Quantifying the factors that influence flows in headwater streams

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In a drought year....
Historical Perspective

- 1930’s deforested landscape
- Hurricane Hazel
1980 -2000 Defining Productive Capacity in streams

- Habitat models (Bowlby and Roff (1986), Steedman (1988), Stoneman and Jones (2000), etc.

Correlate specific habitat features with fish biomass

Guides site specific mitigation..... But planning?
Strategic Implementation
(mid 80’s to present)

Rigorous application of the no-net-loss (net gain) policy on direct fish habitat.....

Did I mention this is Les’s perspective.....
Mid 90’s Watershed planning (requires a landscape perspective)

2006: Three papers
Quantifying landscape influences on biophysical properties of streams
Since 1995 a coalition of partners has been working to understand how disturbance influences stream health (MNR, DFO, EC, MOE, TRCA, GRCA, CLOCA, HRCA, Michigan DNR, GLC, UofT, UofG).
Strong threshold response in fish community to development
LDI = \sum \% \text{ area land cover type} \times \text{LDI rating}

LDI Ratings range from 0.0 for water to 0.9 for roads

18 land cover categories.....
Regression model for Brook Trout

126,000 brook trout < 21% of historic range
Take home message

1. Landscape models better predictors than instream habitat
2. Only 2-3% of residual variation from landscape models explained by competition, habitat or riparian condition
3. Catchment is the best predictor of stream conditions
Protecting direct fish habitat may not be enough

Need to protect processes important to fisheries in areas currently not protected..... **Headwaters**

1. Hydrology (baseflow/peak flows)
2. Geomorphology
3. Connectivity
Factors that influence flows

- **Baseflow**

- **Peak flows**
  Stanfield, L. W. 2009. Understanding the factors that influence headwater stream flows in response to storm events. University of Toronto, Masters Thesis. 75 pp
Poor correlation in small catchments

Minimum size for a permanent flowing stream 17,800 ha!
Check your watershed day

Volunteer agency collaboration

Baseflow at most road Crossings

Inventory perched culverts!
Peak flow Methods

1. Hypothesis Generation
2. Study Area Determination/Site Selection
3. Data Collection
   - Measure Stage Response
   - Estimate Velocity
   - Measure Wetted Area of Response
   - Calculate Event Discharge
   - Measure Rainfall
   - Attribute Catchment Geology/land cover/slope
   - Interpolate Mean Catchment rainfall
   - Summarize Catchment attributes
   - Correlations (bi-plots, RDA)

4. Technique Validation
North-south land use/land cover gradient.....
Measuring stream response

Crest Stage Gauges and Manning’s equation
Estimating $Q$: (Area * Velocity)

Manning’s Equation..... $V = \frac{1}{n} R^{2/3} S^{1/2}$

- Area good...
- Manning’s needs validation
Defining and Attributing site catchments

- Arc-Hydro define catchments
- GIS used to attribute
  - Geology (Quaternary)
  - Land use/land cover (SOLRIS) (LDI)
  - Slope (valley)
Rain event

• Volunteer and agency network to measure rainfall in each catchment
• Extract maximum value for period between sampling (12 events) and rainfall 2 days prior (rb)
Select sites at furthest upstream accessible area, contrast in geology and land use

Rain gauge network (volunteer and agency)
Results

The search for patterns.....
HAR1-05

$LDI = 0.77$ and $BFI = 0.55$

Standardized for each catchment per day
(Q*sec/day/catchment area)
Poorly drained soils.....

consistently higher response in highest development areas,
Moderately well drained soils

High response if really high LDI,.... the rest not perfect!
Well drained soils

GAN20-7
LDI = 0.8 and BFI = 0.69

GLENHOLM
LDI = 0.66 and BFI = 0.69

DA18_hyd
LDI = 0.7 and BFI = 0.69

GAN3-11
LDI = 0.03 and BFI = 0.71

GAN4-17
LDI = 0.04 and BFI = 0.71

GAN3-8
LDI = 0.04 and BFI = 0.71

Poor response in all catchments.... geology rules
Redundancy and Partial Redundancy Analysis

• Used to quantify patterns and evaluate significance
1. Higher poor and well drained soils and LDI > higher discharge
2. Higher rain and moderate drained soils > lower discharge
3. Discharge scores very similar
Both Land use and Geology affect discharges. Rain is not important.... Too messy!

Partial RDA

P=0.33

P=0.02

P=0.002
Conclusions

• Geology and land use are both important..... but lots of variability
• Responses in drought years are not highly correlated with rainfall
  - soil moisture - crop condition?
Implications for “Planning”

1. Headwater systems can generate large volumes of storm water
2. Existing predictive models (means) will not protect headwater stream low or peak flow conditions .... and biota!
3. Most vulnerable areas to change is likely poorly drained soils.... Where development is concentrated or planned!
4. At present cannot predict specific impacts to flows from land use with the possible exception of poorly drained soils
Implications for monitoring

• Crest Stage approaches work well for broad scale studies
  – need to validate Manning’s n
• Existing rain gauge network is inadequate
• Need to invest in both low flow and peak flow monitoring programs.... Can’t rely on predictive models!
CLIMATE CHANGE!

Species at Risk!

U.S. supreme court decision to protect headwater systems under Endangered species Act.
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