Calculating and Mapping Stream Biological Health

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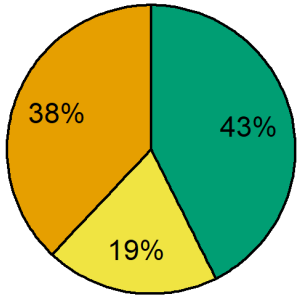
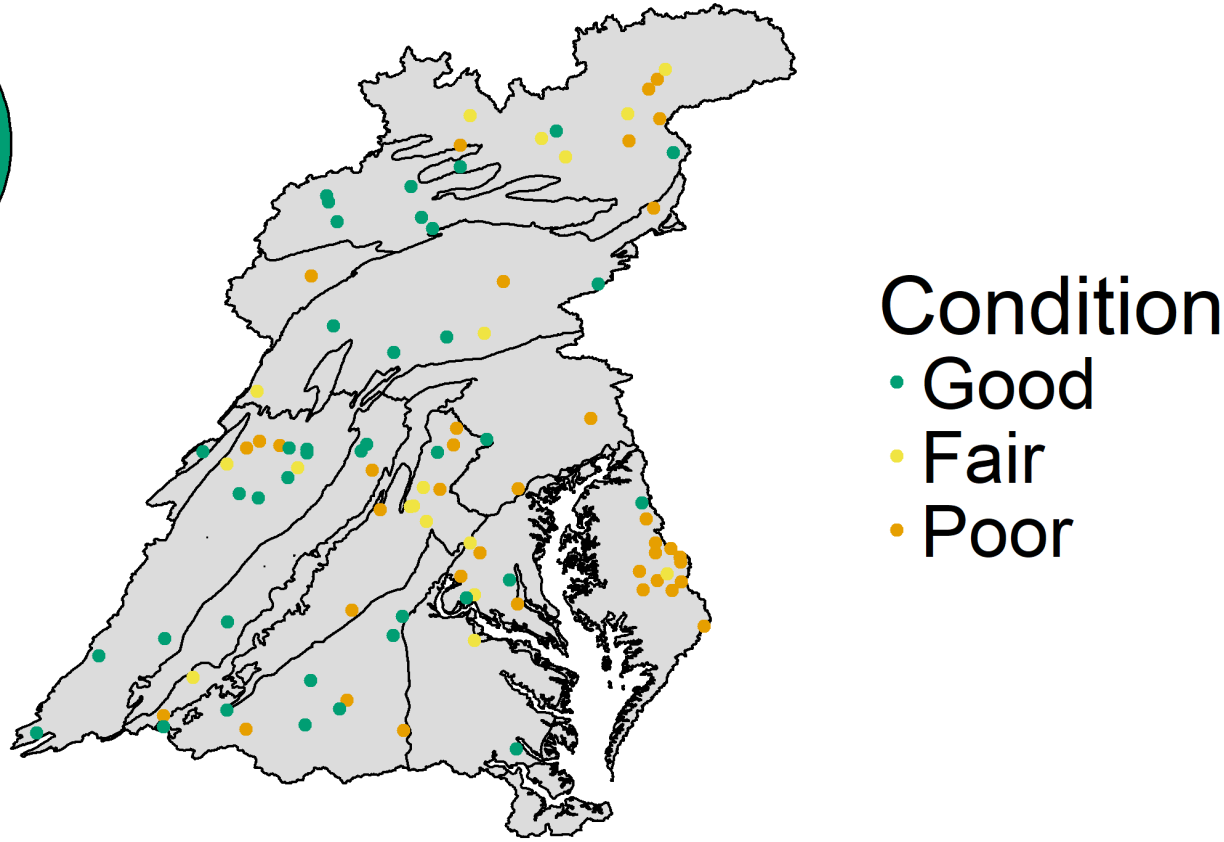
Ideal Scenario

- One sampling design across all jurisdictions
  - Samples collected using the same protocol
  - Samples randomly distributed across the basin
  - Clearly defined sampling periods for trend analysis

National River and Stream Assessment (NRSA)



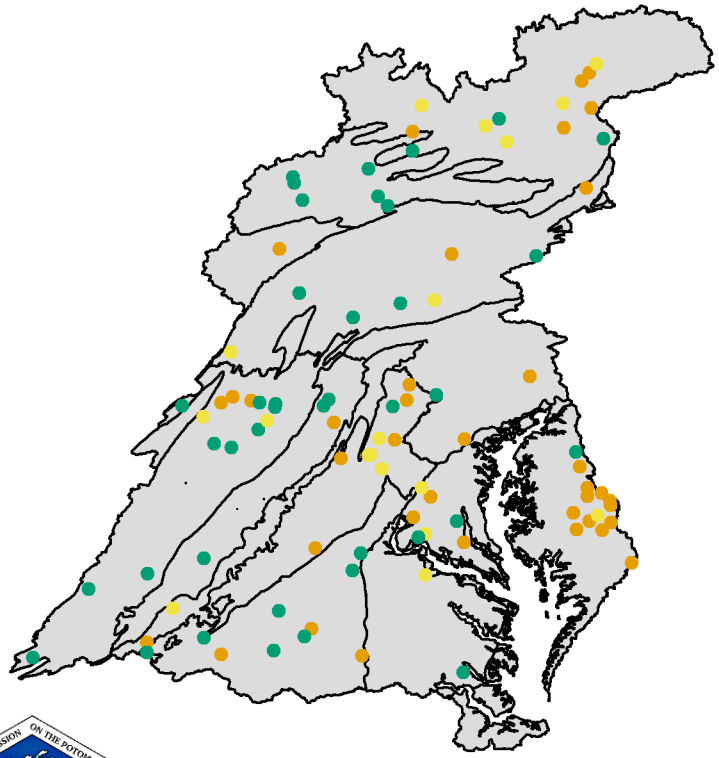


2008-2009

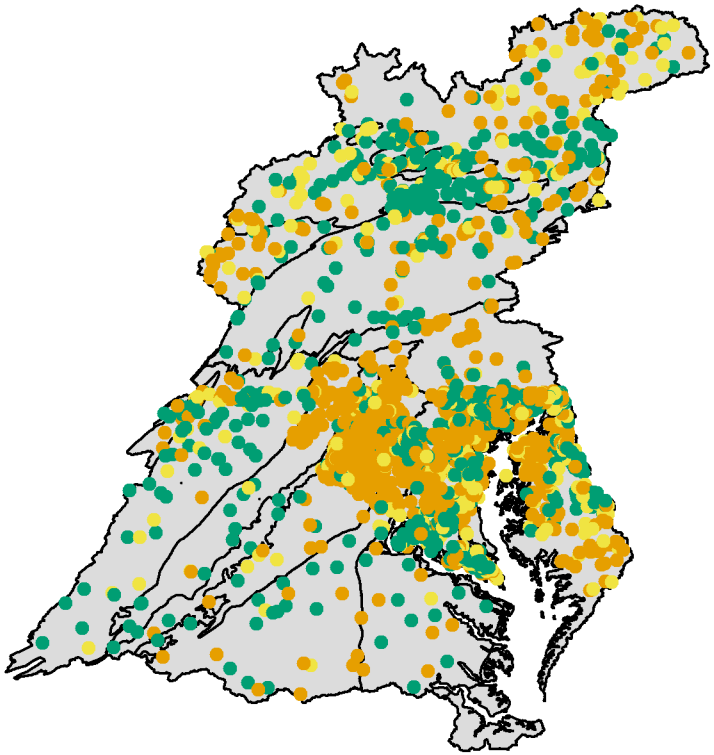
U.S. Environmental Protection Agency. Office of Water and Office of Research and Development. National Rivers and Streams Assessment 2008-2009: A Collaborative Survey (EPA/841/R-16/007). Washington, DC. March 2016. http://www.epa.gov/national-aquatic-resource-surveys/nrsa

NRSA vs. Chessie BIBI

n = 108



n = 2809



Ideal Scenario

- ~~One sampling design across all jurisdictions~~
  - ~~Samples collected using the same protocol~~
  - ~~Samples randomly distributed across the basin~~
  - ~~Clearly defined sampling periods for trend analysis~~

Can we work backwards?

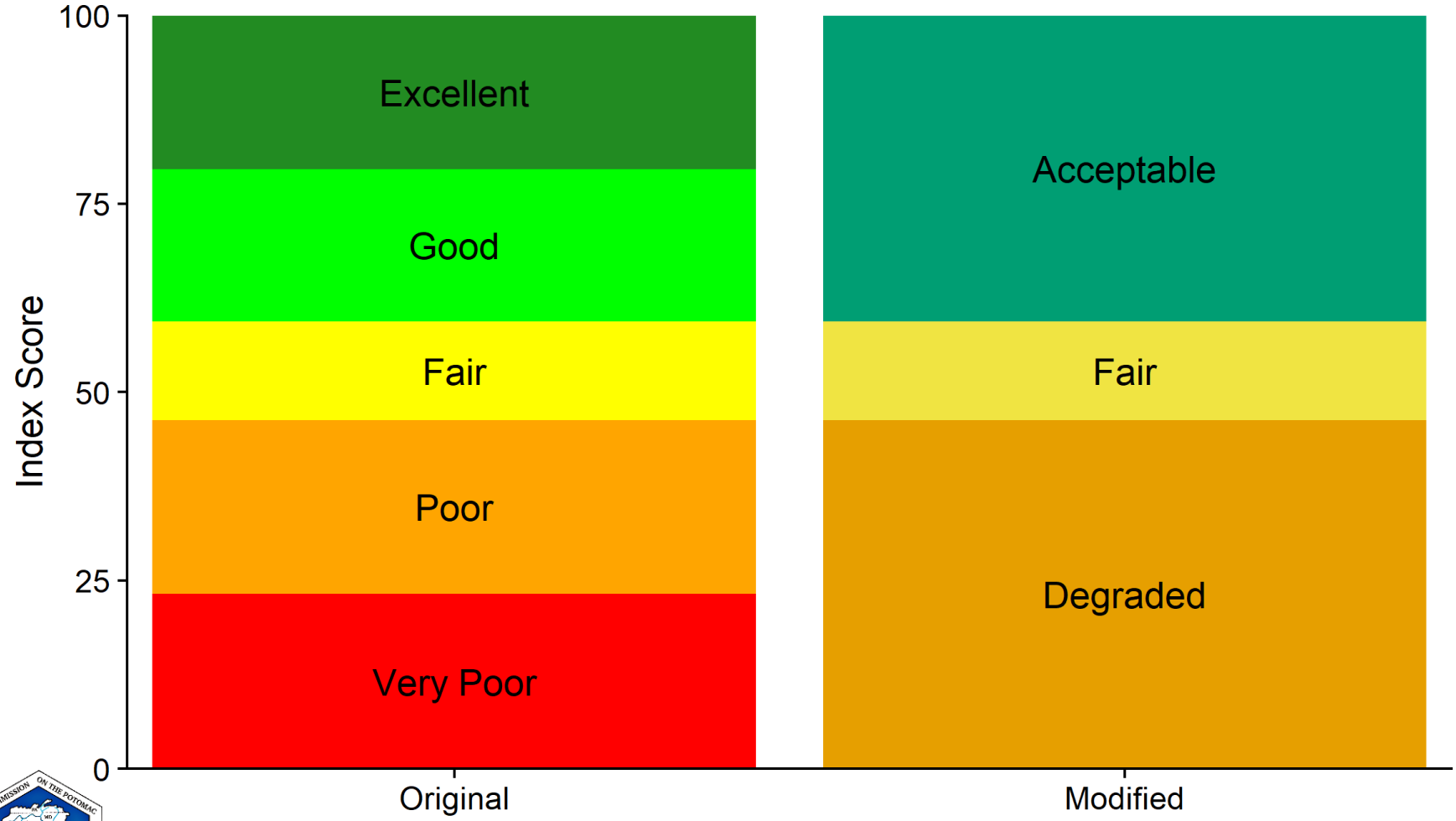
Issues to Keep in Mind

- How to equate a Chessie BIBI rating to stream miles
  - One sampling event equals X amount of miles?
  - Aggregate by a spatial unit (e.g., HUC 12) and use sampling events within a spatial unit cell to represent all stream miles within that spatial unit cell?
- Spatial and Temporal Influence
  - Sampling density and frequency (Sampling Rounds)
  - The amalgamation of two or more random sampling designs does **NOT** equate to a single random sampling design
  - Stream access, generally, leads to a larger proportion of streams sampled in urban areas
  - 2000-2008 vs. 2004-2008 baseline periods (Other Suggestions?)
- Index Resolution
  - Region indices vs. Bioregion indices

Six Methods

1. No Spatial Aggregation
2. Watershed Mean Score
3. Ratings Weighted by Stream Mile
4. Random Sample
5. Bootstrap
6. Random Forest

Modified Ratings

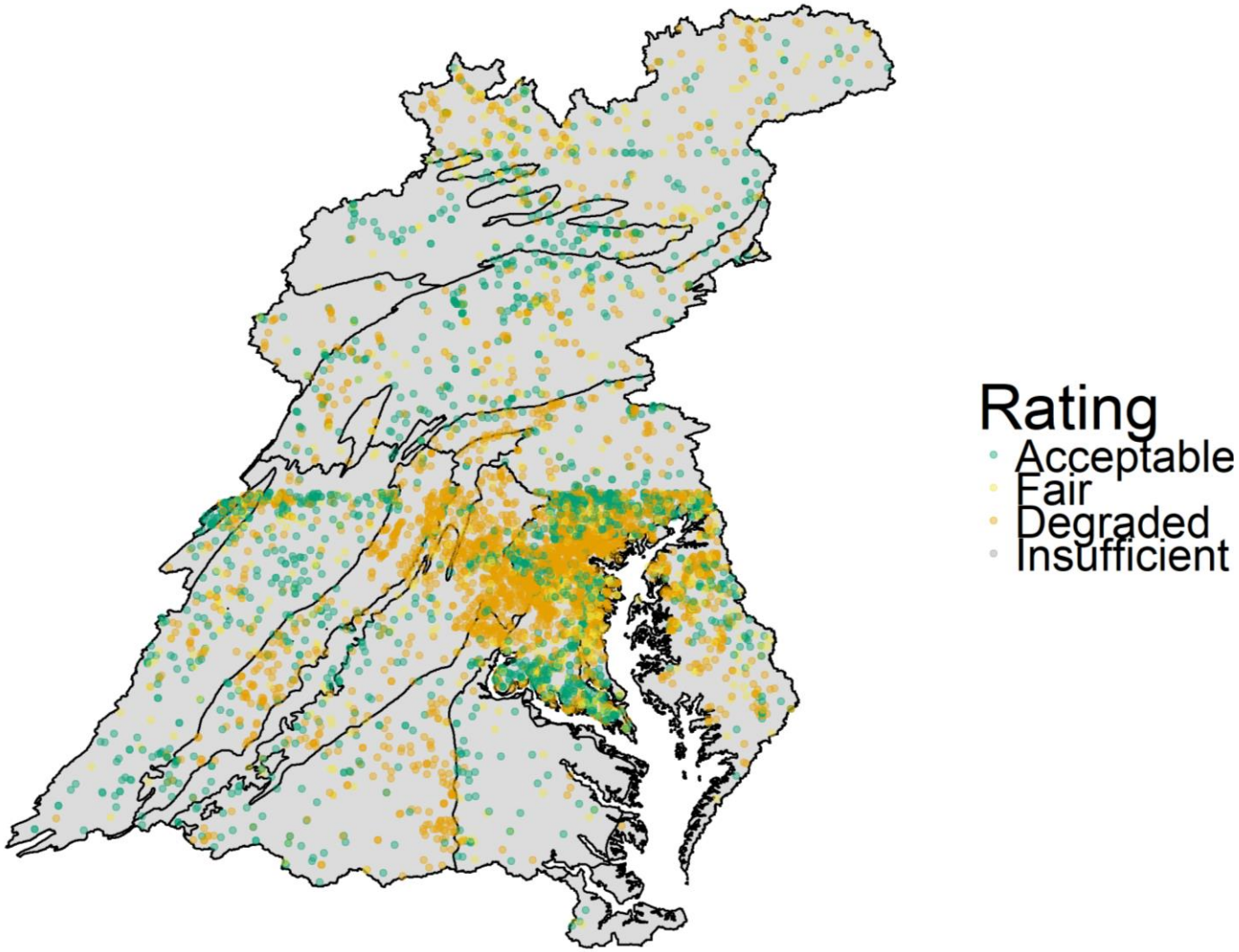


1) No Spatial Aggregation

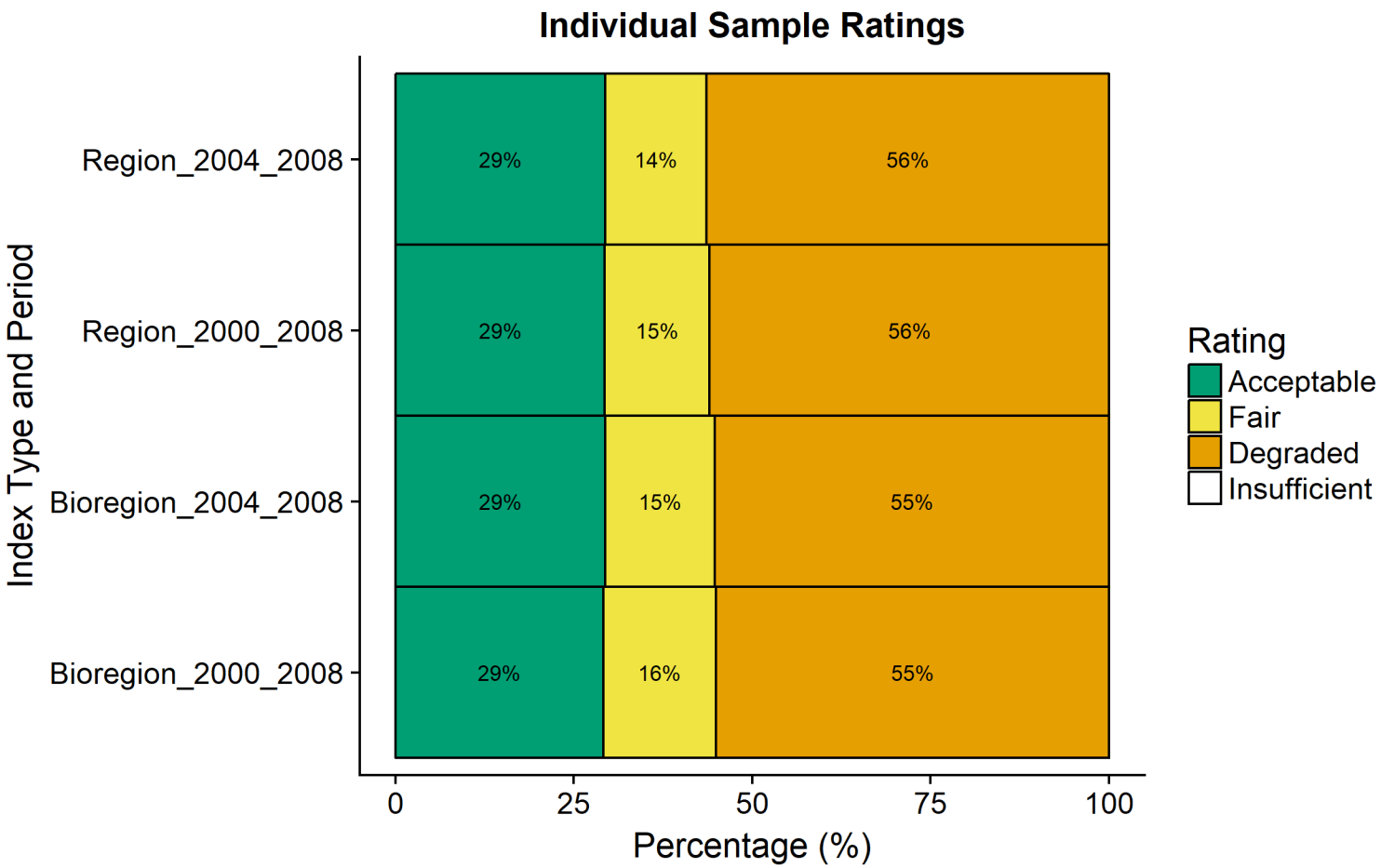
Process

1. The proportion of Acceptable, Fair, and Degraded sampling events found in the basin

1) No Spatial Aggregation



1) No Spatial Aggregation



1) No Spatial Aggregation

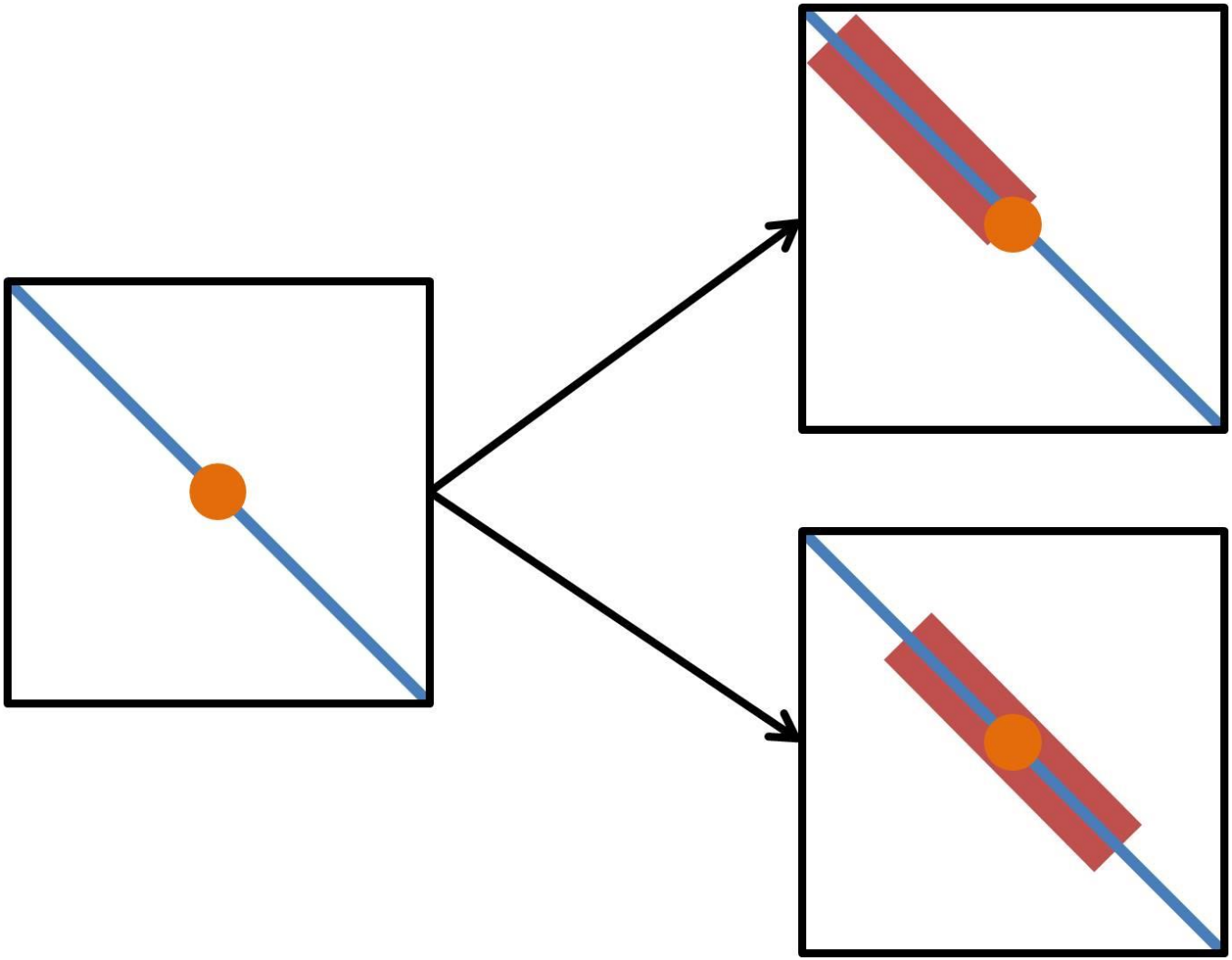
Pros

- Simplest approach (CBP Method)

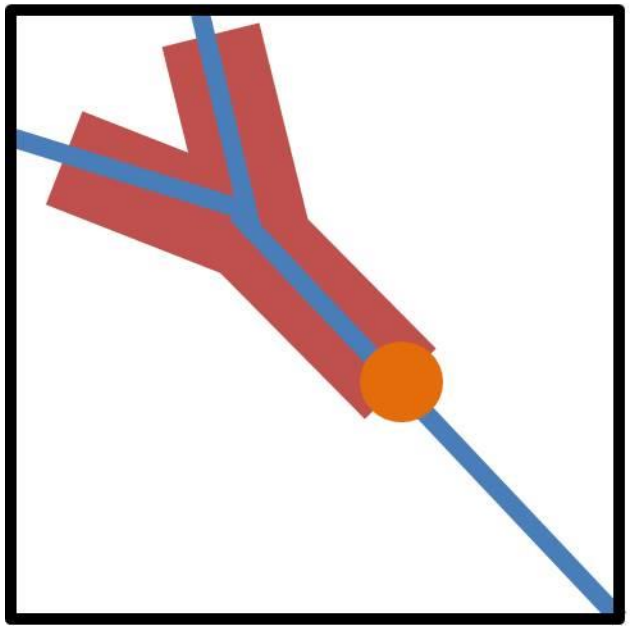
Cons

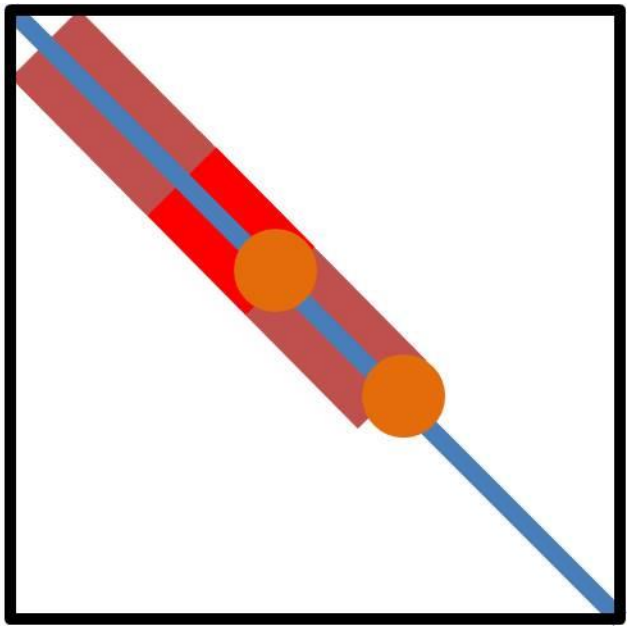
- Spatial bias
  - Frequency and density of samples
- How to convert to stream mile units?
  - Should each point represent one stream mile?
  - Should stream order influence the number of stream miles represented by a point?
  - If the data is mapped, should the representative stream miles be drawn above the sampling point or be split by the sampling point?

1) No Spatial Aggregation

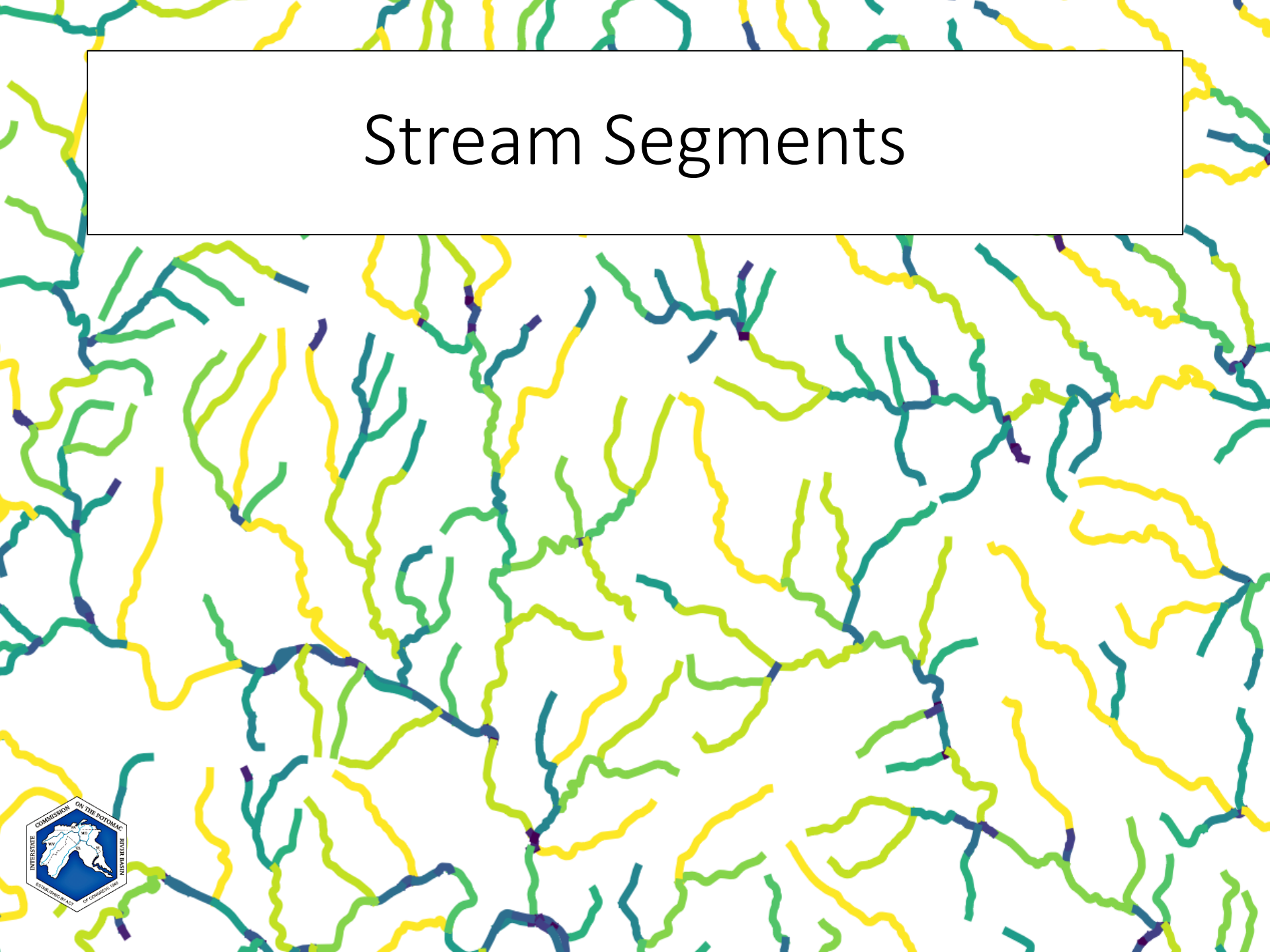


1) No Spatial Aggregation





Stream Segments

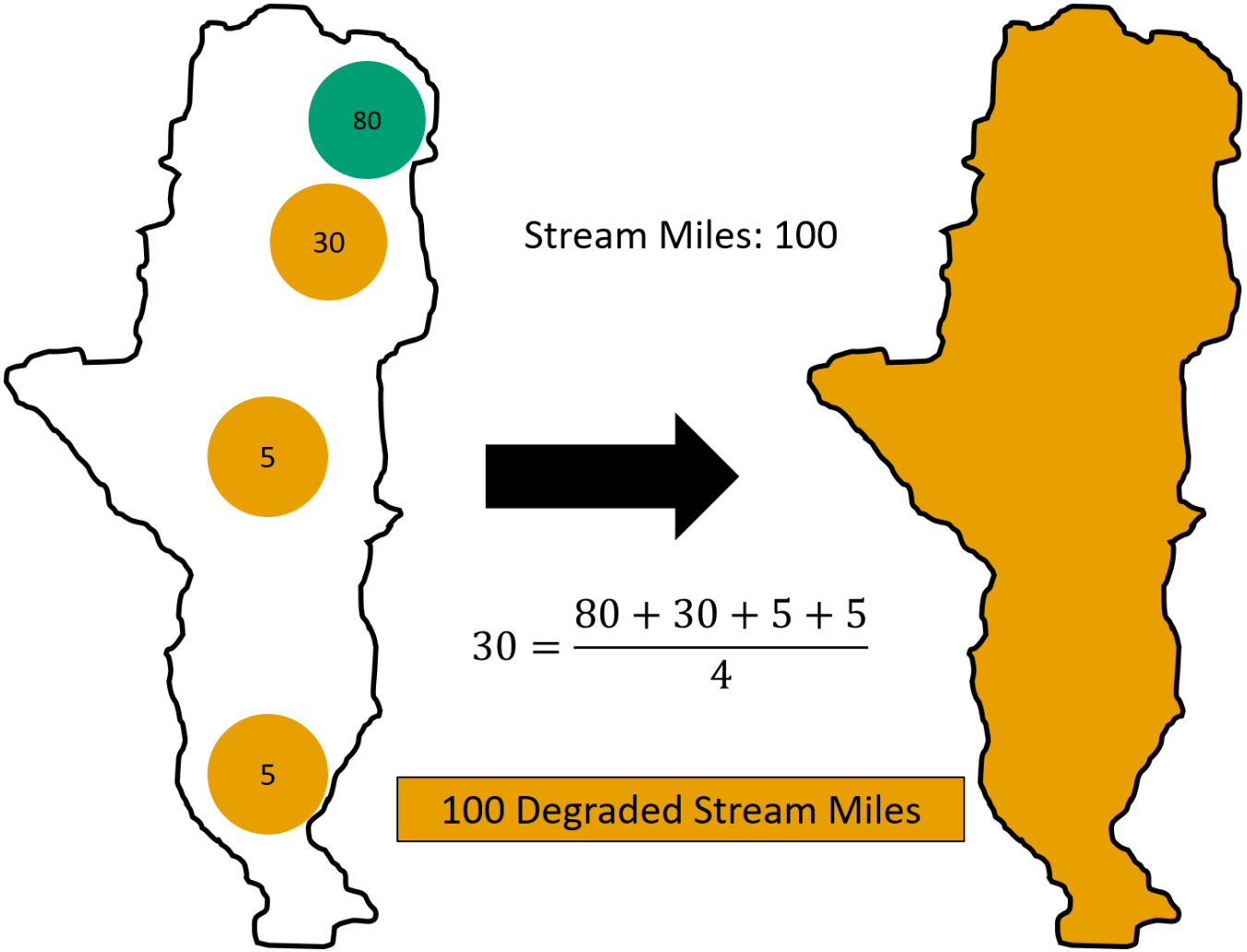


2) Watershed Mean Score

Process

1) Chessie BIBI results are aggregated by a spatial unit (HUC8, HUC10, HUC12, or Catchment)
   - Any spatial unit cells without the appropriate number samples are classified as "Insufficient"
2) The number of stream miles is found for each spatial unit cell
3) The number of stream miles in a spatial unit cell is divided by the number of Chessie BIBI samples reported in the cell
4) Chessie BIBI ratings are weighted by the divided number of stream miles in a spatial unit cell
5) Stream miles are summed by Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level

2) Watershed Mean Score



$$30 = \frac{80 + 30 + 5 + 5}{4}$$

2) Watershed Mean Score

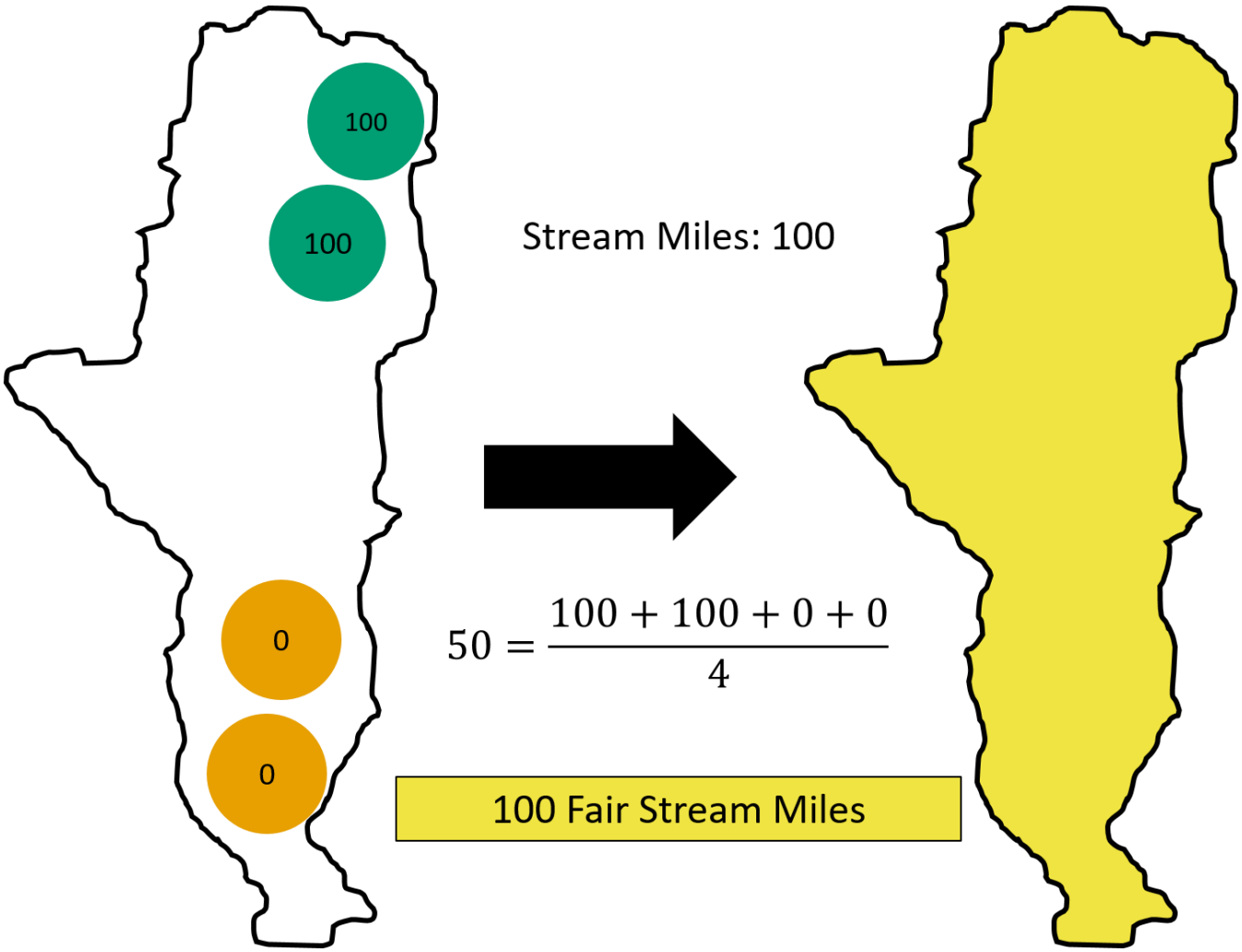
Pros

- Simple calculation
- Can be mapped

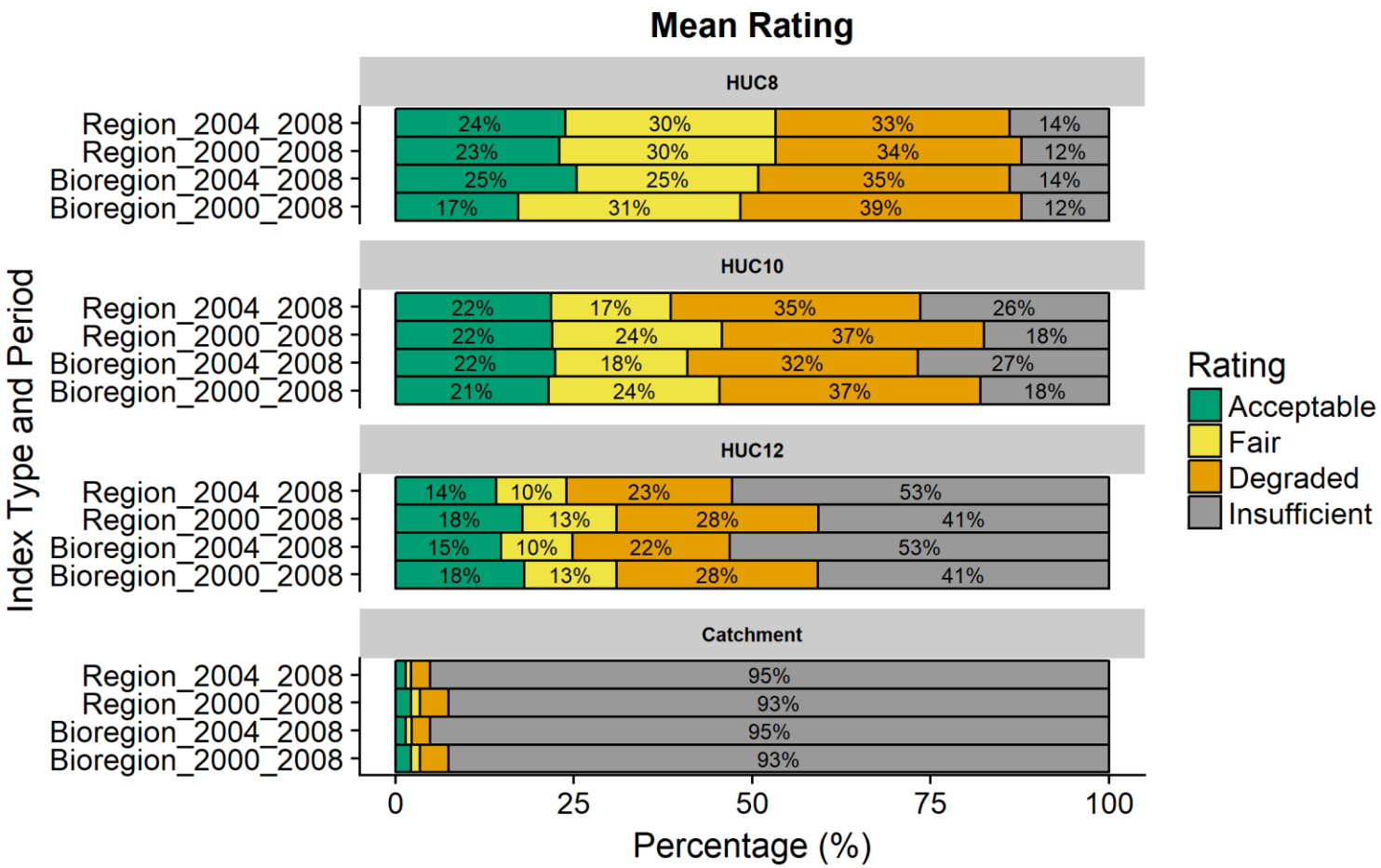
Cons

- Differing sample weights
- Altered ratings
  - Large spatial units tend to be classified as "Fair"

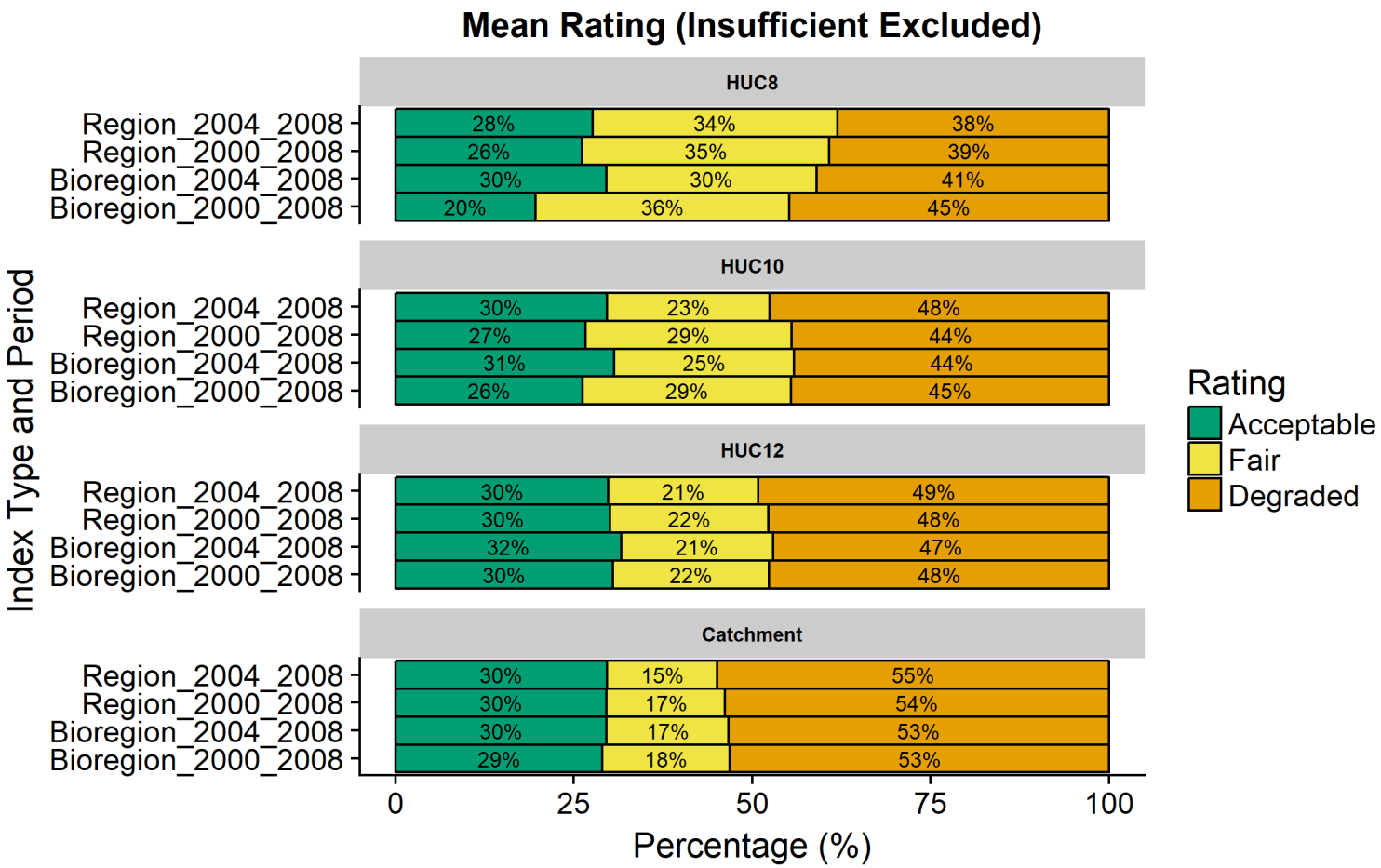
2) Watershed Mean Score



2) Watershed Mean Score



2) Watershed Mean Score

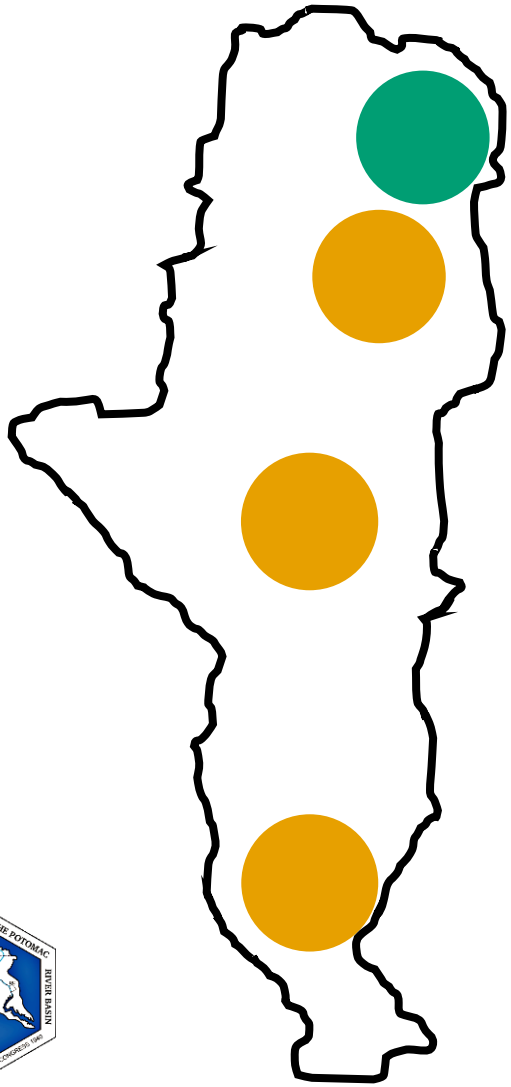


3) Proportional Watershed Rating

Process

1) Chessie BIBI results are aggregated by a spatial unit (HUC8, HUC10, HUC12, or catchment)
   - Any spatial unit cells without the appropriate number samples are classified as "Insufficient"
2) Find the number of stream miles represented in each spatial unit cell
3) Divide the number of stream miles in a spatial unit cell by the number of Chessie BIBI samples reported in the cell
4) Use the divided stream miles as a weighting factor for each Chessie BIBI sample rating
5) Summarize the proportion of stream miles representing Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level

3) Proportional Watershed Rating



Stream Miles: 100

25 Acceptable Stream Miles
25 Degraded Stream Miles
25 Degraded Stream Miles
25 Degraded Stream Miles

3) Proportional Watershed Rating

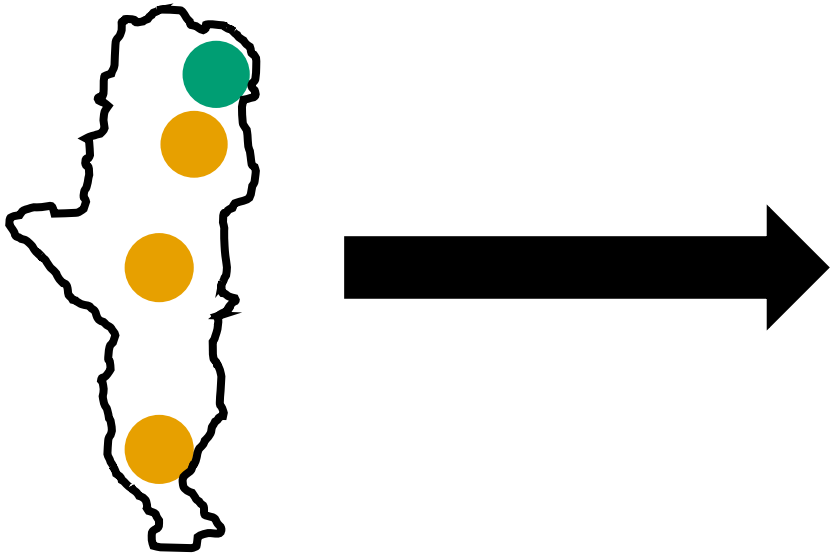
Pros

- Reduces spatial bias
- Representative of original rating

Cons

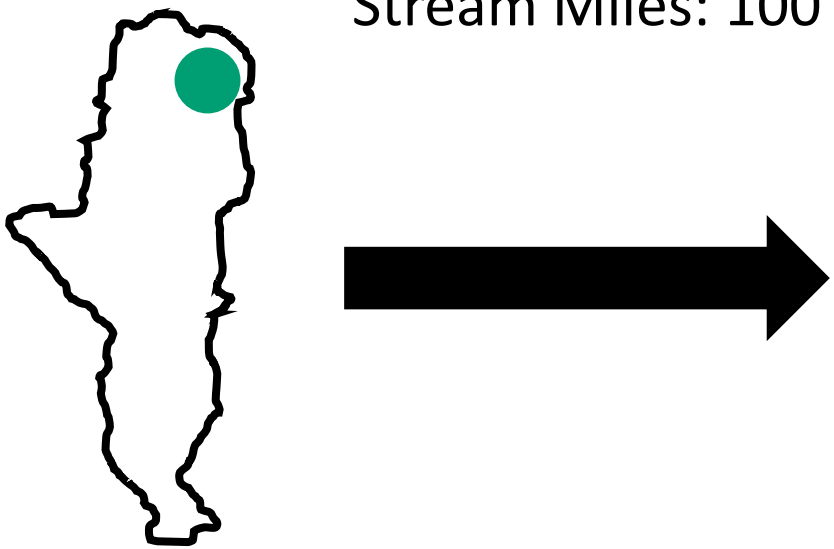
- Differing sample weights
  - Reduces the weight of samples in densely sampled areas
  - Increases the weight of samples in sparsely sampled areas
- Cannot be mapped (assigned weights are arbitrary spatial units)

3) Proportional Watershed Rating



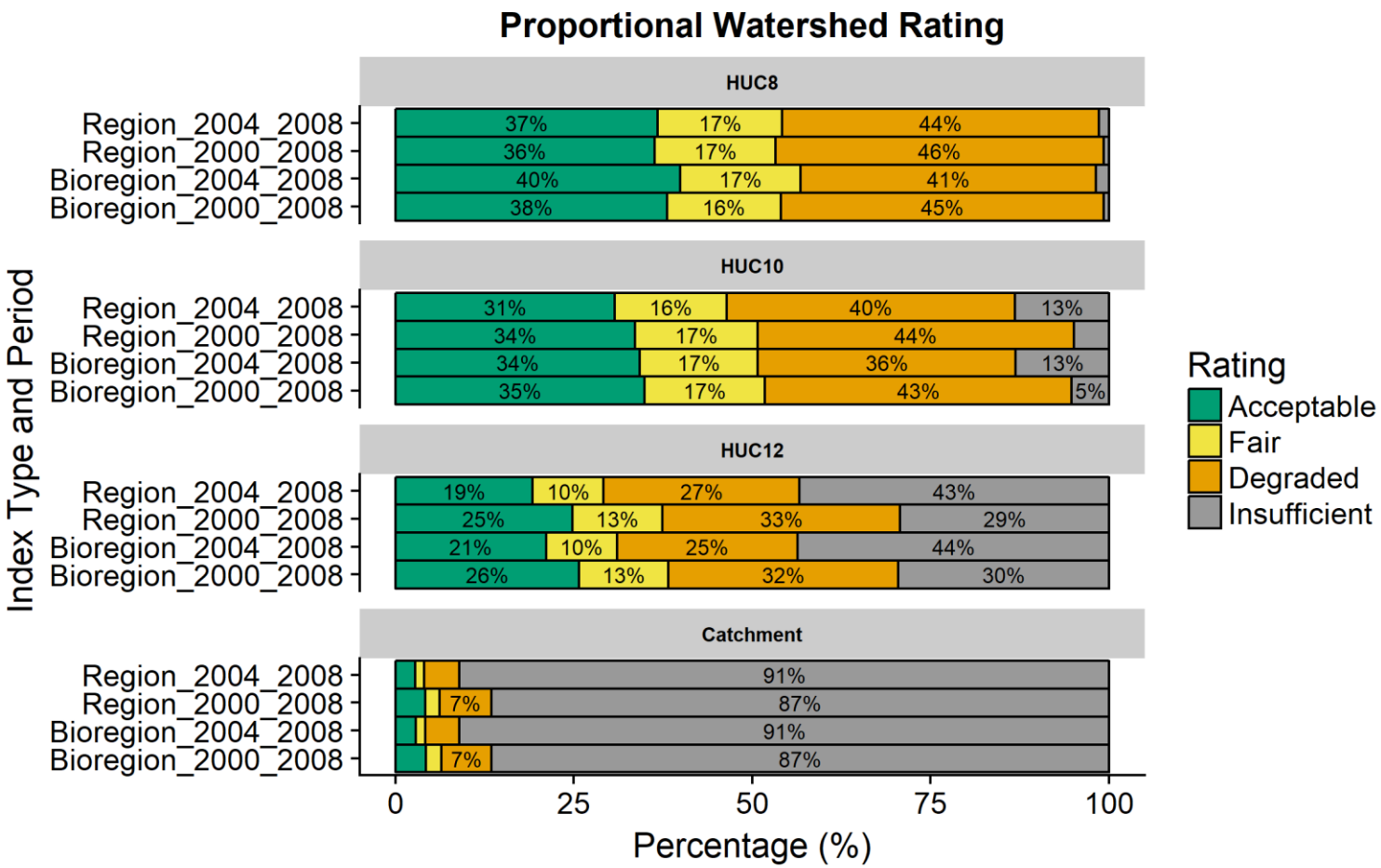
25 Acceptable Stream Miles
25 Degraded Stream Miles
25 Degraded Stream Miles
25 Degraded Stream Miles

Stream Miles: 100

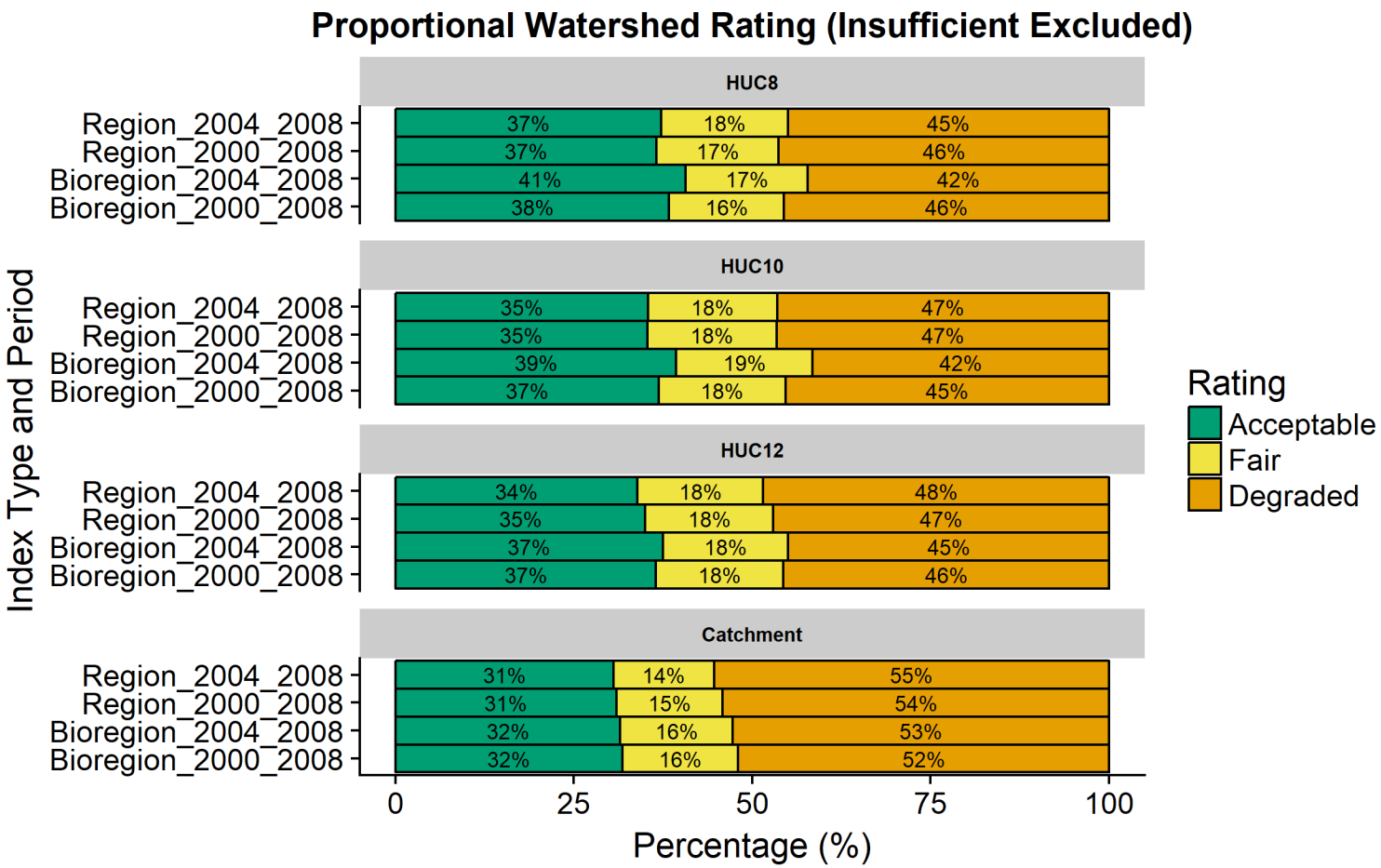


100 Acceptable Stream Miles

3) Proportional Watershed Rating



3) Proportional Watershed Rating

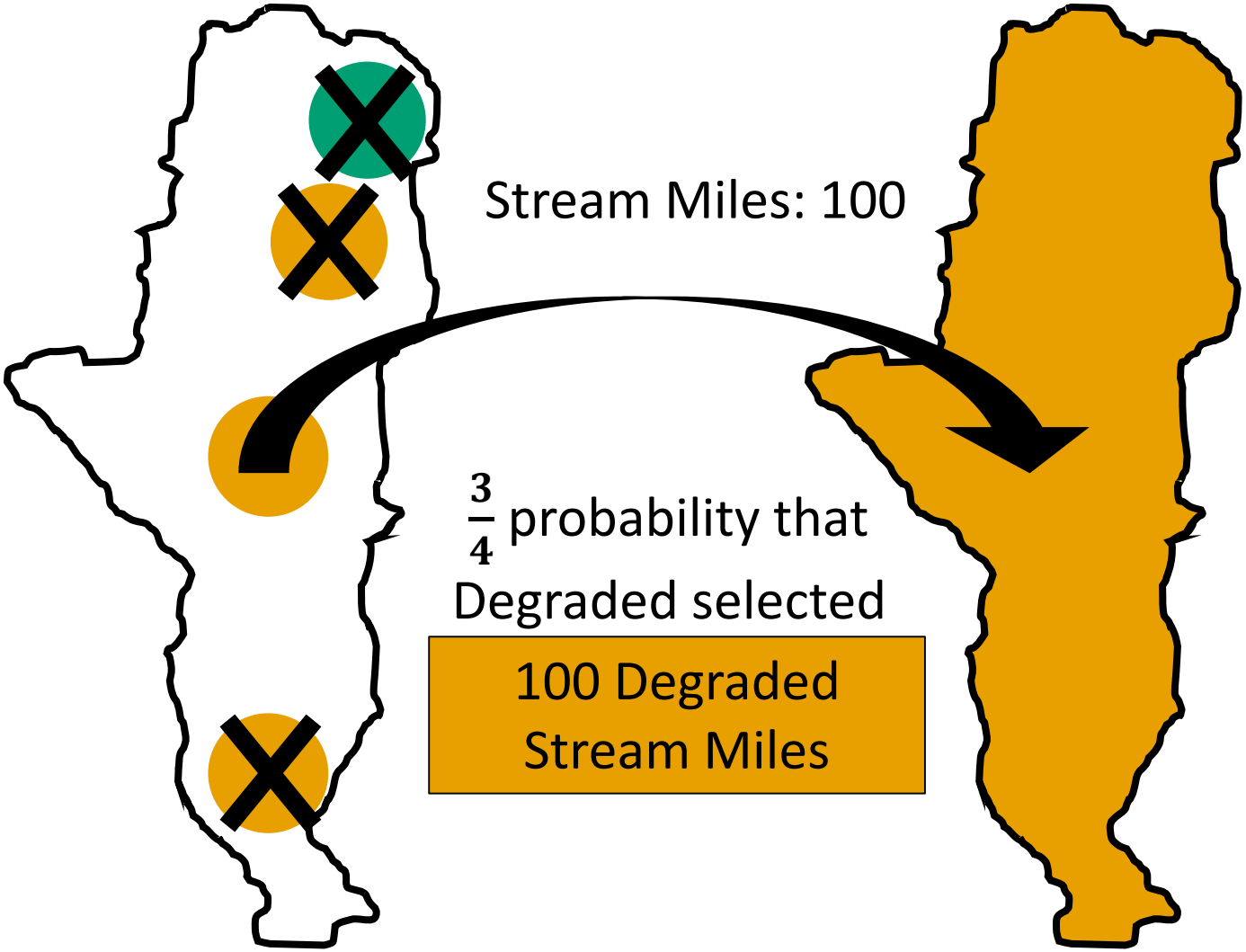


4) Random Sample

Process

1) Chessie BIBI results are aggregated by a spatial unit (HUC8, HUC10, HUC12, or catchment)
   - Any spatial unit cells without the appropriate number samples are classified as "Insufficient"
2) A random sample with replacement of spatial units
3) Find the number of stream miles represented in each spatial unit cell
4) The spatial unit cell rating is weighted by the number of stream miles
5) Summarize the proportion of stream miles representing Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level

4) Random Sample



4) Random Sample

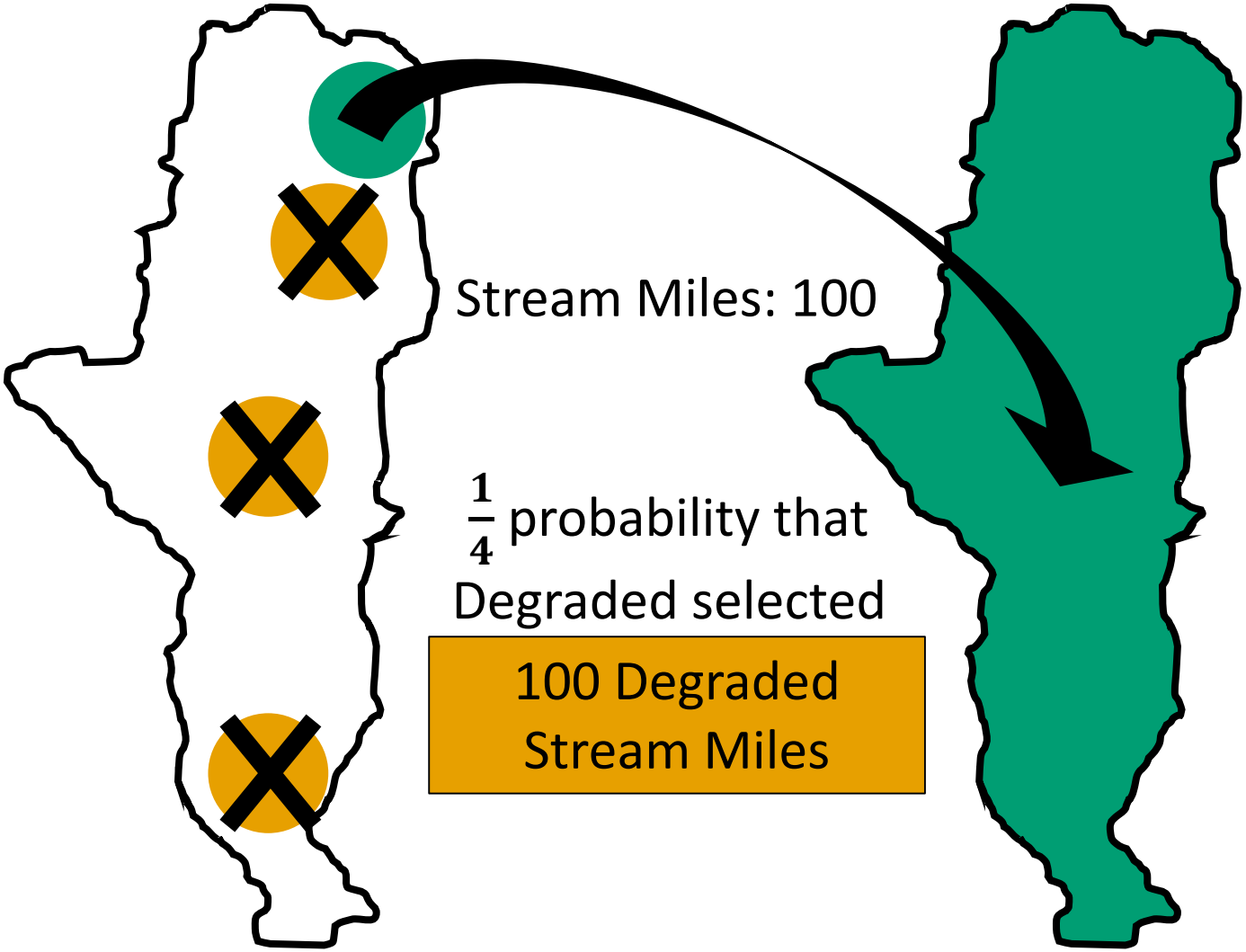
Pros

- Each spatial unit has an equal probability of being selected
- Can be mapped

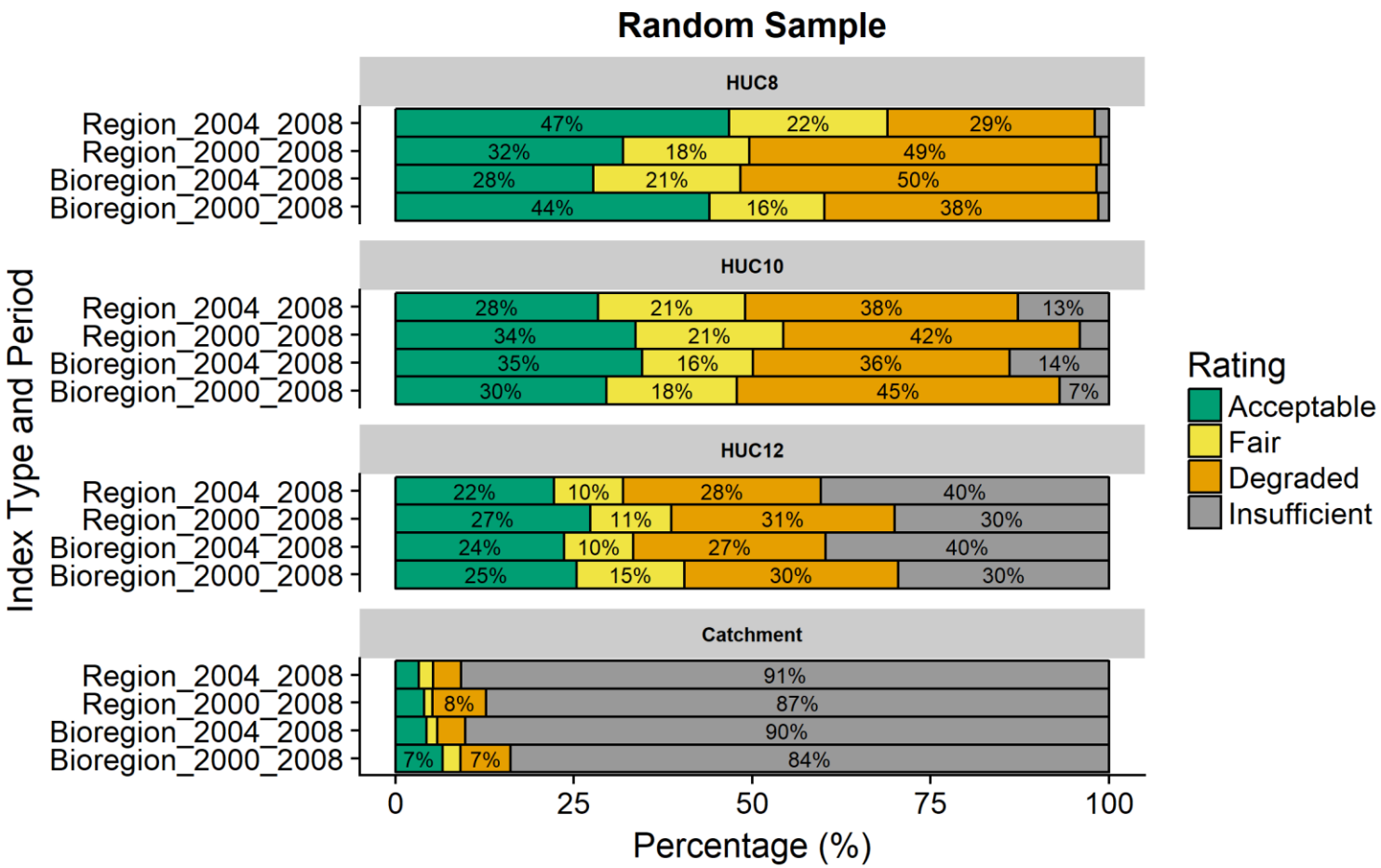
Cons

- Differing sample weights
  - Reduces the weight of samples in densely sampled areas
  - Increases the weight of samples in sparsely sampled areas
- Represented samples (Non-Insufficient)

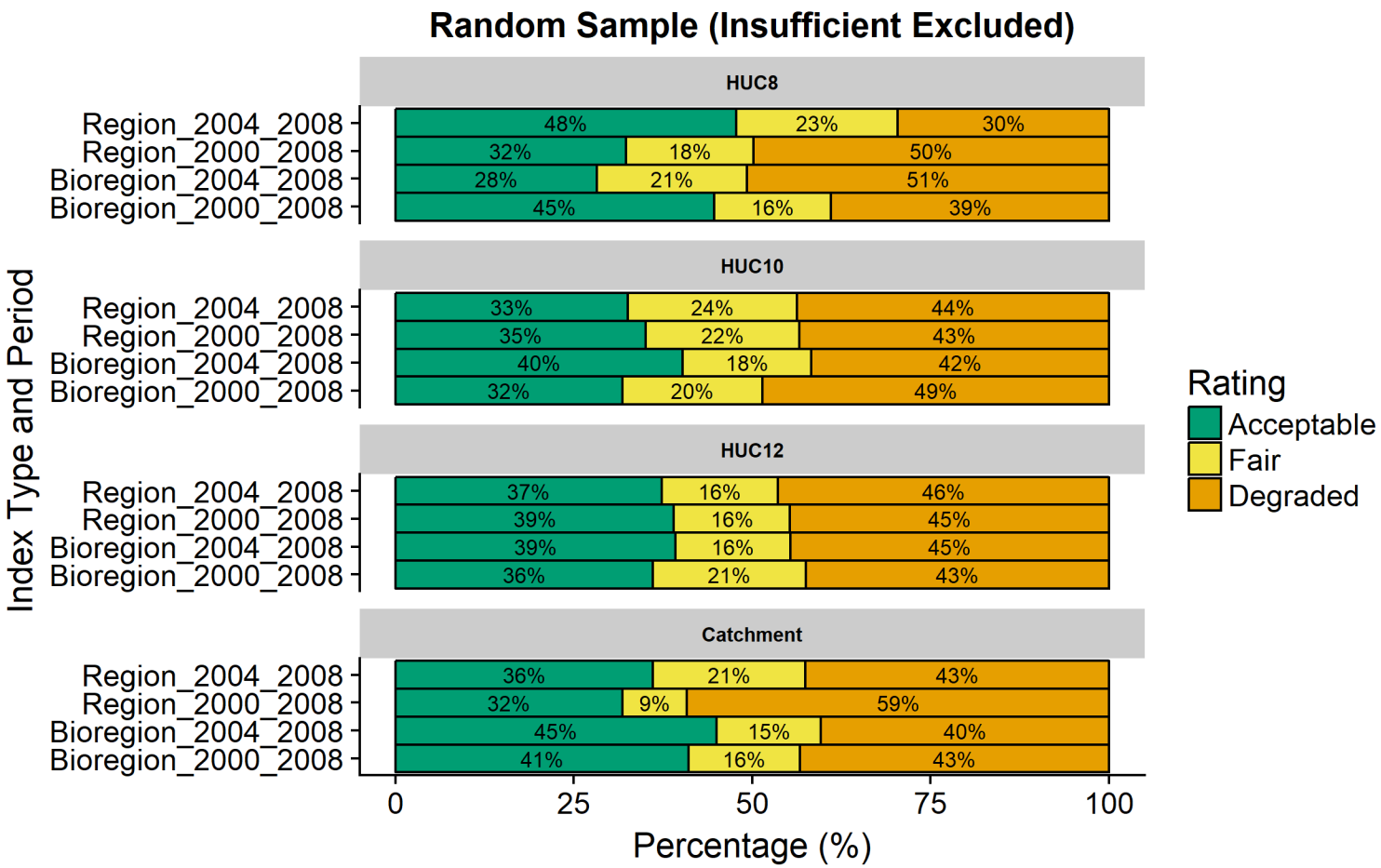
4) Random Sample



4) Random Sample



4) Random Sample

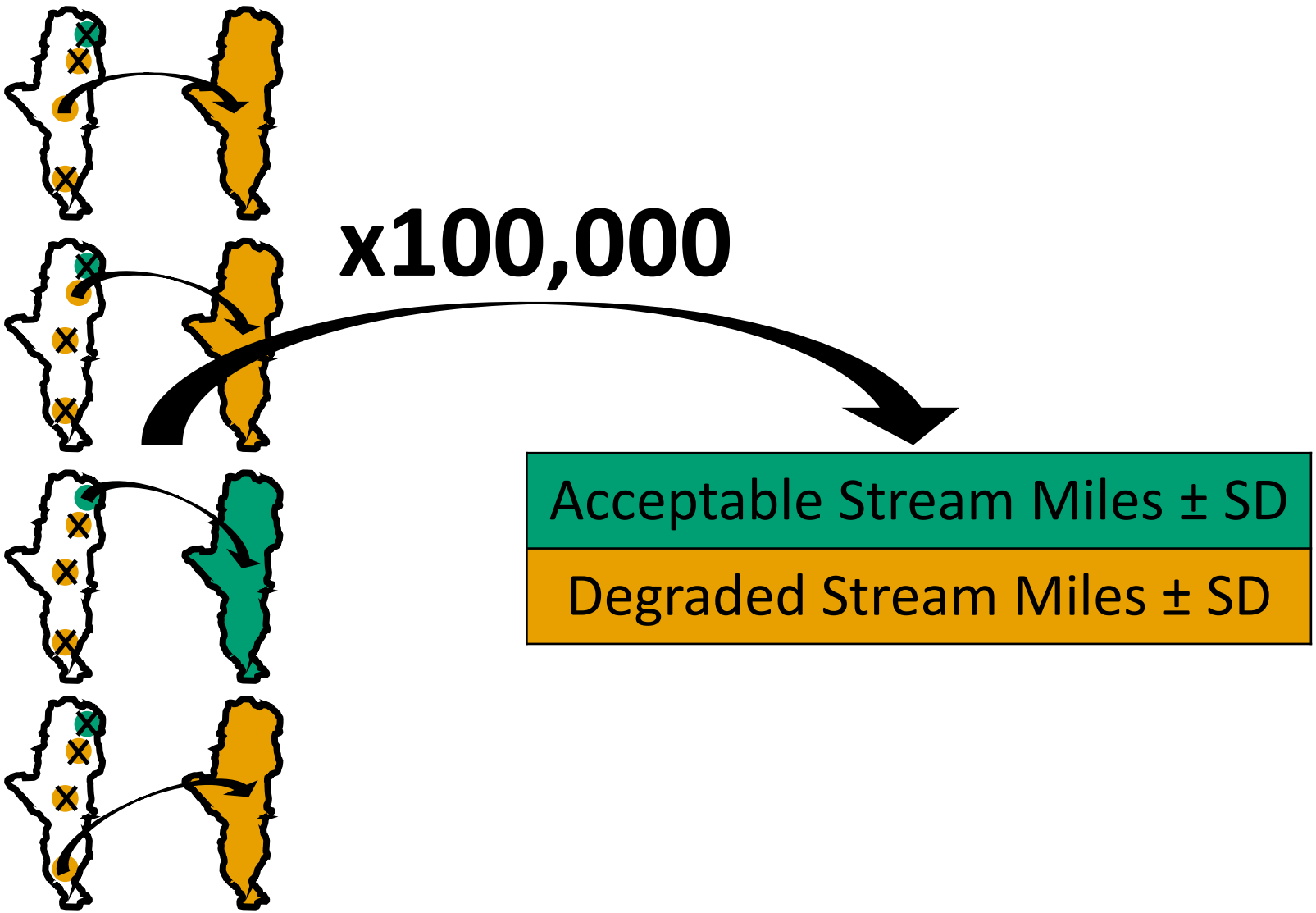


5) Bootstrap

Process

1) Chessie BIBI results are aggregated by a spatial unit (HUC8, HUC10, HUC12, or catchment)
   - Any spatial unit cells without the appropriate number samples are classified as "Insufficient"
2) Iteratively perform a random sample with replacement of spatial units
3) Find the number of stream miles represented in each spatial unit cell
4) For each iteration, spatial unit cell rating is weighted by the number of stream miles
5) For each iteration, summarize the proportion of stream miles representing Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level
6) Find the mean and standard deviation of the proportion of stream miles representing Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level for all iterations

5) Bootstrap


x100,000
Acceptable Stream Miles ± SD
Degraded Stream Miles ± SD

5) Bootstrap

Pros

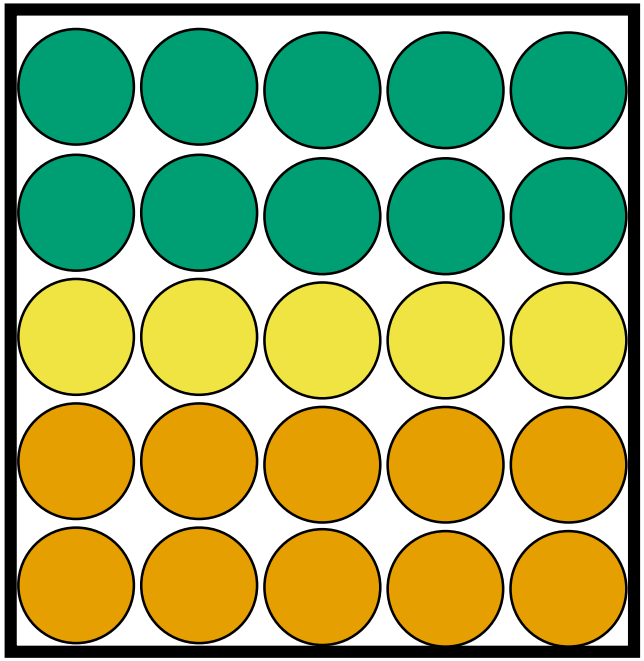
- Each spatial unit has an equal probability of being selected
- Measure of variation around stream condition

Cons

- Differing sample weights
  - Reduces the weight of samples in densely sampled areas
  - Increases the weight of samples in sparsely sampled areas

5) Bootstrap

Reality

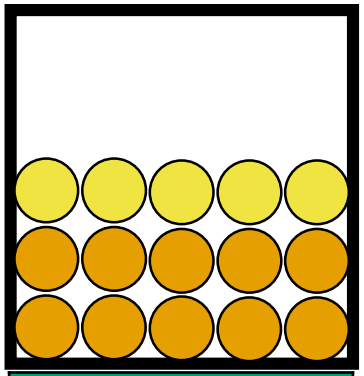


40% Acceptable

20% Fair

40% Degraded

Time Period 1

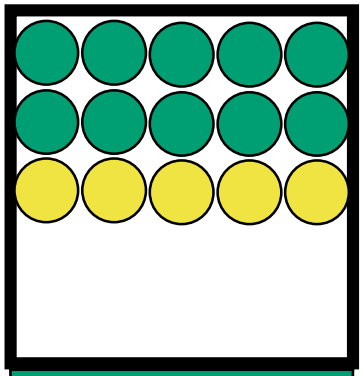


0.0% Acceptable

33.3% Fair

66.7% Degraded

Time Period 2

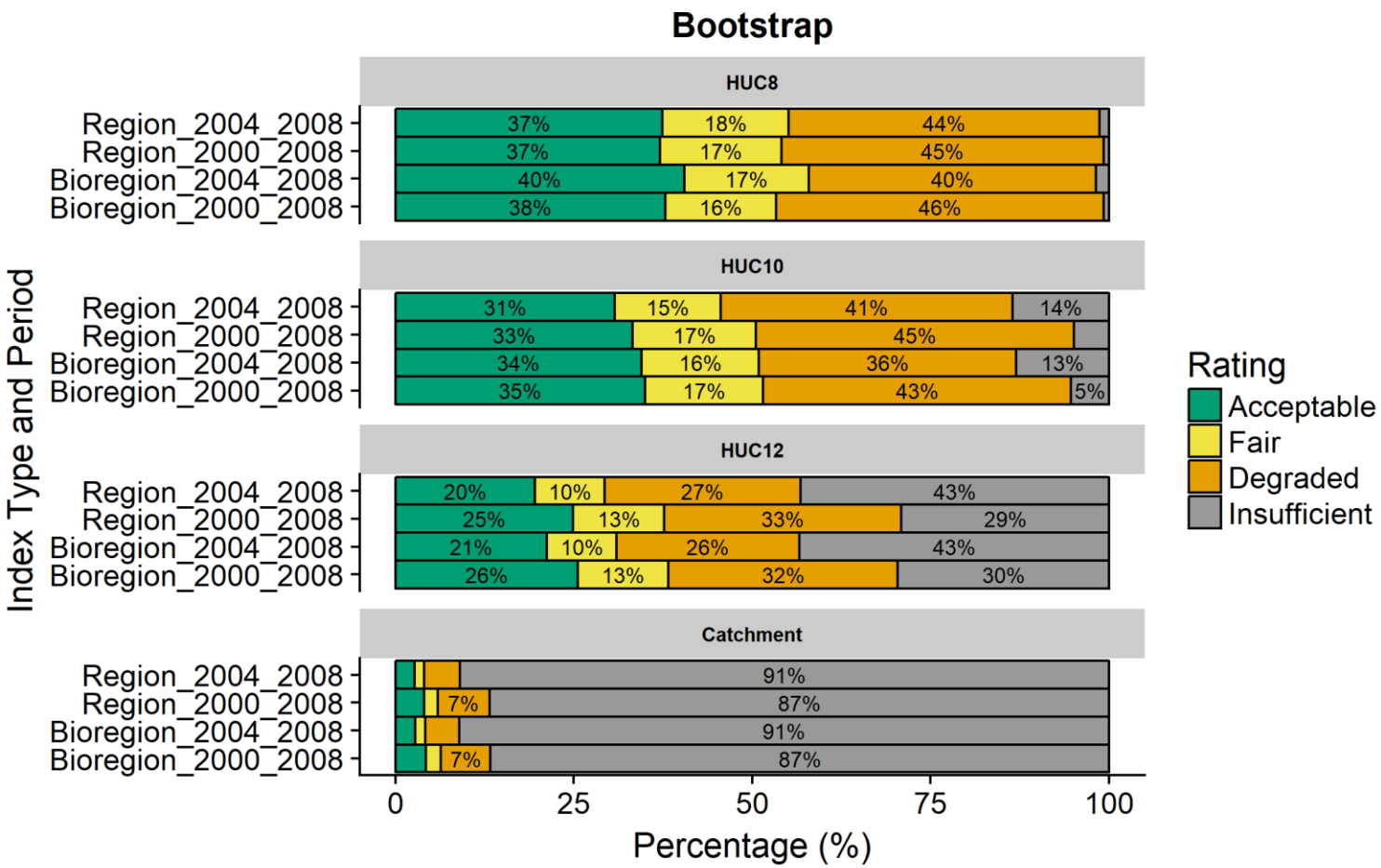


66.7% Acceptable

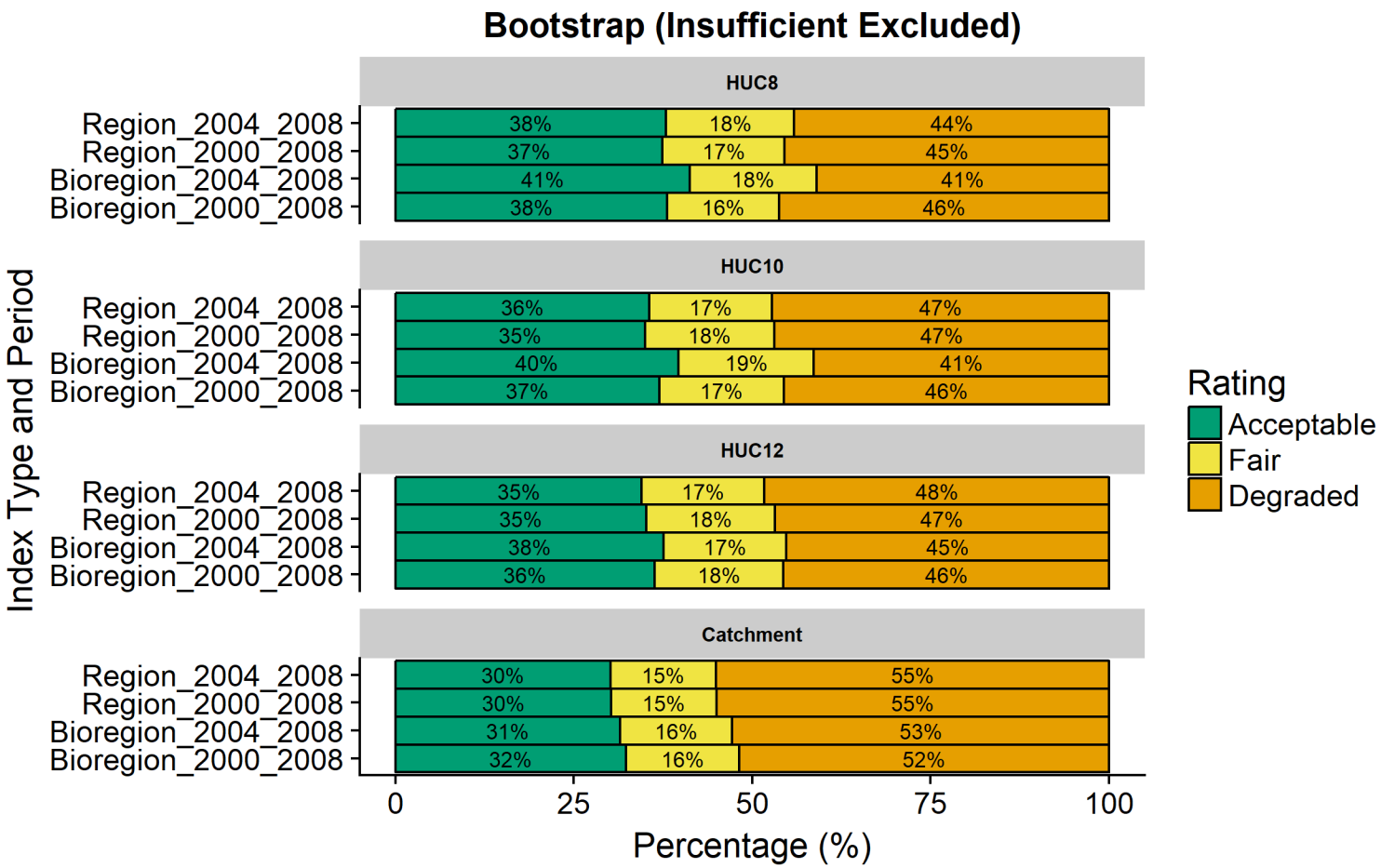
33.3% Fair

0.0% Degraded

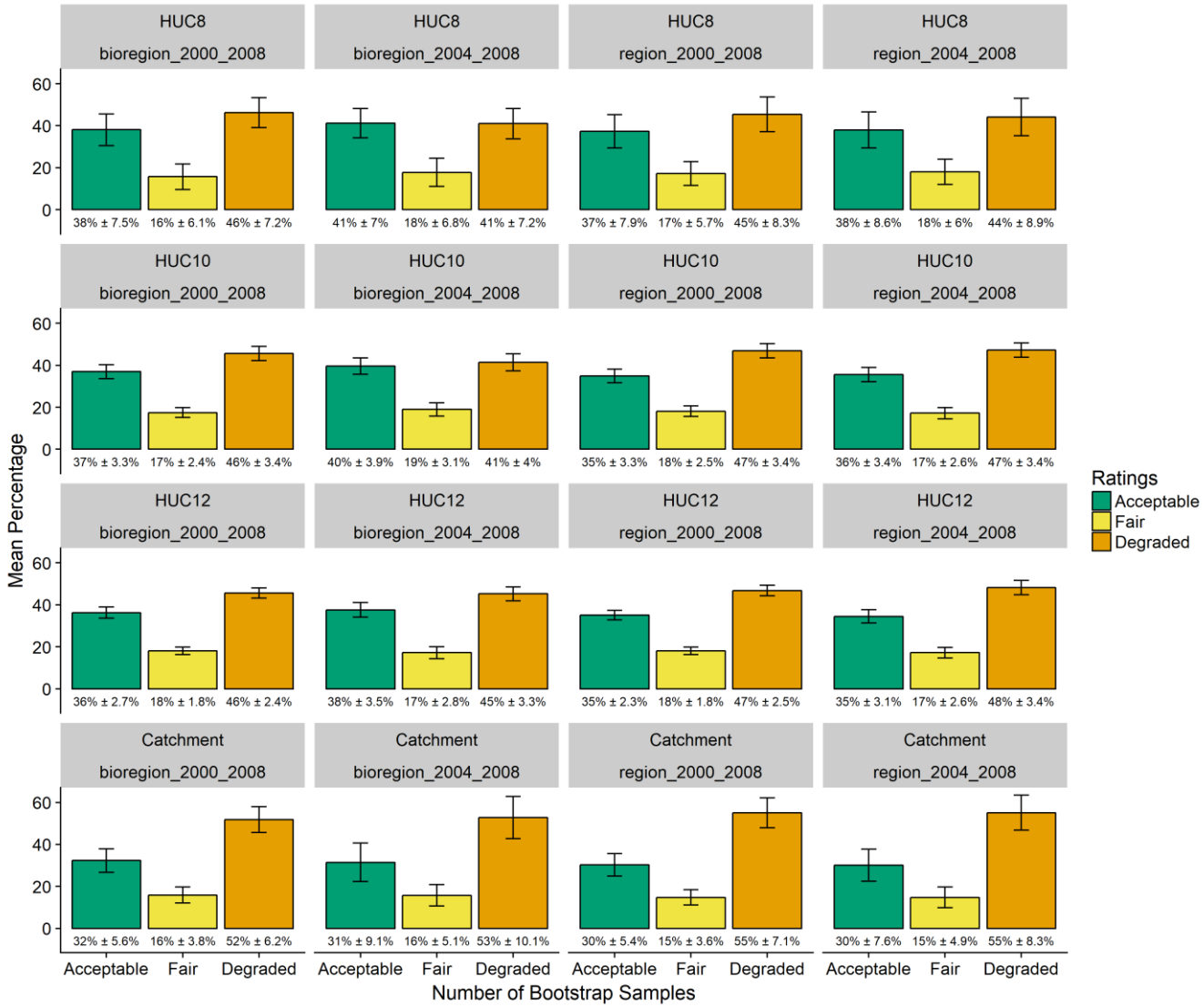
5) Bootstrap


Bootstrap
HUC8
Region_2004_2008
Region_2000_2008
Bioregion_2004_2008
Bioregion_2000_2008
37%
18%
44%
37%
17%
45%
40%
17%
40%
38%
16%
46%
HUC10
31%
15%
41%
14%
33%
17%
45%
34%
16%
36%
13%
35%
17%
43%
5%
HUC12
20%
10%
27%
43%
25%
13%
33%
29%
21%
10%
26%
43%
26%
13%
32%
30%
Catchment
91%
7%
87%
91%
7%
87%
Index Type and Period
0
25
50
75
100
Percentage (%)
Rating
Acceptable
Fair
Degraded
Insufficient

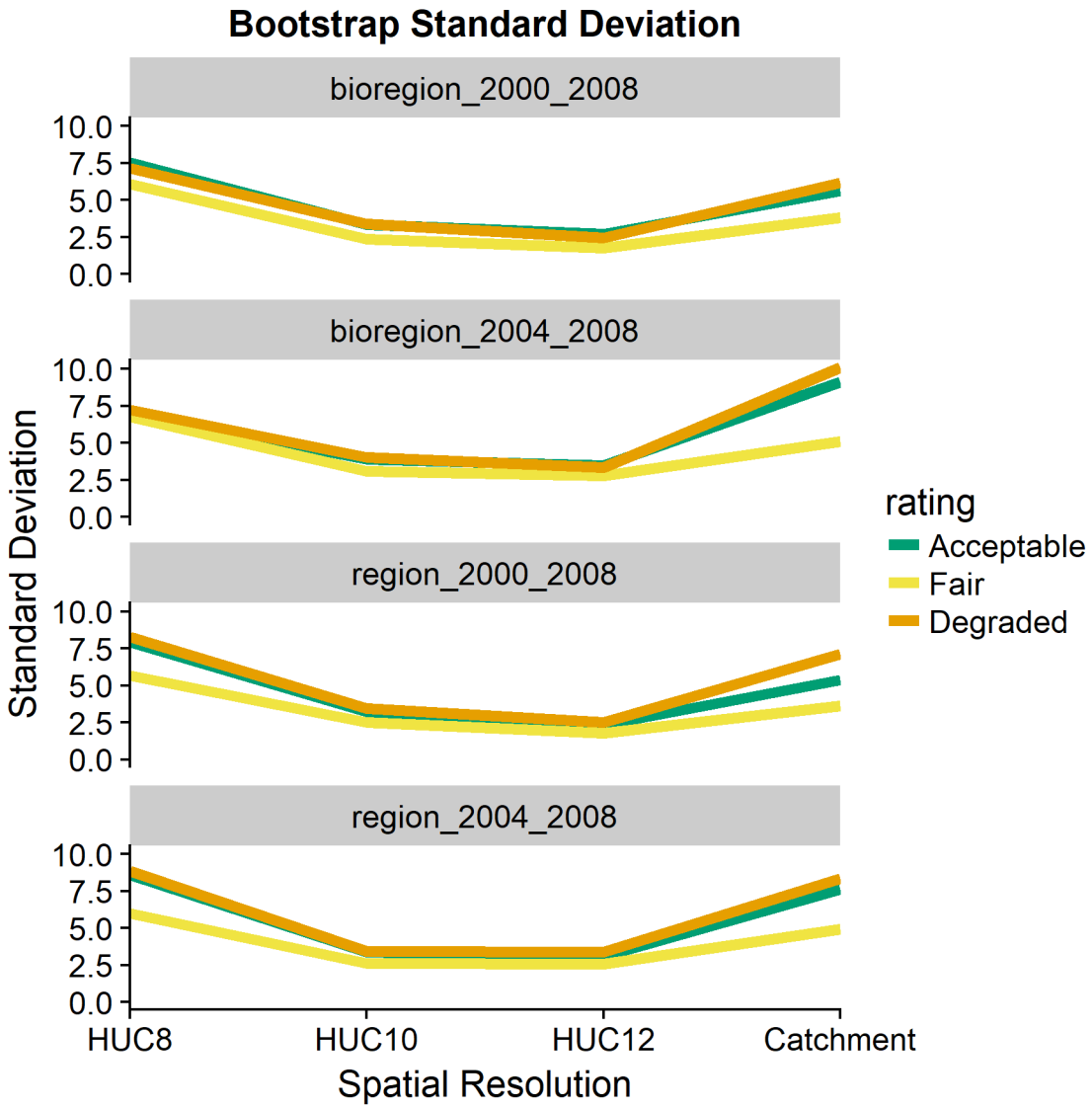
5) Bootstrap


Bootstrap (Insufficient Excluded)
HUC8
Region_2004_2008
Region_2000_2008
Bioregion_2004_2008
Bioregion_2000_2008
38%
18%
44%
37%
17%
45%
41%
18%
41%
38%
16%
46%
HUC10
36%
17%
47%
35%
18%
47%
40%
19%
41%
37%
17%
46%
HUC12
35%
17%
48%
35%
18%
47%
38%
17%
45%
36%
18%
46%
Catchment
30%
15%
55%
30%
15%
55%
31%
16%
53%
32%
16%
52%
Index Type and Period
0
25
50
75
100
Percentage (%)
Rating
Acceptable
Fair
Degraded

5) Bootstrap


HUC8
bioregion_2000_2008
38% ± 7.5%
16% ± 6.1%
46% ± 7.2%
HUC8
bioregion_2004_2008
41% ± 7%
18% ± 6.8%
41% ± 7.2%
HUC8
region_2000_2008
37% ± 7.9%
17% ± 5.7%
45% ± 8.3%
HUC8
region_2004_2008
38% ± 8.6%
18% ± 6%
44% ± 8.9%
HUC10
bioregion_2000_2008
37% ± 3.3%
17% ± 2.4%
46% ± 3.4%
HUC10
bioregion_2004_2008
40% ± 3.9%
19% ± 3.1%
41% ± 4%
HUC10
region_2000_2008
35% ± 3.3%
18% ± 2.5%
47% ± 3.4%
HUC10
region_2004_2008
36% ± 3.4%
17% ± 2.6%
47% ± 3.4%
HUC12
bioregion_2000_2008
36% ± 2.7%
18% ± 1.8%
46% ± 2.4%
HUC12
bioregion_2004_2008
38% ± 3.5%
17% ± 2.8%
45% ± 3.3%
HUC12
region_2000_2008
35% ± 2.3%
18% ± 1.8%
47% ± 2.5%
HUC12
region_2004_2008
35% ± 3.1%
17% ± 2.6%
48% ± 3.4%
Catchment
bioregion_2000_2008
32% ± 5.6%
16% ± 3.8%
52% ± 6.2%
Catchment
bioregion_2004_2008
31% ± 9.1%
16% ± 5.1%
53% ± 10.1%
Catchment
region_2000_2008
30% ± 5.4%
15% ± 3.6%
55% ± 7.1%
Catchment
region_2004_2008
30% ± 7.6%
15% ± 4.9%
55% ± 8.3%
Mean Percentage
0
20
40
60
Acceptable
Fair
Degraded
Number of Bootstrap Samples
Ratings
Acceptable
Fair
Degraded

5) Bootstrap


Bootstrap Standard Deviation
bioregion_2000_2008
bioregion_2004_2008
region_2000_2008
region_2004_2008
10.0
7.5
5.0
2.5
0.0
Standard Deviation
HUC8
HUC10
HUC12
Catchment
Spatial Resolution
rating
Acceptable
Fair
Degraded

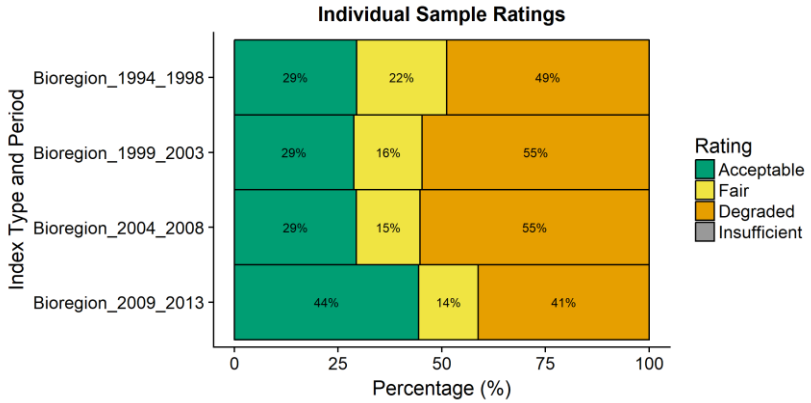
6) Random Forest

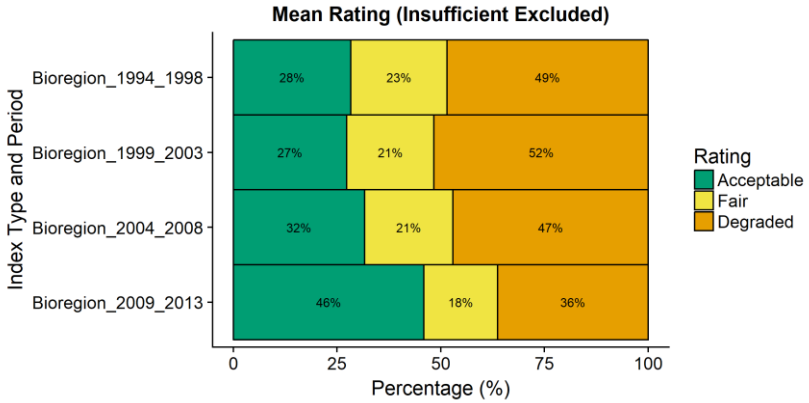
Trend Analysis

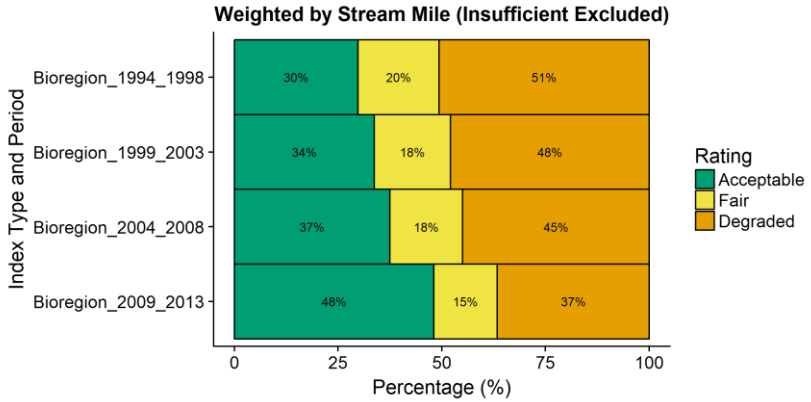
Trend Analysis

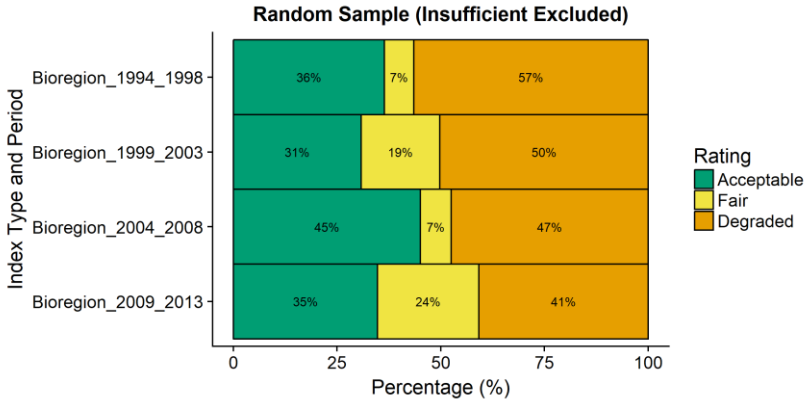
- None of the proposed methods completely eliminate spatial bias
- Spatial bias is not constant across time periods

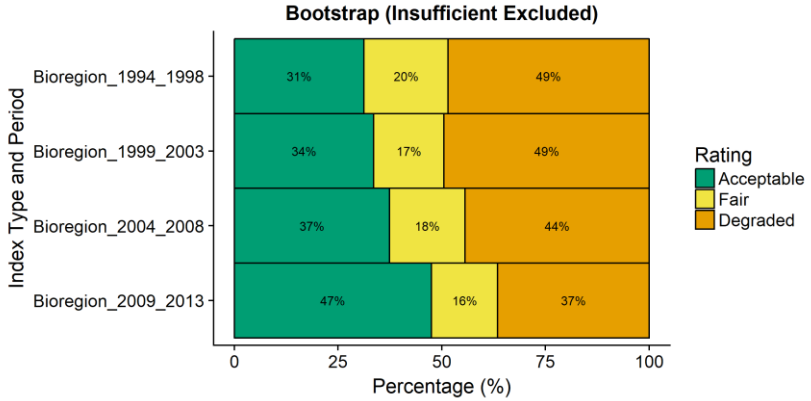
Trend Analysis: Methods 1-5



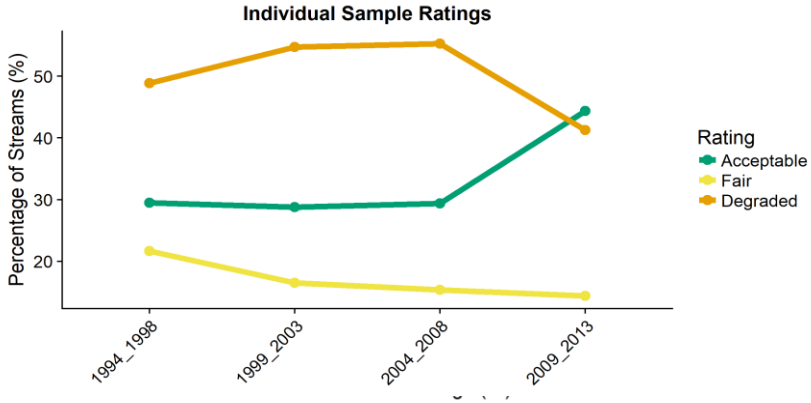


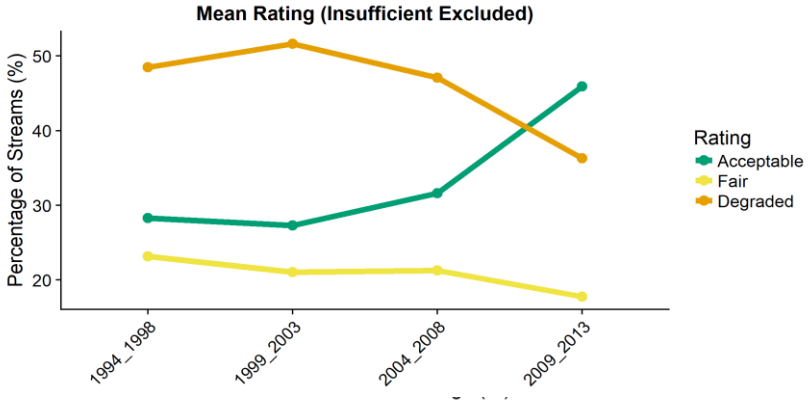


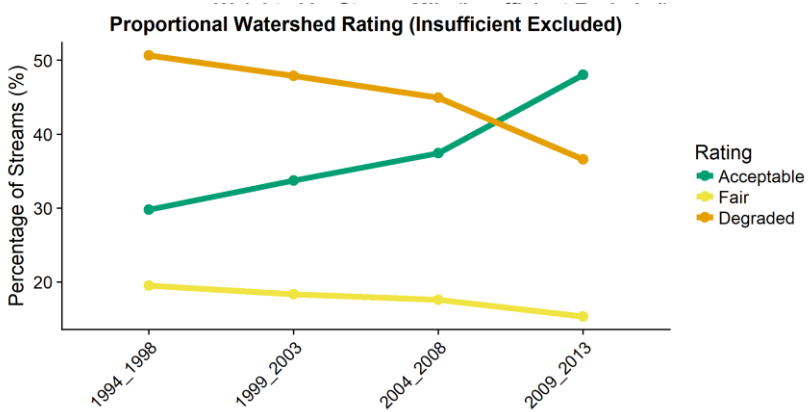


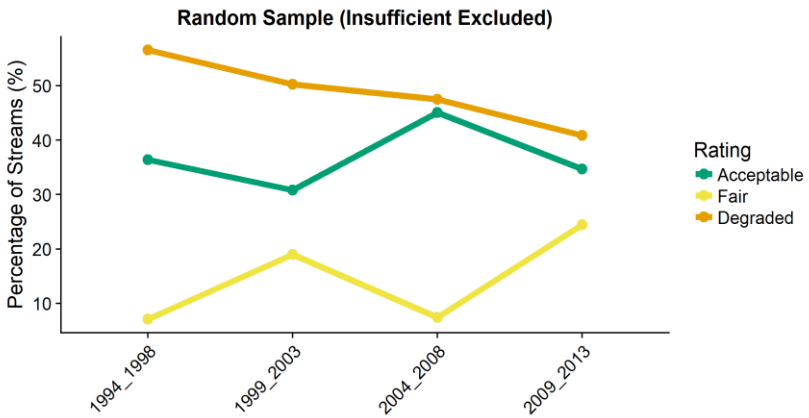


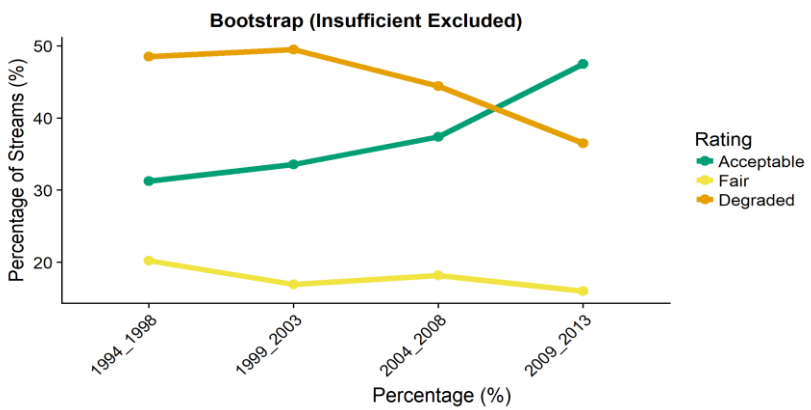
Trend Analysis: Methods 1-5









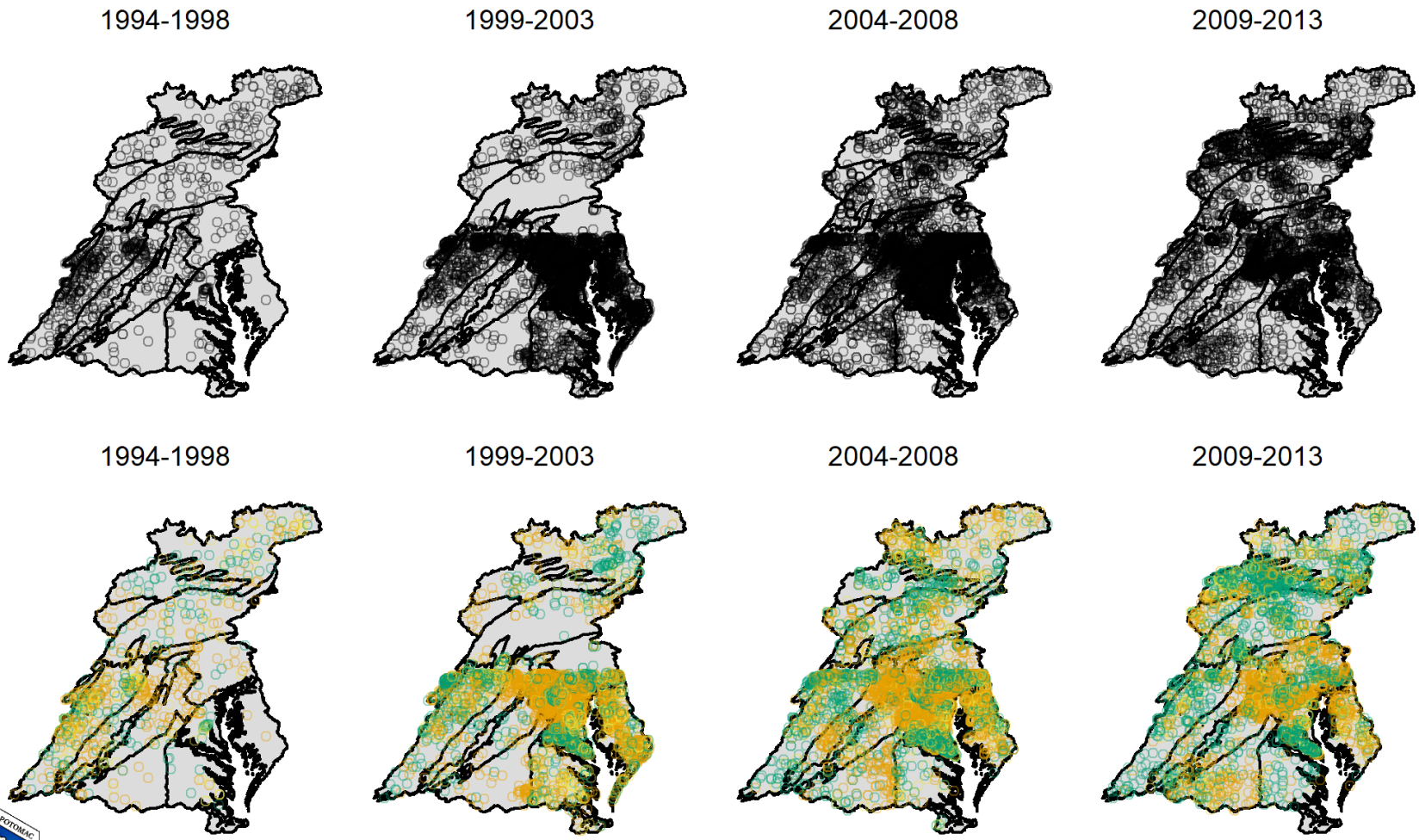


Looks good, right?

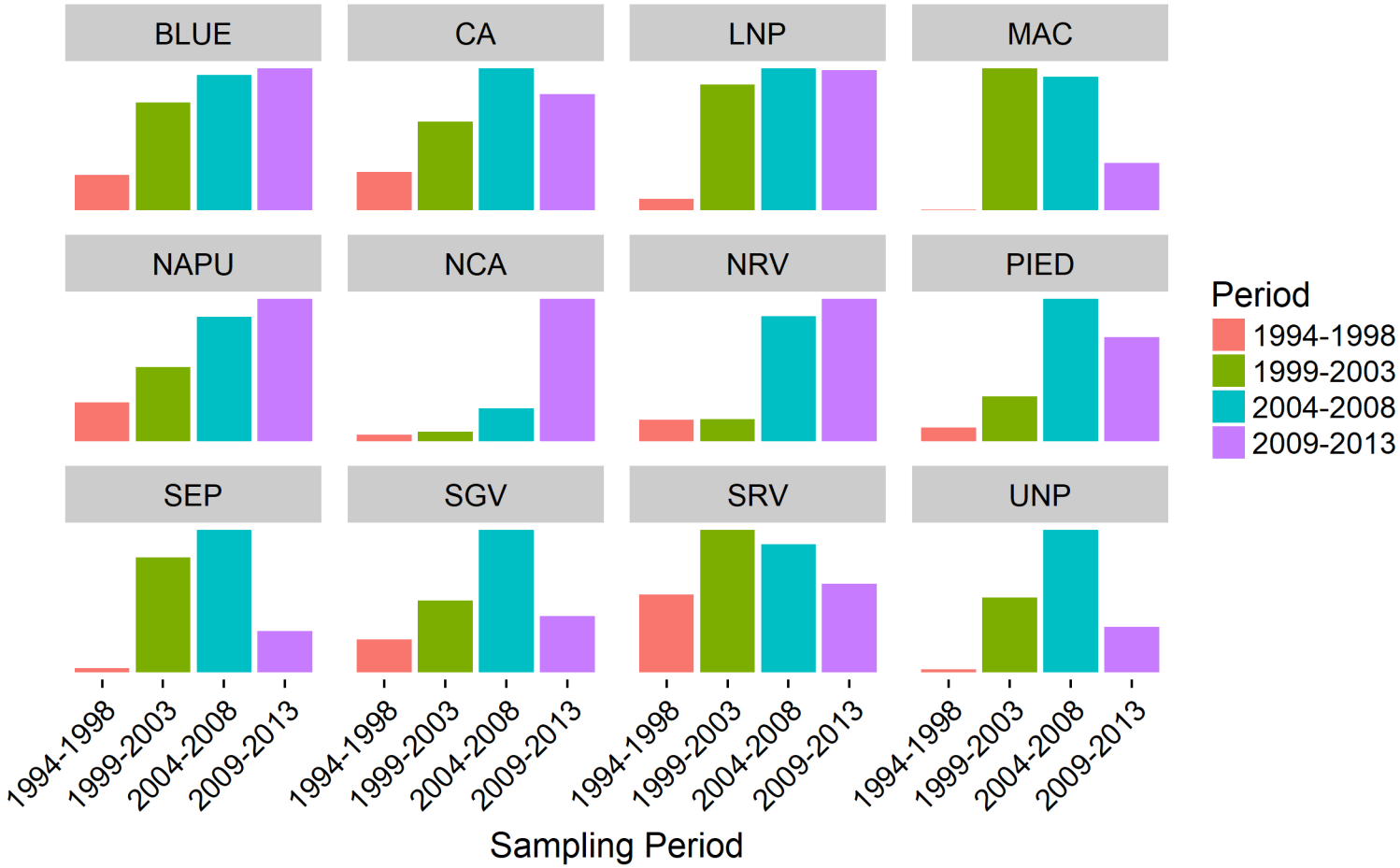
Wrong

(Maybe)

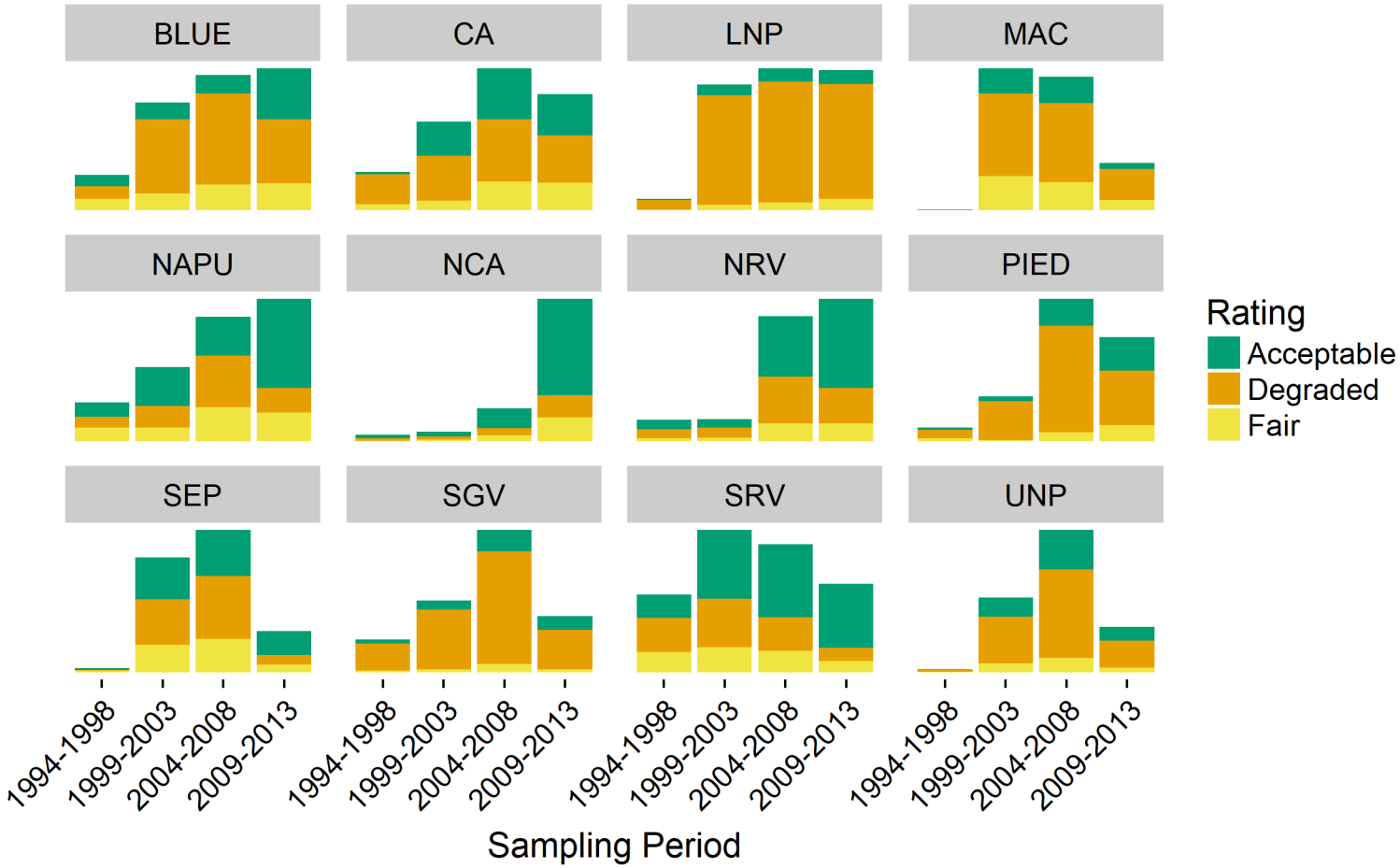
Spatial and Temporal Bias



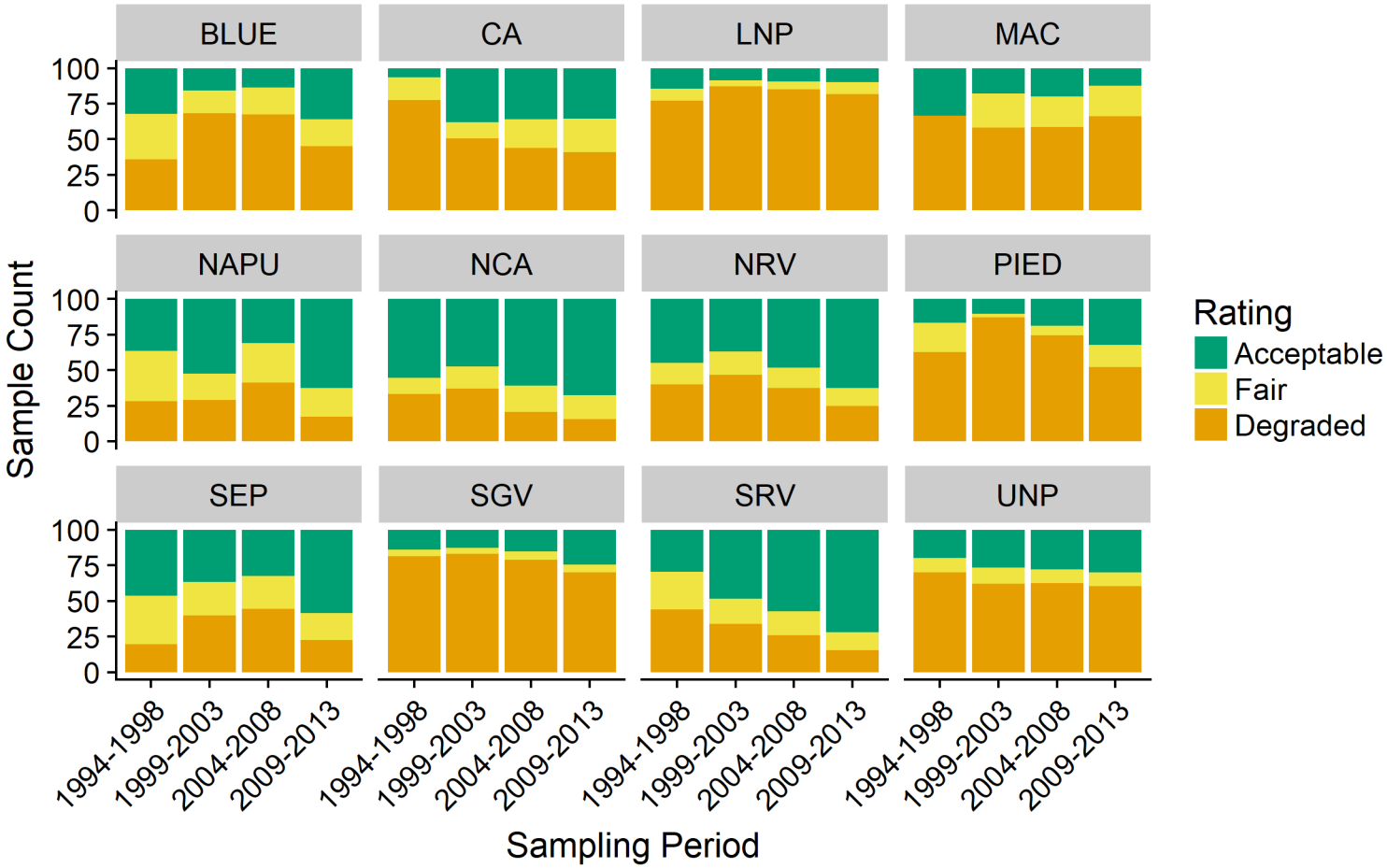
Spatial and Temporal Bias



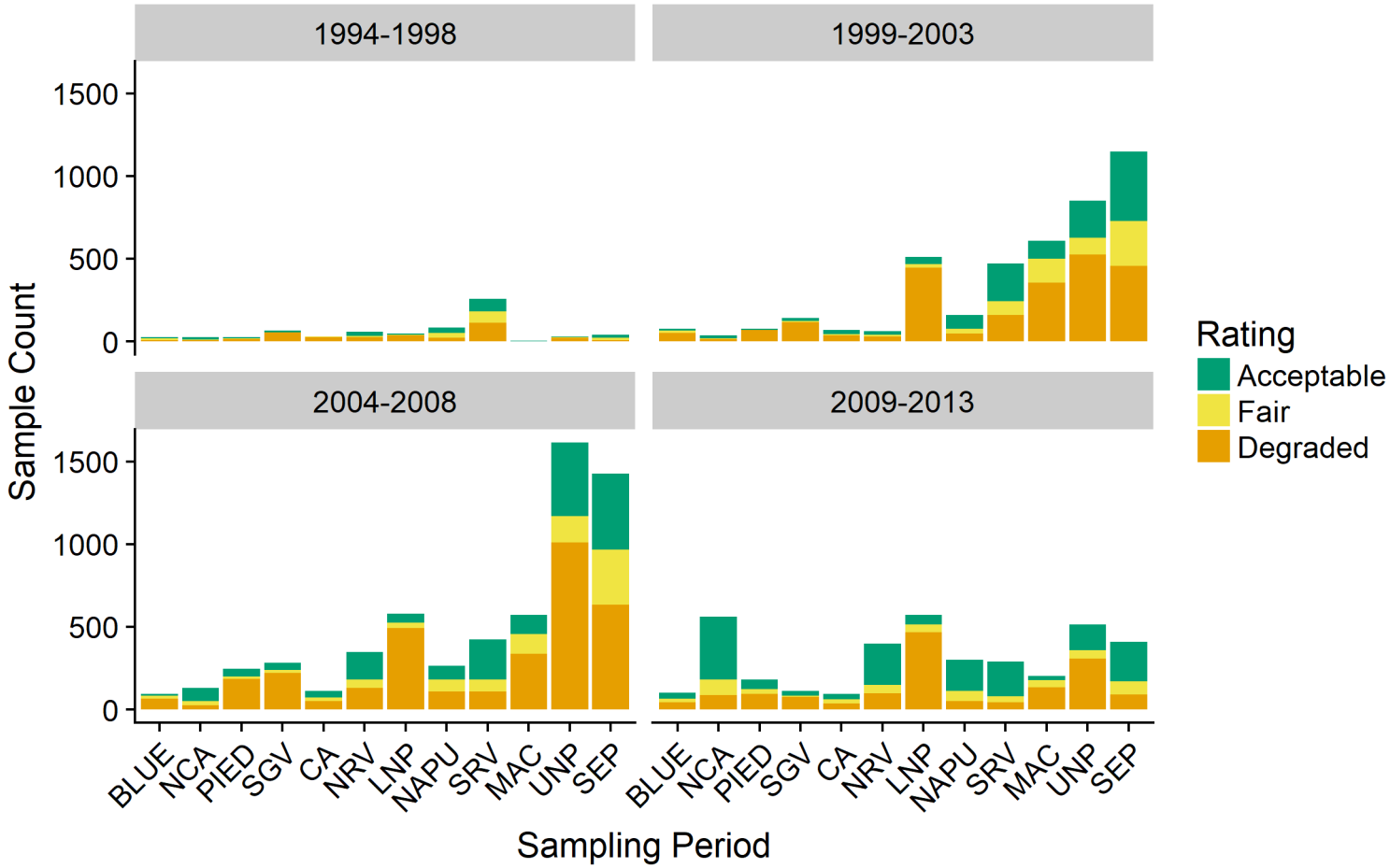
Spatial and Temporal Bias



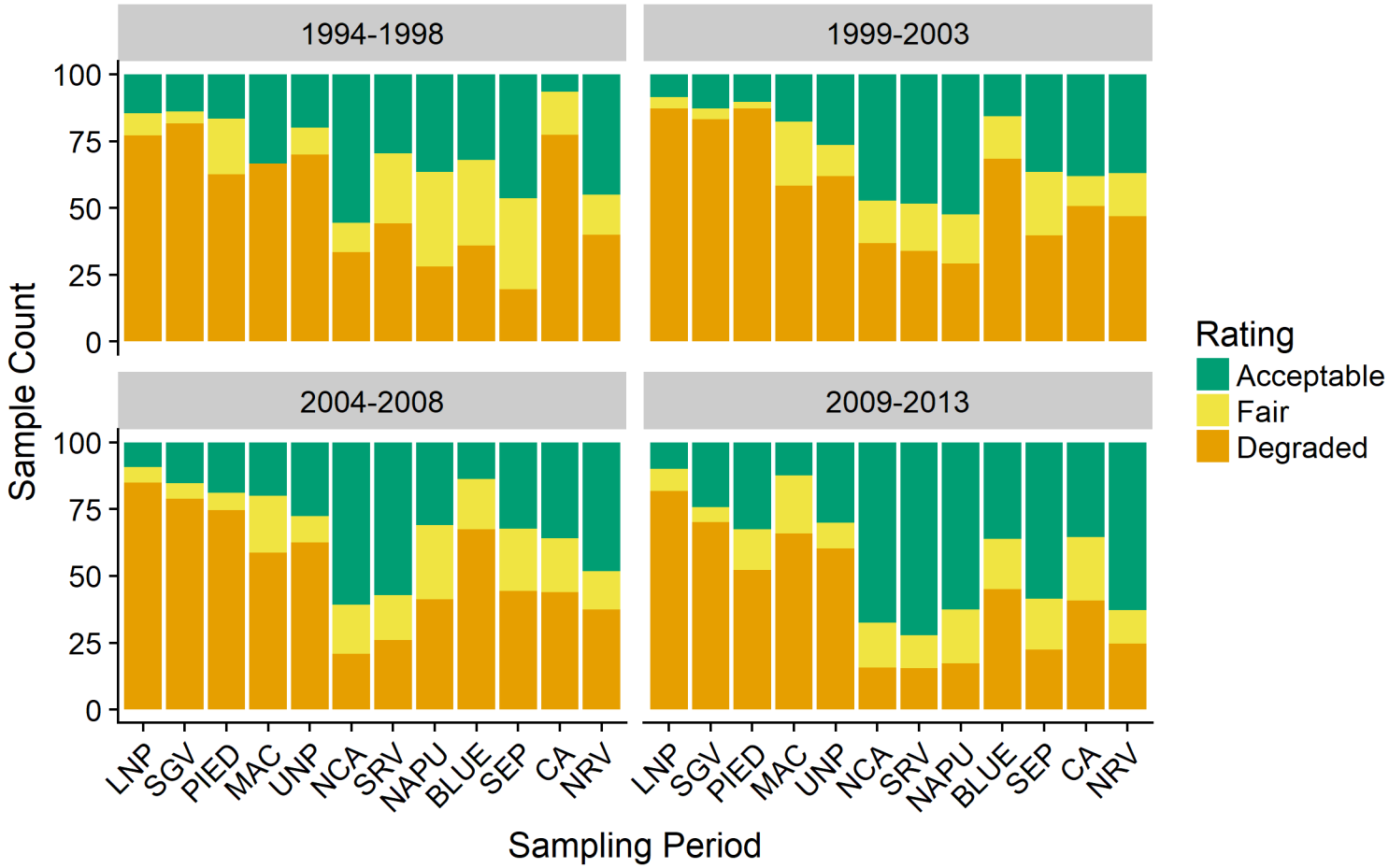
Spatial and Temporal Bias



Spatial and Temporal Bias

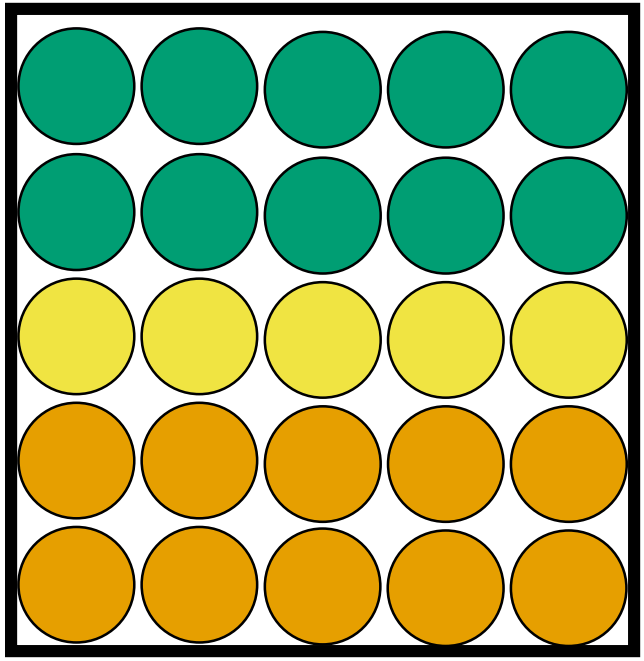


Spatial and Temporal Bias



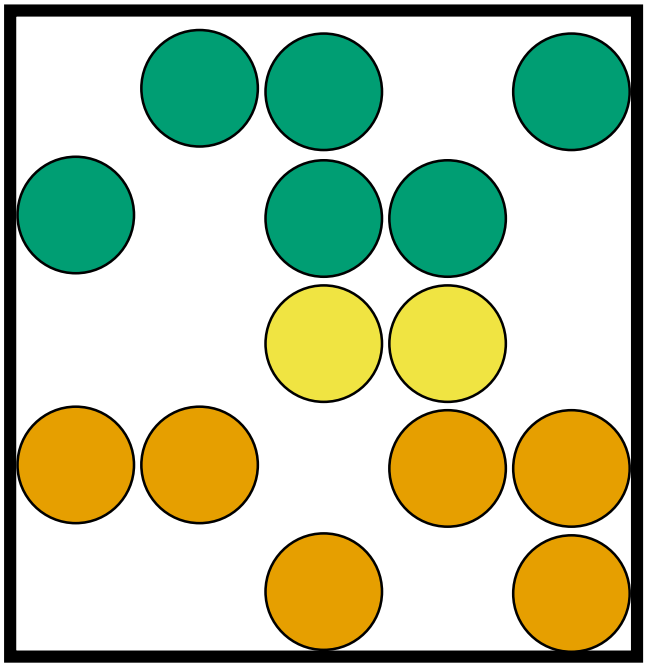
Trend Analysis

Reality



40% Acceptable
20% Fair
40% Degraded

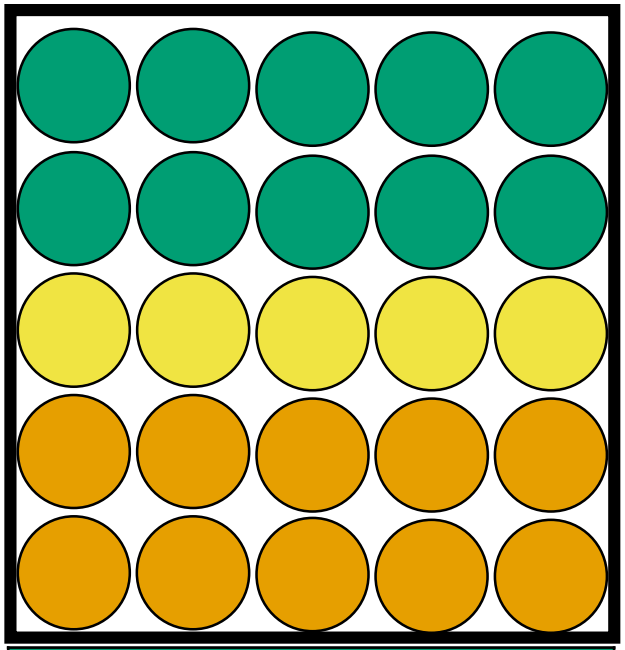
Random Sample



43% Acceptable
14% Fair
43% Degraded

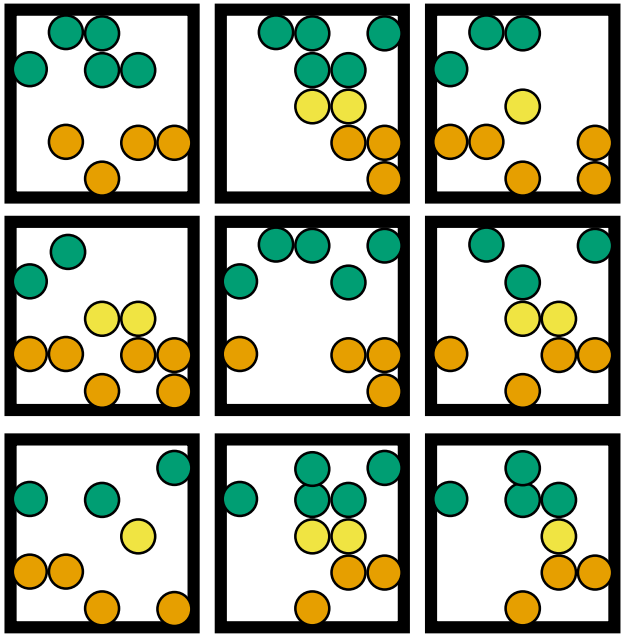
Trend Analysis

Reality



40% Acceptable
20% Fair
40% Degraded

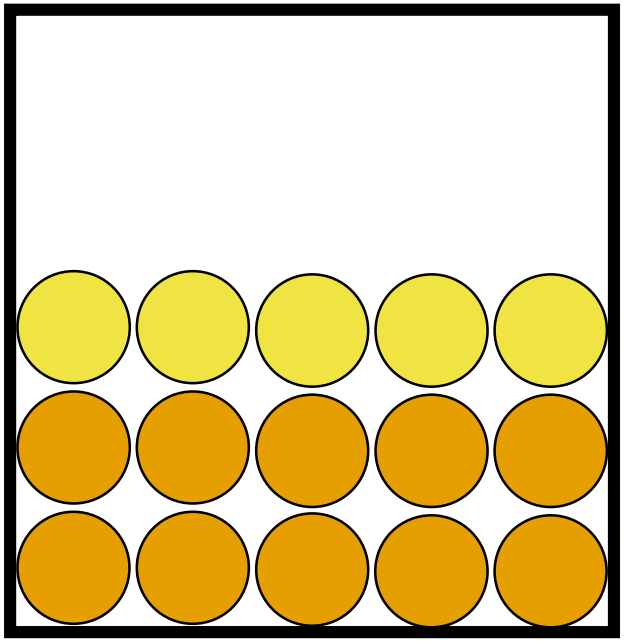
Bootstrap Sample



42.9% ± 3.5% Acceptable
16.2% ± 2.2% Fair
42.9% ± 3.5% Degraded

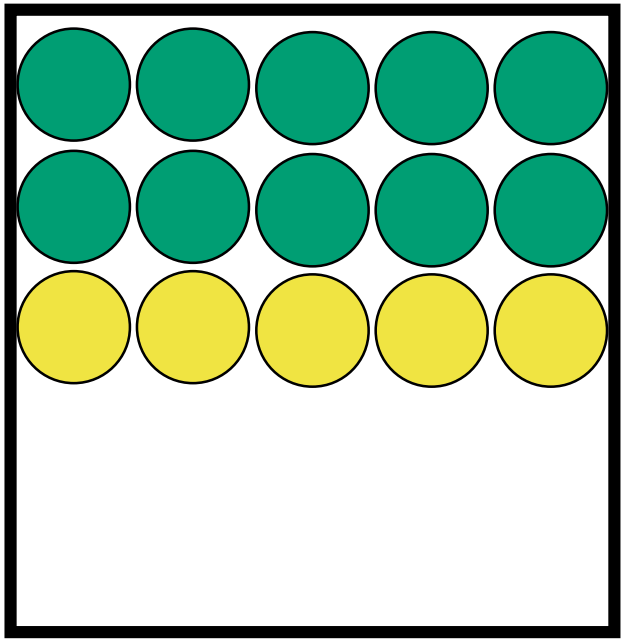
Trend Analysis

Time Period 1



0.0% Acceptable
33.3% Fair
66.7% Degraded

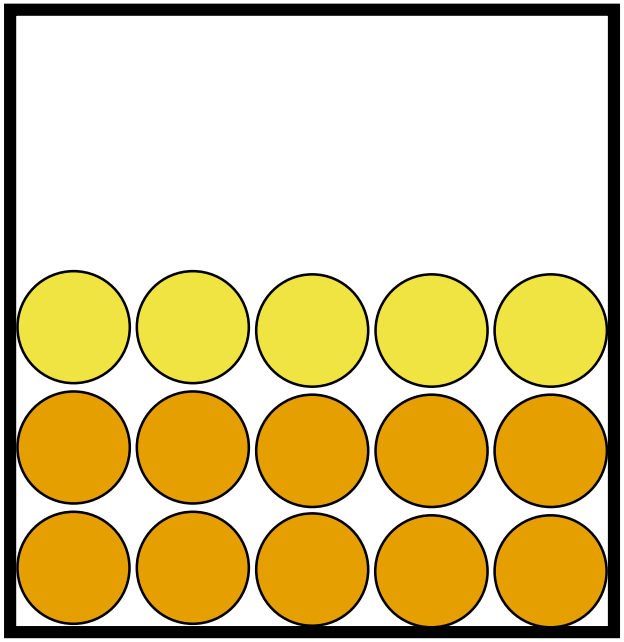
Time Period 2



66.7% Acceptable
33.3% Fair
0.0% Degraded

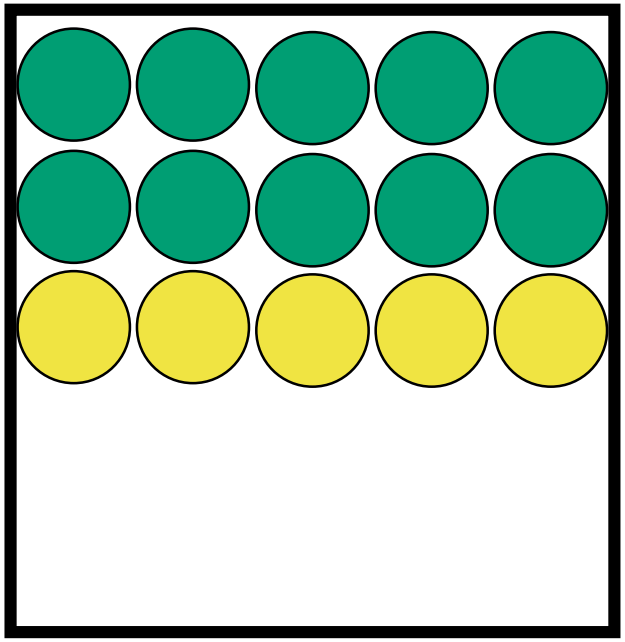
Trend Analysis

Time Period 1



0.0% Acceptable
33.3% Fair
66.7% Degraded

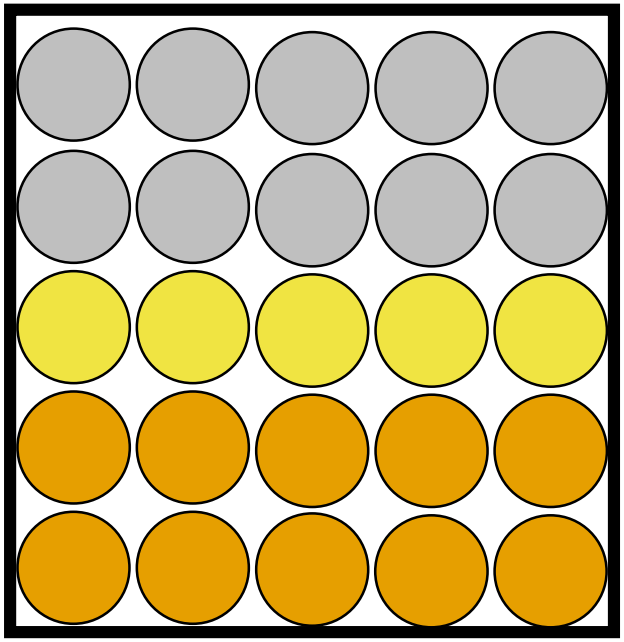
Time Period 2



66.7% Acceptable
33.3% Fair
0.0% Degraded

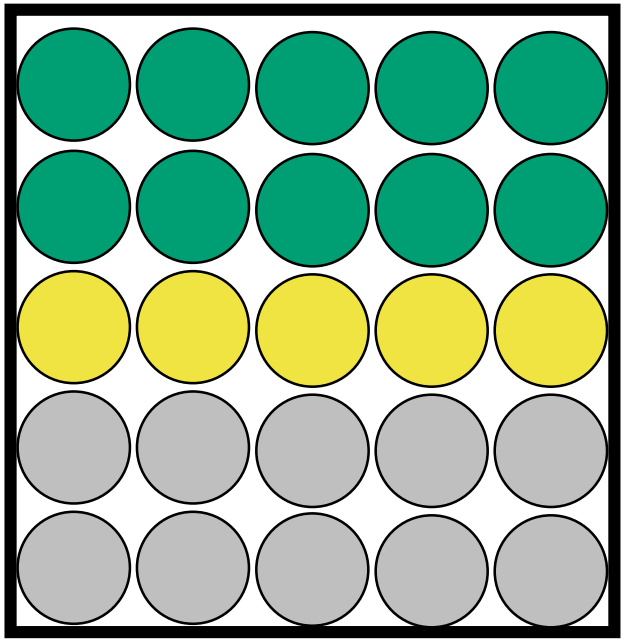
Trend Analysis

Time Period 1



0.0% Acceptable
20% Fair
40% Degraded
40% Insufficient

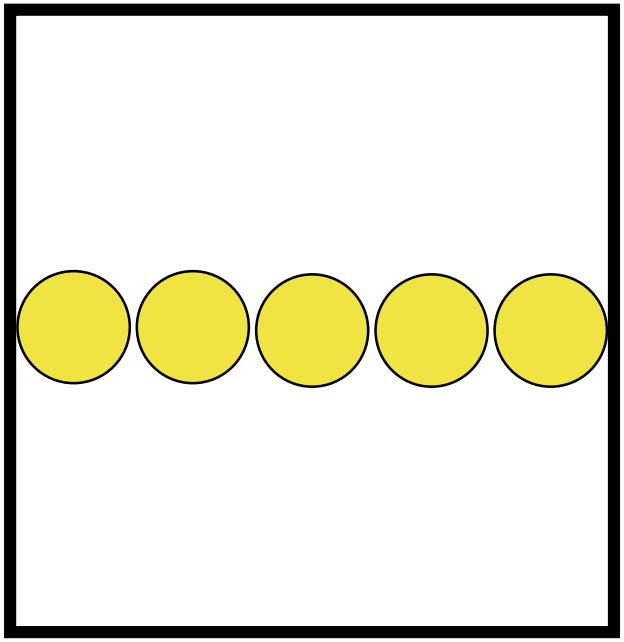
Time Period 2



40% Acceptable
20% Fair
0% Degraded
40% Insufficient

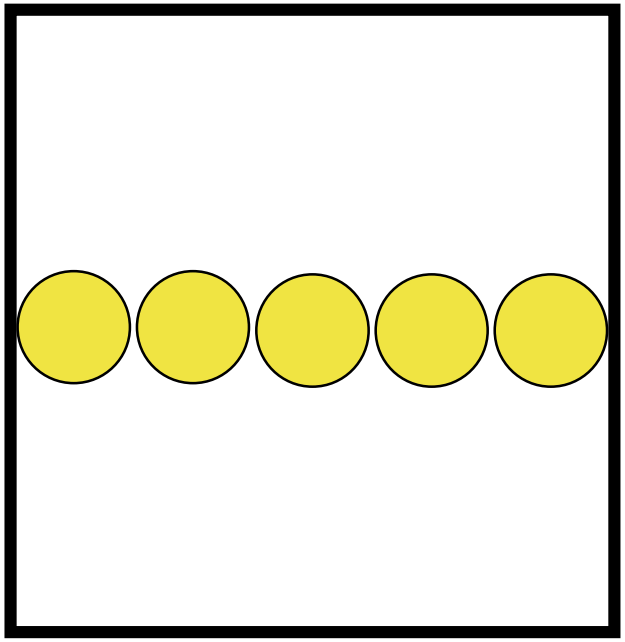
Trend Analysis

Time Period 1



0% Acceptable
100% Fair
0% Degraded
0% Insufficient

Time Period 2



0% Acceptable
100% Fair
0% Degraded
0% Insufficient

Conclusions and Recommendations

- Spatial and temporal discrepancies make it difficult to evaluate trends
- None of the proposed methods
- Recommended next steps:
  1. Blocking design
  2. Spatial autocorrelation reduction
  3. Modeling
     - Random Forest Model
     - Spatial Stream Network (SSN) Model

Questions or Comment?