
Colorado EMAP Assessment and Report

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EMAP Program



- EMAP (Environmental Monitoring and Assessment Program) is a USEPA program.
 - A research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources.
 - The goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of current ecological condition.
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EMAP Objectives

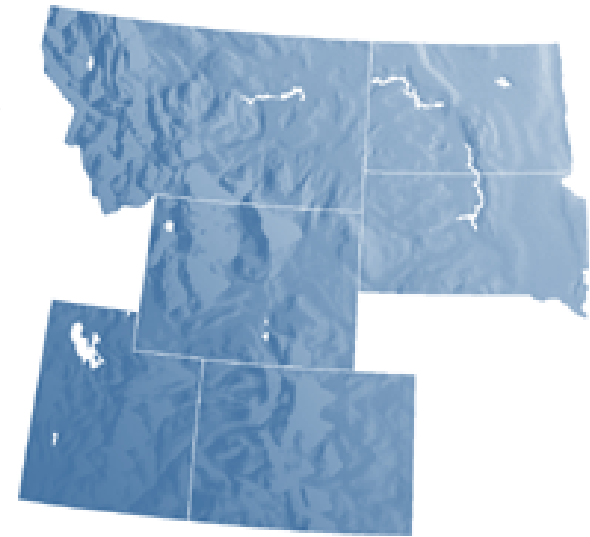


- Advance the science of ecological monitoring and ecological risk assessment.
- Guide national monitoring with improved scientific understanding of ecosystem integrity and dynamics.
- Develop and demonstrate indicators to monitor the condition of ecological resources.

EMAP Components



- EMAP-West - Regions 8, 9 and 10.
- EMAP-West's purpose is to demonstrate the value of the EMAP approach by applying it to environmental problems across a large and diverse geographical region, and to advance the science of ecosystem monitoring.
- Colorado falls in EPA Region 8.



EPA Region 8

Colorado EMAP Contributors

- Design
 - USEPA's Office of Research and Development
 - Implementation (field work)
 - Colorado Division of Wildlife (CDOW)
 - Bioassessment tool development
 - USEPA Region 8, CDOW, CWN (Colorado Watershed Network), USGS and CDPHE Water Quality Control Division (WQCD)
 - Assessment
 - CDPHE WQCD
 - Report
 - CDPHE WQCD
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Presentation Focus

- Design
 - USEPA's Office of Research and Development
 - Implementation
 - Colorado Division of Wildlife (CDOW)
 - **Bioassessment tool development**
 - USEPA Region 8, CDOW, CWN (Colorado Watershed Network) and CDPHE Water Quality Control Division (WQCD)
 - **Assessment**
 - CDPHE WQCD
 - **Report**
 - CDPHE WQCD
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Colorado EMAP Study Components

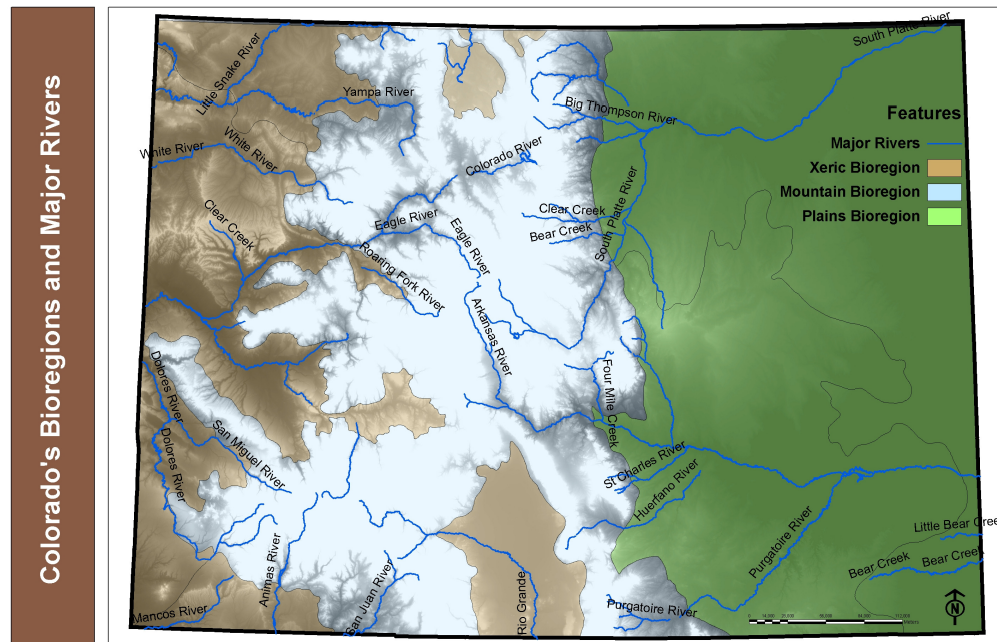
- Data sources and bioregions
 - Reference site determination and uses
 - Bioassessment tool development
 - Stressors
 - Threshold determination
 - Ecological condition
 - Relative risk
 - Discussion of condition
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Data Sources

- Fish
 - Data collected at 91 sites throughout Colorado during EMAP-West project.
 - Periphyton
 - Data collected from 91+ sites, including 69 reference sites from CO, UT and WY.
 - Macroinvertebrates
 - Data from Colorado's EDAS (Ecological Data Application System) database including datasets from:
 - USEPA EMAP-West and USEPA Southern Rockies Regional EMAP
 - Utah State University Science to Achieve Results Program (STAR)
 - USGS NAWQA
 - CDPHE monitoring program
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Bioregions

- Plains, mountains and xeric
- A representation of naturally occurring environmental gradients in the State of Colorado.



Reference Site Determination

- An *a priori* approach used in site classification and establishment of reference condition.
 - Foundation for development and calibration of indices and models.
 - Different criteria used to determine reference for each set of bioassessment tools.
 - Macroinvertebrate tools – Used blend of State WQ Stds, USEPA ORD and WQ Stds from WY and MT.
 - Fish tool – Used USEPA ORD criteria and individually examined by those with specific knowledge of those sites.
 - Periphyton tool – USEPA ORD
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Use of Reference Sites

- Used jointly with stressed sites to determine which metrics provide the most discrimination efficiency.
 - Determine the number of expected taxa at each site (applies to multivariate predictive model).
 - When used in conjunction with observed taxa results in unit-less score associated with taxa loss.
 - Set thresholds for scores from all the bioassessment tools.
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Bioassessment Tool Development

- Developed a series of bioassessment tools for assessing biological condition.
 - Fish – Index of Biological Integrity (IBI)
 - Periphyton – IBI
 - Macroinvertebrates – Multimetric Index (MMI), Multivariate Predictive Model (O/E model)
 - Fish and periphyton IBI's developed within CO-EMAP project.
 - Macroinvertebrate MMI and O/E model developed separately by Tetra Tech, Inc. and Dr. Charles Hawkins of Utah State University, respectively.
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Bioassessment Tool Development

- Fish

- Workshops in July '05 and June '06.
 - 761 autecology metrics compiled from species counts.
 - Autecology metrics = fish preferences and habits
 - Boxplots used to discern Discrimination Efficiency (DE)
...DE's > 75% retained for further evaluation.
 - Metrics categorized based on a series of habits, tolerances and preferences to ensure inclusion of each facet of the biological community that was potentially responsive to disturbance.
 - Process resulted in creation of IBI's for plains and xeric bioregions.
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Bioassessment Tool Development

- Fish

■ Final Fish IBI Metrics

□ Plains bioregion

- Number of nonnative individuals
- % of species that are native herbivores
- % of hider individuals
- % of native species that are long-lived and tolerant to sediment
- % of native individuals that prefer warm-water habitats
- Number of individuals that are benthic and tolerant to sediment

□ Xeric bioregion

- Number of individuals of intermediate tolerance to nutrients and prefer cool water habitat
 - % of hider individuals
 - % of long-lived species with intermediate tolerance to sediment
 - % of species that are lithophilic
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Bioassessment Tool Development

- Periphyton

- IBI workshop occurred in January 2007.
 - 250 diatom metrics assembled from five categories.
 - Data from UT and WY also used.
 - Plains data from CO and WY pooled and randomly split into calibration and test sets.
 - Xeric data from CO and UT pooled and randomly split into calibration and test sets.
 - Mountains data from WY/UT used for calibration set and CO used for test set.
 - Metric screening process similar to Fish IBI process.
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Bioassessment Tool Development

- Periphyton

■ Final Periphyton IBI Metrics

□ Plains

- Cymbella Richness
- Cymbella Percent taxa
- Van Dam (et al. 1994) Trophic Class 5&6 Number of Individuals
- Van Dam (et al. 1994) Oxygen Class 1 Percent Taxa

□ Mountains

- Navicula Richness
 - Cymbella/(Cymbella+Navicula) Percent Taxa
 - Bahls (2004) Mod. & Highly Motile Number of Individuals
 - Van Dam (et al. 1994) Trophic Class 5&6 Richness
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Bioassessment Tool Development

- Periphyton

- Final Periphyton IBI Metrics cont.
 - Xeric
 - Navicula Richness
 - Achnanthes Percent of Individuals
 - Bahls (2004) Mod. & Highly Motile Number of Individuals
 - Van Dam (et al. 1994) Trophic Class 1&2 Percent Taxa



Bioassessment Tool Development

- Macroinvertebrates MMI

- MMI developed by Tetra Tech, Inc. in 2005 as part of a 319 grant project.
 - Different reference criteria = different reference sites
 - Reference sites by bioregion:
 - Mountains, n=77
 - Plains, n=6
 - Xeric, n=4
 - Candidate metrics drawn from five categories.
 - Richness, composition, pollution tolerance, functional feeding group and habit (locomotion)
 - Metric screening process similar to Fish IBI process.
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Bioassessment Tool Development

- Macroinvertebrates MMI

■ Final macroinvertebrate MMI metrics

□ **Plains**

- % Chironomidae
- EPT Taxa
- Hilsenhoff Biotic Index
- % Burrowers
- % Predators

□ **Mountains**

- % Oligochaeta
- Total Taxa
- % Climbers
- % Trichoptera which are Hydropsychidae

□ **Xeric**

- % Coleoptera
 - Diptera Taxa
 - % Dominant Taxa
 - % Climbers
 - Predator Taxa
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Bioassessment Tool Development

- Macroinvertebrates O/E

- RIVPACS (River Invertebrate Prediction and Classification System) assessments determine biological condition by estimating the taxonomic completeness of a standard sample.
 - O/E model describes which taxon are predicted to naturally occur at a site (E) versus which taxon were actually collected by sampling the site (O).
 - “E” is the sum of the probabilities of capture for each taxa.
 - Model output is a number from 0 to 1.
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Bioassessment Tool Development

- Macroinvertebrates O/E

- Developmental steps
 - See pg. 18 of CO-EMAP report
 - 97 reference sites used.
 - 173 OTU's (Organized Taxonomic Units) used to biologically classify sites for the model.
 - 32,767 discriminate models evaluated in order to determine which metric combination maximized precision and minimized bias for each predictor variable.
 - Only map-derived variables were utilized.
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Bioassessment Tool Development

- Macroinvertebrates O/E

- O/E Model Predictor Variables
 - Longitude (decimal degrees)
 - Mean annual air temperature ($^{\circ}\text{C} \times 10$)
 - Log watershed area (km^2)



Stressors

- Ecological stressors examined to assess the direct impacts to stream biota.
 - Water quality and physical habitat characteristics were analyzed to determine which stressors were most influential towards each biological assemblage.
 - Allowed calculation of Relative Risk for each stressor parameter.
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Stressors

- Chemical Stressors
 - Total phosphorus ($\mu\text{g/L}$)
 - Total nitrogen ($\mu\text{g/L}$)
 - Chloride ($\mu\text{eq/L}$)
 - Sulfate ($\mu\text{eq/L}$)
 - Closed headspace pH
 - Physical Habitat Stressors
 - Mean bank canopy density (%)
 - Riparian Disturbance – Sum of all types
 - Turbidity (NTU)
 - Log 10 of Relative Bed Stability
 - Substrate fines – silt/clay/muck (%)
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Thresholds

- Thresholds are necessary in order to classify streams based on level of disturbance.
 - Types
 - Biological indicator thresholds (discussed here)
 - Ecological stressor thresholds
 - Disturbance Classifications
 - Least disturbed
 - Moderately disturbed
 - Most disturbed
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Thresholds

- Biological Indicator Thresholds

- Fish IBI

- Thresholds set at 25th and 5th percentiles of reference site scores
 - Plains and Xeric bioregions only
 - Only 4 Xeric reference sites – incorporated UT/WY reference sites into threshold determination

- Macroinvertebrate MMI and O/E

- Thresholds set at 25th percentile of ALL statewide reference site scores and at the mean of all remaining sites below the 25th percentile of ref sites
 - Each score weighted using percentage of disturbed land cover within 1 km radius around site

- Periphyton IBI

- Same as Macroinvertebrate method
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Thresholds

- Disturbance Class Thresholds

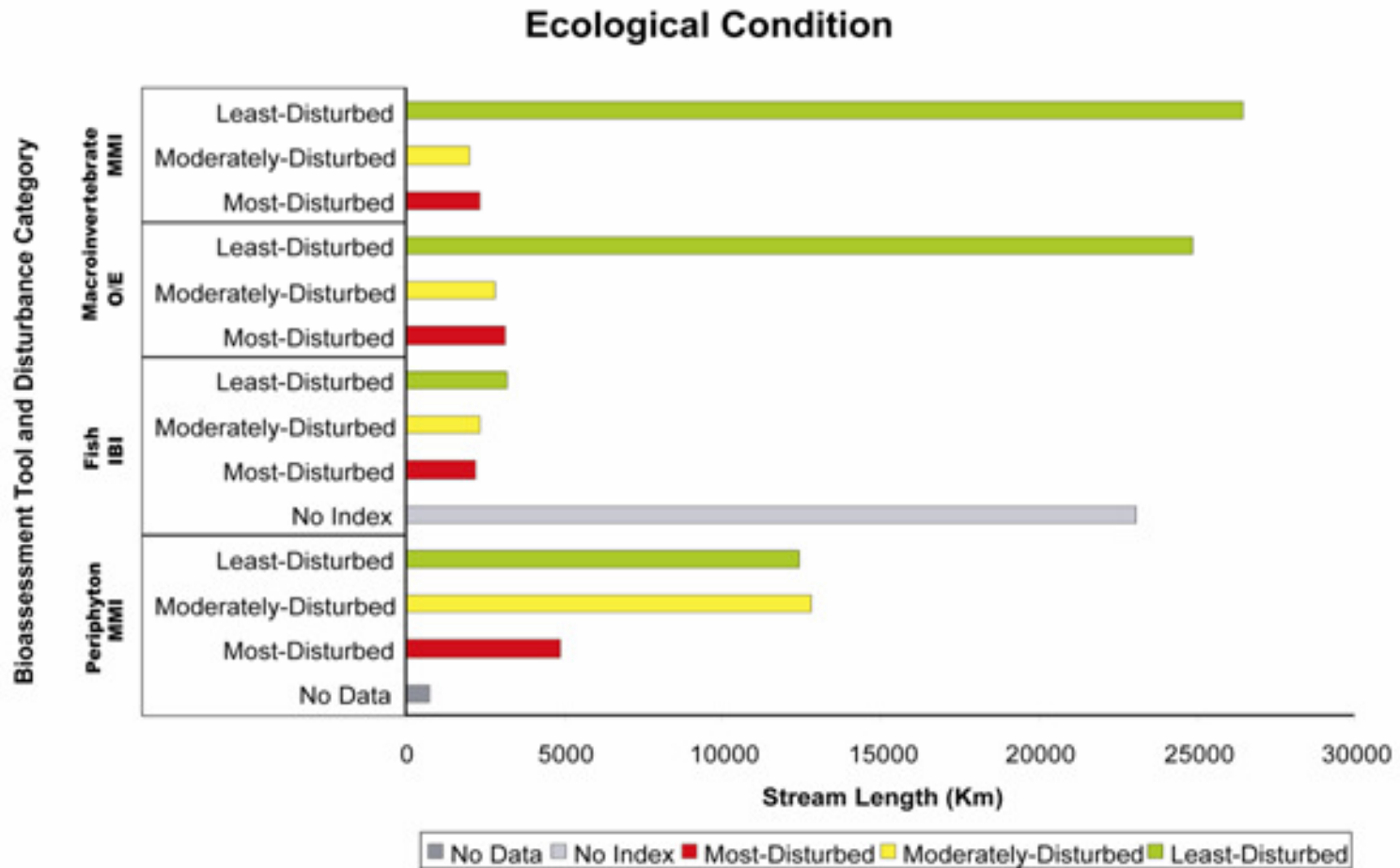
Index	Least-Moderate	Moderate-Most
MMI	55.76	43.02
OE	0.69	0.57
IBI_X	52.21	41.56
IBI_P	66.76	28.79
Periphyton	51.10	25.00

X = Xeric, P = Plains

Ecological Condition

- Ecological condition was reported for only 67 sites that fell within the probability design of the EMAP study.
 - Each of the 67 sites represented a given number of stream miles.
 - Stream miles then totaled for sites representing each disturbance class for each bioassessment tool.
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Ecological Condition



Stressor Condition

- Stressors were ranked using screening criteria developed by USEPA's ORD.
 - Criteria only applied to the 67 probability sites; stream lengths then totaled.
 - Stressors ranked based on proportion of stream length that fell in the most-disturbed class.
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Stressor Extent

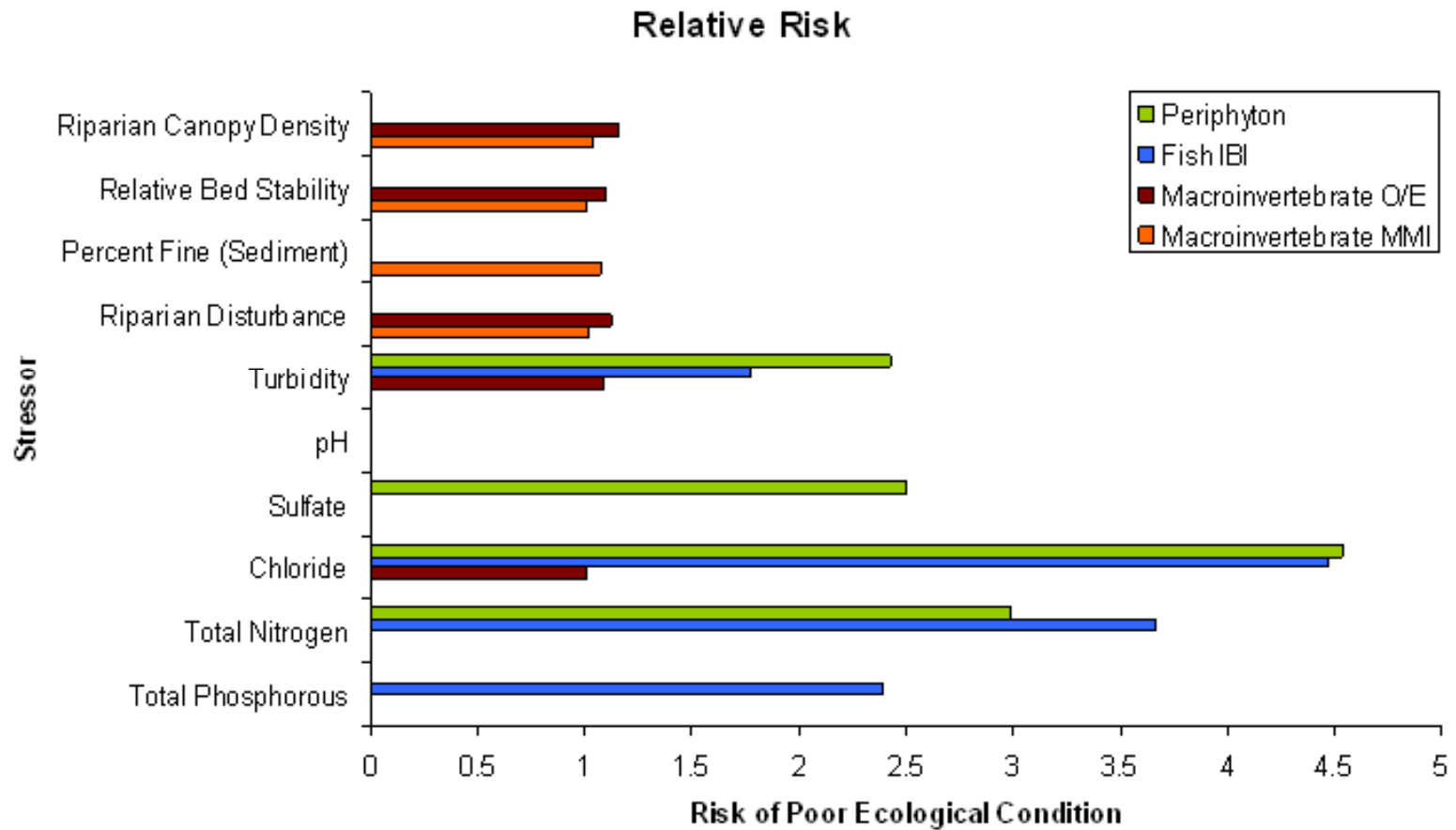
- Results:
 - Turbidity, Total P and Sulfate most widespread stressors in State.

Colorado EMAP Sites		Chemical/Physical Habitat Parameter									
Chemical/Physical Habitat		P	N	CL	SO4	pH	Turbidity NTUs	Riparian Disturbance	Fines %	Relative Bed Stability	Canopy Density
Stressor Extent		ug/L	ug/L	ueq/L	ueq/L						
Disturbance Rank (Most to Least)		2	5	4	3	10	1	7	6	9	8
Reach Length (Km)	Least-Disturbed	24196	29100	27079	20132	30827	7053	20373	22390	25450	21045
	Mod-Disturbed	5109	807	1605	7224		1077	6984	4443	1021	6331
	Most-Disturbed	1521	919	942	1401		1524	376	901	300	357
	No Std				2070		21173			105	
	No Data			1201				3094	3094	3951	3094
Total Length Km		30827	30827	30827	30827	30827	30827	30827	30827	30827	30827
Disturbed Length %	Least-Disturbed	78%	94%	88%	65%	100%	23%	66%	73%	83%	68%
	Mod-Disturbed	17%	3%	5%	23%		3%	23%	14%	3%	21%
	Most-Disturbed	5%	3%	3%	5%		5%	1%	3%	1%	1%
	No Std applied				7%		69%				
	No Data			4%				10%	10%	13%	10%

Relative Risk

- What is Relative Risk?
 - Comparison of biological and stressor condition at sites where both parameters were assessed.
 - Values are derived from calculations that compare proportions of stream length that are classified as Least or Most disturbed at a single site.
 - Calculation output value = risk of having a poor biological condition when a poor ecological condition exists.
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Relative Risk



Discussion of Condition

- Findings:
 - Streams statewide found to be in good condition.
 - Three groups of localized degradation.
 - Where the South Platte River flows out of the Denver metro area
 - Lower Arkansas River
 - Colorado River near Utah border
 - Scores between MMI, IBI and O/E tools exhibited poor correlation.
 - 6% of sites were designated in the same disturbance class by all four indicator tools.
 - 21% of sites showed agreement between three indicator tools.
 - 62% of sites exhibited agreement when only Macroinvertebrate MMI and O/E tools examined.
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Areas of Improvement

- Improvements:
 - Bioassessment tool refinement
 - Inclusion of additional index metrics to lessen emphasis on richness and composition metrics and add highly specialized and sensitive species
 - More accurate reference site determinations
 - BPJ may have led to erroneous *a priori* site classifications in Fish IBI
 - Continued sampling of streams statewide
 - As additional reference and stressed sites are added, metric DE and threshold designation can be re-evaluated
 - Additional reference sites in Mountains bioregion may lead to the development of a Fish IBI for that region
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Outcomes

- Outcomes:
 - Fish and periphyton IBI's developed
 - Useful in monitoring and assessing streams statewide
 - Improved data management tools and programs
 - Allow the State to make rapid assessments of sites
 - Determine ecological condition based on a single sample with some degree of confidence
 - Allow regulators to focus on stream segments where ecological conditions are poor
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References

- Bahls, L. 2004. Diatom biocriteria for Montana streams. Montana Department of Environmental Quality.
 - Van Dam, H., Mertens, A., and Sinkeldam, j. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28:117-133.
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Sources of Information

- CO-EMAP Report
 - <http://www.cdphe.state.co.us/wq/watershed>
 - USEPA EMAP home page
 - <http://www.epa.gov/emap>
 - Development of Biological Assessment Tools for Colorado
 - http://www.cwqf.org/Workgroups/Content/Aquatic_Life/Documents
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Acknowledgements

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