Integrative vs. derivative indicators: which should we use to detect water quality improvements?

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AGU Fall Meeting – Washington, DC 10-14 December, 2018

1. Background

- In catchment science, we are seeking, among many other things, to detect changes in generation of flow and loads that might correspond to human intervention
- In the anthropocene, many 'treatment systems' or Best Management Practices (BMPs) have been installed to improve water quality
- But quantification of impact of BMPs on Water Quality (WQ) has been difficult at best. Why?

2. Hypothesis

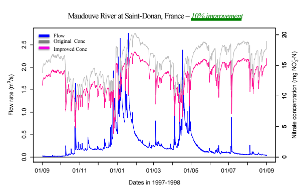
- We hypothesize that to detect water quality changes, one needs to obtain *integrative indicators* because these tend to be more ***robust*** indicators

3. Objectives

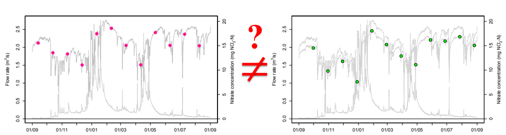
- Show that infrequent concentrations as water quality indicators are not robust in reactive catchments
- Introduce the concepts of *integrative vs derivative* indicators
- Continuous WQ sensors give access to the full *derivative* functions to calculate *integrative* indicators
- Explore methods and conditions to extract most information from full continuous concentration signals

4. Minimum detectable WQ improvement from infrequent concentrations

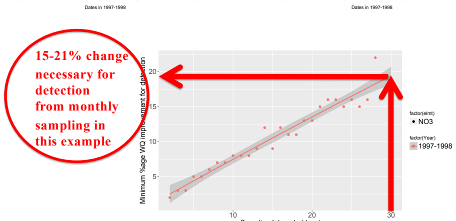
- Use high frequency concentration data, and simulate WQ improvements from 1% to 200%



- Randomly sample the control (initial) and treatment (improved) concentrations at frequencies from 2 to 30 day intervals
- Run a paired t-test between subsample sets, and determine the proportion of the times the treatment subset is different from the control, for a range of improvement levels

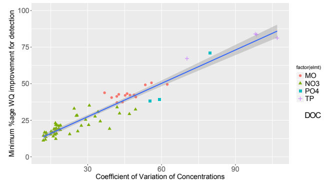


- From this, determine the minimum WQ improvement level needed to be confidently determined (95% of the cases)



5. Concentrations are *not* robust indicators

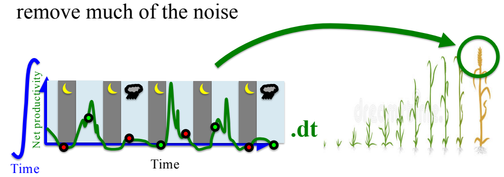
- Large WQ improvement needed to be detectable



6. Detecting treatment effect: the wheat yield analogy

7. *Integrative* vs *derivative* indicator

- Wheat yield corresponds to the integration over time of all the variations of instantaneous wheat productivity, which remove much of the noise

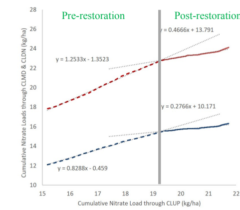


- Partial subsampling of the net productivity function, i.e., the *derivative* function of the yield indicator, would yield a lot less clear effect (green *vs* red dots)

	Treatment tested	Processes & kinetics	*Derivative* indicators	*Integrative* indicators	Difference needed for treatment detection
Wheat	e.g., fertilizer	Inferred	Instantaneous net productivity, not measured	Yield: Measured + replications	SMALL
Catchment	e.g., BMPs	Inferred	Flow and concentrations, ~ measured	Average concentrations and Loads: Estimated, **no replications**	LARGE

8. *Integrative* vs *derivative* WQ indicators

- In hydrology, we only measure the *derivative* functions, i.e., flow and concentrations
- Infrequent samples are a very partial info of the *derivative* water quality signal and are **NOT** replication (*sensu* statistics)
- One *integrative* indicator is cumulative load, but requires frequent samples to be calculated to be robust: WQ sensors can obtain the *derivative* function
- Example of robust (double) *integrative* indicator to detect water quality impact of a stream restoration in NC



- No replication!

9. Big picture vs mechanisms

- We hypothesize that to obtain the big picture on whether there is a water quality change, then integrative indicators are robust
- If we use continuous sensors, we have access to extremely rich info. What can we learn?
- Deconvoluting the *derivative* signal requires modeling, which might give access to mechanisms
- We hypothesize that this becomes possible when the system is not too large and well defined
  - Continuous $[O_2]$ in a wetland coupled with some sort of modeling: high chances to yield info on local mechanisms
  - Unclear whether continuous $[NO_3]$ in large catchment may yield info mechanisms because of confounding factors

11. Conclusions

- *Integrative* indicators, should be preferentially sought to obtain big picture effects
- We should seek to find auto-integrative WQ indicators
- Continuous WQ sensors yield *integrative* and full *derivative* WQ indicators, but must be used with modeling, in conditions to be defined, to unleash all the embedded info

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