Case Study:
What can we detect and when?:
Program Implications

M.J. Paul

D. Bressler

How will climate change affect

- Ability to detect impairment ?
- Ability to identify causes of impairment?
- Adaptive monitoring design?

Climate drivers on streams

- Temperature
- Precipitation: quantity and distribution affects stream hydrology:
  - Seasonal pattern of flow
  - Stream power
  - Erosion
  - Habitat
  - Pollutant loading
  - Nonpoint sources
- Interaction: evapotranspiration and CO_2 concentration

Predicted effects (many regions)

- Increased hydrologic variability
  - More severe annual summer dry period
  - More intense storms
  - Increased winter-spring precipitation: more severe spring flooding
  - More rain, less snow (W. snowpack)
- Increased mean temperature
  - Warmer winters

Evaluating Vulnerability

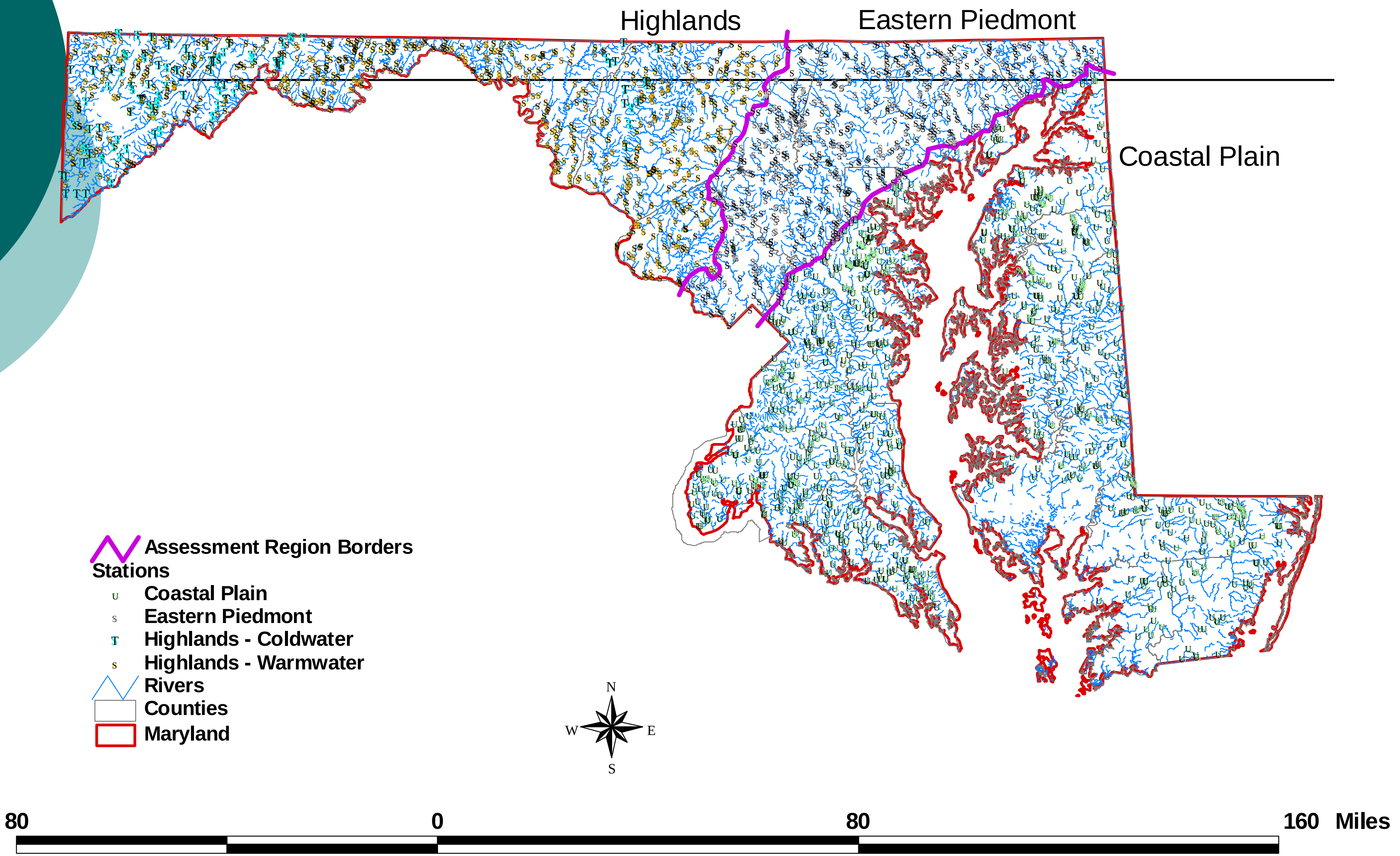
- Detection – Case Study 1
  - What changes are occurring?
  - Can our program detect them?
- Adaptation – Case Study 2
  - How can we adapt our program?

Detection

- Many dimensions of detection
- Focus here on two principal questions:
  - How long will it take to reliably detect a change in the mean native taxa richness of the reference site population?
  - How long will it take to reliably detect a change in mean native taxa richness for a particular site?

Data – Maryland Biological Stream Survey (MBSS)

- 1995-2005
- Fish (summer) and bugs (spring)
- Land cover, water chemistry
- 5-year rotating basin design
- Stream segments stratified by order; sites selected from list frame of segment-miles
- Used Piedmont and highlands regions: 0-100% urban, some agriculture


Highlands
Eastern Piedmont
Coastal Plain
Assessment Region Borders
Stations
Coastal Plain
Eastern Piedmont
Highlands - Coldwater
Highlands - Warmwater
Rivers
Counties
Maryland
N
W
E
S
80
0
80
160 Miles

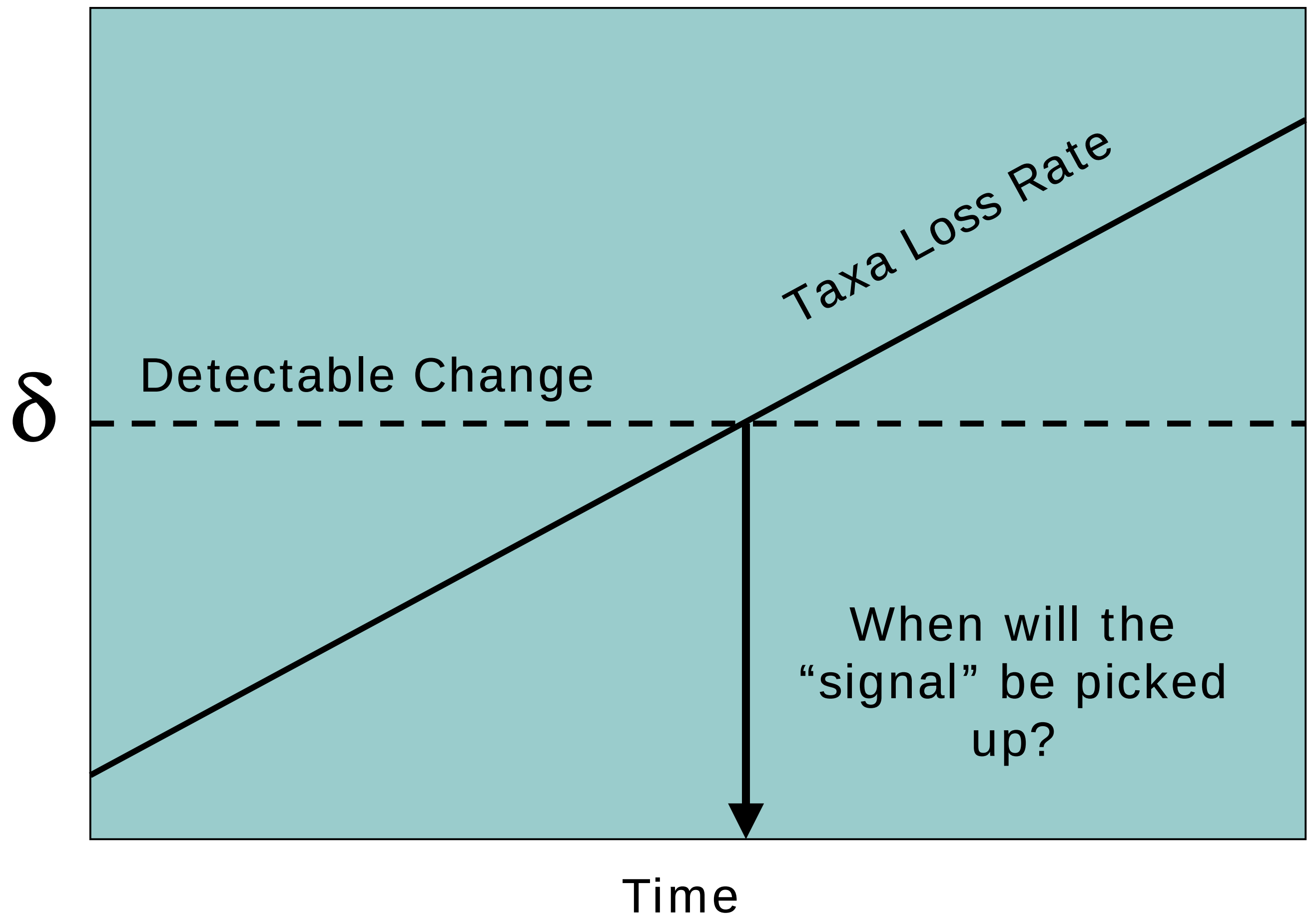
Methods

- Power analysis approach

$$\delta^2 = \frac{2 \times (Z_\alpha + Z_\beta)^2 \times \sigma^2}{n}$$

- Detectable change for an assessment program

Methods


Taxa Loss Rate
Detectable Change
δ
When will the
“signal” be picked
up?
Time

Methods

- Power analysis approach

$$\delta^2 = \frac{2 \times (Z_\alpha + Z_\beta)^2 \times \sigma^2}{n}$$

- Detectable change for an assessment program
- Need two things:
  - Variance
  - What changes might be expected

Variance

- Standard program variability
- MBSS repeat visits to sentinel sites
  - 29 sites
  - Repeat visits over last 6 years
- Gives an estimate of standard interannual variability (σ^2)

Expected Changes

- Scientific Literature
- Climate (NAST 2001)

	Average Annual Temperature (º C) Increases by 2100	
Region	**Min**	**Max**
Northeast/Mid-Atlantic	2.6	5
Southeast	2.3	5.5
Midwest	2	6
Great Plains	3	
West	4	6
Pacific Northwest	3 (by 2050)	

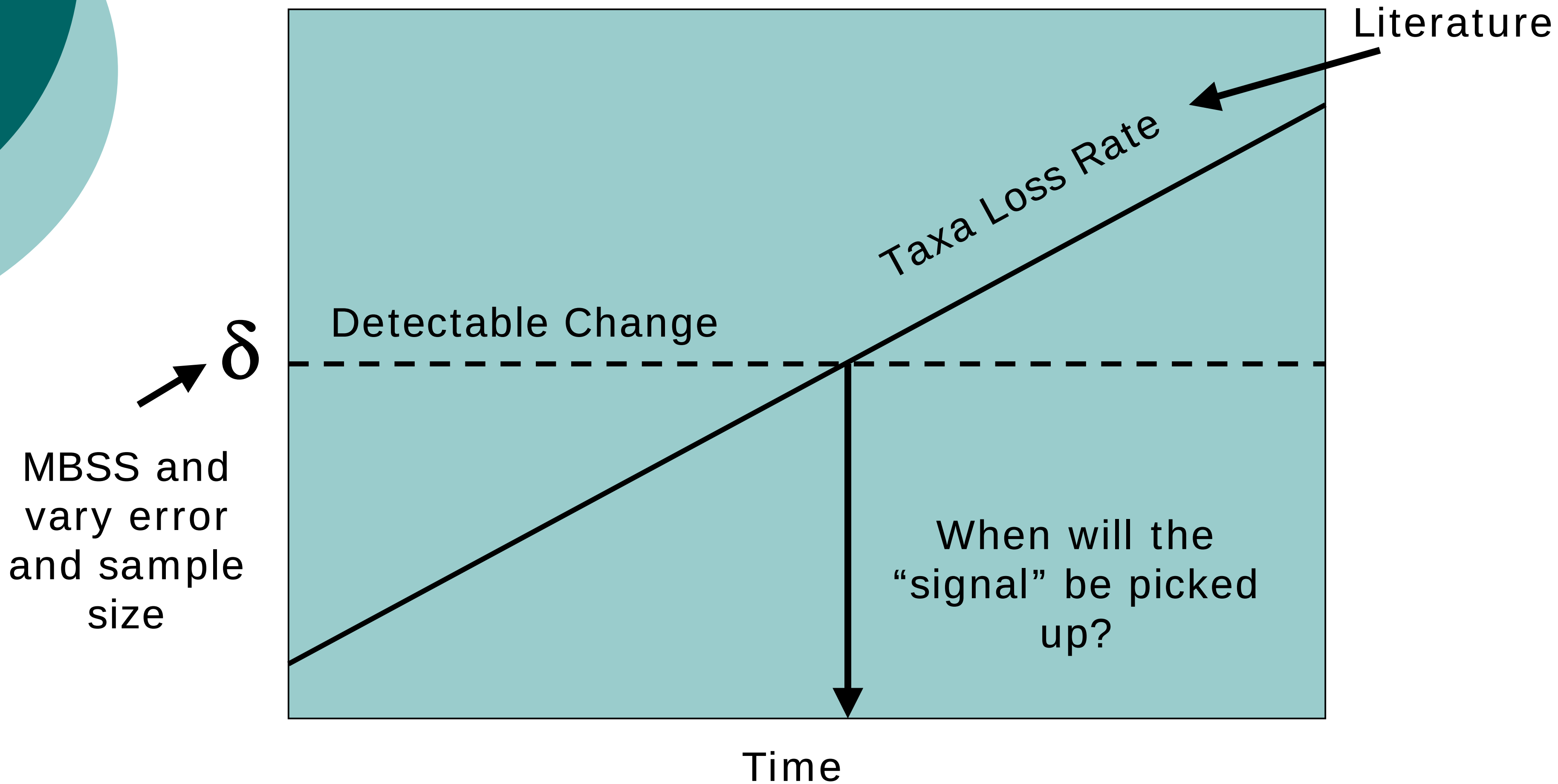
Expected Changes

- Scientific Literature
- Macroinvertebrates
  - 4.6 taxa per degree C (HIGH)
    - Daufresne et al. 2003
  - 1.0 taxa per degree C (LOW)
    - Lehigh University 1960
- Fish
  - 2.0 taxa per degree C (FISH)
    - Gammon 1971

Expected Changes

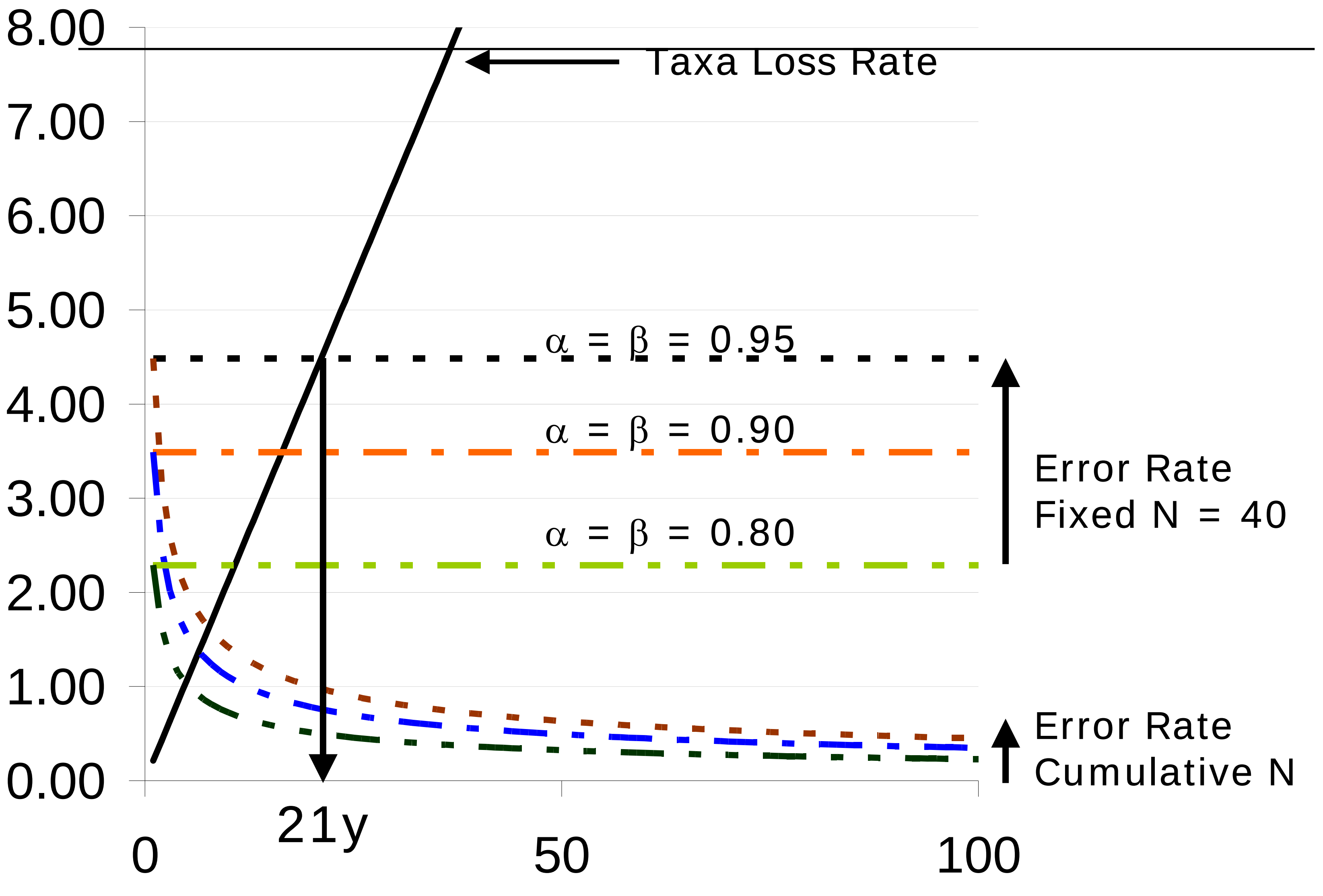
- Scientific Literature
- Combine loss rates and climate change
  - 4.6 taxa per degree C
  - 5 degree C increase by 2100
  - 23 taxa by 2100 = 0.2 taxa per year

Methods


Literature
Taxa Loss Rate
Detectable Change
δ
MBSS and vary error and sample size
When will the "signal" be picked up?
Time

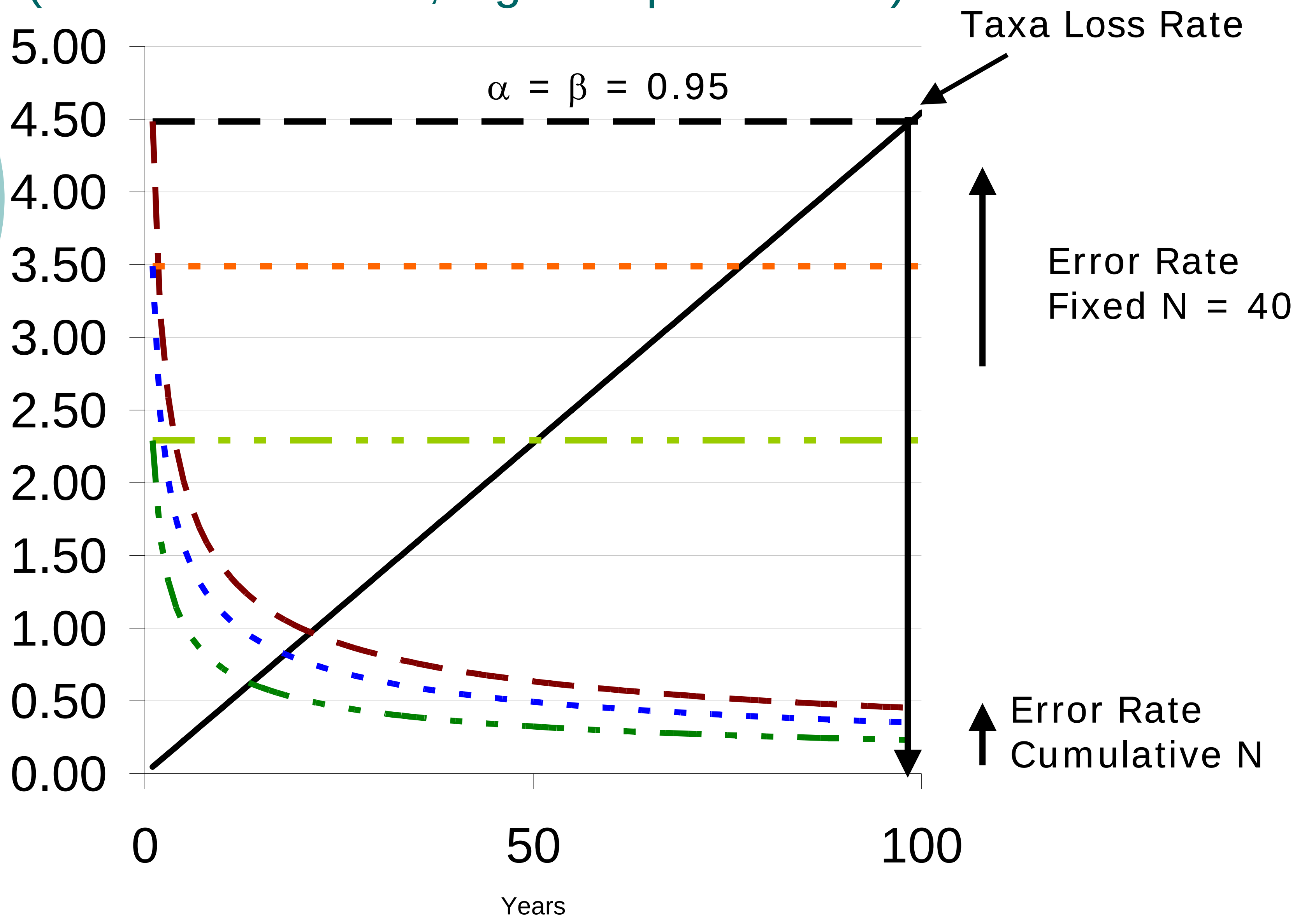
Macroinvertebrate Richness

(high taxa loss rate, high temp. scenario)



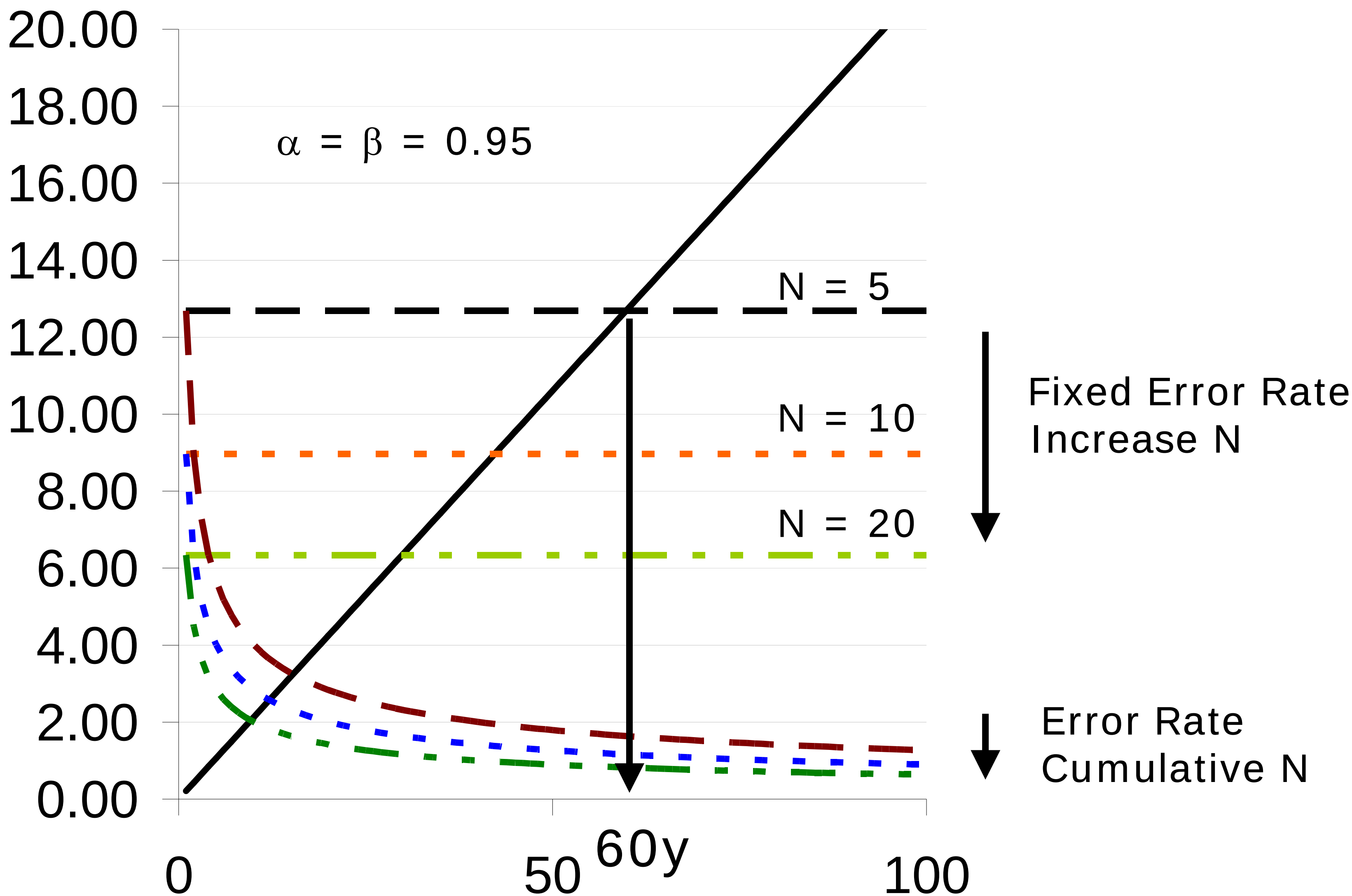
Macroinvertebrate Richness

(low taxa loss rate, high temp. scenario)



Macroinvertebrate Richness

(high taxa loss rate, high temp. scenario)



Data Summary – Northeast/Mid-Atlantic

		Northeast/Mid-Atlantic
Maximum Predicted Temperature Increase by 2100		
Macroinvertebrates - High Taxa Loss Rate (4.6 per degree C)		
	$\alpha=\beta=0.95$	**21**
	$\alpha=\beta=0.8$	**11**
Macroinvertebrates - Low Taxa Loss Rate (1 per degree C)		
	$\alpha=\beta=0.95$	**98**
	$\alpha=\beta=0.8$	**51**
Fish Taxa Loss Rate (3.6 per degree C)		
	$\alpha=\beta=0.95$	**28**
	$\alpha=\beta=0.8$	**14**

Data Summary – Northeast/Mid-Atlantic

Minimum Predicted Temperature Increase by 2100		
Macroinvertebrates - High Taxa Loss Rate (4.6 per degree C)		
	$\alpha=\beta=0.95$	**41**
	$\alpha=\beta=0.8$	**21**
Macroinvertebrates - Low Taxa Loss Rate (1 per degree C)		
	$\alpha=\beta=0.95$	**>100**
	$\alpha=\beta=0.8$	**97**
Fish Taxa Loss Rate (3.6 per degree C)		
	$\alpha=\beta=0.95$	**53**
	$\alpha=\beta=0.8$	**27**

Results

- Decrease required error rate (α/β), quicker to detect a change
- Increase N, quicker to detect a change
- Low taxa loss rate, slower to detect a change
- Lower temperature scenario, slower to detect a change

Summary

- How long will it take to reliably detect a change in the mean native taxa richness of the reference site population?

Macroinvertebrates, N=40 reference sites, $\alpha=\beta=0.8$

- High temp. scenario
  - ~11y at high taxa loss rate, ~51 years if slower
- Low temp. scenario
  - ~21y at high taxa loss rate, ~97 years if slower
- Sooner if N increases

Summary

- How long will it take to reliably detect a change in mean native taxa richness for a particular site (watershed)?

  Macroinvertebrates, N=10 reference sites, $\alpha=\beta=0.8$
  - High temp. scenario
    - ~22y at high taxa loss rate, ~100 years if slower
  - Low temp. scenario
    - ~42y at high taxa loss rate, >>100 years if slower
  - Sooner if increase N

Implications

- Probabilistic vs targeted designs
- Sample reference/sentinel sites regularly
- Protect reference/sentinel sites
- Keep N as high as practical
- Relax error rates
- Use regional estimates of variability and climate scenarios
- Run analysis to estimate detection power