Ecological Integrity Assessment: An Approach for Assessing Ecosystem Condition to Guide Conservation and Management

Ecological Integrity

" the ability of an ecosystem to support and maintain a balanced adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region"*

- Reference condition implicit (i.e. “natural” habitats)

“an ecosystem having the full range of organisms and ecological processes expected with no or minimal human influence.” **

- Reference condition explicit (i.e. no or minimal human influence)

*Karr J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Manager 5:55-68.

**EPA 2005. Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards: Tiered Aquatic Life Uses – August 10, 2005 (EPA-822-R-05-001)

Reference Condition

- Very important to define
  - Restoration targets & ecological assessment are anchored to this definition
- Not necessarily what the ecosystem *should* be, rather the state that is *valued*
- Natural Range of Variability
  - temporal and spatial range of ecosystem processes under which contemporary ecosystems evolved
  - includes historical, human activities
  - can be difficult to empirically describe

*Stoddard, J.L., D.P. Larsen, C.P. Hawkins, R.K. Johnson, and R.H. Norris. 2006. Setting Expectation for the Ecological Condition of Streams: The Concept of Reference Condition. Ecological Applications 16(4): 1267-1276.


What is an Ecological Integrity Assessment?

What is an EIA?

- Multi-metric index of ecological integrity
- Ratings are based on deviation from natural range of variability
- Metrics are rated and integrated into an overall assessment of ecological integrity
- Scores/Ratings are produced for the following categories:

Landscape Context	Biotic Condition
Abiotic Condition	Size

= Ecological Integrity

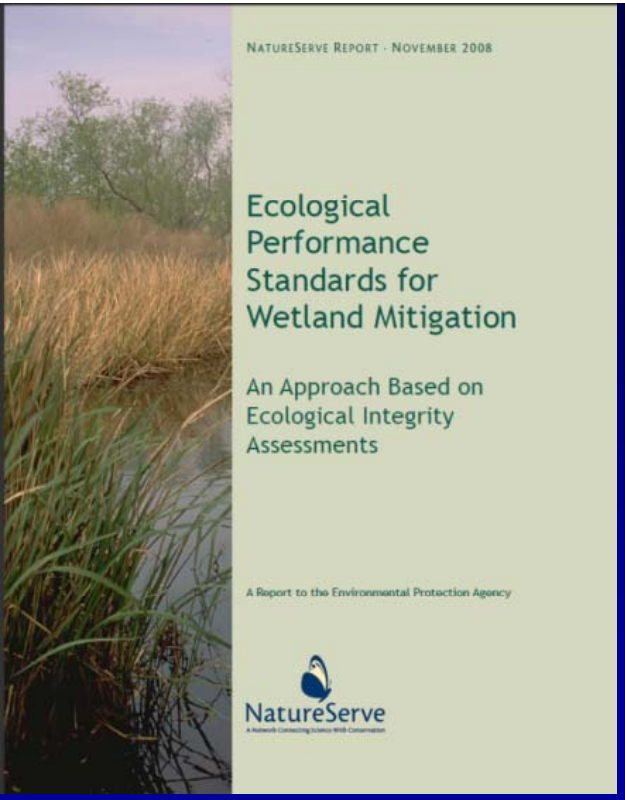
- Results communicated in a Scorecard format

What is an EIA? (cont.)

- NatureServe Ecological System Classification
- EIA is part of Natural Heritage Network Methodology
- Builds on other assessment tools
- Can be applied as Remote/Rapid/Intensive assessment

Practicalities of Measurement

Level 1 – Remote Assessment	Level 2 – Rapid Field Assessment	Level 3 – Intensive Assessment
General description: Landscape condition assessment	**General description:** Rapid site condition assessment	**General description:** Detailed site condition assessment
Evaluates: Condition of individual areas/occurrences **using** remote sensing indicators	**Evaluates:** Condition of individual areas/occurrences **using** relatively simple field indicators	**Evaluates:** Condition of individual areas/occurrences **using** relatively detailed quantitative field indicators
Based on: •GIS and remote sensing data •Layers typically include: –Land cover / use –Other ecological types	**Can be based on:** •Stressor metrics (e.g., ditching, road crossings, and pollutant inputs); and •Condition metrics (e.g., hydrologic regime, species composition)	**Can be based on:** •Indicators that have been calibrated to measure responses of the ecological system to disturbances (e.g., indices of biotic or ecological integrity)
Potential uses: •Identifies priority sites •Identifies status and trends of acreages across the landscape •Identifies condition of ecological types across the landscape •Informs targeted restoration and monitoring	**Potential uses:** •Promotes integrated scorecard reporting •Informs monitoring for implementation of restoration or management projects •Supports landscape / watershed planning •Support s general conservation and management planning	**Potential uses:** •Promotes integrated scorecard reporting •Identifies status and trends of specific occurrences or indicators •Informs monitoring for restoration, mitigation, and management projects



Regional Models

National Models for Wetlands (mitigation)

Rocky Mountain Subalpine-Montane Riparian Shrublands Ecological System

October 21, 2005

Ecological Integrity Scorecard

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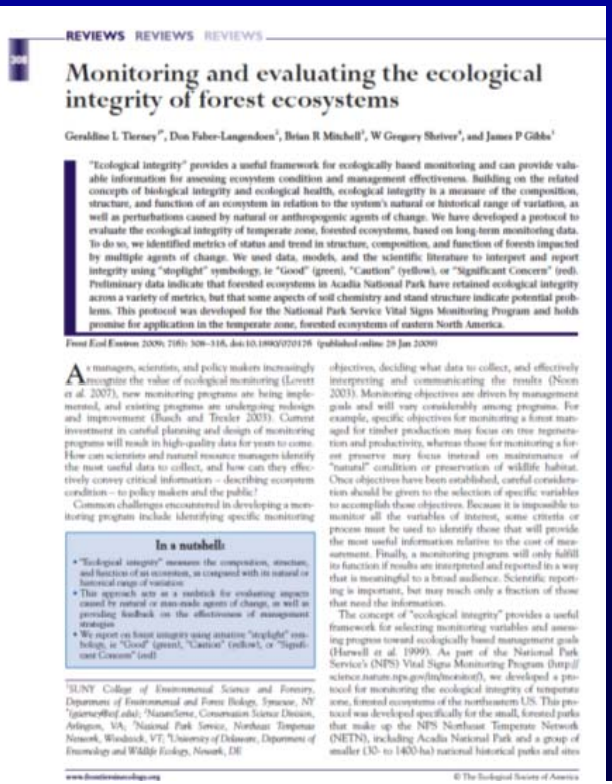

REVIEWS REVIEWS REVIEWS

Monitoring and evaluating the ecological integrity of forest ecosystems

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"Ecological integrity" provides a useful framework for ecologically based monitoring and can provide valuable information for assessing ecosystem condition and management effectiveness. Building on the related concepts of biological integrity and ecological health, ecological integrity is a measure of the composition, structure, and function of an ecosystem in relation to the system's natural or historical range of variation, as well as perturbations caused by natural or anthropogenic agents of change. We have developed a protocol to evaluate the ecological integrity of temperate zone, forested ecosystems, based on long-term monitoring data. To do so, we identified metrics of status and trend in structure, composition, and function of forests impacted by multiple agents of change. We used data, models, and the scientific literature to interpret and report integrity using "stoplight" symbology, ie "Good" (green), "Caution" (yellow), or "Significant Concern" (red). Preliminary data indicate that forested ecosystems in Acadia National Park have retained ecological integrity across a variety of metrics, but that some aspects of soil chemistry and stand structure indicate potential problems. This protocol was developed for the National Park Service Vital Signs Monitoring Program and holds promise for application in the temperate zone, forested ecosystems of eastern North America.

Front Ecol Environ 2009; 7(6): 308–316, doi:10.1890/070176 (published online 28 Jan 2009)

As managers, scientists, and policy makers increasingly recognize the value of ecological monitoring (Lovett et al. 2007), new monitoring programs are being implemented, and existing programs are undergoing redesign and improvement (Busch and Trexler 2003). Current investment in careful planning and design of monitoring programs will result in high-quality data for years to come. How can scientists and natural resource managers identify the most useful data to collect, and how can they effectively convey critical information – describing ecosystem condition – to policy makers and the public?

Common challenges encountered in developing a monitoring program include identifying specific monitoring objectives, deciding what data to collect, and effectively interpreting and communicating the results (Noon 2003). Monitoring objectives are driven by management goals and will vary considerably among programs. For example, specific objectives for monitoring a forest managed for timber production may focus on tree regeneration and productivity, whereas those for monitoring a forest preserve may focus instead on maintenance of "natural" condition or preservation of wildlife habitat. Once objectives have been established, careful consideration should be given to the selection of specific variables to accomplish those objectives. Because it is impossible to monitor all the variables of interest, some criteria or process must be used to identify those that will provide the most useful information relative to the cost of measurement. Finally, a monitoring program will only fulfill its function if results are interpreted and reported in a way that is meaningful to a broad audience. Scientific reporting is important, but may reach only a fraction of those that need the information.

In a nutshell:

- "Ecological integrity" measures the composition, structure, and function of an ecosystem, as compared with its natural or historical range of variation
- This approach acts as a yardstick for evaluating impacts caused by natural or man-made agents of change, as well as providing feedback on the effectiveness of management strategies
- We report on forest integrity using intuitive "stoplight" symbology, ie "Good" (green), "Caution" (yellow), or "Significant Concern" (red)

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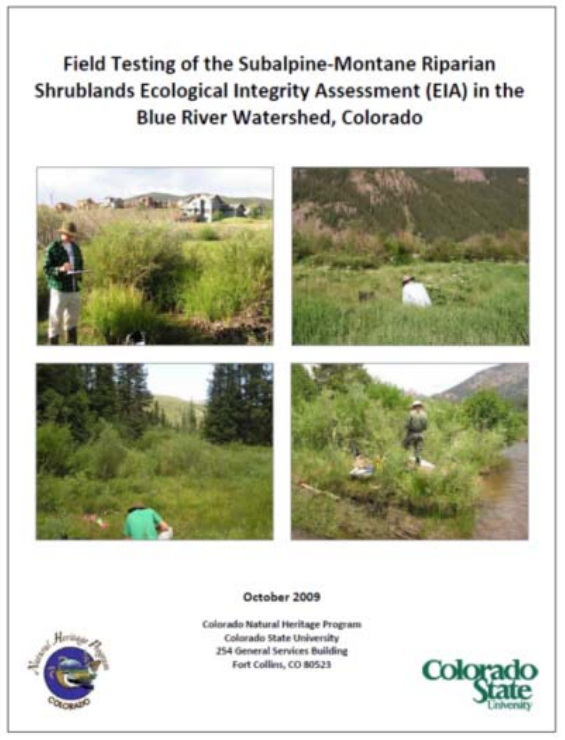
Quantitative Calibration of Regional Models

National Models for Uplands (Frontiers in Ecology: 7(6): 308-316)




EIA Development

EIA Development

1. Identify Key Ecological Attributes & Metrics

- Review literature and historical records
- Characterize *multiple*, apparently undisturbed examples

2. Develop Measurement Protocols

- Ensure systematic application of EIA

3. Define Thresholds for Metric Ratings

- Examine specific impact of human-induced alterations in known occurrences

4. Integrate Metric Ratings into Category Scores

- Ecological Category Scores
- Overall Ecological Integrity Score

Level 2 Metrics - Shrub Steppe

Rank Factor	Key Ecological Attribute	Metric
Landscape Context	Landscape Structure	Landscape Connectivity
		Surrounding Land Use Index
Biotic Condition	Vegetation	Cover of Native Plants
		Floristic Quality Assessment
		% Native Forbs
		% Cover of Native Bunchgrasses
		% Cover of Fire-sensitive Shrubs
		Ratio of Structural Stages (closed vs. open vs. grassland)
		% Cover of Increasers
Abiotic Condition	Soils/Physiochemical Structure	% Cover Cryptogamic Crust
		Soil Quality
	Natural Disturbance Regimes	Fire interval
		Herbivory
Size	Size	Absolute Size
		Relative Size

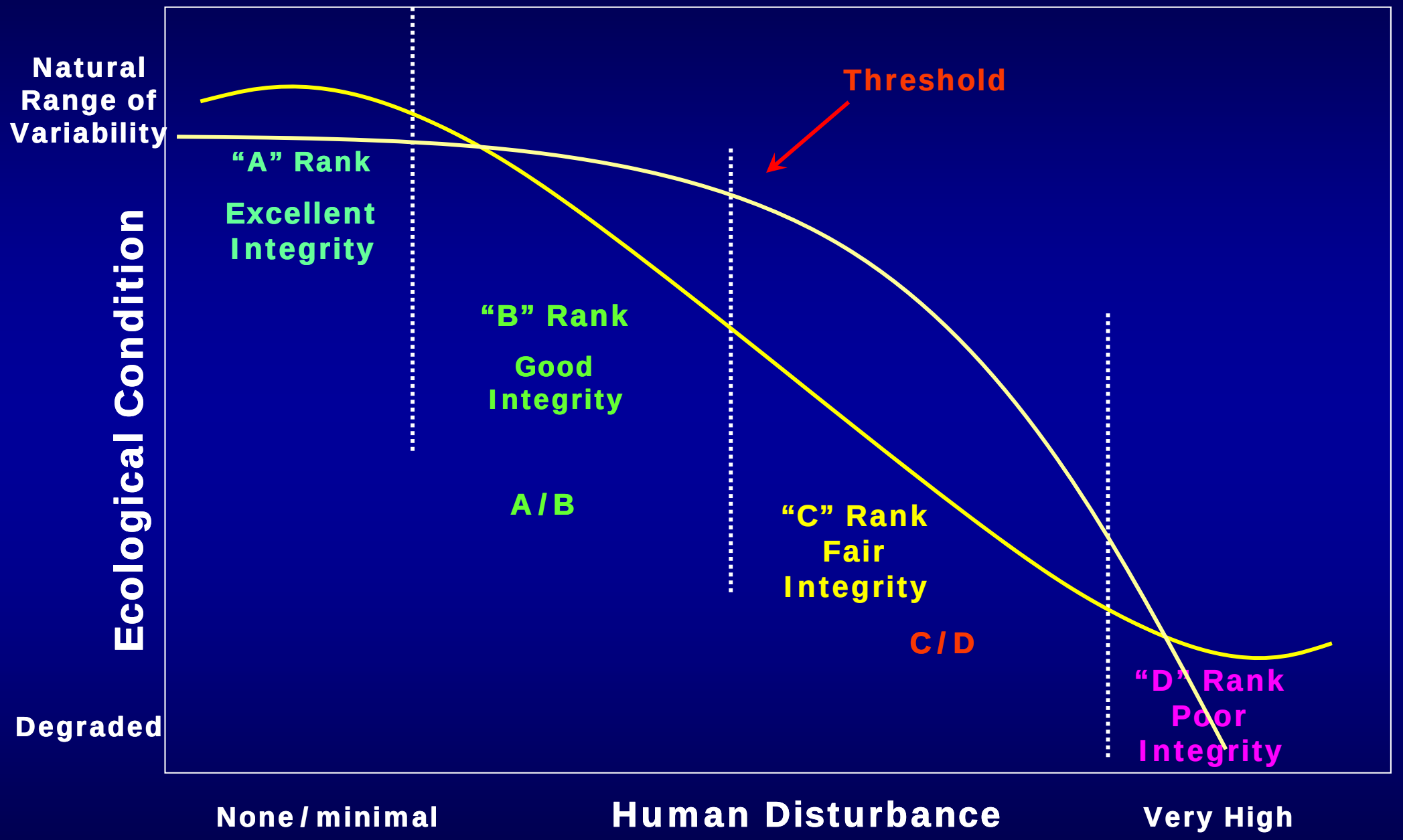
Metric Ranks – Shrub Steppe

Category	Key Ecological Attribute	Metrics	Metric Rating Criteria			
			Excellent (A)	Good (B)	Fair (C)	Poor (D)
Biotic Condition	Vegetation	% Cover Native Plants	>95% cover	80-95% cover	60-80% cover	< 60% cover
		FQA (Mean C)	Mean C >6	Mean C 5-6	Mean C 4-5	Mean C <4
		% Cover Native Bunchgrasses	>75% cover	60-75% cover	50-60% cover	< 50%
		% Cover Fire-sensitive shrubs	< 25% cover; well-spaced	25-35%;		> 40% cover; dense
		% Cover Cryptogammic Crust	>80% cover of vascular plant interspaces; high diversity of lichens and/or mosses in crust	>60% cover of vascular plant interspaces; moderate diversity lichens/mosses (at least 3-4 species)	>30% cover of vascular plant interspaces; monotypic early-successional mosses abundant); lichens with low cover	Absent OR <30% cover of vascular plant interspaces; crust with low diversity

Metric Ranking Criteria

- Characterize metric in reference & disturbed conditions
  - Field characterization
  - Literature
  - Best professional judgment
- Estimate metric thresholds/ratings
- Assumptions, justifications, etc. documented

Establishing Metric Ratings

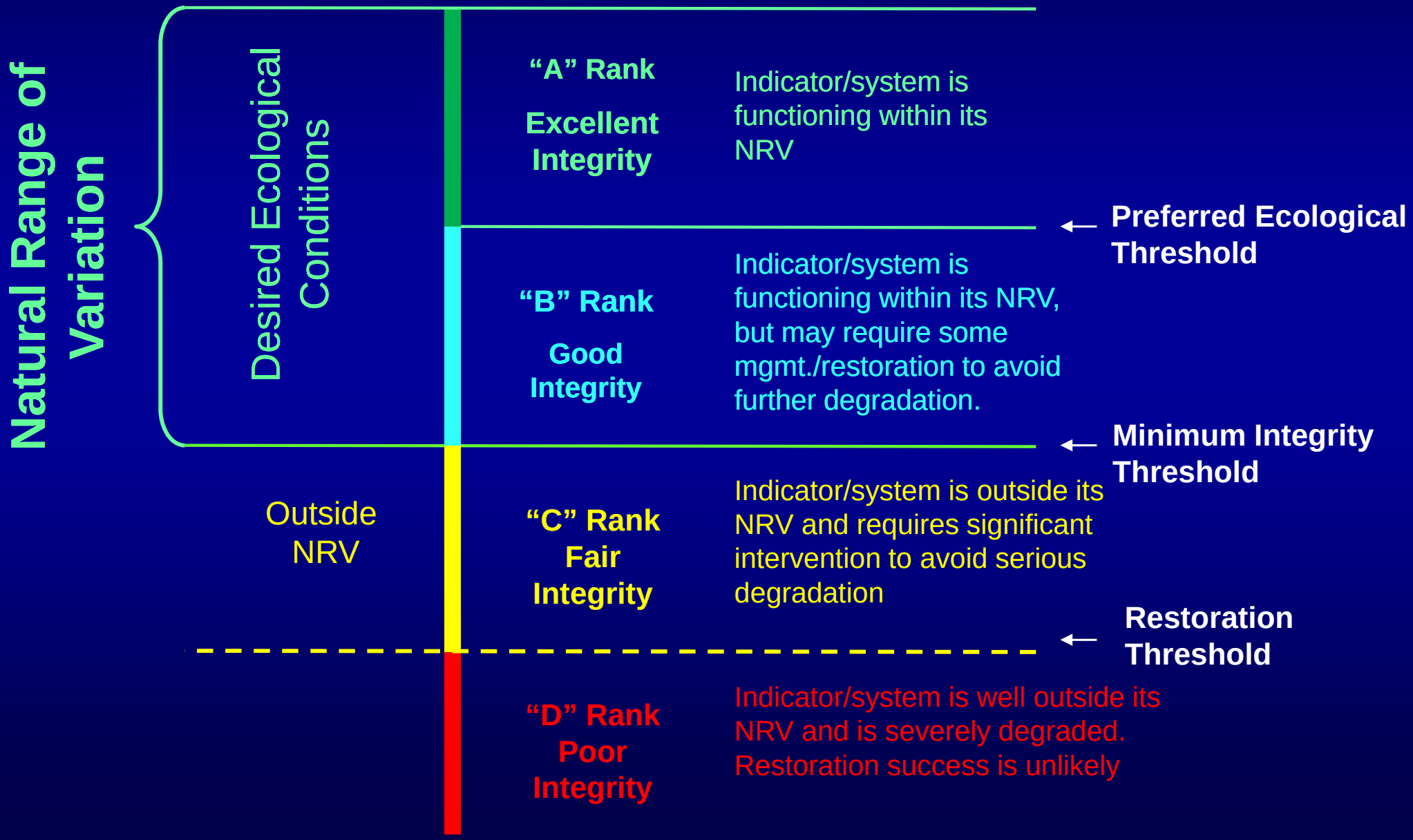


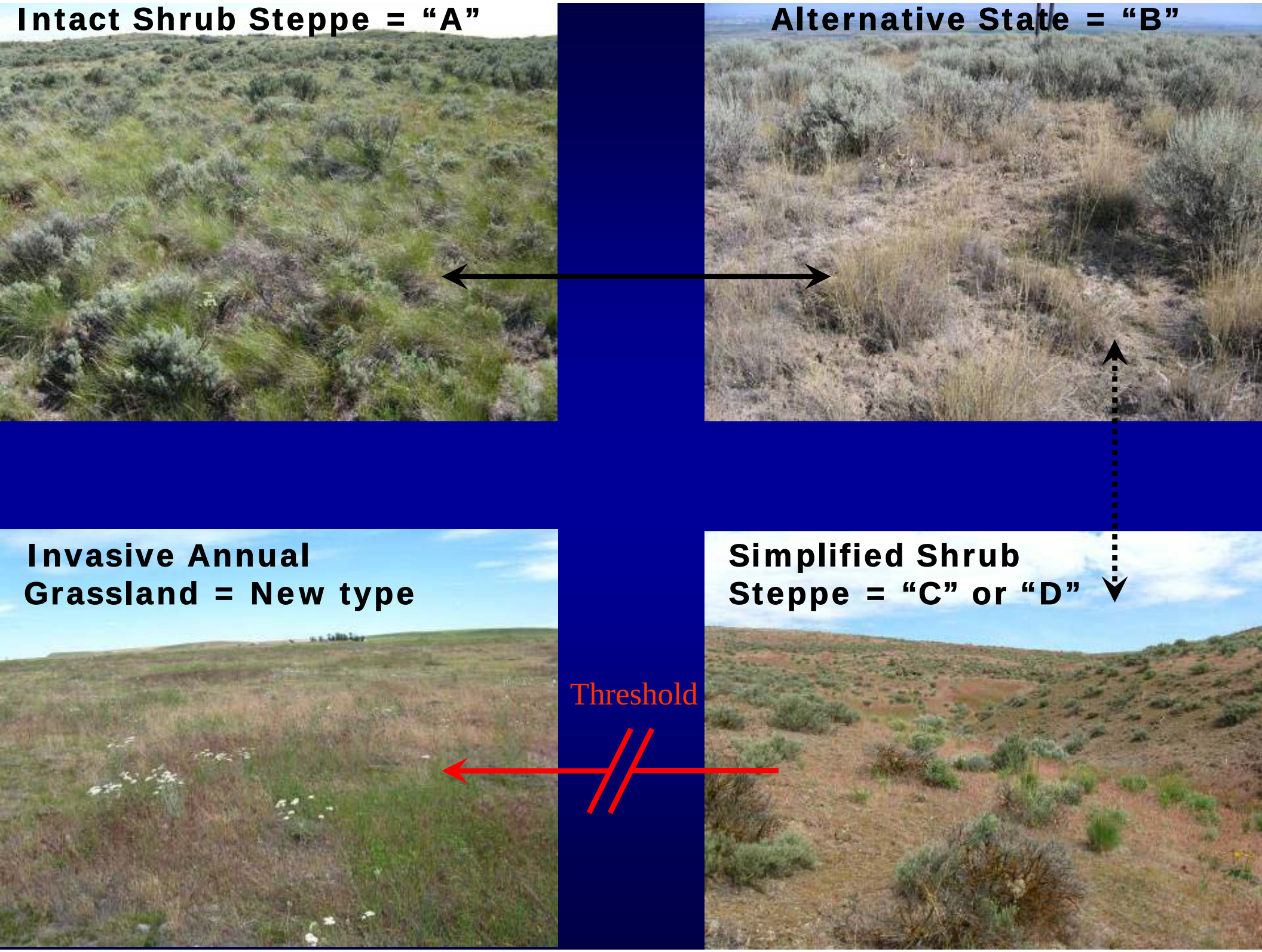
Graph adapted from: Davies and Jackson. 2006. Ecol. Appl. 16(4)

General Metric Rating Definitions

Rank Value	Description	
A Excellent	▪ highest quality site ▪ functioning within natural disturbance regimes ▪ unfragmented, natural landscape ▪ size is larger than minimum dynamic area	▪ biotic/abiotic components are well within natural range of variability ▪ invasives/non-natives absent ▪ comprehensive set of key indicator species
B Good	▪ not among the highest quality sites ▪ still functioning within natural disturbance regimes ▪ largely natural, minimally fragmented landscape ▪ size is larger than minimum dynamic area	▪ biotic/abiotic components are within natural ranges of variation ▪ Invasives/non-natives are present in minor amounts ▪ many (but not all) key plant and animal indicators are present
C Fair	▪ has some unfavorable characteristics ▪ functioning slightly outside natural disturbance regimes ▪ moderately fragmented, natural landscape ▪ size is smaller than minimum dynamic area	▪ biotic/abiotic components are somewhat altered outside their natural range of variation ▪ invasives/non-natives may be a sizeable minority of the species abundance ▪ Some management is needed to maintain or restore these major ecological attributes
D Poor	▪ has severely altered characteristics ▪ highly fragmented, landscape with little natural habitat ▪ size is very small or well below the minimum dynamic area	▪ biotic/abiotic components are severely altered from their natural range of variation; ▪ invasives/non-natives exert a strong negative impact ▪ little long-term conservation value without restoration (may be difficult or uncertain)

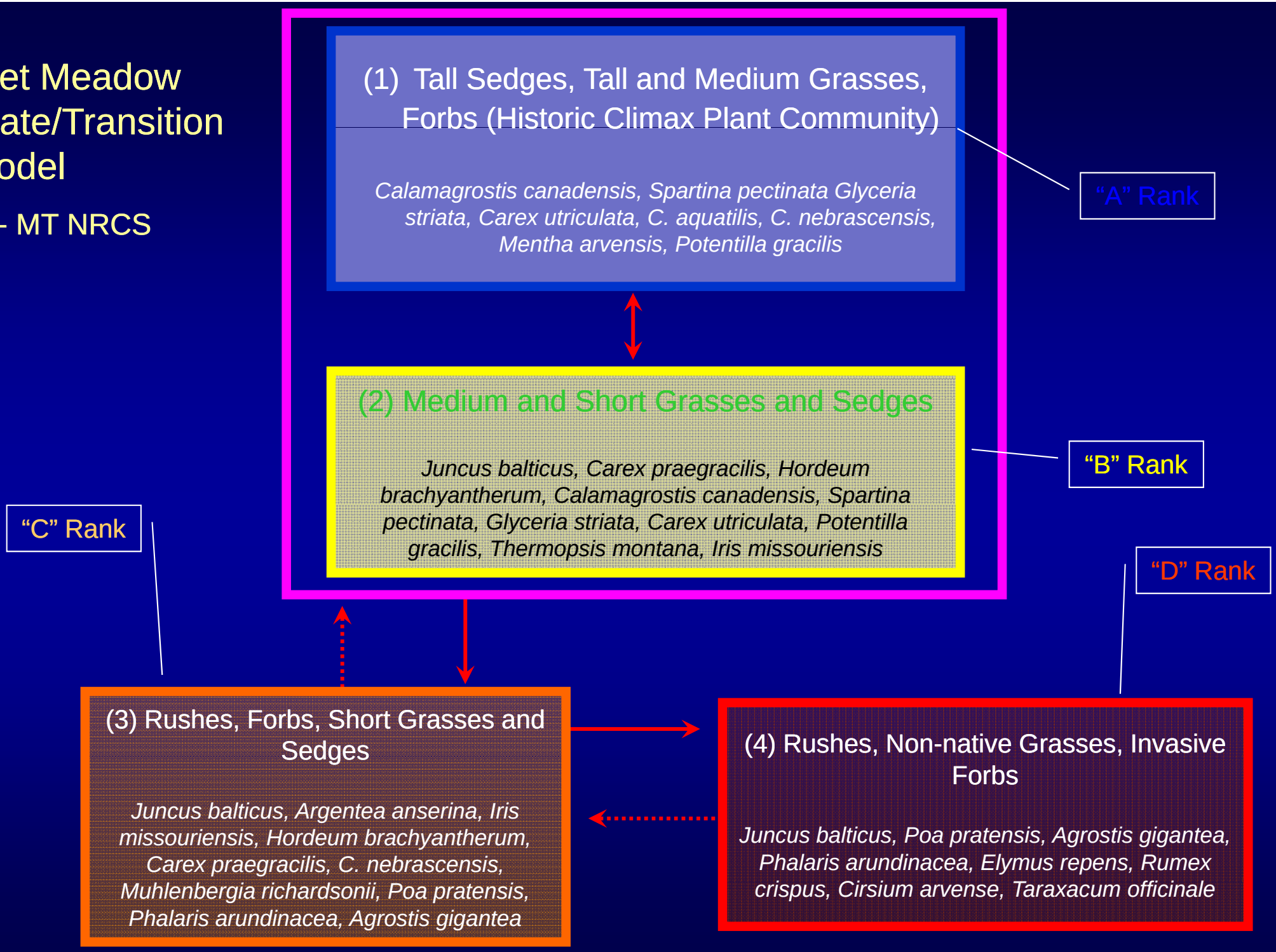
Ecological Variation & Thresholds




Intact Shrub Steppe = “A”
Alternative State = “B”
Invasive Annual Grassland = New type
Simplified Shrub Steppe = “C” or “D”
Threshold

Wet Meadow State/Transition Model

- MT NRCS



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- **B.2.2. Floristic Quality Index (Mean C)**

Definition: The mean conservatism of all the native species growing in the riparian area.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Plants grow in habitats in which they are adapted to, including biotic and abiotic fluctuations associated with that habitat (Wilhelm and Masters 1995). However, when disturbances to that habitat exceed the natural range of variation (e.g. many human-induced disturbances), only those plants with wide ecological tolerance will survive and conservative species (e.g. those species with strong fidelity to habitat integrity) will decline or disappear according to the degree of human disturbance (Wilhelm and Master 1995; Wilhelm personal communication, 2005).

The Floristic Quality Index (FQI), originally developed for the Chicago region (Swink and Wilhelm 1979, 1994) is a vegetative community index designed to assess the degree of "naturalness" of an area based on the presence of species whose ecological tolerance are limited (U.S. EPA 2002). FQI methods have been developed and successfully tested in Illinois (Swink and Wilhelm 1979), Missouri (Ladd 1993), Ohio (Andreas and Lichvar 1995), southern Ontario (Oldham et al. 1995), Michigan (Herman et al. 1996), Indiana (Coffee Creek Watershed Conservancy, 2001), and North Dakota (Northern Great Plains Floristic Quality Assessment Panel, 2001).

The Colorado Floristic Quality Assessment Panel is currently assigning coefficients of conservatism to the Colorado flora. Initial testing of the Colorado FQI should begin in 2006 and available for use shortly thereafter. However, calibration of the FQI will likely occur over many years of use and thus this metric will need to be updated accordingly.

Measurement Protocol: Species presence/absence data need to be collected from the riparian area. Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the riparian system and make notes of each species encountered. A thorough search of each macro- and micro-habitat is required. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Mack 2004; Peet et al. 1998).

The metric is calculated by referencing only native species C value from the Colorado FQI Database (*in development*; *expected to be completed in 2006*), summing the C values, and dividing by the total number of native species (Mean C).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 4.5	3.5-4.5	3.0 – 3.5	< 3.0

Data: Colorado FQI Database (*in development*; *expected to be completed in 2006*)

Scaling Rationale: In the Midwest, field studies using FQI have determined that a site with a Mean C of 3.0 or less is unlikely to achieve higher C values thus this value was used as the Restoration Threshold (between Fair and Poor). In other words, those sites have been disturbed to the degree that conservative species are no longer able to survive and or compete with the less conservative species as a result of the changes to the soil and or hydrological processes on site (Wilhelm and Masters 1995). Sites with a Mean C of 3.5 or higher are considered to have at least marginal quality or integrity thus this value was used as the Minimum Integrity Threshold (between Good and Fair) (Wilhelm and Masters 1995). The threshold between Excellent and Good was assigned based on best scientific judgment upon reviewing the FQI literature. Although it is not know if these same thresholds are true for the Southern Rocky Mountains, they have been used to construct the scaling for this metric. As the FQI is applied in this region, the thresholds may change.

Confidence that reasonable logic and/or data support the index: High