Linking Land Use Change, Stream Geomorphology, and Aquatic Integrity in Changing Forested Landscapes

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Our research clearly shows that there are links between watershed and river corridor land use, stream geomorphic condition and aquatic ecosystem health. Although the complexity of these linkages is not fully captured in land use characterization or rapid geomorphic assessments, these planning and general assessment tools provide a reasonable first approximation of stream ecological integrity and can guide forested watershed planning and protection efforts.

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Project Summary

- Development is changing the landscape of the Northern Forest, dividing large woodlots into smaller parcels as suburban areas expand. The increasing densities of roads and buildings and higher levels of forest fragmentation are threatening the health of the streams and rivers in these changing watersheds. Our project was designed to develop a management tool that can help identify watersheds and streams that are threatened by urban development and target those areas where local land use planning can protect these aquatic ecosystems before they become seriously degraded.

Project Summary, 2

- When land use changes, runoff patterns also change, and stream channel form, or geomorphology, becomes altered. This can have serious implications for macroinvertebrates, fish, and birds that depend on healthy stream channel habitats. By sampling streams in both good and poor geomorphic condition, we first identified those habitat conditions most essential to kingfishers, a water-dependent bird, and other aquatic biota. Then, using GIS and statistical modeling, we linked land use patterns to measures of stream habitat and ecological condition. Finally, we examined likely patterns of development to predict what they might mean for stream condition in the future.

Project Summary, 3

- Our results clearly show that there are links between watershed and river corridor land use, stream geomorphic condition and aquatic ecosystem health. Although the complexity of these linkages is not fully captured in land use characterization or rapid geomorphic and habitat assessments, these planning and general assessment tools can provide a reasonable first approximation of stream ecological integrity. This is positive news for the large number of organizations that are using geomorphic approaches as a regular part of watershed planning and risk assessment efforts designed to target streams and watershed in greatest need of restoration and conservation.

Project Summary, 4

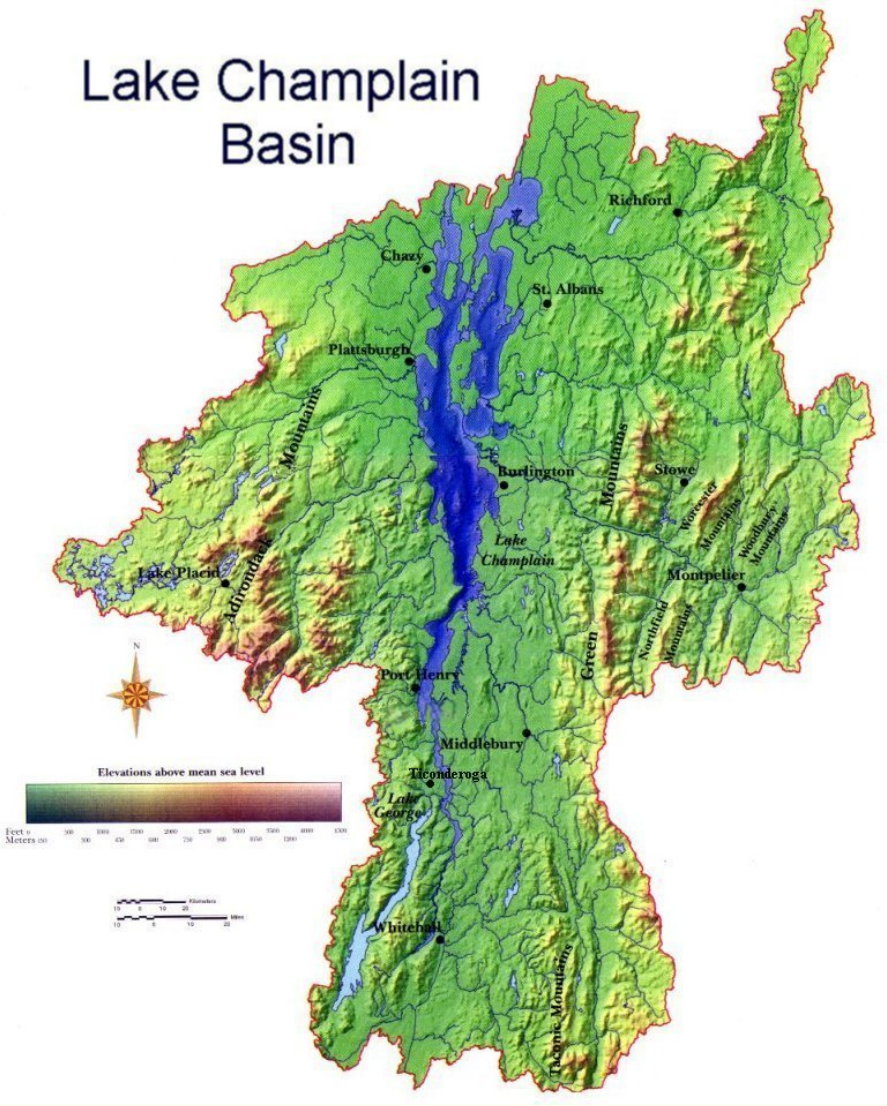
- Although no hard and fast thresholds were identified, we did find that when a watershed contained greater than 7% urban area or greater than 25% agricultural area, stream geomorphic condition declined. In general, streams in better geomorphic condition, and thus ecological condition, were associated with riparian corridors that had more forested area and more forest stand structural complexity (e.g., dead tree density and basal area). In our hierarchical classification system, watersheds with these forest characteristics were considered a priority for conservation, especially in areas threatened by rapid exurban growth.

Background and Justification

- Across the Northern Forest, contiguous woodlots are being subdivided into small parcels as transportation networks improve and exurban growth and development increase.
- This increasing fragmentation and higher density of impervious surfaces can lead to reduced soil water recharge and retention capacity, more rapid runoff, increased rates of erosion and sediment transport in streams, and impairment of aquatic ecosystems.
- A better understanding of the relationship between increased development and stream ecosystem integrity will facilitate more effective land use planning for watersheds and water resources in the Northern Forest.

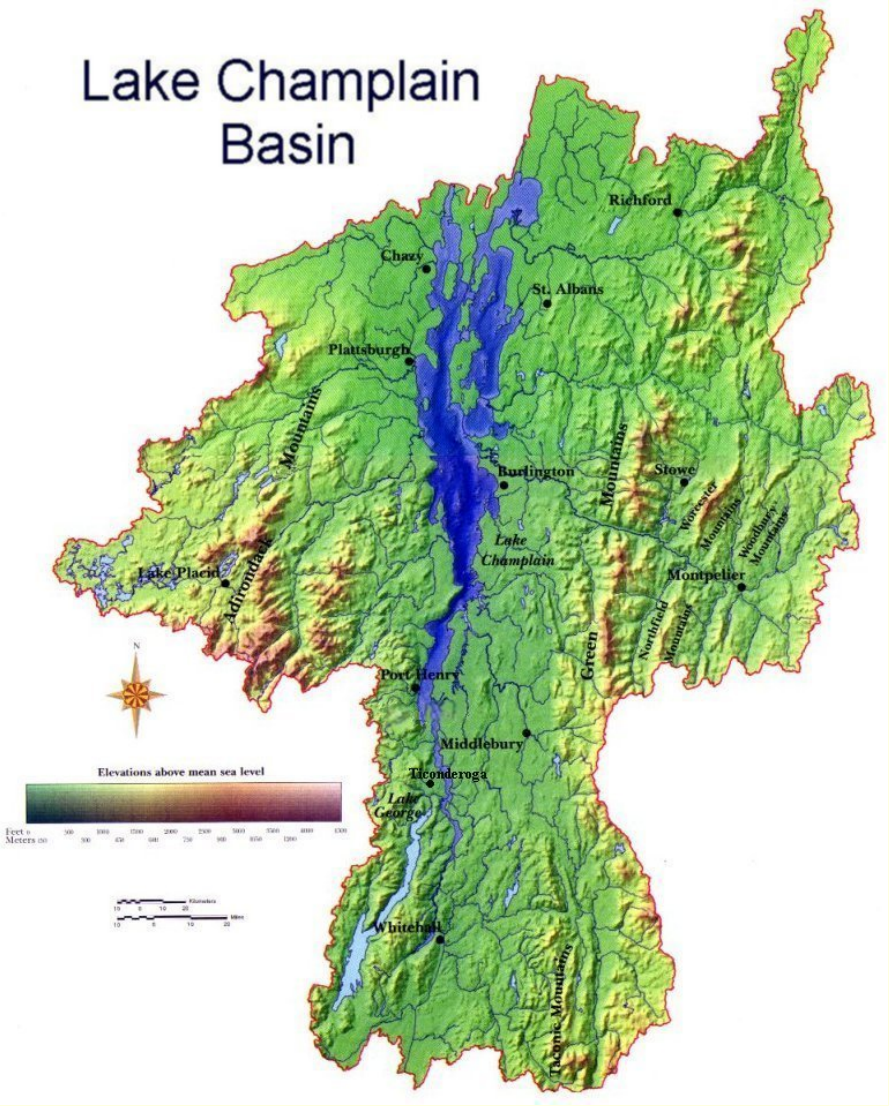
Linked Aquatic-Terrestrial Ecosystem

- Stream, river, and lake conditions reflect activities on the land. We asked 3 questions:
  - How does stream hydrology and geomorphology relate to stream ecological integrity?
  - How do forest fragmentation and changes in watershed land use affect stream condition and ecological integrity?
  - Can we predict where land use planning is needed to conserve ecological integrity?



Methods

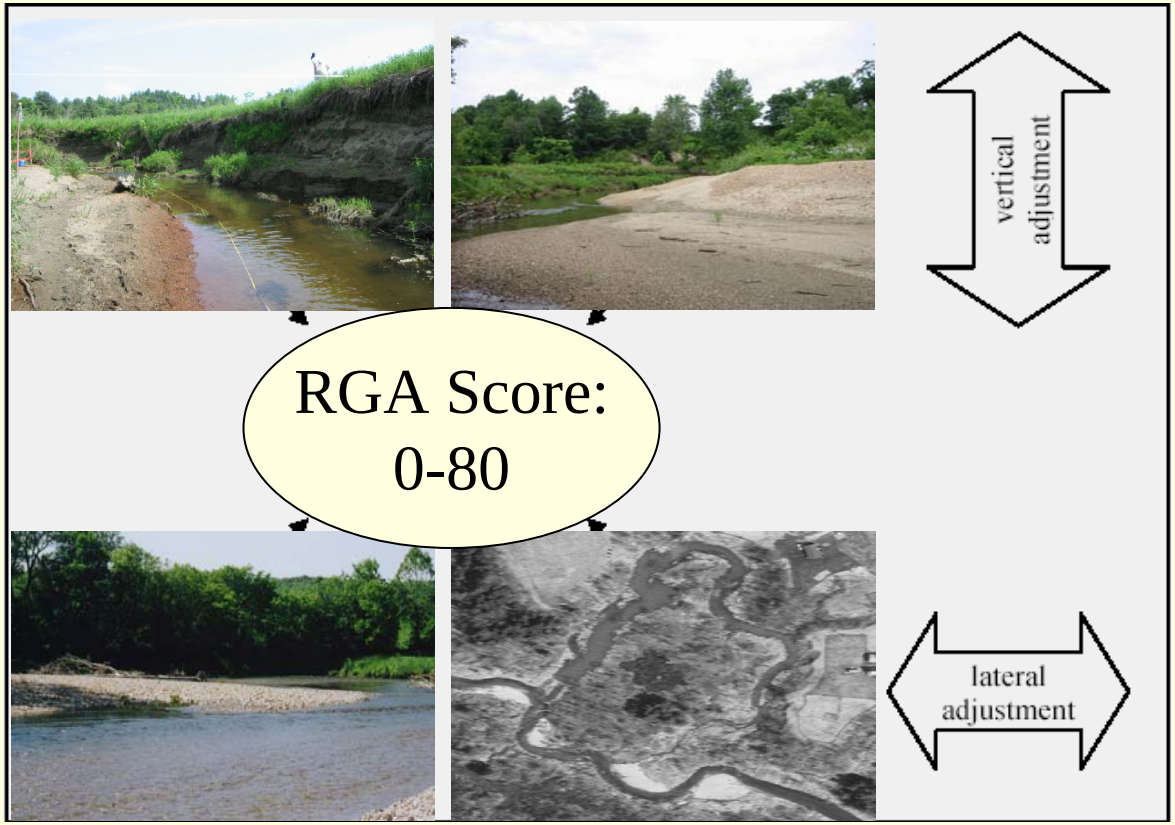
- We selected stream reaches and watersheds across a gradient in geomorphic condition and encompassing a variety of riparian and watershed land uses.
- For each reach and watershed unit, we evaluated stream geomorphic condition, land use, riparian buffer characteristics, and ecological integrity.



Rapid Geomorphic Assessment

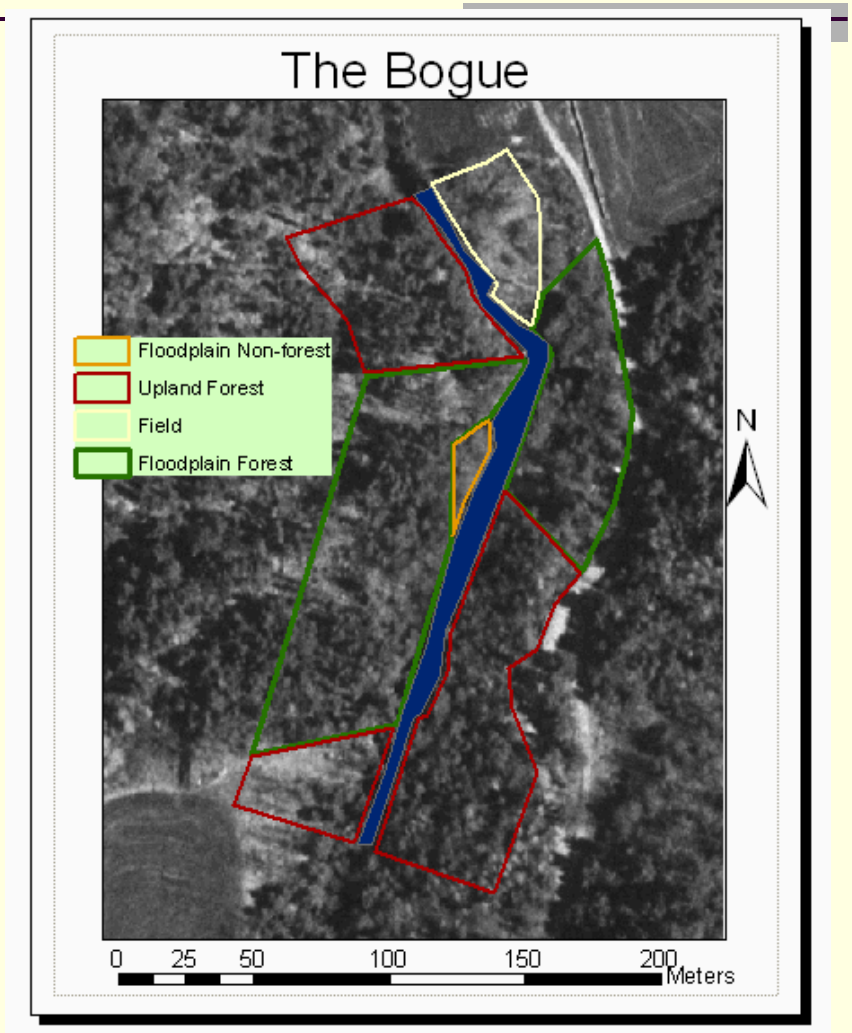
- To evaluate geomorphic condition, we used a scoring system based on observable or easily measurable characteristics of streams and rivers

1. Major channel adjustment processes (vertical and horizontal) are examined.
2. Scores from both adjustment process evaluations are combined to determine an overall RGA score.



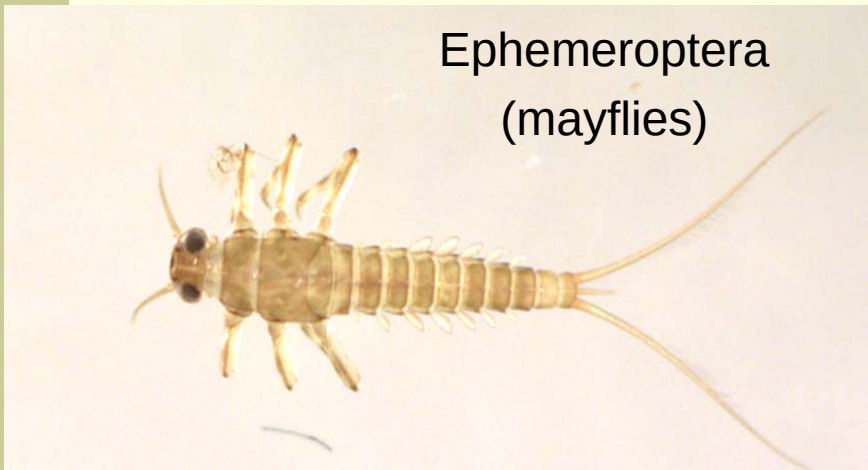
Riparian Forest Characteristics

- Riparian forests were sampled in a 50m buffer on each side of the stream.
- RGA scores were significantly correlated with percent forest cover in this buffer.
- Streams running through forests with greater structural complexity (trees of variable size, some standing dead trees) were in the best geomorphic condition.



Riparian forest habitat mapping

Macroinvertebrates



- Macroinvertebrates were sampled in 4-6 riffles in each reach.
- Some macroinvertebrates are sensitive to changes in physical habitat and need sediment in specific size ranges.
- Macroinvertebrate communities responded to small scale changes in riffles; there were small positive associations between EPT diversity and RGA scores.

Fish – move among habitats

Brook trout

Seining for fish and a connected floodplain wetland

- Fish were sampled in 4-6 pools in each reach.
- Fish also have specific habitat requirements, but use a larger habitat area.
- Fish abundance, diversity, and condition were significantly correlated to stream condition.

Results Summary – macroinvertebrates and fish

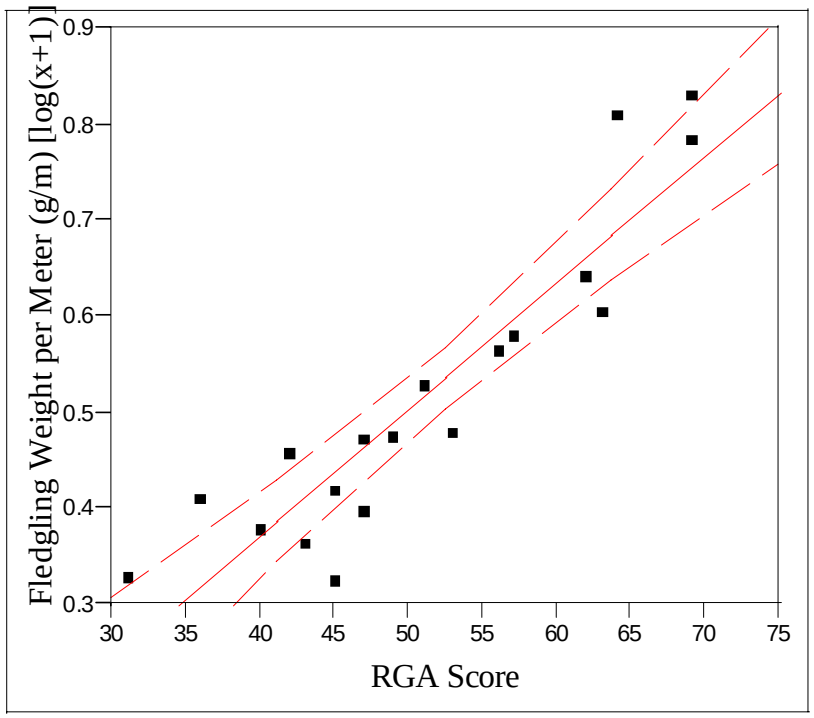
- Macroinvertebrate density and fish biomass were correlated (r = 0.76), and both were positively associated with RGA score.
- Bed aggradation had a particularly negative effect on both groups. Sources of sediment include agriculture, timber harvest, and suburban development.
- Stronger associations were found between fish metrics and reach-scale geomorphic condition than those with macroinvertebrate metrics and geomorphic condition despite the widespread use of macroinvertebrates in stream assessment programs

Birds – respond both to stream quality and riparian corridor condition

- Kingfishers are a cosmopolitan, water dependent species. Their population dynamics might “indicate” overall stream health.
- We examined reproductive success as a measure of habitat condition and available food.

Kingfisher adult (above) and fledglings (left)

Relationship between Fledgling Brood Weight/Territory Meter and RGA Score



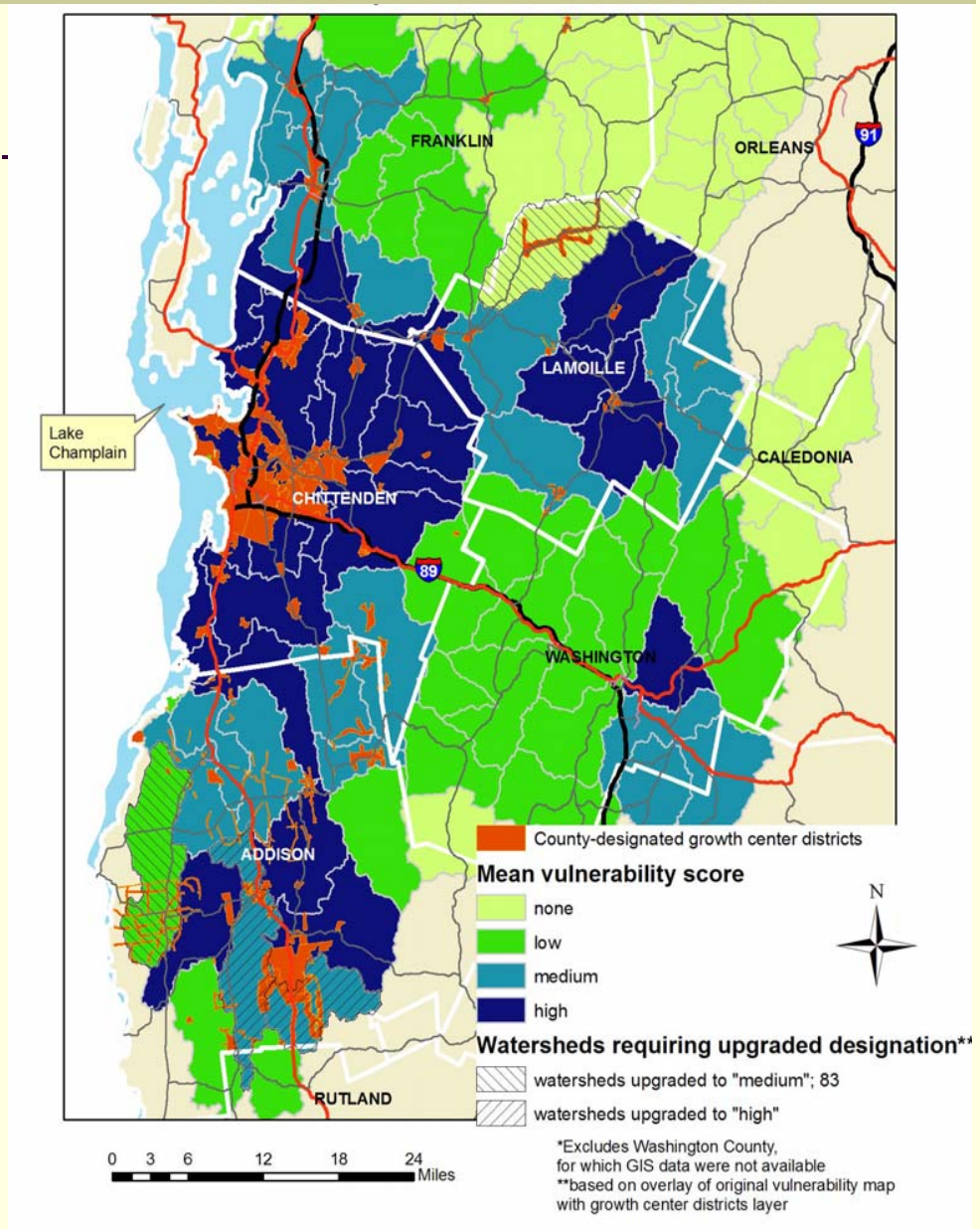
Regression results - fledgling brood weight/territory meter and Rapid Geomorphic Assessment score

- Stream reaches in good geomorphic condition supported kingfisher broods with greater weights.
- Parental pairs required longer territories along stream reaches in poor geomorphic condition than along streams of better condition.

Land Use And Vulnerability Analysis

- We mapped current land use using 2002 Landsat imagery supplemented by other data.
- We then used simple models based on drive time to employment centers and site suitability (Act 250 criteria) to predict where new development was likely to occur.
- Finally, we examined the implications for conservation and restoration based on known relationships between land use, RGA and watershed conditions.

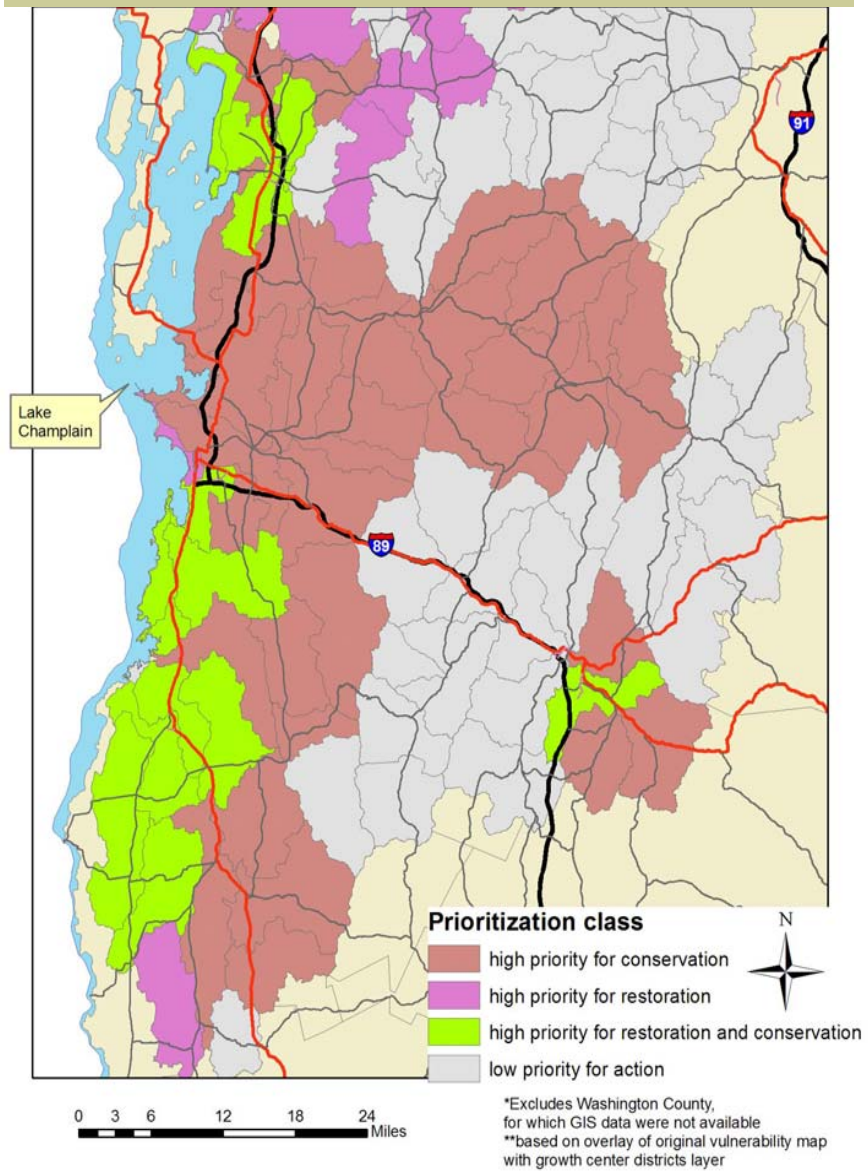
Designated Growth Centers and Vulnerability Scores for West Central Vermont



Targeting for Conservation and Restoration

- Watersheds with unimpaired streams and medium or high vulnerability to development were classified as “high priority for conservation.”
- Watersheds with impaired streams and low vulnerability to development were classified as “high priority for restoration.”
- Watersheds with impaired streams and medium or high vulnerability to development were classified as “high priority for conservation and restoration.”

Conservation and Restoration Priority Classes for HUC 12 Watersheds



Project Outcomes

- Our research has shown that:
  1. RGA scores and aquatic community characteristics are valuable measurement endpoints for watershed-level ecological risk assessment.
  2. Loss of forest cover, particularly in the riparian corridor, leads to declining stream condition and loss of aquatic biota.
  3. GIS tools can help visualize the ecological impacts of current and future land use change and thus inform future policy debates at the local, state, and regional levels.

Outreach Activities and Impacts

- We made regular presentations of our results to local watershed associations and conservations groups.
- Our data are being used by Vermont Department of Environmental Conservation and Department of Fish and Wildlife, The Nature Conservancy, and USFS Green Mountain Forest as part of efforts to update Vermont's geomorphic and habitat assessment protocols and to rank impairments in watersheds.
- Our results are being used by the Vermont Agency of Natural Resources, the EPA, and other stakeholders to evaluate restoration projects being considered as part of Vermont's watershed planning initiative.
- The land use date base has been provided to regional planning commissions, the State of Vermont, and is available through the Vermont Center for Geographic Information (VCGI).

Implications for the Northern Forest

- As watershed land use changes, stream condition and ecological integrity also change.
- Forest cover and structural complexity in the riparian corridor are particularly important for maintaining stream ecological integrity.
- Planning and general assessment tools like land use characterization and rapid geomorphic assessments provide a reasonable first approximation of stream ecological integrity and can guide forested watershed protection efforts.

Future Directions

- Because watershed and riparian land use are linked to stream geomorphic condition and ecological integrity, a more refined predictive model of future population growth and development pressures would be extremely useful in watershed planning efforts.
- Econometric modeling approaches continue to develop and now show great promise for predicting build-out scenarios under a variety of conditions. Although data availability remains an issue, these modeling approaches should be pursued in future applications.

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Hession, W.C., C.M. Cianfrani, M.N. DeWolfe, D. Lefever, and M.C. Watzin. In preparation. Streambank Retreat and Phosphorus Inputs in the Lake Champlain Basin, Vermont. Journal of the American Water Resources Association.

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Watzin, M.C., A. Troy, W. Keeton, and W.C. Hession. *In preparation.* A hierarchical classification system for identifying watersheds and stream in need of conservation or restoration.

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DeWolfe, M.N., Streambank Erosion: Quantification and Management in the Lake Champlain Basin of Vermont, Masters Thesis, Civil & Environmental Engineering, University of Vermont, 2004.

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