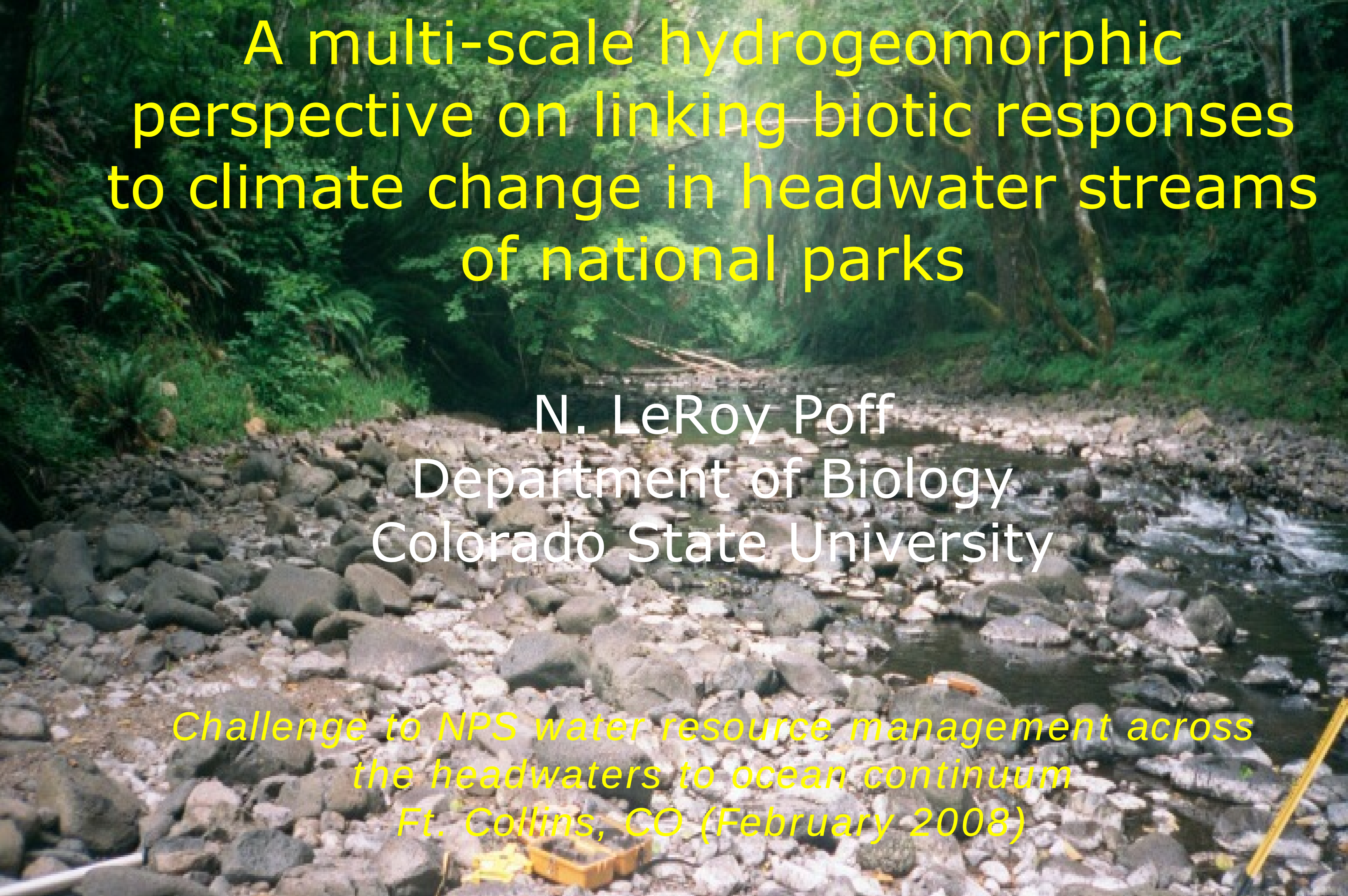


A multi-scale hydrogeomorphic perspective on linking biotic responses to climate change in headwater streams of national parks

N. LeRoy Poff
Department of Biology
Colorado State University

Challenge to NPS water resource management across the headwaters to ocean continuum
Ft. Collins, CO (February 2008)

Basic Question: How to predict species distribution and community composition in stream habitats?

Key Premise:

Species succeed when their biological attributes are well matched to the local environment.

Approach:

- Define environmental template
- Identify key biological attributes
- “Mechanistic” environment-response relationship

Aquatic insects
Variety of morphological, life history, tolerance traits
“mechanistically” to environmental drivers?

Stream communities

Can be defined in terms of …

- Species identities / taxonomy (e.g., diversity)
- "Functional" composition
  - IDEA: Characterize the ***traits*** of species in the community, rather than the taxonomic identity.

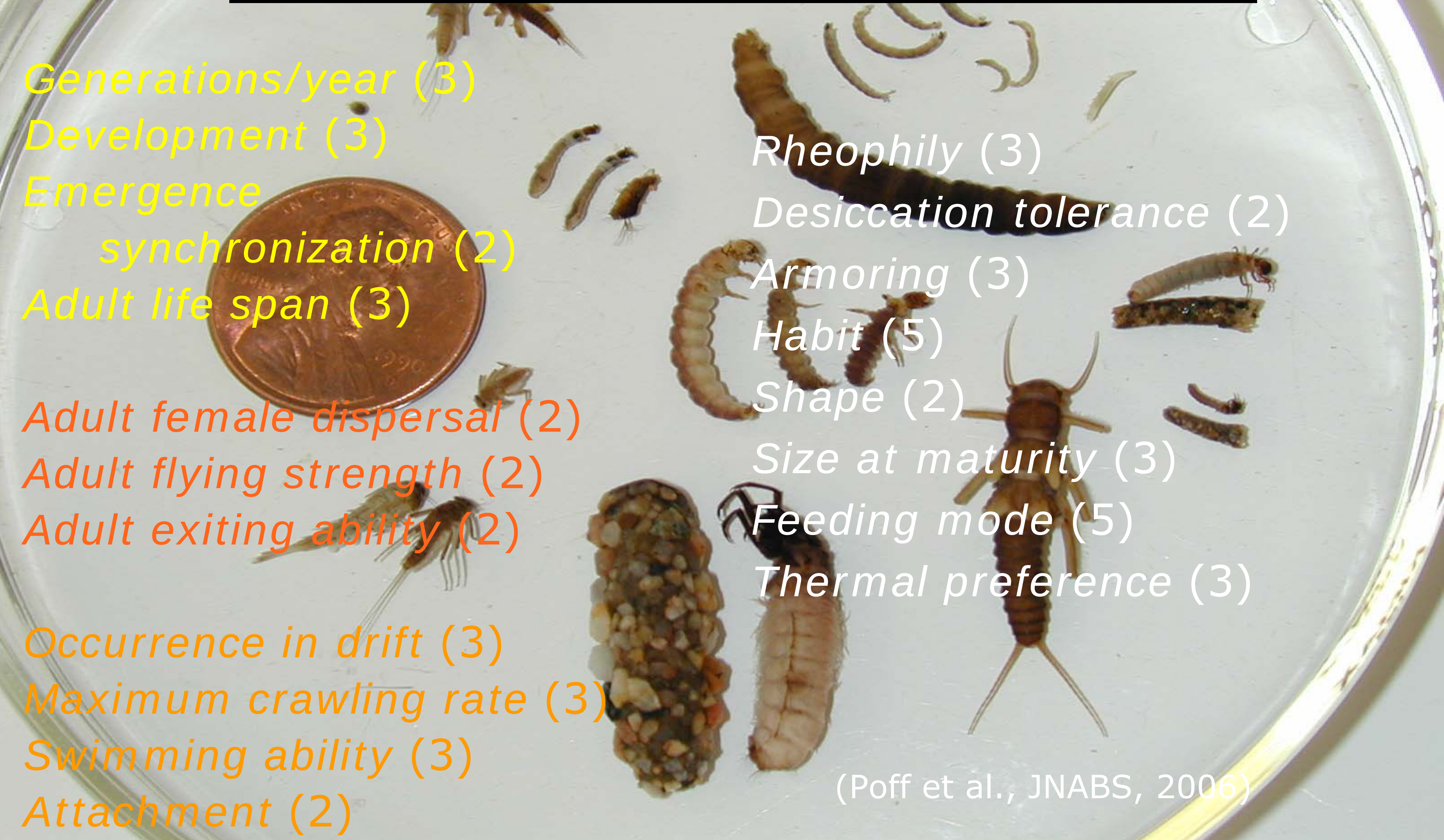
ADVANTAGES:

- Traits related directly to environmental forces, thus provide "mechanistic" basis for prediction
- Traits can be applied across biogeographic boundaries (i.e., many spatial and taxonomic scales)

Examples:

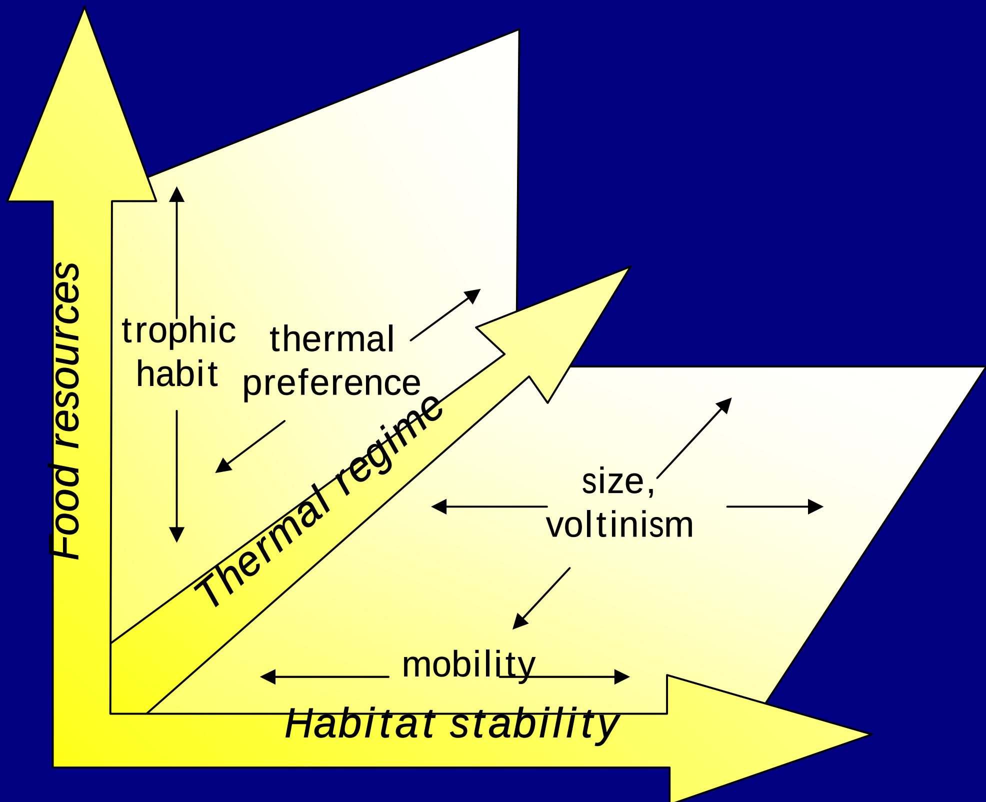
- Functional Feeding Groups
- Tolerance to environmental stressors, such as high temperature, disturbance, etc.

Traits for North American lotic insects
(19 traits; 54 states, or 'modalities')



Key Environmental Drivers
- Habitat structure & dynamics
- Temperature
- Food resources

Species responses
- What traits should vary "mechanistically"?



Trait responses along environmental gradients

(Poff et al., JNABS, 2006)

The environmental template is multi-scaled!

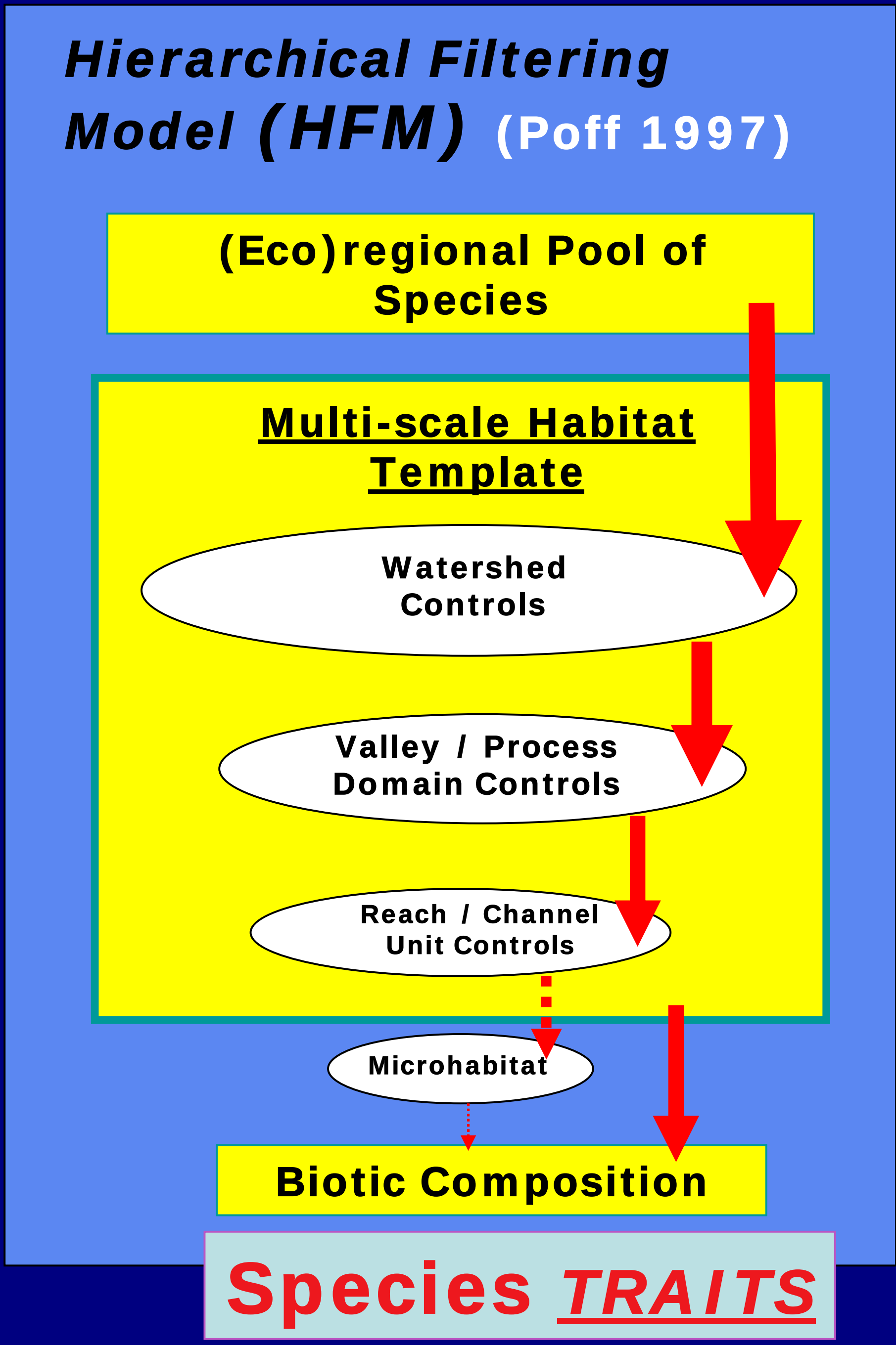
For example:

Watershed geology constrains local flow regime and geomorphology

Watershed climate regulates local hydrologic regime and water temperature

Prediction: Habitats with similar sets of multi-scale filters should have species with similar attributes

(Assuming dispersal, minimal biotic interactions)



Watershed geology:

Can influence sediment production, stream peak flow and baseflow characteristics, water temperature and chemistry at the local site scale.

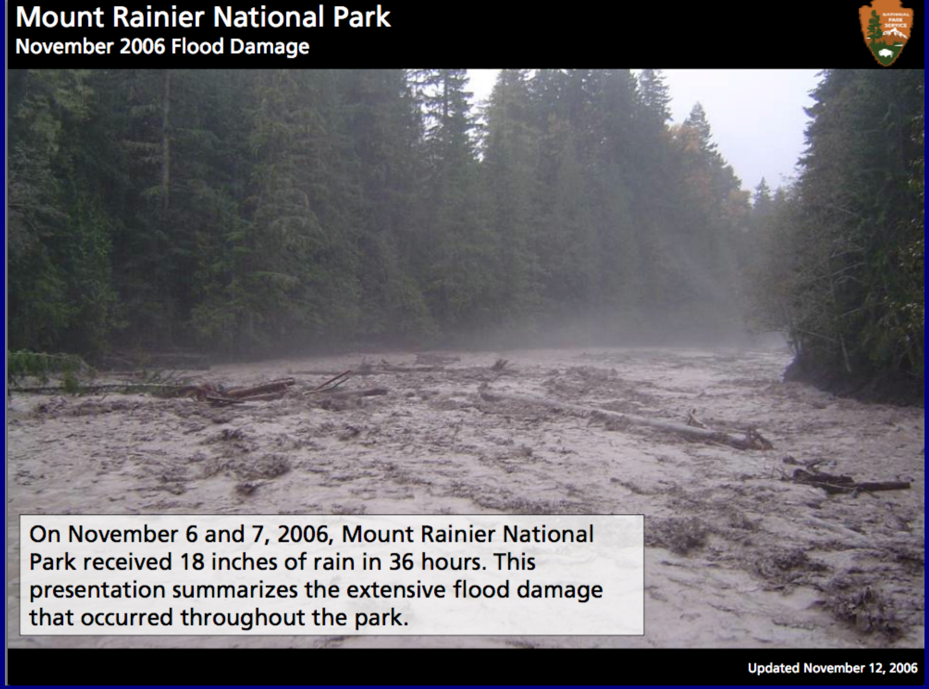
(Here, 2 undisturbed streams in Oregon Coast Range.)

Hydrogeomorphic (HGM) Perspective

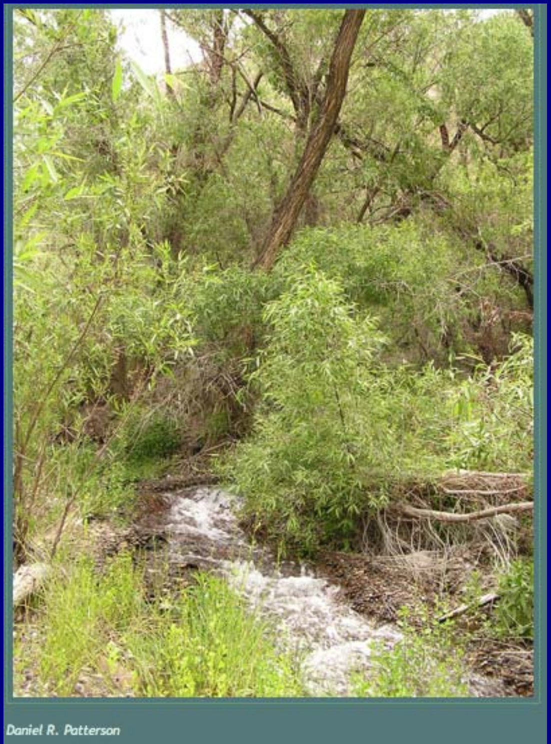
- Physical habitat *interacts* with flow regime to define the structure and dynamics of local habitat.

- **Disturbance** is a key process dictating species success and organizing biological communities in stream systems.

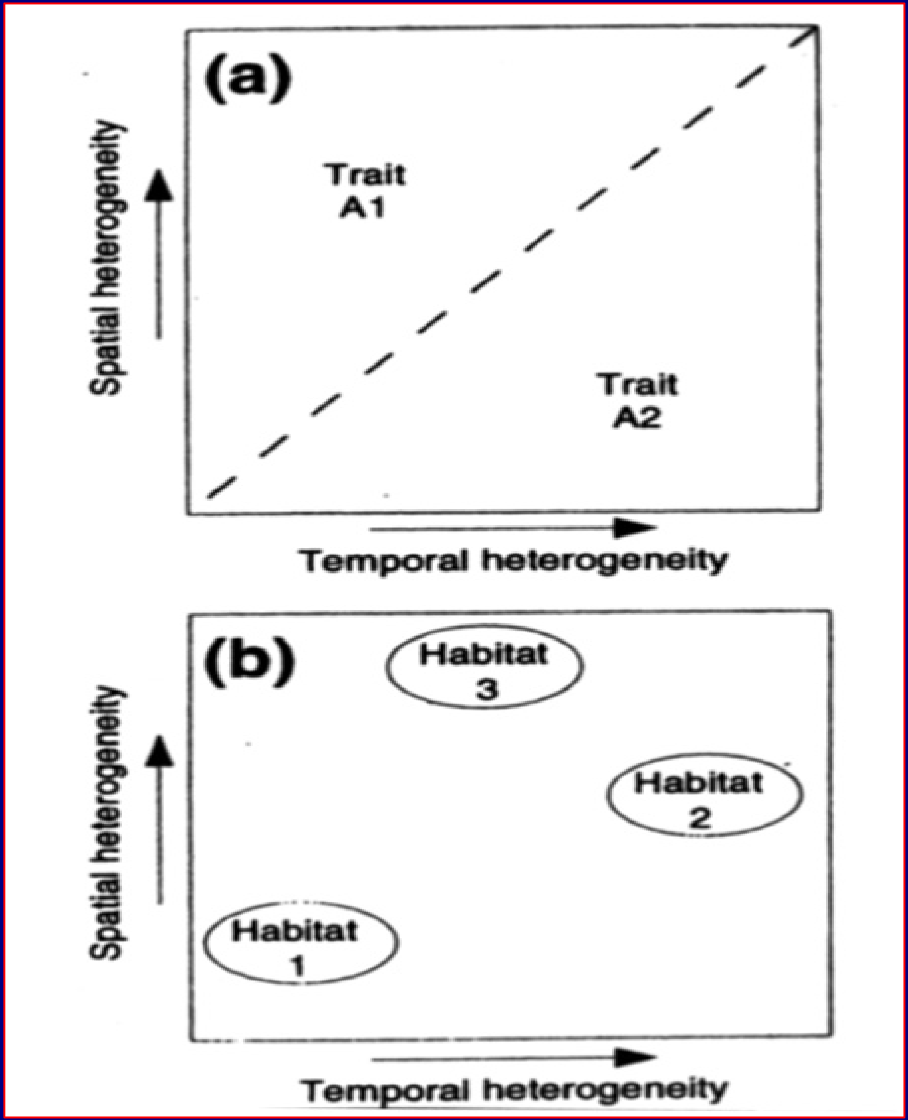
- High flows and low flows, their timing and duration act as natural selective agents on aquatic (and riparian) species.


Mount Rainier National Park
November 2006 Flood Damage
On November 6 and 7, 2006, Mount Rainier National Park received 18 inches of rain in 36 hours. This presentation summarizes the extensive flood damage that occurred throughout the park.
Updated November 12, 2006


Mount Rainier National Park
November 2006 Flood Damage
Former shoreline
8 3:45PM
An aerial view of the former Sunshine Point Campground


Daniel R. Patterson

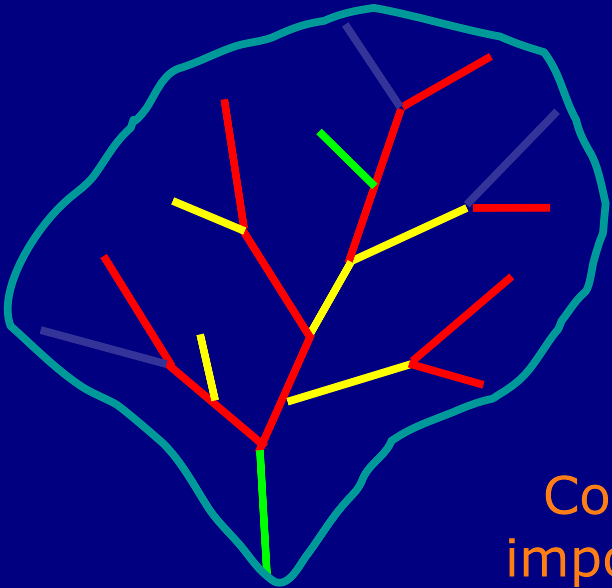
Ecological Theory and Disturbance



(Townsend & Hildrew, Freshwater Biology, 1994)

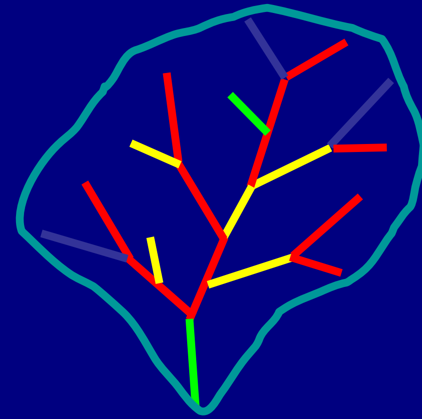
Biological characteristics will vary across hydro-geomorphic units.

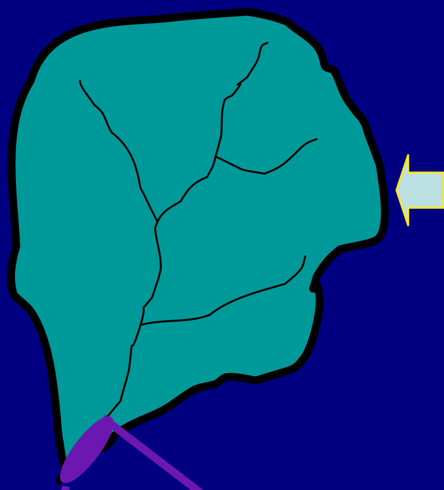
Example: Pool-riffle reach within a low energy, sediment rich subbasin vs. high energy, sediment poor subbasin)



Connectivity important also!

Describe spatial variation in HGM templates





Precipitation
Temperature
Geology
Land cover

Change with
Geographic Setting

Species success and community structure

Local habitat structure and dynamics

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R82863601

WATERSHED SCALE (15)

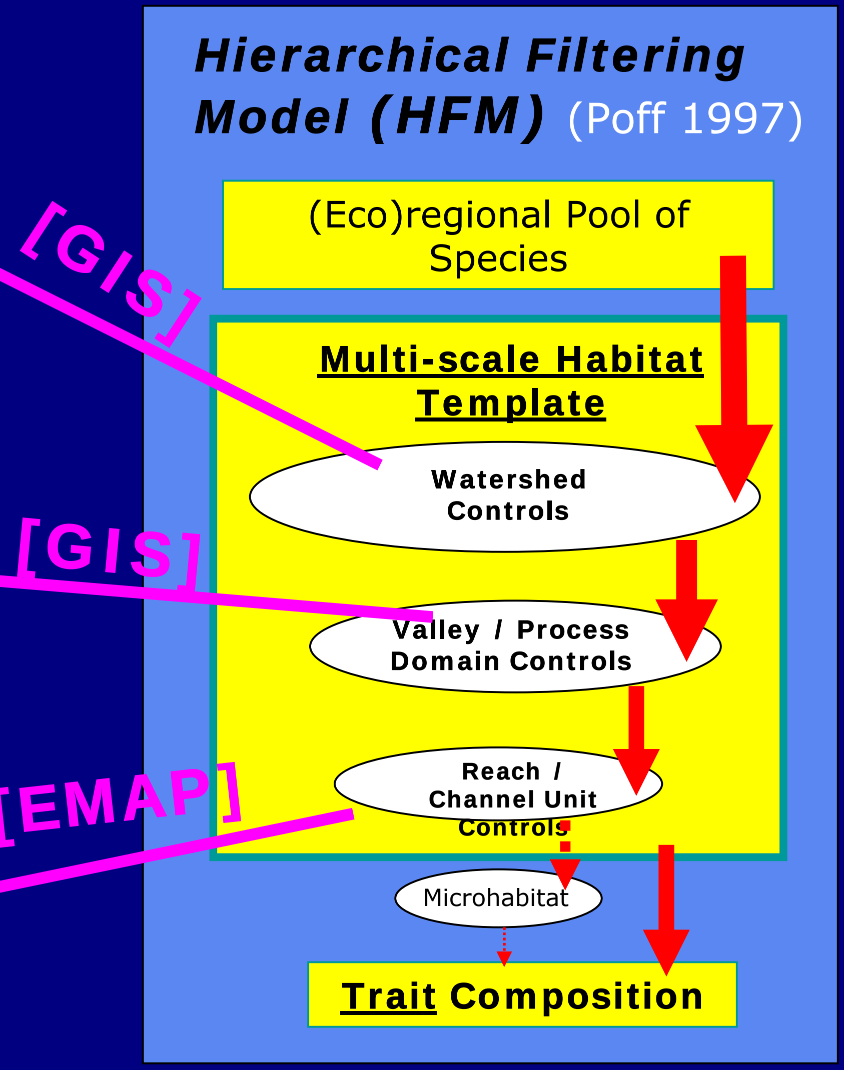
- Geomorphic (2)
- Geology (3)
- Climate (3)
- Hydrology (4)
- Land Use (3)

VALLEY (link) SCALE (7)

- Geomorphic (4)
- Land Use (3)

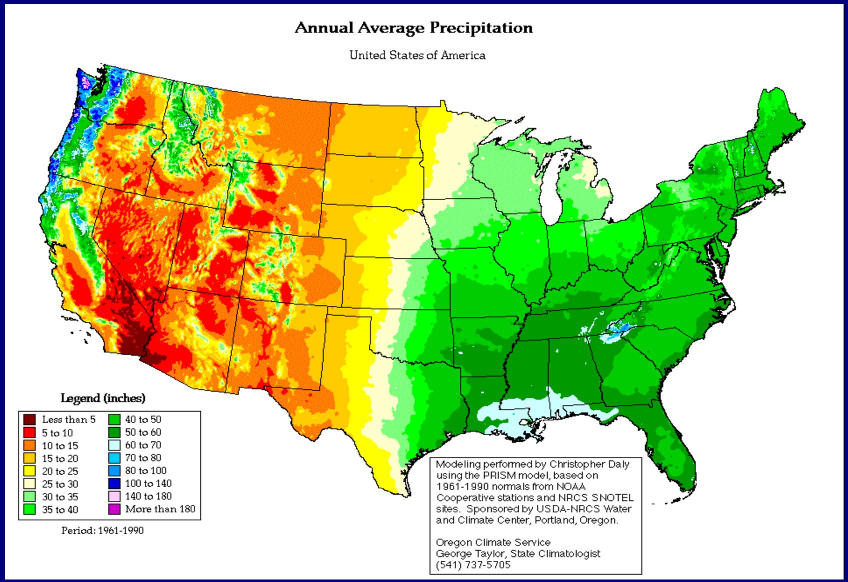
REACH SCALE (11)

- Geomorphic (4)
- Riparian (3)
- Substrate (4)

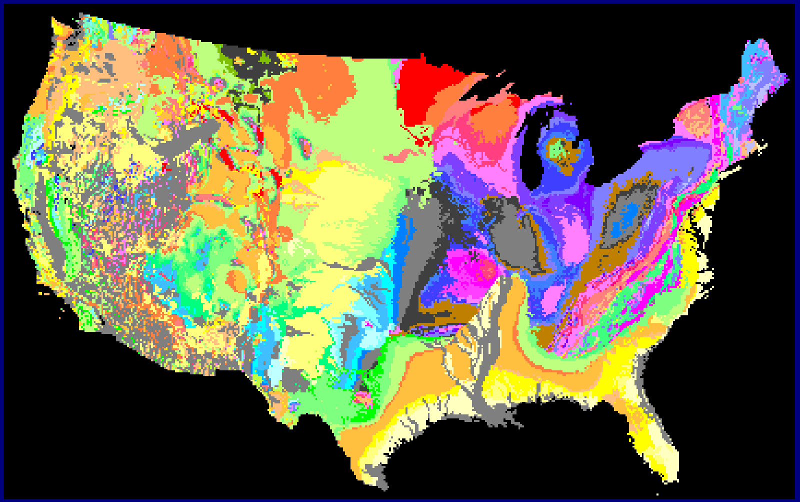


Geographic variation in flow regimes

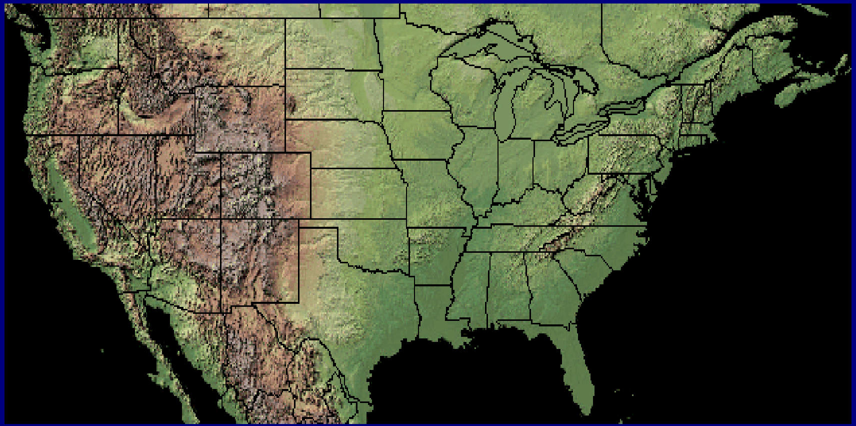
Precipitation (1961-1990)



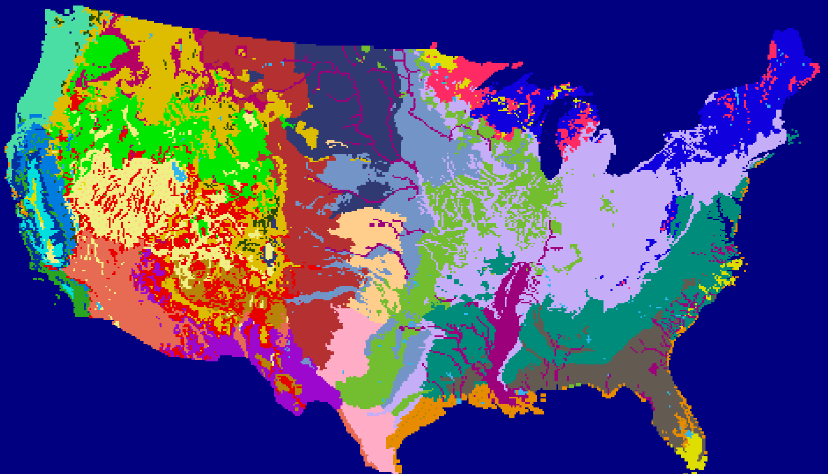
Geology



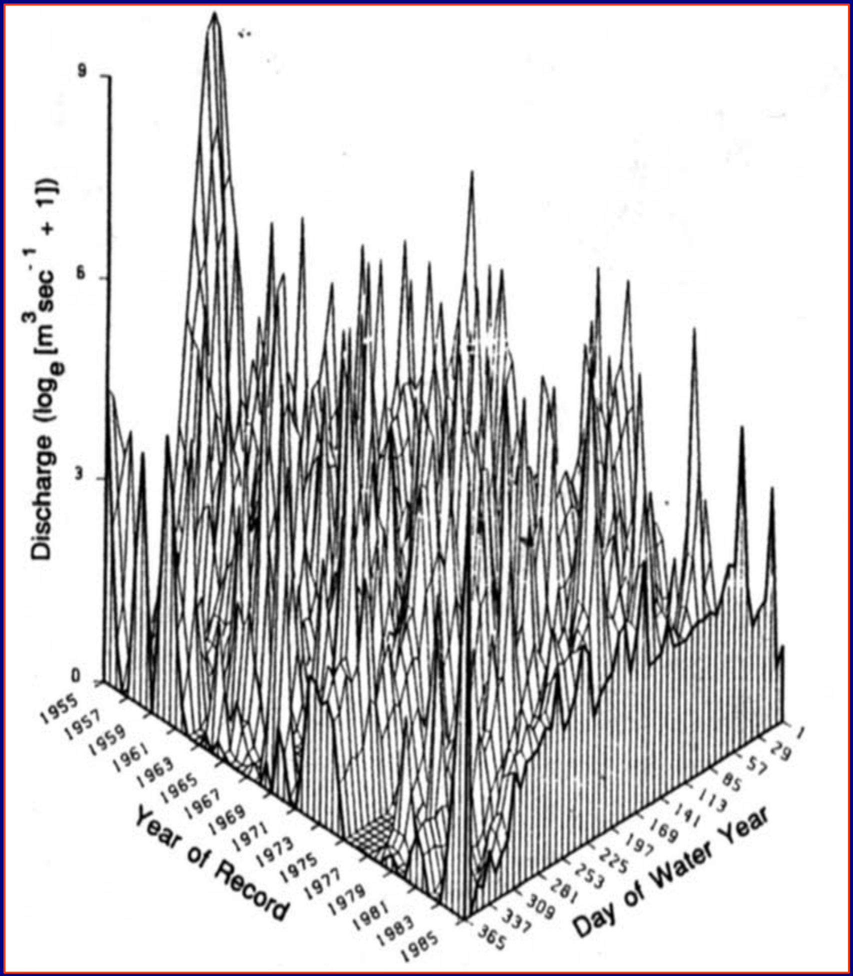
Topography



Vegetation



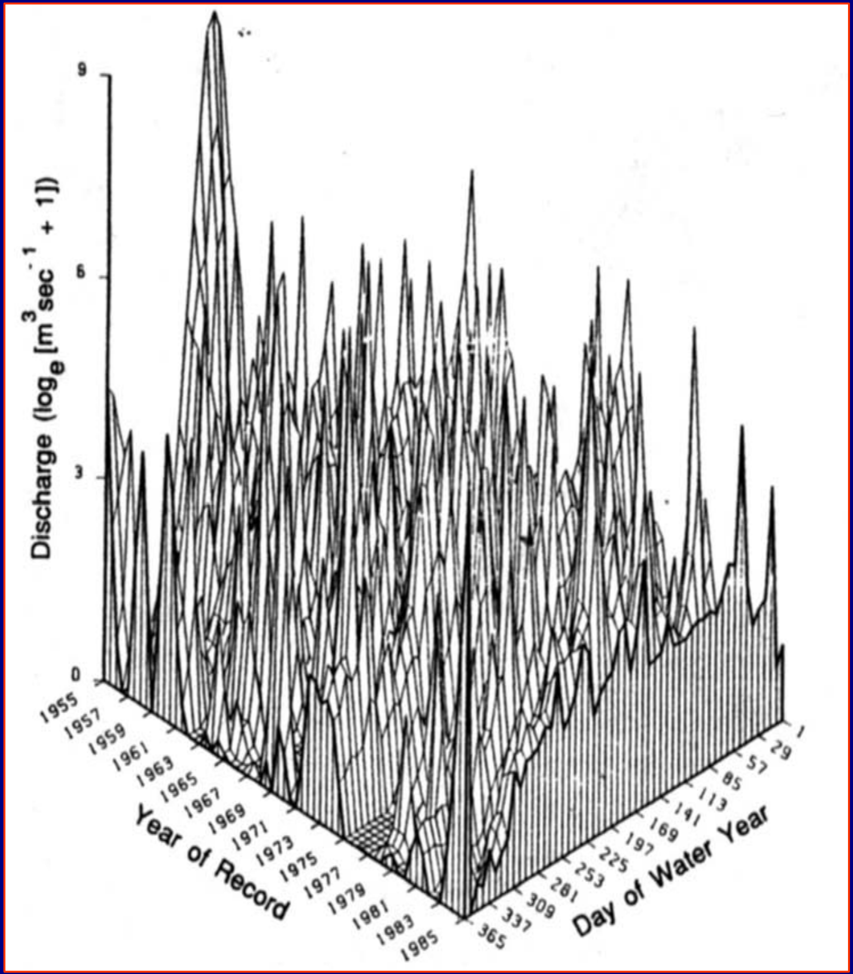
Streams differ in natural flow regimes

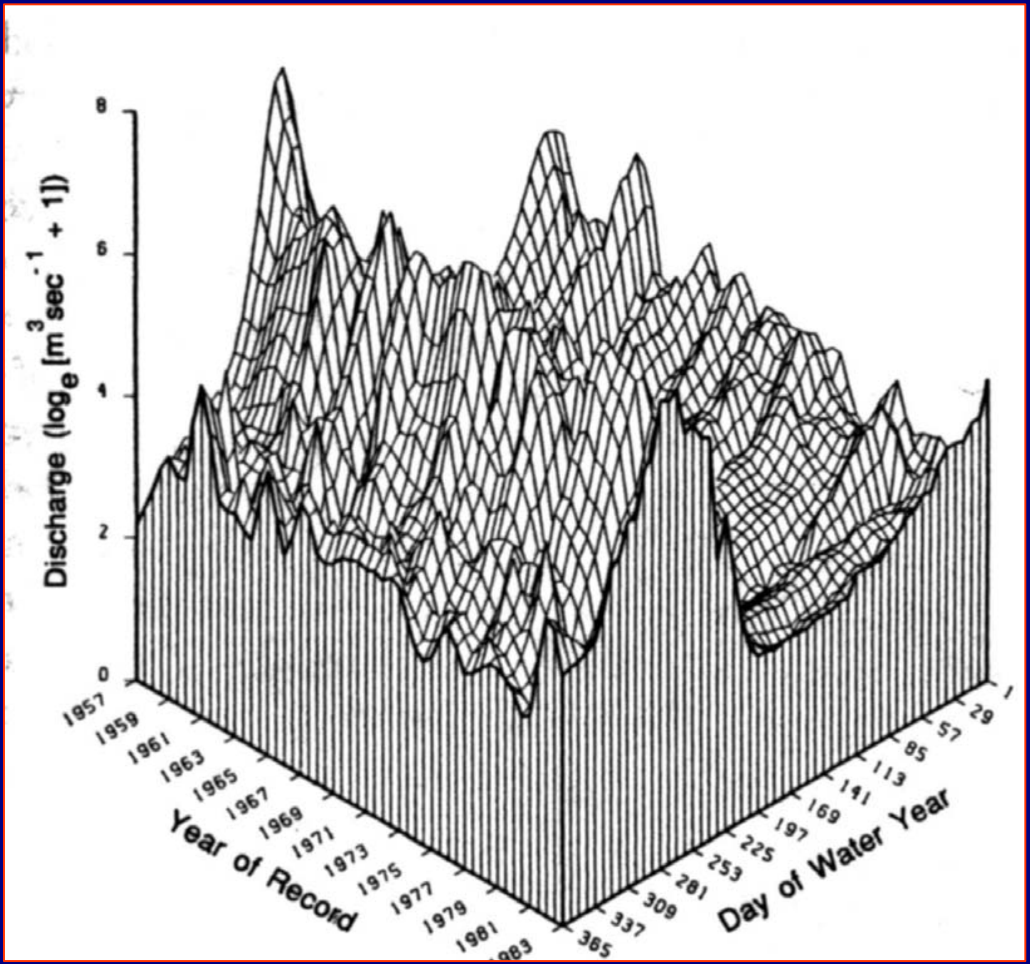


Components of flow regime

- magnitude
- frequency
- duration
- timing (predictability)
- rate of change

Streams differ in natural flow regimes

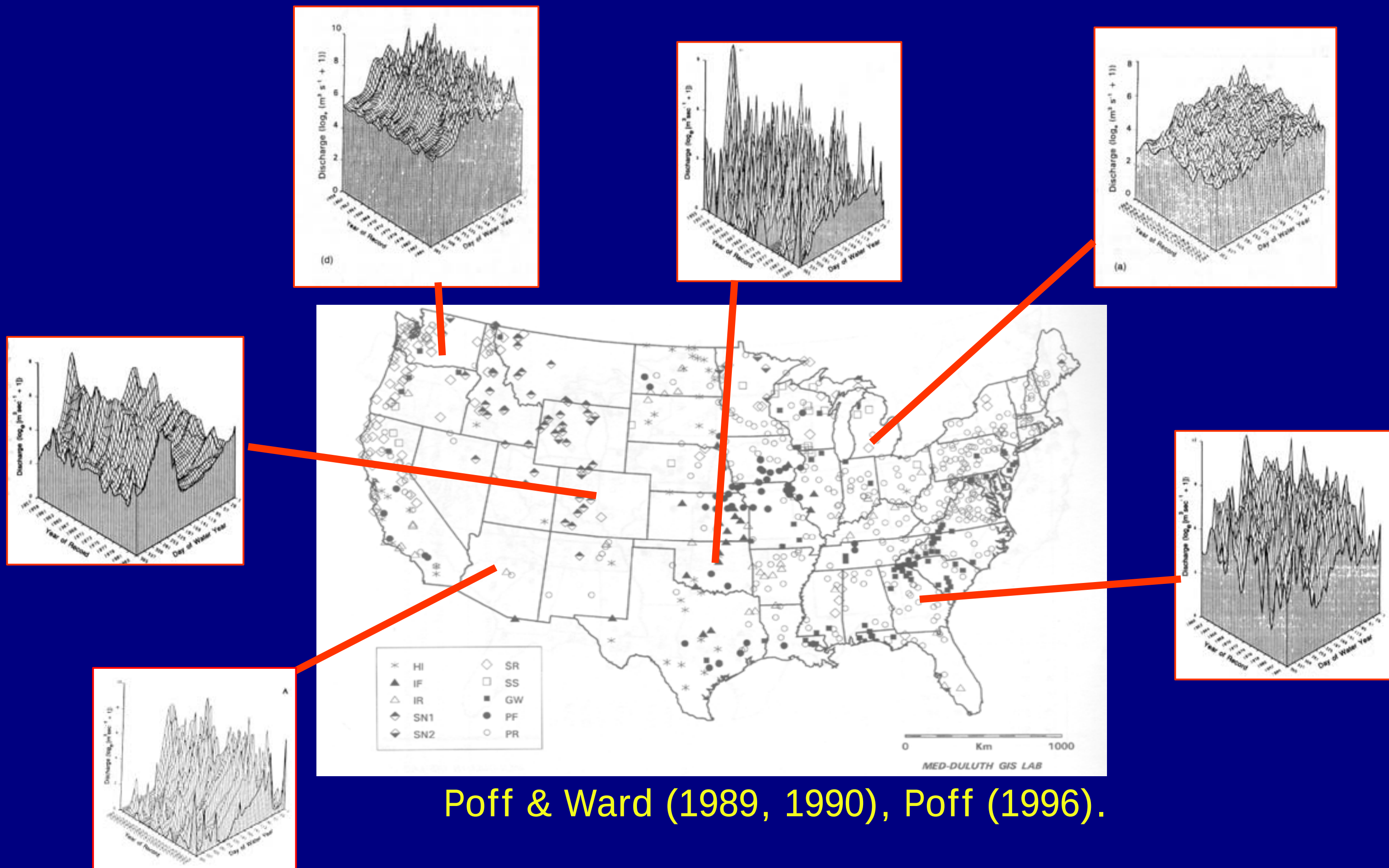




Hydrogeogrpahy of natural flow regimes in U.S.

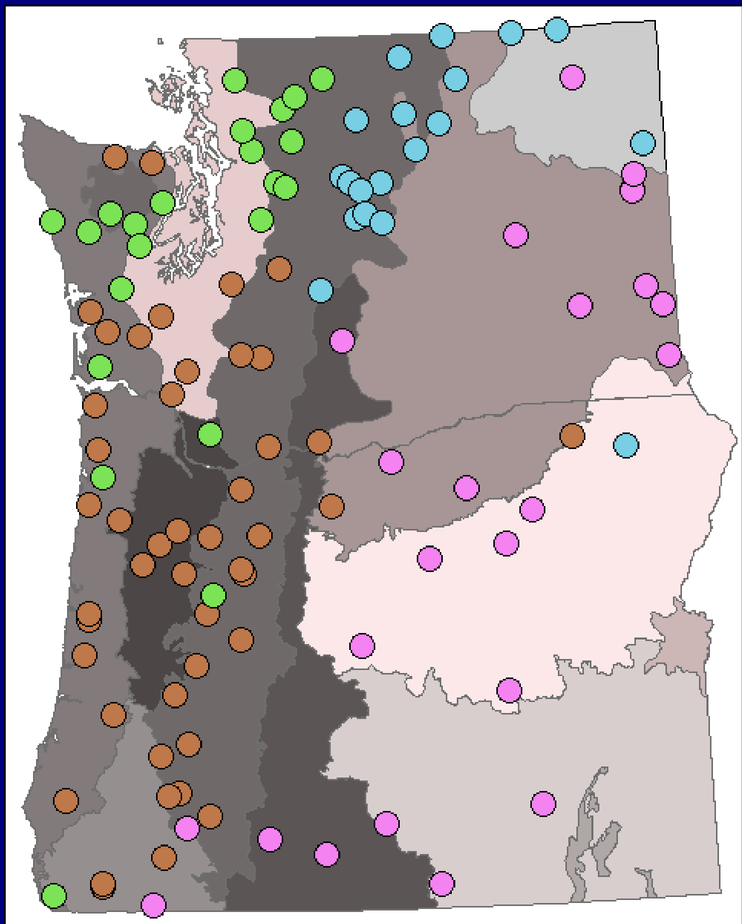
–Extract statistical variables from long-term hydrographs to estimate components of disturbance regime

–Classify types of natural disturbance regimes to provide foundation for a priori ecological predictions



Poff & Ward (1989, 1990), Poff (1996).

More regional scale

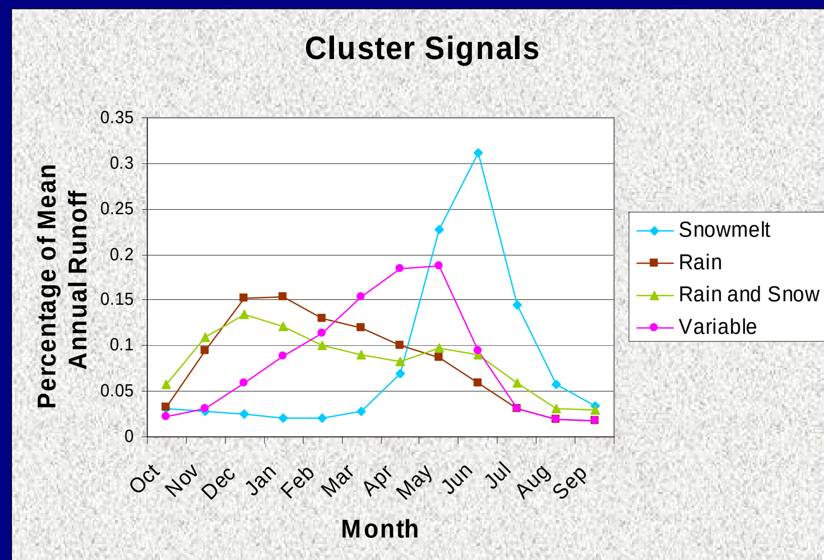


Flow Regime Type

USGS Gauging Stations

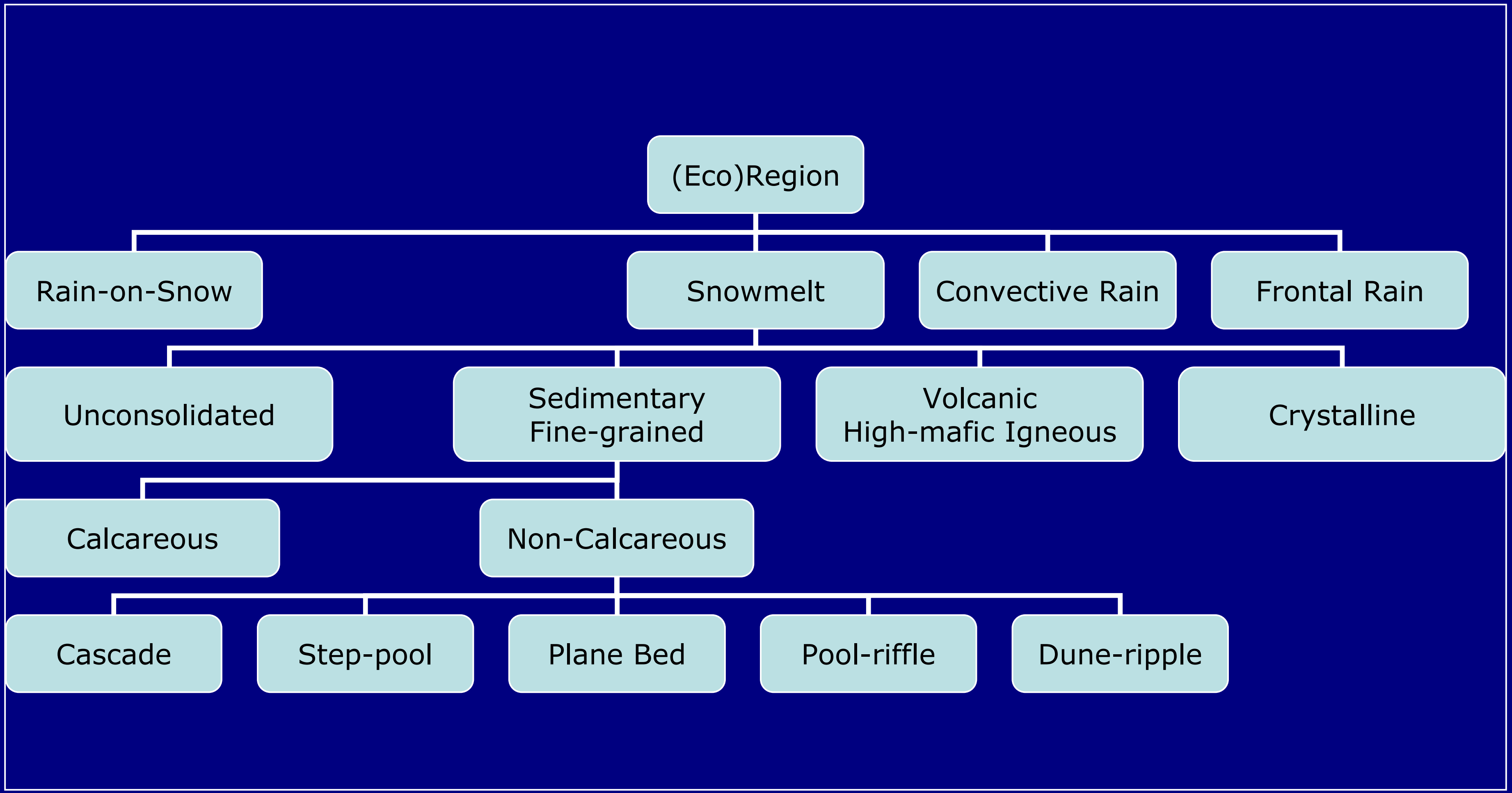
ALL4PCA

- Snowmelt
- Rain
- Rain and Snow
- Variable

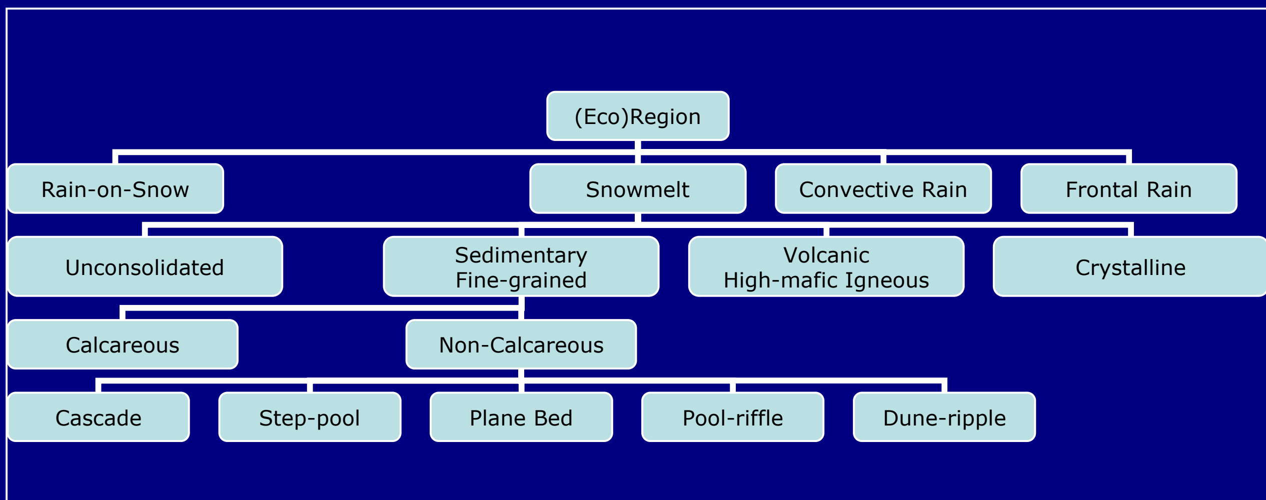


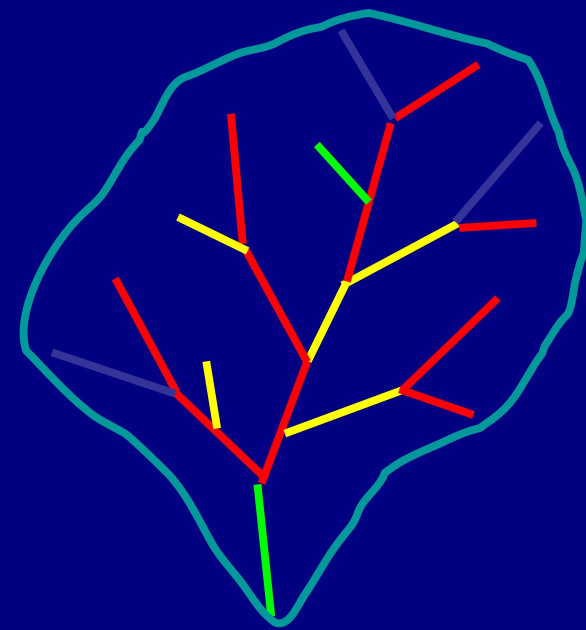
National Parks span broad HGM gradient

HGM Classification (for large extent)
(1° controls on among-site variation)

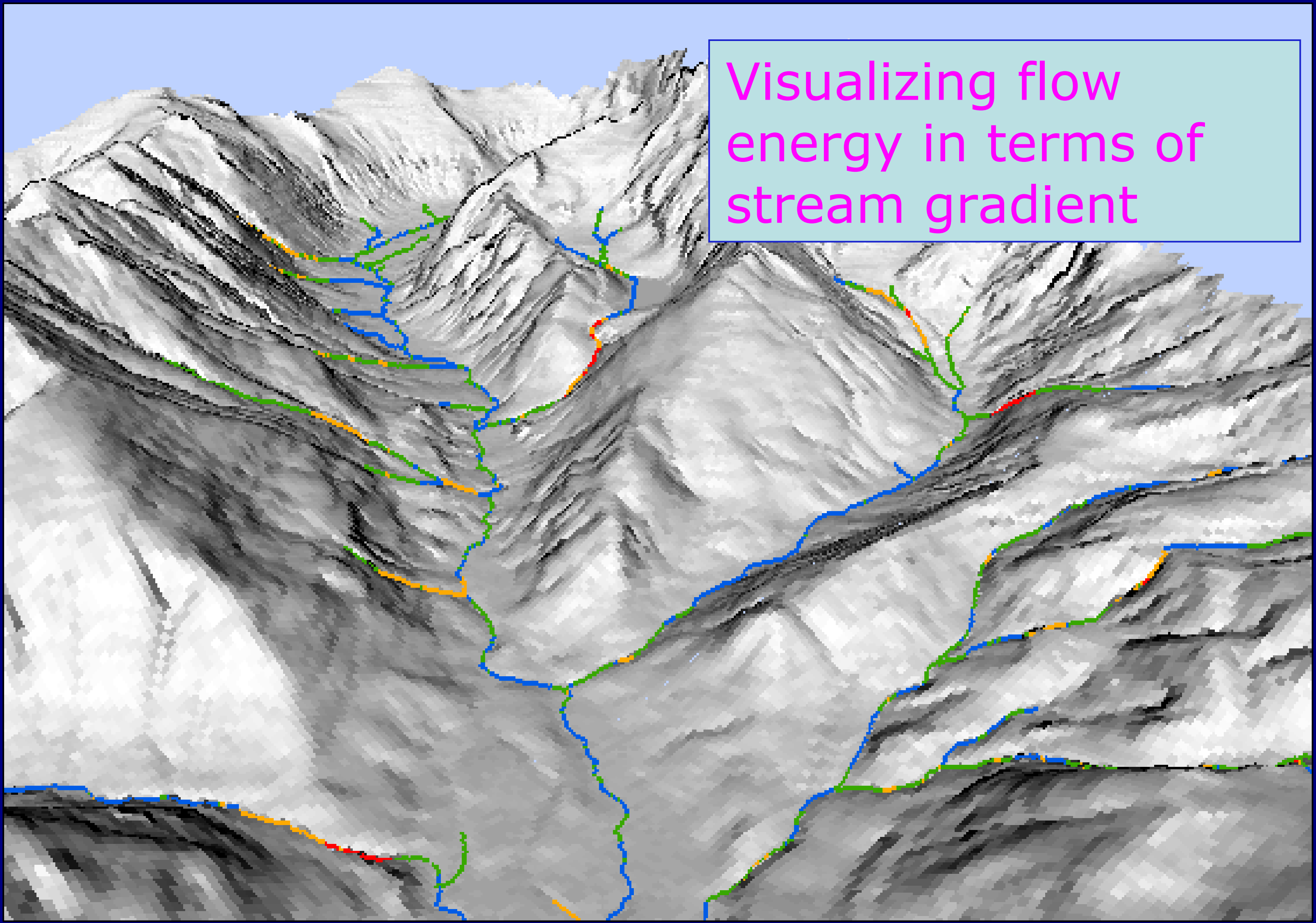


Within a smaller region (e.g., park) map watersheds to guide sampling and monitoring efforts





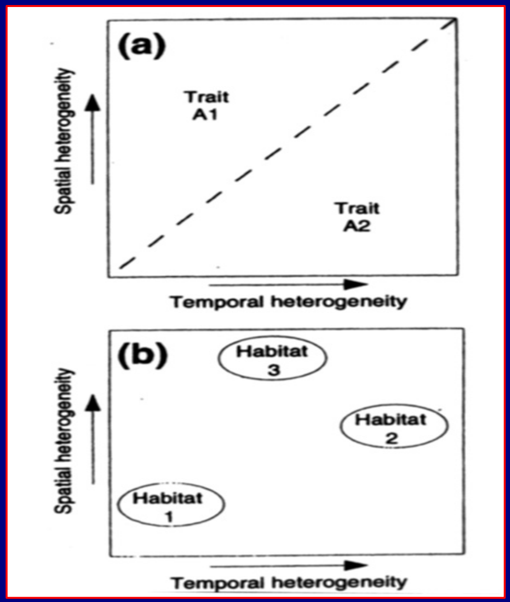
Mapping stream networks to identify similar HGM types - *example*

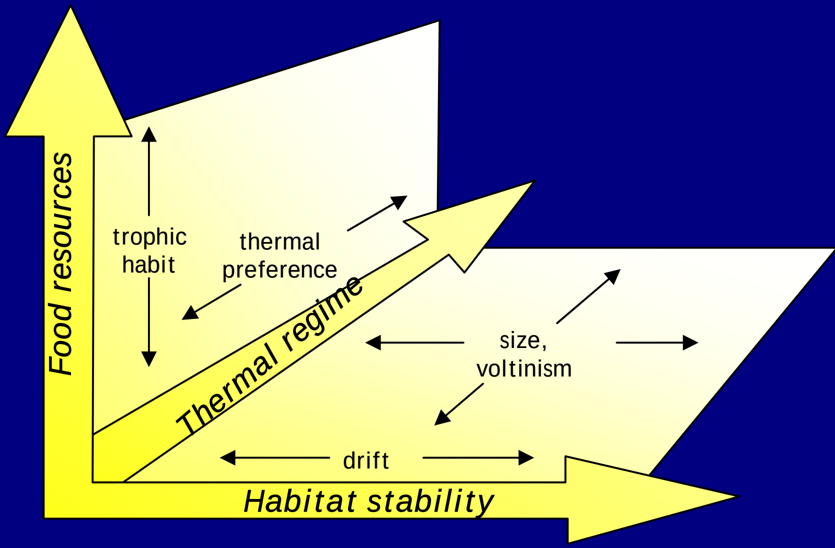


Anticipating Climate Change?

Develop "baseline" biological data for different hydrogeomorphic settings (within context of other environmental drivers (e.g., temperature))

Project biological responses to change in flow regime as mediated by geomorphic settings.





Differential vulnerability of National Parks to climate change?

Different regions will experience different kinds of change in temperature and precipitation.

How will new flow regimes translate into modified disturbance regimes given the existing HGM templates?

Which habitats in which parks are most vulnerable or sensitive to change?

<u>Examples:</u>

High elevation western parks - snowmelt shifting to rain on snow? Or earlier snowmelt runoff?

Low elevation, arid lands - refuges from drying?


Thank you

Disturbance Tolerance

bi/multivoltine* OR *abundant juvenile drifter* OR *strong swimmer* OR *strong adult flyer

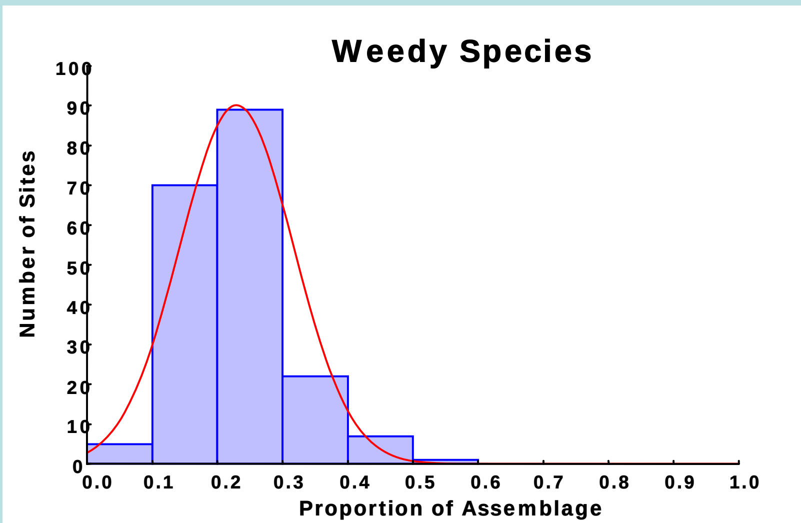
HFM Expectation:

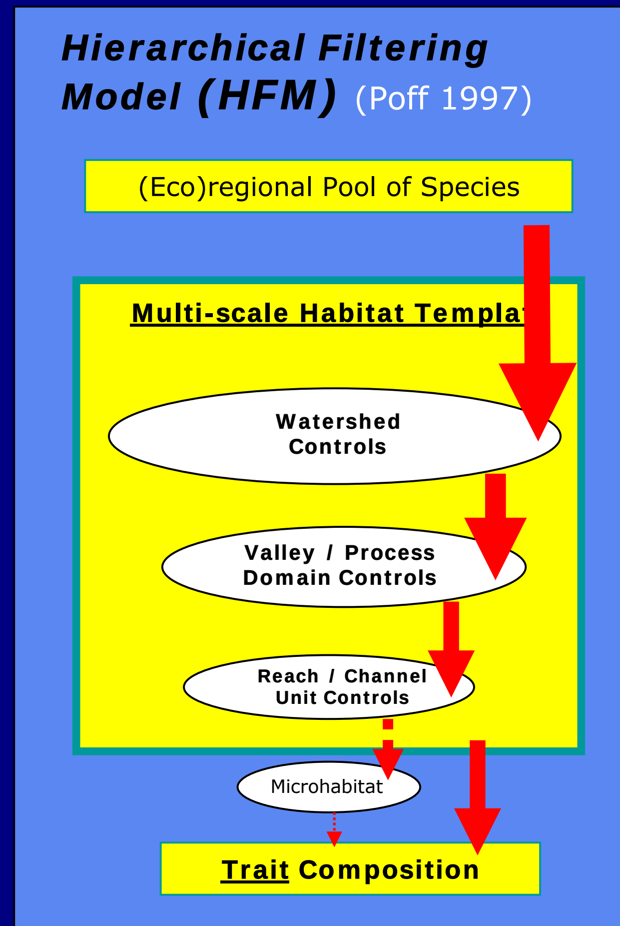
- **-> WS flow regime**
- **-> Local bed stability**

Disturbance Tolerance

bi/multivoltine OR high drift OR strong swimmer OR strong flyer

mean = 0.23





Disturbance Tolerance

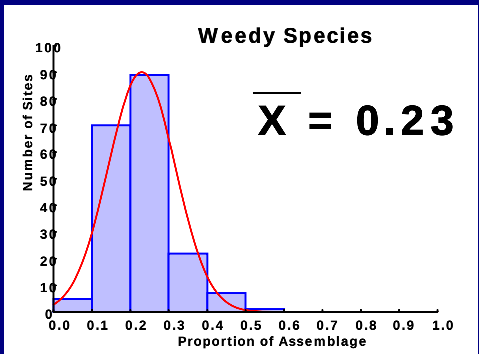
(Model R^2 = 0.68)□

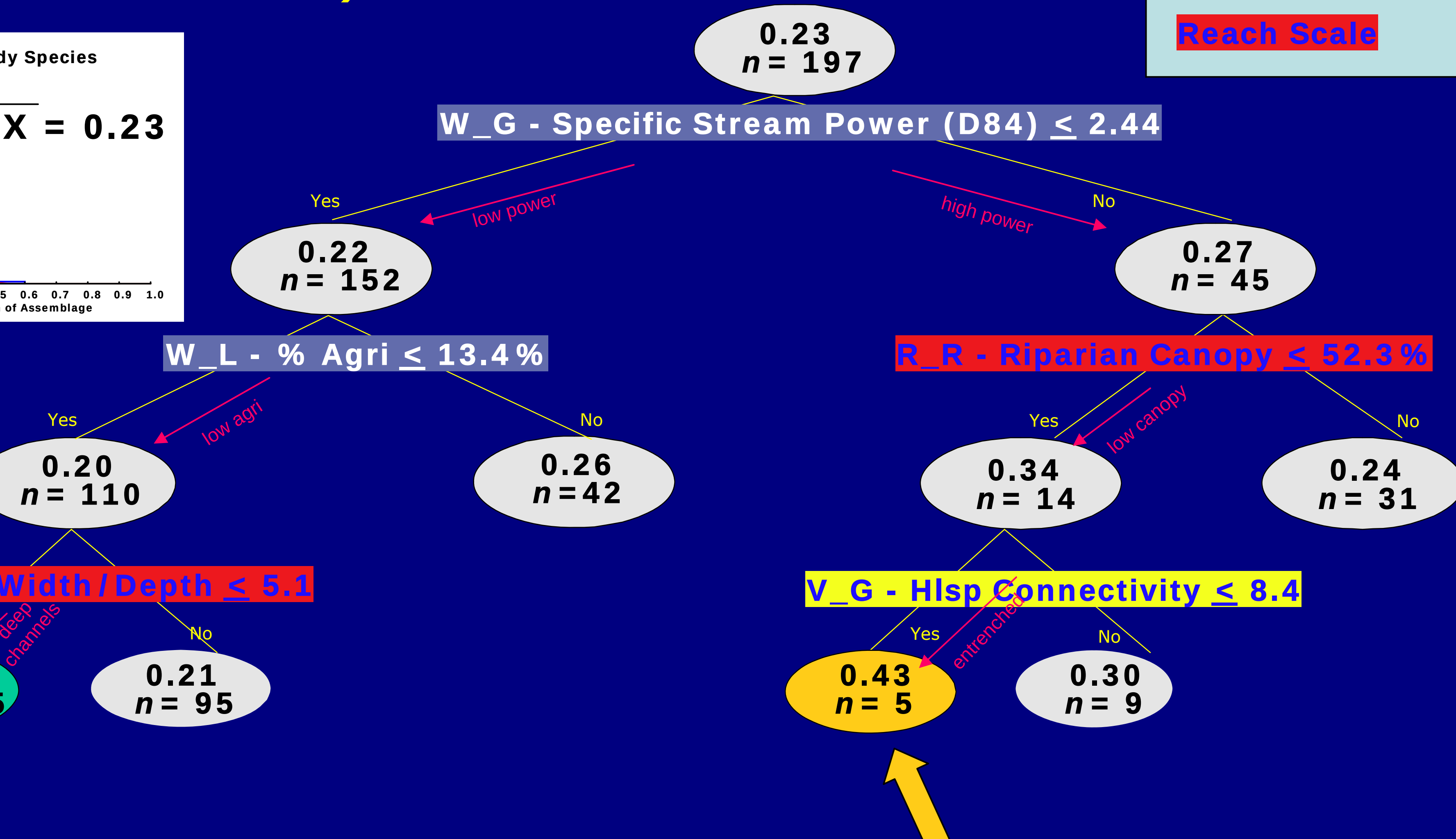
Filters

Watershed Scale

Valley Scale

Reach Scale



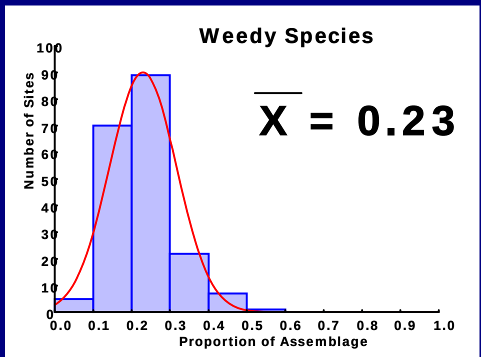


15 sites with fewest weedy

5 sites with most weedy

Disturbance Tolerance

(Model R^2 = 0.68)□

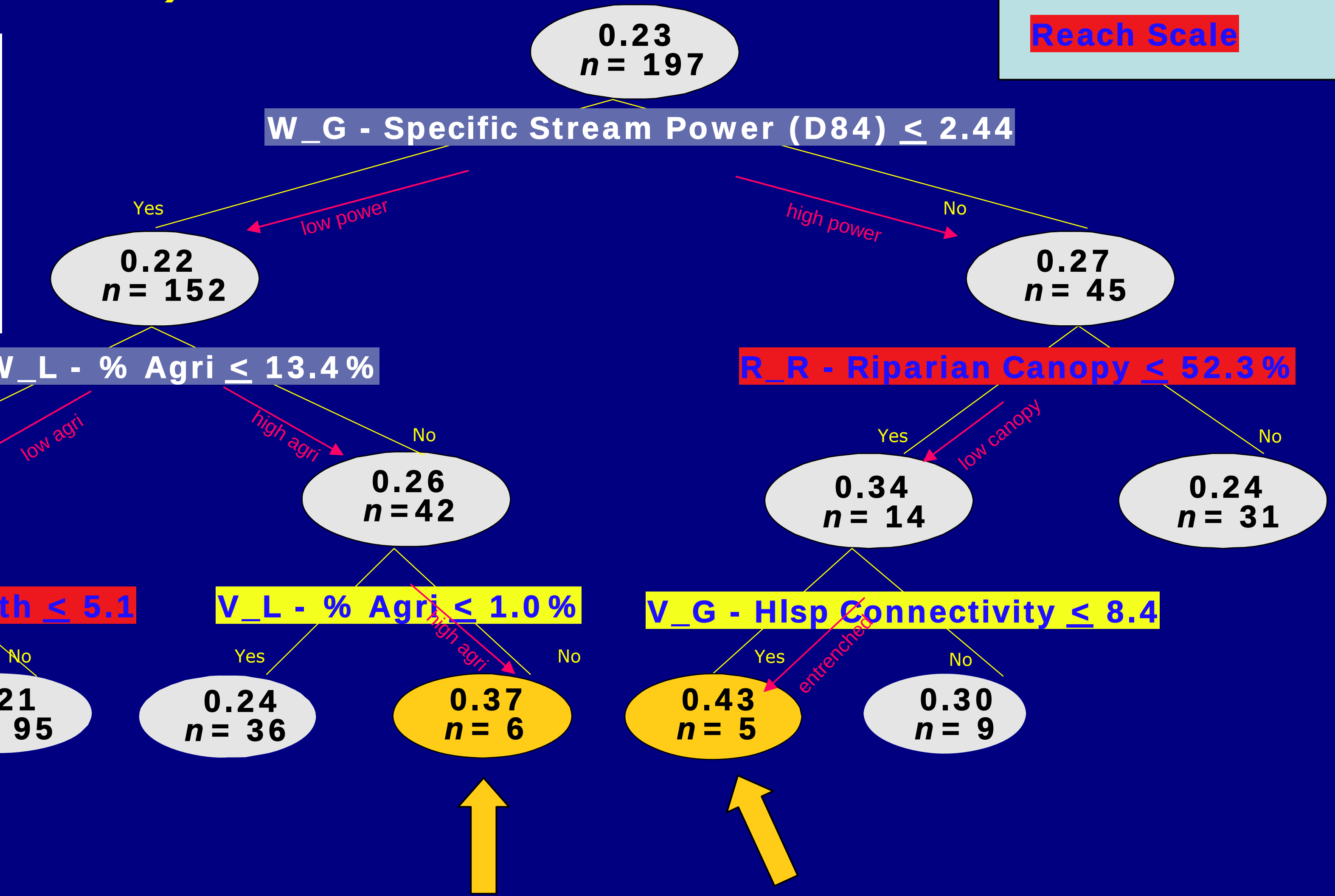


Filters

Watershed Scale

Valley Scale

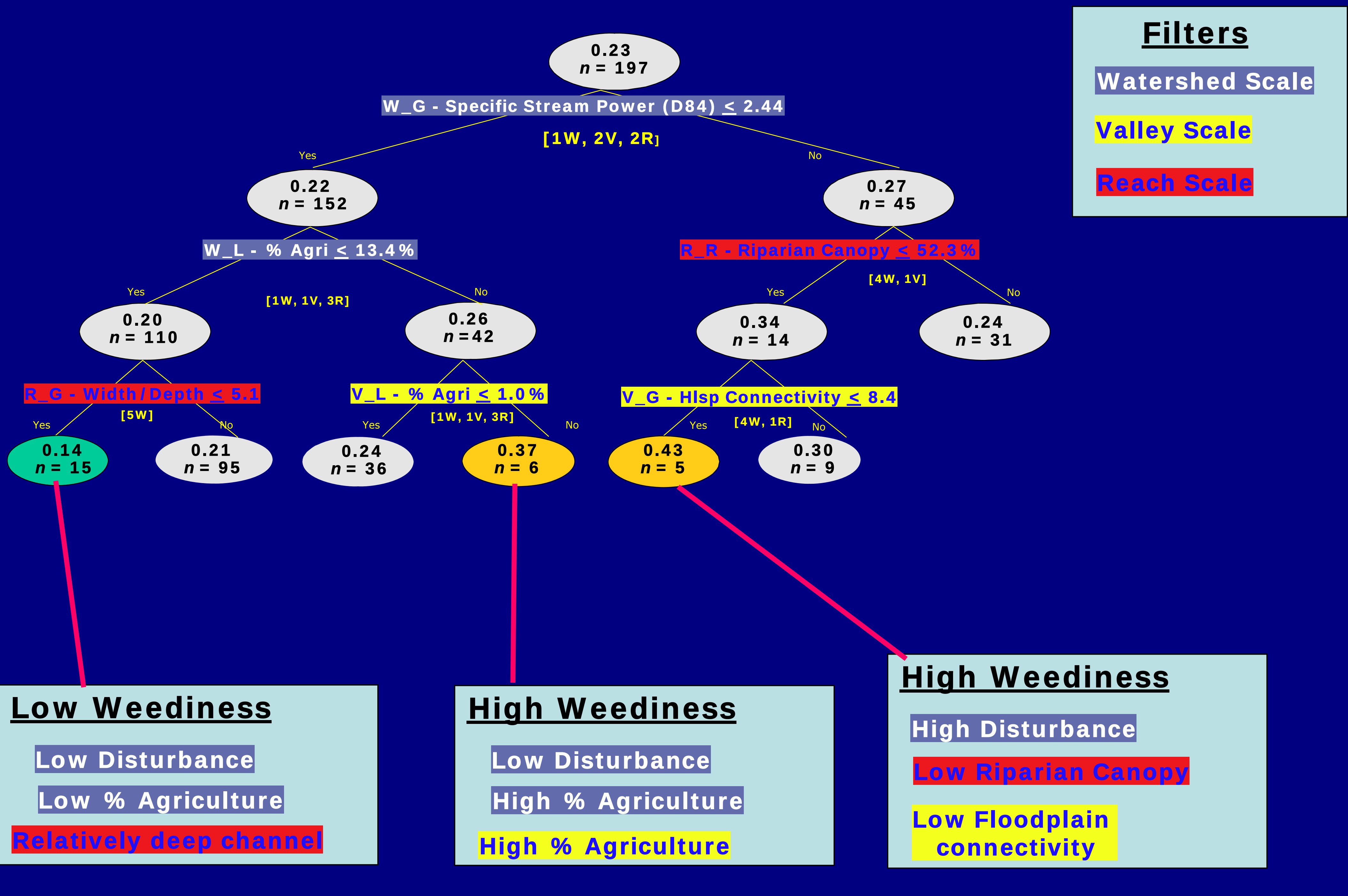
Reach Scale



15 sites with fewest weedy

Context matters!

5 sites with most weedy


0.23
n = 197
W_G - Specific Stream Power (D84) ≤ 2.44
[1W, 2V, 2R]
Yes
No
0.22
n = 152
W_L - % Agri ≤ 13.4%
[1W, 1V, 3R]
Yes
No
0.20
n = 110
R_G - Width/Depth ≤ 5.1
[5W]
Yes
No
0.14
n = 15
0.21
n = 95
0.26
n = 42
V_L - % Agri ≤ 1.0%
[1W, 1V, 3R]
Yes
No
0.24
n = 36
0.37
n = 6
0.27
n = 45
R_R - Riparian Canopy ≤ 52.3%
[4W, 1V]
Yes
No
0.34
n = 14
V_G - Hlsp Connectivity ≤ 8.4
[4W, 1R]
Yes
No
0.43
n = 5
0.30
n = 9
0.24
n = 31
Filters
Watershed Scale
Valley Scale
Reach Scale
Low Weediness
Low Disturbance
Low % Agriculture
Relatively deep channel
High Weediness
Low Disturbance
High % Agriculture
High % Agriculture
High Weediness
High Disturbance
Low Riparian Canopy
Low Floodplain connectivity

WATERSHED SCALE (15)

Hydrology_ (modeling from Sanborn & Bledsoe 2006)

- 7-day minimum flow/mean annual flow
- Average duration of low pulses (day)
- Specific mean annual runoff (m3/km2)
- Mean number of discrete flood events (year−1)

Climate

- Aspect (degrees)
- August temperature (°C)
- Five-month (Nov–Mar) winter temperature (°C)

Geology

- Sedimentary geologic type (%)
- Volcanic geologic type (%)
- Calcareous rock (%)

Geomorphology

- Watershed slope (m/m)
- Mean specific stream power scaled to D84
  [Surrogate for shear stress (average of all link-scale slope * DA^0.5)]

Land Use

- Barren (%)
- Forested (%)
- Agricultural (%)

VALLEY BOTTOM SCALE (7)

Geomorphology

- Distance weighted stream power (km2)
- Last link specific stream power (S*A^0.4)
- Average hillslope connectivity (m)
- Valley entrenchment (m)

Land Use

- Barren (%)
- Forested (%)
- Agricultural (%)

REACH SCALE (11)

Geomorphology

Channel slope (%)
Channel sinuosity (m/m)
Mean bankfull width/depth ratio (m/m)
Relative roughness—D84/R

Riparian

Riparian canopy present (proportion of reach)
Proportion riparian disturbed by human land uses
Riparian canopy density (%)

Substrate

Substrate (mm)
Sand and fines particles (%)
Volume LWD in bankfull channel (m3/m2)
Substrate mobility (=Slope*(A/D84)^0.4)