Headwater Candidate Reference Reaches

- Reference condition concept
- Importance of headwaters
- Scoring approach

Reference Condition

Ecological integrity is defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitat of the region"

Drivers of stream condition

Natural Factors + Disturbance = Stream Condition

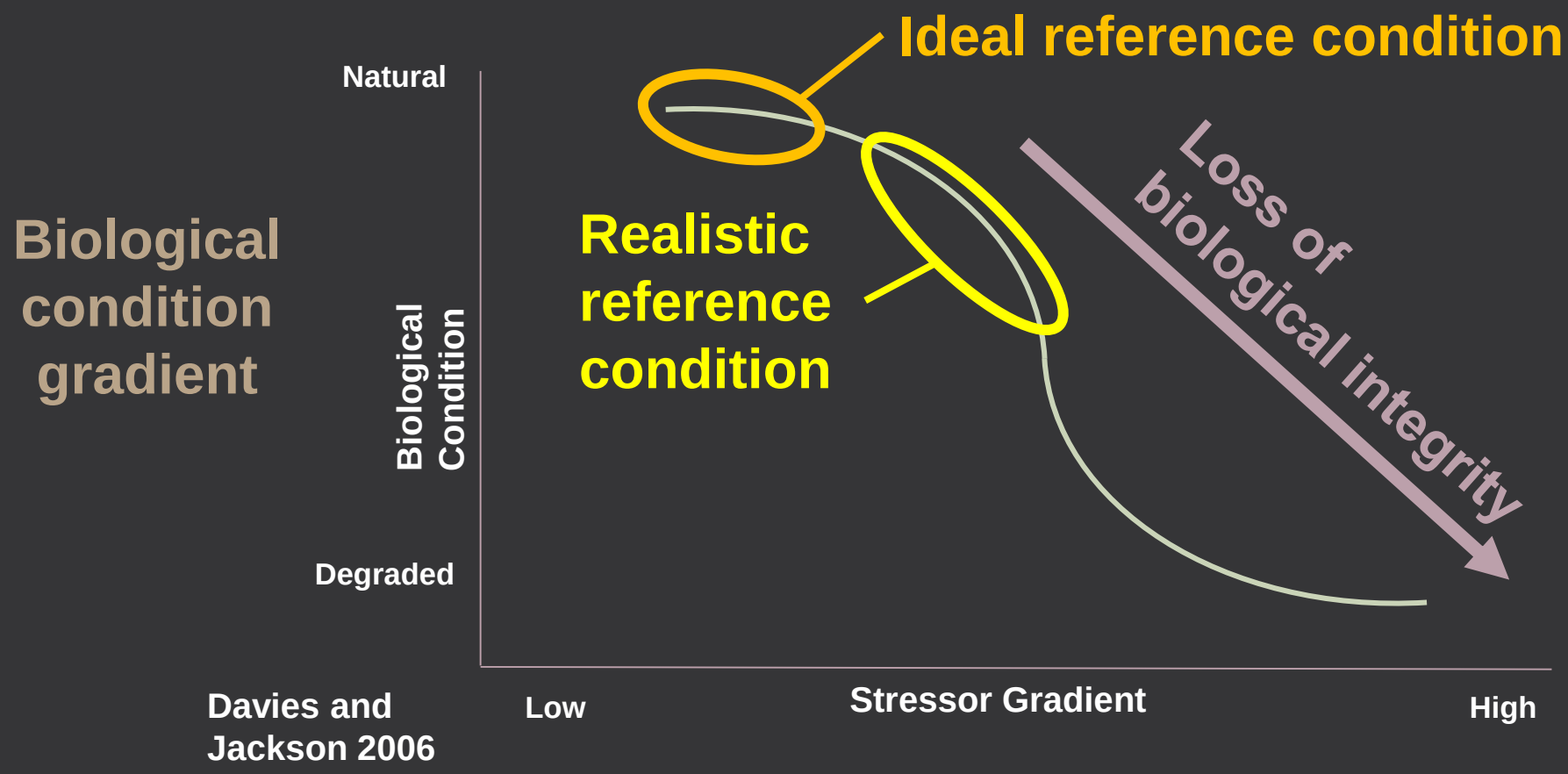
- **Natural factors – such as elevation, geology, soil**
- **Disturbance – chronic; human caused**
- **Both can differ regionally**
- **Grassland streams ≠ Ozark streams**

Ozark

Grassland

Reference Condition

Ecological integrity is defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitat of the region"



Headwaters & Threat Indexing

- **Headwaters are varied and diverse members of stream networks**
  - Typically <10 km^2 watershed area
  - Closely linked to landscape
    - 79% of river length in US
  - Maintain stream flows, sediment loads, nutrient inputs, etc.
  - Often under-sampled

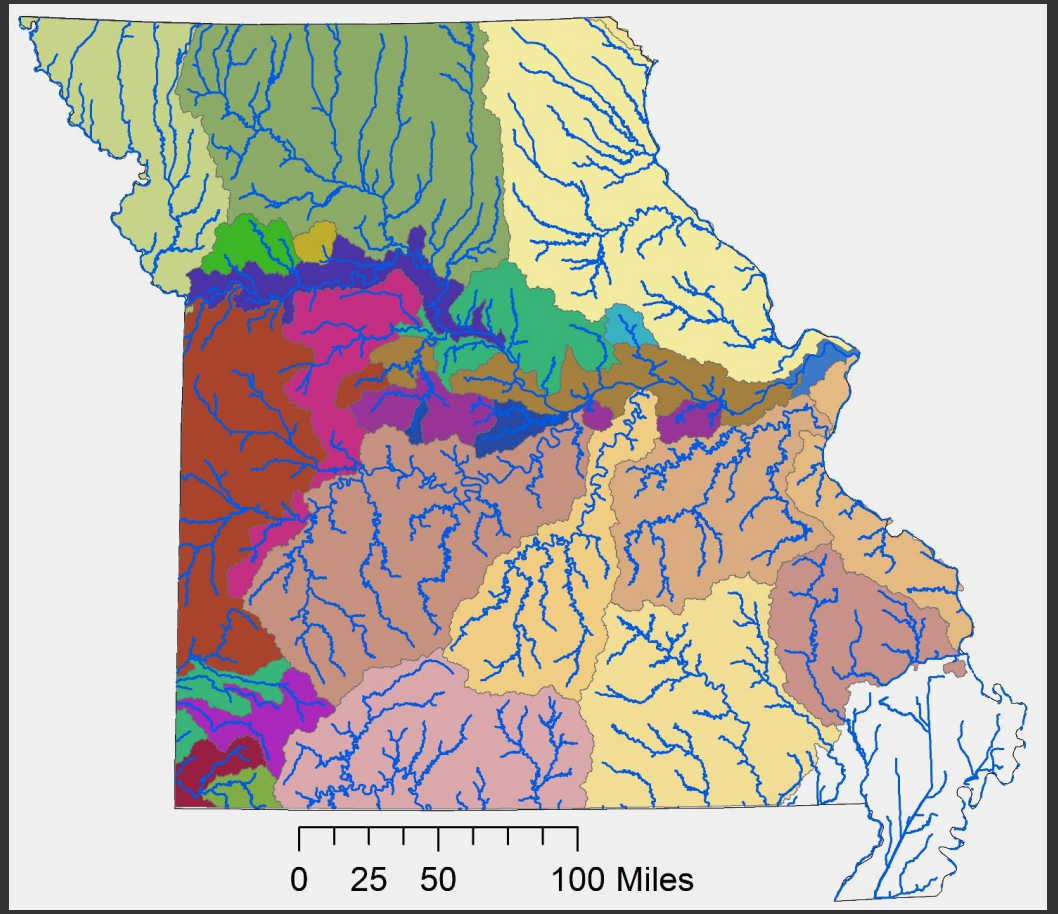
- **Coarse-filter conservation planning and prioritization tools**
  - Landscape-level threat indexing
  - Multimetric index

Colvin et al. 2019. Fisheries 44(2):73-91

Process to identify candidate reference streams

Step 1: determine watershed boundaries for streams with similar characteristics

- Based on previous MO research
  - Sowa et al. 2007; Annis et al. 2010
  - Similar geology, soil, hydrology, topography, and evolutionary history
- Assessment regions (N=33)



Process to identify candidate reference streams

Step 2: remove headwaters too small to likely have flowing water

- Dropped headwaters with drainage area < 0.4 mi^2
  - Avoid waterways without relatively consistent surface water

Process to identify candidate reference streams

Step 3: calculate disturbance metrics for each headwater

Metric	Date Published	Source
CAFO* Sites (no./km^2)	2012	Missouri Department of Natural Resources
NPDES† Sites (no./km^2)	2012	Missouri Department of Natural Resource
Landfills (no./km^2)	2008	Missouri Department of Natural Resources
Registered Hazardous Waste Sites (no./km^2)	2010	Missouri Department of Natural Resources
Superfund Sites (no./km^2)	2010	Missouri Department of Natural Resources
Dams (no./km)	2010	Missouri Department of Natural Resources
Road/Stream Crossings (no./km)	2008	Missouri Resource Assessment Partnership
Coal Mines (no./km^2)	2008	Missouri Resource Assessment Partnership
Lead Mines (no./km^2)	2007	Missouri Resource Assessment Partnership
Mines (Other) (no./km^2)	2007	Missouri Resource Assessment Partnership
Sand/Gravel Mines (no./km)	2008	Missouri Department of Natural Resources
Cultivated Crop (% watershed area)	2006	Multi-Resolution Land Characteristics Consortium
Pasture/Hay (% watershed area)	2006	Multi-Resolution Land Characteristics Consortium
Imperviousness (% watershed area)	2006	Multi-Resolution Land Characteristics Consortium

Process to identify candidate reference streams

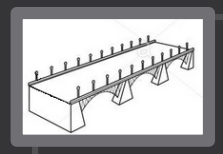
Step 4: metric density quartiles and scores per assessment region

- **Literature-based thresholds for impervious surface (IS) and cultivated crops (CC) (% area within watershed)**
  - **IS: 0 = 0%; 1 = >0 to 5%, 2 = >5 to 10%, 3 = >10 to 15%, 4 = >15%; Yoder et al. 1999, Paul and Meyer 2001**
  - **CC: 0 = 0%, 1 = >0 to 10%, 2 = >10 to 35%, 3 = >35 to 50%, 4 = >50%; Wang et al. 1997, Roth et al. 1996**

Process to identify candidate reference streams

Step 4: metric density quartiles and scores per AU

Quartiles for remaining 12 metrics



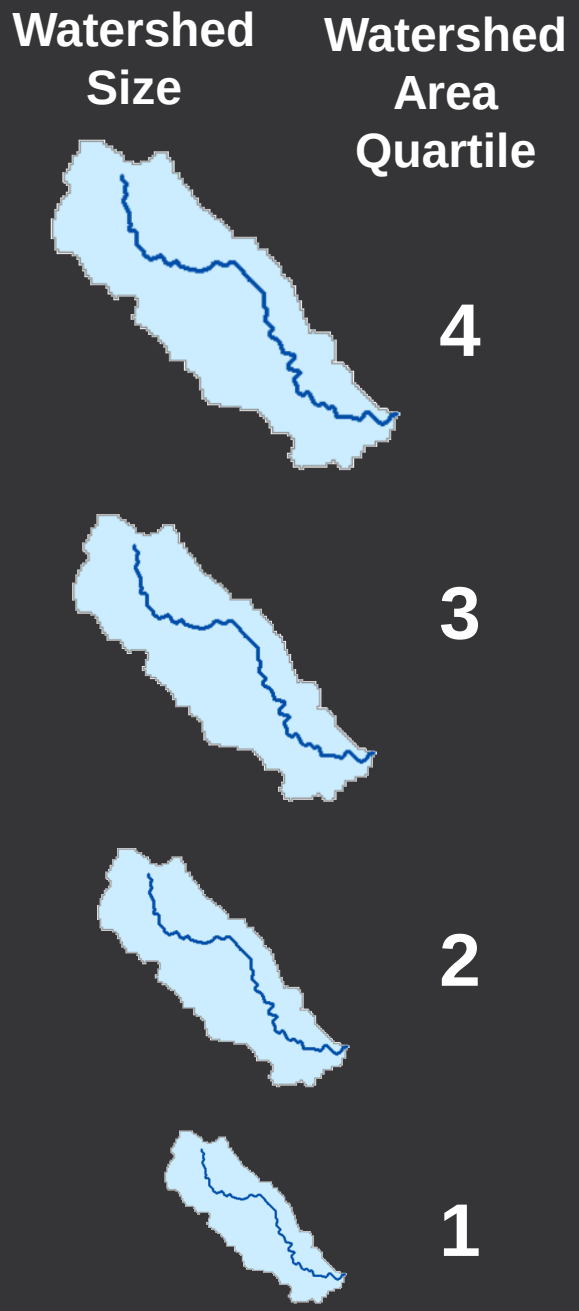
- Quartiles for remaining 12 metrics
  - No literature based thresholds found

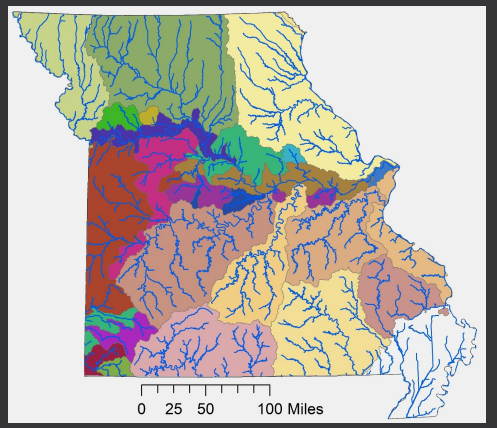
\+ Repeat for 11 additional metrics + Sum all 14 scores = Disturbance index score

Process to identify candidate reference streams

Step 5: classify watershed size per assessment region

- Avoid small watershed bias
  - Small watersheds = lower likelihood of disturbance
  - Many more small watersheds
- Calculated quartiles for watershed area by AR

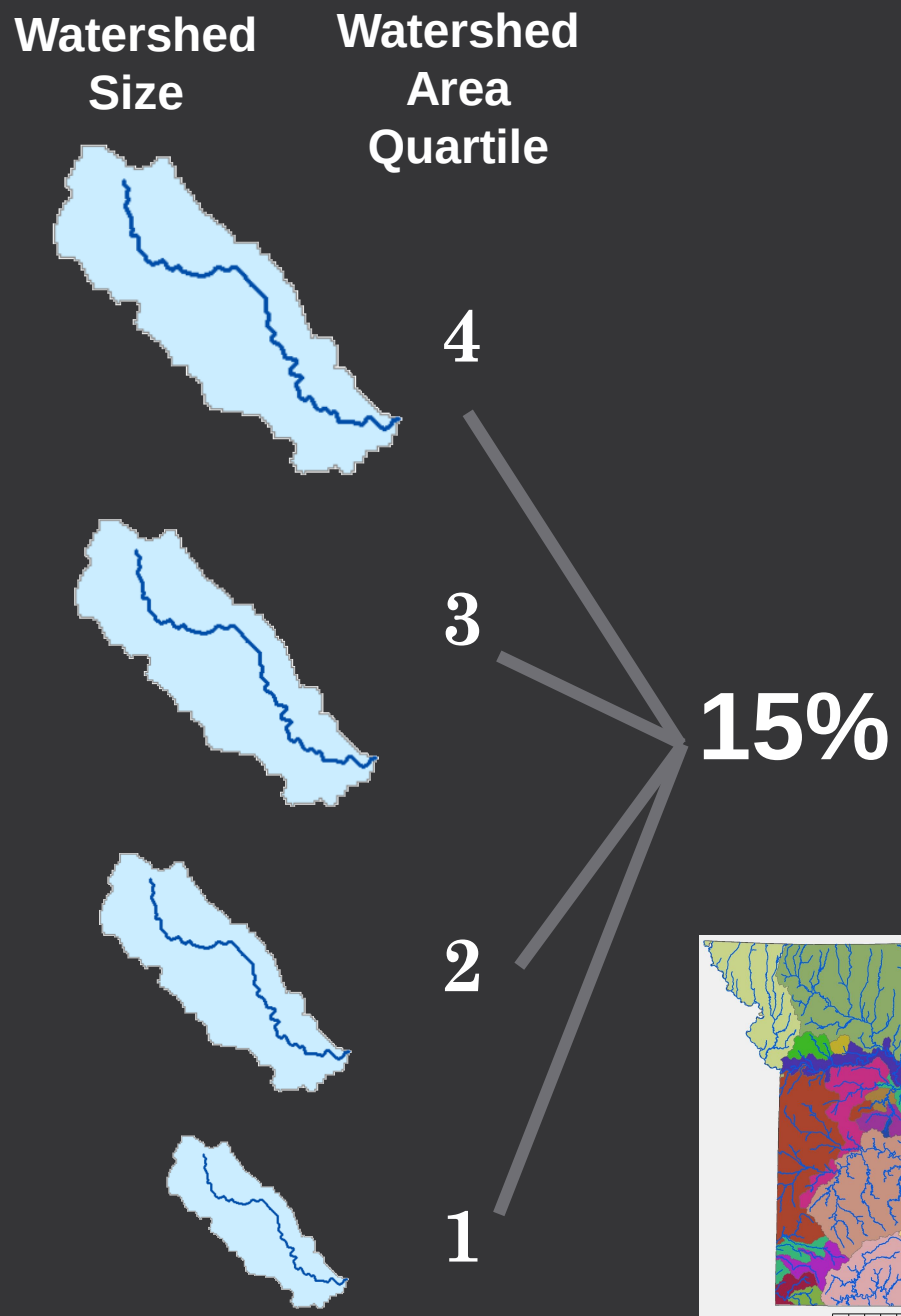




Process to identify candidate reference streams

Step 6: select 15th percentile

- First cut: selected headwaters from the lowest 15th percentile of disturbance index scores per AR and watershed area quartile
- Better representation of headwater diversity



Process to identify candidate reference streams

Step 7: recalculate disturbance scores for subset of headwaters

- Recalculated disturbance scores for subsetted streams by AR using same threshold/quartile approach
- Removed stream segments with a disturbance score of 4 (highest disturbance) for any metric

Examples:

ID	Crops	Imp Surface	Dams	Pasture/Hay	Mines SG	Stream Xings	Mines Coal	Mines Lead	CAFOs	Mines Other	Landfills	NPDES	Superfund	Hzrd Waste
4161	1	1	0	3	0	4	0	0	0	0	0	0	0	0
923	3	1	0	3	0	4	0	0	0	0	0	0	0	0
5773	3	1	0	3	0	0	0	0	0	0	0	0	0	0

- Final candidate list N = 7,640

Least threatened

Reference Condition

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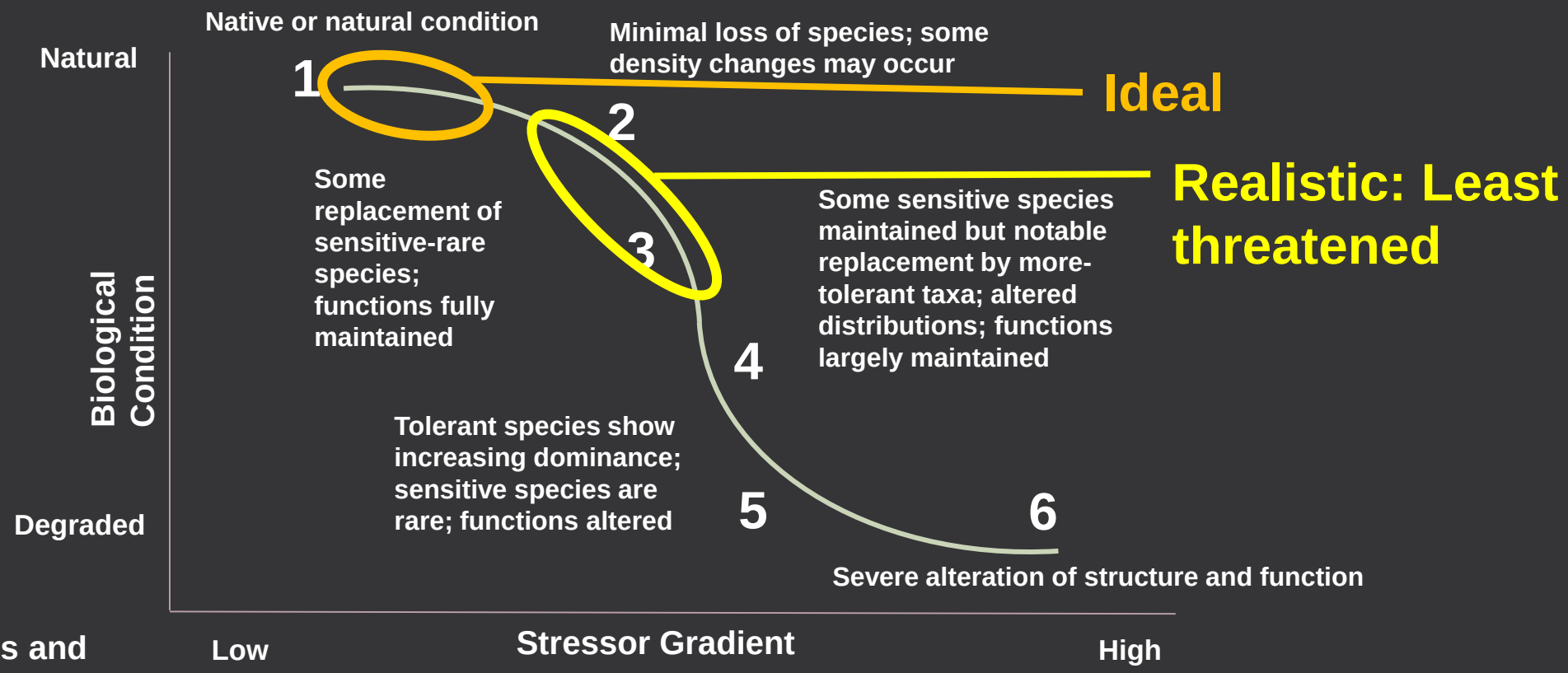

Davies and Jackson 2006

Questions?

Disturbance metrics for each headwater

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Questions?

References

Annis, G. M., and coauthors. 2010. Developing synoptic human threat indices for assessing the ecological integrity of freshwater ecosystems in EPA Region 7. University of Missouri, Columbia, Missouri.

Hyndman, R. J., and Y. Fan. 1996. Sample quantiles in statistical packages. The American Statistician 50:361-365.

Kleekamp, E. 2016. Development of reference reaches for Missouri streams. Final Report to the Missouri Department of Natural Resources, Watershed Protection Program. Report Number G13-NPS-08, Jefferson City, MO.

Paul, M. J., and J. L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32(1):333-365.

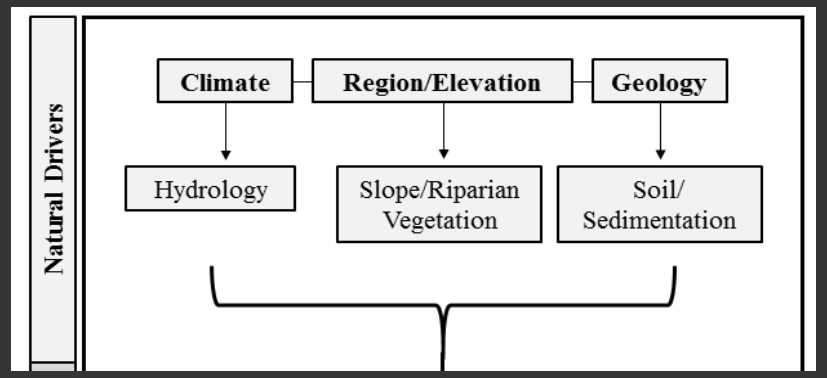
Roth, N. E., J. D. Allan, and D. L. Erickson. 1996. Landscape influences on stream biotic integrity assessed at multiple spatial scales. Landscape Ecology 11(3):141-156.

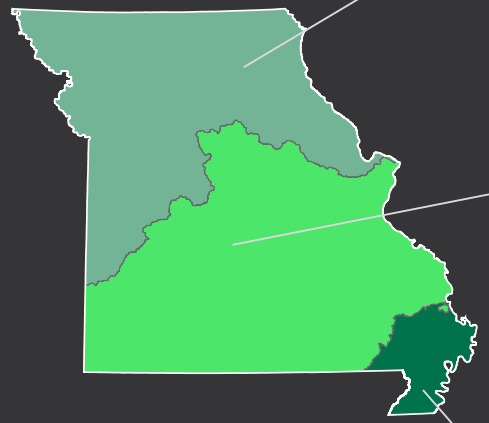
Sowa, S. P., G. Annis, M. E. Morey, and D. D. Diamond. 2007. A gap analysis and comprehensive conservation strategy for riverine ecosystems of Missouri. Ecological Monographs 77(3):301-334.

Wang, L., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams. Fisheries 22(6):6-12.

Yoder, C. O., R. J. Miltner, and D. White. 1999. Assessing the status of aquatic life designated uses in urban and suburban watersheds. Proceedings of the National Conference of Retrofit Opportunities for Water Resource Protection in Urban Environments. Pp. 16-28. EPA/625/R-99/002.

Natural Drivers: Characteristics of Missouri's Ecoregions





Central Plains
- Little groundwater influence
- Low dissolved oxygen
- High turbidity
~ 10.3 m/km headwater gradient

Ozarks
- High groundwater influence
- High dissolved oxygen
- Low turbidity
- Coarser substrate
~ 17.4 m/km headwater gradient

MS Alluvial Basin
- Low groundwater influence
- Low dissolved oxygen
- High turbidity
~ 2.6 m/km headwater gradient