Biostimulatory thresholds to meet biointegrity goals

Presentation to Science Advisory Panel

Dec 12, 2018

Goals for today

- Present analyses to identify range of biostimulatory thresholds
  - Modeling responses
  - Validating thresholds
  - Evaluating error rates
- Highlight key decision points for identifying thresholds
  - Probability
  - Biointegrity (BI) goal (assessment endpoint)
- Review relationship between error rates and multiple lines of evidence

Principles and assumptions

- Thresholds are a scientific product, which may help set management targets in policy, regulatory programs.
- A risk-based approach (e.g., logistic regression) is an appropriate way to identify statewide thresholds
- We sought to identify numeric thresholds to reduce risk of failing to meet biointegrity goals, as measured with standard indices
  - Other biological indicators may provide additional information about strengths and shortcomings of proposed thresholds
- Managing biostimulatory substances (e.g. nutrients) may not always be the sole way to address to meet biointegrity goals
  - Other stressors are often present

Approach

- Assemble statewide data set of biointegrity (BI) and biostimulatory data
- Classify sites as meeting/not meeting ranges of BI goals (e.g., 1st %ile of ref)
- Create single-variable LR models to predict likelihood of meeting BI goal at increasing levels of biostimulatory stress
- Identify thresholds where likelihood is sufficiently high (e.g., 80%)
- Validate biostimulatory thresholds with relative risk assessment
- Identify lowest validated threshold across indices (for each BI goal and biostimulatory factor)
- Evaluate error rates (i.e., meeting BI goal) associated with exceeding single, multiple thresholds
- Supplement with additional analysis (e.g., species-level response, reference distributions)

We set out to identify statewide numbers

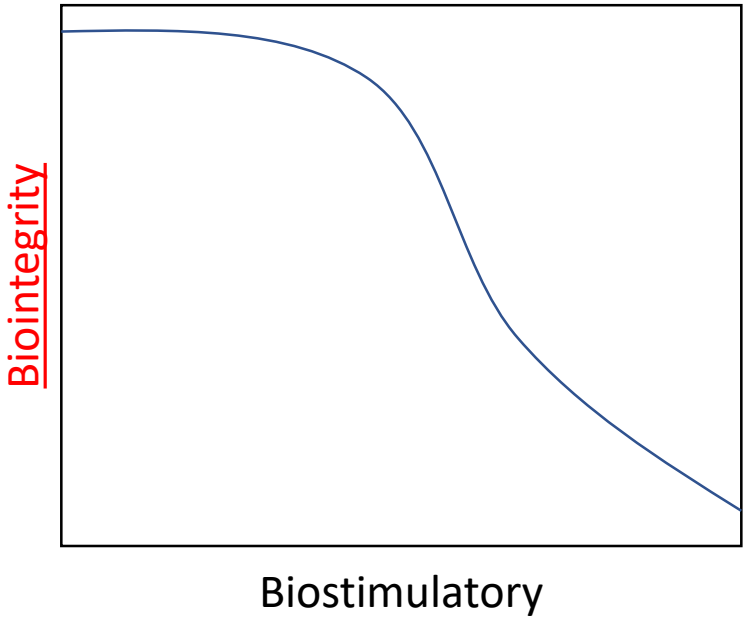
Shortcomings of this approach:

- Ignores complicating interactions among biostimulatory factors
  - E.g., moderate levels of N and P can create bigger problems than high levels of N alone.
- Ignores complicating influence of natural factors
  - Although indices are robust, responses in some stream types may be stronger than others
  - Shading, flow may moderate impacts of high nutrient concentrations

A watershed approach allows better exploration of these concerns, where appropriate

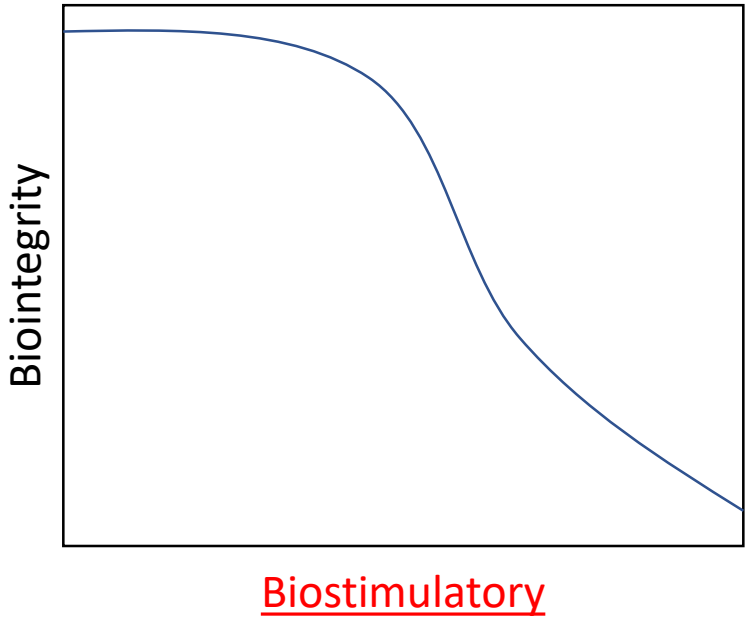
Biointegrity data

- CSCI
- ASCI
  - Diatom
  - Soft-bodied algae
  - Hybrid



- Biointegrity goals
  - 1st, 10th, and 30th percentiles of reference
  - BCG3 and BCG4 (other levels too sparse in dataset to model)

Biostimulatory data



Nutrients

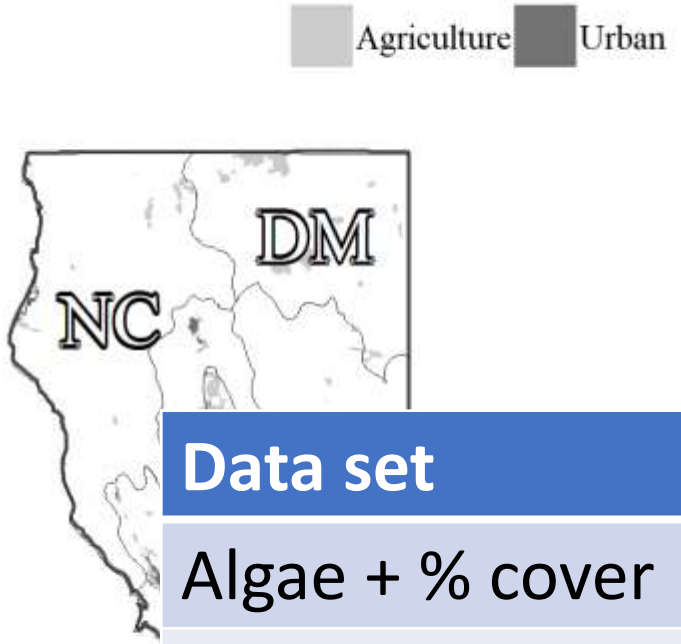
- Total N (mg/L)
- Total P (mg/L)

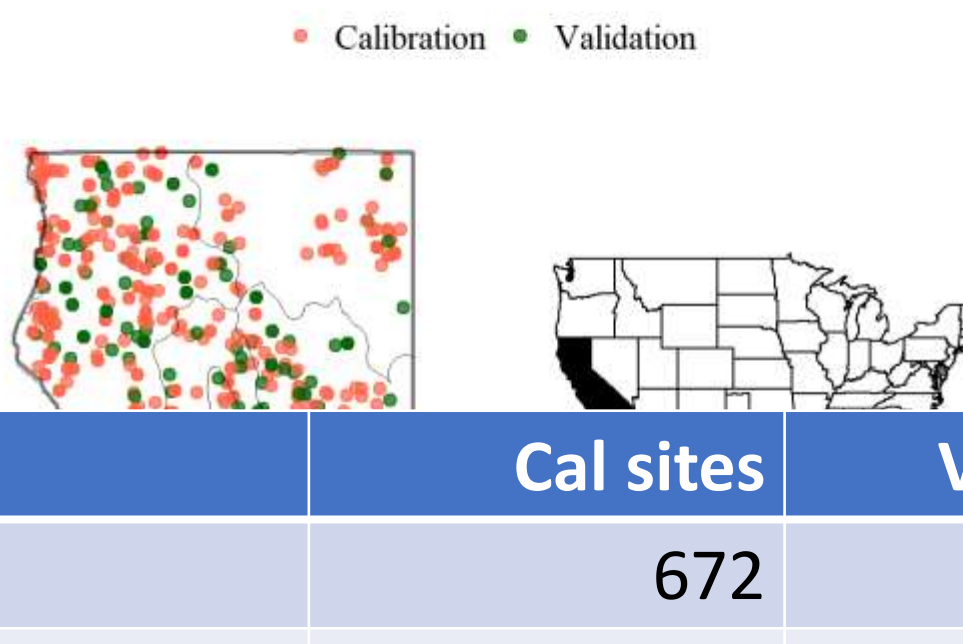
Organic matter

- Benthic chlorophyll-a (mg/m^2)
- Benthic AFDM (mg/cm^2) (multiply by 10 to convert to g/m^2)
- % macroalgae cover

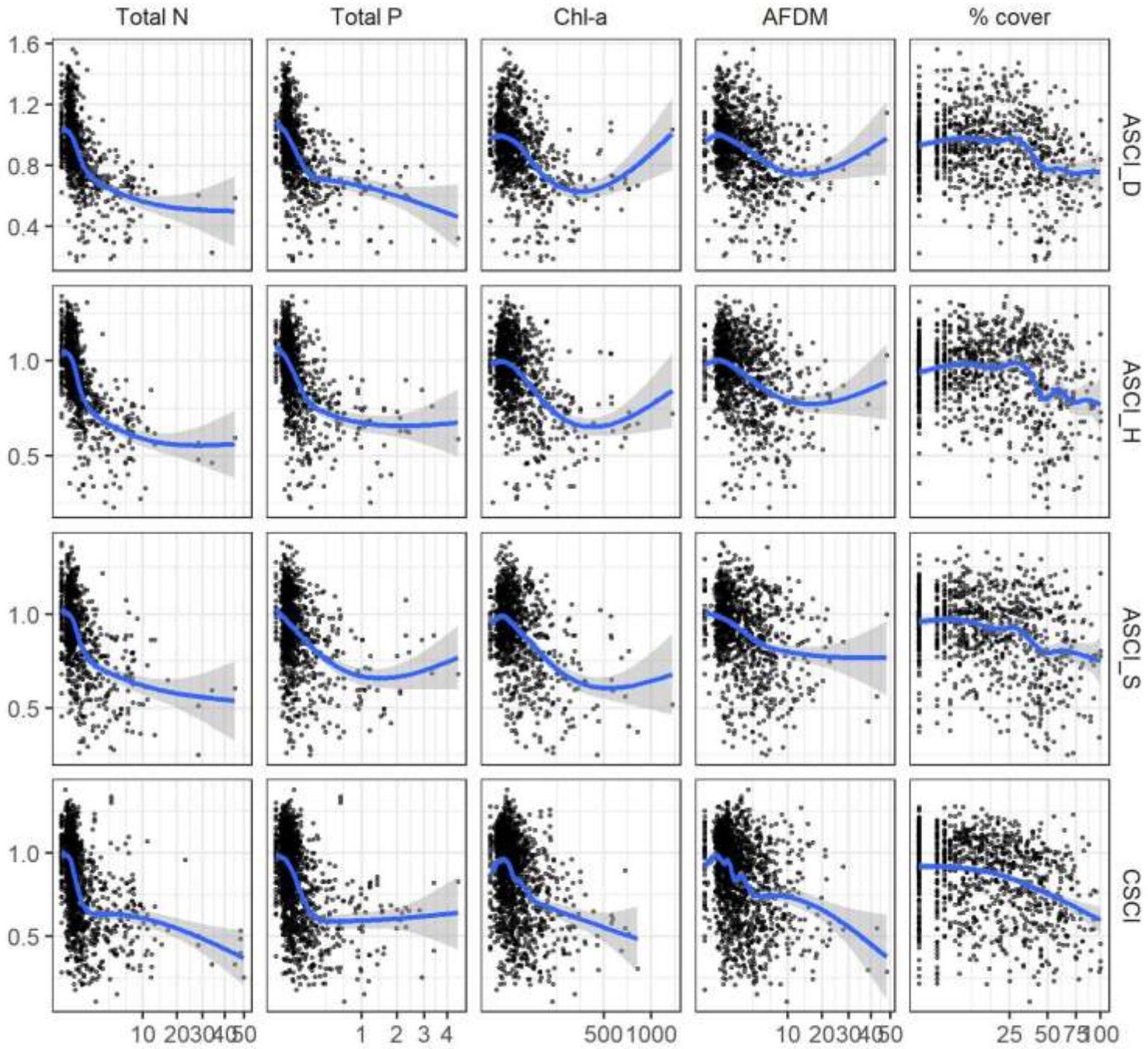
(a) Land use and regions

(b) Data set





Data set	Cal sites	Val sites
Algae + % cover	672	218
Algae + other biostimulatory	765	248
BMI + % cover	766	250
BMI + other biostimulatory	1184	389



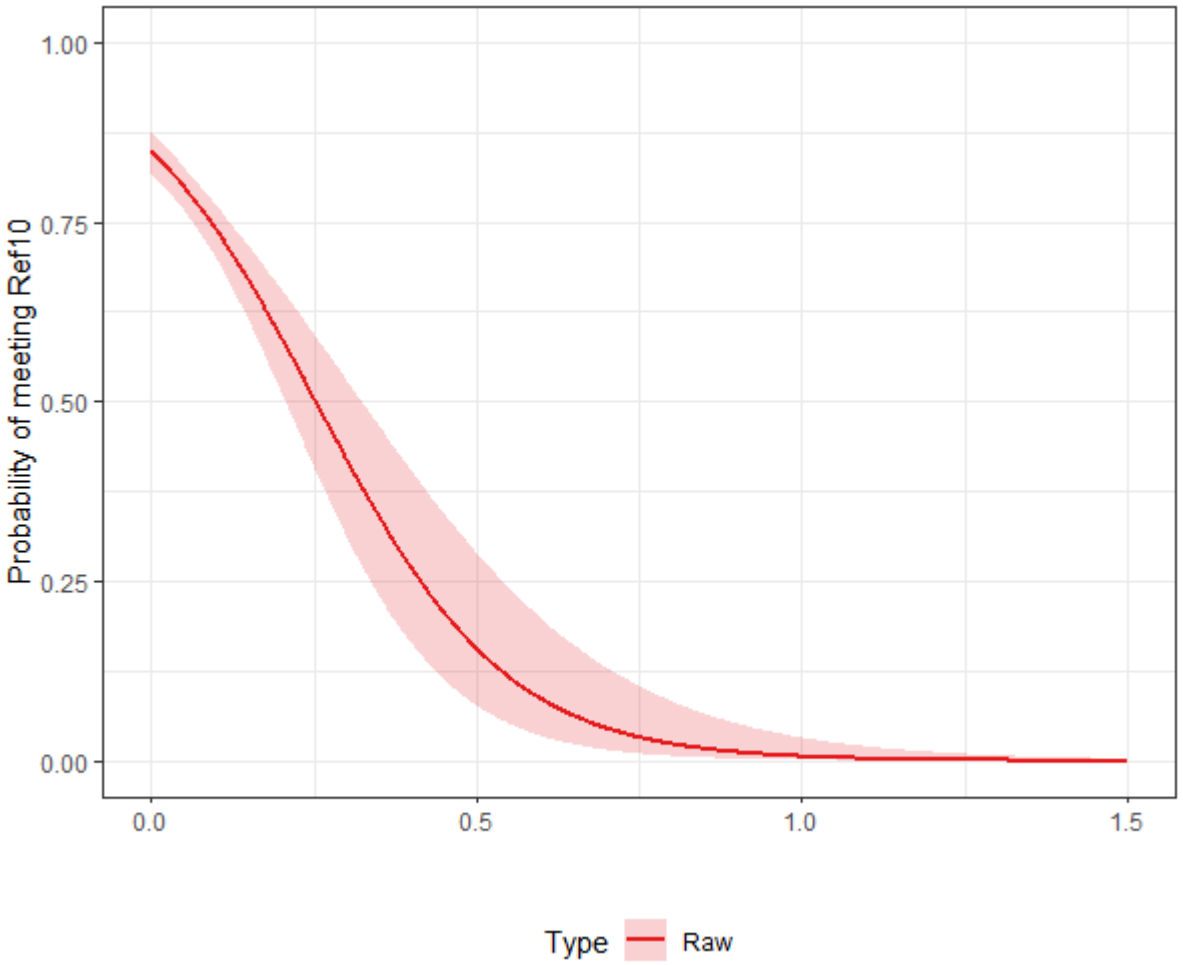
Relationships are noisy

Responses happen at low concentrations.

Calibrate 100+ models

- One each for every combination of:
  - 4 biointegrity indices
  - 5 biointegrity goals
  - 5 biostim factors
- Significant relationships for nearly all (96%). Exceptions:
  - ASCI_S achieving BCG4 based on AFDM, chl-a, or TP
  - ASCI_D achieving BCG4 based on AFDM
- Accuracy in predicting attainment of BI goal ranged from 54 to 99%

Apply models over a range of values

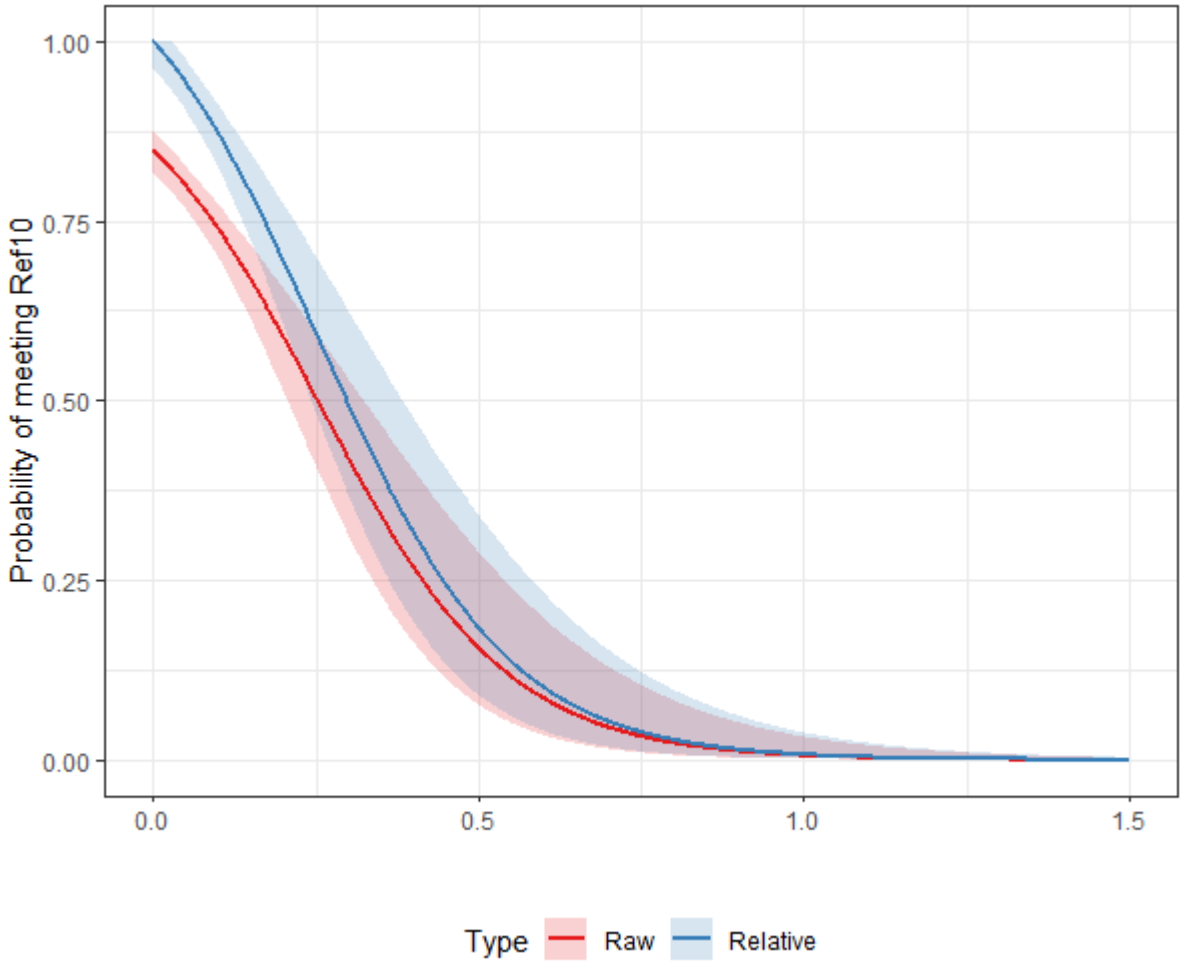


We expect to find threshold below this max:

Biostimulatory factor	Max level evaluated*
Total N	3 mg/L
Total P	1.5 mg/L
Chlorophyll-a	300 mg/m^2
AFDM	75 mg/cm^2
% cover	100%

*Larger ranges have since been evaluated

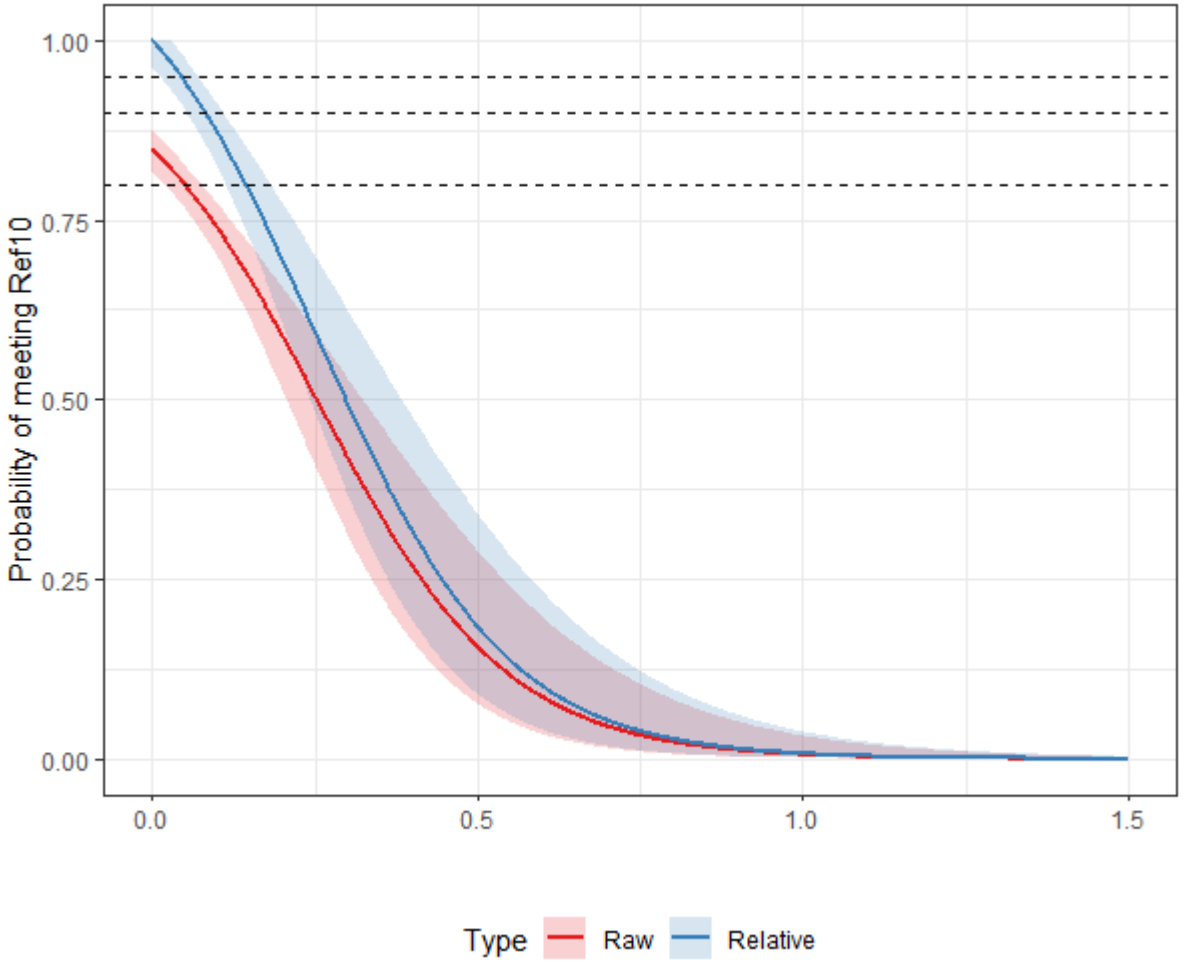
Relativize to account for background level of impacts



Result: Higher eut. thresholds.

“Likelihood” becomes “relative likelihood”

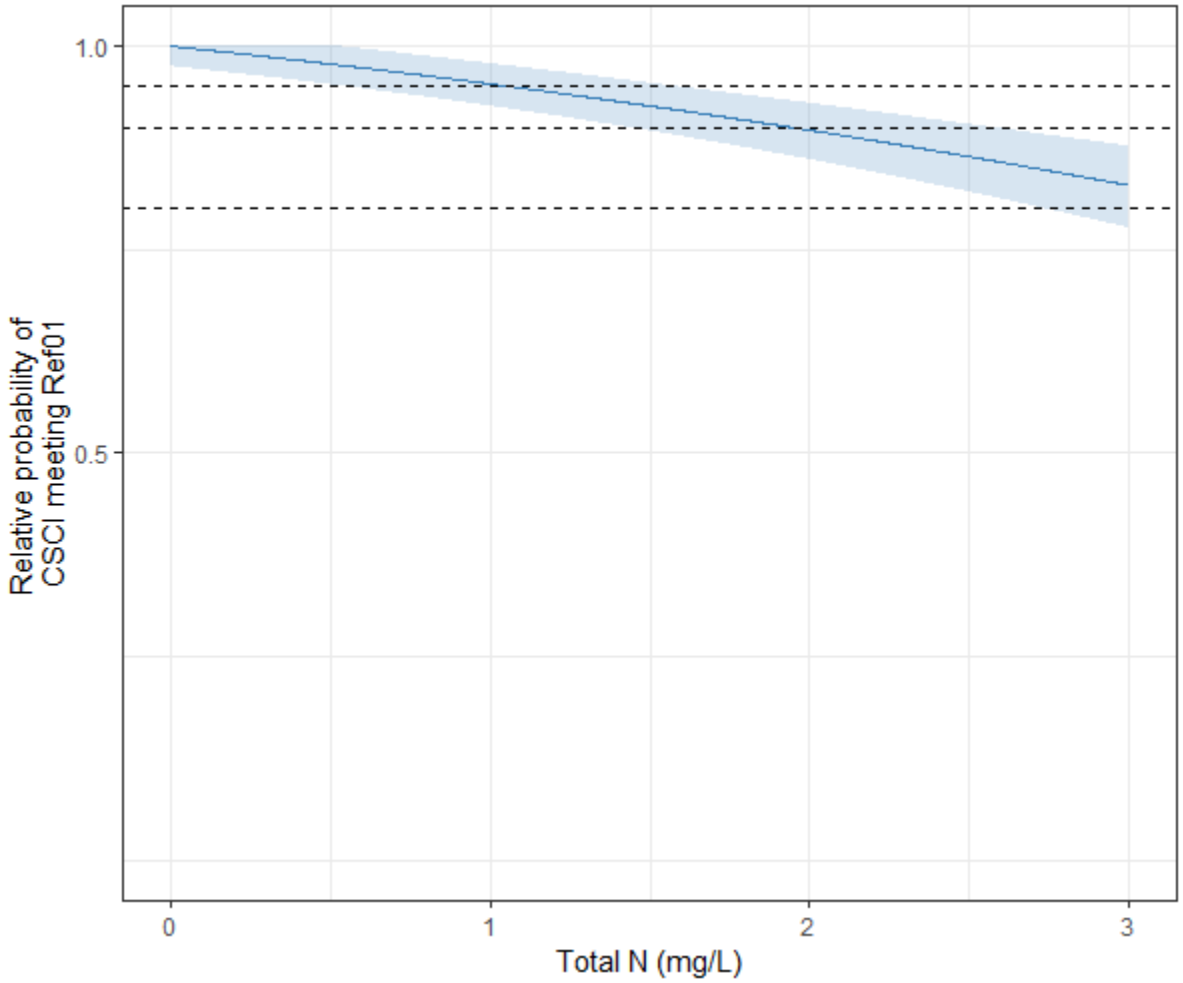
Identify thresholds where likelihood is sufficiently high



“Sufficiently high” is both a technical and policy decision

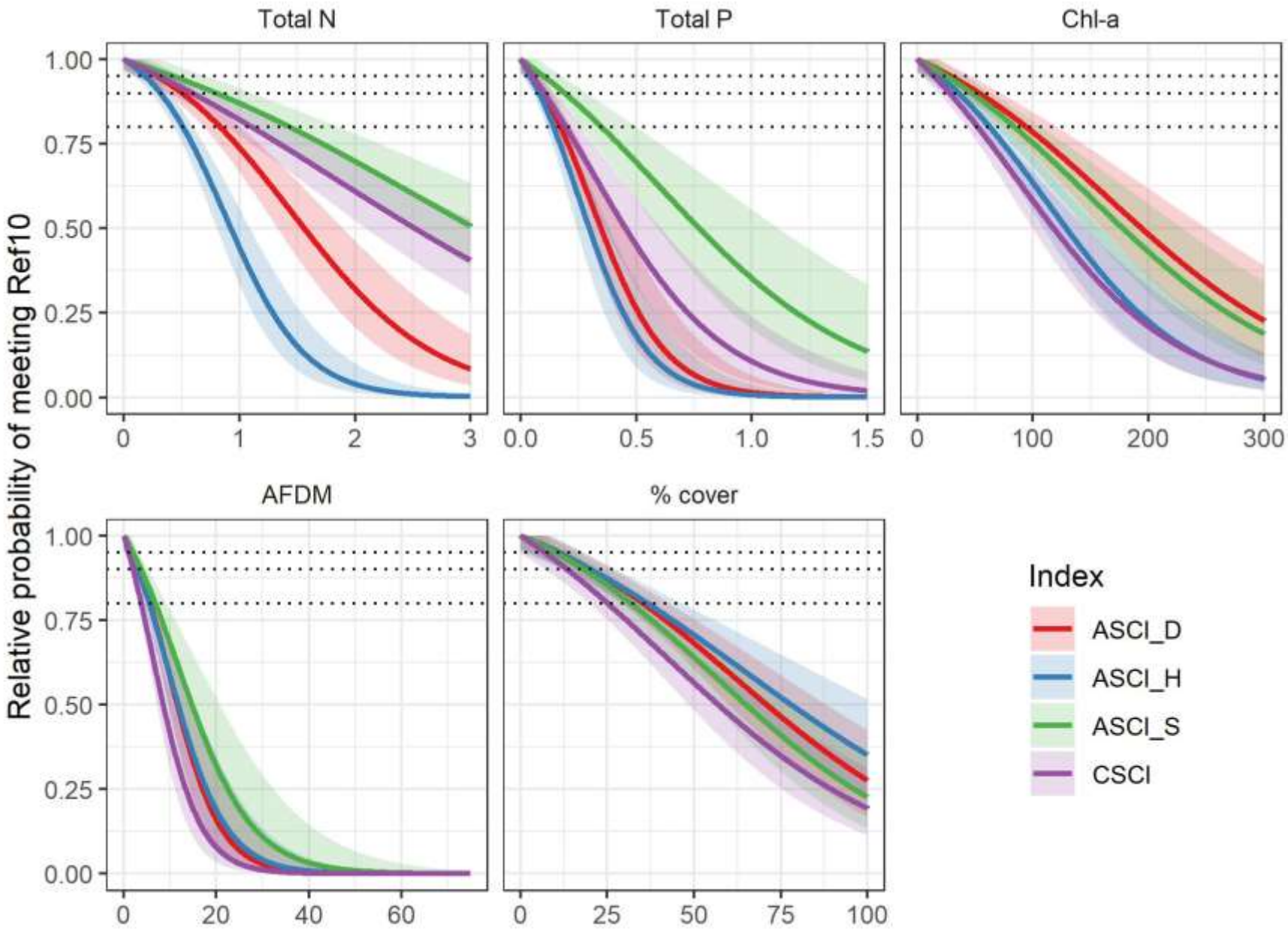
- Technical:
  - Does the threshold validate?
- Policy:
  - Risk tolerance?
  - Balance errors of overprotection vs. underprotection?

Identify thresholds where likelihood is sufficiently high



Sometimes, no threshold found within evaluated range at evaluated probabilities.

“Even if stress is high, we are not sufficiently increasing the risk of failing to meet our [low] goal”



In general, ASCI-H and CSCI were more sensitive than ASCI-D, ASCI-S

Validation through relative risk assessment

Relative risk: If a site exceeds a biostimulatory threshold, does that increase the likelihood of failing to meet a biointegrity goal?

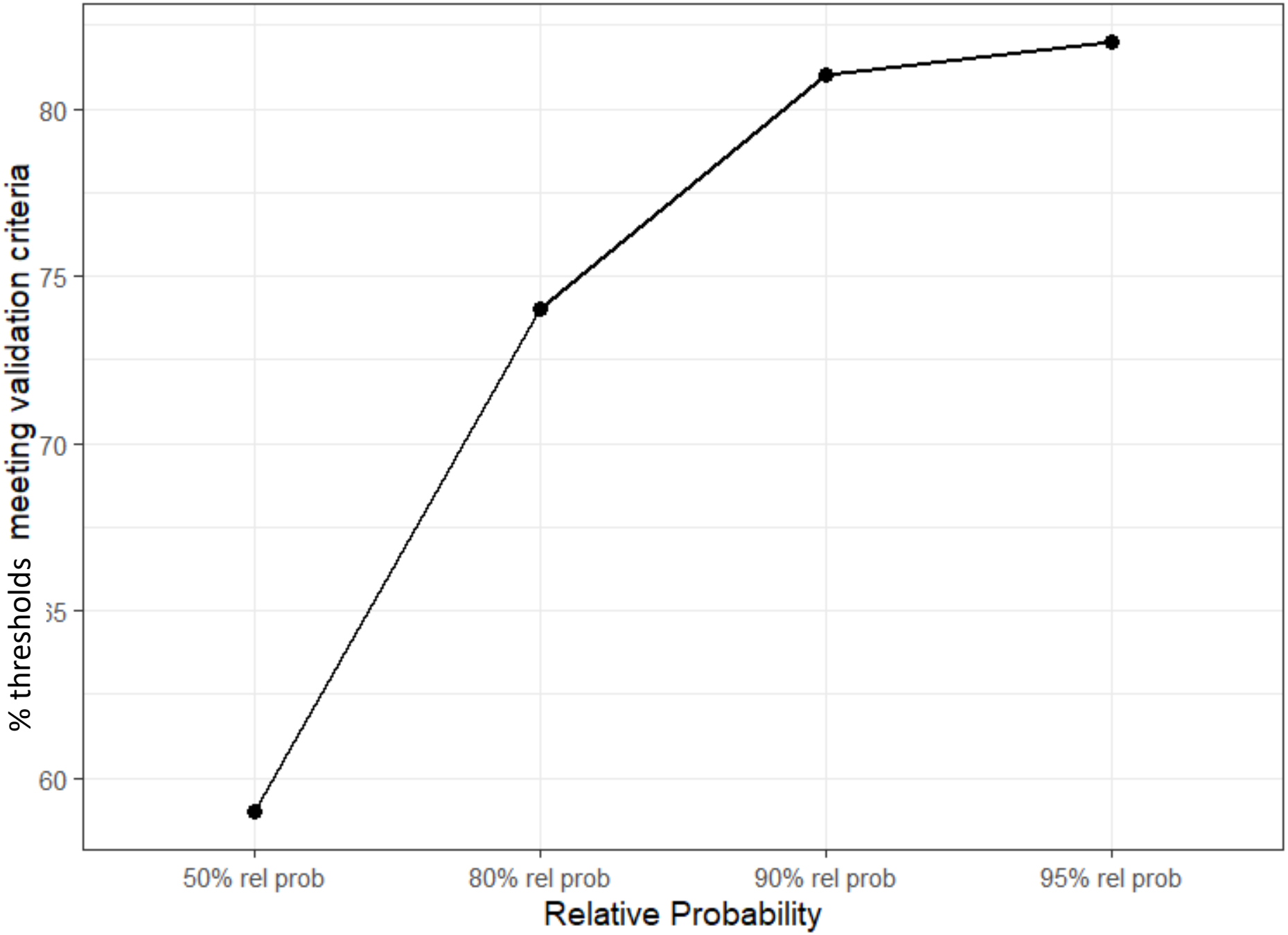
Calculated in both cal and val data sets:

$$\frac{\text{Frequency of BI failures where threshold is exceeded}}{\text{Frequency of BI failures where threshold is met}}$$

Validation = Both cal and val risk significantly greater than 1 ($p < 0.05$).

Different probabilities for different risk tolerances

- We evaluated three options:
  - 80%
  - 90%
  - 95%
- Example statement: “If I keep total P below 0.08, I have a 90% chance of meeting my biointegrity goals.”
- Validation was best with 90% and 95%

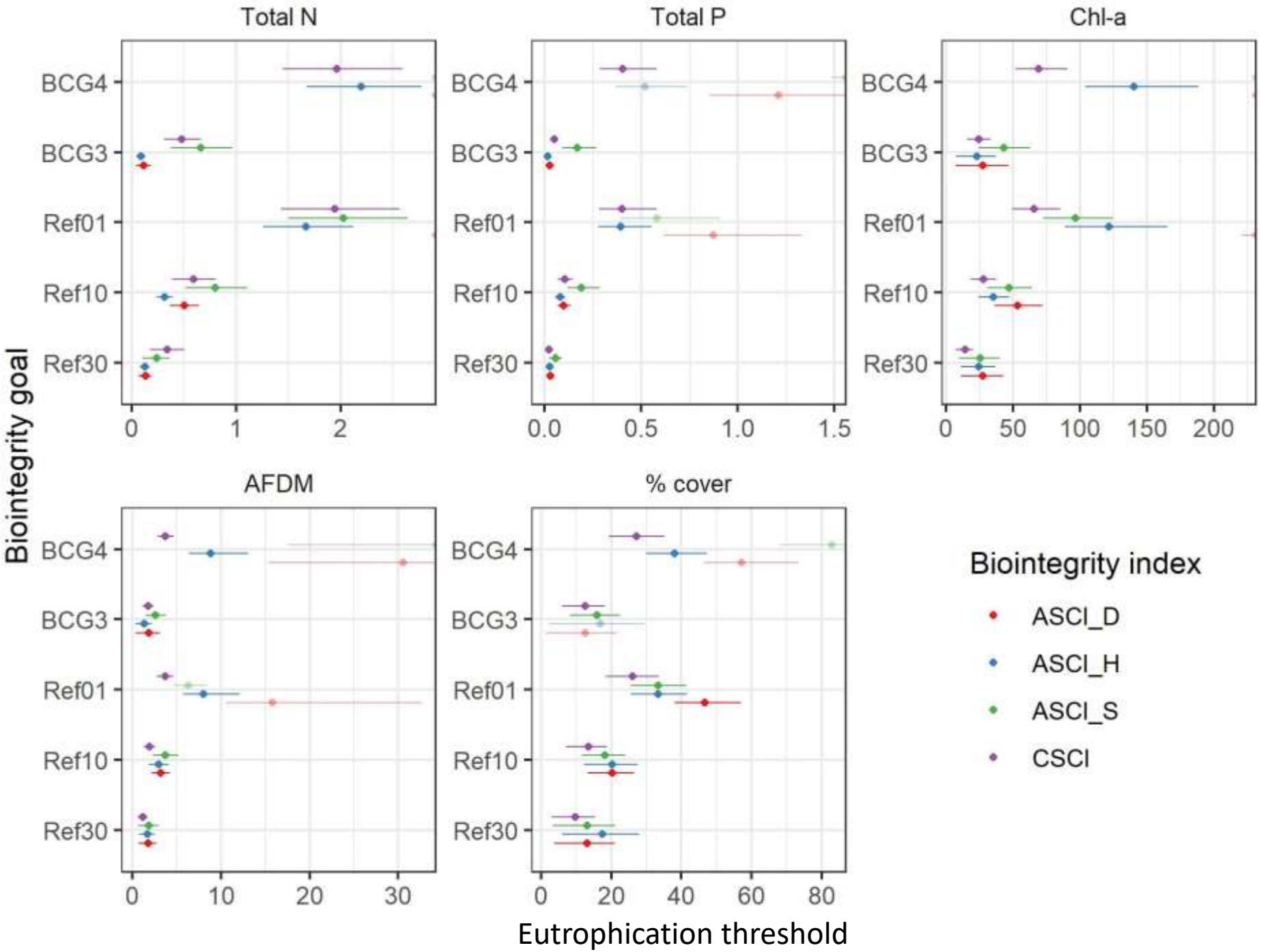


Higher probabilities resulted in more thresholds getting validated

This approach identifies ranges of thresholds:

- Across 4 indices (we selected the lowest validated threshold)
- Across 5 BI goals
- Across 3 relative probabilities

For simplicity, we focus on results for Ref10-90% relative probability,
but this choice is not a policy recommendation.



Thresholds to achieve a range of BI goals with 90% relative probability

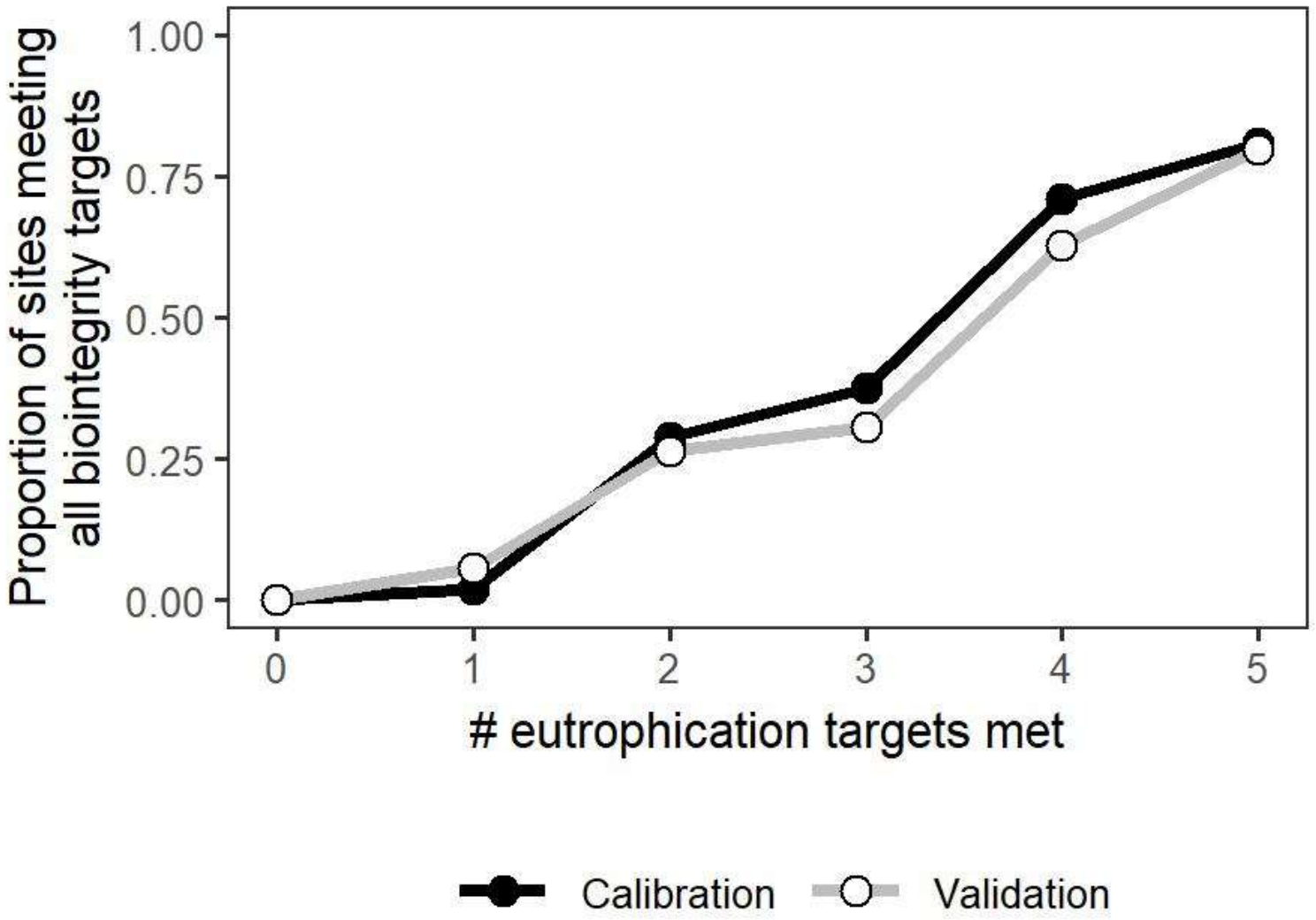
Dark colors: Passed validation

Faint colors: Failed validation

Summary of thresholds (Ref10, 90% prob)

Biostimulatory factor	Lowest validated threshold (index)	Highest validated threshold (index)	Relative Risk
Total N	0.32 (ASCI-H)	0.80 (ASCI-S)	11.3
Total P	0.08 (ASCI-H)	0.19 (ASCI-S)	5.6
Chl-a	28 (CSCI)	58 (ASCI-D)	2.4
AFDM	2.0 (CSCI)	3.7 (ASCI-S)	2.4
% cover	13 (CSCI)	21 (ASCI-D)	1.9

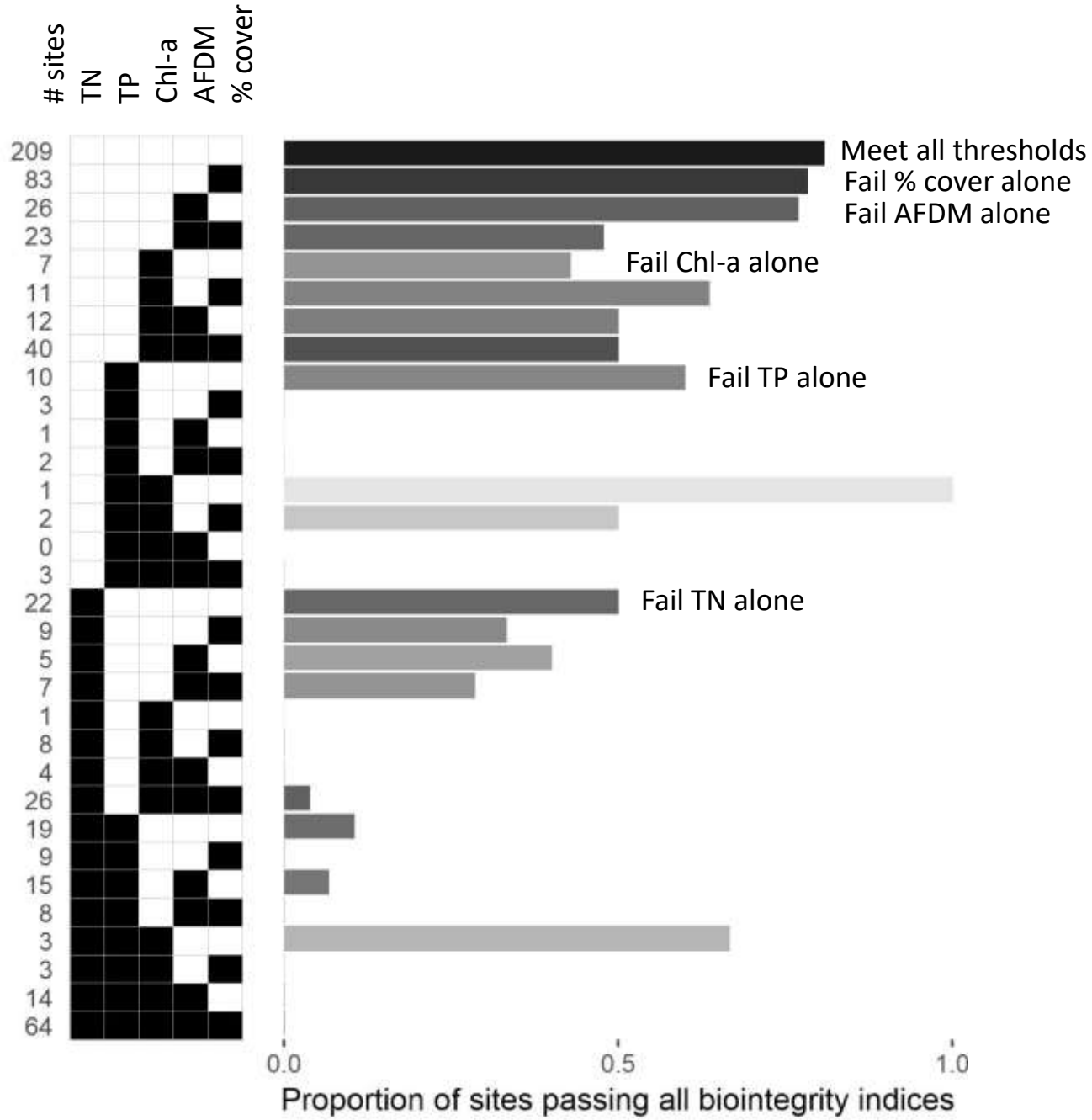
Error analysis example, based on Ref10-90% thresholds



Failing single threshold: High (>50%) error rate

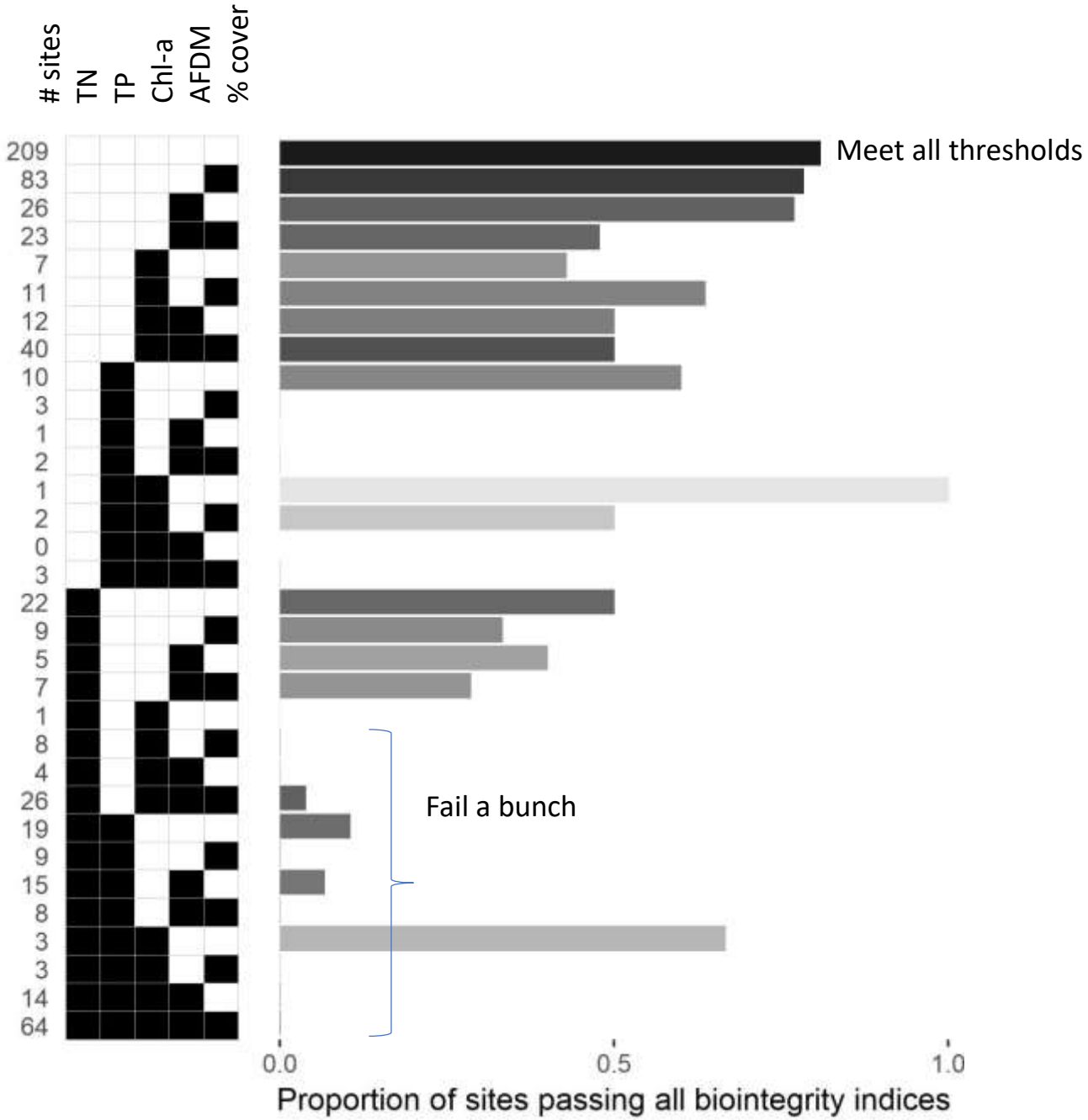
- Consistent with risk-based approach

Much lower (<37%) when multiple thresholds are exceeded.



Organic matter—especially % cover, AFDM—had the highest error rates.

Revise analysis after options have been identified.



Best success when multiple thresholds are exceeded

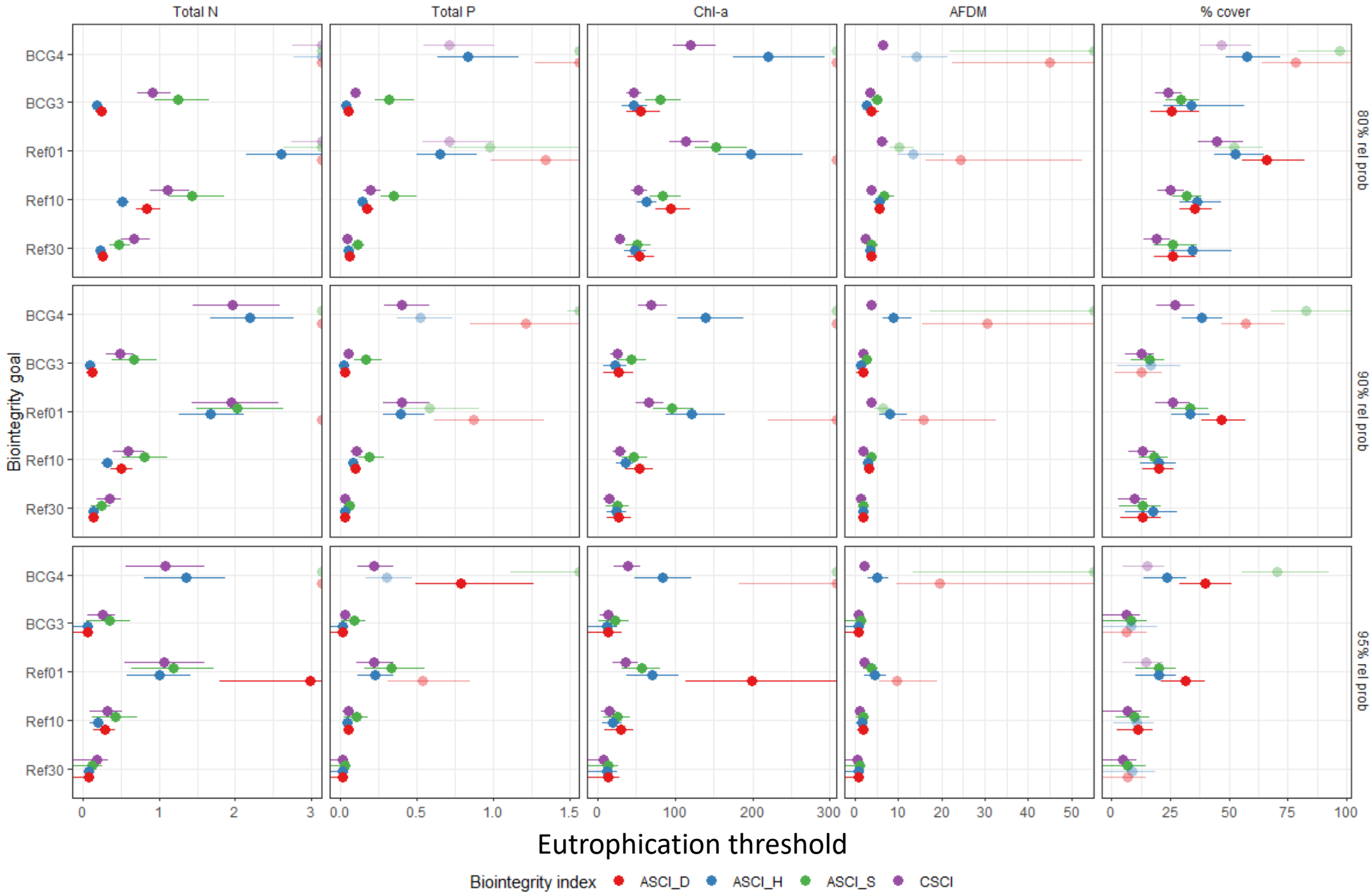
Next steps

- Draft manuscript currently in review by advisory group
- Manuscript revisions will follow advisory group feedback, clarification of options preferred by WB

Water Board Charge Questions:

- Comment on the adequacy of the data set, analytical approach, model performance evaluation, uncertainty, and soundness of the conclusions presented in Mazor et al. (in prep). Comment on the applicability of the findings to assessments conducted outside the bioassessment index period.
- To develop these models, the Tech Team made simplifying assumptions about the influence of natural factors, and about interactions among biostimulatory factors. Are these assumptions appropriate? Are some more important than others?
- Are there technical ways to address stakeholder concerns?


Questions?


Total N
Total P
Chl-a
AFDM
% cover
80% rel prob
90% rel prob
95% rel prob
Biointegrity goal
BCG4
BCG3
Ref01
Ref10
Ref30
0
1
2
3
0.0
0.5
1.0
1.5
0
100
200
300
0
10
20
30
40
50
0
25
50
75
100
Eutrophication threshold
Biointegrity index
ASCI_D
ASCI_H
ASCI_S
CSCI

Summary of thresholds (Ref10, 95% prob)

Biostimulatory factor	Lowest validated threshold (index)	Highest validated threshold (index)	Relative Risk
Total N	0.18 (ASCI-H)	0.43 (ASCI-S)	12.3
Total P	0.04 (ASCI-H)	0.10 (ASCI-S)	5.5
Chl-a	15 (CSCI)	29 (ASCI-D)	2.4
AFDM	1.0 (CSCI)	2.0 (ASCI-S)	2.7
% cover	7 (CSCI)	11 (ASCI-D)	1.7

Summary of thresholds (Ref10, 80% prob)

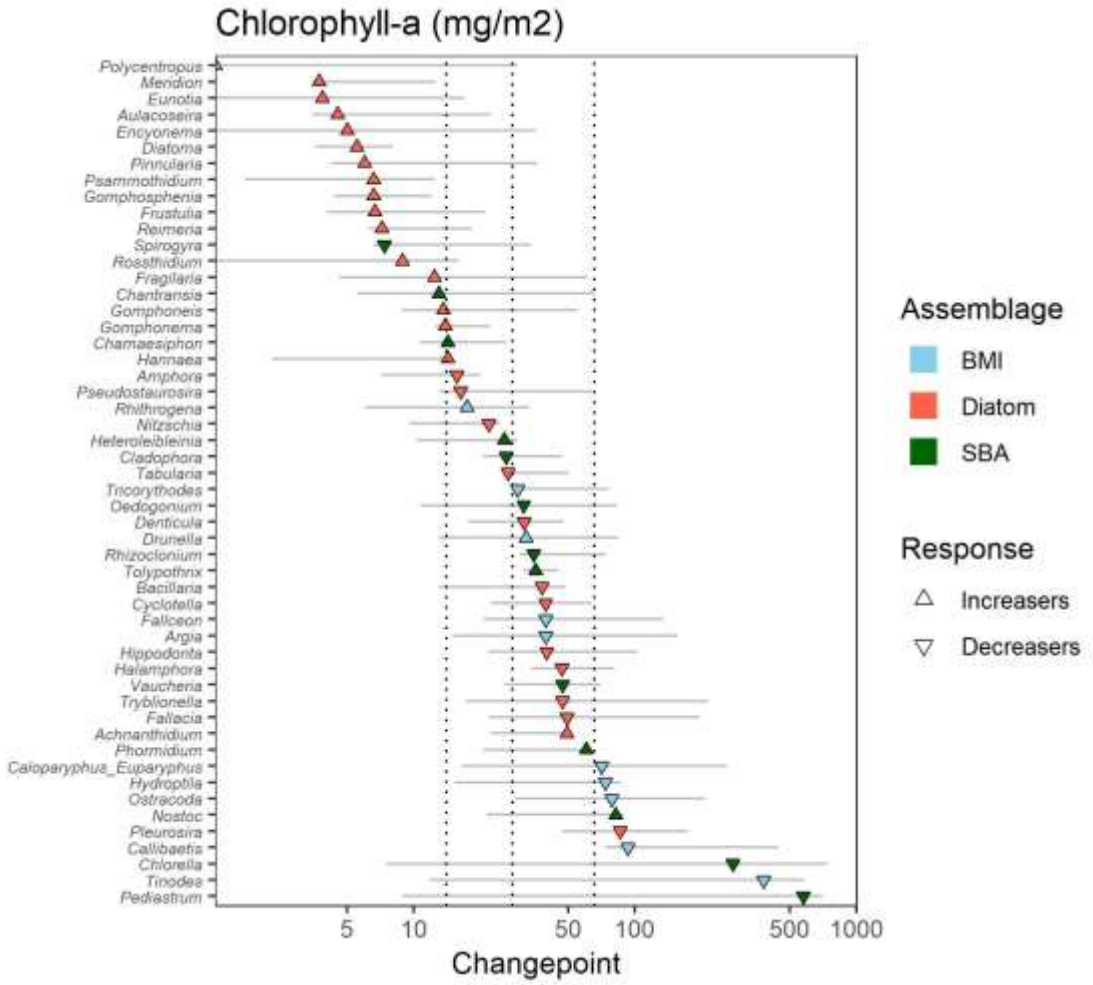
Biostimulatory factor	Lowest validated threshold (index)	Highest validated threshold (index)	Relative Risk
Total N	0.51 (ASCI-H)	1.40 (ASCI-S)	8.4
Total P	0.14 (ASCI-H)	0.35 (ASCI-S)	4.4
Chl-a	52 (CSCI)	94 (ASCI-D)	2.6
AFDM	3.8 (CSCI)	6.8 (ASCI-S)	2.2
% cover	25 (CSCI)	37 (ASCI-D)	2.0

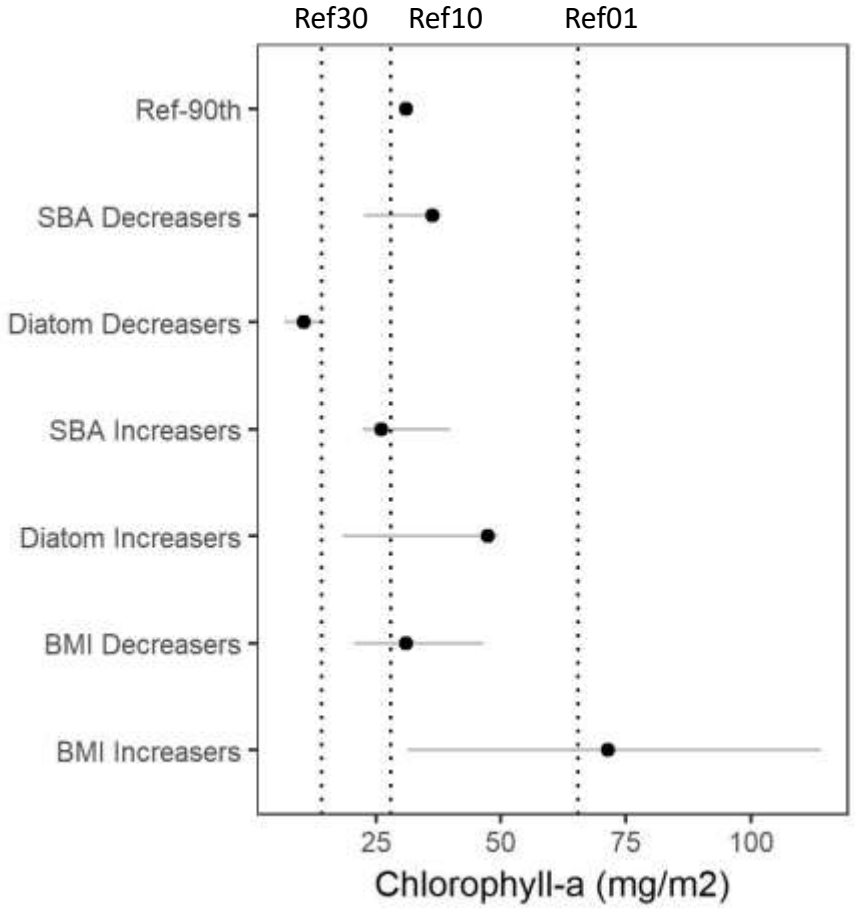
Additional evidence supporting thresholds

- TITAN: Identifies change-points along gradients associated with taxa/whole assemblages
- Reference distributions
- Other modeling approaches (e.g., piecewise regression)

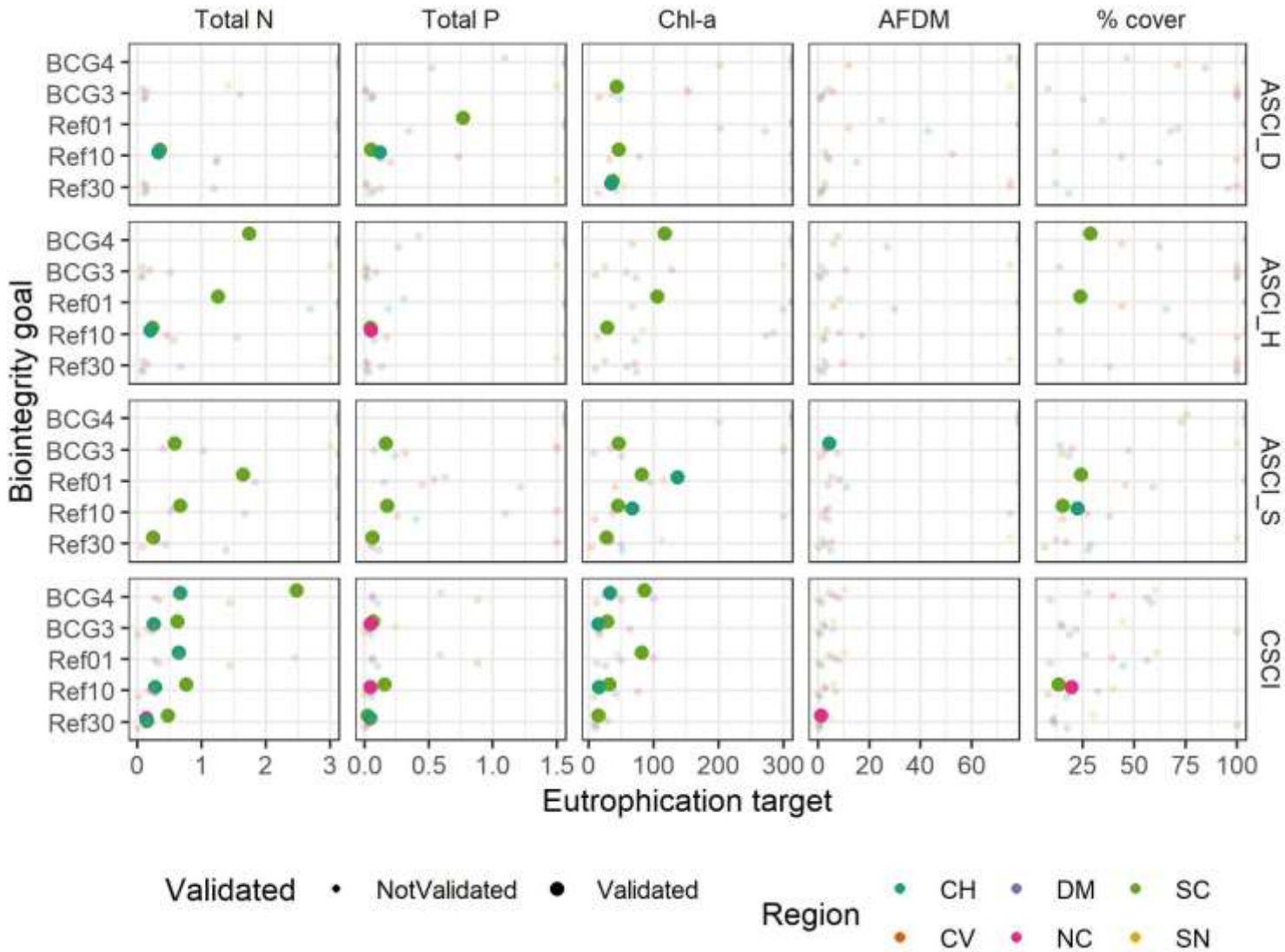
Example with Chlorophyll-a

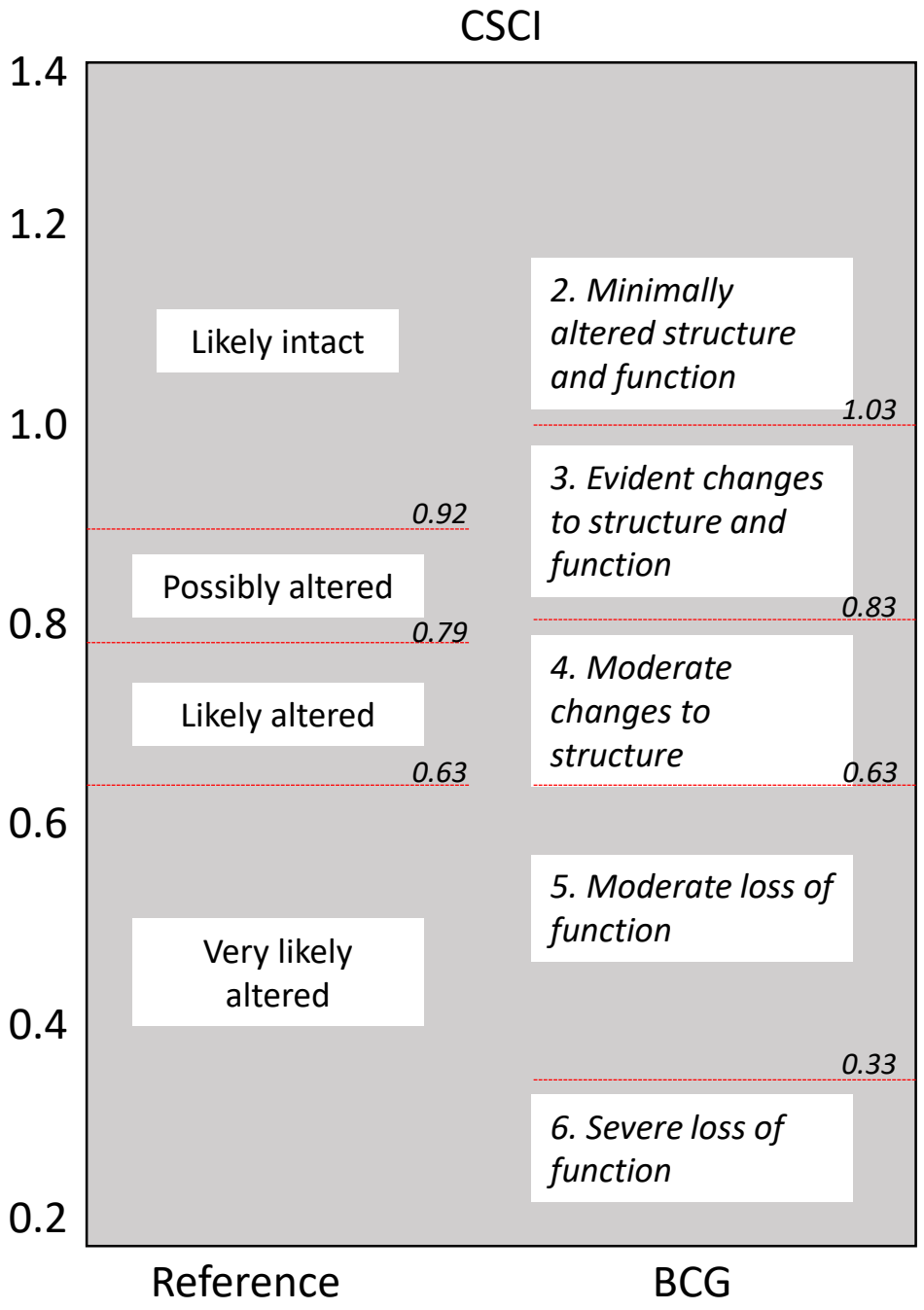
How do ref-based thresholds (dotted lines) compare?

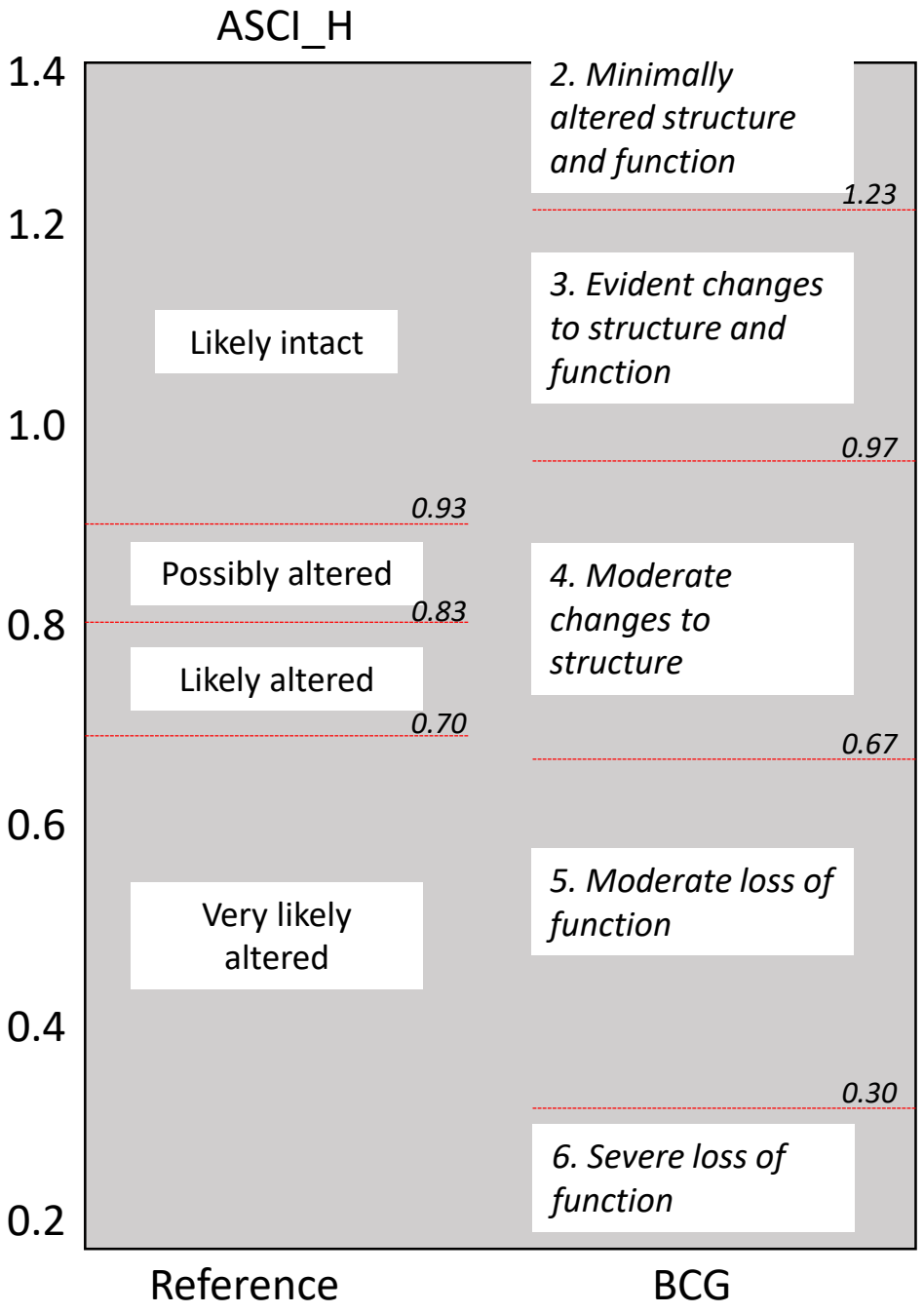




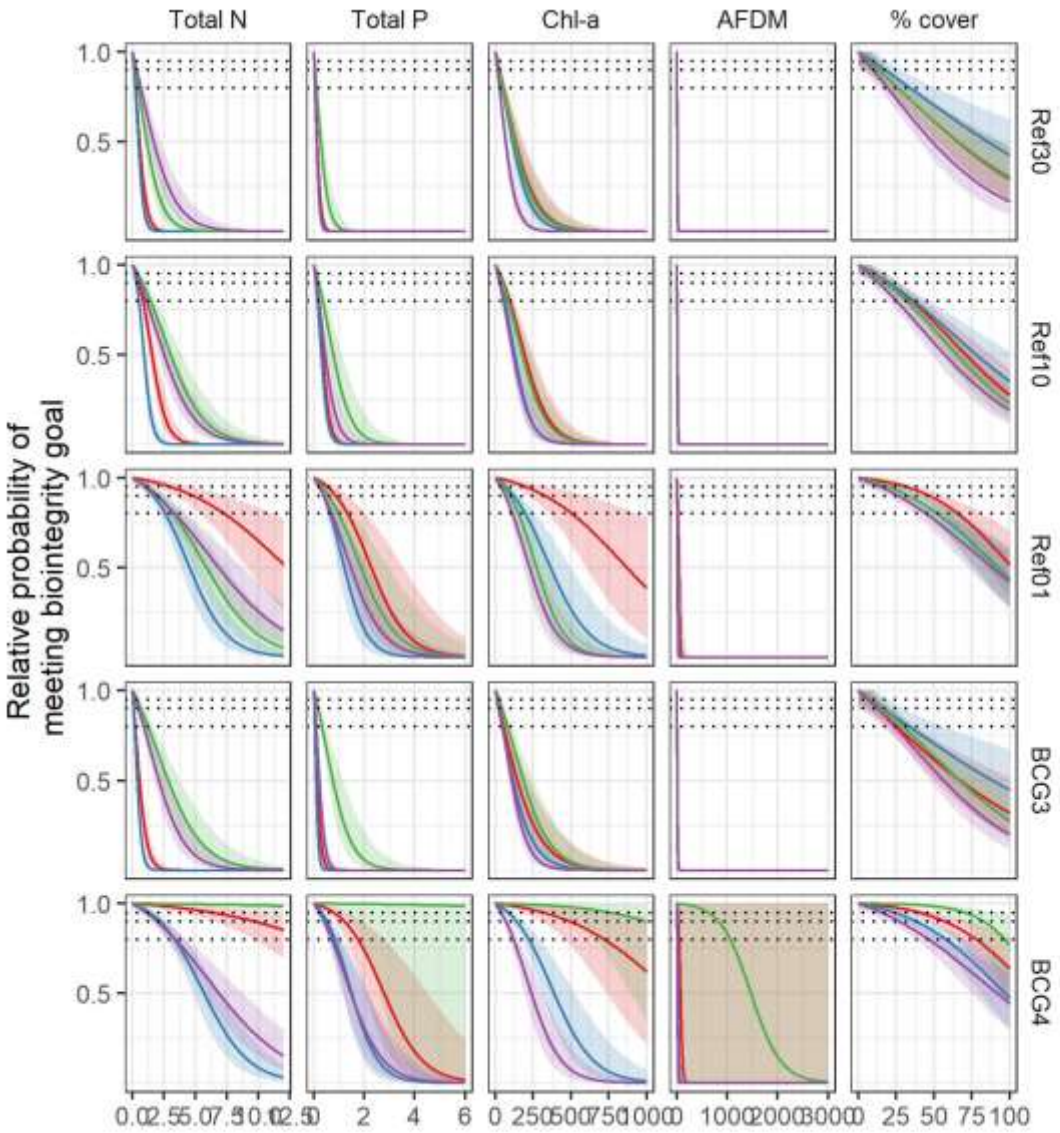
Regional thresholds: Rare success rarely matters

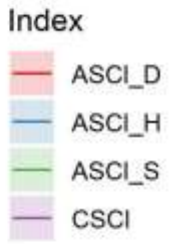


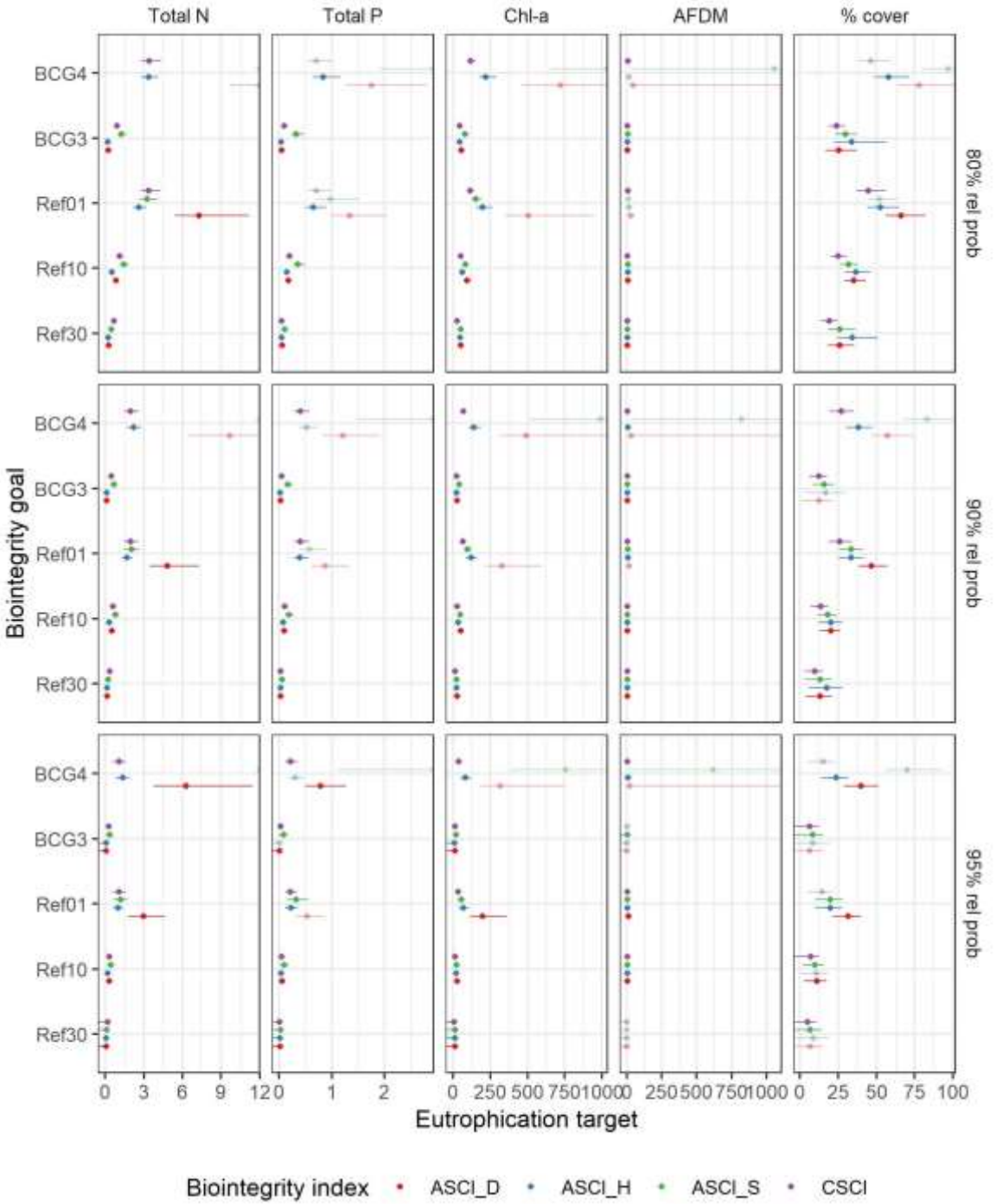

CSCI
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Likely intact
Possibly altered
Likely altered
Very likely altered
2. Minimally altered structure and function
3. Evident changes to structure and function
4. Moderate changes to structure
5. Moderate loss of function
6. Severe loss of function
1.03
0.92
0.83
0.79
0.63
0.63
0.33
Reference
BCG

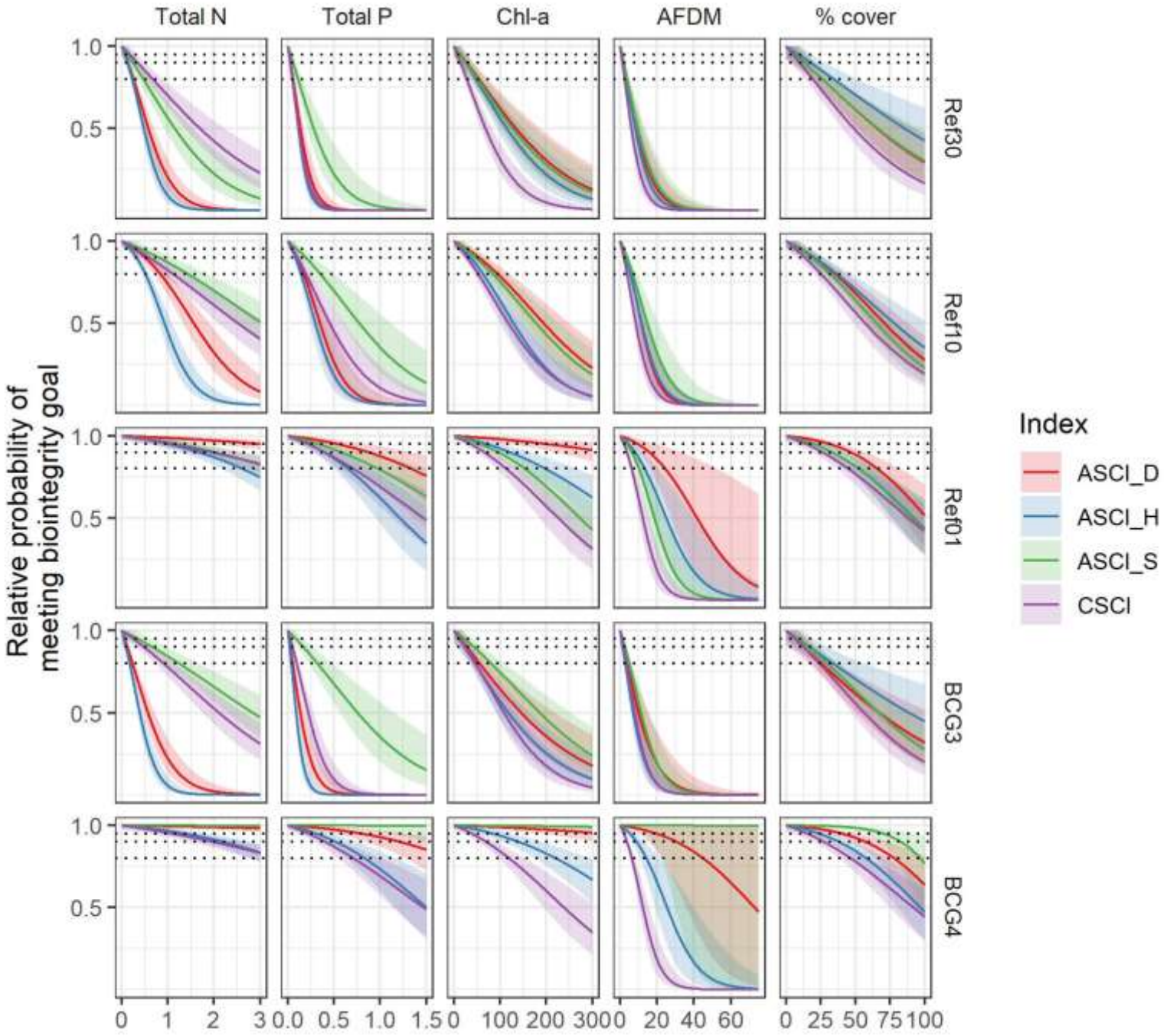

ASCI_H
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Likely intact
Possibly altered
Likely altered
Very likely altered
2. Minimally altered structure and function
3. Evident changes to structure and function
4. Moderate changes to structure
5. Moderate loss of function
6. Severe loss of function
1.23
0.97
0.93
0.83
0.70
0.67
0.30
Reference
BCG

Extended ranges



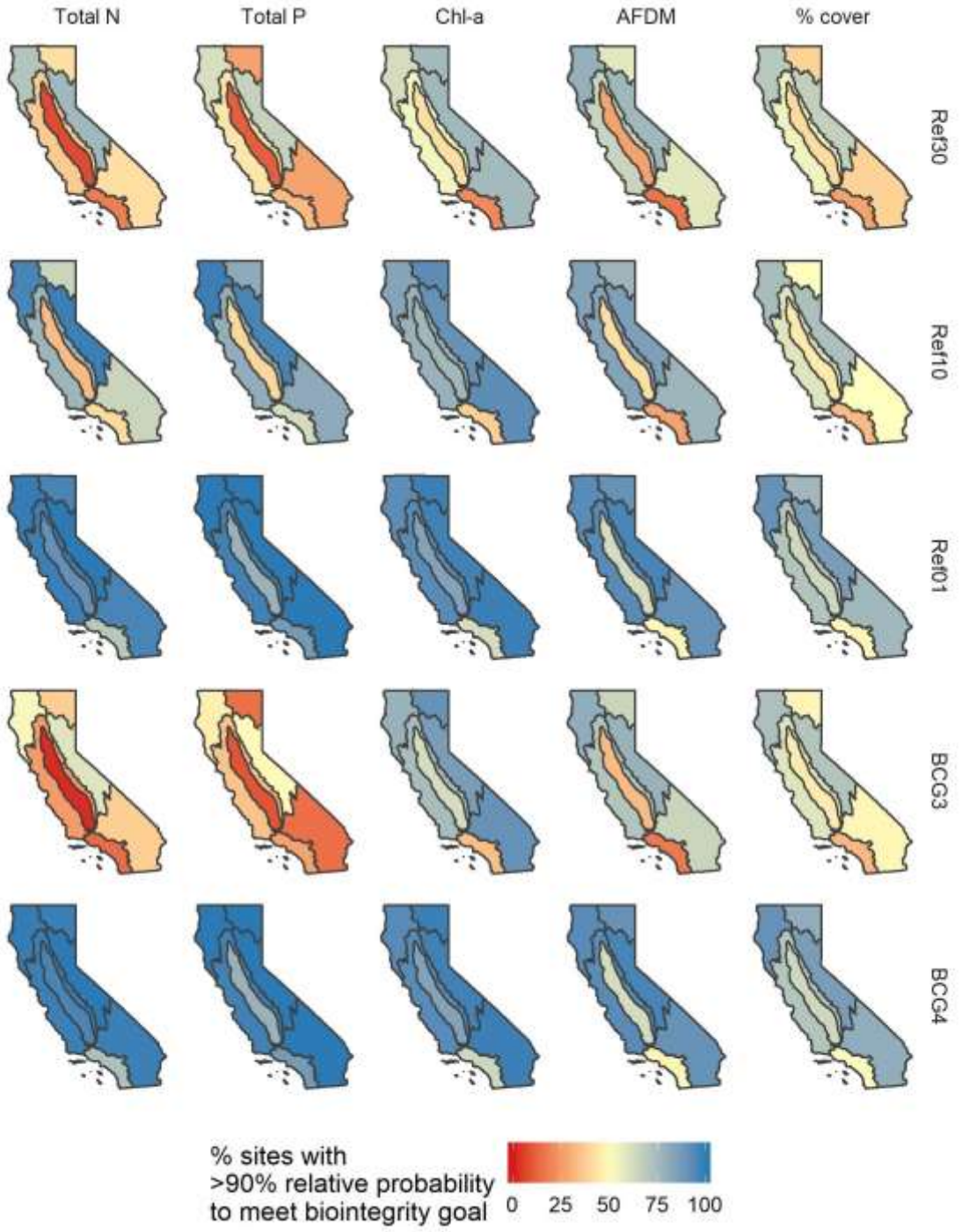






Relationships were noisier or weaker for “low” BI goals (Ref01).

threshold-setting may be challenging for those goals.

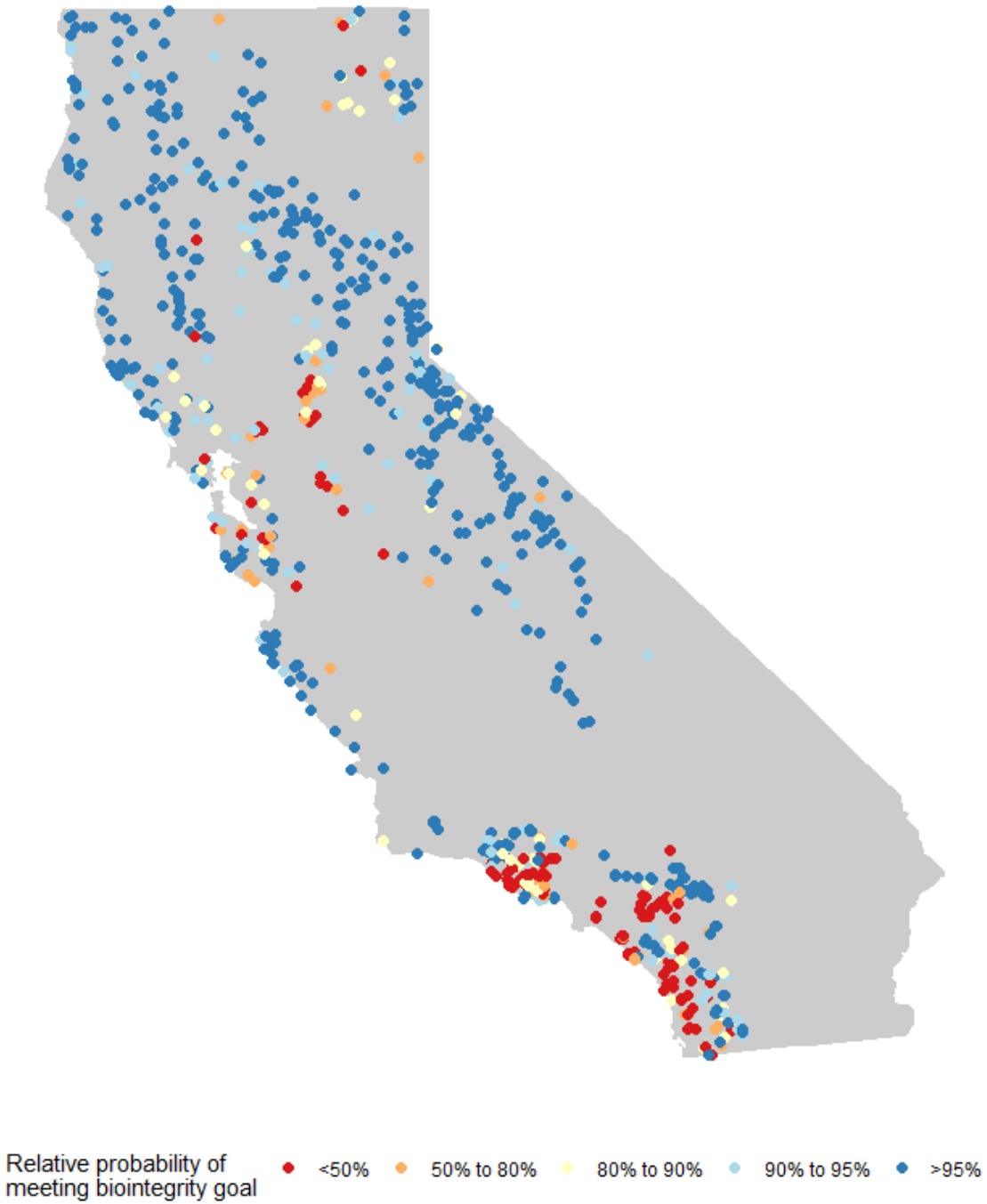


Most pervasive exceedance: % cover

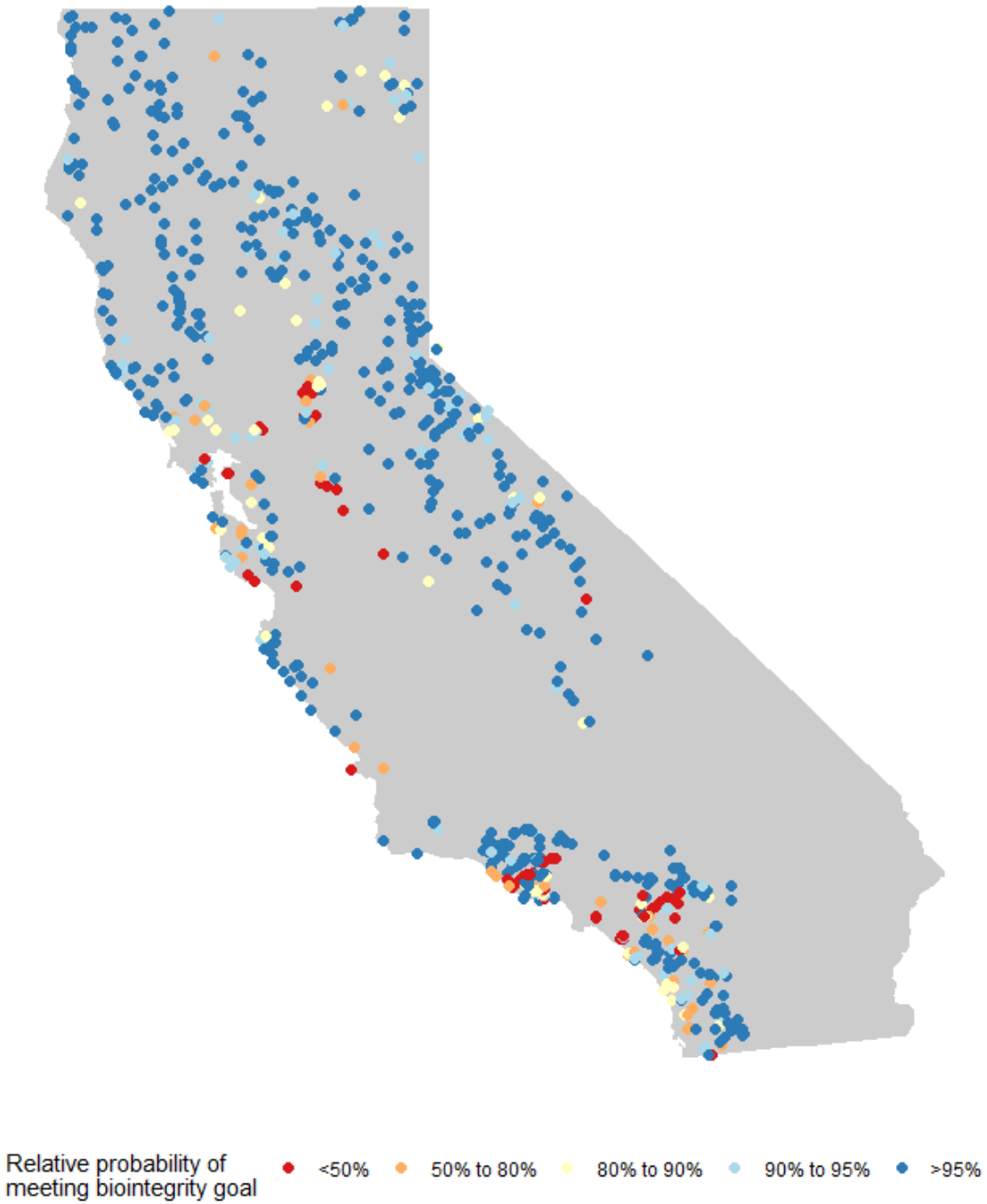
Nutrient threshold exceedances are most extensive in Central Valley

OM exceedances are notably frequent in South Coast

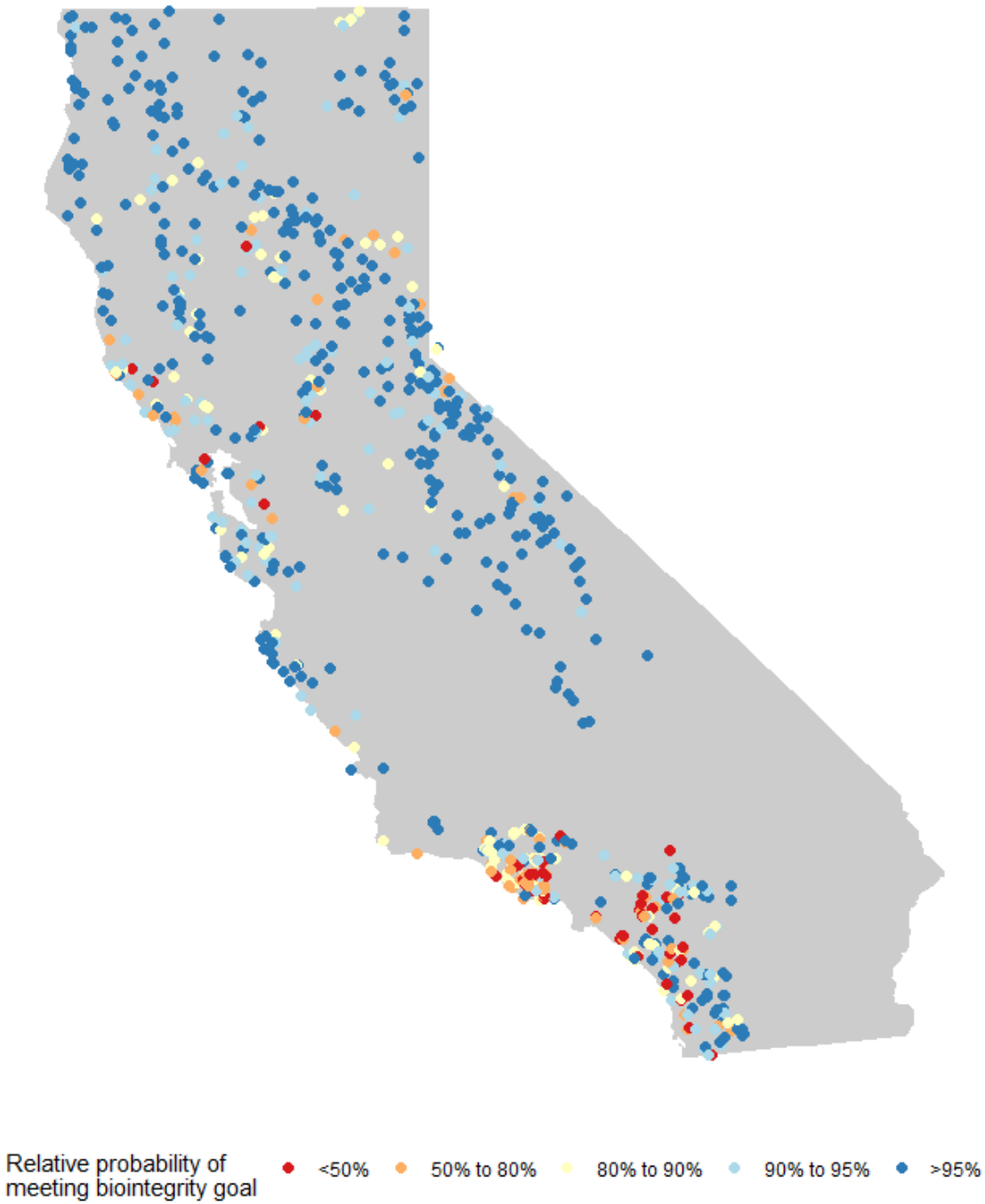
Relative likelihood of meeting Ref10 goal based on Total N



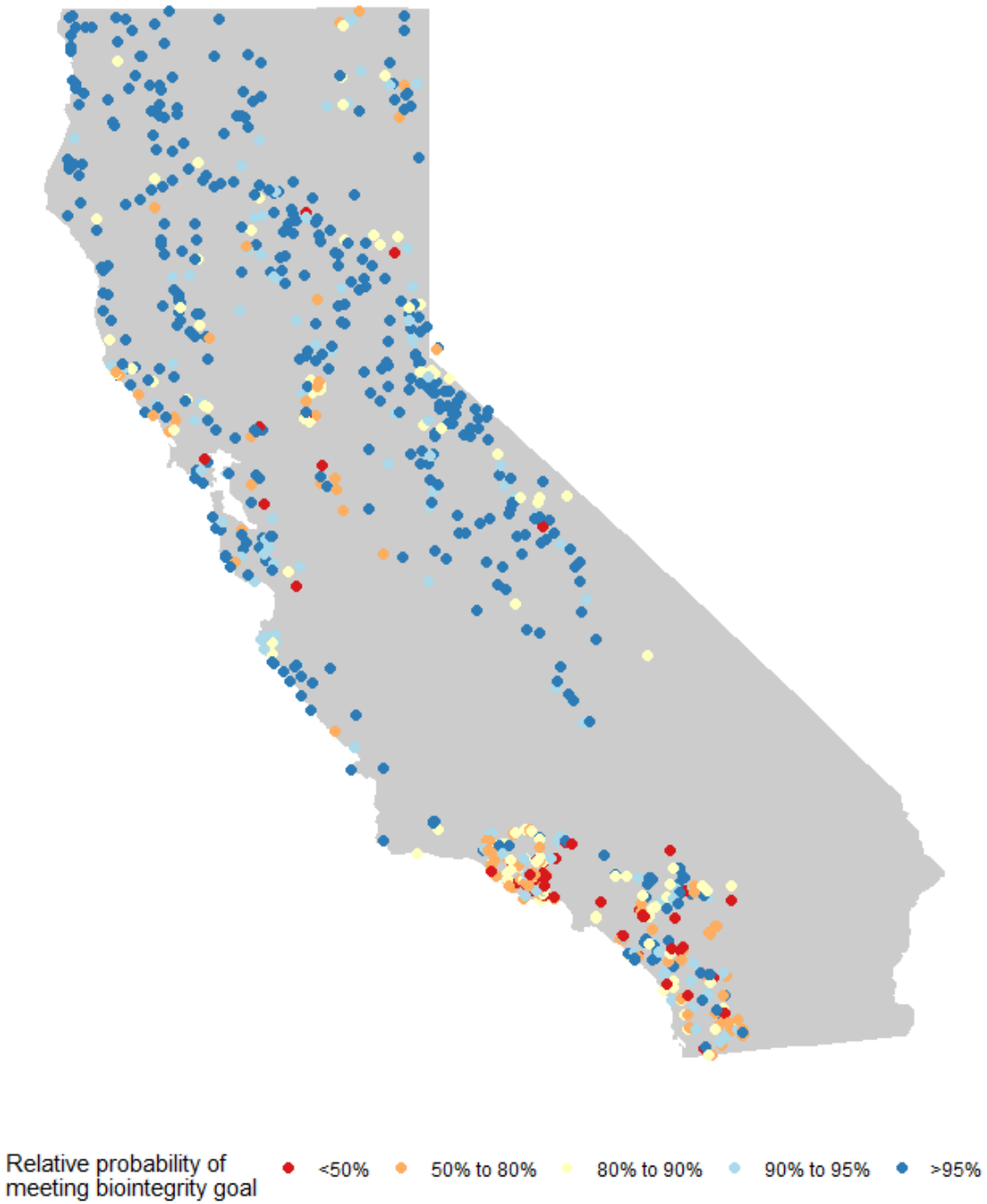
Relative likelihood of meeting Ref10 goal based on Total P



Relative likelihood of meeting Ref10 goal based on Chlorophyll-a



Relative likelihood of meeting Ref10 goal based on Ash-Free Dry Mass



Relative likelihood of meeting Ref10 goal based on % cover