Stream Monitoring/Research Study Design Workshop

Benthos

Sponsored By:
Southern Ontario & Eastern Region Stream Monitoring and Research Teams,
Toronto Region Conservation Authority

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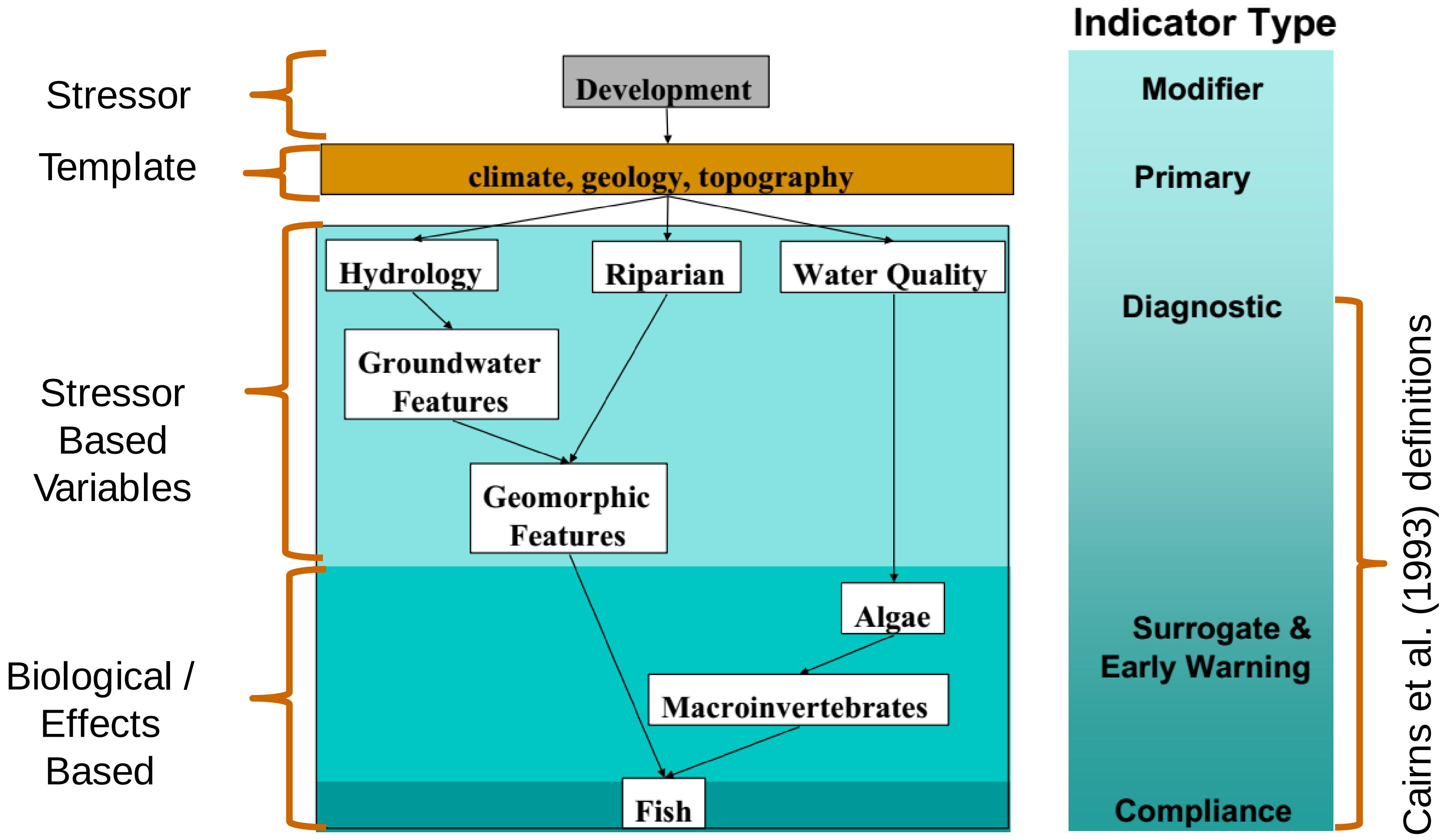
Outline

- Why benthos?
- How?
  - Collection methods
  - Taxonomic level
  - Indices
- When?
- What kinds of change matter?

Why?


Indicator Type
Stressor
Template
Stressor Based Variables
Biological / Effects Based
Development
climate, geology, topography
Hydrology
Riparian
Water Quality
Groundwater Features
Geomorphic Features
Algae
Macroinvertebrates
Fish
Modifier
Primary
Diagnostic
Surrogate & Early Warning
Compliance
Cairns et al. (1993) definitions

How?

- Travelling Kick samples
  - E.g., OBBN, OSAP, CABIN
    - Shorelines, riffles, pools
    - Higher diversity, normally more sensitive taxa

- Stationary Disturbance
  - E.g. OSAP, EPA, Surber
    - Shallow, moderate velocity
    - EPT targeted, comparison between like habitats


- Grabs
  - E.g., Ponar, Ekman,
    - Deep depositional areas
    - Normally more tolerant taxa

- Cores
  - Paleo samples; reconstruct lake history


- Artificial Substrates
  - Standardize substrate
  - Eliminate sediment effect


- Selective Indicator Taxa
  - Presence of EPT (E.g., OSAP) or exoskeletons
  - Screening tool

How Continued

- Kicks with coarse sieves, i.e., 1000 um (circa 1960’s)
  - To capture relatively large insects (e.g., mayflies, stoneflies, caddisflies)
  - Still widely used today, e.g., EPA, S2M2)
- Quantitative (circa 1980’s)
  - Surber, Neill-Hess Cylinder, Ekman, Ponar
  - Fine mesh (i.e., < 200 um) to capture most organisms
- Quantitative Federal EEM (1990s to present)
  - Surber, Neill-Hess Cylinder, Ekman, Ponar
  - Samples nested within stations, areas, zones of exposure
  - Fine mesh (i.e., 500 um)
  - 400 um mesh (?!)

How Continued

- Semi Quantitative
  - Traveling Kick and Sweep
  - CABIN (1990's to present)
    - 3 minute traveling kick through representative habitats
    - Relies on expertise of samplers to ensure all habitats sampled in unbiased way
    - 400 um mesh
    - Mainly focuses on Riffle habitats,
      - No explicit way of incorporating reach level variability
  - OBBN/OSAP (early 2000's to present)
    - 3 minute transect kick through two riffles and one pool
    - 500 um mesh
    - Habitat variables quantified

  - Both generate relative abundance of taxa, taxonomy and number of taxa identified varies

How Continued

- Consider your units of replication
  - Multiple quantitative samples (i.e. Hess) within a reach vs semi-quantitative (traveling kick and sweep)
    - Quantitative samples estimate densities in the areas sampled but less habitat is covered
      - Generally get lower species richness
      - Get estimates of variability within the area
      - Good if doing a BACI study and habitats in control and impact areas are nearly identical
      - Bad if habitats differ between areas sampled because you are no longer contrasting comparable communities – i.e. comparing riffles in one habitat with pools in another
      - Is variance among replicate samples separated by a few meters relevant when your monitoring question is on the scale of several km of stream, a watershed, or bigger?

How Continued

- Consider your units of replication
  - Multiple quantitative samples (i.e. Hess) within a reach vs semi-quantitative (traveling kick and sweep)
    - Semi-quantitative samples allow relative densities to be estimated over a broader range of habitats
      - Generally higher species richness
      - Don’t really get estimates of within area variability
        - » OBBN uses transects in 2 riffles and 1 pool, quite small for estimating variance
      - Allows you to compare entire reaches (assuming you can sample full transects)
      - Need to replicate across reaches – hence RCA being a preferred study design for Benthos when evaluating reach level variance with semi-quantitative techniques

Taxonomic Level

- Nematoda – phylum
- Cnidaria – genus
- Turbellaria – species
- Porifera – species (?)
- Annelids – species
- Snails - species
- Clams – genus/species
- Mussels – species
- Mayflies – genus/species
- Caddisflies – genus/species
- Stoneflies – genus/species
- Diptera – genus/species
- Odonata – genus/species

- Not all can be identified confidently based on larval/early life stages
- Taxonomic level affects calculated index values
  - Diversity
  - Richness
  - Evenness
  - Tolerance indices (e.g., Hilsenhoff)
- Does not affect
  - Total numbers
  - % EPT

Taxonomic Level Practicality

- 27 Group
  - Mix of phylum, order and class
- Family
  - Widely used
  - Inconsistencies are challenging for analysis (e.g., some to family …
- Lowest feasible taxonomic level
  - Appropriate within a study, challenging to extend to broader studies
  - Need to deal with “ambiguous” taxa

Data management is a challenge for broad scale studies

Timing

- Fully aquatic organisms are always present
  - E.g., snails, clams, crayfish, leeches, worms

- Insects with flying adult stages are not always large enough to be collected or identified
  - Summer diapause stages might not be present in samples
  - E.g., mayflies, stoneflies, caddisflies
- Fall samples provide highest diversity
  - E.g., OBBN fall or spring, OSAP no guidelines
- Summer samples can reflect worst-case, and may correlate better with fish responses

Indices / Interpretation

- Environmental Effects Monitoring (EEM)
  - Density (#/m^2)
  - Richness (number of taxa)
  - Evenness
  - Similarity to Reference (Bray-Curtis)
- Other conventional
  - % EPT (% mayfly, stonefly, caddisfly)
  - HBI (Hilsenhoff Biotic Index)
  - Multivariate techniques (ordinations, clustering)
  - Taxa Richness: widely used but highly dependent on comparable taxonomic capabilities and reporting
  - Functional groups (feeding, habitat, dispersal, voltinism, etc.)

Hilsenhoff

Table-1: Evaluation of water quality using the family-level biotic index (Hilsenhoff, 1988)

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Hilsenhoff's family-level tolerance values may require modification for some regions.

Mandaville, S.M. 2002. Benthic Macroinvertebrates in Freshwaters-Taxa Tolerance Values, Metrics, and Protocols. ii. June 2002. (http://lakes.chebucto.org/H-1/tolerance.pdf)

Family-level tolerances

Table-2 : Tolerance Values for macroinvertebrates for application in the Modified Family Biotic Index and other metrics (Bode *et al*., 1996; Hauer & Lamberti, 1996; Hilsenhoff, 1988; Plafkin *et al*., 1989)

Plecoptera	
Capniidae	1
Chloroperlidae	1
Leuctridae	0
Nemouridae	2
Perlidae	1
Perlodidae	2
Pteronarcyidae	0
Taeniopterygidae	2
Ephemeroptera	
Baetidae	4
Baetiscidae	3
Caenidae	7
Ephemerellidae	1
Ephemeridae	4
Heptageniidae	4
Leptophlebiidae	2
Metretopodidae	2
Oligoneuriidae	2
Polymitarcyidae	2
Potomanthidae	4
Siphlonuridae	7
Tricorythidae	4
Trichoptera	
Brachycentridae	1
Calamoceratidae	3
Glossosomatidae	0
Helicopsychidae	3
Hydropsychidae	4
Hydroptilidae	4
Lepidostomatidae	1
Leptoceridae	4
Limnephilidae	4
Molannidae	6
Odontoceridae	0
Philpotamidae	3
Phryganeidae	4
Polycentropodidae	6
Psychomyiidae	2
Rhyacophilidae	0
Sericostomatidae	3
Uenoidae	3
Amphipoda	
Gammaridae	4
Hyalellidae	8
Talitridae	8
Isopoda	
Asellidae	8
Decapoda	6
Acariformes	4
Mollusca	
Lymnaeidae	6
Physidae	8
Sphaeridae	8

Odonata	
Aeshnidae	3
Calopterygidae	5
Coenagrionidae	9
Cordulegastridae	3
Corduliidae	5
Gomphidae	1
Lestidae	9
Libellulidae	9
Macromiidae	3
Megaloptera	
Corydalidae	0
Sialidae	4
Lepidoptera	
Pyralidae	5
Neuroptera	
Sisyridae	
Climacia sp.	5
Diptera	
Athericidae	2
Blephariceridae	0
Ceratopogonidae	6
Blood-red Chironomidae (Chironomini)	8
Other Chironomidae (including pink)	6
Dolochopodidae	4
Empididae	6
Ephydridae	6
Muscidae	6
Psychodidae	10
Simuliidae	6
Syrphidae	10
Tabanidae	6
Tipulidae	3
Coleoptera	
Dryopidae	5
Elmidae	4
Psephenidae	4
Collembola	
Isotomurus sp.	5
Oligochaeta	8
Hirudinea	
Bdellidae	10
Helobdella	10
Polychaeta	
Sabellidae	6
Turbellaria	4
Platyhelminthidae	4
Coelenterata	
Hydridae	
Hydra sp.	5

Genus/species tolerances

Taxa	Tolerance	Feeding Habit	Reference
ANNELIDA (true worms)			
POLYCHAETA (freshwater tube worms)			
SABELLIDA			
Sabellidae			
Manayunkia speciosa	6	c-g	Bode *et al.*, 1996
OLIGOCHAETA (aquatic worms)	5	c-g	Barbour *et al.*, 1999
LUMBRICINA	8	c-g	Barbour *et al.*, 1999
Undetermined Lumbricina	8	c-g	Bode *et al.*, 1996
LUMBRICULIDA			
Lumbriculidae	8	c-g	Bode *et al.*, 1996
Lumbriculus sp.	8	c-g	Bode *et al.*, 1996
Stylodrilus heringianus	5	c-g	Bode *et al.*, 1996
Undetermined Lumbriculidae	8	c-g	Bode *et al.*, 1996
TUBIFICIDA			
Enchytraeidae			
Undetermined Enchytraeidae sp. 1	10	c-g	Bode *et al.*, 1996
Undetermined Enchytraeidae sp. 2	10	c-g	Bode *et al.*, 1996
Undetermined Enchytraeidae	10	c-g	Bode *et al.*, 1996
Tubificidae	10	c-g	Barbour *et al*, 1999
Aulodrilus americanus	8	c-g	Bode *et al.*, 1996
Aulodrilus limnobius	8	c-g	Bode *et al.*, 1996
Aulodrilus piqueti	8	c-g	Bode *et al.*, 1996
Aulodrilus pluriseta	8	c-g	Bode *et al.*, 1996
Aulodrilus sp.	8	c-g	Bode *et al.*, 1996
Branchiura sowerbyi	10	c-g	Bode *et al.*, 1996
Ilyodrilus templetoni	10	c-g	Bode *et al.*, 1996
Isochaetides freyi	10	c-g	Bode *et al.*, 1996
Limnodrilus cervix	10	c-g	Bode *et al.*, 1996
Limnodrilus claparedeianus	10	c-g	Bode *et al.*, 1996
Limnodrilus hoffmeisteri	10	c-g	Bode *et al.*, 1996
Limnodrilus profundicola	10	c-g	Bode *et al.*, 1996
Limnodrilus udekemianus	10	c-g	Bode *et al.*, 1996

Genus/species tolerances

EPHEMEROPTERA (mayflies)			
Ameletidae			
Ameletus ludens	0	c-g	Bode *et al.*, 1996
Ameletus sp.	0	c-g	Bode *et al.*, 1996
Siphlonuridae	7	---	Hauer & Lamberti, 1996
	7	c-g	Barbour *et al.*, 1999
Siphlonurus sp.	7	c-g	Bode *et al.*, 1996
Isonychiidae			
Isonychia	2	c-f	Barbour *et al.*, 1999
Isonychia bicolor	2	c-g	Bode *et al.*, 1996
Isonychia obscura	2	c-g	Bode *et al.*, 1996
Baetidae	4	---	Hauer & Lamberti, 1996
	4	c-g	Barbour *et al.*, 1999
Acentrella ampla	6	c-g	Bode *et al.*, 1996
Acentrella sp.	4	c-g	Bode *et al.*, 1996
Acerpenna macdunnoughi	5	c-g	Bode *et al.*, 1996
Acerpenna pygmaea	4	c-g	Bode *et al.*, 1996
Baetis brunneicolor	4	c-g	Bode *et al.*, 1996
Baetis flavistriga	4	c-g	Bode *et al.*, 1996
Baetis intercalaris	5	c-g	Bode *et al.*, 1996
Baetis pluto	6	c-g	Bode *et al.*, 1996
Baetis tricaudatus	6	c-g	Bode *et al.*, 1996
Baetis sp.	6	c-g	Bode *et al.*, 1996 Barbour *et al.*, 1999
Callibaetis sp.	7	c-g	Bode *et al.*, 1996
Centroptilum sp.	2	c-g	Bode *et al.*, 1996
Cloeon sp.	4	c-g	Bode *et al.*, 1996
Heterocloeon curiosum	2	scr	Bode *et al.*, 1996
Heterocloeon sp.	2	scr	Bode *et al.*, 1996
Labiobaetis propinquus	6	c-g	Bode *et al.*, 1996
Undetermined Baetidae	6	c-g	Bode *et al.*, 1996

How? …in Ontario

- BioMAP (1993)
  - Quantitative and qualitative sampling
  - Lowest Practical Level
  - BioMAP index
    - Rates taxa according to position in river continuum which is assumed to relate to tolerance to degraded conditions
- OSAP S2M2 (Ontario Stream Assessment Protocol)
  - Qualitative, Major Group Level
  - HBI_{major_group}
- OBBN/OSAP (S2M3)(Ontario Benthic Biomonitoring Network)
- OSAP S1M1
  - Screening level survey for broad scale studies

https://desc.ca/sites/default/files/OBBN%20Protocol%20Manual_Compressed.pdf

How much change matters?

Degrading

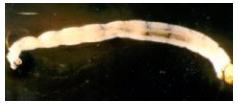
- Subtle changes exceeding background variability (±2SD rule)




- Degrading over time / getting worse


- Dominated by a few ‘tolerant’ groups






- No benthos

Take Home Messages

- Having a concise and quantifiable question is essential because:
  - Lots of techniques and taxonomic options
  - Cost increases exponentially with increasing level of taxonomy and numbers of benthos collected…
- Consider future uses of data and adopt a hierarchical structure for data management of catches
- Consider how/if nested sampling can assist in spatially extensive studies

Literature Cited

- Hilsenhoff, W. L. 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist. 20:31-39.
- Jones, C., K.M. Somers, B. Craig and T.B. Reynoldson. 2007. Ontario Benthos Biomonitoring Network: protocol manual. https://desc.ca/sites/default/files/OBBN%20Protocol%20Manual_Compressed.pdf
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