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ECOSYSTEMS SERVICES RESEARCH PROGRAM

BUILDING A SCIENTIFIC FOUNDATION FOR SOUND ENVIRONMENTAL DECISIONS

Simulated response of mercury and nitrogen to land cover change in a large river basin

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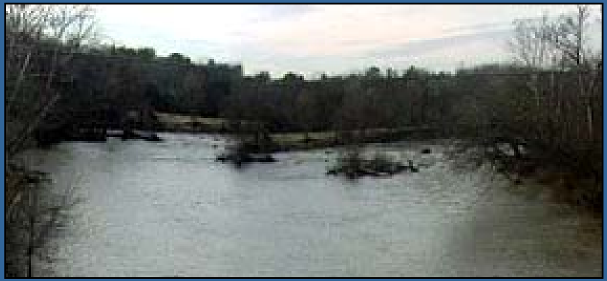
Presentation Outline

- **Research and modeling challenges: understanding coupled watershed mercury and nitrogen fluxes**
- Modeling flux response of mercury and nitrogen to land cover change in the Upper Cape Fear River Basin, North Carolina, USA
- Implications for management and future challenges

Overview of linkages between inorganic N and Hg in watershed soils, surface waters, & biota

- Fish tissue Hg and acidic N deposition: ↓ pH, ↑ MeHg production, ↑ fish MeHg concentration (*Driscoll et al. 1994*)
- NO_3^- = thermodynamically/energetically preferred e-acceptor over SO_4^- = ↓ SO_4^- reduction, ↓ methylation with ↑ NO_3^- in anoxic hypolimnion (*Todorova et al. 2009*)
- Beaver ponds = high rates of microbial activity = ↑ MeHg, but ↓NO_2-NO_3 (*Roy et al. 2009*)
- Forest soil pools of Hg = influenced by soil C and N (*Obrist et al. 2009*):
  - High sorption of organic C and N groups, retain Hg deposition
  - High soil C and N pools = ↑ productivity = ↑ Hg deposition inputs via leaf and litter fall



Haw River (NOAA-NWS, 2008)

Haw River (NC Green Power, 2005)

Coupled N & Hg research & management challenges

- Effects of land use or climate change on water quality in large river basins: typically one particular chemical constituent (e.g., inorganic nitrogen) or a group of similarly reacting chemicals (e.g., nutrients).
- Long-term studies or management decisions: rarely simultaneously focus on excess nitrogen and methyl mercury (MeHg).
- Strategies focusing exclusively on reducing nitrogen in surface waters might counteract or benefit efforts to attenuate mercury.
- Important for assessing impacts of regional scale river basins (from uplands to estuaries) on coastal waters.

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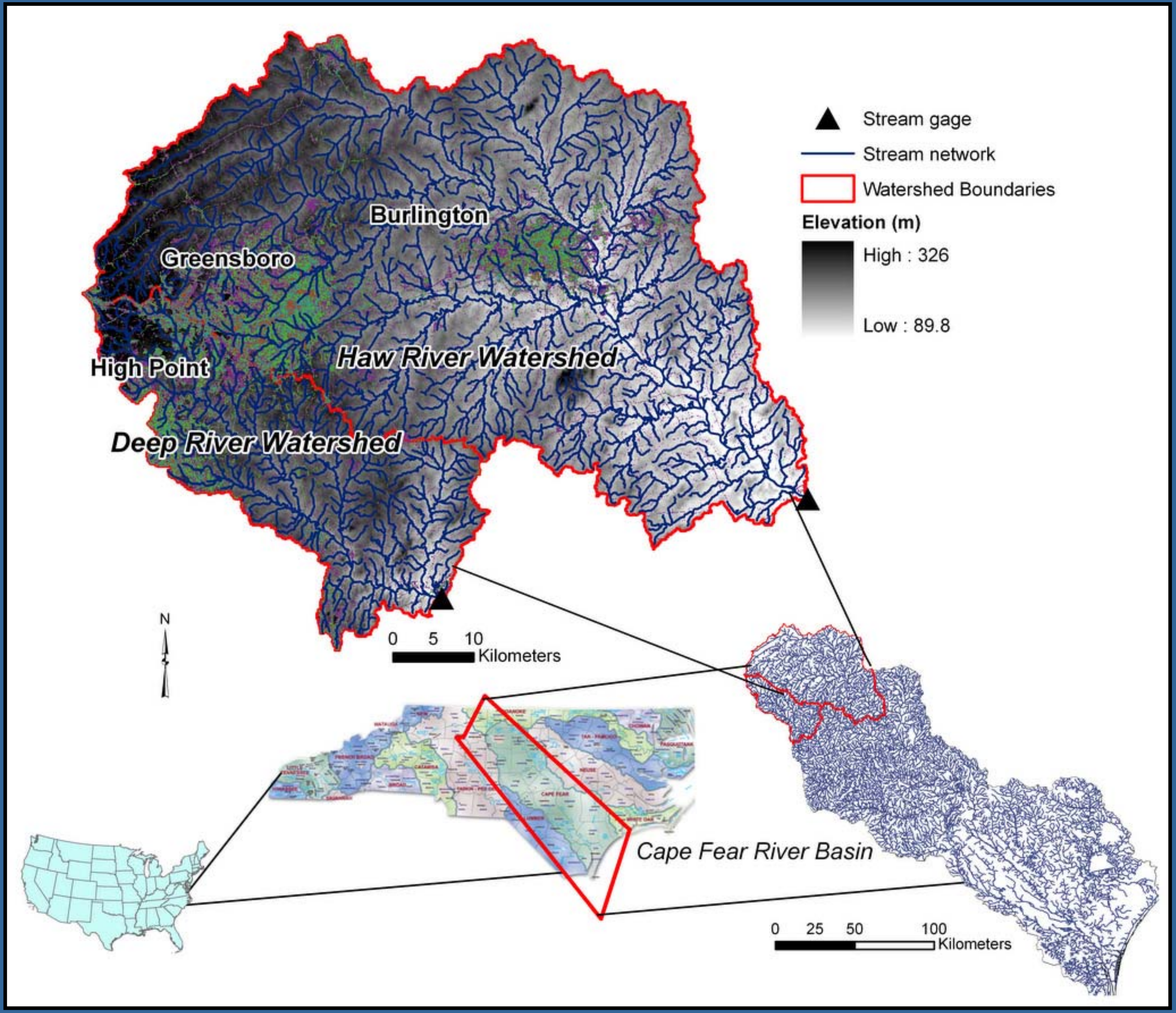
What are the Hg (MeHg, Hg (II)) and N (NO_3-N) flux responses from watersheds to land cover changes?



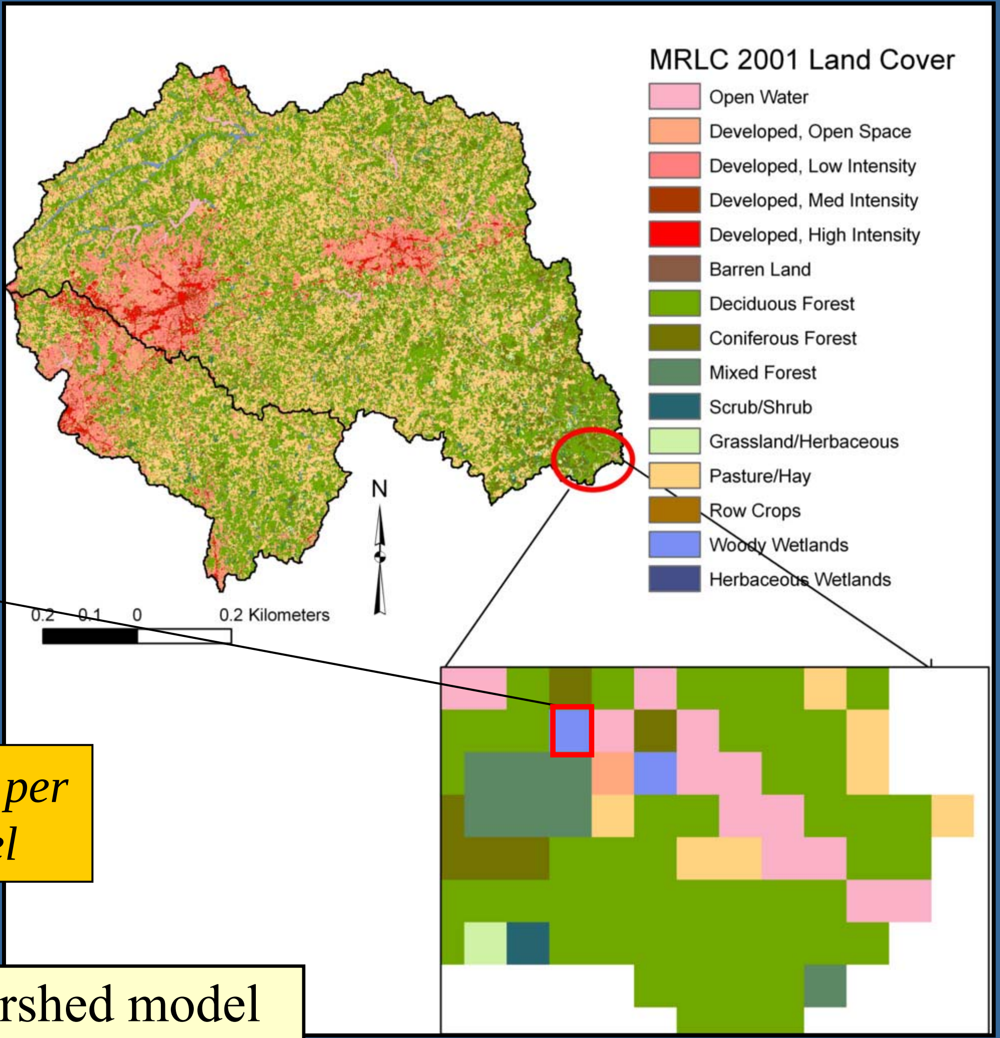
- *The Deep (903 km² above stream gage) and the Haw River (3296 km² above stream gage):*
- *Piedmont Region watersheds*
- *Headwaters of the Cape Fear River Basin, North Carolina (approx. 24,000 km²)*

Watershed models

Grid Based Mercury Model: watershed-scale spatially-explicit estimates of daily water, sediment, and mercury fluxes from each land cover type to surface waters

H_20, Hg, and sediment cycling, mass balance, and flow routing per grid cell

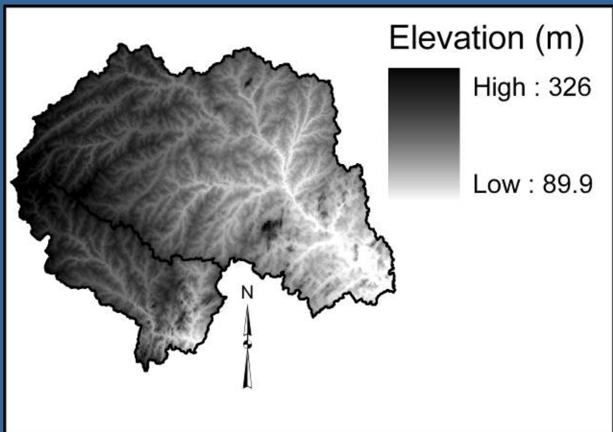
Transfer of daily runoff per land cover to N model

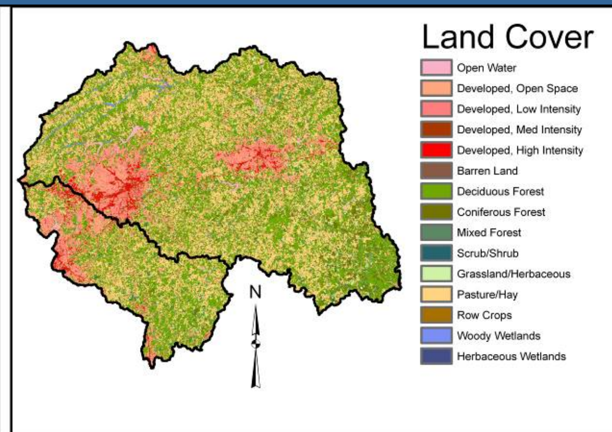


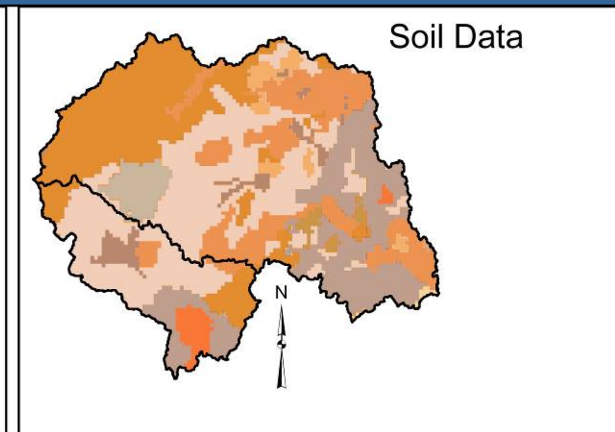
Simple N flux model: a dynamic watershed model that calculates daily nitrate (NO_3-N) in runoff for each land use across the watershed and as a lumped value at a watershed assessment point (based on SWAT and INCA).

Spatial data inputs for GBMM and N model

Grids scaled to 90 m x 90 m

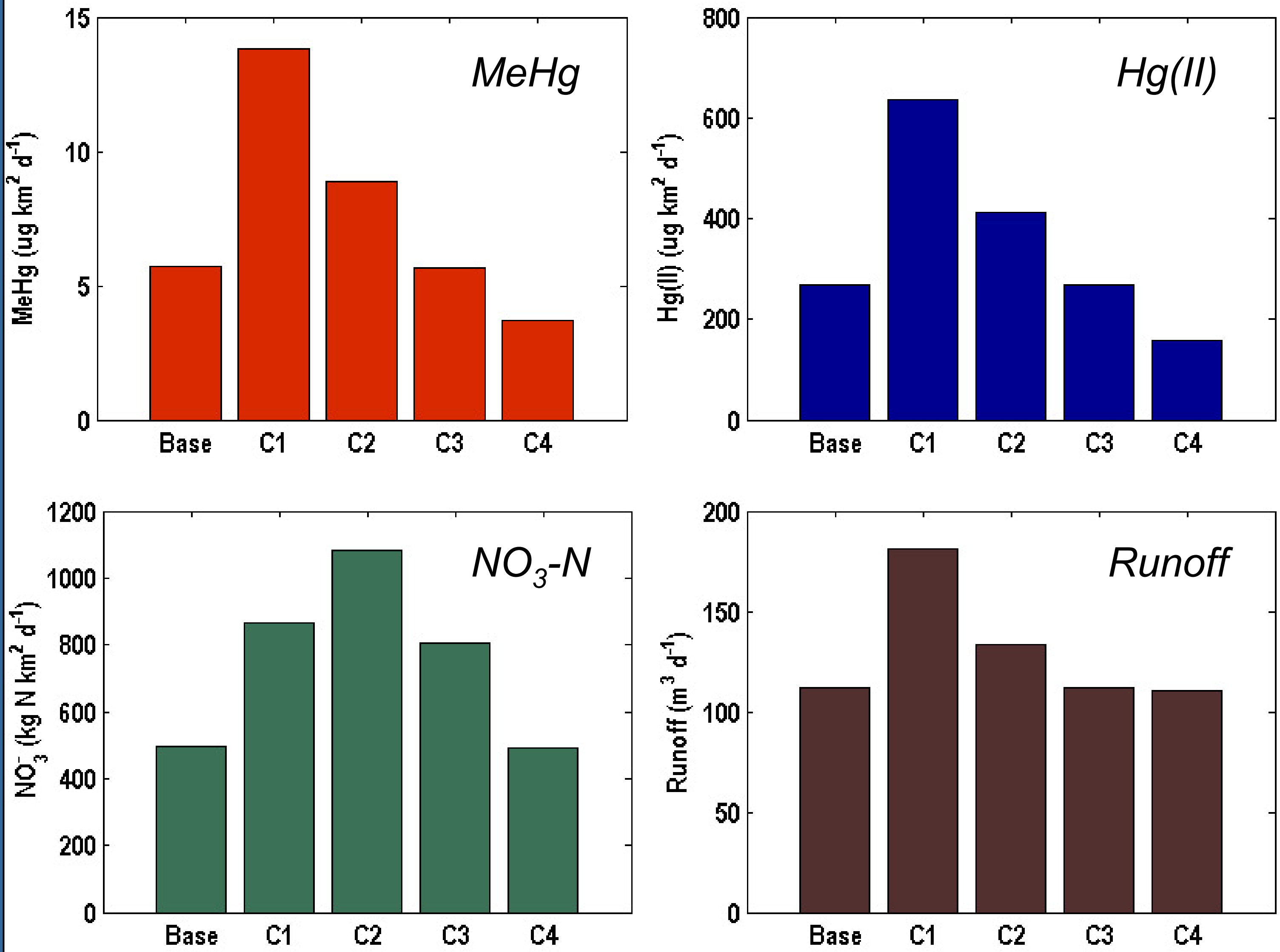






- Simulate base land cover (MRLC 2001) in GBMM and N model
  - Output (flux, load): MeHg, Hg(II), NO_3-N
- Reclassify land cover for (100% transition) from one land cover to other (e.g., pasture to mixed forest)
- Simulate reclassified land cover in GBMM
- Transfer runoff to N model; simulate in N model

Haw River Watershed	
LC (type)	*LC(%)*
Open Water	1.5
Developed	17.7
Barren	0.1
Forested	45.3
Shrub/Scrub	1.7
Grassland	3.5
Pasture/Hay	28.0
Row Crops	1.4
Wetlands	0.9

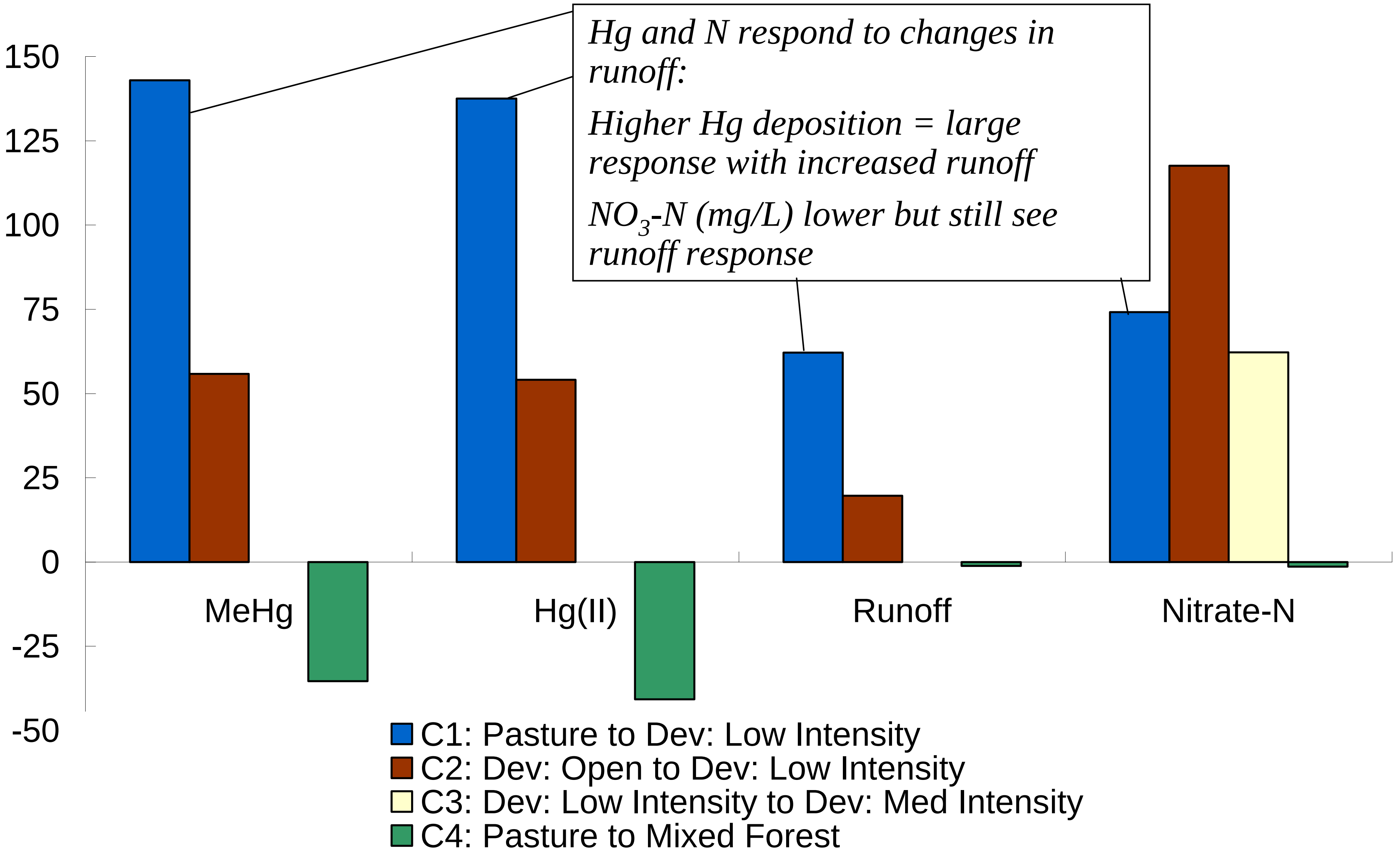


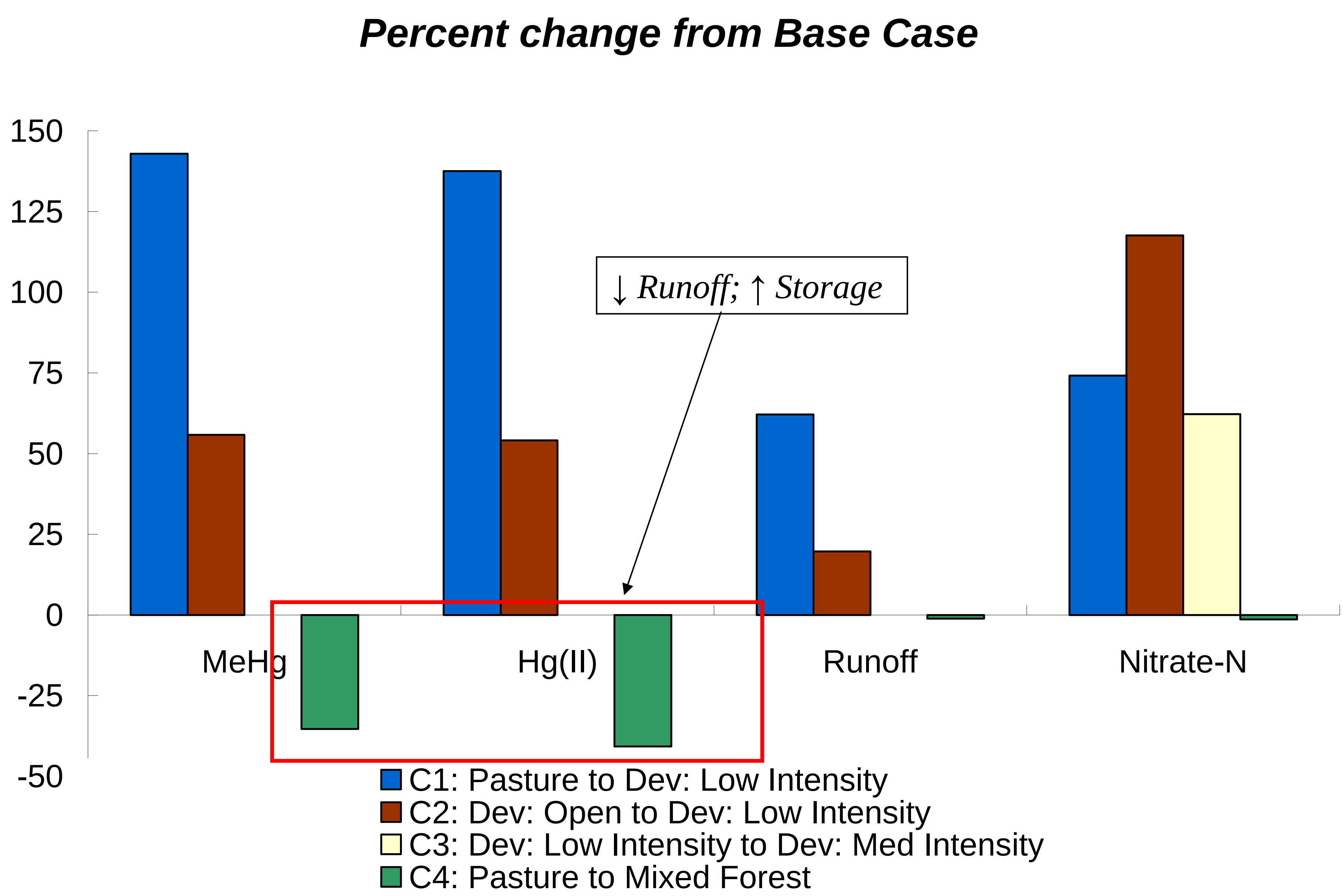
LAND COVER CHANGE SCENARIOS:
Base: Calibrated GBMM with Best Management Practices on Pasture Land
C1: Pasture to Developed: Low Intensity
C2: Developed: Open Space to Developed: Low Intensity
C3: Developed: Low Intensity to Developed: Medium Intensity
C4: Pasture to Mixed Forest

Preliminary annual results: 2002

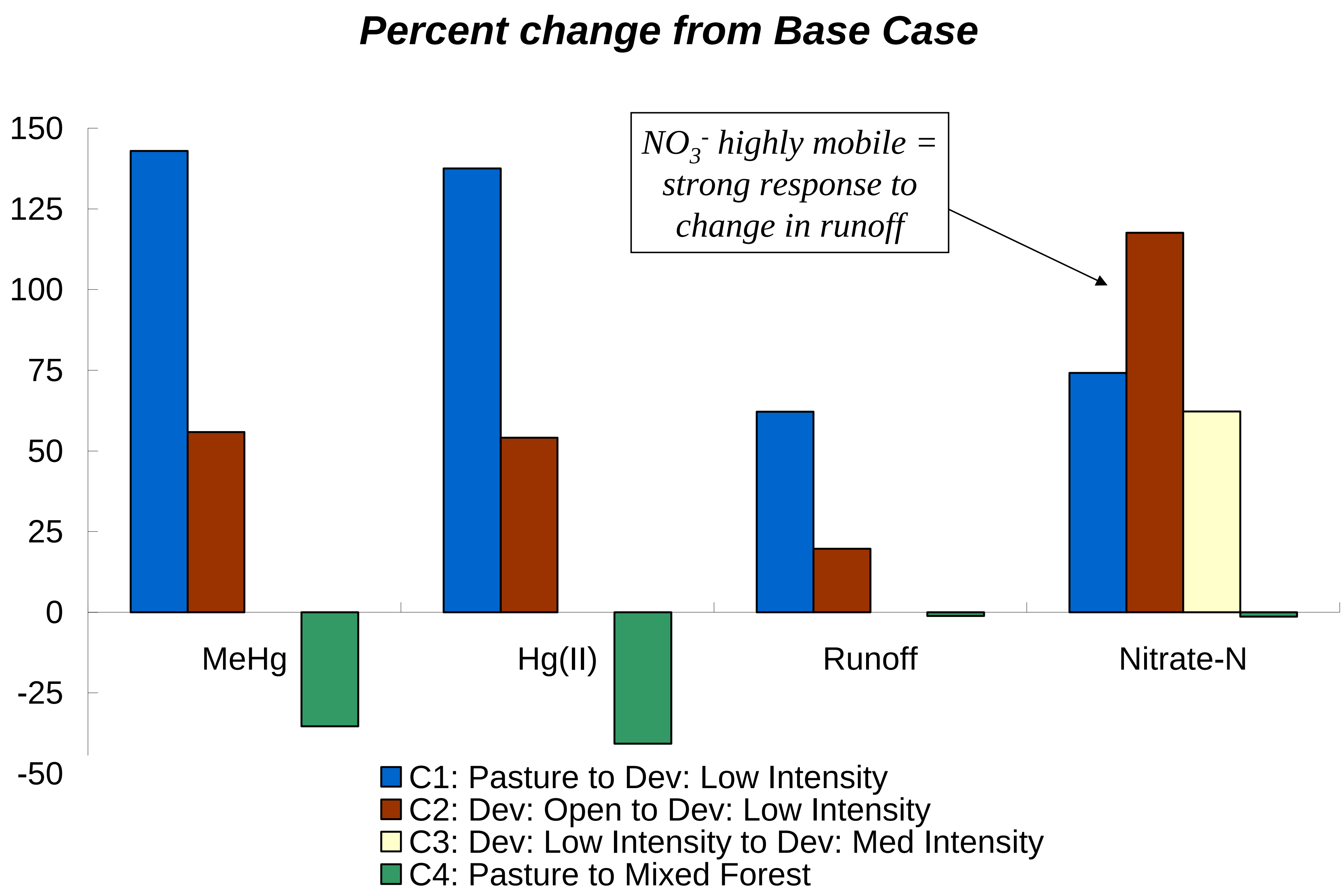
- Hg and NO_3-N respond to land cover changes
- Magnitude of change varies among each
- MeHg and Hg (II) typically follow the runoff response
- NO_3-N response = not just from change in runoff (C1): decrease in concentration

Percent change from Base Case





Percent change from Base Case
150
125
100
75
50
25
0
-25
-50
↓ Runoff; ↑ Storage
MeHg
Hg(II)
Runoff
Nitrate-N
C1: Pasture to Dev: Low Intensity
C2: Dev: Open to Dev: Low Intensity
C3: Dev: Low Intensity to Dev: Med Intensity
C4: Pasture to Mixed Forest



Percent change from Base Case
150
125
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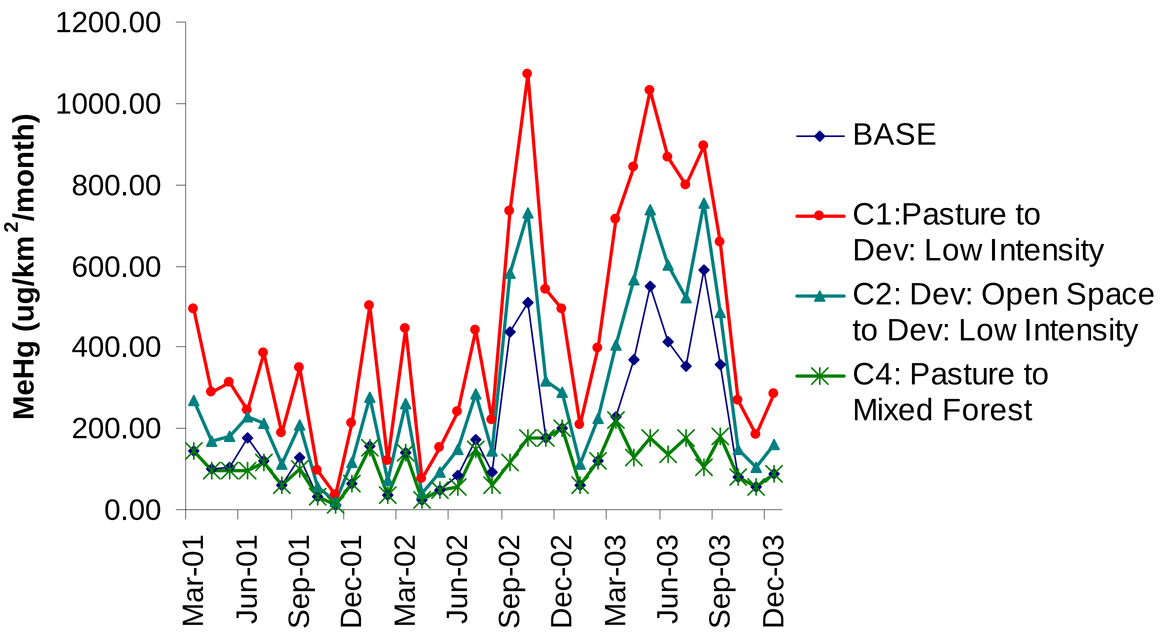
50
25
0
-25
-50
NO3- highly mobile = strong response to change in runoff
MeHg
Hg(II)
Runoff
Nitrate-N
C1: Pasture to Dev: Low Intensity
C2: Dev: Open to Dev: Low Intensity
C3: Dev: Low Intensity to Dev: Med Intensity
C4: Pasture to Mixed Forest

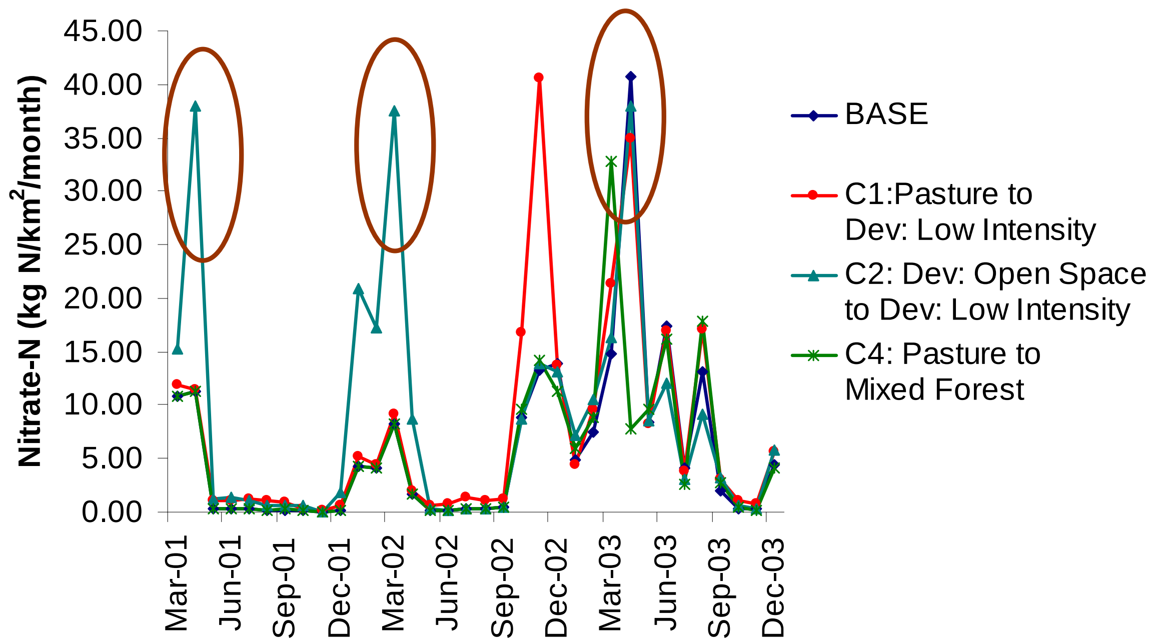
Seasonal Signals?

•MeHg: no strong trend

•NO_3-N: C2 peaks in spring = runoff response

•Currently, no sewage, septic inputs = 0 seasonal influence on N





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What does this mean for research/management?

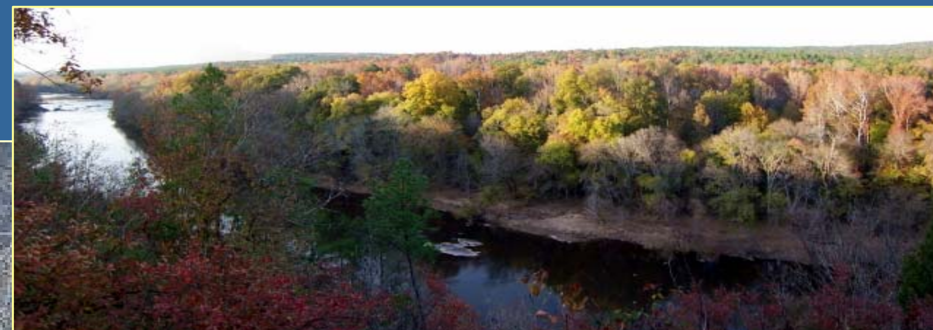
- Land cover change affects Hg and N response differently:
  - Different chemical transformations and response to flow (e.g. particulate vs. soluble forms of Hg; NO_3-N very mobile)
- Draining wetlands for construction:
  - ↑methylation and storage in wetlands, ↑flux of MeHg during removal;
  - ↓ denitrification, ↑increase flux of N
- Cape Fear: (chlor-alkali, cement kiln construction, wetland removal and Hg flushing):
  - Coastal ecosystem: N is a limiting nutrient (sewage, agriculture runoff = eutrophication issues)
  - Strategic spatial arrangement of wetlands
    - ↑ denitrification, ↓ N load, but promote methylation

Next challenges

- Assimilating all subbasins in Cape Fear and linking to a dynamic water body fate and transport model (WASP)
  - Translate effects to estuarine waters
- Increasing complexity of nitrogen model (e.g, ammonia volatilization), bounding rxn rate coefficients
- Estimating spatially explicit proportional changes (rather than 100% conversion)

Haw River, NC, J. Pons, 2009

Questions?


Cape Fear River (R. Taylor, 2007)


NASA/Decumanus (2004)


Haw River (NC Green Power, 2005)

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