AN EVALUATION OF SIX BIOLOGICAL MODELS USED TO ASSESS THE CONDITION OF LARGE STREAMS FROM A STATEWIDE MONITORING NETWORK IN MONTANA

2001-2005

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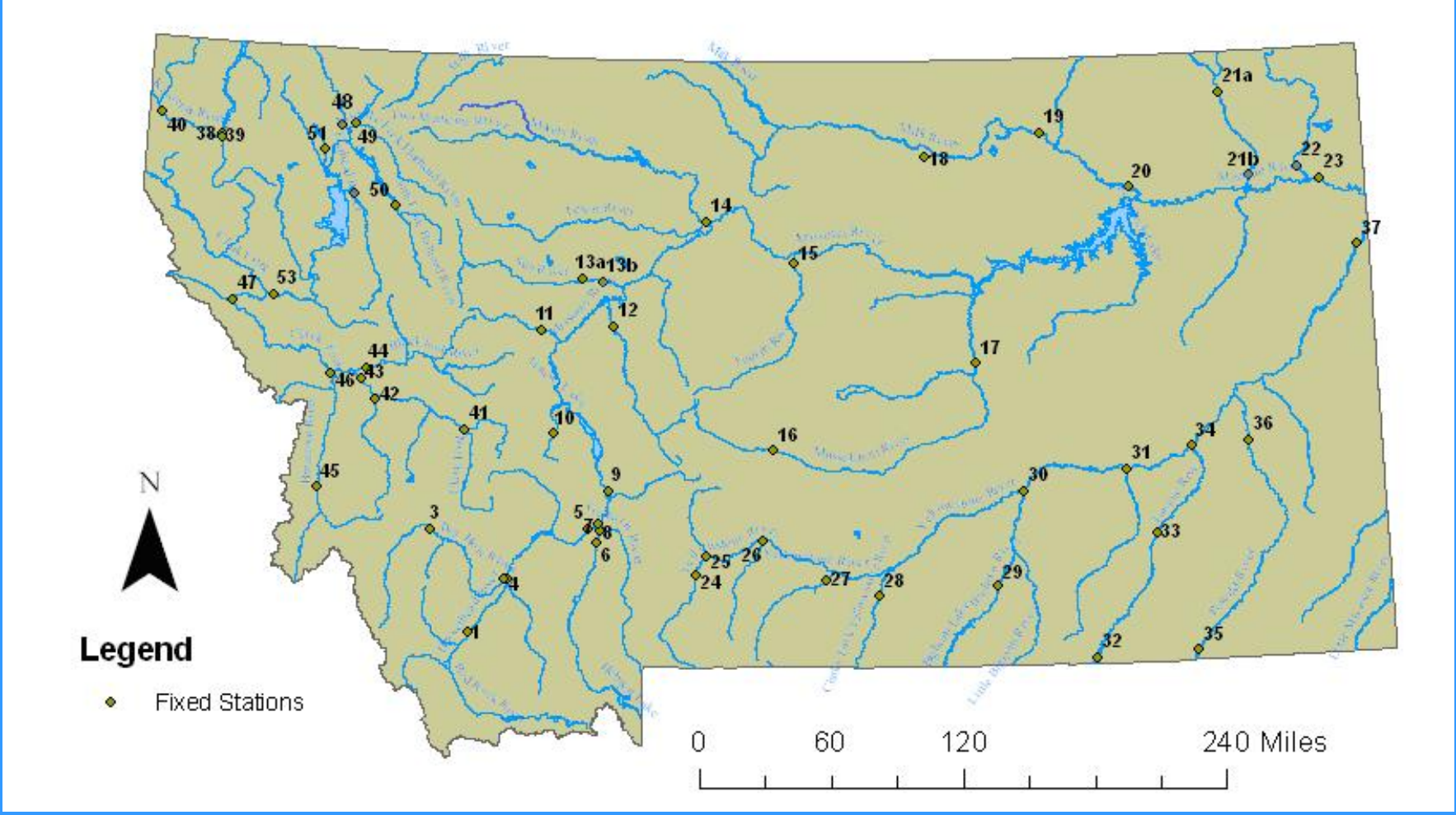


Montana map with fixed-station site locations

Physical and Chemical data collected from 1999-2005

Periphyton data collected from 2001-2003

Macroinvertebrate data collected from 2001-2005

Biological Models to Assess Condition

- **3 Historic Protocols**
  - Macroinvertebrate IBI for Mountains and Valleys
  - Macroinvertebrate IBI for Plains
  - Periphyton Index of Biological Integrity
- **2 Current Protocols**
  - Macroinvertebrate Multimetric Index
  - Macroinvertebrate (O/E) RIVPAC-like model
- **1 Under Development**
  - Diatom Increaser Taxa Model

Table 1. Summary of biological condition assessments using periphyton IBI

River Basin	Percentage of sites with excellent/good, fair, and poor conditions using the periphyton IBI[1]		
	Excellent/Good	Fair	Poor
Missouri	52%	35%	13%
Yellowstone	57%	22%	21%
Columbia	56%	31%	13%

Table 2. Summary of O/E and Diatom Increaser Taxa model results

River Basin	Percentage of sites that are non-impaired and impaired using O/E[1] and Increaser Taxa[2] Models			
	Nonimpaired		Impaired	
	O/E	Increaser Taxa	O/E	Increaser Taxa
Missouri	63%	38%	37%	62%
Yellowstone	33%	45%	67%	55%
Columbia	71%	38%	29%	62%

Table 3. Summary of biological condition assessments using macroinvertebrates

River Basin	Percentage of sites with slight, moderate, and severe conditions using macroinvertebrate IBI[1] and MMI[2]					
	Slight Impaired/Good		Moderate/Fair		Severe/Poor/Very Poor	
	IBI	MMI	IBI	MMI	IBI	MMI
Missouri	30%	80%	55%	10%	15%	10%
Yellowstone	25%	75%	50%	25%	25%	0%
Columbia[3]	78%	57%	22%	42%	0%	0%

e.g. Missouri River Basin: non-impairment ranged from 30% - 80%

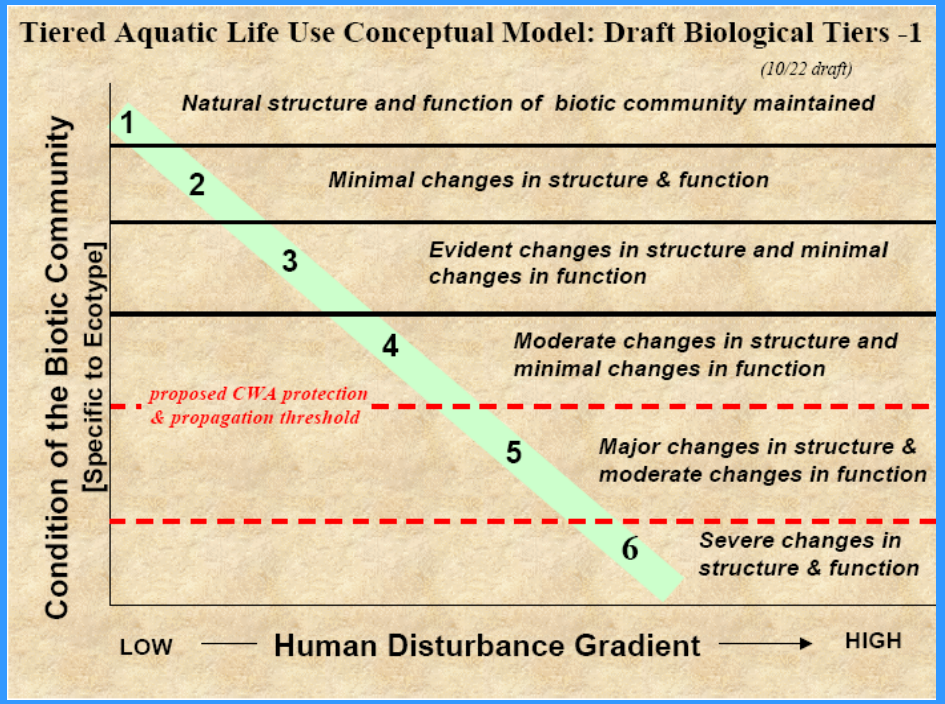
CHANGED OBJECTIVE:

Evaluated performance of biological models using a multi-stressor / human disturbance gradient

Multi-stressor Gradient

- **Stressors:** environmental factors (physical, chemical or biological) that adversely affect aquatic organisms, typically at a site or reach scale.
- **Disturbance gradient:** describes human activities that occur on the land at the landscape level (e.g., percent cropland)

Conceptual biological condition model.



Used Informed BPJ to develop the Multi-Stressor Gradient

- Physical and chemical data were used to rank sites into three classes of impairment:
  - Slight,
  - Moderate
  - Severe
- Confidence of assessments were also ranked as:
  - High
  - Moderate
  - Low (did not use)
- Ranked the sites within each impairment class.

Followed TALU Draft Guidance

(descriptive gradients for physical and chemical characteristics)

Geomorphology

Slight

Tier 1: Stream tends to be narrow with good access to its flood plain unless naturally confined

Tier 2: Minimum indication that the stream is widening or getting shallower

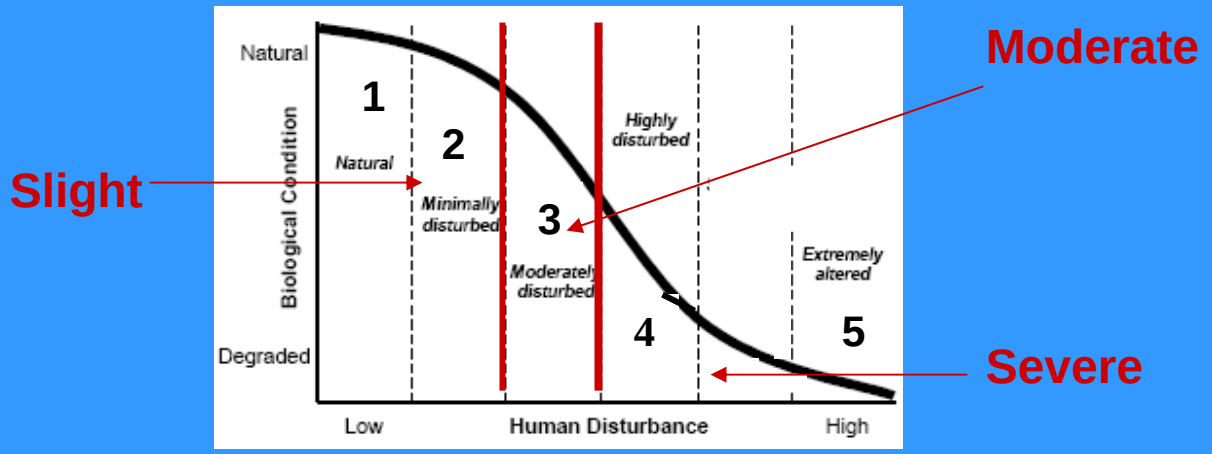
Moderate

Tier 3: Obvious signs of downcutting and moderate entrenchment or the stream is showing signs of getting wider and shallower

Severe

Tier 4: Stream tends to be artificially wide and shallow and/or entrenched and does not have access to its flood plain.

Tier 5: Stream is entrenched or has braided channels with longitudinal and transverse bars



Shields River

Parameter	Samples	Max	Min	Mean	Agency	Comments
Flow instantaneous (cfs)	20	1,110	35	345	USGS	
Dissolved Oxygen (mg/L)	5	11.5	8.8	10.2	DEQ	
pH (standard units)	20	8.8	8.0	8.4	USGS	
Specific Conductance (uS/cm)	20	512	196	370	USGS	
Temperature (degrees Celsius)	20	18.5	3.5	11.5	USGS	
Sodium Adsorption Ratio	10	1	0.3	0.7	USGS	
Sulfate (mg/L)	10	33.2	8.40	22.4	USGS	
Total Hardness (mg/L as CaCO3)	10	220	90	161	USGS	
Total Suspended Sediment (mg/L)	20	523	7	90	USGS	
Total Ammonia + Organic Nitrogen (mg/L as N)	20	1.4	0.18	0.5	USGS	
Nitrite plus Nitrate (mg/L as N)	20	0.301	ND	0.101	USGS	
Total Phosphorus (mg/L)	20	0.670	0.009	0.112	USGS	
Chlorophyll *a* *(mg/square meter)*	6	119	40	72	DEQ	1 Duplicate
Arsenic, total-recoverable (ug/L)	10	4	ND		USGS	
Cadmium, total-recoverable (ug/L)	10	0.1	ND		USGS	
Copper, total-recoverable (ug/L)	10	17	0.8	3.8	USGS	
Lead, total-recoverable (ug/L)	10	9	ND		USGS	
Mercury, total-recoverable (ug/L)	2	ND	ND	ND	DEQ	
Selenium, total-recoverable (ug/L)	2	ND	ND		DEQ	
Zinc, total-recoverable (ug/L)	10	35	ND	10	USGS	
Bed Sediment Metals (mg/kg)	1				DEQ	Not Elevated
E. coli Bacteria (2-3 measures/sampling event)	3	94	34	72	DEQ	

Moderate

Compared results to draft nutrient criteria

Sites used to develop a multi-stressor gradient to evaluate the biological models.

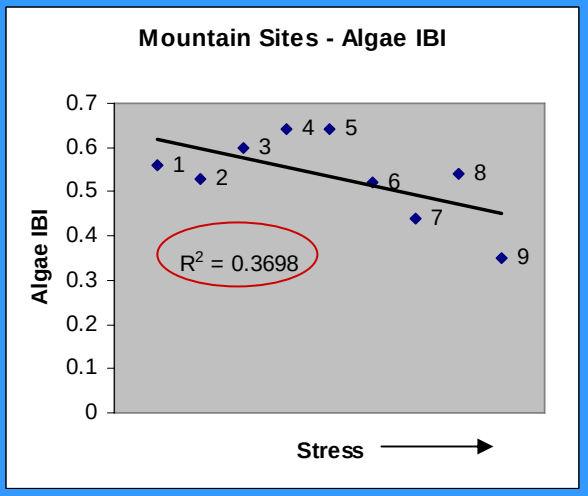
Classes

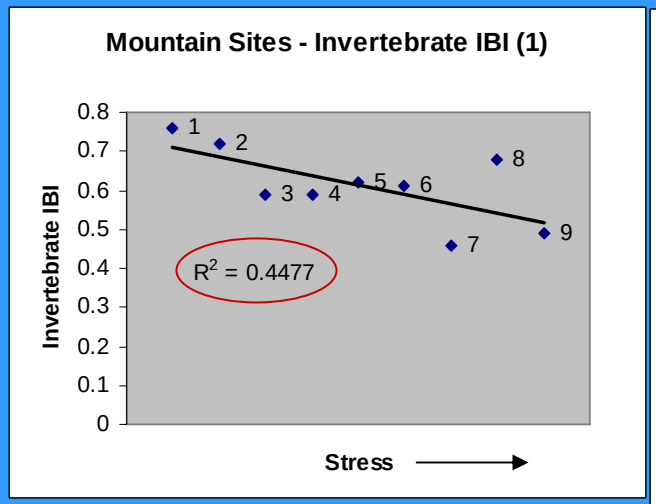
- Mountains
- Valleys and Foothills
- Plains

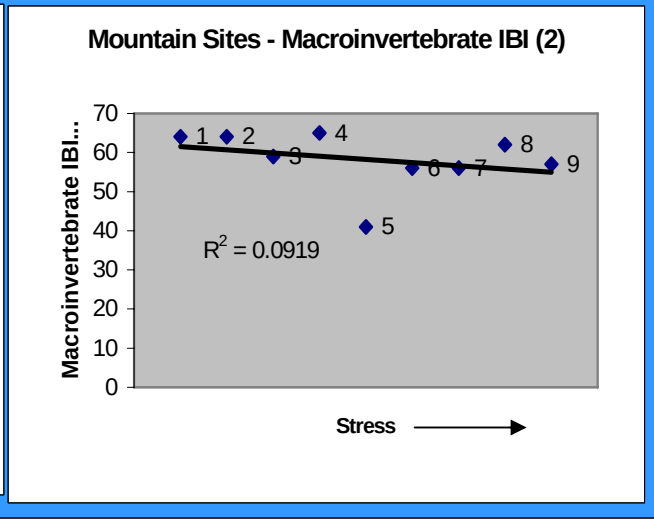
Stress Ranking	Site	Degree	Confidence
1	North Fork Flathead	Slight	High
2	South Fork Flathead	Slight	High
3	Middle Fork Flathead	Slight	High
4	Dearborn	Slight	Moderate
5	Swan River	Slight	Moderate
6	Rock Creek	Slight	Moderate
7	Blackfoot	Slight	Moderate
8	Boulder	Slight	Moderate
9	Judith	Slight	Moderate
10	Stillwater	Slight	Moderate
11	Big Hole at Wise River	Moderate	Moderate
12	Musselshell at Harlowton	Moderate	Moderate
13	Whitefish River	Moderate	Moderate
14	Fisher River	Moderate	Moderate
15	Bitterroot at Missoula	Moderate	Moderate
16	Madison	Moderate	Moderate
17	Smith	Moderate	Moderate
18	Sun	Moderate	Moderate
19	Shields River	Moderate	Moderate
20	Clark Fork at St. Regis	Moderate	Moderate
21	Little Blackfoot	Moderate	High
22	Clark Fork @ Turah	Moderate	High
23	Big Hole at Twin Bridges	Moderate	High
24	Gallatin	Moderate	High
25	Beaverhead near Dillon	Moderate	High
26	Beaverhead near Twin Bridges	Moderate	High
27	Big Horn near Big Horn	Moderate	Moderate
28	Big Horn near Hardin	Moderate	Moderate
29	Powder at Locate	Moderate	Moderate
30	Milk River near Nashua	Severe	Moderate
31	Jefferson	Severe	High
32	Prickly Pear	Severe	High
33	Clarks Fork of Yellowstone	Severe	High
34	Teton River	Severe	High
35	Musselshell at Mosby	Severe	High
36	Tongue @ Miles City	Severe	High
37	Rosebud	Severe	High

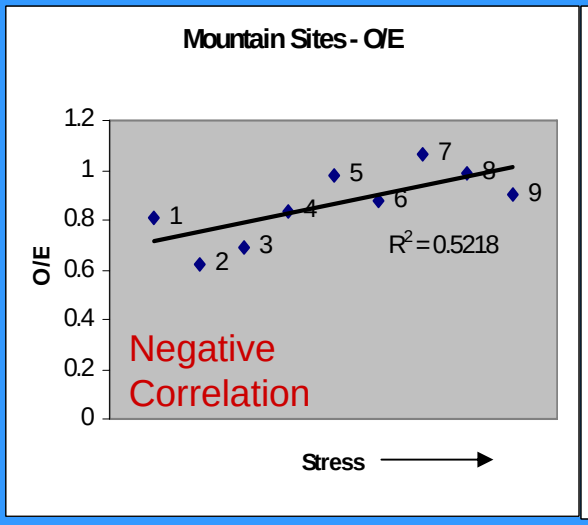
Correlation with Multi-Stressor Gradient

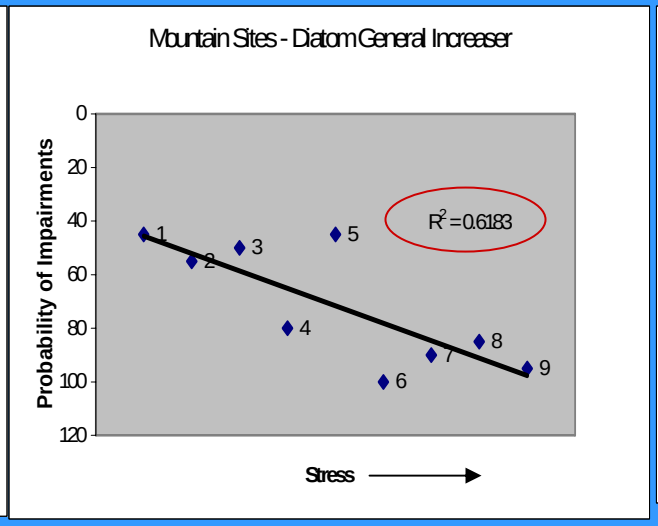
Multi-stressor / Biological-response Plots for Mountain Sites.

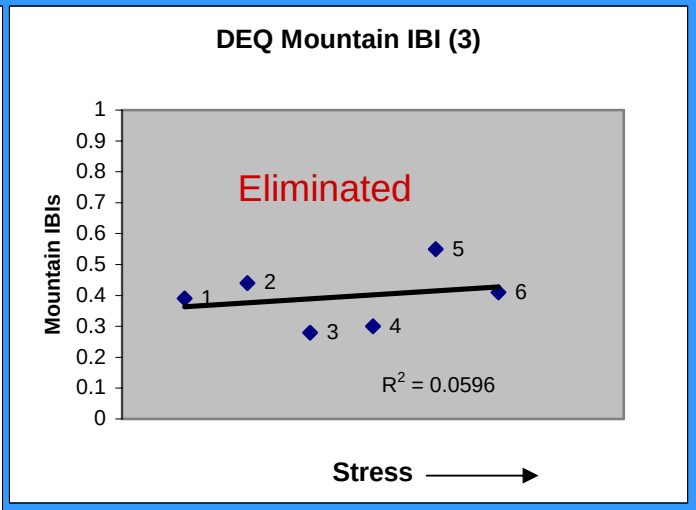






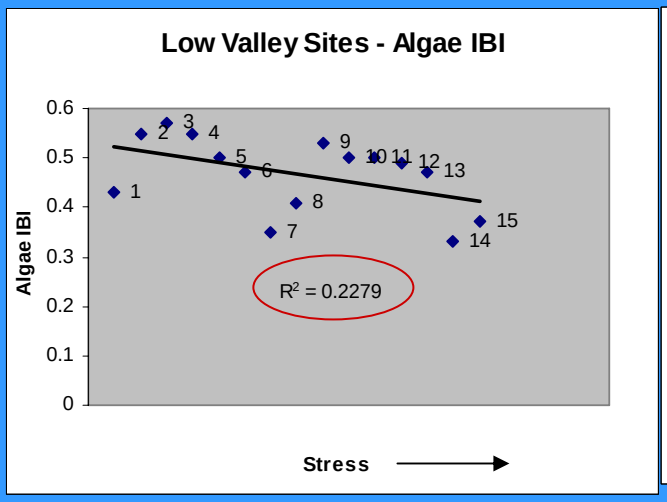


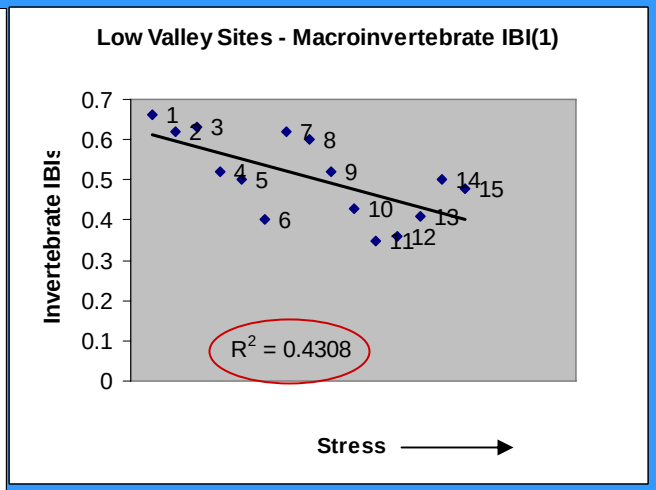


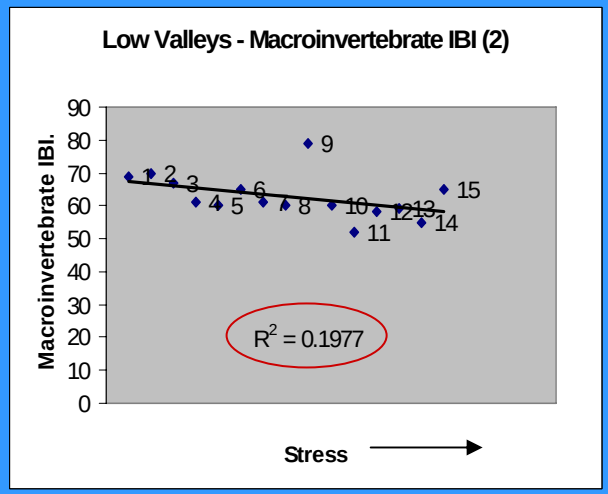


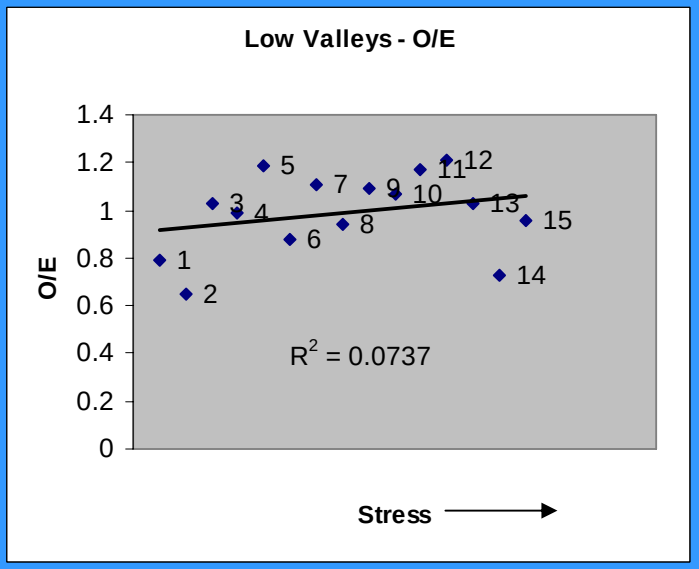
Each data point represents a mean for 3-5 samples

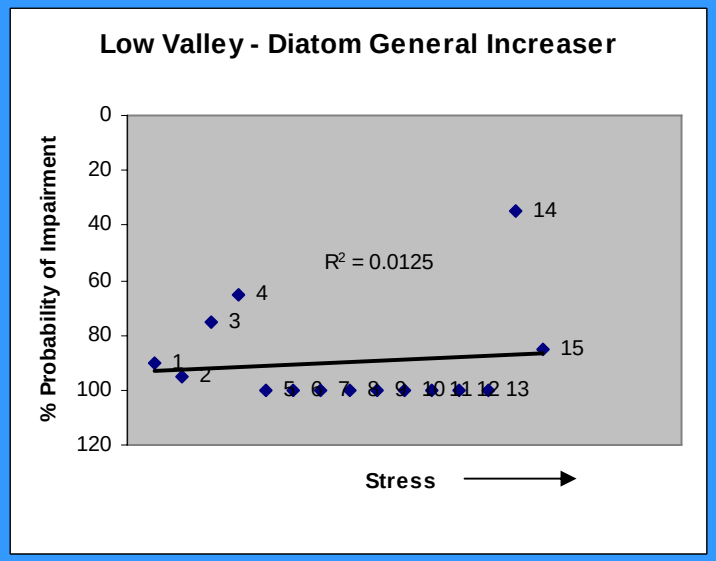
Multi-stressor / Biological-response Plots for Low Valley Sites











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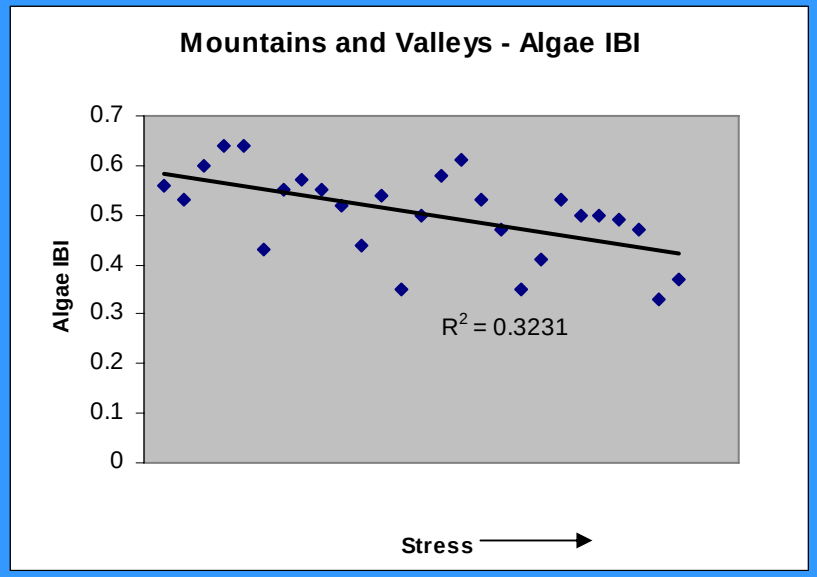
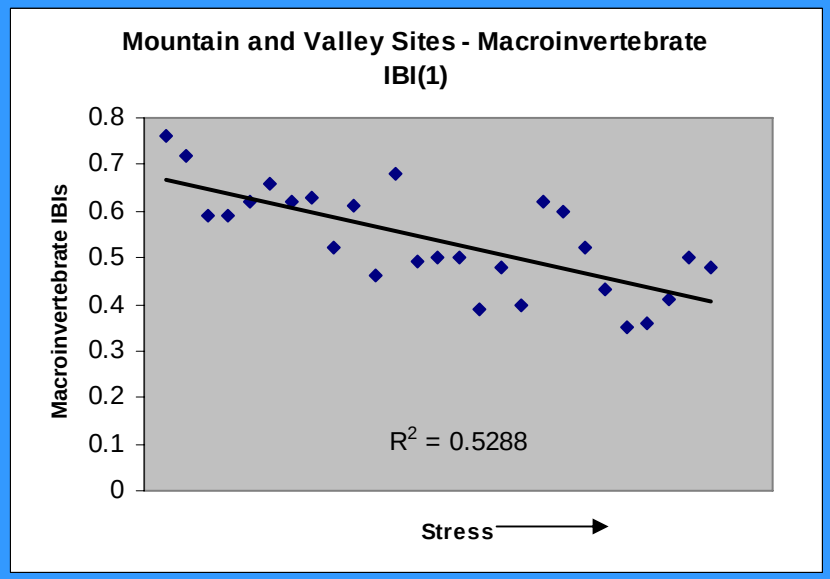
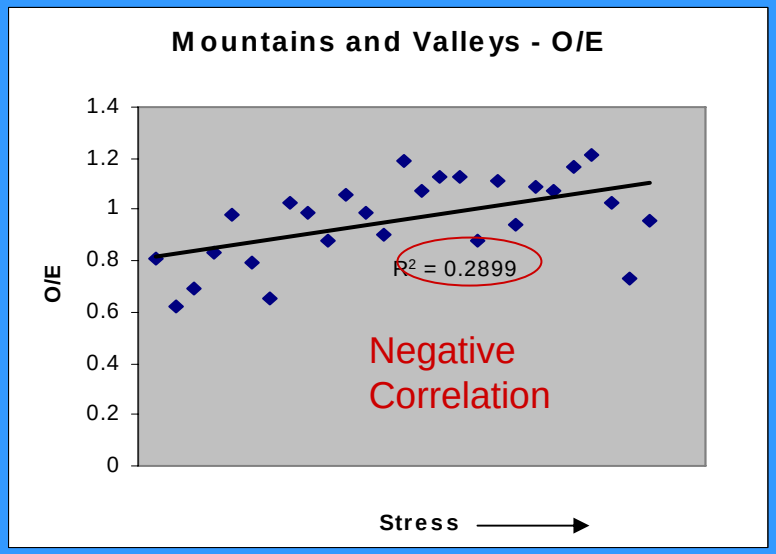
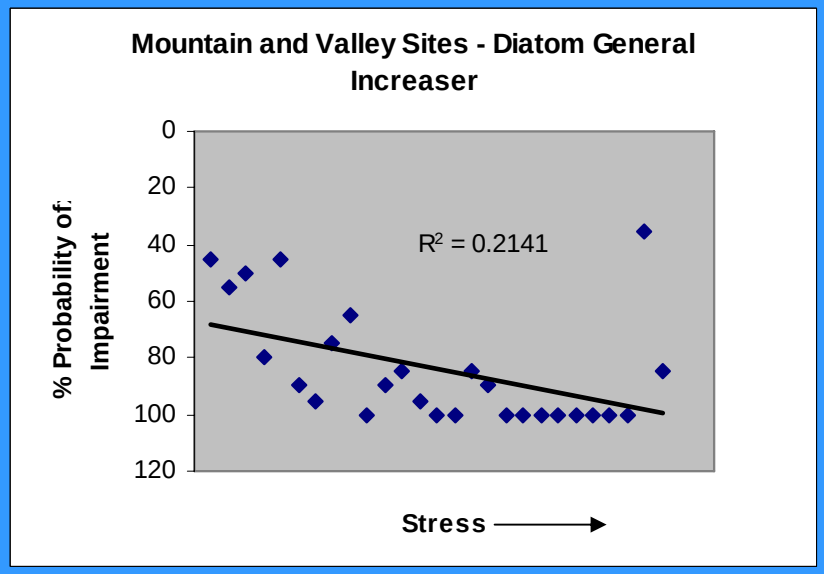
Multi-stressor / Biological-response Plots for Mountain and Valley Sites





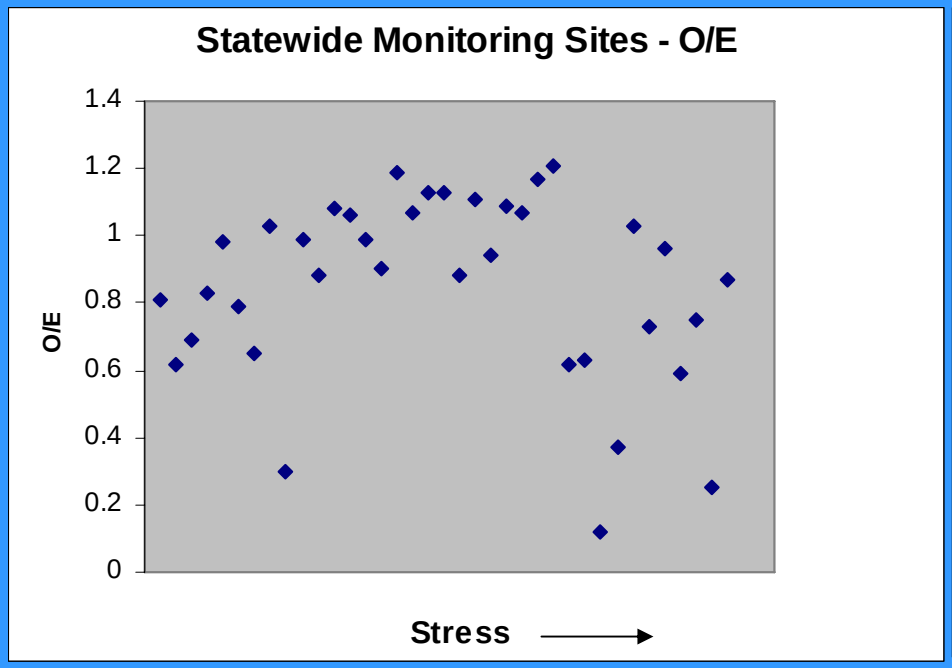


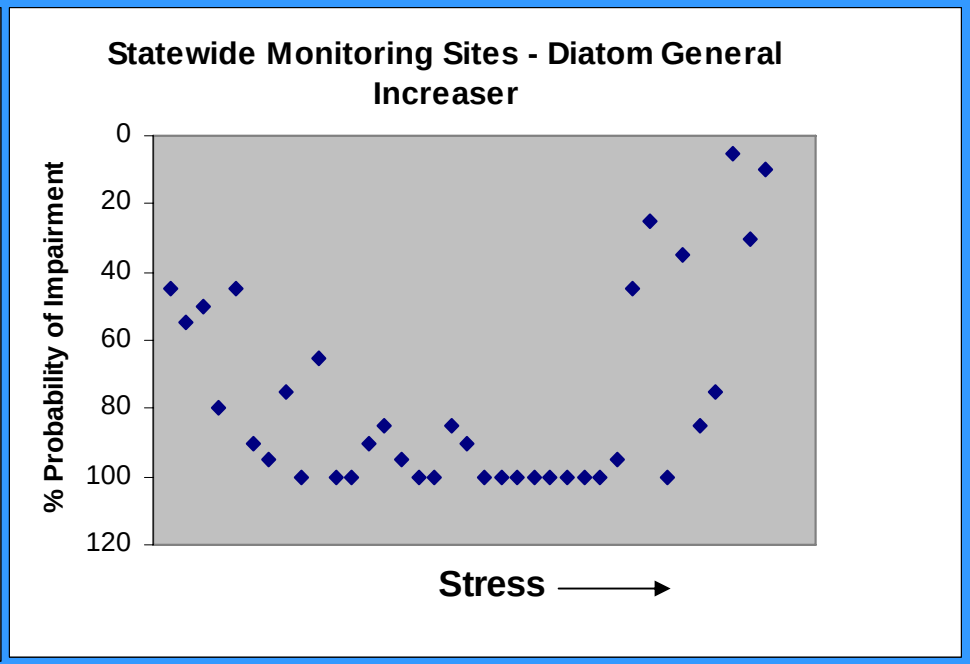


Each data point represents a mean for 3-5 samples

Multi-stressor / Biological-response Plots for all SWM Sites

(Includes Plains Ecoregion)



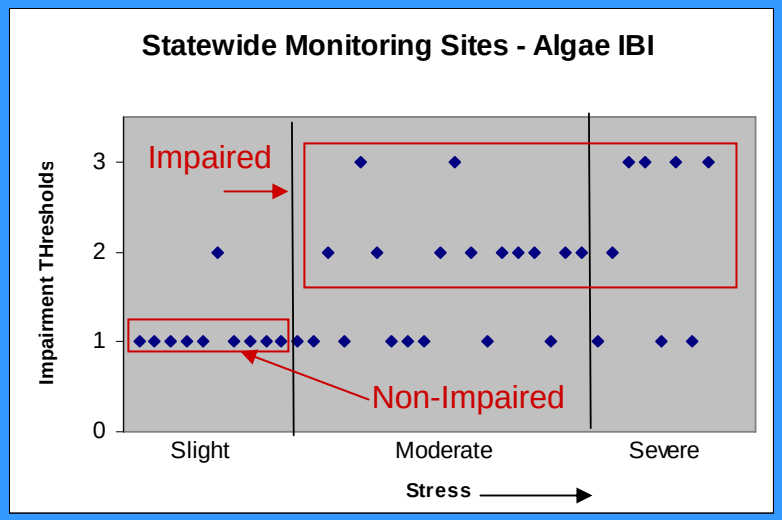


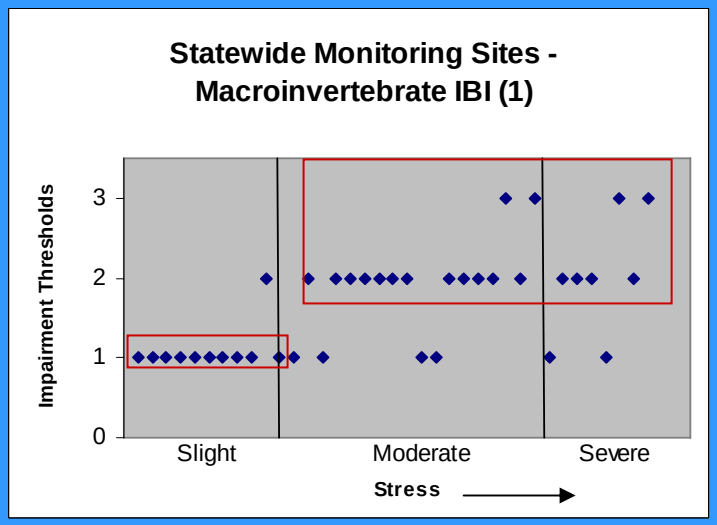
Non-linear Response

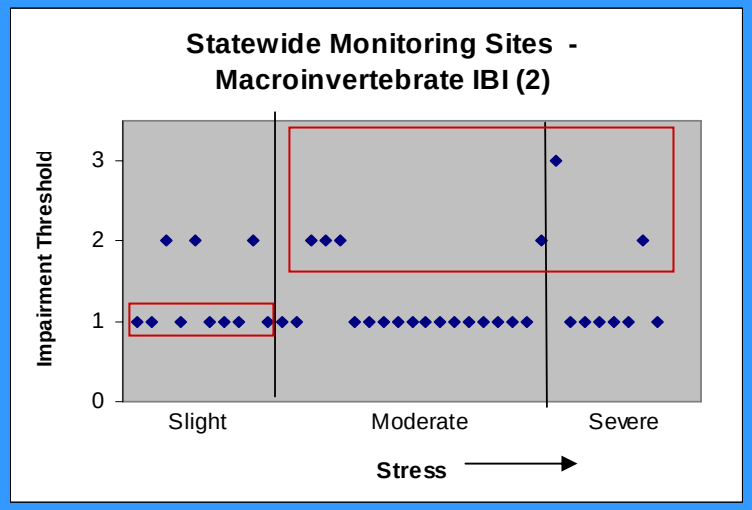
Each data point represents a mean for 3-5 samples

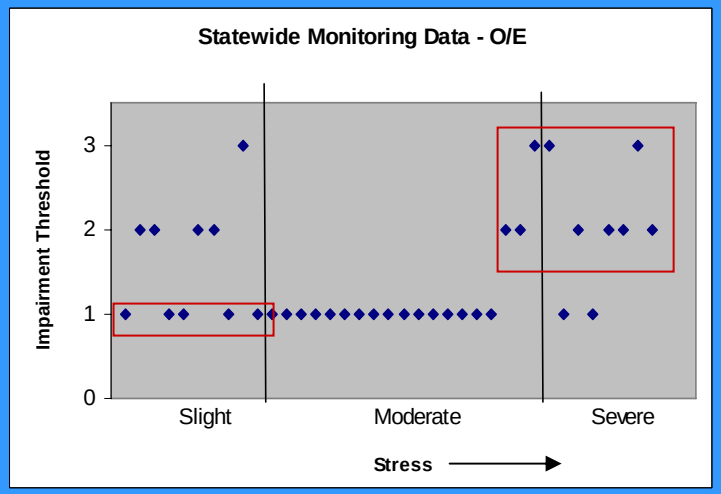
Evaluation of Biological Thresholds

Evaluation of Biological Impairment Thresholds
(plotted against multi-stressor gradient for all SWM sites)









1 = slight; 2 = moderate; 3 = severe

Estimating Confidence Levels for Mountain Sites

Evaluation of bioassessment models for mountain sites.		
Bioassessment models	Percent Agreement with Stressor Gradient (N=9)	Estimated Probability of Error
Diatom General Increasers	89% agree; Likely	11% Non-significant
Algae IBI	78% agree; Likely	22% Non-significant
Macroinvertebrate IBI (1)	78% agree; Likely	22% Non-significant
Macroinvertebrate IBI (2)	77% agree; Likely	22% Non-significant
O/E	33% agree; Most unlikely	67% Non-significant

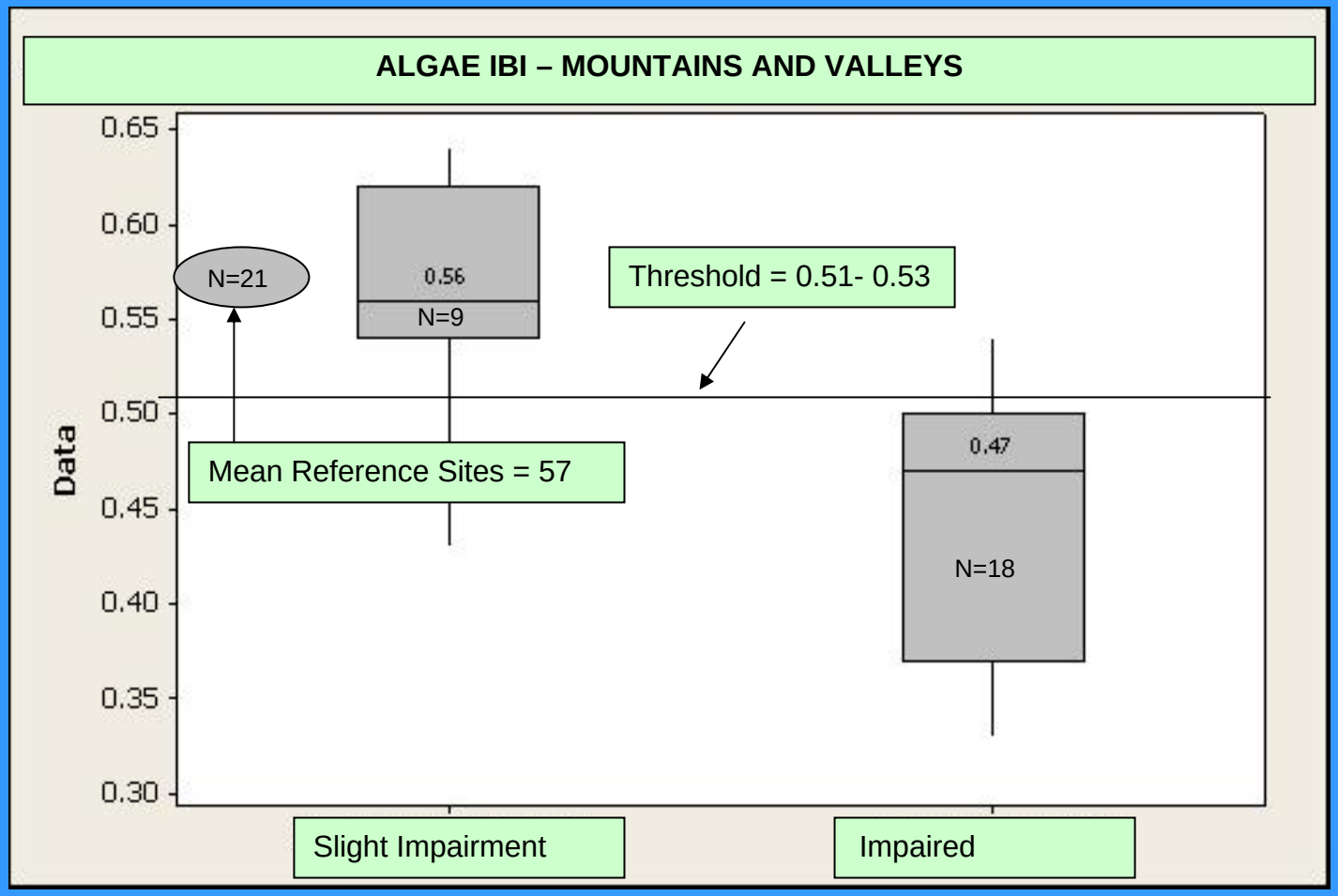
Evaluation of bioassessment models that agree for mountain sites.		
Bioassessment models	Percent Agreement with Stressor Gradient (N=9)	Estimated Probability of Error
Agreement between Algae and Macroinvertebrate IBI (1)	The models agree with each other at 100% of the sites; 78% of the models that agree with each other also agree with the stressor gradient; Likely	**5% Significant**
Agreement between Algae IBI, Macroinvertebrate IBI (1) and Diatom General Increasers	The models agree with each other at 67% of the sites; 100% of the models that agree with each other also agree with the stressor gradient; Very Likely.	1% Highly Significant
Agreement between O/E and Macroinvertebrate IBI (2)	The models agree with each other at 33% of the sites; 67% of the models that agree with each other also agree with the stressor gradient; Likely	15% Non-significant

Example of how the confidence Level was estimated when the biological models agreed:
e.g.: If two models errors are estimated to be 0.25 and 0.20 then the estimated error is: 0.25*0.20 = 5% when the models agree.

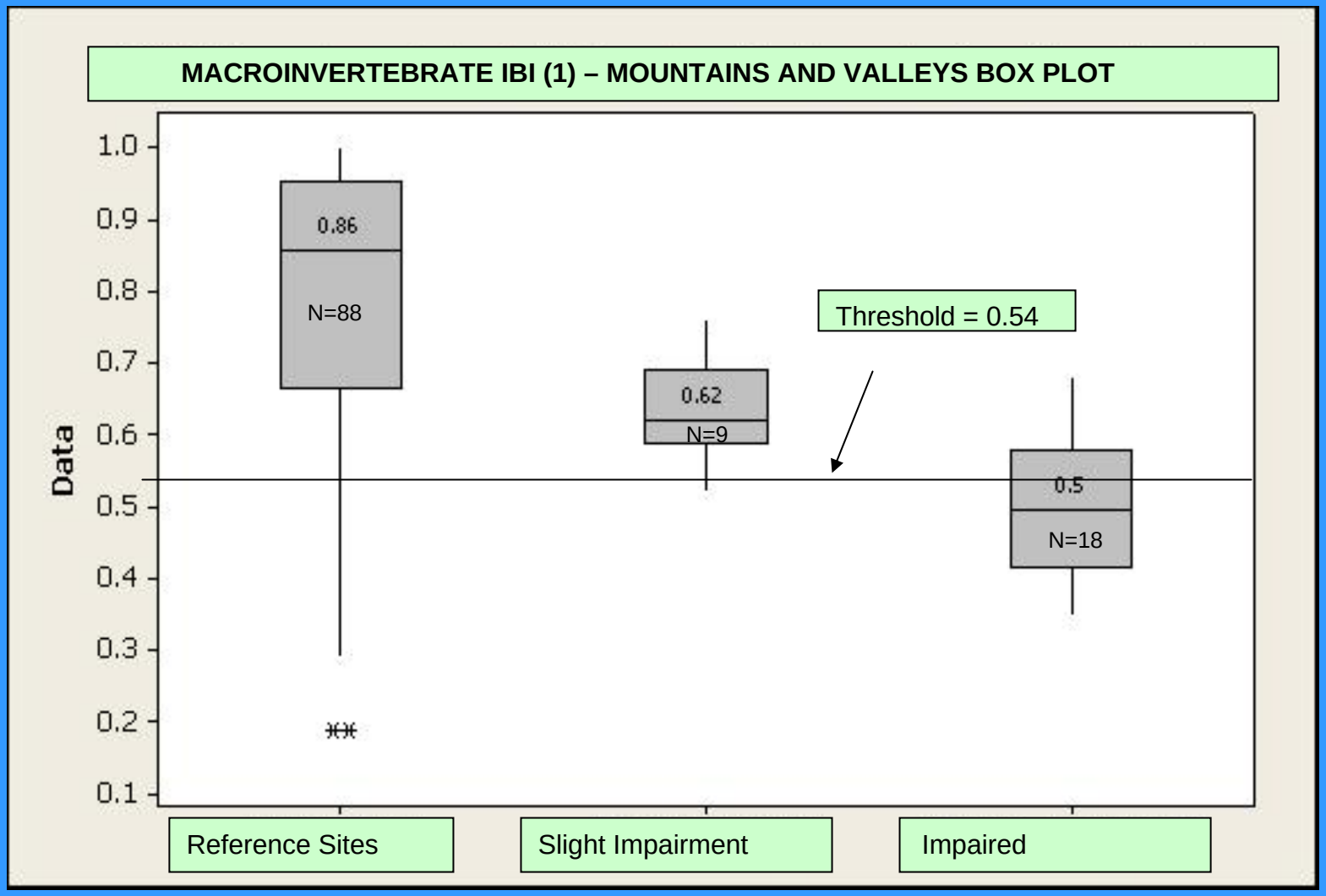
Estimating Confidence Levels for Valley Sites

Evaluation of bioassessment models for valley sites.		
Bioassessment models	Percent Agreement with Stressor Gradient (N=15)	Estimated Probability of Error
Diatom General Increasers	80% agree; Likely	20% Non-significant
Algae IBI	86% agree; Likely	14% Non-significant
Macroinvertebrate IBI (1)	80% agree; Likely	20% Non-significant
Macroinvertebrate IBI (2)	33% agree; Most unlikely	67% Non-significant
O/E	27% agree; Most unlikely	73% Non-significant

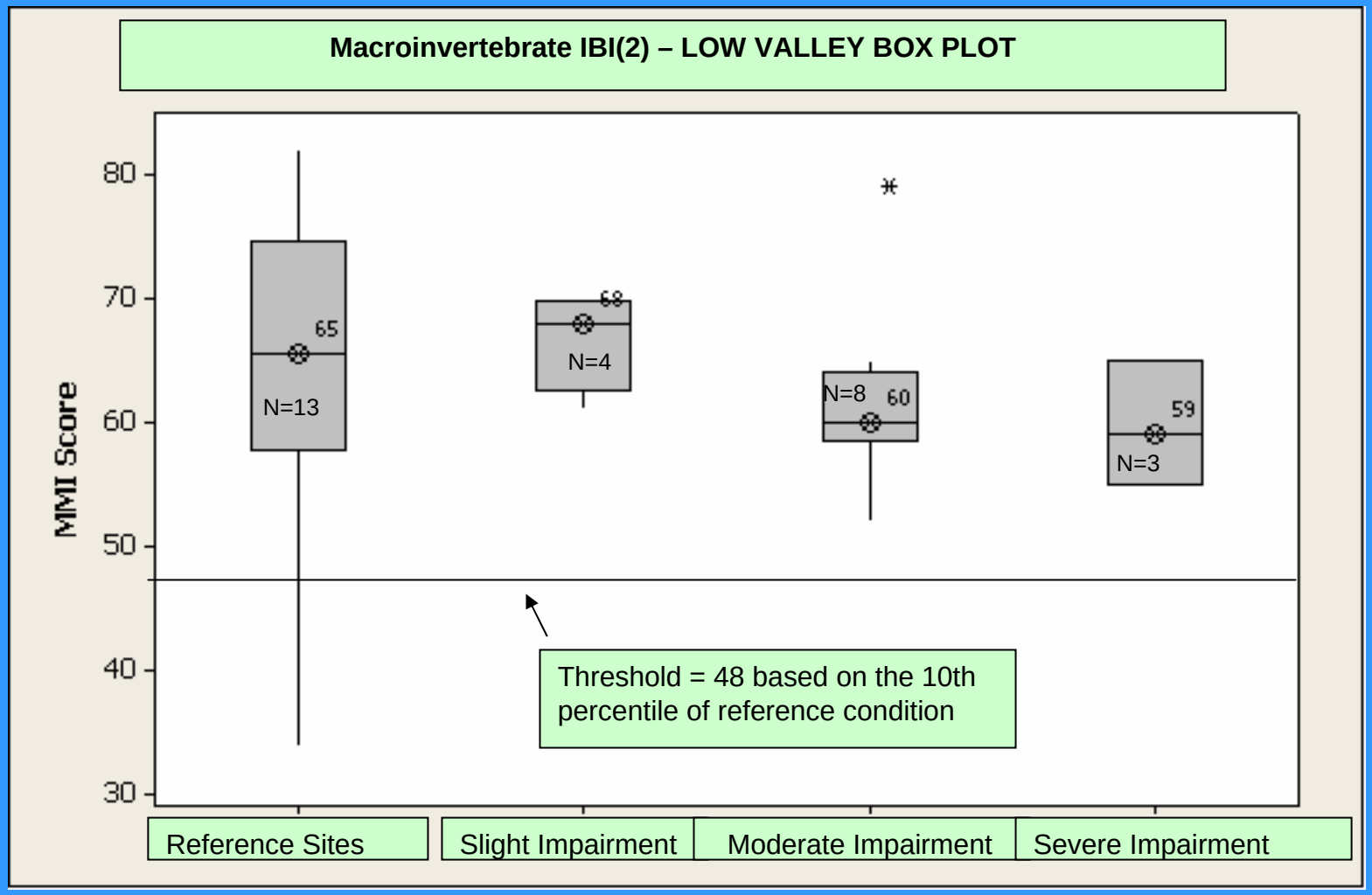
Evaluation of bioassessment models that agree for valley sites.		
Bioassessment models	Percent Agreement with Stressor Gradient (N=15)	Estimated Probability of Error
Agreement between Algae and Macroinvertebrate IBI (1)	The models agree with each other at 73% of the sites; 100% of the models that agree with each other also agree with the stressor gradient; Very Likely	**3% Significant**
Agreement between Algae IBI, Macroinvertebrate IBI (1) and Diatom General Increasers	The models agree with each other at 60% of the sites; 100% of the models that agree with each other also agree with the stressor gradient; Very Likely	1% Highly Significant
Agreement between O/E and Macroinvertebrate IBI (2)	The models agree with each other at 80% of the sites; 25% of the models that agree with each other also agree with the stressor gradient; Most unlikely	49% Non-significant



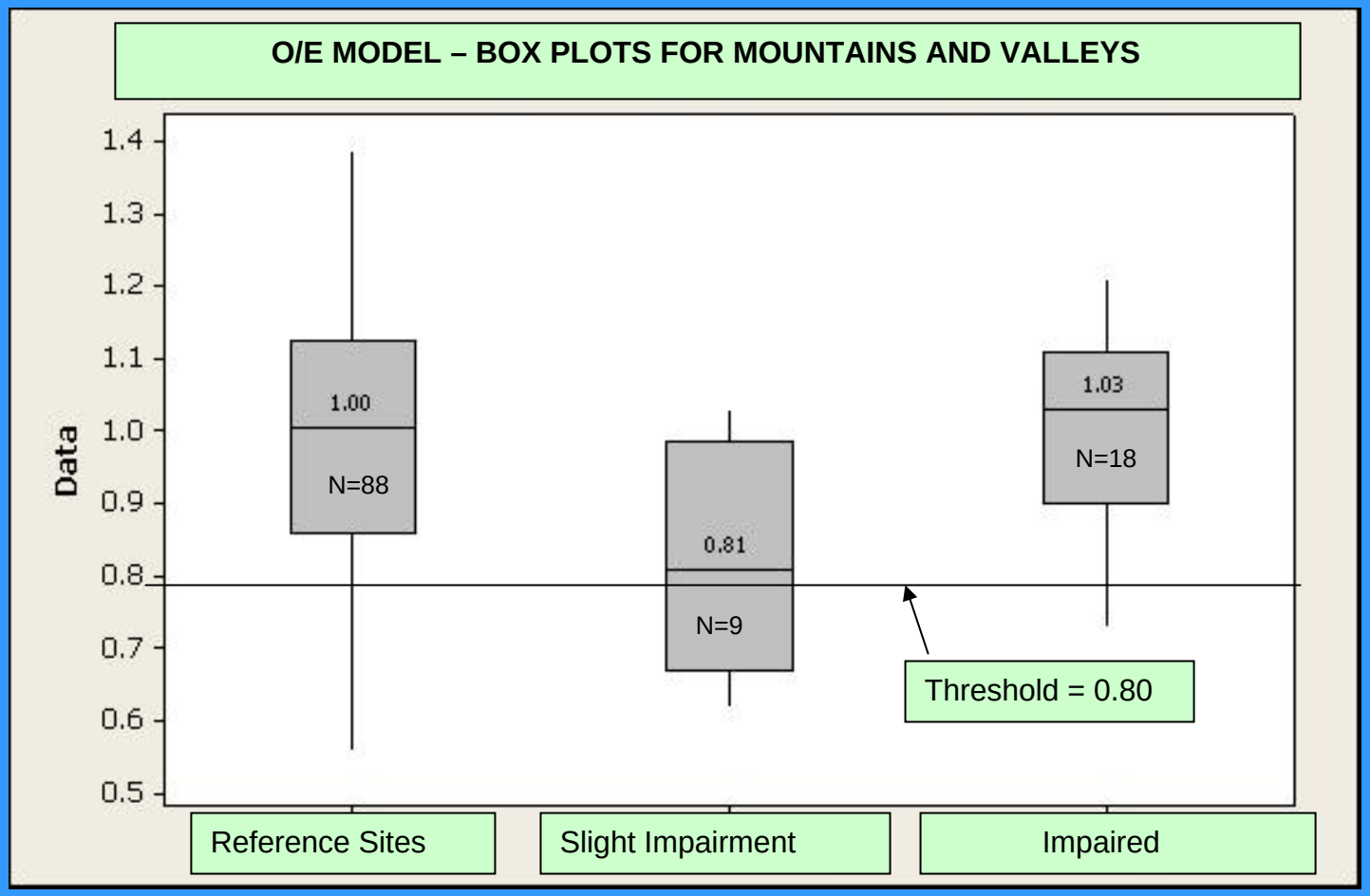
Algae IBI (1) box and whisker plots for mountain and valley sites.



Macroinvertebrate IBI box and whisker plots for mountain and valley sites.

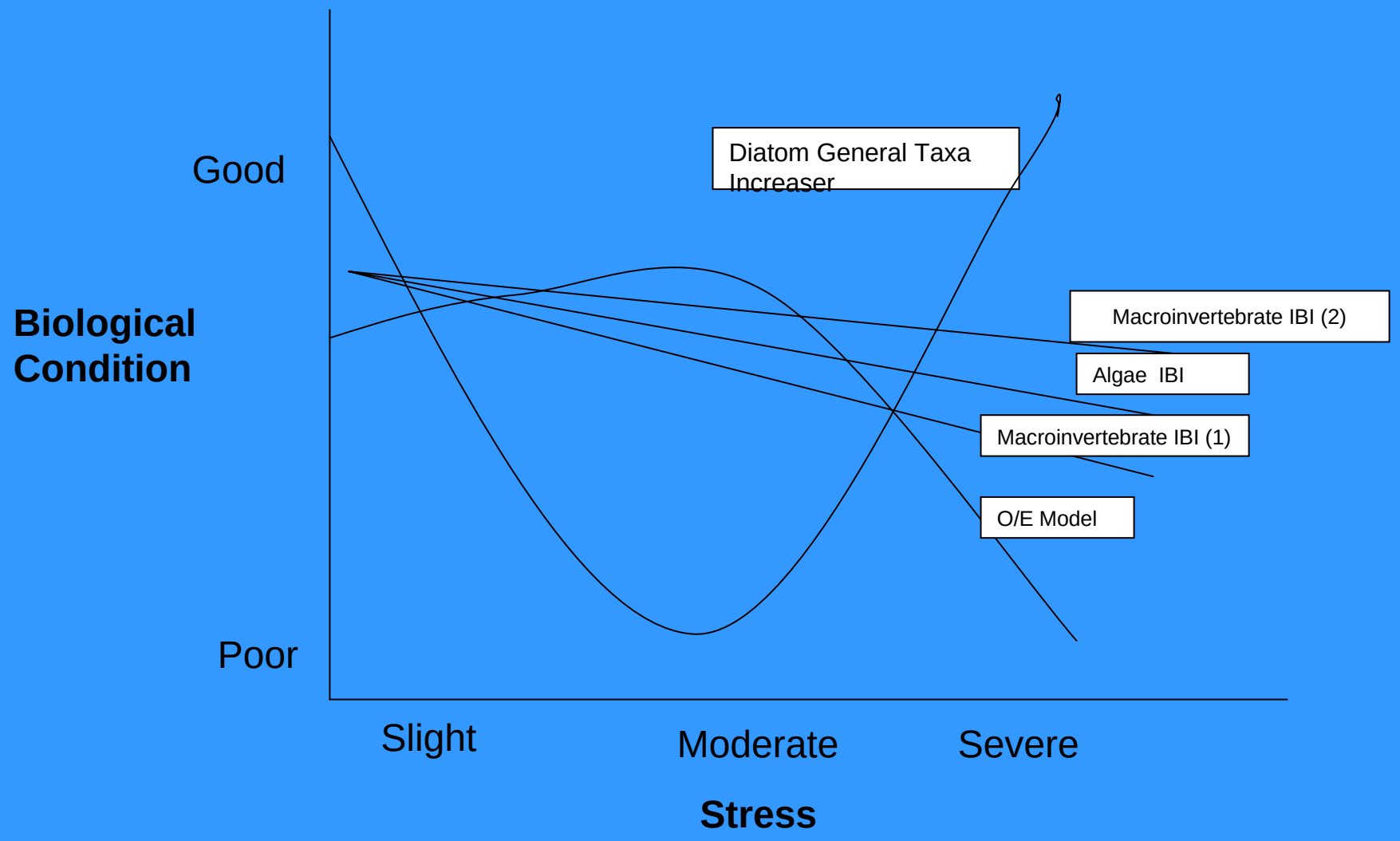


Macroinvertebrate IBI (2) box plots for low valleys.



O/E model box plots for mountains and valleys.

Biological Model Responses



Conclusions

- The algae IBI and macroinvertebrate IBI(1) agreed with each other and the multi-stressor gradient at approximately **70%** of the sites that were located in the mountains and valley ecoregions.

- The level of confidence was slightly improved when the “diatom general increaser taxa” model also agreed. This occurred at nearly **60%** of the sites.

- The level of confidence of all bioassessment models was low in the plains ecoregion.

- Conclusions are based on my assumption that the multi-stressor disturbance gradient is correct.