Response patterns of macroinvertebrate indicators to landscape and hydrologic alteration across multiple spatial scales in the Western U.S.
Acknowledgements:

Team members and funding

a) Jason May (CA), Anne Brasher (UT), Larry Brown (CA), Chris Konrad (WA), Terry Maret (ID), Bob Black (WA), Ian Waite (OR), Terry Short (CA), Anne-Marie Matherne (NM), Tim Rowe (NV), Donna Knifong (CA), Bob Ourso (AK), Kurt Carpenter (OR).

b) Funding provided by NAWQA Status and Trends Program

c) We also thank the numerous field biologists, hydrologists, taxonomists (Brandy, Dan, Joe, John and others), and technicians that collected and processed all the data we used in these analyses.
Overview of Presentation

1. Project components
2. Data sources and analysis tools
3. Brief synopsis on landscape alteration and hydrologic modification as it relates to this project
4. Overview of scale related assessments
5. Summary of results by component
6. Conclusions and future work
7. How are these findings relevance to the bioassessment community and managers
Project components:

(1) Assess relations between stream flow parameters and MBI metrics across western U.S. (n = 115)
- Flow parameters encompass high, low and central tendency flows
- Characterize magnitude, duration, frequency, timing and variation in flow regime

*Konrad, Brasher, and May - submitting to Freshwater Biology*
Project components- continued

(2) Analysis of MBI relations to catchment-based measures of landscape alteration and hydrologic infrastructure across multiple spatial scales (n = 332)

*May, Brown, Short, Konrad, Maret and Brasher sending to Landscape Ecology*
Component 2 continued..

- Analysis consists of 5 MBI metrics vs.
  - Two measures of percent developed land (AG + URB land use) on basin and segment scale
  - Two measures of hydrologic infrastructure
    - # dams and km manmade channels in the watershed
  - Over three spatial scales
    - West-Wide
    - Biome (MTN = WET/XER = DRY)
    - Biome-regions (MTN1-4 and XER1-4)
IR 6 Sampling locations

**Explanation**
- All IR6 sites
- IR6 site with Robust Hydrology* *(5 or more years of record)*

MRB = Major River Basin

MRB-6
GB

MRB-7
PNW

MRB-8
CAL.
Data sources and analysis tools

• Invertebrate RTH data collected during 1993-2002 by the NAWQA program only use one year rep.

• Habitat by NAWQA protocols

• Flow information: USGS NWIS

• Landscape variables:
  • Landuse/Land cover-NLCDe
  • Hydrologic Infrastructure: NHD, NID

• Preliminary analyses:
  • Univariate and multivariate statistics
  • BIOTDB/IDAS-Metrics and taxa list files: started with 157 bug metrics formulated on lowest practical level typically genus information
Data sources and analysis tools

• Nonparametric Screening Procedure-VB based Macro
  • A statistically based bi-variate screening tool that identifies negative and positive ceilings and floors
  • Quantile regression (similar to upper bound or lower bound regression)
Figure 2. Conceptual Diagram of Potential Metric Response Patterns

a) Negative Ceiling;  
b) Negative Floor;  
c) Positive Ceiling;  
d) Positive Floor
Background on landscape alteration and hydrologic infrastructure
Distribution of NAWQA sites West-Wide by Percent Development Basin (%AG + %URB-LU/LC)

- 'Least' Developed: <25%
- 'Moderately' Developed: 25<x<75%
- 'Highly' Developed: >75%

Regions:
- Great Basin
- Pacific North West
- California
PDB is moderately to strongly correlated with a number landscape and local features

<table>
<thead>
<tr>
<th>Watershed Characteristics</th>
<th>PDB</th>
<th>Habitat (Channel)</th>
<th>PDB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>0.116</td>
<td>%Pool</td>
<td>-0.241</td>
</tr>
<tr>
<td>Longitude</td>
<td>-0.329</td>
<td>%Riffle</td>
<td>-0.499</td>
</tr>
<tr>
<td>Drainage area</td>
<td>0.124</td>
<td>%Run</td>
<td>0.504</td>
</tr>
<tr>
<td>Mean Basin Elevation</td>
<td>-0.538</td>
<td>Mean Open Canopy</td>
<td>0.124</td>
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<tr>
<td>Mean slope</td>
<td>-0.685</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Landscape/hydrologic characteristics</th>
<th>PDB</th>
<th>Habitat (particle size)</th>
<th>PDB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Density</td>
<td>0.547</td>
<td>%BR</td>
<td>0.025</td>
</tr>
<tr>
<td>1990 Pop dens</td>
<td>0.635</td>
<td>%SILT</td>
<td>0.426</td>
</tr>
<tr>
<td>SUM_FOR-b</td>
<td>-0.632</td>
<td>%COBBLE</td>
<td>-0.52</td>
</tr>
<tr>
<td>#ManMade Channels</td>
<td>0.454</td>
<td>%BOULDER</td>
<td>-0.464</td>
</tr>
<tr>
<td>#Dams</td>
<td>0.282</td>
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</tbody>
</table>

Spearman’s correlation coefficients

PDB = % developed basin (AG+URB land use)
Pervasiveness of Hydrologic Infrastructure Across the West

Number of Dams in Basin:
- 0
- 1 to 5
- 6 to 31
- 32 to 448

Length of Man Made Channels:
- 0
- 0.01 to 0.31 km
- 0.32 to 1.94 km
- 1.95 to 87.6 km
Background on spatial scale in aquatic assessments
So What do we mean by Scale??
Something like this ‘Presidential-babushka’ scale??

Scaling of Presidential ‘___________’
Nested in hierarchical organization
Scales are linked via evolution and history of impacts
Biotic/Abiotic characterization based on a geographic and spatial hierarchy.....

Results of Flow regime-invertebrate metric assessments
Graphical examples of MBI metric-streamflow regime relations

- **EPT Richness** vs. **CV of Ann. Min Streamflow**
- **Scrubner abundance** vs. **CV Monthly Mean Streamflow**
- **Percent Daily Change in Streamflow** vs. **Dominance**
- **Median Annual Number of High flow events**
MBIs were responsive to a variety of streamflow parameters

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<thead>
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<th>ABUN</th>
<th>NONINp</th>
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<td><strong>Central Tendency Flow Parameters</strong></td>
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<td>100-day mean</td>
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<td>% Daily Change</td>
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<td>CV month</td>
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Associations of selected streamflow and invertebrate metrics (p < 0.05 that bivariate ranks were independent; **bold**, p < 0.01; blank, p > 0.05). Ceilings indicated with "C", floors indicated with "F", and direction of association indicated by "P" for positive and "N" for negative.
General Summary of Findings

Obj. 1 Flow regime perspective

- Daily streamflow variability was associated with the most invertebrate metrics such as richness, evenness, and diversity, and relative abundance of feeding groups and specific taxa.
Biogeographic scale assessments of landscape alteration and hydrologic infrastructure

**BIOME_REGIONS**

**XERIC**
- ▲ Eastern Plateau
- ◇ Southern Basins
- ○ Northern Basins
- ◯ California Lowlands

**MOUNTAINS**
- ▼ Southern Rockies
- ● Southwestern Mountains
- +++ Pacific Northwest
- ★ Northern Rockies

*Stoddard et al 2005; Omernik Level II*
PCA: Flow regime parameters and landscape features were widely distributed across all biome-regions.

**Elevation and Slope**
- 2 landscape factors
- 3 stream flow parameters

**Forested basin**
- 2 stream flow parameters

**Percent Developed Basin**
- 2 measures of human density
- 1 stream flow parameter

**Basin Size**
- 3 reservoir parameters
- 5 stream flow parameters

**Hydro-Infrastructure**
- 3 reservoir parameters
- 5 stream flow parameters

**PC1 (32%)**

**PC2 (21%)**

**Biome-Region**
- XE-EPLAT
- MT-SROCK
- XE-SOUTH
- MT-SWEST
- XE-NORTH
- MT-PNW
- XE-CALIF
- MT-NROCK

[\(n = 107\)]
PCA performed on ranked data
Figure 2. Conceptual Diagram of Potential Metric Response Patterns
a) Negative Ceiling; b) Negative Floor; c) Positive Ceiling; d) Positive Floor
### Biotic response patterns across scale: West-Wide

#### West-Wide (n = 332)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>EPTR</th>
<th>ShanDiv</th>
<th>RichTOL</th>
<th>Dom5</th>
<th>DivFFG</th>
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</thead>
<tbody>
<tr>
<td>Developed Basin (%)</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>P</td>
<td>N</td>
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<tr>
<td>Developed Segment (%)</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>P</td>
<td>N</td>
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<tr>
<td>Length of manmade channels (km)</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>P</td>
<td>N</td>
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<tr>
<td>Number of dams in basin</td>
<td>N</td>
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<td>P</td>
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</tr>
</tbody>
</table>

Relations listed as N = Negative or P = Positive significant patterns at p = 0.05. (--) Indicates a non-significant relation.
### Response Patterns across scale: Mountain biome scale

#### All Mountain sites (n = 142)

<table>
<thead>
<tr>
<th>Parameter</th>
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<td>P</td>
<td>P</td>
<td>N</td>
</tr>
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<td>N</td>
<td>P</td>
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<tr>
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#### Biome region scale

**Mountain Pacific Northwest (n = 73)**

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<tr>
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<td>Developed Segment (%)</td>
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<td>P</td>
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</table>
### Response Patterns across scale: Xeric biome scale

#### All Xeric sites (n = 190)

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<th>Dom5</th>
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<td><strong>Landscape Alteration Parameters</strong></td>
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<td>Developed Basin (%)</td>
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<td>P</td>
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<td>Developed Segment (%)</td>
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<td>P</td>
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<td><strong>Hydrological Infrastructure Parameters</strong></td>
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<td>Length of manmade channels (km)</td>
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<tr>
<td>Number of dams in basin</td>
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</table>

#### Biome Region Scale

**Xeric California (n = 42)**

<table>
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<tr>
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<td><strong>Landscape Alteration Parameters</strong></td>
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<td>Developed Basin (%)</td>
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<tr>
<td>Developed Segment (%)</td>
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<td><strong>Hydrological Infrastructure Parameters</strong></td>
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<td>Number of dams in basin</td>
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</tbody>
</table>
General Summary of Findings
Obj. 2 landscape perspective

- EPT richness, Shannon diversity, and functional feeding group diversity all showed significant declining patterns with increasing measures of human influence across multiple spatial scales.

- Dominance of the 5 most abundant taxa and richness of tolerant invertebrates were positively correlated with increasing patterns of human influence and were consistent across spatial scales.

- EPT richness and RichTol were the most responsive to our measures of landscape alteration and hydrologic infrastructure.
Conclusions

• Invertebrates responded to a broad range of streamflow parameters.

• Daily streamflow variability was associated with the most invertebrate metrics.

• Landscape alteration and hydrologic infrastructure surrogate variables presented here work reasonably well as a variables for linking biotic response to human influence across multiple spatial scales.
Next steps...

- Finalize scale based analyses via quantile regression
- Analysis of multi-year data to gain understanding of the effects on water year on our assessments
- Ecological models for prediction and prioritization of restoration activities.
- Future analysis may incorporate species traits for a less variable signal and better understanding of community processes
Relevance to the public and managers

- Potential for altering flow management strategies for maximizing biotic integrity
- Prioritization of watersheds for further investigation or restoration activities
- Factors/associations identified in these analyses can potentially serve a base line for regional planning and assessment efforts
Thank you
Effect of NZ Mud Snail in our data set

Sites with high abundance of Hydrobiid snails-mostly NZ mud snail
<table>
<thead>
<tr>
<th>Metric</th>
<th>HIGH FLOW</th>
<th>LOW FLOW</th>
<th>AMBIENT FLOW</th>
<th>RECENT FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Magnitude</strong></td>
<td>Geometric mean annual max daily flow, Maximum monthly flow,</td>
<td>Median annual minimum streamflow, Minimum monthly flow</td>
<td>Mean, Mean for month of sample, Mean daily runoff (mm)</td>
<td>100-day mean, 100-day mean/Q50, 100-day max, 100-day min, 100-day max/Q10, 100-day min,</td>
</tr>
<tr>
<td></td>
<td>Maximum Monthly Q as fraction of mean streamflow</td>
<td></td>
<td></td>
<td>100-day high flow duration, 100-day low flow duration</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>Q10 (flow exceeded 10 percent of the time)</td>
<td>Q90, Median annual number of continuous low flow days</td>
<td>Median TQMean</td>
<td>100-day peaks</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>Median annual number of peaks over Q10, Number of months with peak</td>
<td>Months with low flows</td>
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</tr>
<tr>
<td><strong>Variability</strong></td>
<td>Inner quartile of annual max daily flow, Standard deviation of annual</td>
<td>CV of annual minimum streamflow</td>
<td>Daily CV, Percent daily change in streamflow, Max Monthly Q/Min Monthly Q</td>
<td>100-day % daily change</td>
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<td>number of peaks</td>
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<tr>
<td><strong>Timing</strong></td>
<td>Month of maximum monthly streamflow</td>
<td>Month of minimum monthly streamflow</td>
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</table>
Screening for Flow-Invertebrate Relations

Divide plots into quadrants around an origin \((r,s)\) where \(r\) is the rank of the streamflow metric and \(s\) is the rank of the invertebrate metric.

Probability of finding a point in:
- Quadrant 1 (lower left) is \((r/n)(s/n)\)
- Quadrant 2 (upper left) is \((r/n)(n-s)/n\)
- Quadrant 3 (upper right) is \((n-r)/n (n-s)/n\)
- Quadrant 4 (lower right) is \((n-r)/n s/n\)

Identify quadrants and associated origins with statistically significant fewer points than expected using the binomial distribution.
Distribution of IR6 sites scored according to EMAP-West IBIs (rescaled to 100%)
WEMAP-IBI in relationship select measures
Xeric-Tan; Mountain-Green [1-yr REP]
Without two Snake R sites highly influenced by NZ MUD SNAIL