What do we mean by structure and function?

**Ecological structure**
- focal habitat types
- Diversity of habitats
- channel configuration
- focal species
- functional group
- species diversity

**Ecological Function**
- food web interactions
- nutrient processing/uptake
- production (primary or secondary)
- decomposition
- detoxification

What determines structure and function?

Flow regime is a ‘master variable but ... understanding them is a multivariate problem

- Flow regime
- Energy balance
- Tributary connectivity
- Rates of biogeochemical processes
- Sediment size distribution
- Organic matter input
- Thermal regime
- Litter inputs
Let's focus on one structural element: biotic diversity

Diversity of Phyla Found in Running Waters

- Protists: amoebae, ciliates, diatoms, green algae
- Meiofauna: flat worms, nematodes, rotifers, gastrotrichs
- Macro-invertebrates: crustaceans, snails, bivalves
- Ascomycete fungi
- Bacteria – photoautotrophs, chemoautotrophs, blue-green bacteria
- Mosses, flowering plants

Main components of biodiversity

1. The number of species (species richness)
2. The evenness of the distribution of individuals between species
3. Differences in their functional traits

‘functional types or groups’?
Sets of species, each of which has:
- similar effects on an ecosystem process
- or
- similar responses to environmental conditions

Why worry about diversity >>>>
Why does biodiversity matter when restoring a stream?

Because...

Ecosystem level processes are related to diversity

...so the ability of a restored stream to function "properly" depends on getting the diversity 'right'

Because...

Ecosystem stability is related to diversity

So... restored streams with a diversity of functional groups have a higher probability of persistence

(likely that all species capable of performing a particular process will be lost given some disturbance)
Invasibility is influenced by diversity

Because...

Number of pest outbreaks related to biodiversity

Because...

Knops et al. 1999
What factors promote diversity in streams?

First, take care of or be aware of the big insults.

... no sense fiddling with the sinuosity if ethylene glycol is running into the stream.

Restoration of stream biodiversity

1. Diversity increases with habitat heterogeneity
2. Diversity linked to distance to source populations
3. Diversity linked to population size because of extinction risk
4. Diversity highest at intermediate levels of natural disturbance
5. Given 1. and 2. equal, diversity increases with productivity
1. Diversity increases with habitat heterogeneity

Niche partitioning in minnows

FIGURE 9.1 Ecological segregation among eight species of cyprinids in a Mississippi stream. Only Eryxymba bicuculata and Notropis longirostris failed to separate on the axes shown, and the former was the sole nocturnal feeder in the assemblage. W, N. tempanius; S, N. signigeminis; E, N. tempanius; R, N. tempanius; L, N. tempanius; C, N. obscurus; B, L. longirostris; E, Eryxymba bicuculata. (From Baker and Ross, 1981.)

Can we manipulate the factors promoting diversity in a restoration context? ... heterogeneity

Ecological structure affected by the interaction of flow and substrates
Flow influences at multiple scales

Small scale:
flow habitat preferences, body morphologies, and motilities

This blackfly larvae is adapted to exploit the velocity profile near the substrate.

FIGURE 6.6. (a) The typical breathing status of a blackfly larva (Simulium notatum complex). The larval body extends downstream at progressively greater deflection from vertical with increasing current velocity, and is oriented 90-180ø tangentially as can be seen by following the line of the ventral setae used. The position of the gular clypeal fan in upper and lower, rather than side by side. The boundary layer (depth where 20% of maximum flow) begins at roughly the height of the upper fan (Chace and Craig, 1986). (b) Details of clypeal fan: (i) head of a normal larva seen from beneath, with clypeal fans fully open; (ii) Simulium triarticulatum with uniform fringe of microsetae; (iii) Scaphium with short and short microsetae. (From Chace, 1986; SEM photomicrographs courtesy of D.A. Craig.)
Habitat heterogeneity & restoration

Geomorphic Heterogeneity = $d_{84}/d_{50}$

Time since restoration

Biological response

HH control

LH
**Benthic Primary Production and Respiration**

biofilm colonized tile assay
light/dark bottle incubation
measured at 4, 8, 15 & 25 d

- **LH riffles**
- **HH riffles**
- **Reference riffles**

Gross productivity (mg O₂ m⁻² hr⁻¹)

- trt < 0.05
- day < 0.01
- trt * day = 0.50

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**2. Diversity linked to distance to source populations**

**Local populations →→ metapopulations**

- Salamanders – esp. headwater species
- Riparian vegetation
- Macrophytes
- Wetland marsh plants

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**Core - satellite populations**
Regional Filter
- Climate
- Dispersal barriers
- Edaphic limits

Restoration Site ‘Filter’
- Resource availability
- Local dispersal
- Habitat stability and heterogeneity

Local Processes ‘Filter’
- Abiotic conditions
- Biotic interactions

Restored Community

Regional diversity
(species pool & dispersal can constrain restoration)

Number of local fish species (in a single pool) in Virginia streams directly related to number of regional species regardless of scale (but note slope decreases as regional scale increases)

Can we manipulate the factors promoting diversity in a restoration context? ... distance to source populations

Watershed context: restoring "dead" tributaries & paths of colonization

3. Diversity linked to population size because of extinction risk

Must maintain populations in core areas

As $N$ decreases, random variation in vital rates increases extinction risk.

As $N$ decreases, loss of genetic variation enhances extinction risk.
Can we manipulate the factors promoting diversity in a restoration context? ... population size

- Periodic statewide surveys in addition to site-by-site followup for survival
- 1999 study-
  - 82% of sites >200 tree/ac
  - 60% planted survival
  - Over 1/3 nat. regen.
- 2002 study-
  - 78% planted survival
  - ¼ nat. regeneration
  - 87% survival (CREP)

From Anne Hairston-Strange, MD Forest Service

Riparian Restoration - Survival Challenges in Maryland

Weeds
Vines
Shade
Insects
Disease
Deer
Rodents
Mowers etc.
Planting
Wet Site
Shelters
Drought

% plots with problem

% live
4. Diversity highest at intermediate levels of natural disturbance

Intermediate disturbance hypothesis (Connell, 1978)

- **A variety of species can tolerate the conditions, but none dominate.**
- **Strong competitors monopolize resources.**
- **Only a few tolerant species can survive or recolonize.**

**Frequency of Disturbance**

*Restoration implications: why variability in Q (esp floods) is important to restore*

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**Intermediate Disturbance Hypothesis**

Disturbance intensity & area effects on diversity

![Graph showing disturbance intensity and area effects on diversity.]

**Open bars** low frequency of disturbance (1/wk)
**Gray bars** high frequency (2/wk)
**Black bar** undisturbed controls

Macroinvert species richness (+1 SD) in disturbance treatments & controls

McCabe & Gotelli 2000. Oecologia 124:

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Can we manipulate the factors promoting diversity in a restoration context? ... disturbance regime

**Riparian Areas**

- Floods create bare moist germination beds necessary for pioneer species recruitment
- New cohorts of cottonwoods and willows come up with each appropriate flood event (magnitude and timing are important)
- River migration and aggradation creates lateral age zonation of stands across the floodplain

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Arizona

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(Rivers and Riparian Zones)
Floods

- Riparian ecosystems are disturbance-adapted
- Timing, magnitude and frequency are important
- Tamarisk has thrived when natural flood regimes have been modified.
- remove vegetation
- moisten and re-distribute sediments
- flush salts

Saltcedar “invasion”
5. Given 1. and 2. are equal, diversity increases with productivity

Interplay of disturbance and resource availability

Abiotic factors dominate – only short-lived, good colonizers, or resilient species persist

Non-interactive assemblages

Maximun species diversity

Interactive assemblages

Abiotic & biotic controls in dynamic equilibrium = coexistence

Populations are growing faster, poor competitors are quickly excluded.

Dynamic equilibrium model of Huston (1979, 1994)

Can we manipulate the factors promoting diversity in a restoration context? ... productivity

Yes...restore the processes that support the desired productivity

Flow regime – Sediment flux – Energy inputs

E. Bernhardt, Duke Univ. unpub
So.. how can sites be modified to enhance diversity?

- Take care of the major insults
- Restore/manage **processes** that support services (flow, sediment, energy)
- Maximize spatial heterogeneity of resources
- Restore ‘desired’ productivity (abundant & diverse food base: autochothonous or allochthonous)
- Provide appropriate disturbance regimes
- Introduce/plant large populations
- Place close to source of colonists

Can we manipulate the factors promoting diversity in a restoration context?

**Restoration of stream biodiversity**

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Maryland example: importance of spatial context

- 1st order stream
- 74% High Density Res
- 14% Bedrock
- 52% “Run” Habitat

What should be done to restore it?