Using Algae to Help Establish Numeric Water Quality Criteria and Nutrient Reduction Targets

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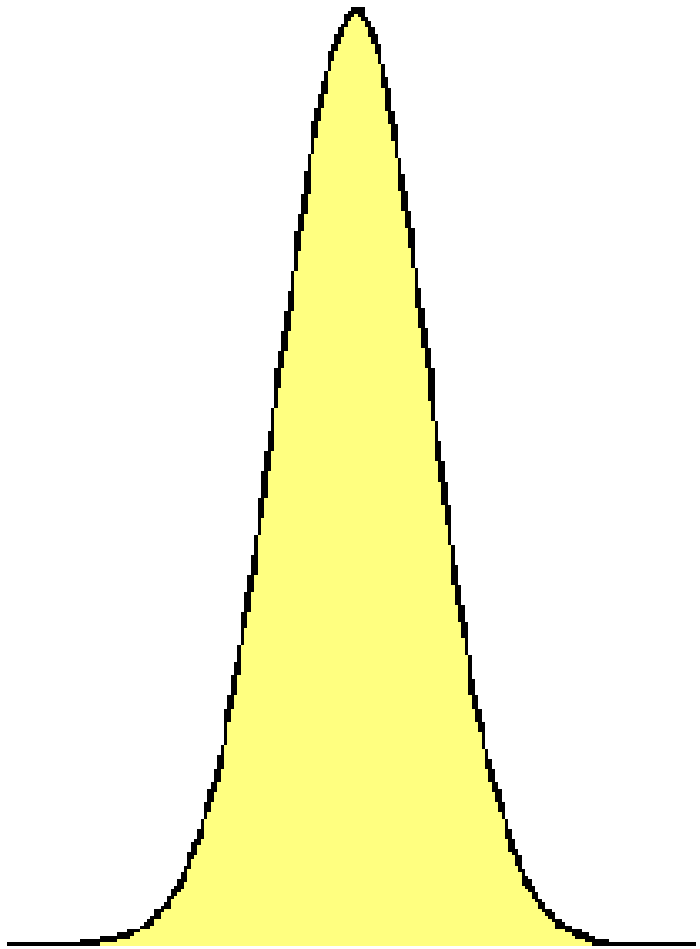
Nutrients as a Stressor

- Nutrients (nitrogen and phosphorus) are one of the leading causes of water quality impairment in the U.S.

- Because N and P are naturally found at varying concentrations in the environment, development of nutrient criteria/reduction targets are challenging

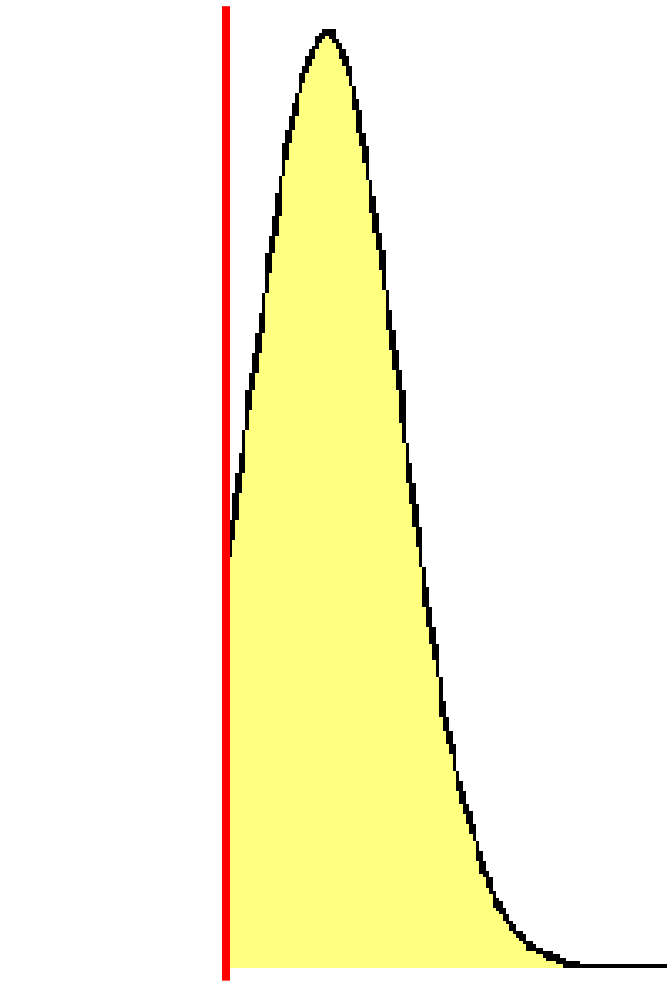
Nutrient Criteria Guidance

- U.S. E.P.A. has developed nutrient criteria guidance documents
- Numeric criteria recommendations have also been published for use by states and tribes if they choose not to develop their own

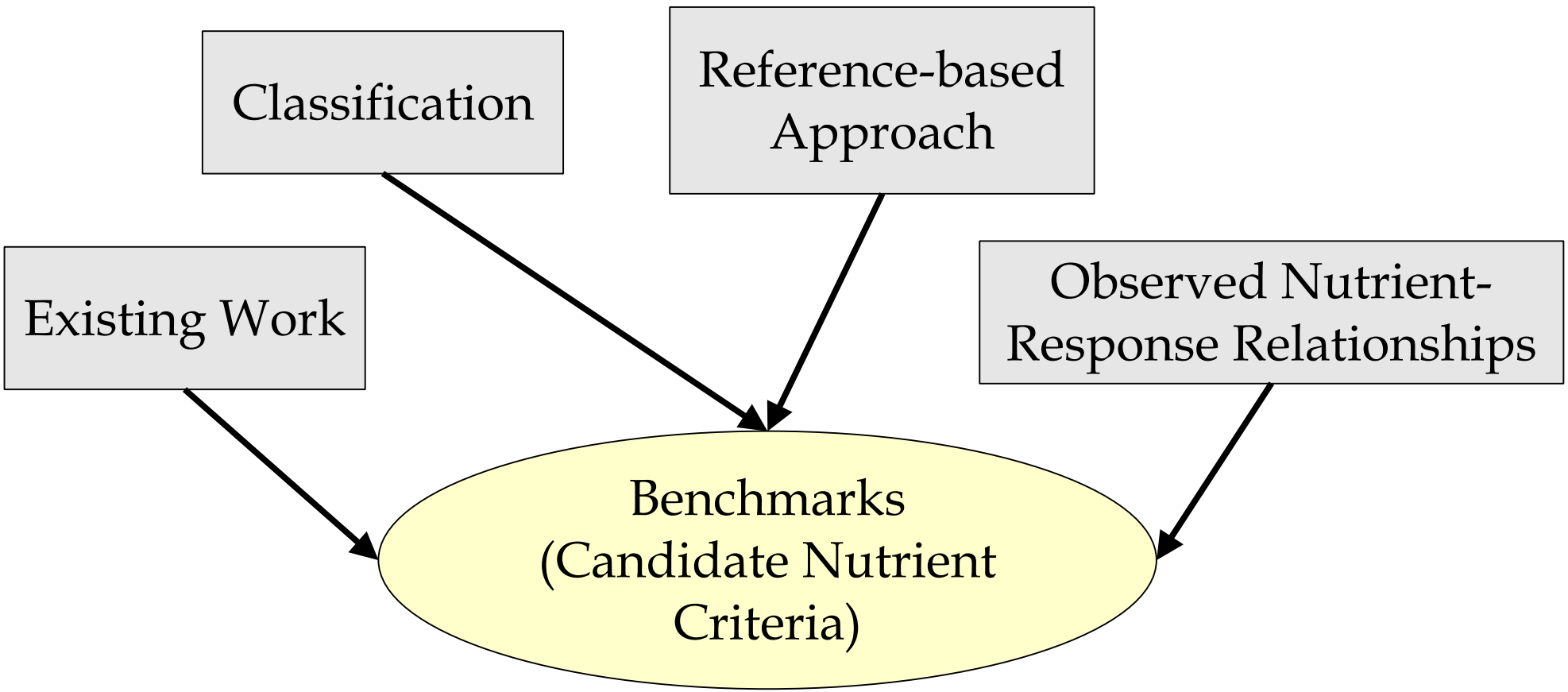


Nutrient Criteria Guidance

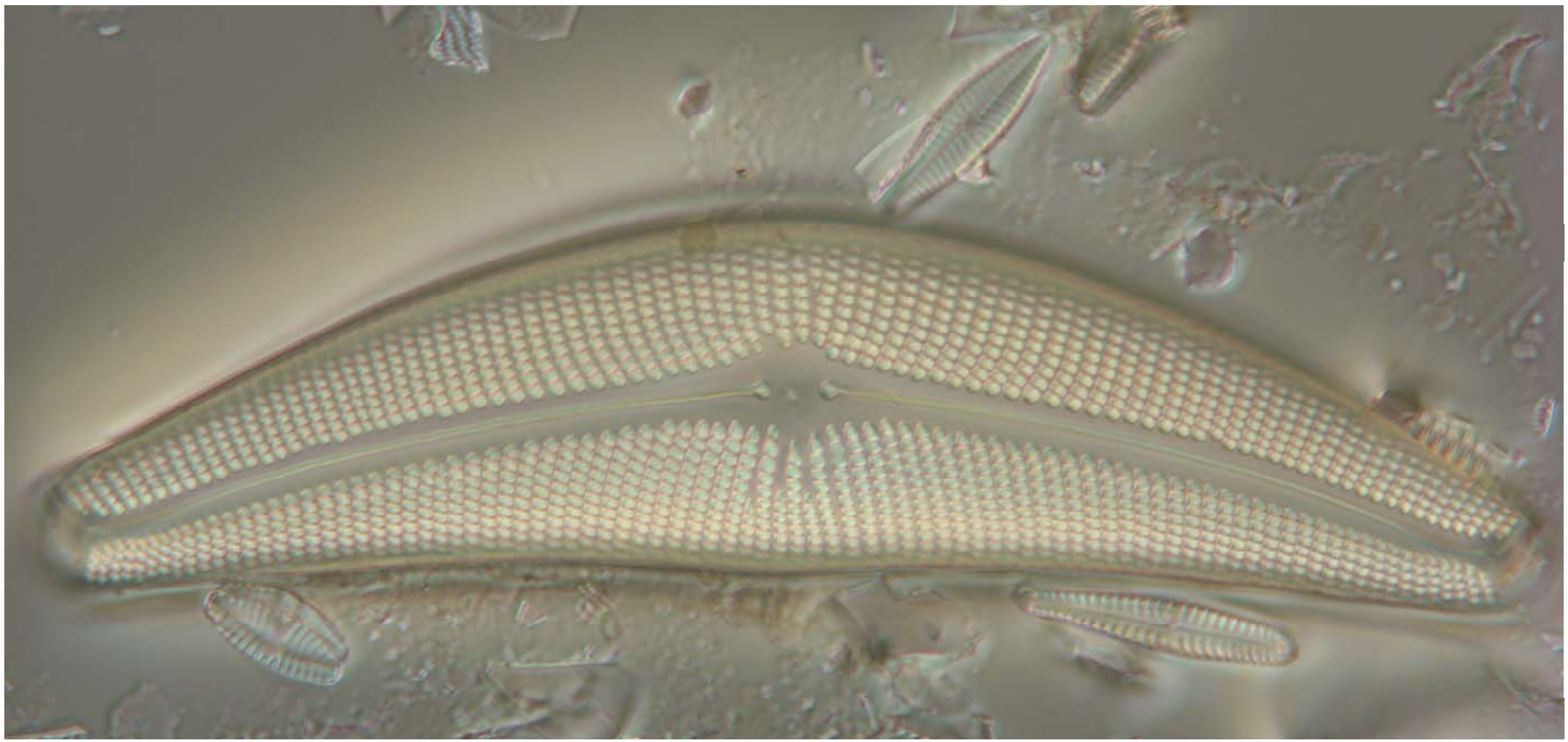
- Most of these published numbers are based on the lower 25th percentile of the measured nutrient concentrations
- This would mean that 75% of all streams fail to meet numeric standards



U.S. Environmental Protection Agency Guidance for Nutrient Criteria Development

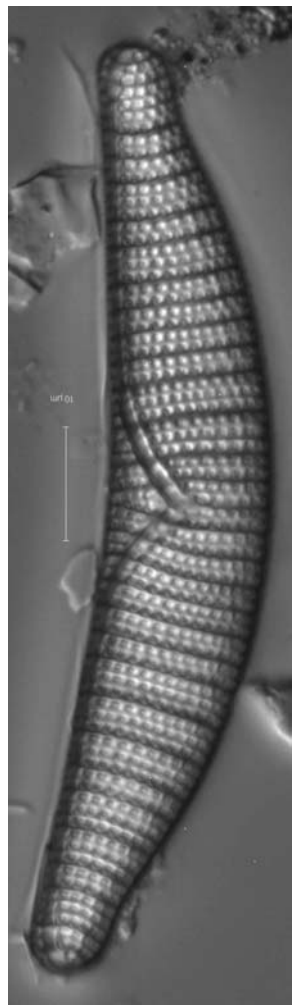


Algae Can Be Used to Develop Criteria Using Each of These Approaches



Using Algae to Develop Criteria

- Algae respond directly to nutrients
- Species assemblages are diverse and respond differentially to nutrients
- Algae influence several numeric and narrative water quality standards (e.g., biostimulation, DO, pH)
- Algae are directly or indirectly related to multiple beneficial uses
- Algae provide a more reliable indicator of excess nutrients than one-time water column measurements of nutrients



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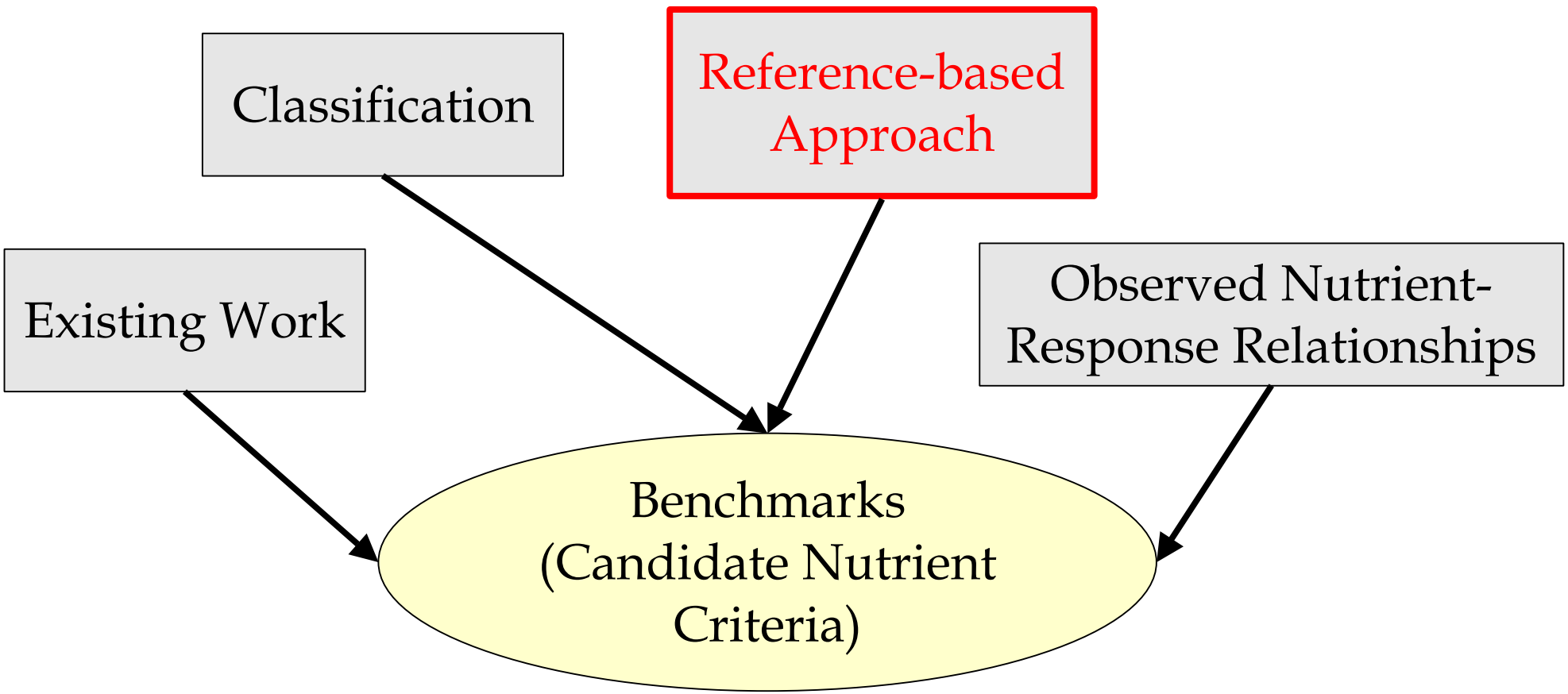

Defining “Reference”

- “Reference” is poorly defined, but is generally interpreted to mean pristine, minimally disturbed, or pre-European settlement
- This may be over-protective and may not provide for assimilative capacity of the system
- Others ways of defining expected conditions have been developed

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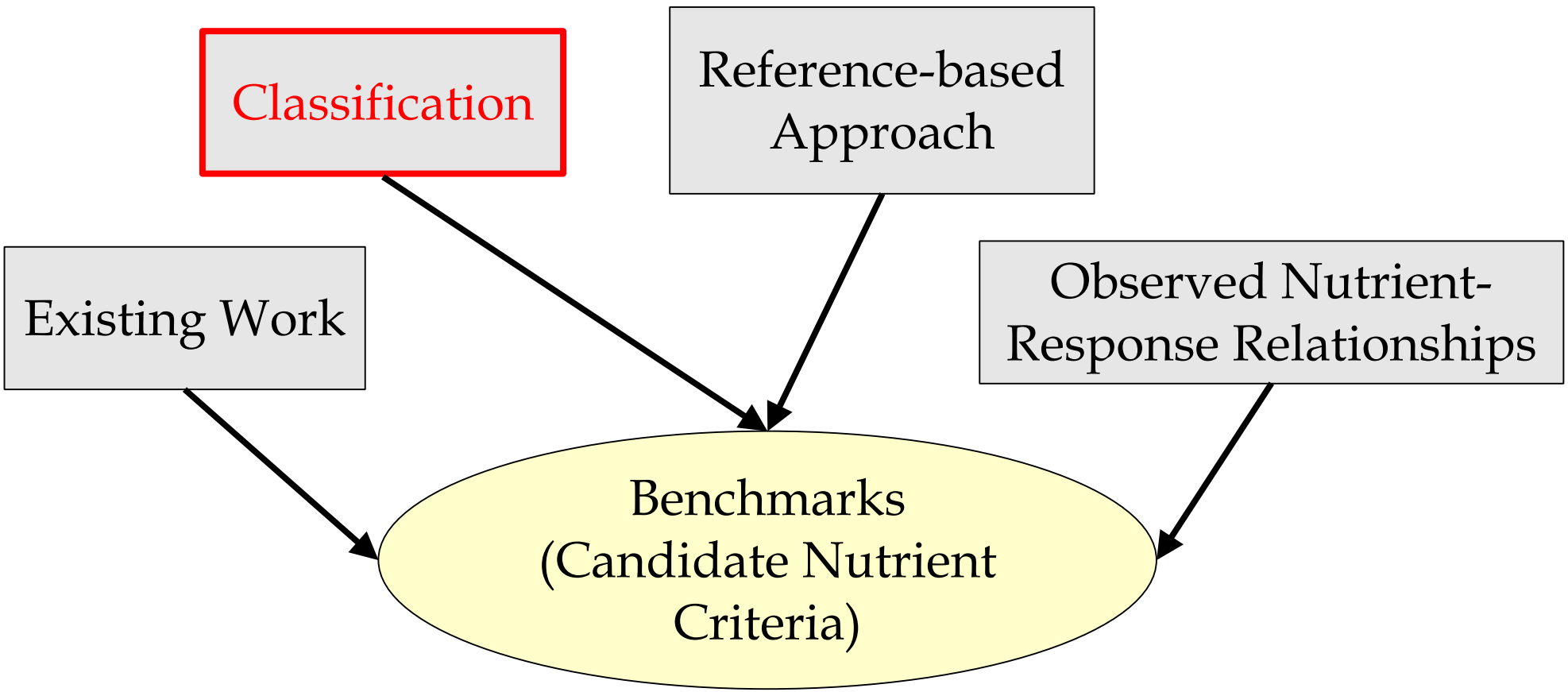


Stream Classification

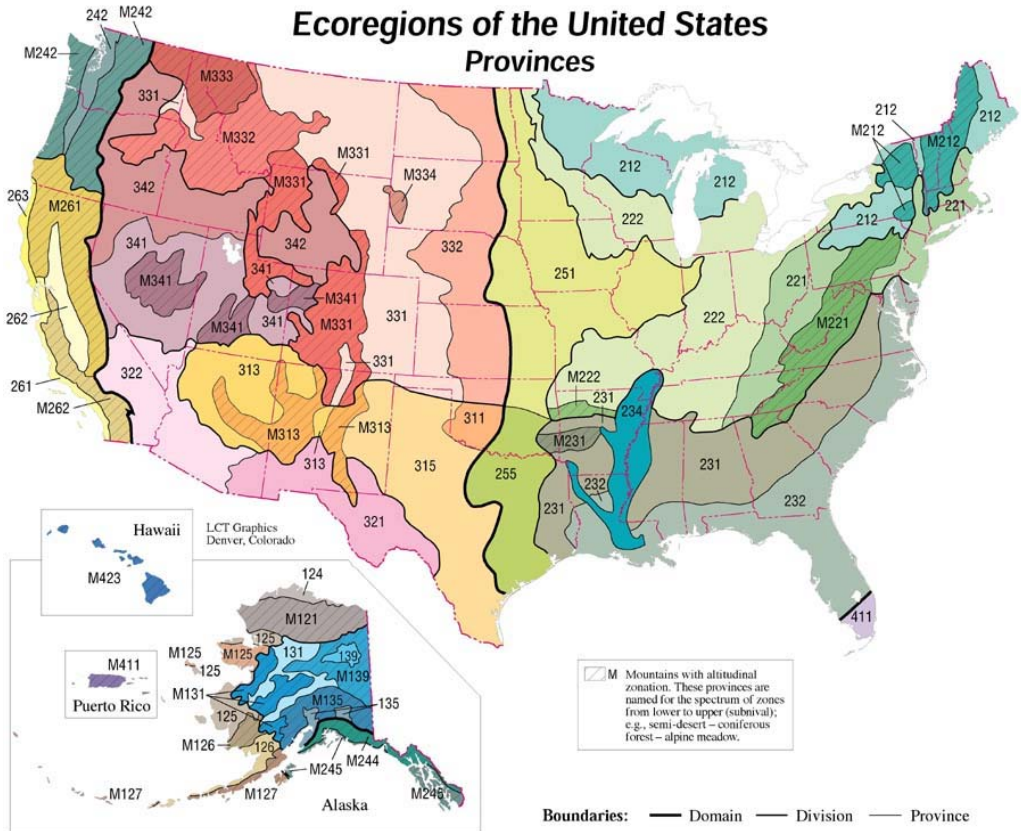
Standard Method

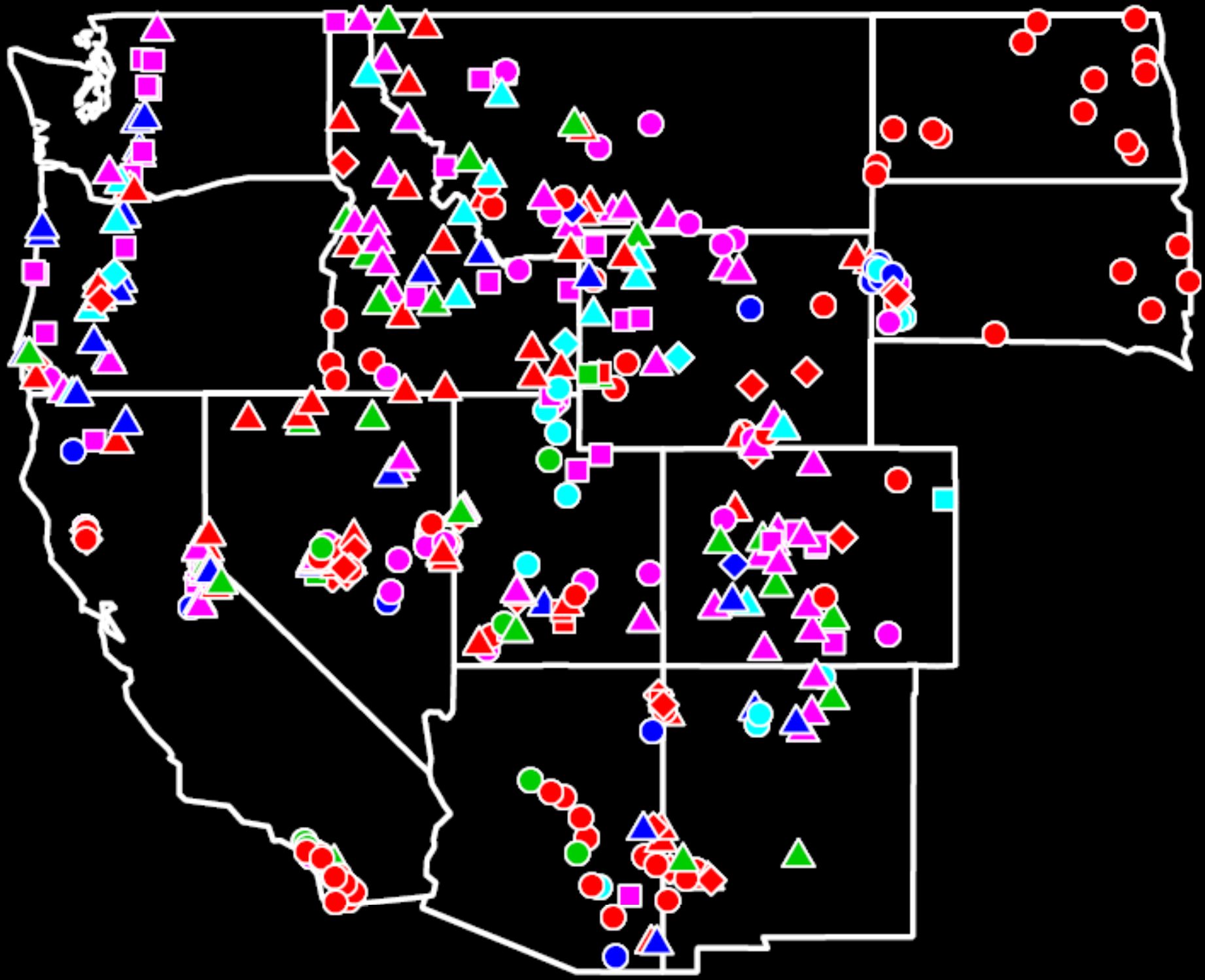
- Geospatial Classifications (e.g., Bailey's or Omernik's Ecoregions)

Species Composition Approach to Classification

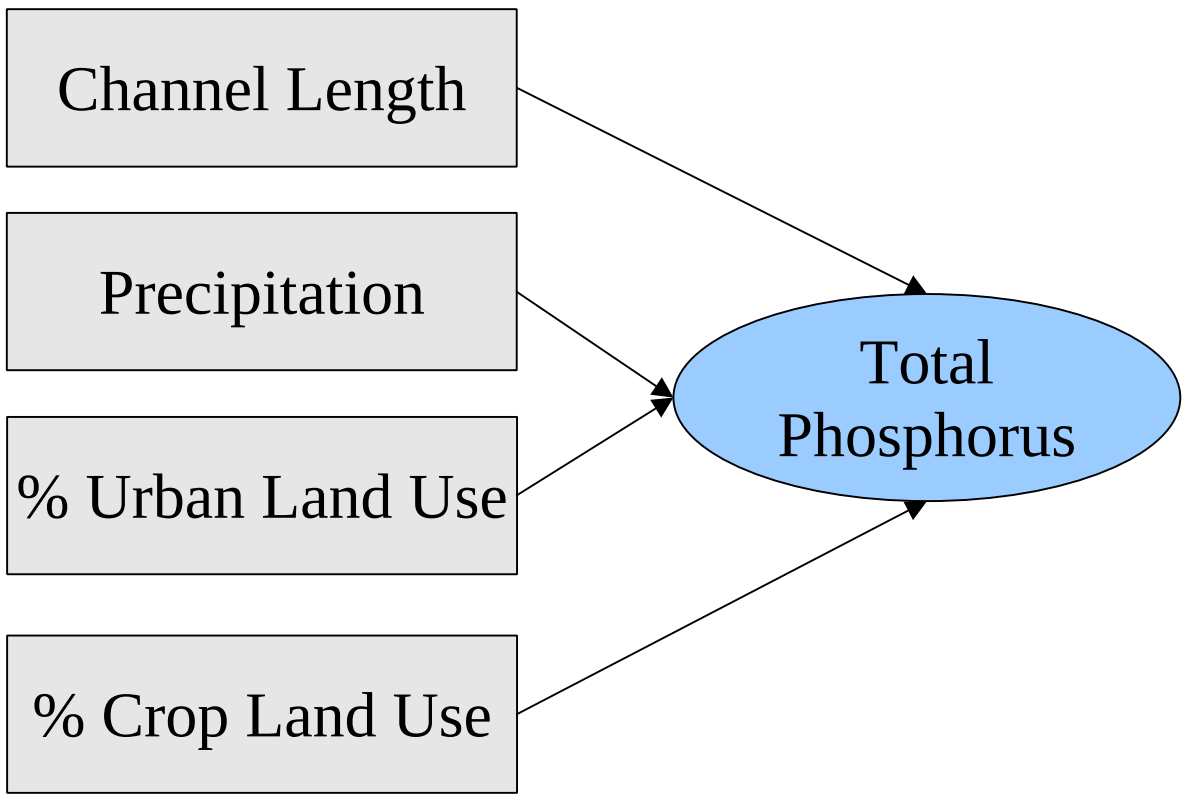
- No/minimal *a priori* assumptions regarding geospatial constraints on species composition

- Species composition defines the classes





Site-specific Expectations: An Alternative to Classification



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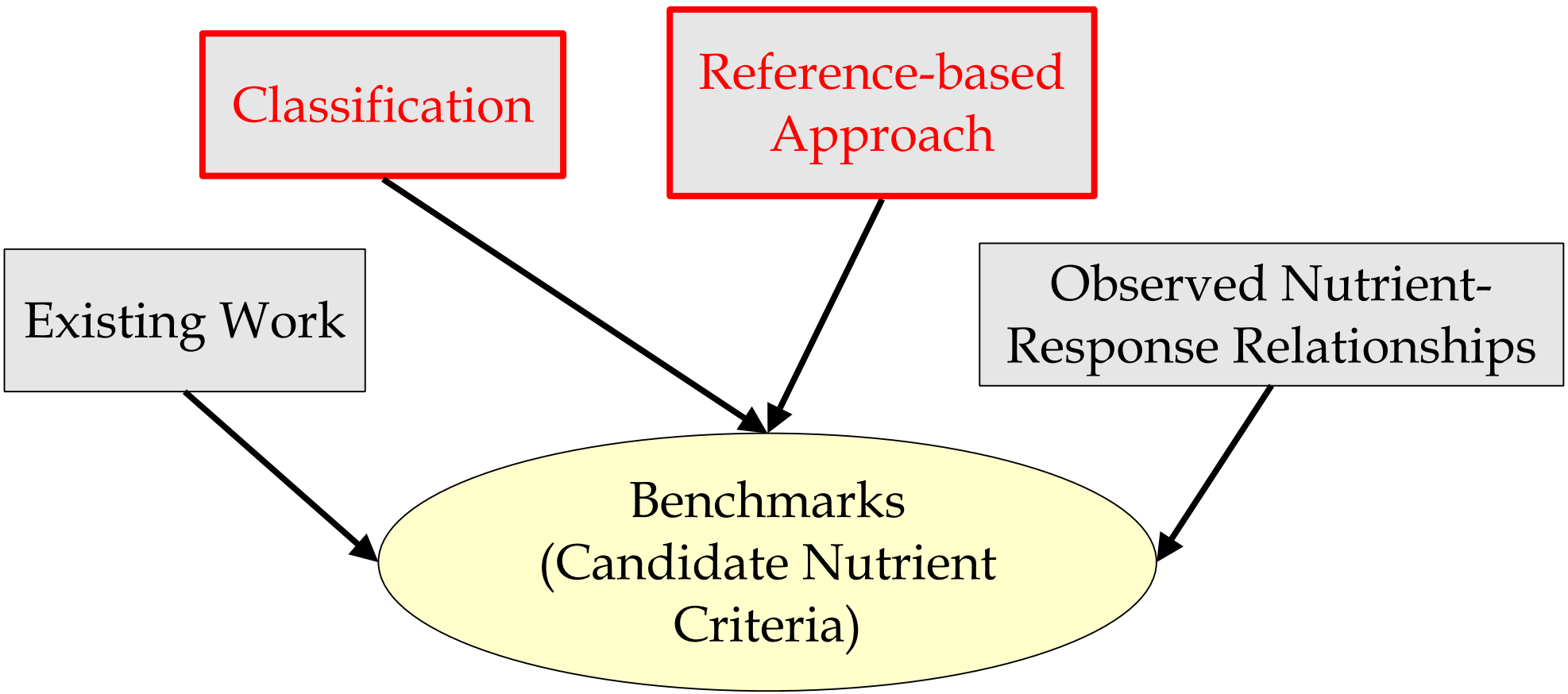
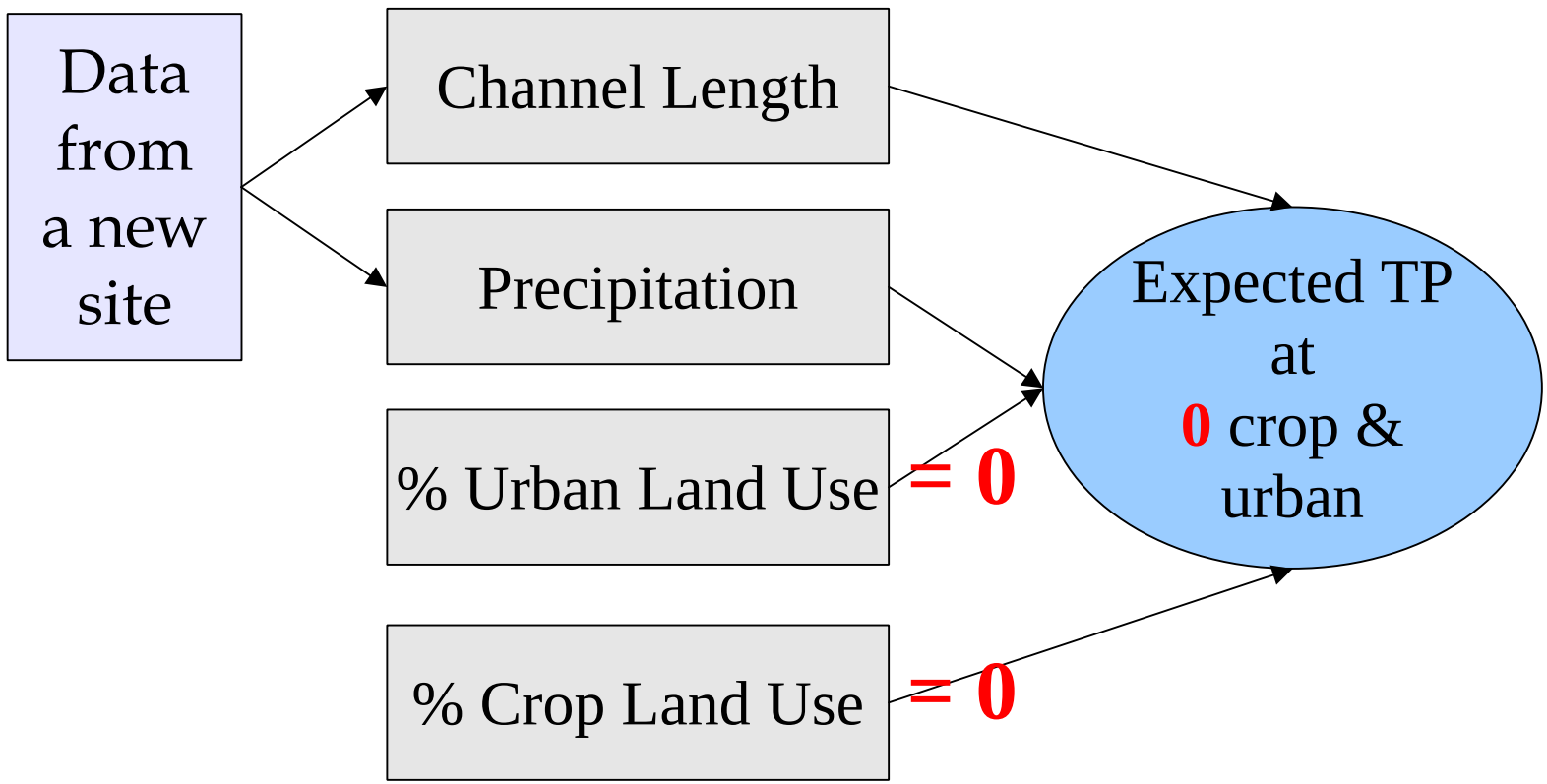


Inferring Reference TP Concentration



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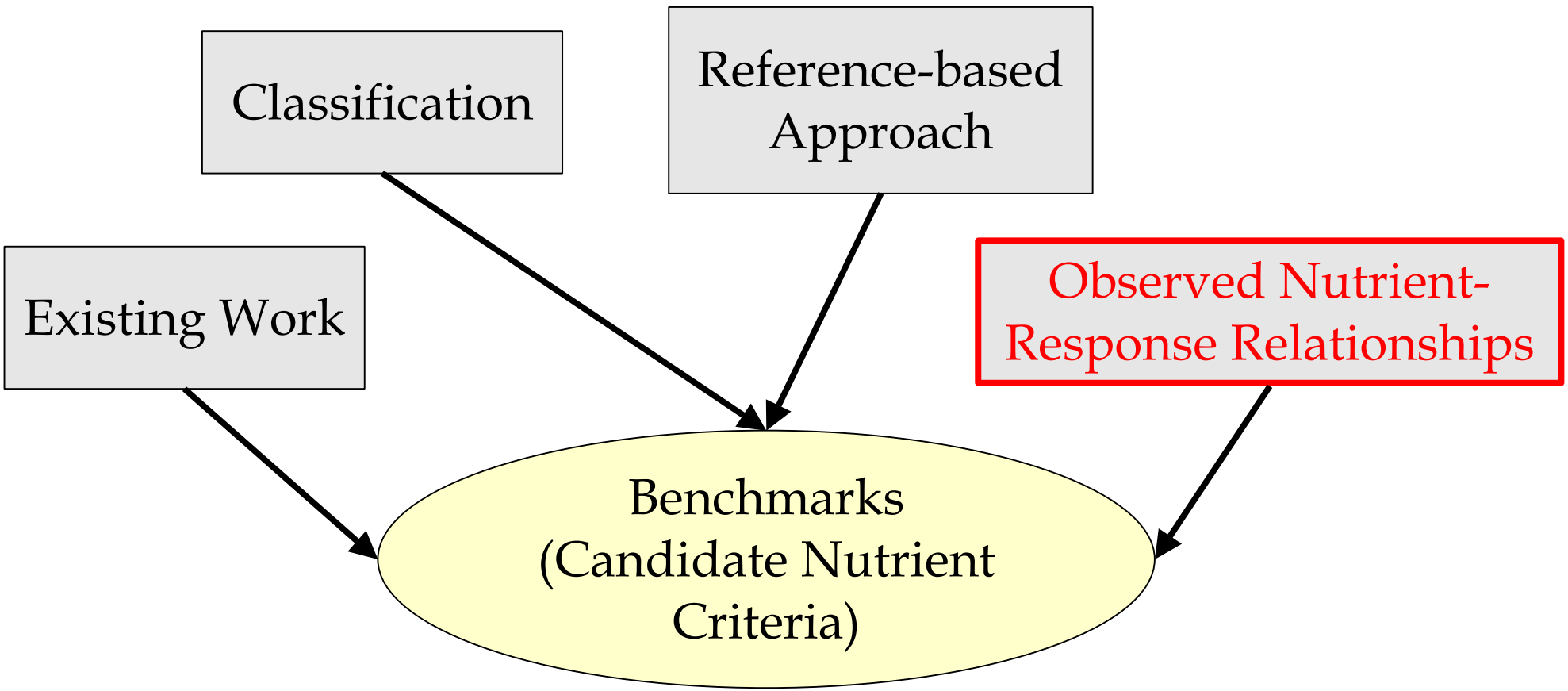
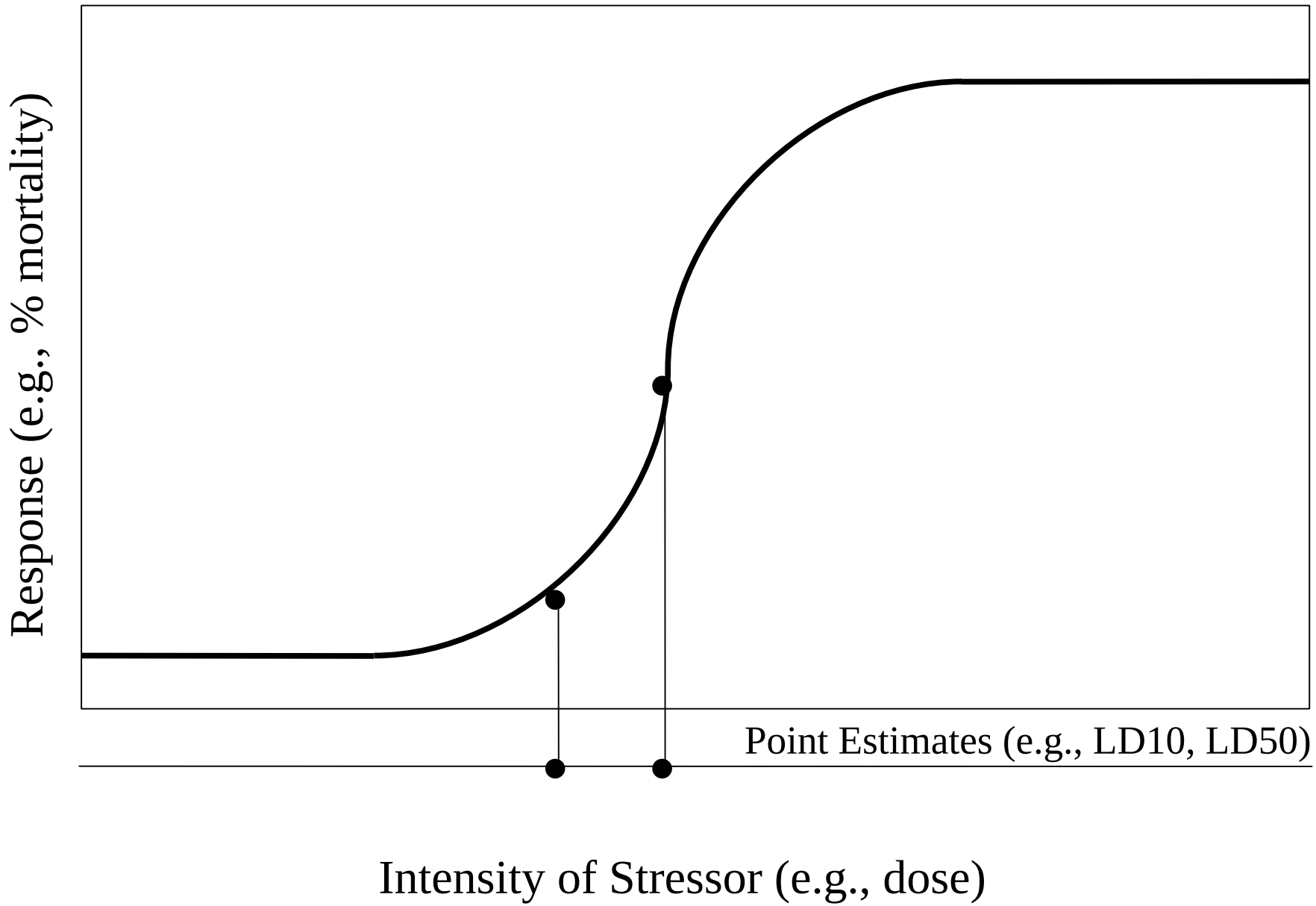


Typical Stressor-Response Relationship



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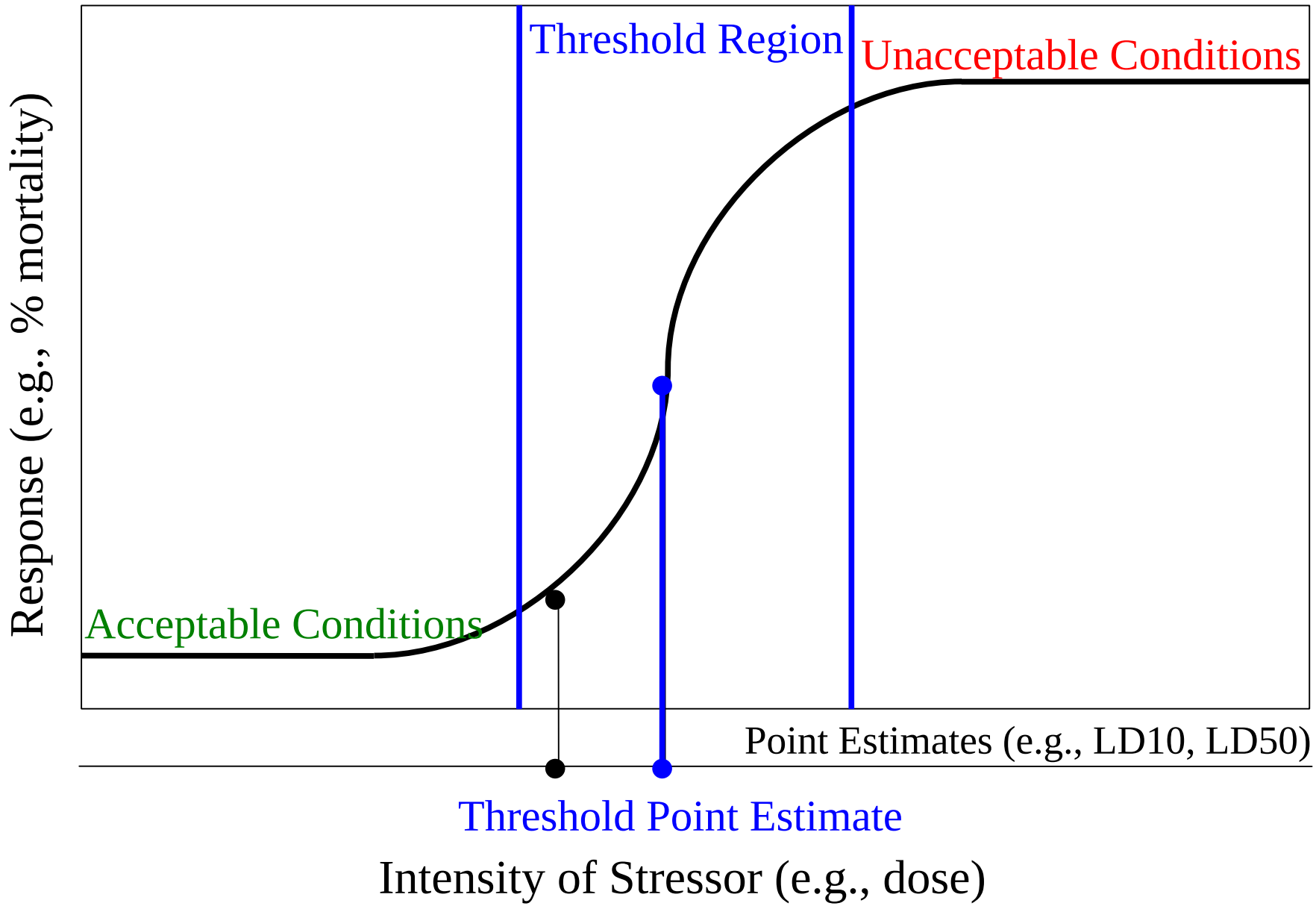
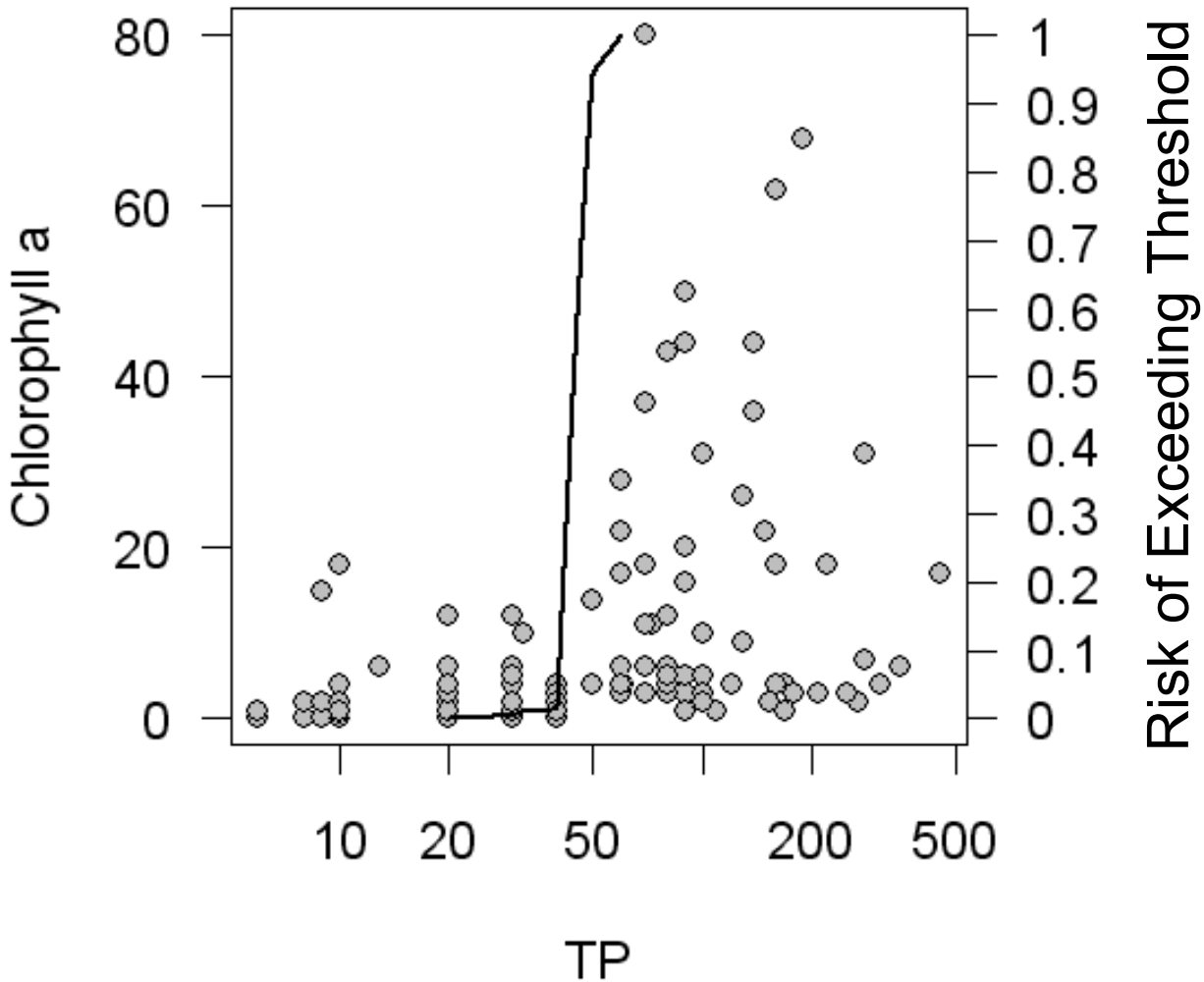


Quantifying the Threshold

- Algae respond at very low levels in the laboratory; laboratory settings also exclude other potentially important ecological factors
- Use of observational field data in some capacity is probably necessary
- Thresholds can be determined with associated uncertainty, allowing interpretation of the “risk of exceeding the threshold”
  - Bootstrapping
  - Bayesian

TP-Chlorophyll Relationship Observed in Michigan Streams and Rivers



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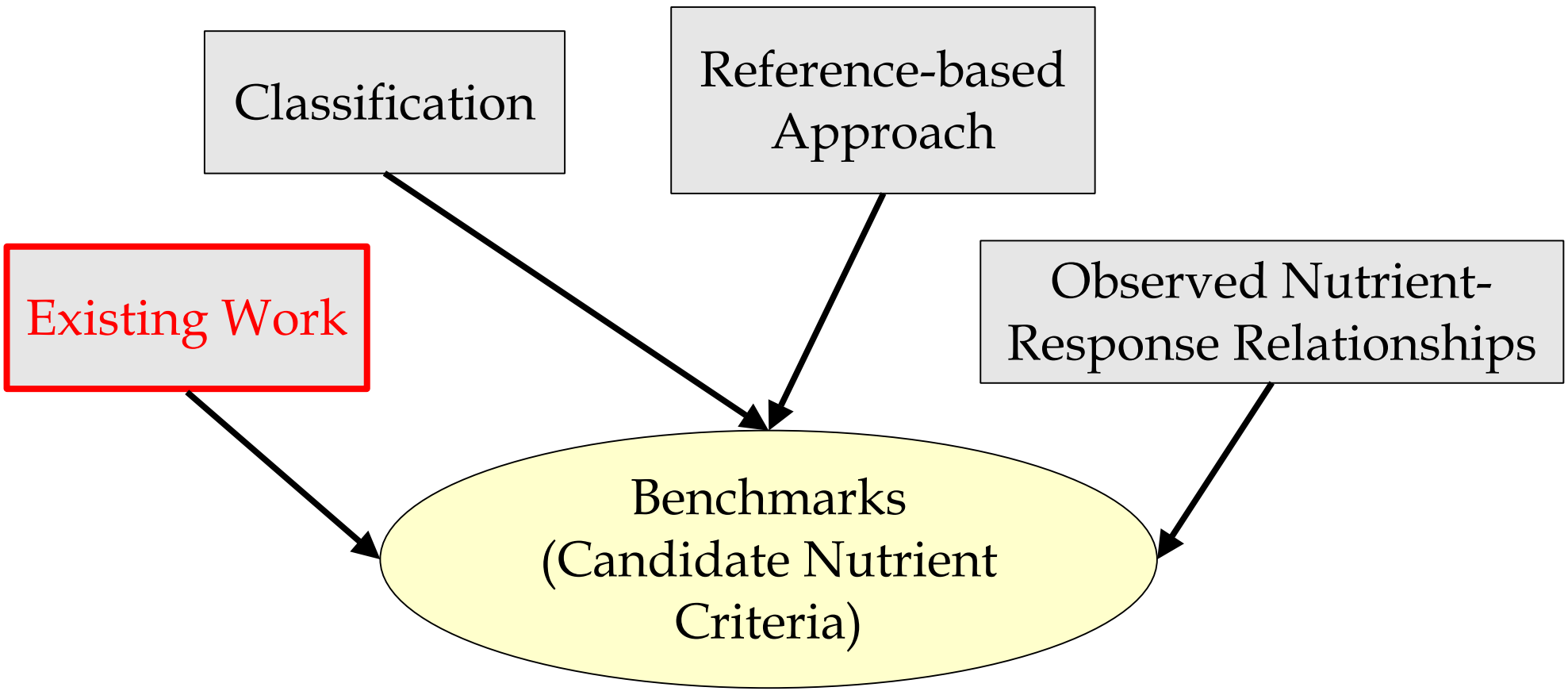
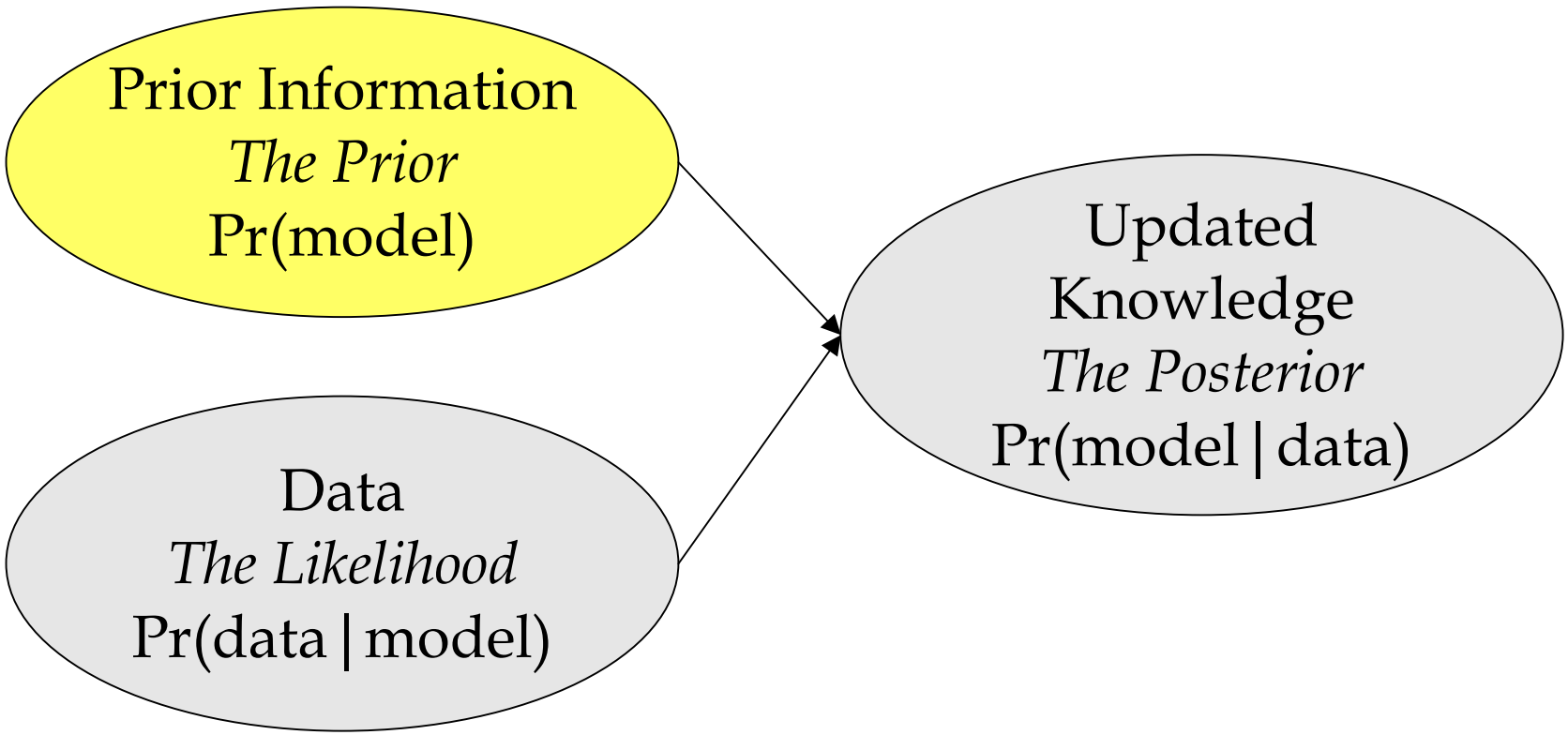


Bayesian Inference



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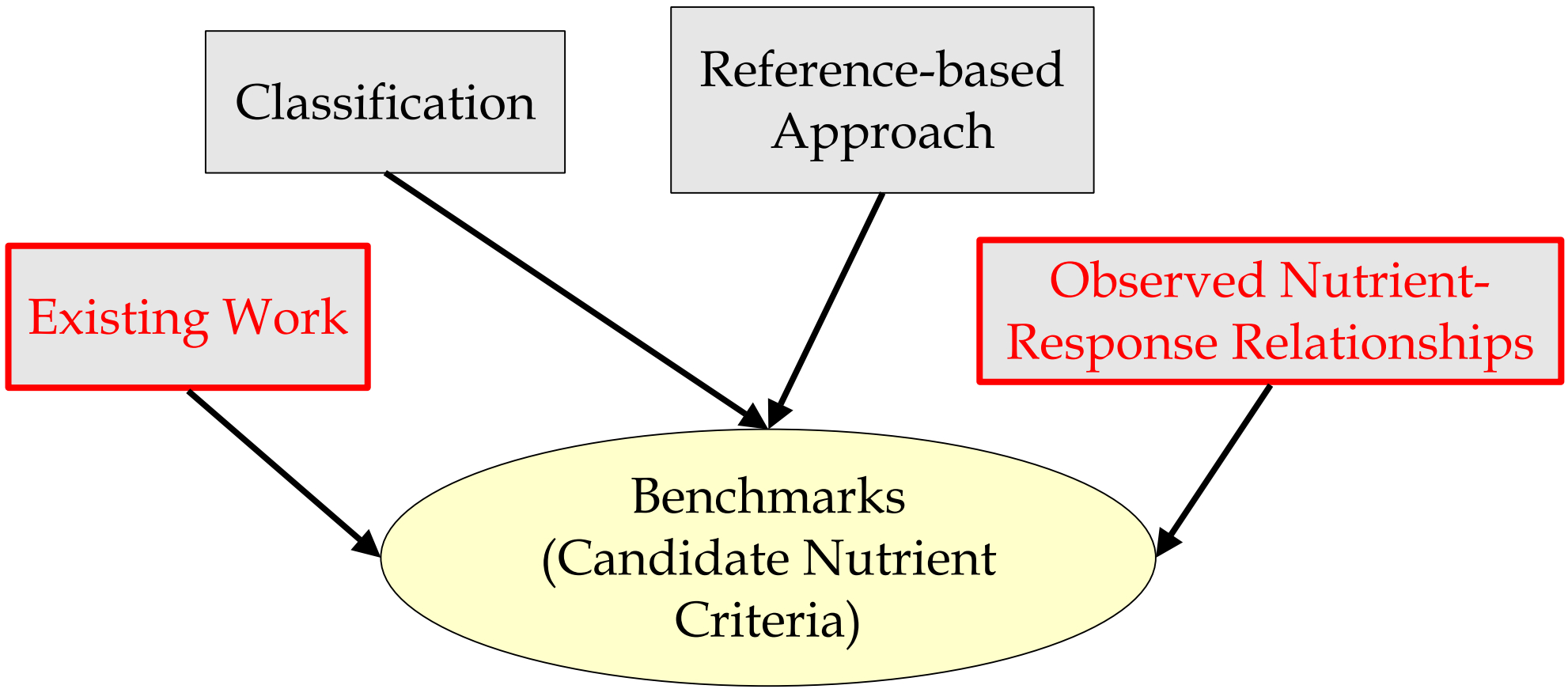
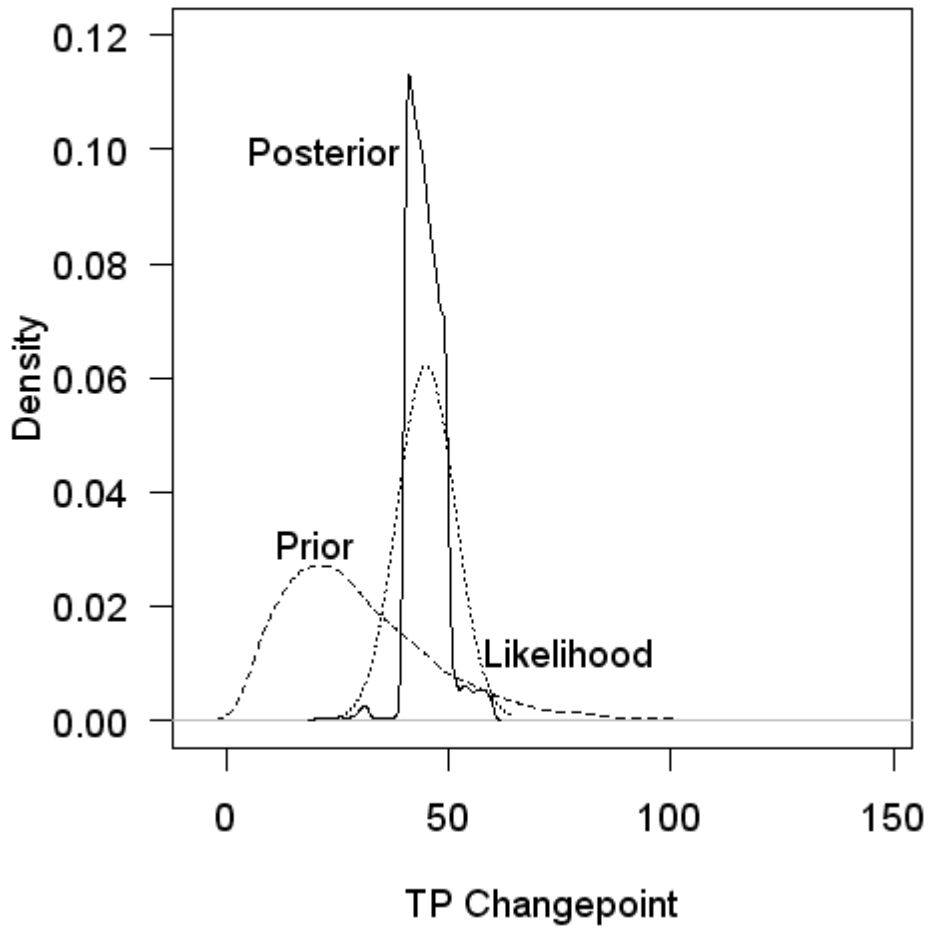


Prior Threshold Information

- Threshold (from Dodds et al. 2002)
  - 30 μg TP/L
- Mean chlorophyll below the threshold (estimated from Nieuwenhuyse and Jones 1996)
  - 1.2 μg chla/L
  - 13.3 μg chla/L

Effects-based Information



Integrating the Information

- Thresholds provides an effects-based information
- Inference models provide expected reference levels of TP and a site-specific “classification”
- Both methods can integrate previous research using Bayesian statistics
- How can the information be integrated to create a TP benchmark (candidate nutrient criterion)?

Relative Risk Framework

- Relative risk (RR) measures the influence of some risk factor on a specified outcome
- In epidemiology, RR is calculated as the incidence rate among individuals exposed to the risk factor, divided by the incidence rate in those not exposed to the risk factor
  - E.g., smokers are X times more likely to die from lung cancer than non-smokers

Relative Risk for Developing Nutrient Benchmarks

- What is the risk of exceeding the TP-chlorophyll threshold at current TP levels, relative to the probability of exceeding the threshold at reference levels of TP?
- At what level of TP is the probability of exceeding the threshold to equal the probability of exceeding the threshold at reference levels of TP?

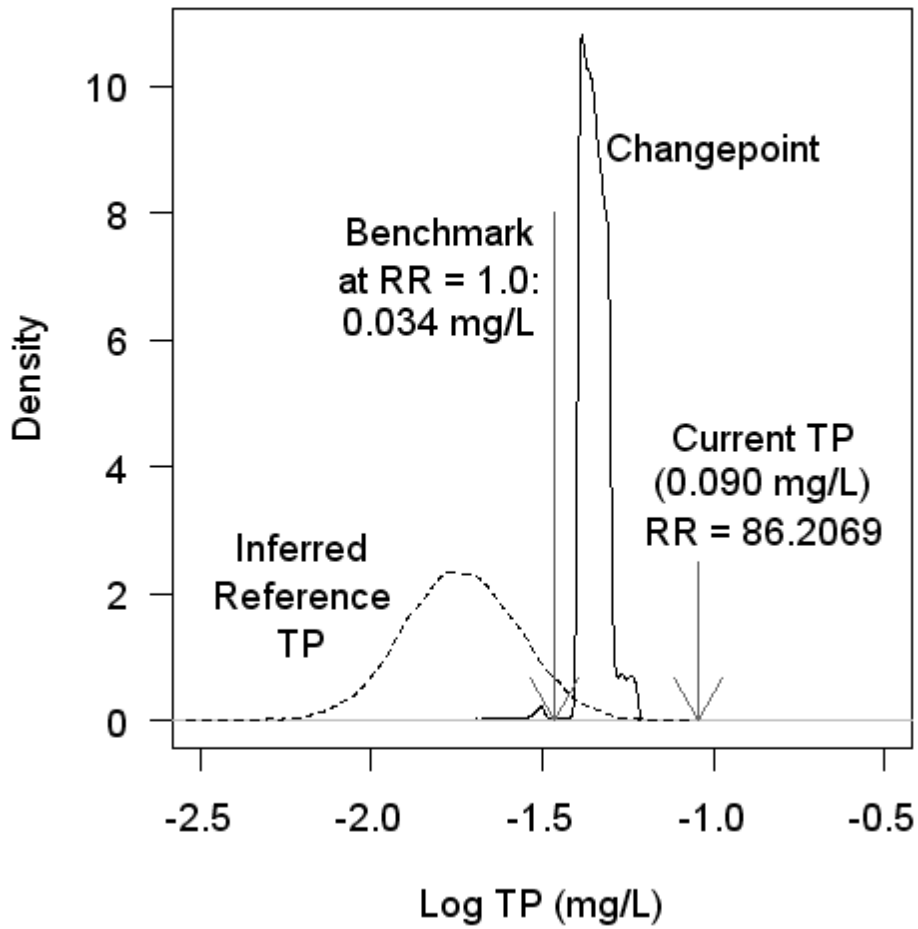
Calculating Relative Risk

$$\text{Current RR} = \frac{\text{Probability threshold has been passed at current TP}}{\text{Probability of exceeding the threshold at reference TP}}$$

$$\text{RR} = 1 = \text{Probability of exceeding the threshold at reference TP}$$

Benchmark is set at TP level where RR = 1

Example: Cass River, Michigan



Summary

- This approach provides a formal method for integrating various sources of information recommended by the USEPA for nutrient criteria development
- The method acknowledges uncertainty in predictions, which is vital for making informed management decisions
- Relative risk is a value that is easy to explain to policy makers and stakeholders