Alternative Tier II SSROs that Acknowledge Non-Contaminant Effects

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Introduction

- Tier I Guidelines
  - Compare a PHC or PHC fraction to a guideline.
- Tier II Guidelines
  - Allow limited modifications.
  - CCME (2006), Alberta Environment (2010), OMOE (2011).
- Alberta Environment has a provision for deriving ecotoxicologically based Tier 2 SSROs but no process.

Challenges

- Derivation of ecotoxicologically-based Tier II SSROS challenged by:
  - Representativeness of toxicity test species.
  - Reconciling lines of ecotoxicological evidence.
  - Presence of non-contaminant effects.
  - Strong relationships between and among, COPCs and non COPCs.
  - Describing the relationship between COPCs, non COPCs and observed toxicity.
  - Cost of establishing generally applicable dose responses that also acknowledge non-contaminants.

Site-Specific Solution

toxicity = f(COPCs, non-contaminants)

- Determine level of protection warranted and estimate effects at site locations where toxicity tests not conducted.
  - Pass, delineate and remediate, site accessibility restrictions, etc.
- Approach has been used successfully.

Wide Area Solution

toxicity = f(COPCs, non-contaminants, **site**)

- If no site effect, model is generally applicable proceed as before.
- Determine level of protection warranted and estimate effect concentrations.
  - Pass, delineate and remediate, site accessibility restrictions, etc.

Data Reduction (1)

- **Challenge**: Multicollinearity

1. If two variables are highly correlated; say %OC and % clay, the final variable selected as a TMF can be arbitrary.
2. Highly correlated variables lead to singularities in

$$\hat{B} = \left(X'X\right)^{-1} X'Y$$

the solution to $Y = BX + \varepsilon$.

Data Reduction (2)

- **Solution**: <u>D</u>ata <u>R</u>eduction
  - Singular value decomposition of correlation matrix or PCA.
  - Reduces dimensionality of non-contaminant variable matrix by creating synthetic variables or "heuristics".

Data Reduction (3)

- **Outcome**:

toxicity = f(COPCs, non-contaminants, site)

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toxicity = f(COPCs, fewer non-contaminants, **PC scores**, site)

Model Averaging (1)

- **Challenge**:

  - May have several models that describe the toxicity test response "adequately".
  - Using a single model that is assumed correct leads to overstated achieved levels of significance in hypothesis testing (Chatfield, 1995).

Model Averaging (2)

- **Solution**:
  - Average the parameters for different models fit to the same dataset (Burnham and Anderson, 2002; Claeskens and Hjort, 2008).
  - An "information theoretic" approach as individual models are objectively weighted by the AICc (Sugiura, 1978).
  - Thus conclusions reached by one clearly superior model are not dismissed by averaging over weak, non-informative models.
  - Can assess relative importance of variables.

DRAMA

- Overall

Data Reduction

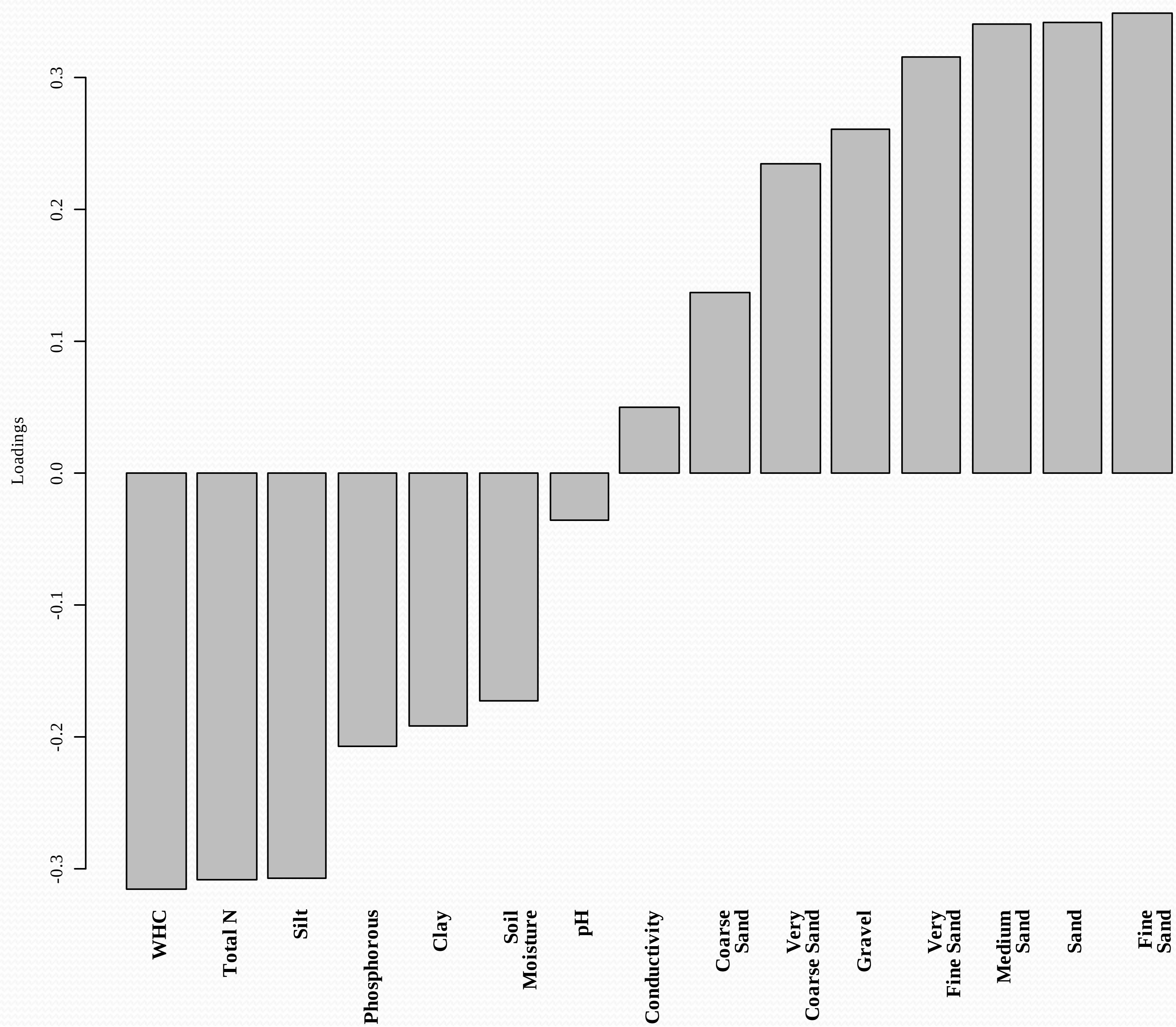
↓

Model Averaging

- DRAMA

Available Studies

- Ecotoxicity assessments were conducted at 3 sites contaminated with PHCs.
- Issues:
  - One site co-contaminated with metals.
  - Slightly varying list of non COPCs measured.
  - Only 3 species consistently used:
    - northern wheatgrass (*Elymus lanceolatus*)
    - earthworm (*Eisenia andrei*)
    - springtail (*Folsomia candida)*
  - Experimental design.



Loadings
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
WHC
Total N
Silt
Phosphorous
Clay
Soil Moisture
pH
Conductivity
Coarse Sand
Very Coarse Sand
Gravel
Very Fine Sand
Medium Sand
Sand
Fine Sand

Variables Selected

- Data reduction used to choose 4 pedologic variables from the 15 measured consistently.
  - PC1, pH, clay, moisture
- As no single PHC fraction was dominant among the 3 studies, sum of F2-F4 fractions were used.

Models Selected

Three general model forms:

1. (PHC + PC1 + pH + C + M)*Sj + Sj
2. PHC + PC1 + pH + C + M + Sj
3. PHC + PC1 + pH + C + M

- Allowed subsets of any 4 variables for a total of 17 models.

Results – Northern Wheat Grass

Response	Model	Degrees of Freedom	AICc	w_i	Pseudo R^2
Shoot Dry Mass	2	17	448.520	0.947	0.840
	1	20	454.285	0.053	0.843
Shoot Length	6	17	1146.266	1.000	0.865
Root Dry Mass	1	20	283.492	0.924	0.744
	4	17	288.493	0.076	0.719
Root Length	4	17	1299.189	0.261	0.702
	15	7	1299.284	0.249	0.645
	16	7	1299.654	0.207	0.644
Emergence	13	6	48.916	0.883	0.941
	8	8	52.968	0.117	0.941

Relative Importance of Variables

	E. lanceolatus					*F. candida*		Mean
	Shoot Dry Mass	Shoot Length	Root Dry Mass	Root Length	Emergence	Survival	Progeny	
Study	1.000	1.000	1.000	0.499	0.117	0.147	1.000	0.680
Clay	1.000	0.999	1.000	0.750	1.000	0.884	0.920	0.936
pH	1.000	0.997	0.927	0.427	1.000	0.601	1.000	0.850
Moisture	1.000	0.027	1.000	0.982	1.000	0.566	0.517	0.727
PC1	0.999	1.000	0.978	0.964	1.000	0.965	0.710	0.945
PHC	0.055	1.000	0.987	0.929	0.000	0.998	0.864	0.690

DRAMA Benefits

- Invertibility issues associated with multicollinearity obviated.
- Issue of arbitrary selection and differing interpretations due to presenting only one model are sidestepped.
- Summary model uses objective weighting.
- Model averaging correctly deals with uncertainty in model selection instead of ignoring it (Wang et al. 2009).
- Acknowledging model uncertainty in risk assessment is critical (Bailer et al. 2005).

DRAMA Analysis Conclusions (1)

- Non-contaminant variables were always “important” variables and for some northern wheat grass responses, the only predictor of toxicity.
- Overall, PHCs were less important than non-PHCs in explaining toxicity test responses.

DRAMA Analysis Conclusions (2)

Surprisingly, and on an overall basis, results were predictable among sites suggesting, or at least not precluding, that models may be more broadly applicable.

Recommendations

- Experimental designs
  - Should be modified for developing Tier II SSROS.
  - Current practices are not as cost-effective as they could be.
- Collect additional data
  - Choose sites representing nodes of the TMF matrix.
  - Review PHC toxicity data and select an optimal set of responses.
  - Standardize analyte list (COPCs and pedologic) possibly guided by current results as well as literature.

Acknowledgements

This research was supported by:

- Canadian Association of Petroleum Producers (CAP) and Explorers and Producers Association of Canada (EPAC) through the Alberta Upstream Petroleum Research Fund(AUPRF).
- Environment Canada - Program for Energy Research and Development
- Stantec Consulting Ltd. (R&D Fund), 2012.