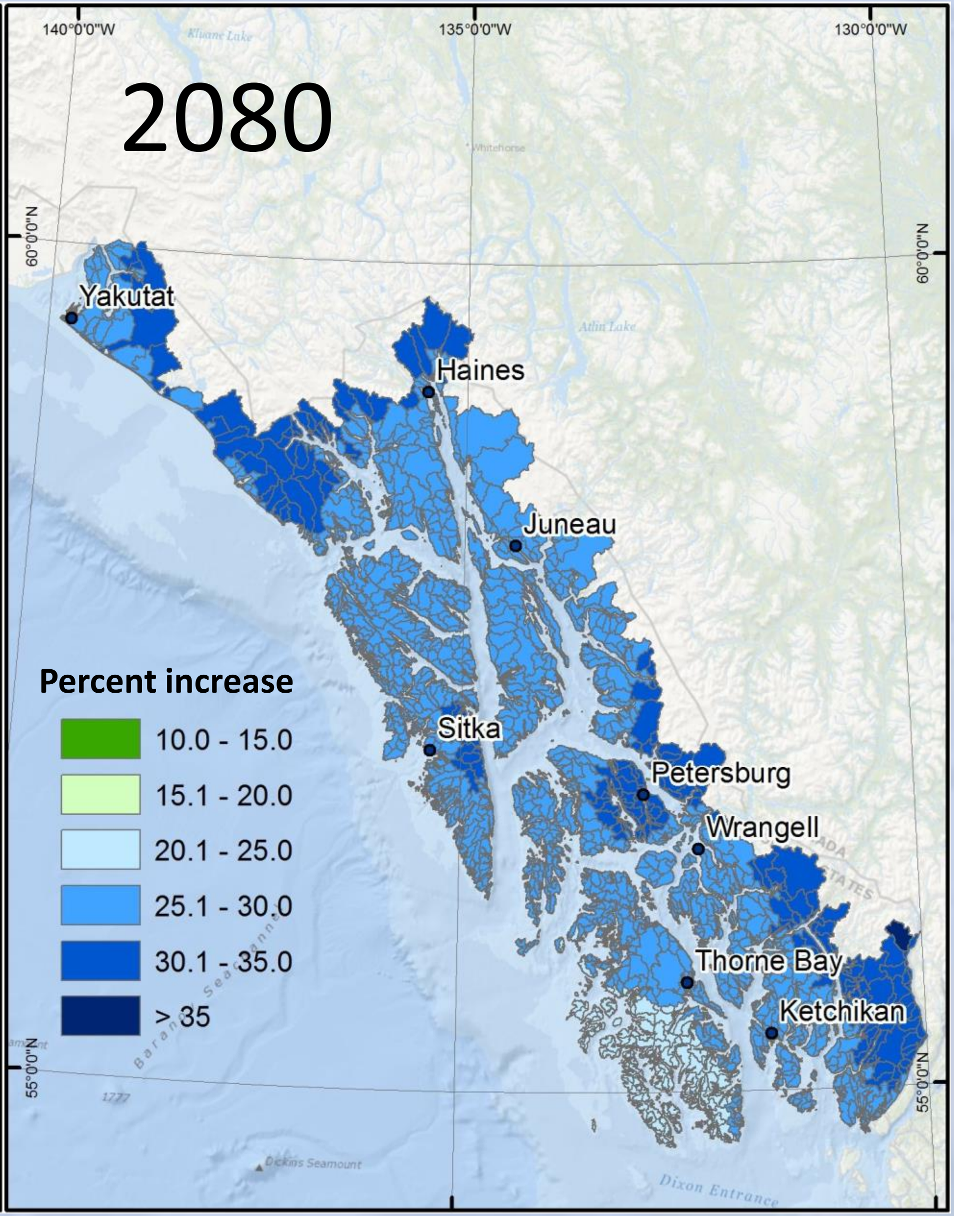
  Regional hydrologic model (Curran et al. 2003) to predict current and future mean annual flood size (a.k.a., “bankfull flood”, Q_2, 50% flood).

Why focus on mean annual floods?

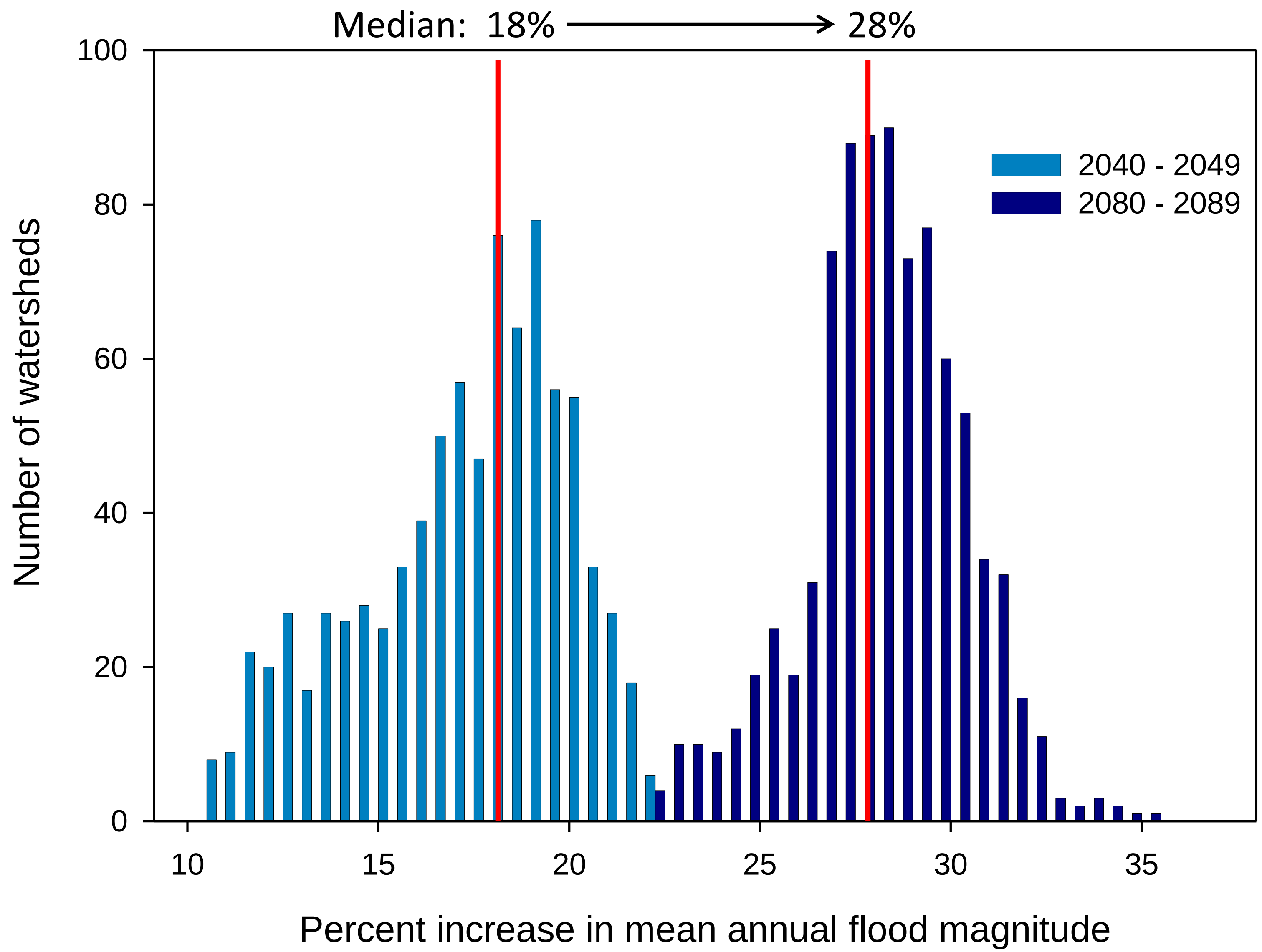
- Given enough time, rivers **construct their own channels**.
- A river channel is characterized in terms of its ***bank-full geometry***.
- ***Bank-full geometry*** is defined in terms of river width and average depth at ***bank-full discharge***.
- ***Bank-full discharge*** (~Q_2) is the flow discharge when the river is just about to spill onto its floodplain.
- Floods with this recurrence interval should have a pervasive influence on salmon populations, as opposed to less frequent, higher magnitude floods that may only impact individual cohorts.

A warmer, wetter future for SE AK will produce larger mean annual floods (Q_2)





A warmer, wetter future for SE AK will produce larger mean annual floods

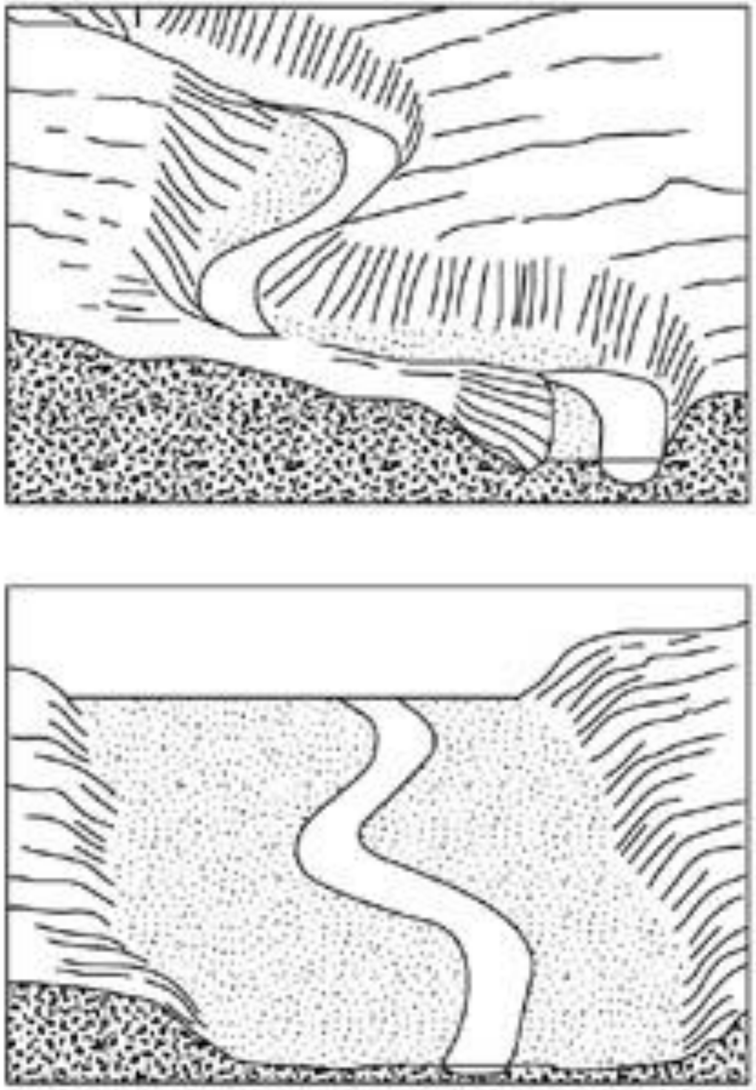


- What is their sensitivity to hydrologic change?

Substrate change (D50, scour) sensitive to changes in flow depth, not necessarily discharge.

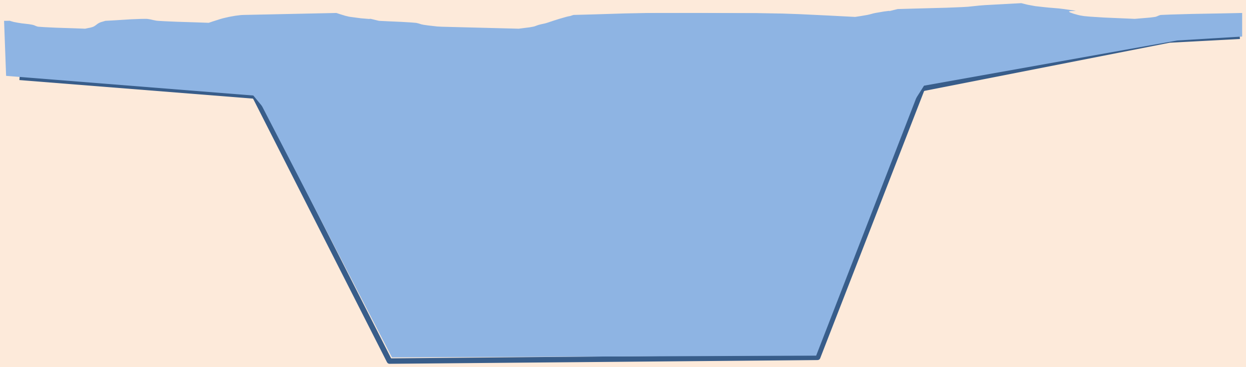
Need to understand reach scale variation in discharge-flow depth relationships.

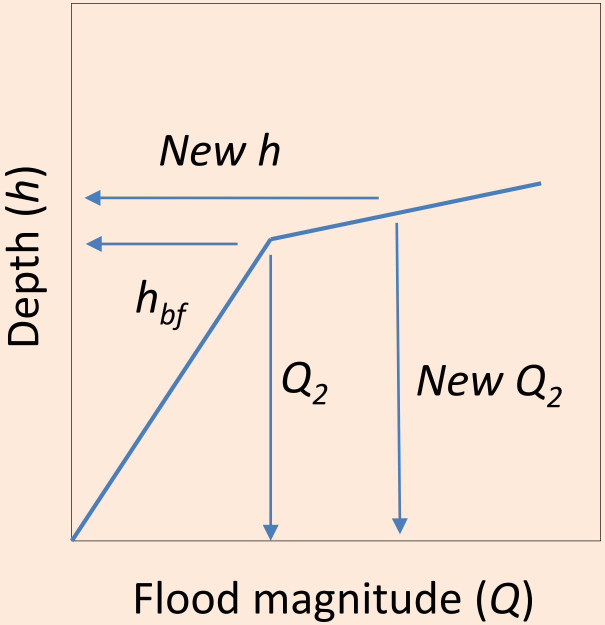
Confined (CO)



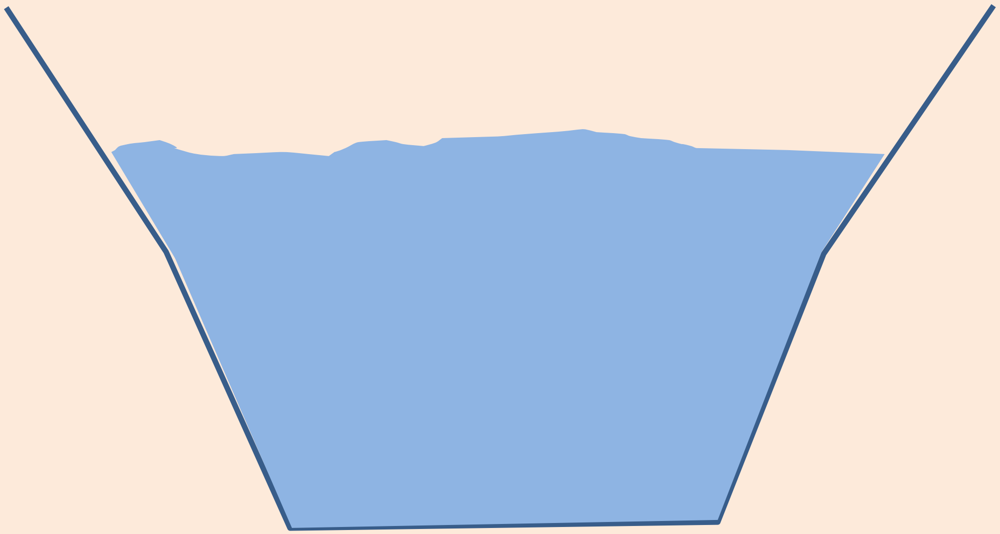
Unconfined (UN)

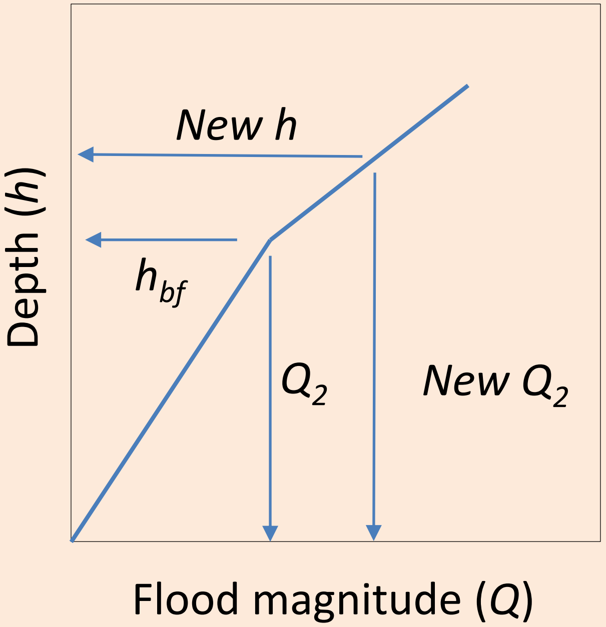
Static channel morphology
Unconfined channels





Static channel morphology
Confined channels

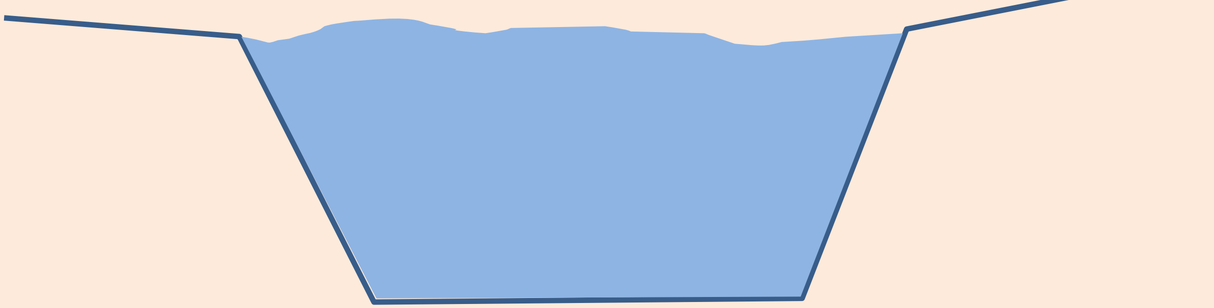


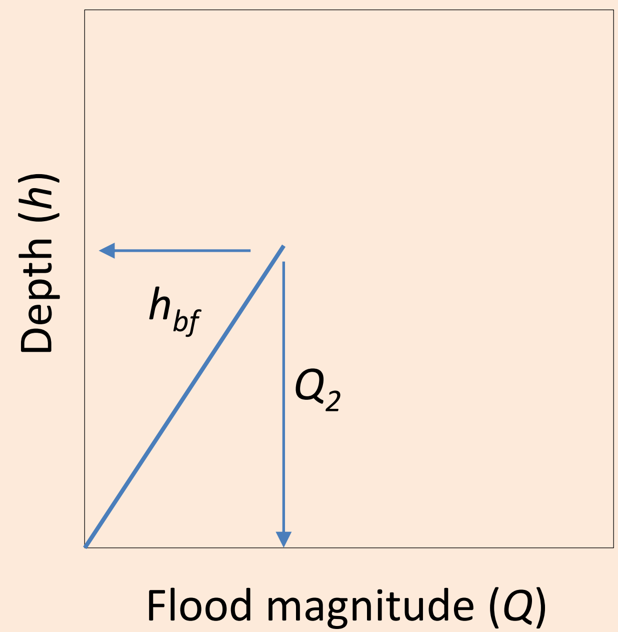


- What is their sensitivity to hydrologic change?

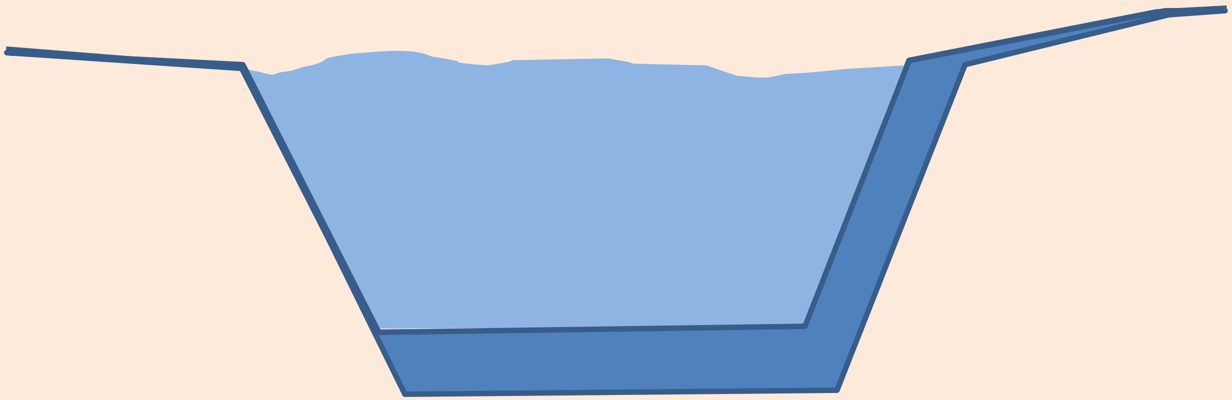
Channels may change in multiple dimensions.

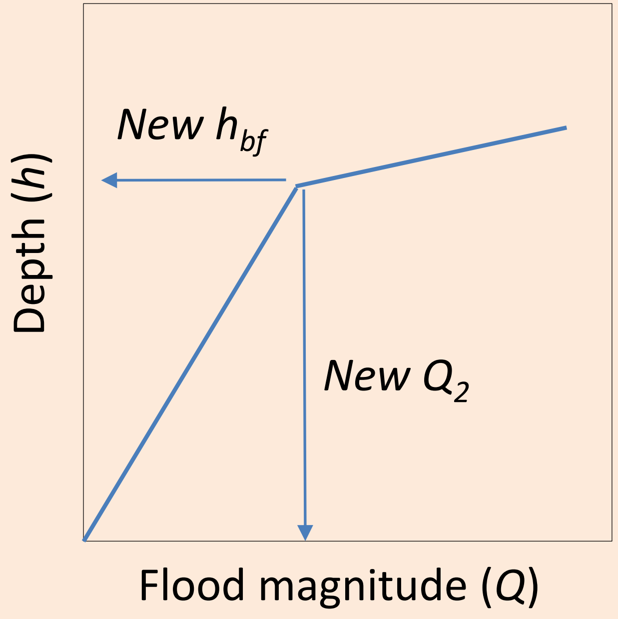
Dynamic channel morphology
Unconfined channels



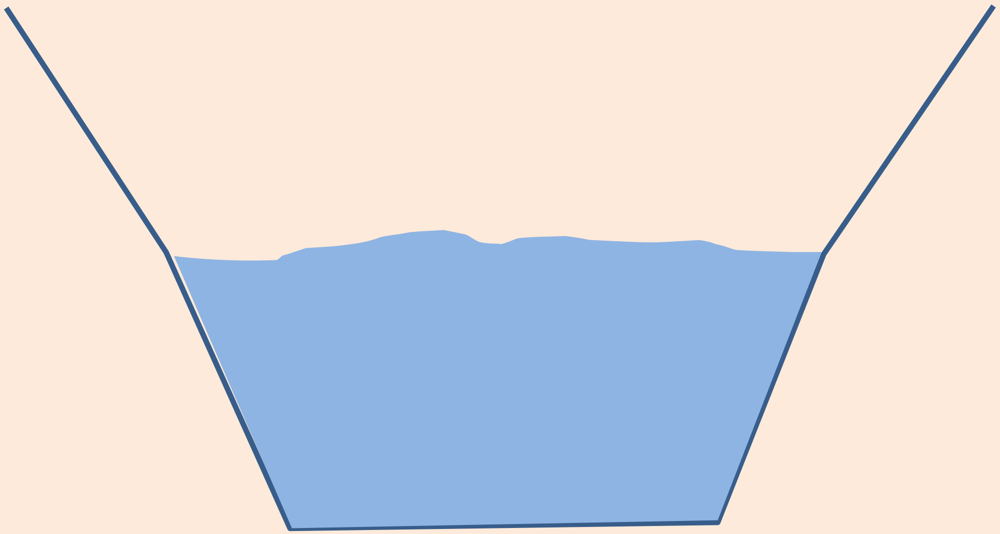


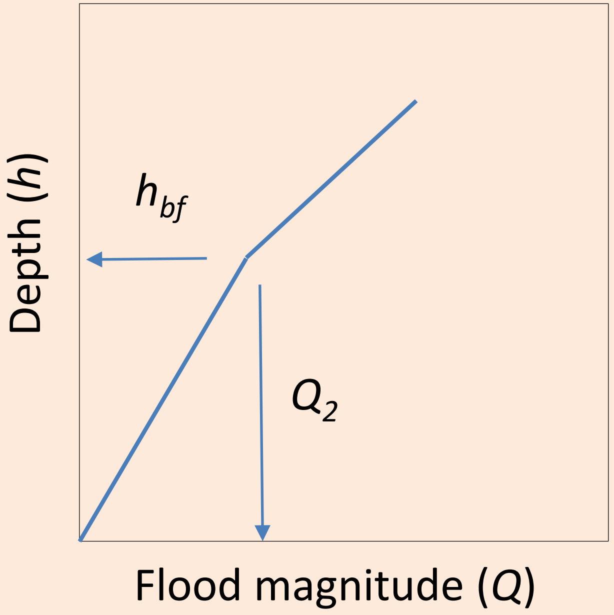
Dynamic channel morphology
Unconfined channels



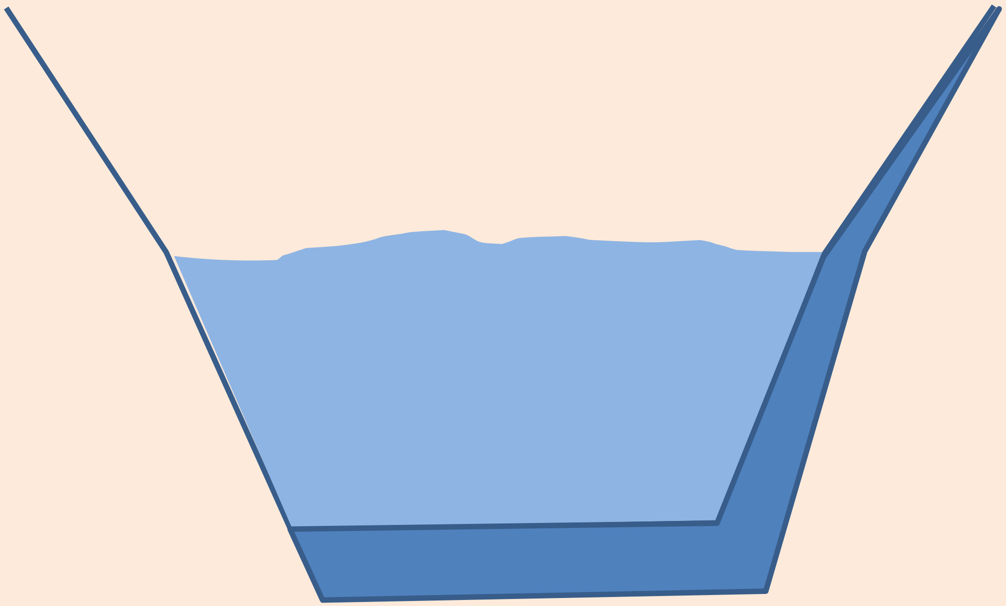


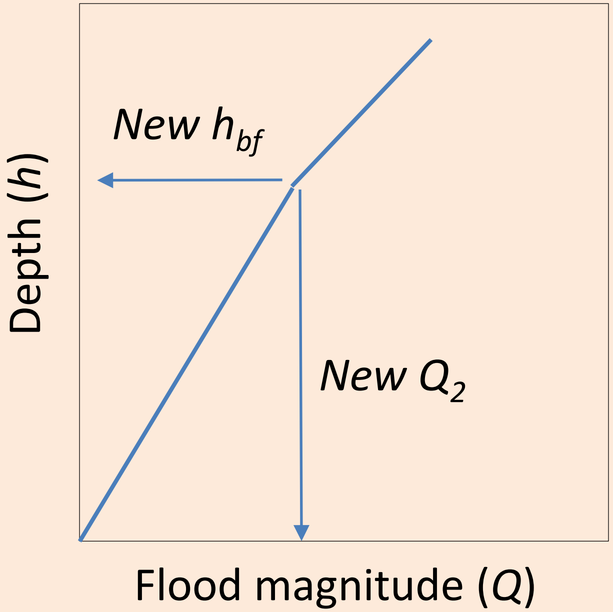
Dynamic channel morphology
Confined channels





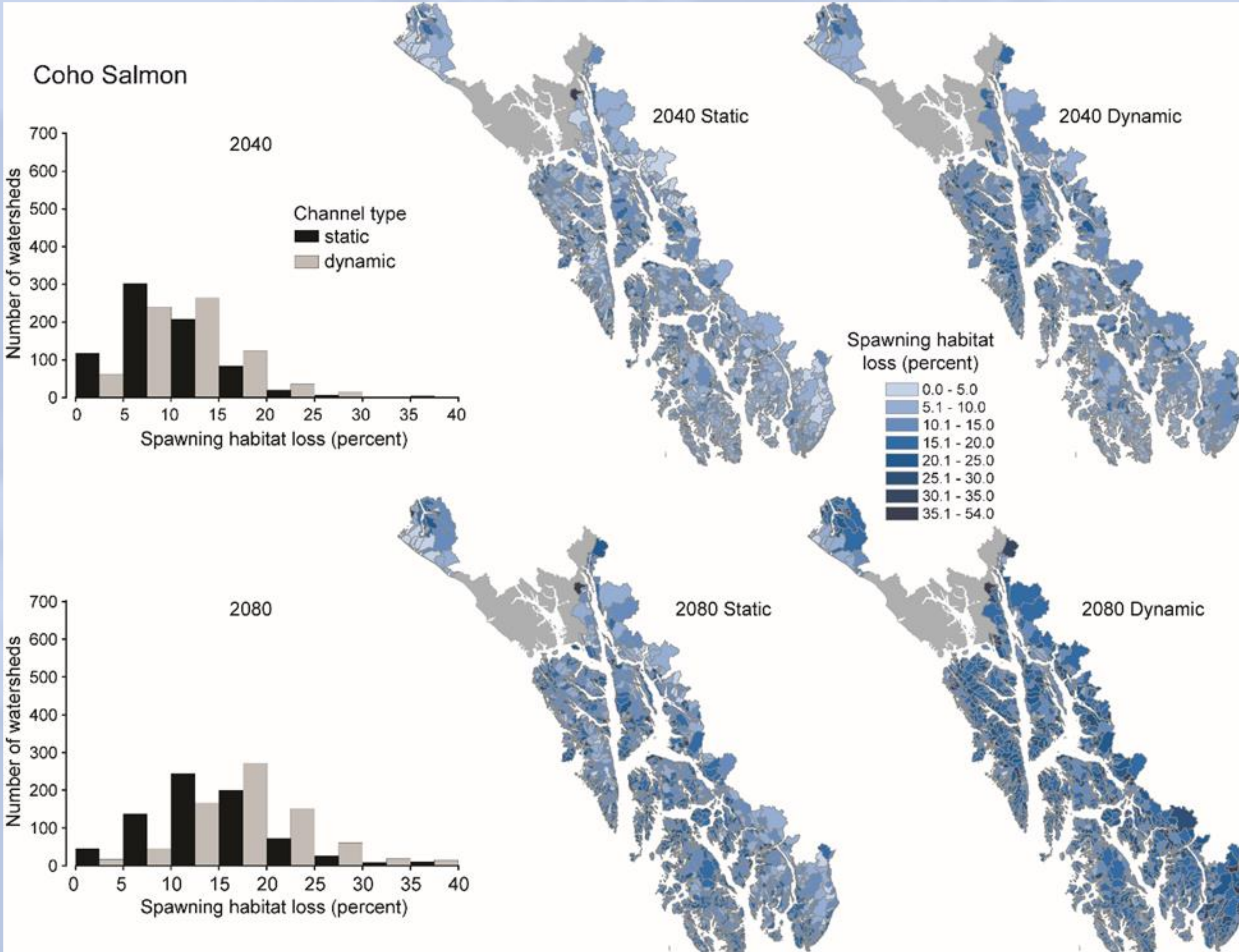
Dynamic channel morphology
Confined channels



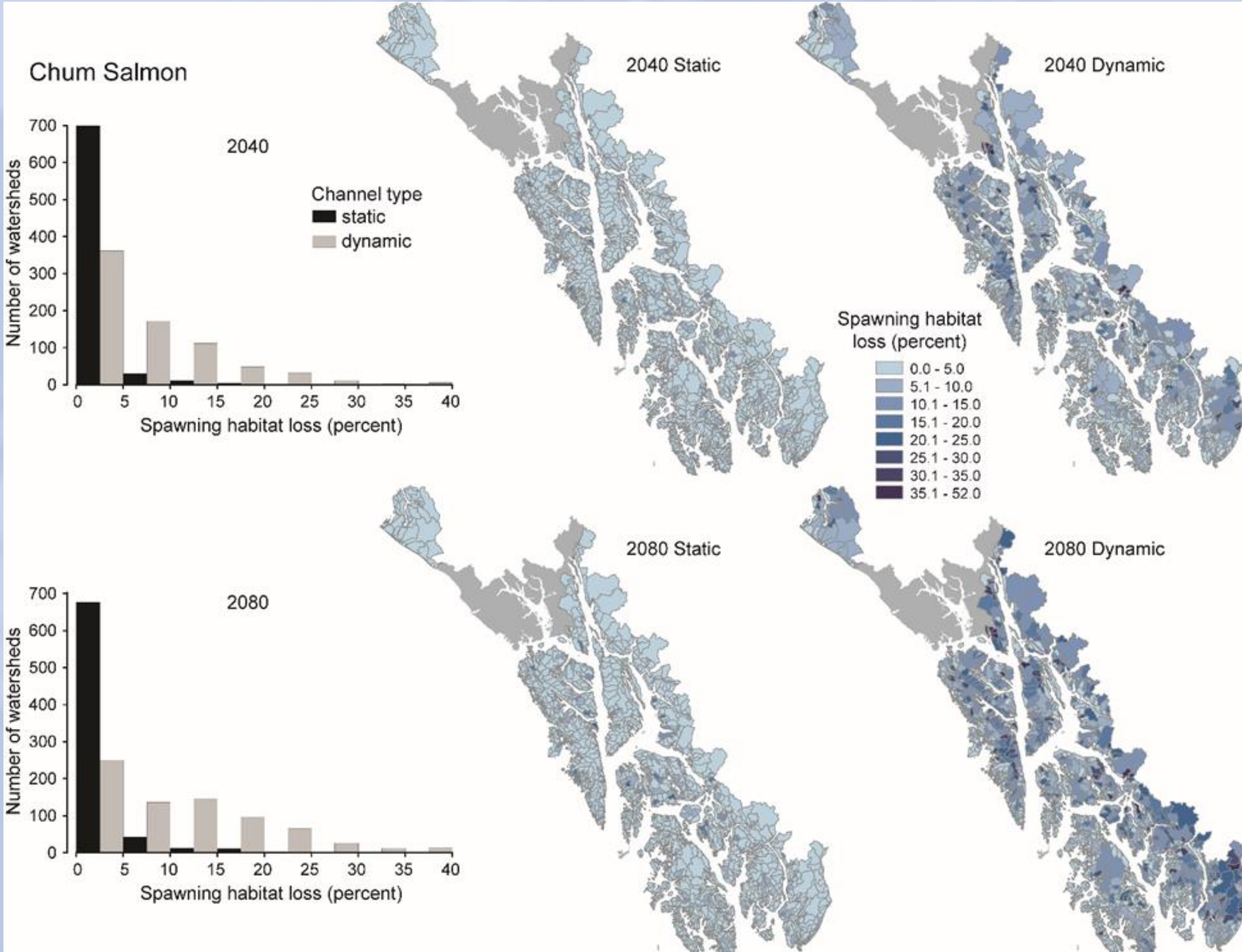


Scenarios

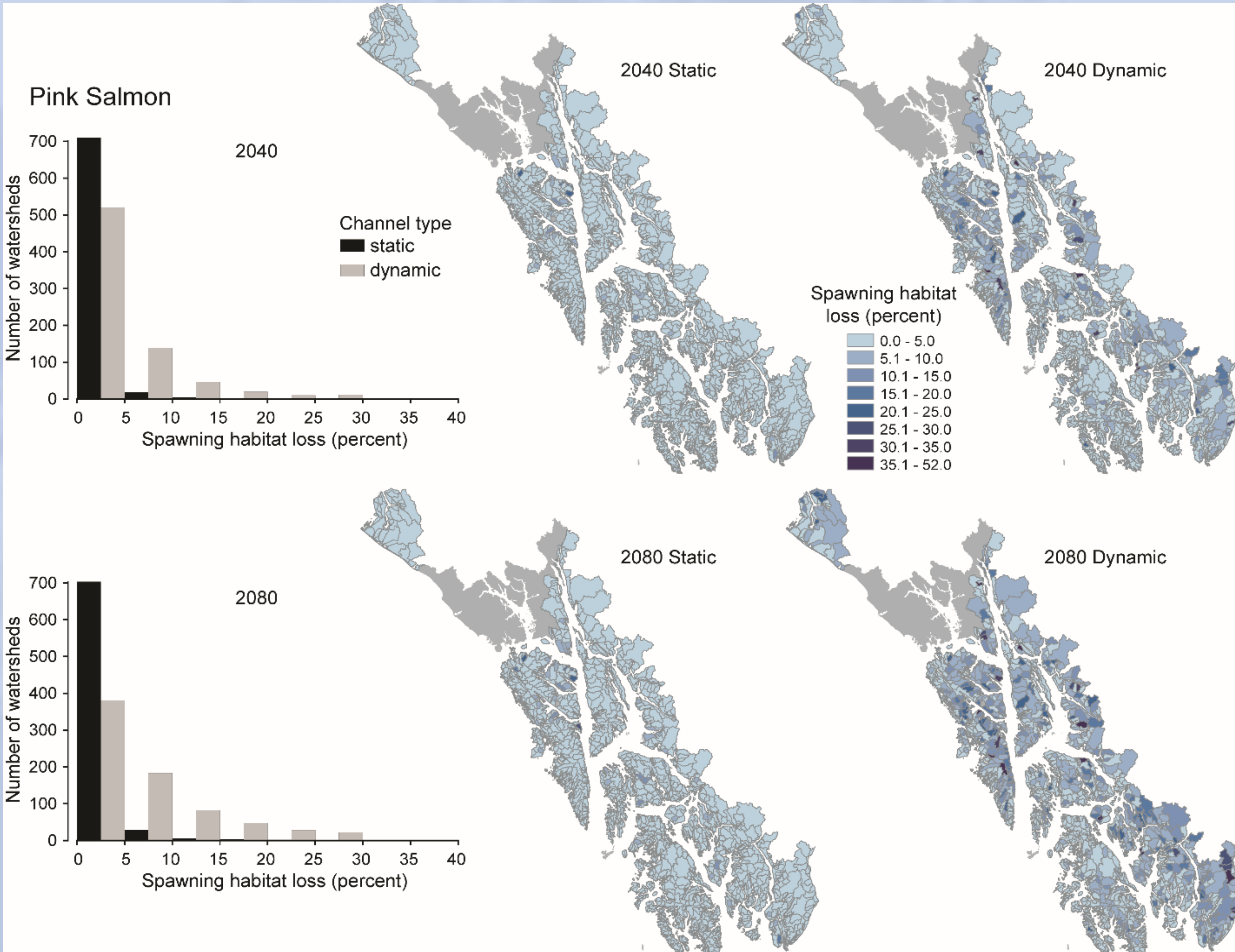
Static	Dynamic
Change in flow depth (h):	Change in flow depth (h):
Confined: h now << h future	Confined: h now < h future
Unconfined: h now = h future	Unconfined: h now < h future



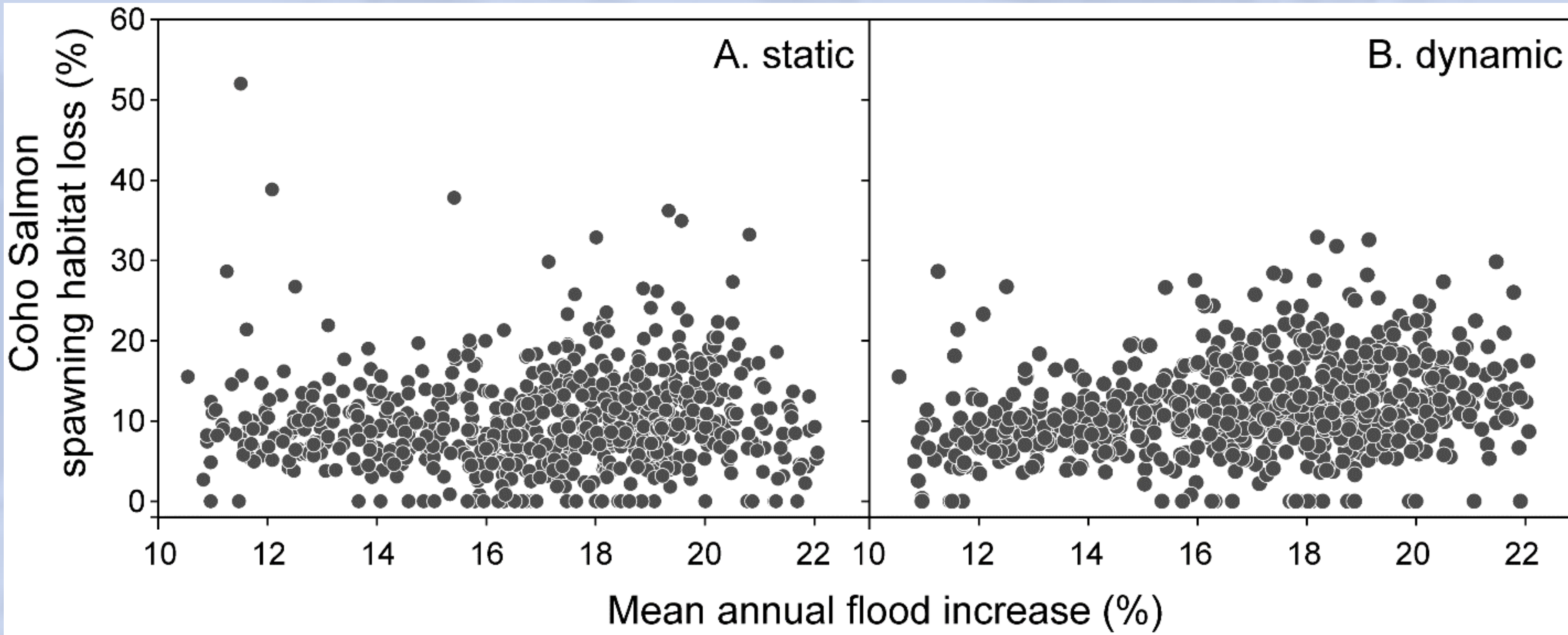
Coho Salmon
2040
2080
Number of watersheds
Spawning habitat loss (percent)
Channel type
static
dynamic
2040 Static
2040 Dynamic
2080 Static
2080 Dynamic
Spawning habitat loss (percent)
0.0 - 5.0
5.1 - 10.0
10.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 - 30.0
30.1 - 35.0
35.1 - 54.0

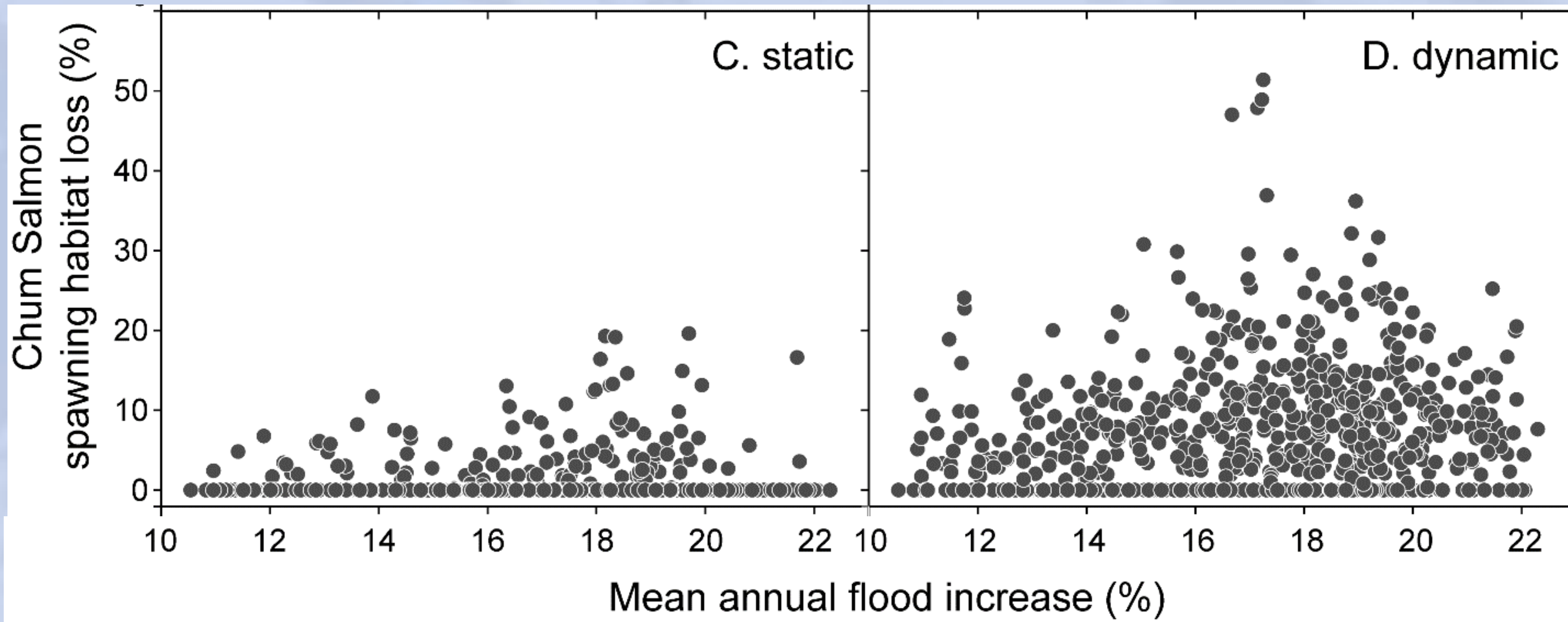


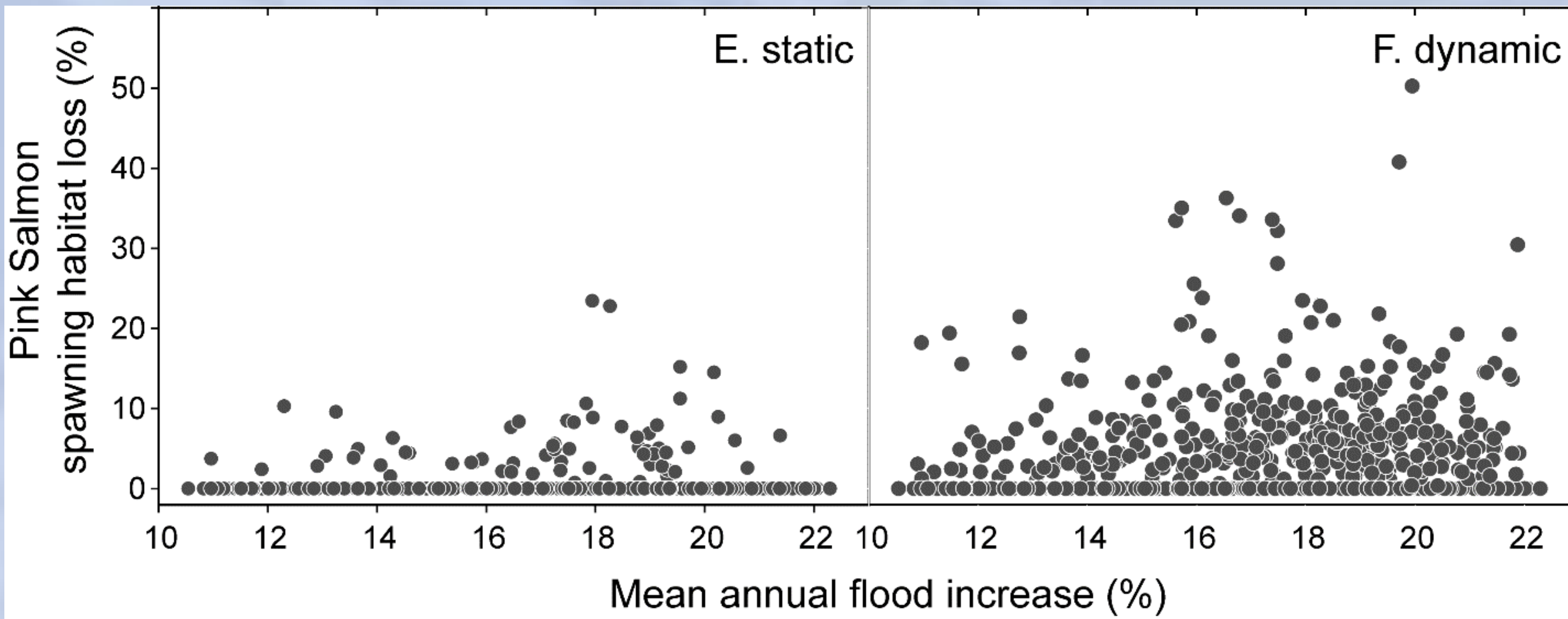
Chum Salmon
2040
Channel type
static
dynamic
Number of watersheds
Spawning habitat loss (percent)
2040 Static
2040 Dynamic
Spawning habitat loss (percent)
0.0 - 5.0
5.1 - 10.0
10.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 - 30.0
30.1 - 35.0
35.1 - 52.0
2080
2080 Static
2080 Dynamic



Pink Salmon
2040
2080
Number of watersheds
Spawning habitat loss (percent)
Channel type
static
dynamic
0
100
200
300
400
500
600
700
0
5
10
15
20
25
30
35
40
2040 Static
2040 Dynamic
2080 Static
2080 Dynamic
Spawning habitat loss (percent)
0.0 - 5.0
5.1 - 10.0
10.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 - 30.0
30.1 - 35.0
35.1 - 52.0


A. static
B. dynamic
Coho Salmon spawning habitat loss (%)
Mean annual flood increase (%)
0
10
20
30
40
50
60
10
12
14
16
18
20
22


C. static
D. dynamic
Chum Salmon spawning habitat loss (%)
Mean annual flood increase (%)
0
10
20
30
40
50
10
12
14
16
18
20
22


E. static
F. dynamic
Pink Salmon spawning habitat loss (%)
Mean annual flood increase (%)
0
10
20
30
40
50
10
12
14
16
18
20
22

Conclusions:

- Mean annual flood magnitudes may increase ~18% and 28% by the 2040s and 2080s (high spatial variability).
- Exposure to flow change is not necessarily a good measure of vulnerability.
- Expect high response diversity largely driven by topographic and geomorphic complexity and species habitat preferences.
- Geomorphic context is extremely important for understanding stream habitat vulnerability to climate change.

Next steps?

- Framework can accommodate improved data quality.
- Incorporation into life cycle models.
- Integration with other disturbance models (stochastic input of sediment and wood, etc.).