# Hydrologic Retention within Stream Channels: where, when, and how this effects nutrient retention

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A pristine stream in a politically unstable setting or with no supporters is not a healthy stream because it is not sustainable. The stream and human society are interdependent parts of the same system. - *Meyer, 1987*

## Goods & Services within a “Healthy Stream”

clean water for drinking

water supply for irrigation/industry

uncontaminated foods (fish)

swimming, boating

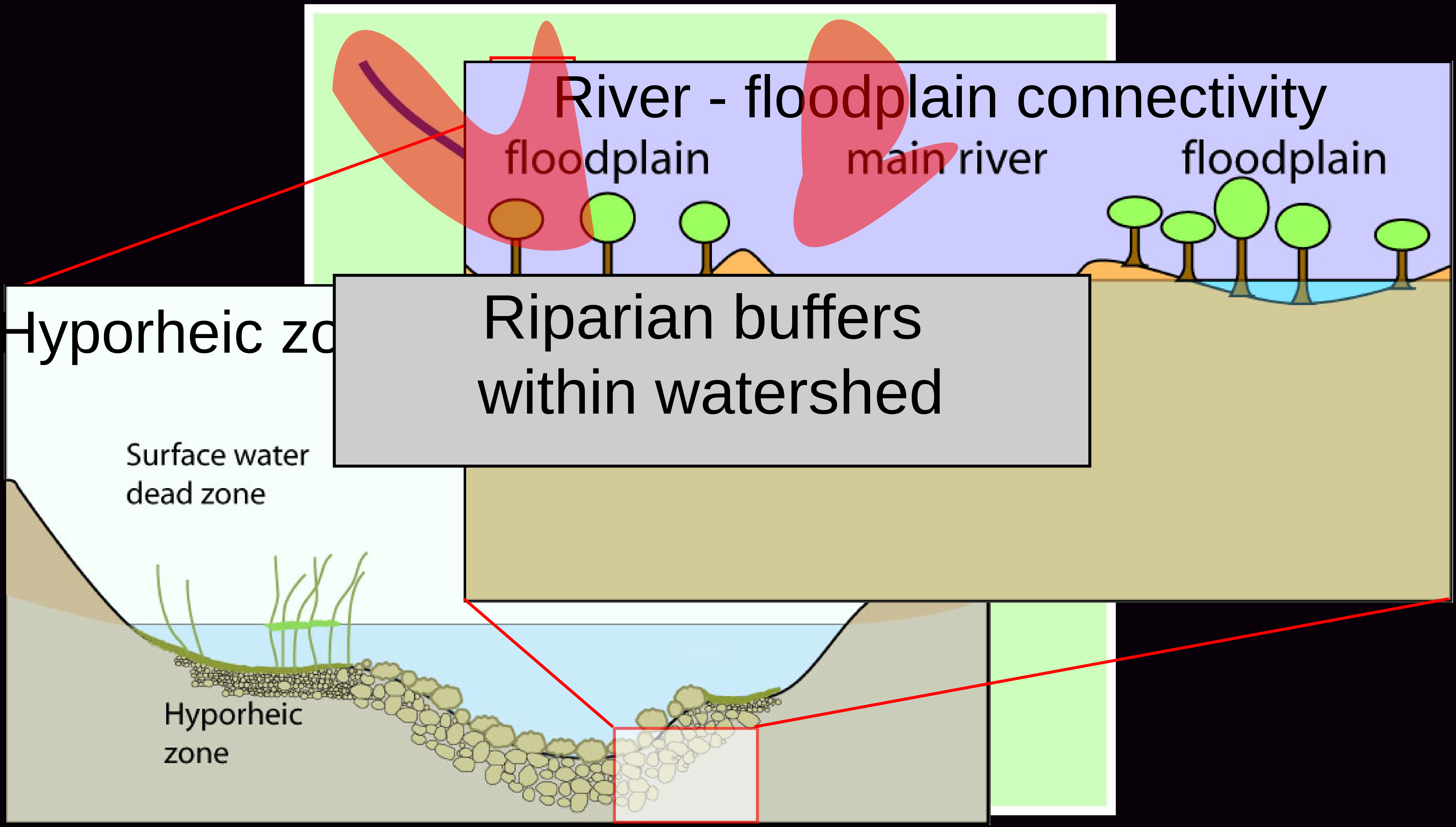
biodiversity

storing / regenerating essential nutrients

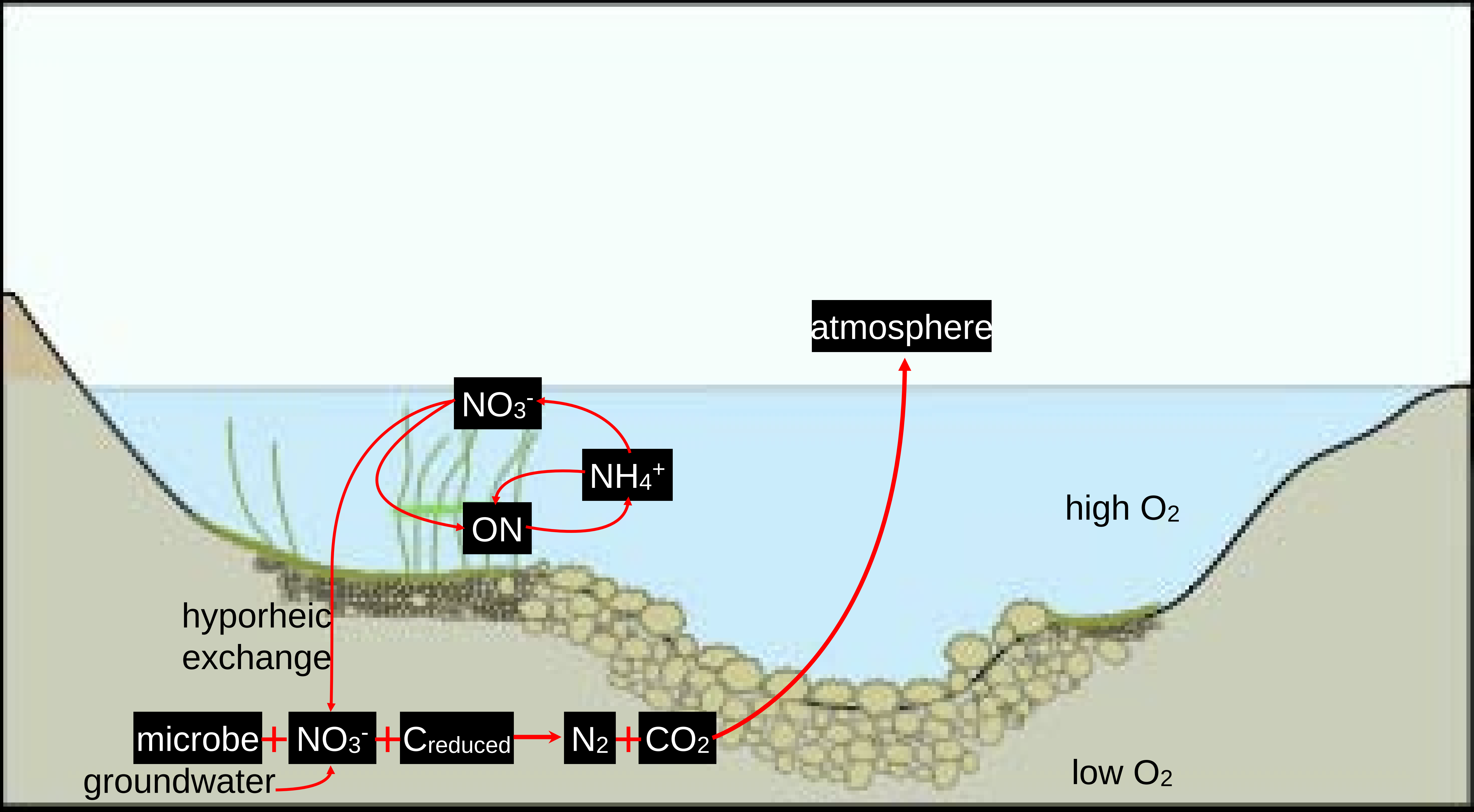
***removal of excess nutrients***

from Meyer1997

# Nutrient retention: from landscape through the stream network



# Denitrification - *DNF*

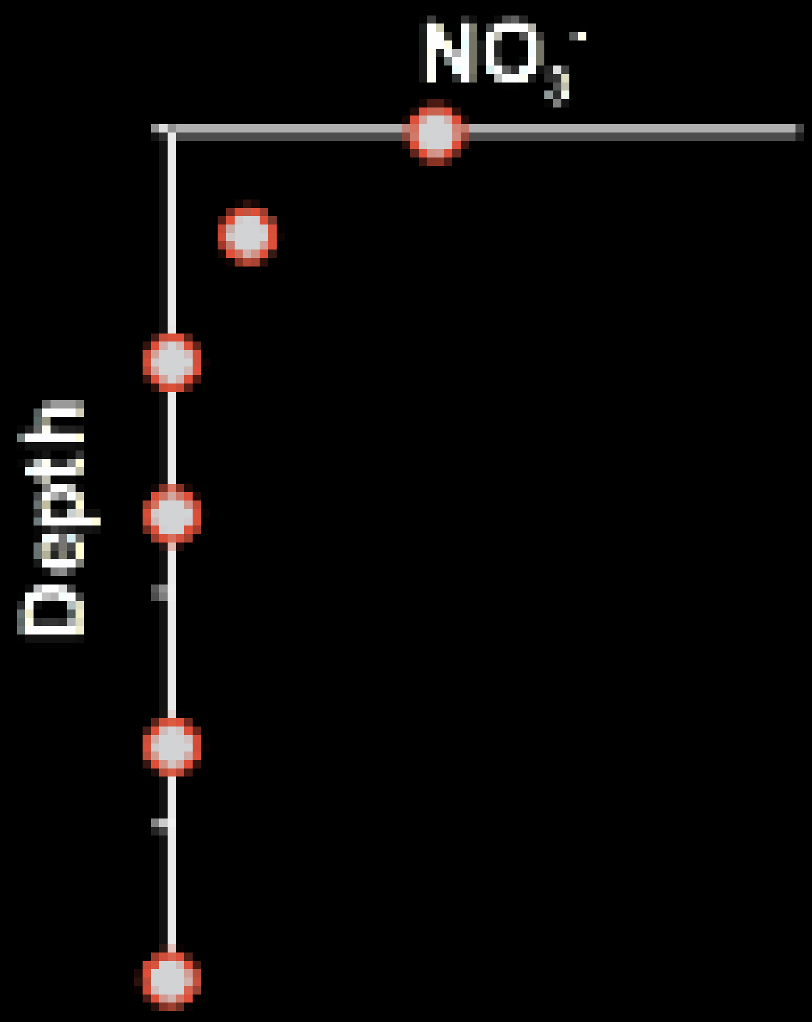


# Conditions for DNF

- low $O_2$

- labile reduced carbon (e.g., Zernetske et al., 2011)

- $NO_3^-$ availability



# DNF frequently *supply* limited

- $k_{DNF}$ >> N-supply
- N-supply = *f*(exchange, low $NO_3^-$)
  - limited exchange (e.g., clogging) → degraded stream
  - lower $NO_3^-$ availability → healthy stream
- May also be carbon limited

# Where does retention happen?

# In-stream residence time

**Residence time:**

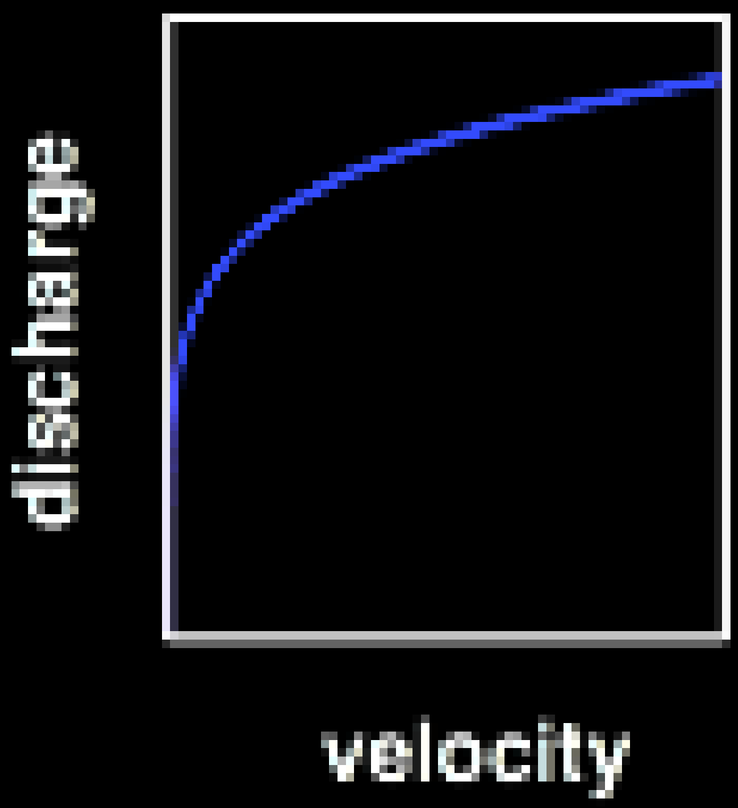
- single station:⬇Q, ⬇V, ⬆RT
- lower stream order: ⬇Q, ⬇V

**Implications:**

⇧ residence time during baseflow

⇧ sediment contact in small streams

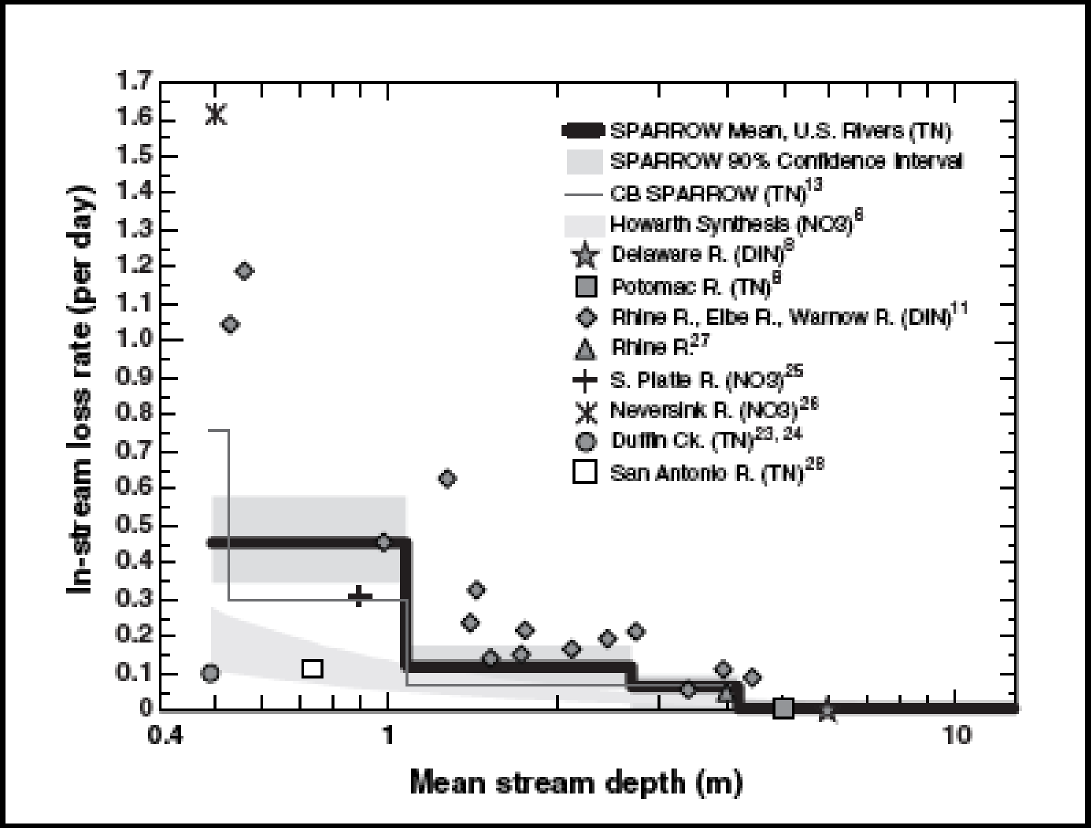
⇧ potential for nutrient transformation



# Lower order channels

<u>headwaters:</u>

- low depth
- high contact area with sediments

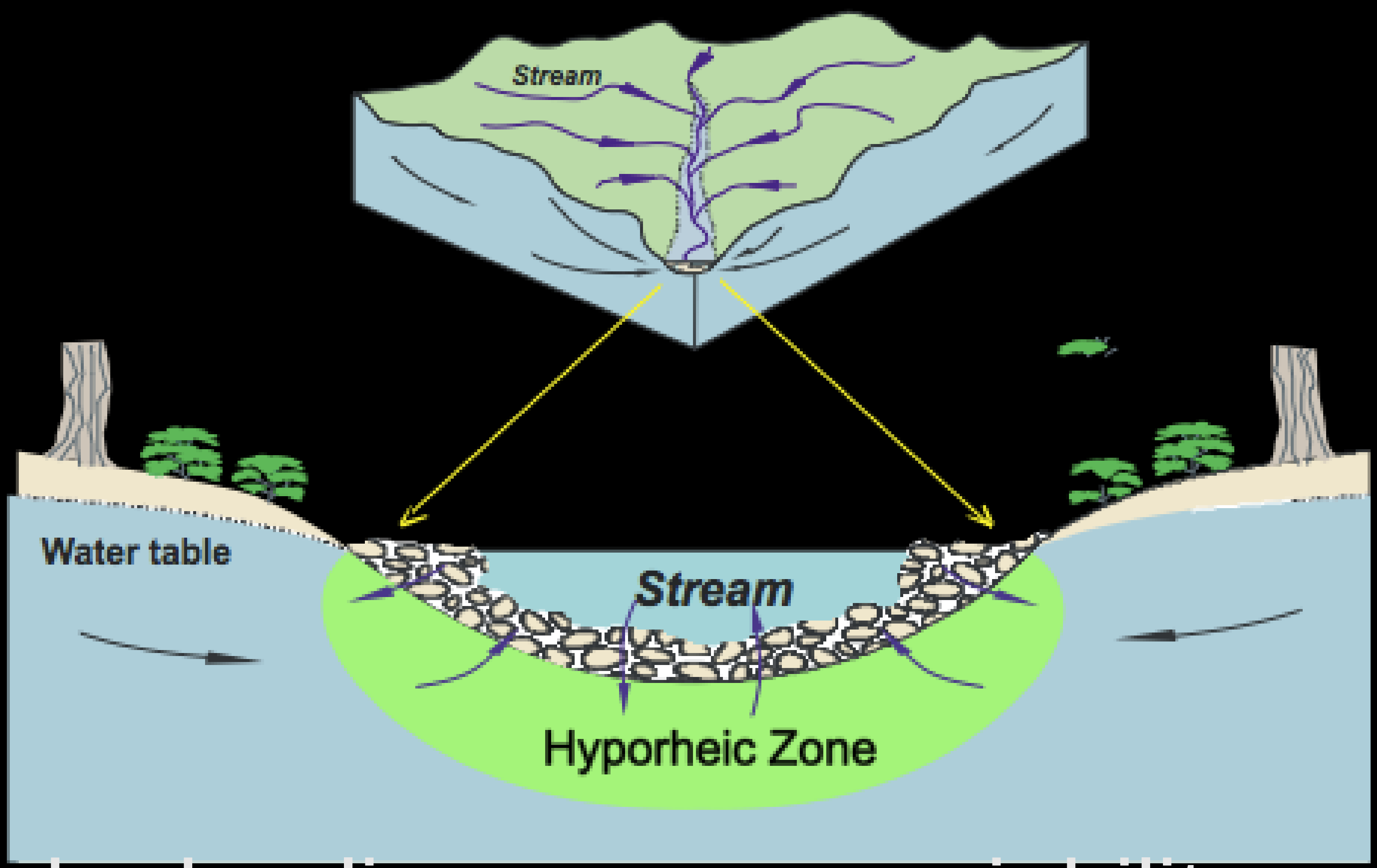



Alexander et al., 2001

# “Storage zones” slow water down

- pools, surface water dead zones
- hyporheic flowpaths

# Hyporheic Flowpaths



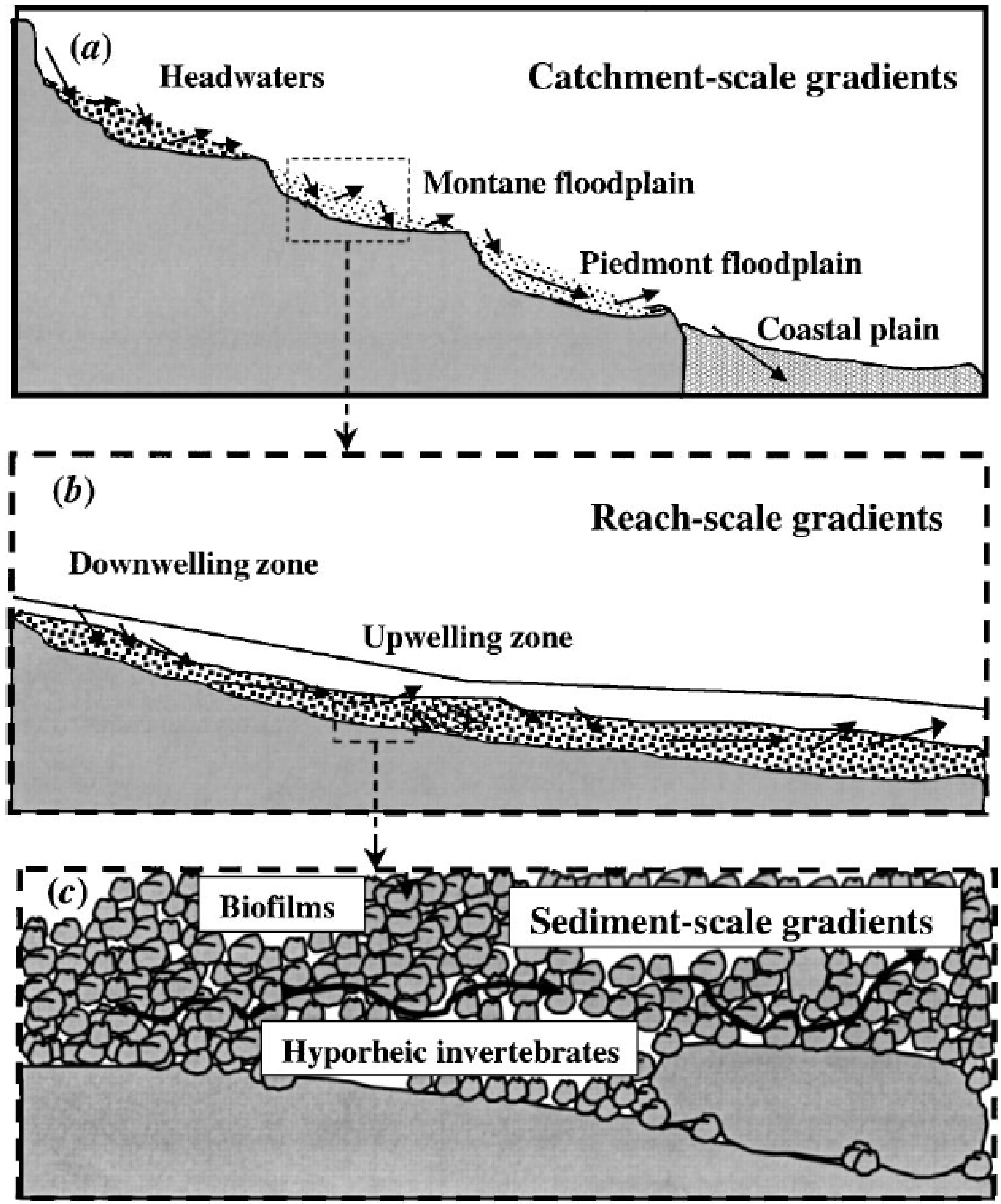

hydraulic pressure variability + porosity

# Hyporheic

Exchange:

- nutrients
- carbon
- water
- biota

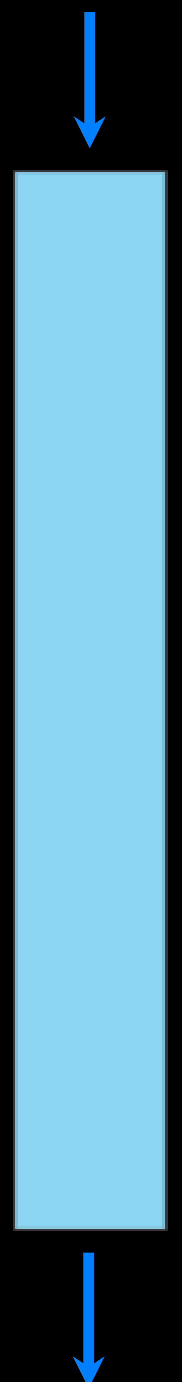
Microhabitat development



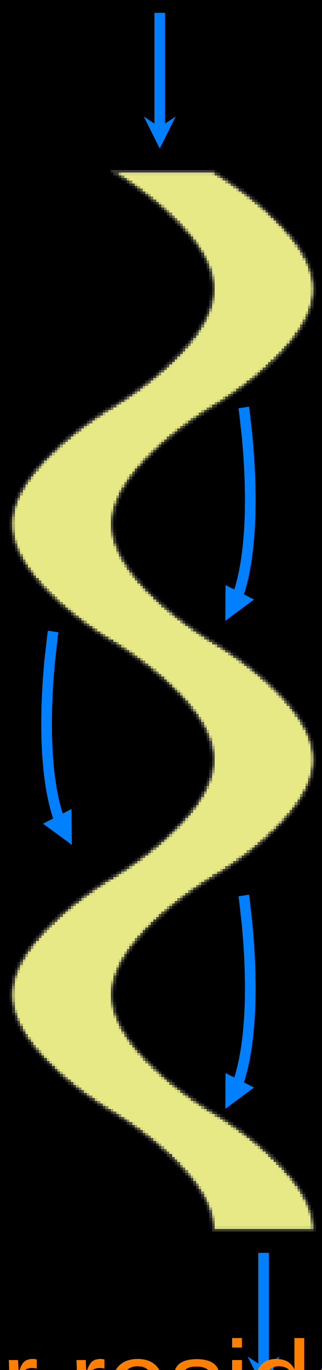

Boulton et al., 1998

# Stream channel

"Pipe"



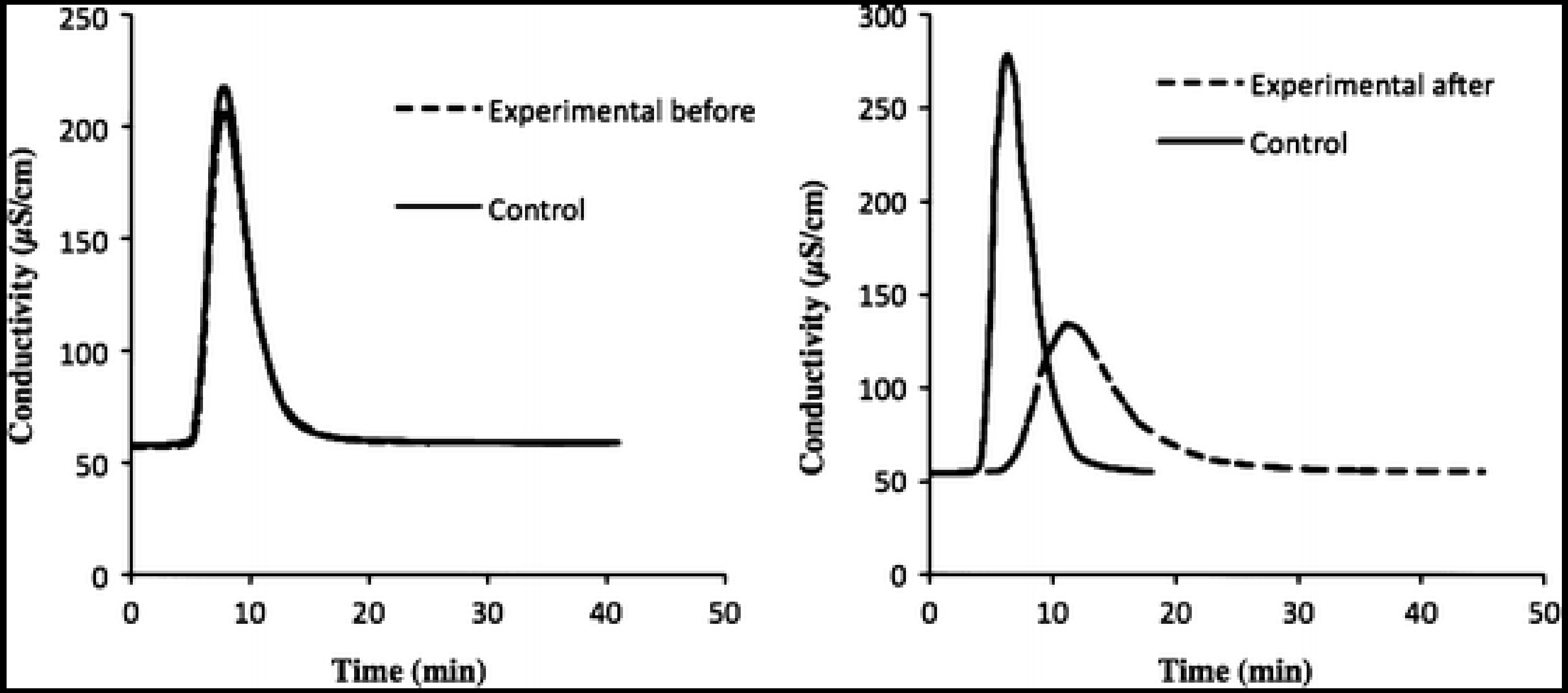
"Natural" greater geomorphic complexity, greater width



Get water out, fast transport

Higher residence time & contact with surfaces

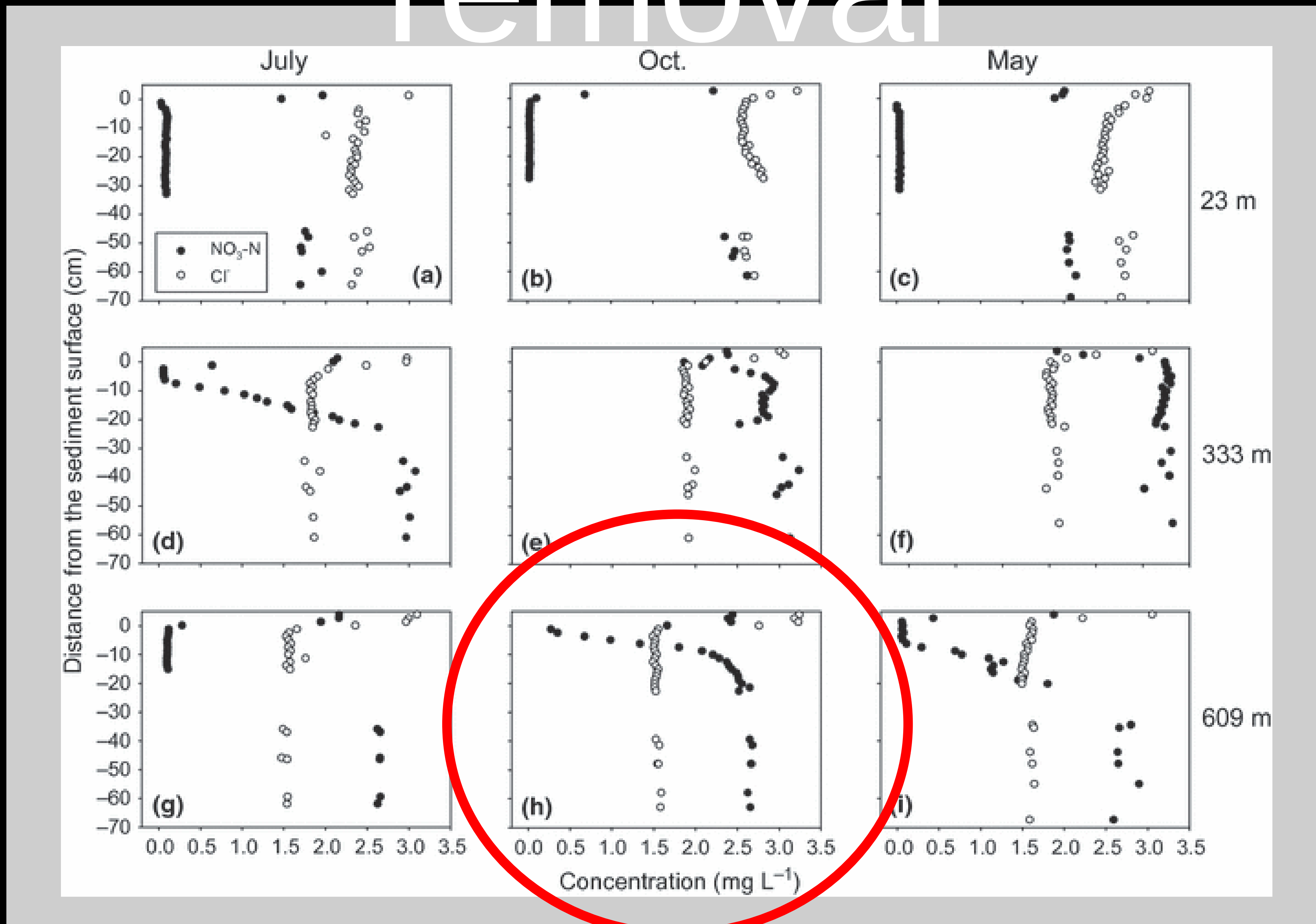
# Example: Add wood to stream, increase in complexity




before wood after wood addition

Elosogi et al., 2010

# Upwelling: $NO_3^-$ removal





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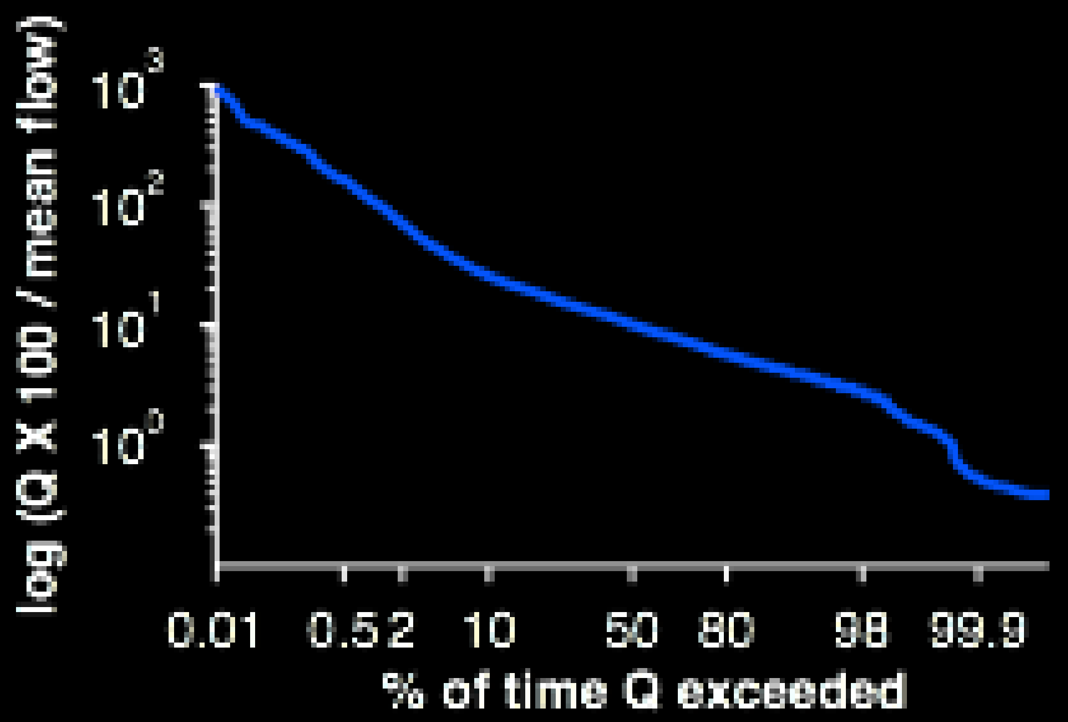
# When are stream channels retaining nutrients?

# Streams are dynamic

# Temporal Scale of Interest

- Daily? Storm? Seasonal? Annual?

| $Q_{daily} < Q_{average, annual}$ | | |
|---|---|---|
| River | % annual yield | % time |
| Chickahominy River | 27 | 69 |
| James River | 32 | 70 |
| Craig Creek | 27 | 73 |
| Shenandoah River | 20 | 75 |
| Susquehanna River | 30 | 65 |



# Local vs. downstream

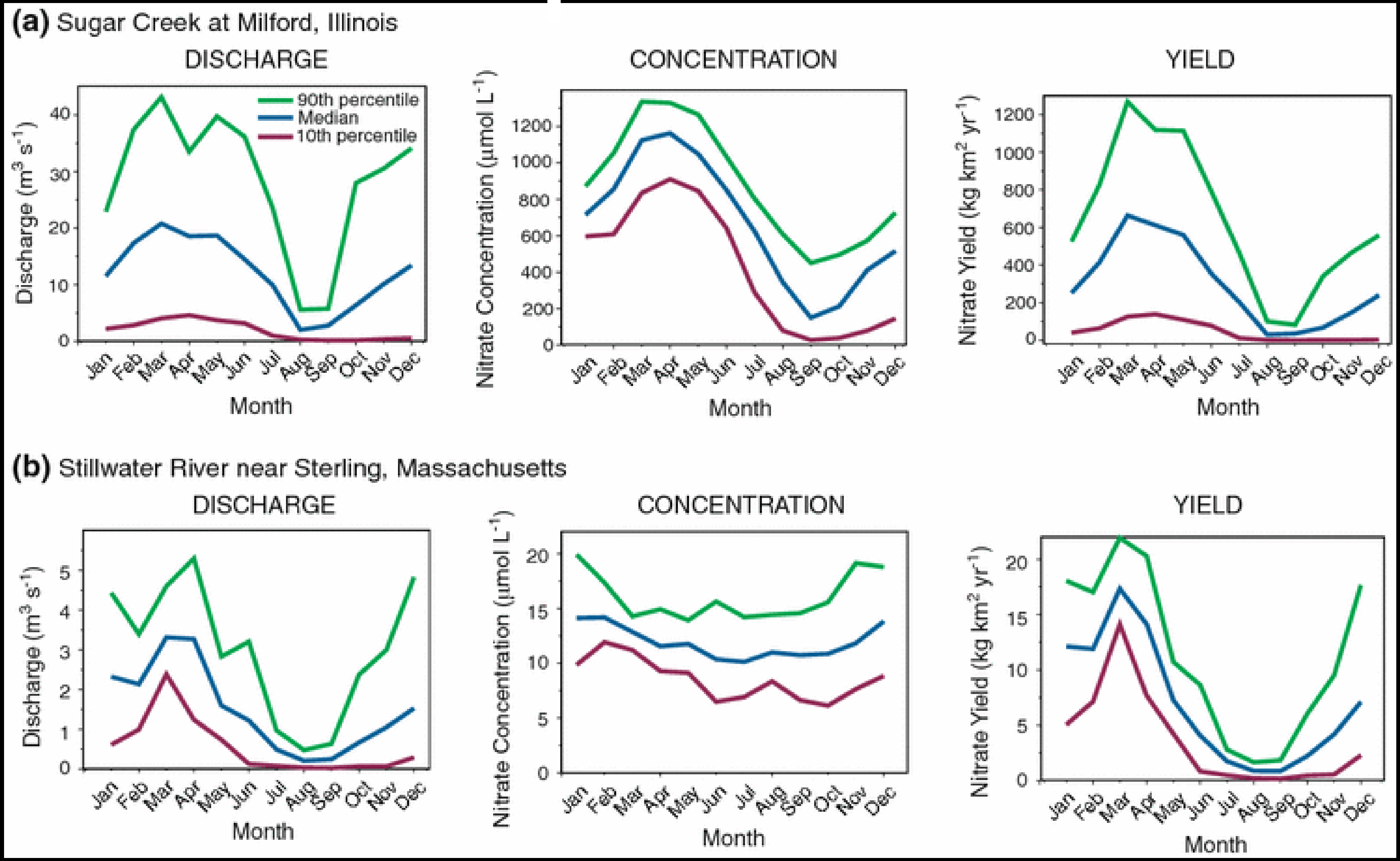
Baseflow: high residence time, contact with sediments, high in-stream reactions: In-stream processes important!

Stormflow: lower residence time, less contact with sediments: in-stream processes << stream flux

In-stream nutrient retention: water quality during baseflow

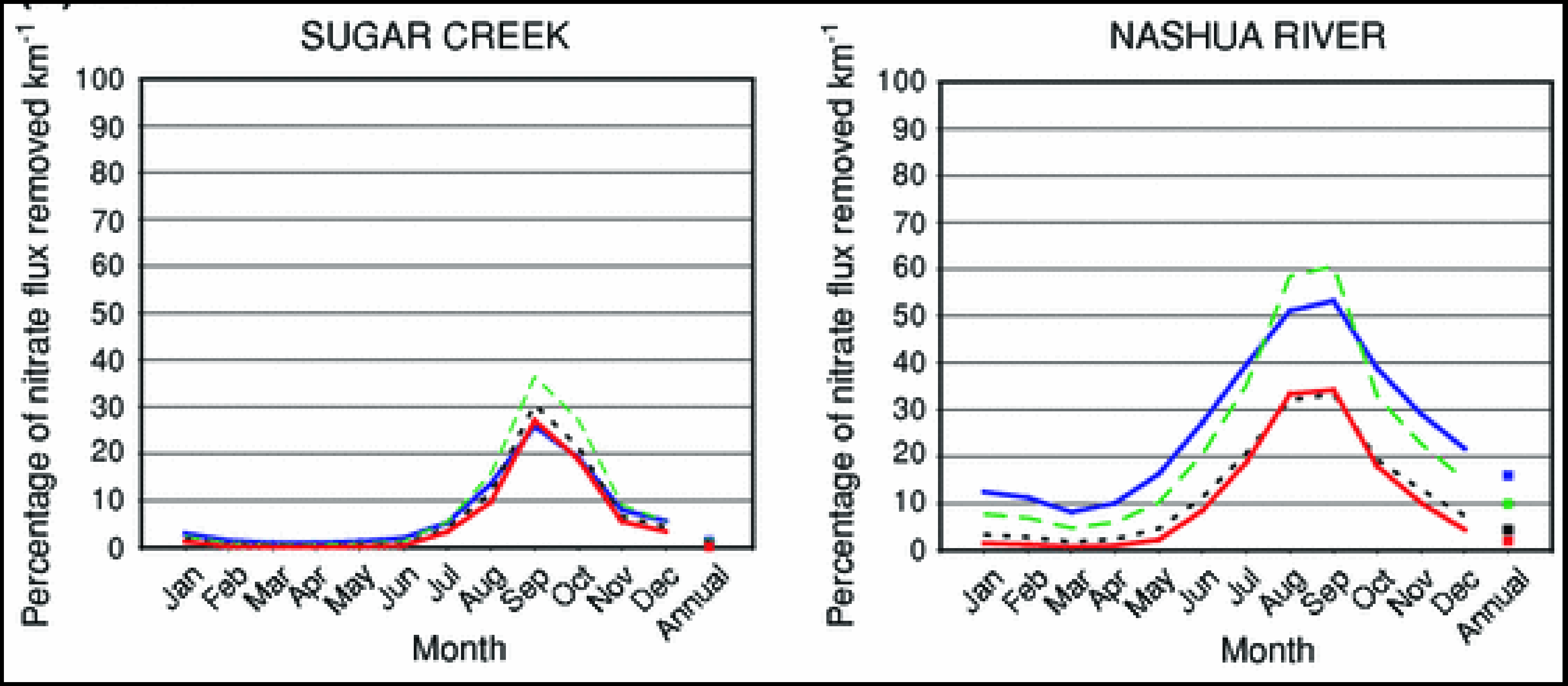
Do “natural” streams have higher nutrient retention?

# Landuse: Variable N inputs



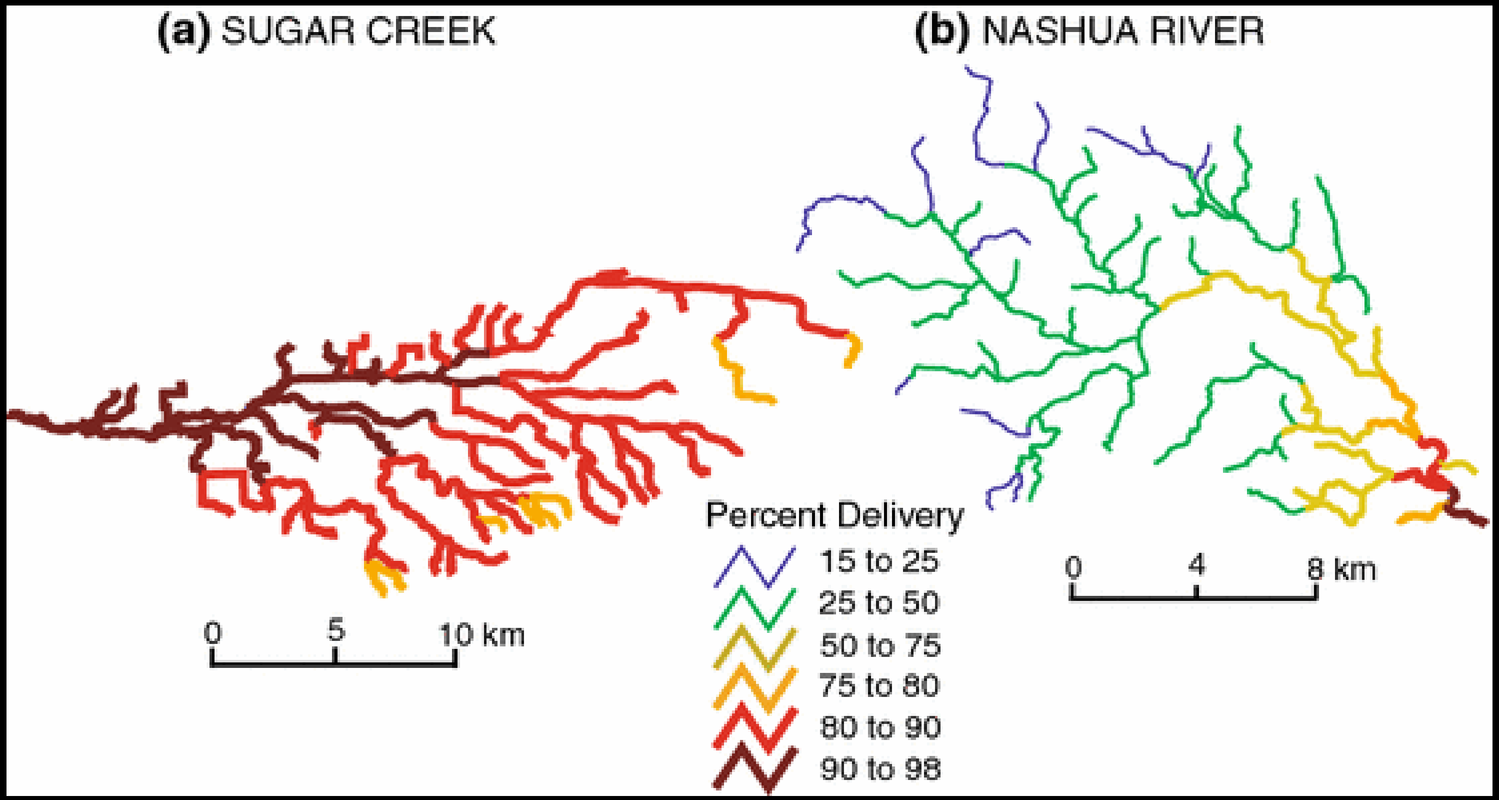

Alexander et al., 2009

# Greater % removal in non-ag stream




Alexander et al., 2009

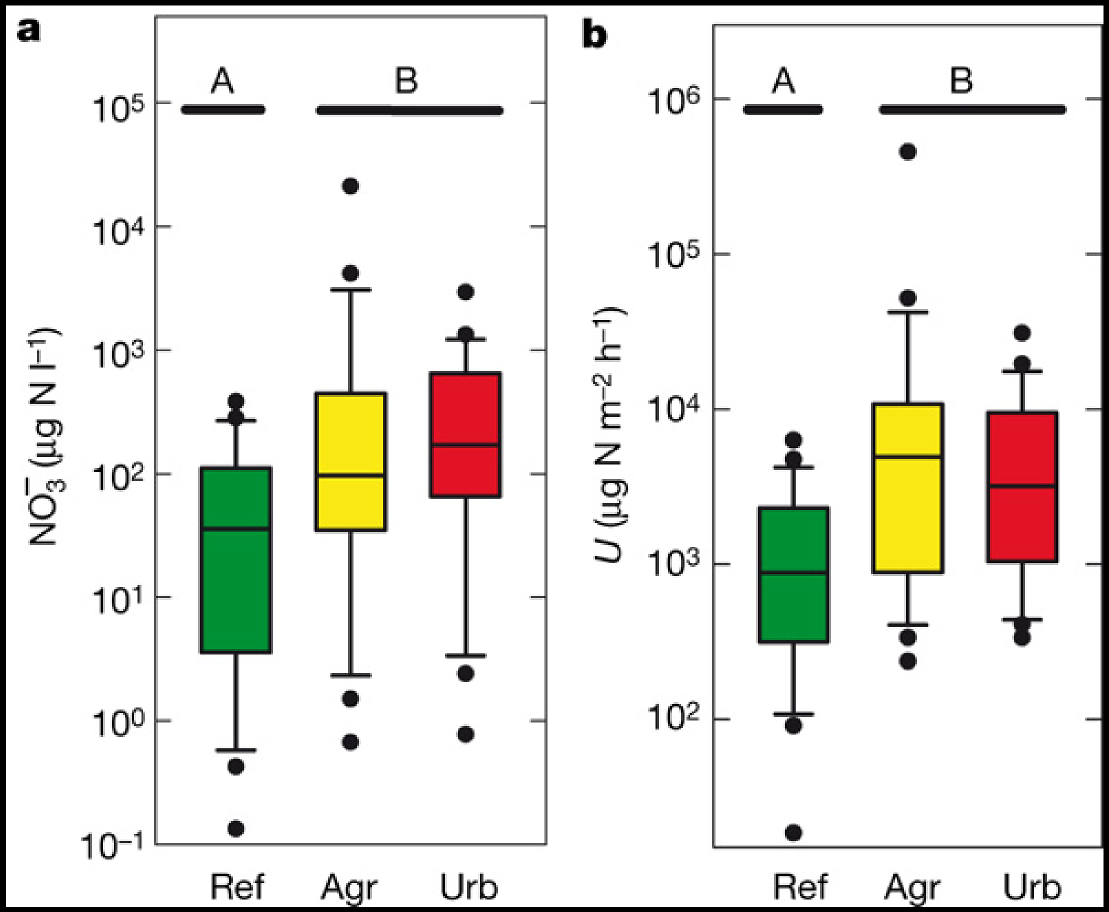
# % delivered during May

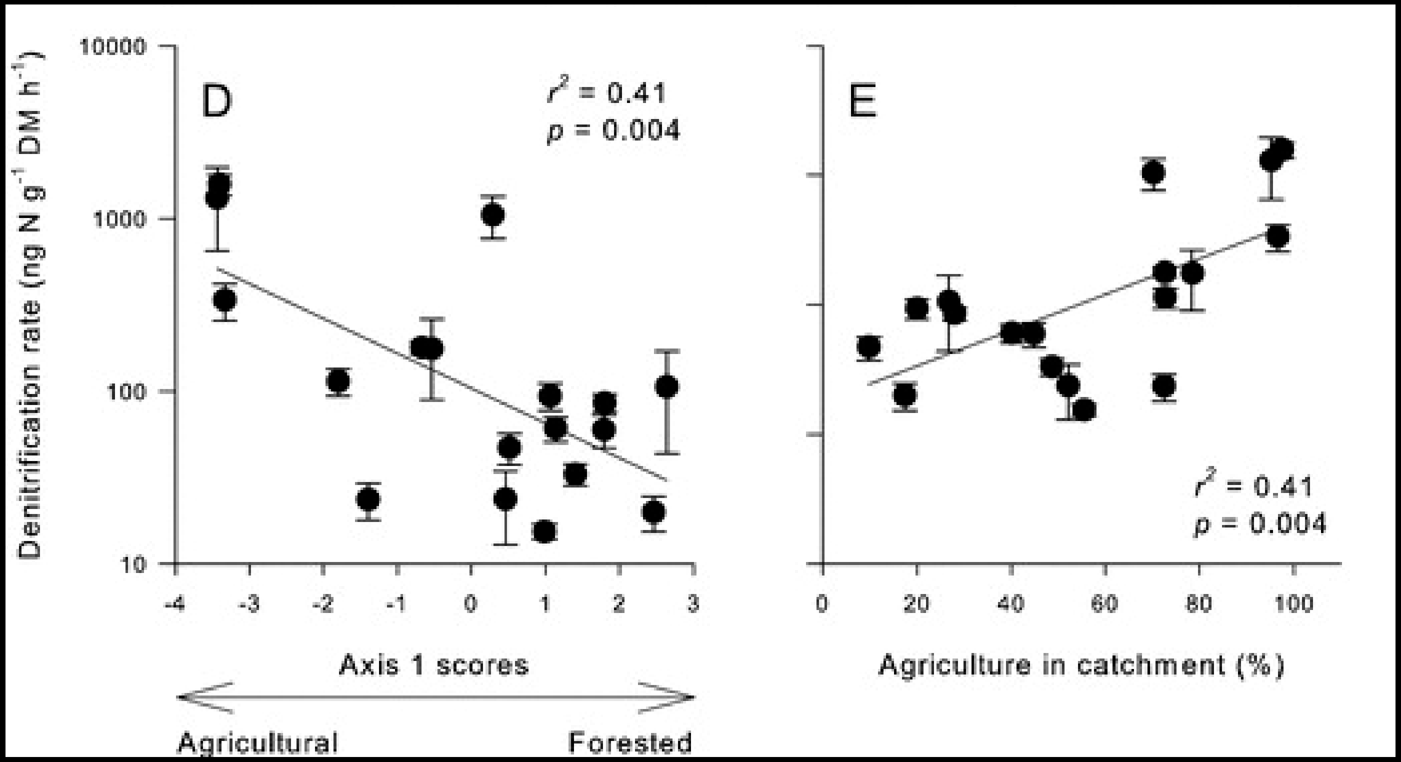



little removal within ag-stream during higher flow period

Alexander et al., 2009

# DNF rate: higher in impacted streams



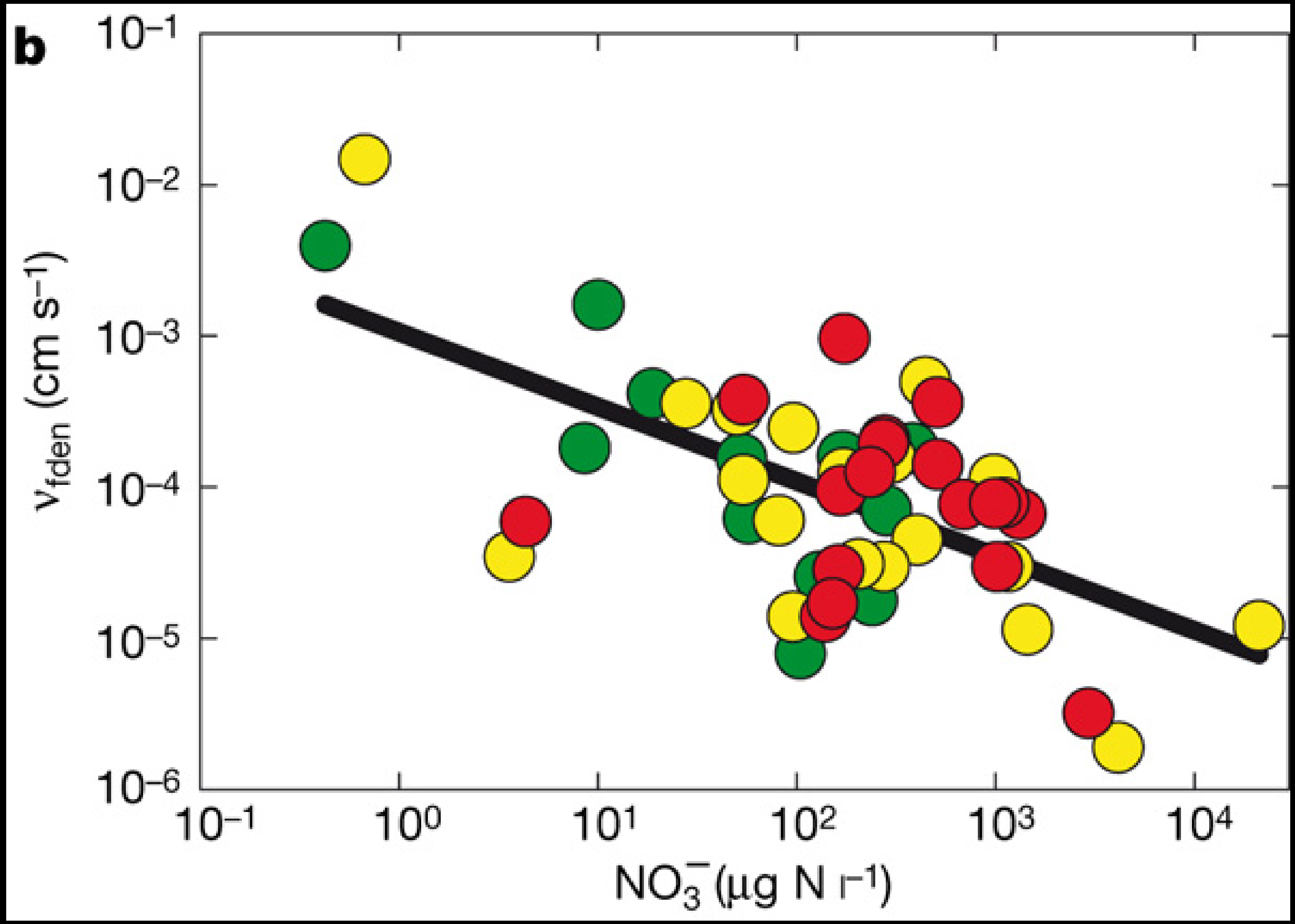




higher DNF rate & $NO_3^-$ in urban/ag

Mullholland et al., 2008

Arango & Tank, 2008

# But $v_f \ncong f$(landuse)




Mullholland et al., 2008

# Conclusions

When: baseflow = greatest RT

Where: storage zones, redox gradients, sw/gw interface, upwelling zones = higher RT

Healthy streams:

- greater % $NO_3^-$ removal = not overwhelmed by landscape delivery, greater RT/contact area
- current studies do not indicate differences in $v_f$ across landuse types - but may not fully represent channel complexity