Developing Riparian Vegetation Flow Response Guilds in the Grand Canyon

By
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and Aquatic Ecology Center

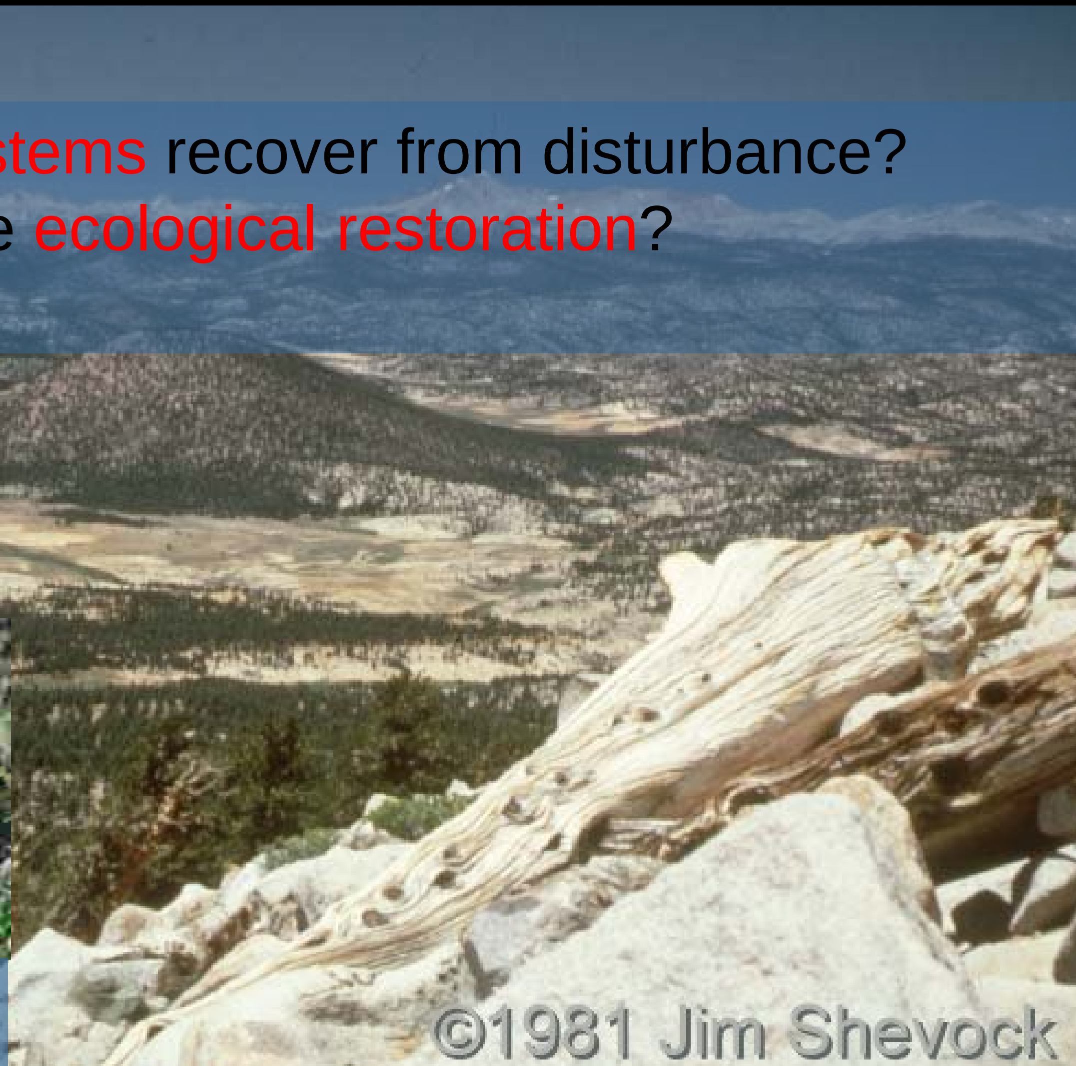
Talk Outline

- My Background (in three slides)
- Review of Workplan Objectives
- Identifying Riparian Vegetation Flow Response Guilds in Grand Canyon
- Moving forward

Prologue:

Golden Trout Wilderness, Sierra Nevada

- How riparian ecosystems recover from disturbance?
- How do we measure ecological restoration?



Golden Trout (*Oncorhynchus mykiss aguabonita*)

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A Riparian and Wetland Journey

Narrowleaf cottonwood riparian forest (*Populus angustifolia*), San Luis Valley, Colorado

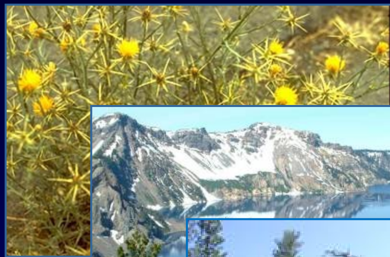
Riparian forest, Cascade Mountains, Oregon

Acid geothermal fen, Lassen Volcanic NP, CA

Skaghard Turlough, Burren National Park, Ireland

Klamath Network Vital Signs Monitoring

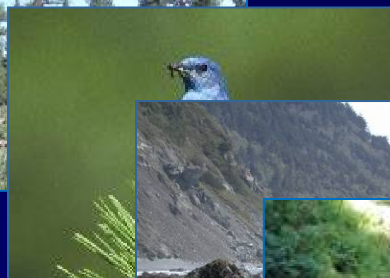
National Park Service
U.S. Department of the Interior



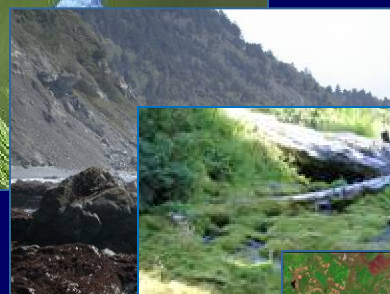
1. Non-native, invasive species

2. Keystone and Sensitive Plant and Animals (Whitebark pine, aspen, amphibians)

3. Vegetation Communities



4. Bird Communities



5. Intertidal Communities

6. Water Quality
7. Aquatic Communities

8. Landcover, use, pattern

9. Cave Communities
10. Cave Environment

11. Weather & Climate

12. Air Quality

Core Vital Signs

Unfunded Vital Signs

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Riparian Monitoring Objectives/Elements

Grand Canyon Monitoring and Research Center 2013-14 Workplan

The work proposes:

1. To use ecological and life-history traits of riparian plant species found along the Colorado River downstream from Glen Canyon Dam to define flow response guilds (sensu Merritt and others, 2010.)….
   (Today's presentation: Sarr et al. 2015)

2. To use traits of response guilds to identify ecological states for riparian vegetation and those conditions (flow scenarios) that cause states to switch. This approach recognizes a multi-state pathway and multiple steady states as a way to describe riparian vegetation dynamics.
   ✓ (Completed : Ralston et al. 2014)

3. To use remotely sensed imagery to quantify landscape scale changes in vegetation type and amount and to conduct change detection analysis of vegetation since 2002.
   (Joel Sankey's 2014 presentation: Sankey et al. In Revision)

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Monitoring Riparian Vegetation in Grand Canyon

Approach Developed in 2012-2013, some refinement in 2014, with monitoring protocol under development

Vegetation is monitored annually near the end of the growing season (August – Early October)

Mixed Sampling Panel Approach

- Randomly selected Channel Margin, Debris Fan, Sandbar Sites (70-96 sites)
- Permanent (always revisit) Sandbar Sites (42 sampling sites)

Sampled on separate river trips

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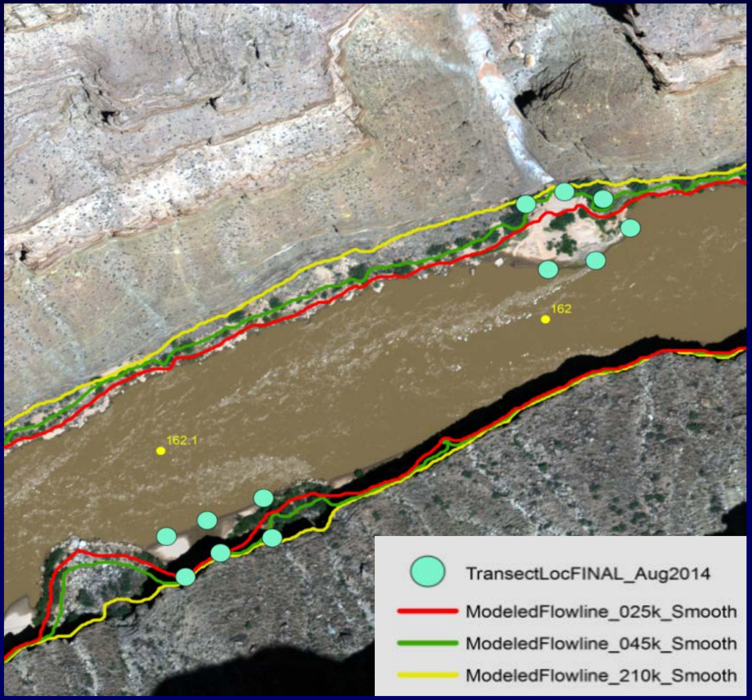
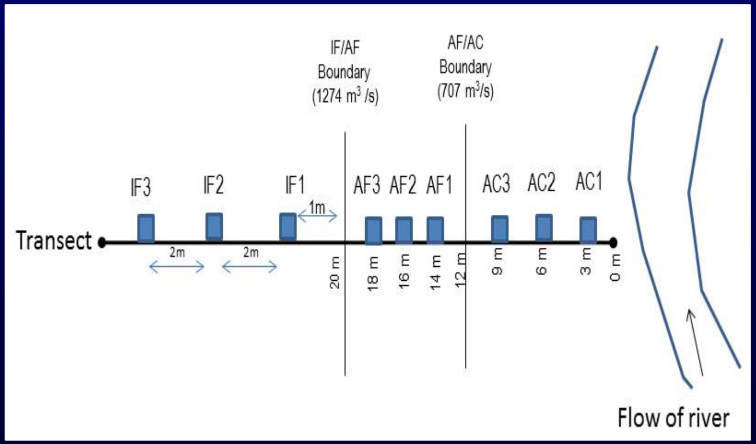
Monitoring Riparian Vegetation in Grand Canyon

- Three or four transects/site
  - Nine 1m x 1m quadrat samples/ transect
- Apportioned with Stratified systematic design
  - Active Channel (3)
  - Active Floodplain (3)
  - Inactive Floodplain (3)
- Data Collected
  - Vegetation presence and cover, including overhanging vegetation
  - Height above river
  - Soil texture
- See Emily Palmquist Poster!





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Monitoring Riparian Vegetation in Grand Canyon

- Strengths
  - Feasible (and fun)!
  - Yields abundant floristic data across an array of riparian habitats
  - Is fairly easy to learn and a great venue for including volunteers, collaborators
  - Provides a reliable framework for allied riparian research
  - Integrated with remote sensing/landscape scale mapping
- Weaknesses
  - Yearly sampling could damage vegetation
  - Safety on, damage to steep river banks
  - Sample approach is slanted towards smaller plants
  - Structural and demographic information is limited

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Guilds and Functional Group Classifications

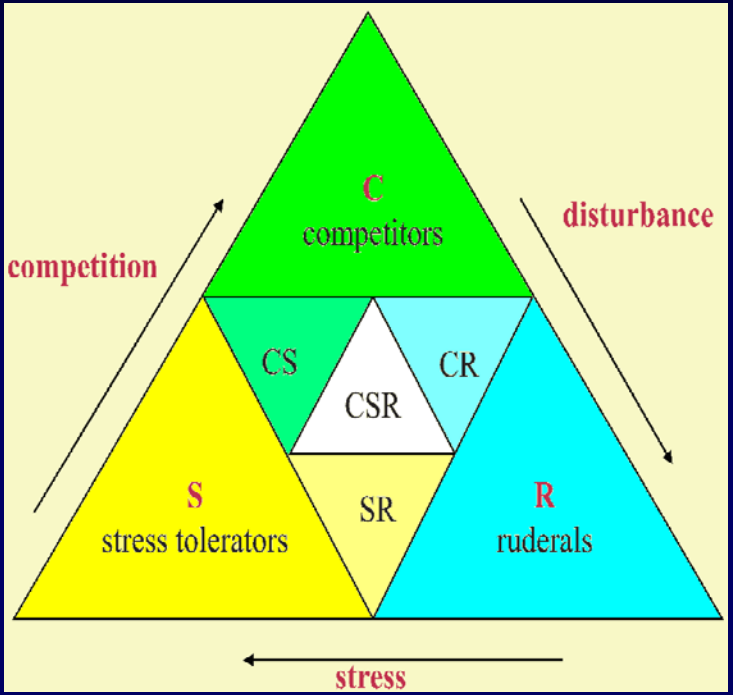
Guild = ***A group of functionally similar organisms***

Theoretical Basis-Functional Group Classifications

- Grime 1977 CSR -(Competitor, Stress Tolerator, Ruderal) scheme

- Riparian Vegetation Flow Response Guilds (Merritt et al. 2010)

- Potential Applications in Grand Canyon
  - By linking flow probabilistically to guild presence, we have a mechanistic linkage to riparian vegetation response



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Guilds and Functional Group Classifications

Three Applications

1. Riparian Tree Regeneration in Oregon

2. Changes in Vegetation along an Impounded River in Spain

3. Developing Riparian Vegetation Flow Response Guilds in Grand Canyon

Guilds and Functional Groups – An Application

Predicting Riparian Tree Regeneration in Oregon

- 23 Riparian Trees
- Looking for general patterns of regeneration across climatic, topographic and disturbance gradients
- Classified into 5 functional groups based on *Flood, Drought, Shade, Heat Tolerance,* and *Seed Size*

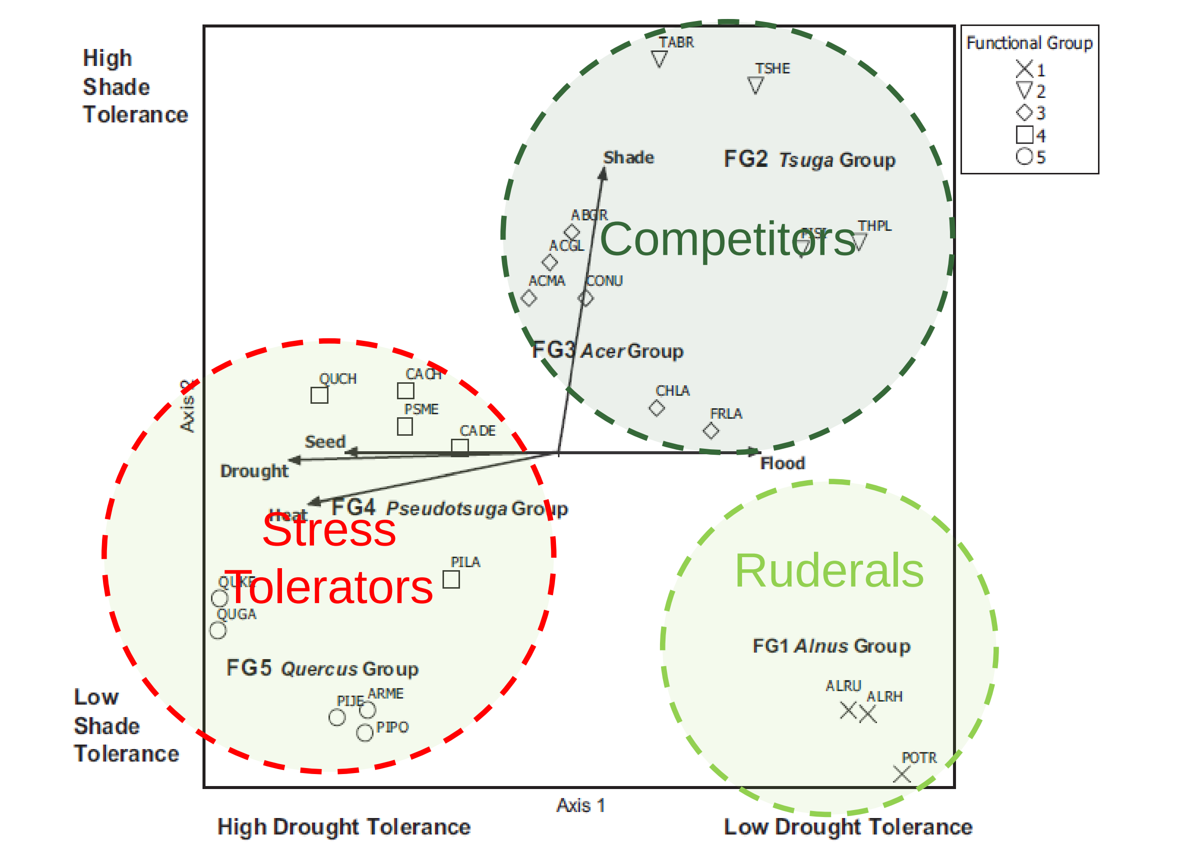

Fig. 2. Ordination of riparian tree species (triangles) in two dimensional attribute space. Species names are provided for each code in Table 1. Vectors represent the five life history characteristics with length and coordinates proportional to the correlations with the ordination axes (seed – seed size; heat – heat tolerance; drought – drought tolerance; flood – flood tolerance; shade – shade tolerance). Functional groups are coded in legend: Functional Group 1 (FG1) drought and shade intolerant (*Alnus* Group); FG2 – drought intolerant very shade tolerant (*Tsuga* Group); FG3 – moderately drought tolerant, shade tolerant (*Acer* Group); FG4 – drought tolerant, moderately shade tolerant (*Pseudotsuga* Group); FG5 – very drought tolerant, shade intolerant (*Quercus* Group).

Sarr, D., D. Hibbs, J. Shatford, and R. Momsen. 2011. Riparian Tree Regeneration in Western Oregon: The Roles of Life History, Environmental Gradients, and Disturbance. *Forest Ecology and Management.* 261(7):1241-1253.

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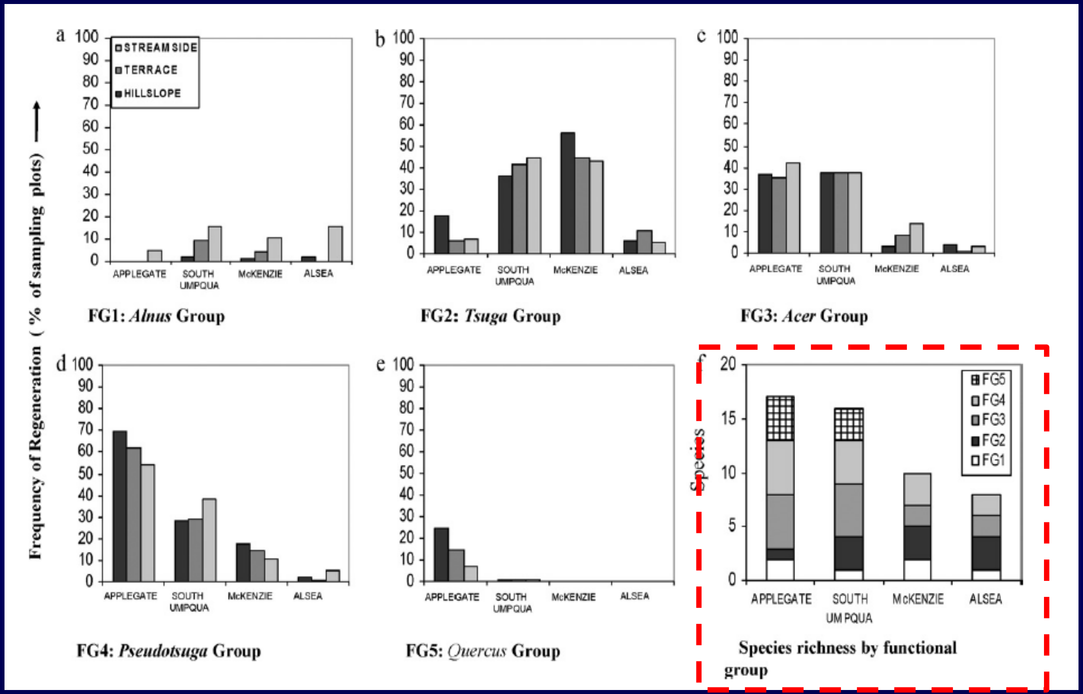
Tree Regeneration Patterns

Species Distributions Followed life history expectations

- **Ruderals were most common near streams**
- **Stress Tolerators were most common in driest climates**
- **Competitors were common in wet climates away from stream edge**
- **Species diversity was highest in the driest watersheds, because stress tolerators could coexist with stronger competitors**
- **Life history classification greatly assisted interpretation of regeneration**

Geographic and Topographic Patterns of Tree Regeneration (frequency)



Dry ⟷ Wet

Sarr, D., D. Hibbs, J. Shatford, and R. Momsen. 2011. Riparian Tree Regeneration in Western Oregon: The Roles of Life History, Environmental Gradients, and Disturbance. *Forest Ecology and Management.* 261(7):1241-1253.

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Guilds and Functional Groups – An Application

Effects of Impoundment on Riparian Vegetation in Tietar River Basin, Spain

- 14 Riparian Trees
- Classified into 9 guilds based on 20 traits AND field data (314 vegetation "bands")
- Evaluated changes in vegetation composition between 77 predam and 230 postdam "bands"

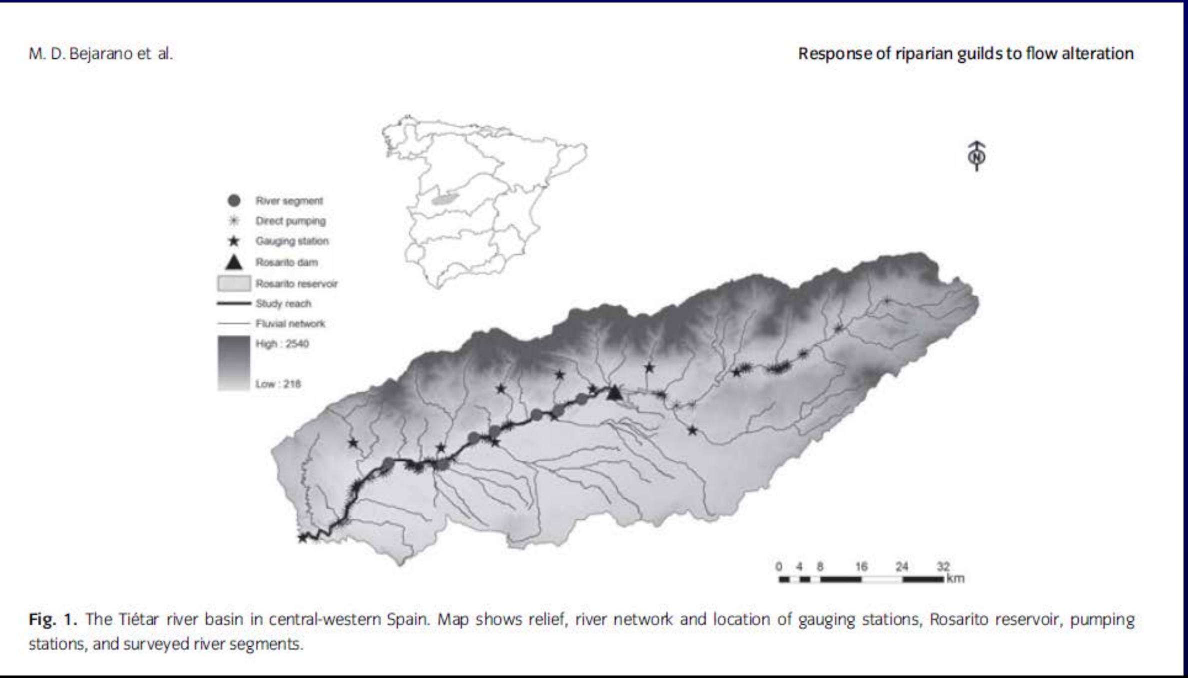

Fig. 1. The Tiétar river basin in central-western Spain. Map shows relief, river network and location of gauging stations, Rosarito reservoir, pumping stations, and surveyed river segments.

Bejarano, M.D., M. Gonzalez del Tanago,D. Garcıa de Jalon, M. Marchamalo, A. Sordo-Ward, and J. Solana-Gutie. 2012. Responses of Riparian Guilds to Flow Alterations in a Mediterranean stream. *Journal of Vegetation Science* 23 (2012)443–458

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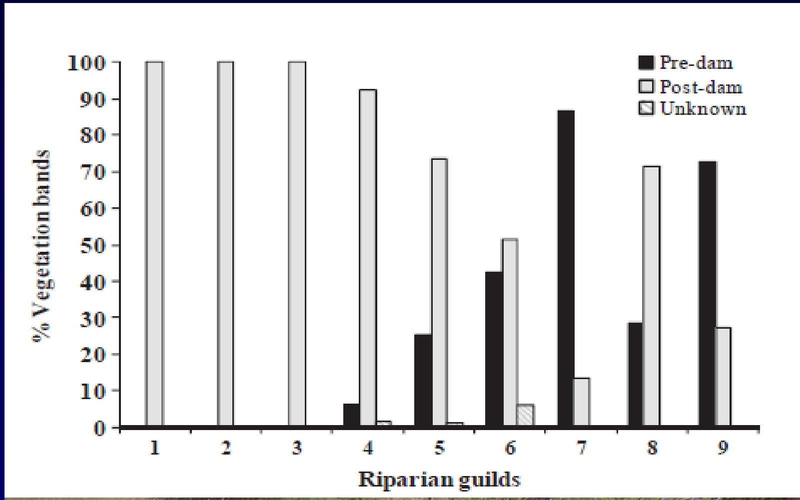
Guilds and Functional Groups – An Application

Effects of Impoundment on Riparian Vegetation

- Interesting terminology Drought Tolerance/Flow Association
- Xeric/Torrential guilds are exclusively postdam
- Vegetation encroachment on channel since impoundment
- Moisture, flooding, soil texture, canopy are primary gradients structuring vegetation
- Substrate effects are most pronounced below dam, diminishing downstream



Tamujo (*Fleuggea tinctoria*) Shrubland
Credit: Wikimedia commons

Bejarano, M.D., M. Gonzalez del Tanago,D. Garcıa de Jalon, M. Marchamalo, A. Sordo-Ward, and J. Solana-Gutie. 2012. Responses of Riparian Guilds to Flow Alterations in a Mediterranean stream. *Journal of Vegetation Science* 23 (2012)443–458

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Developing Riparian Vegetation Flow Response Guilds for Grand Canyon

Building a Traits Database for Colorado River Riparian Vegetation

- **Palmquist and Ralston reviewed literature and online data to develop a traits database for 114 species sampled in Grand Canyon from 2012-2013**
- **Traits emphasized physiological and morphological attributes.**

Physiological Traits

- Anaerobic Tolerance
- Drought Tolerance
- Salinity Tolerance
- Shade Tolerance

Morphological Traits

- Height at Maturity
- Rooting Depth
- Vegetative Reproduction
- Seed Size

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Delineation of Riparian Vegetation-Flow Response Guilds (Guild Classification)

- Unsupervised Guild Classification
  - Gower Distance Metric

Hierchical cluster analysis (HCA)

- Supervised Guild Classification
  - Rank Transformed
  - Upweighted
    - Anaerobic Tolerance
    - Drought Tolerance
    - Height at Maturity
  - Used a Euclidean Distance measure

Hierchical cluster analysis (HCA)

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Preliminary results, do not cite (Sarr et al., in prep.)

Evaluating Candidate Guilds

- Unsupervised Guild Classification

- Supervised Guild Classification

Candidate Guilds
(From HCA)

Candidate Guilds
(From HCA)

SIMPROF Permutation Test of Group Significance
Create "factor"

Principal Coordinates Analysis Ordination (Visualization)

Minimum Group Size Criterion (3 or more species)

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Preliminary results, do not cite (Sarr et al., in prep.)

Results: Guilds and Functional Group Classifications for Grand Canyon Riparian Systems

- Unsupervised Guild Classification
  - Seven Candidate Guilds

- Supervised Guild Classification
  - Ten guilds, but three had less than three species, so
  - Seven Candidate Guilds

Significant Data Reduction

Given 114 species, each guild averages about 17 species

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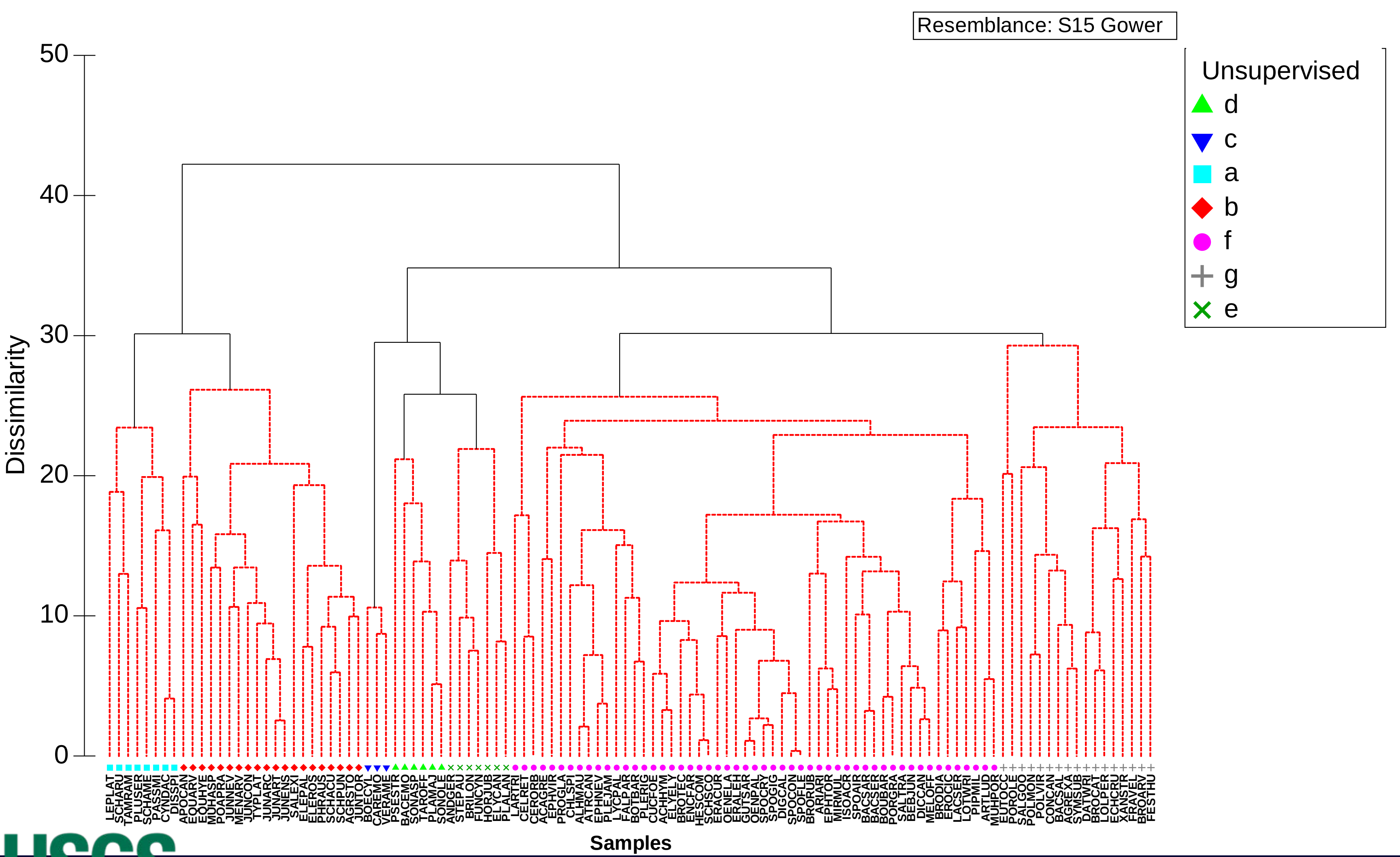
Preliminary results, do not cite (Sarr et al., in prep.)

Cluster Analysis Results (Dendrogram)

Unsupervised Classification



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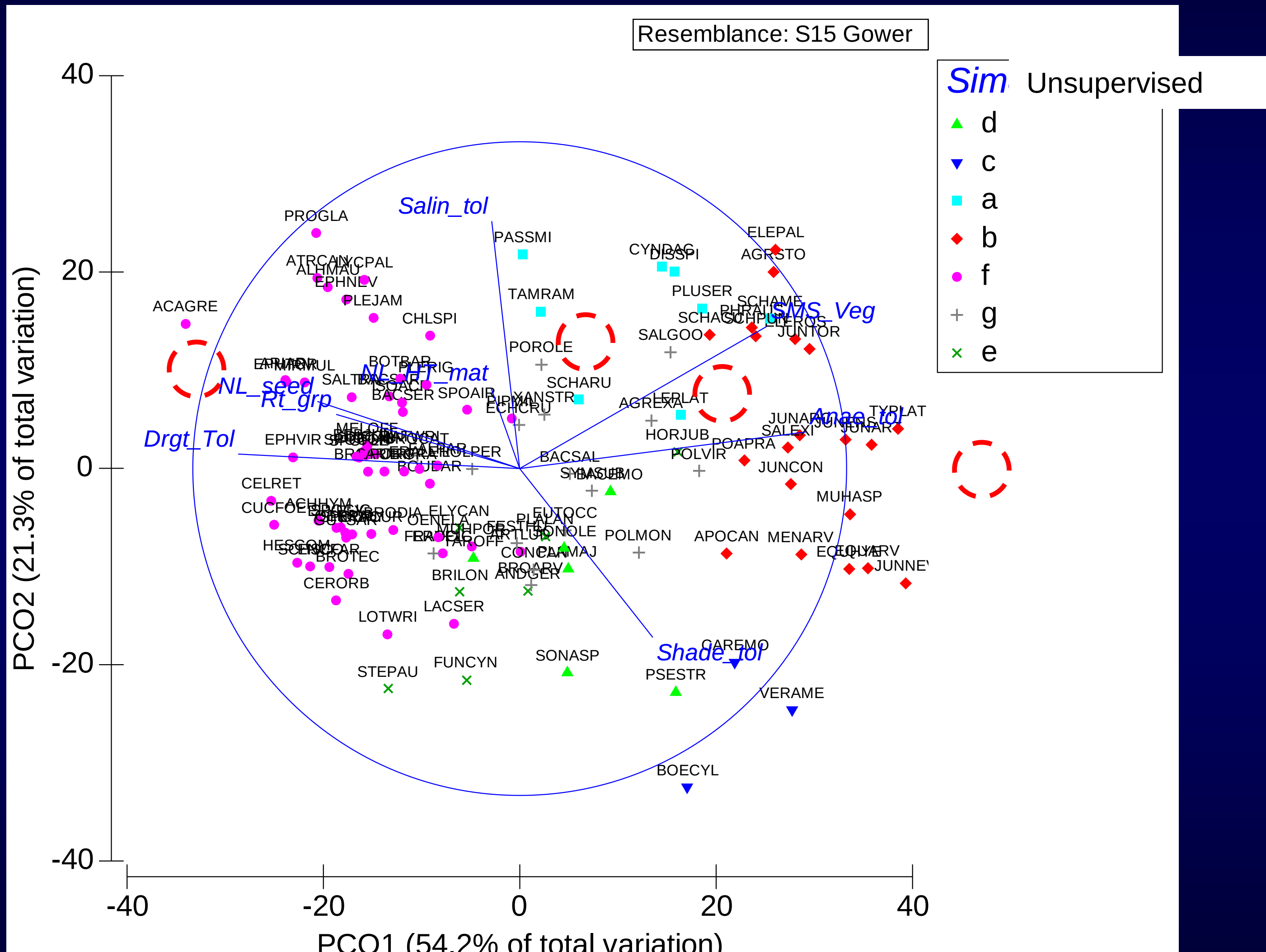
Cluster Analysis Results

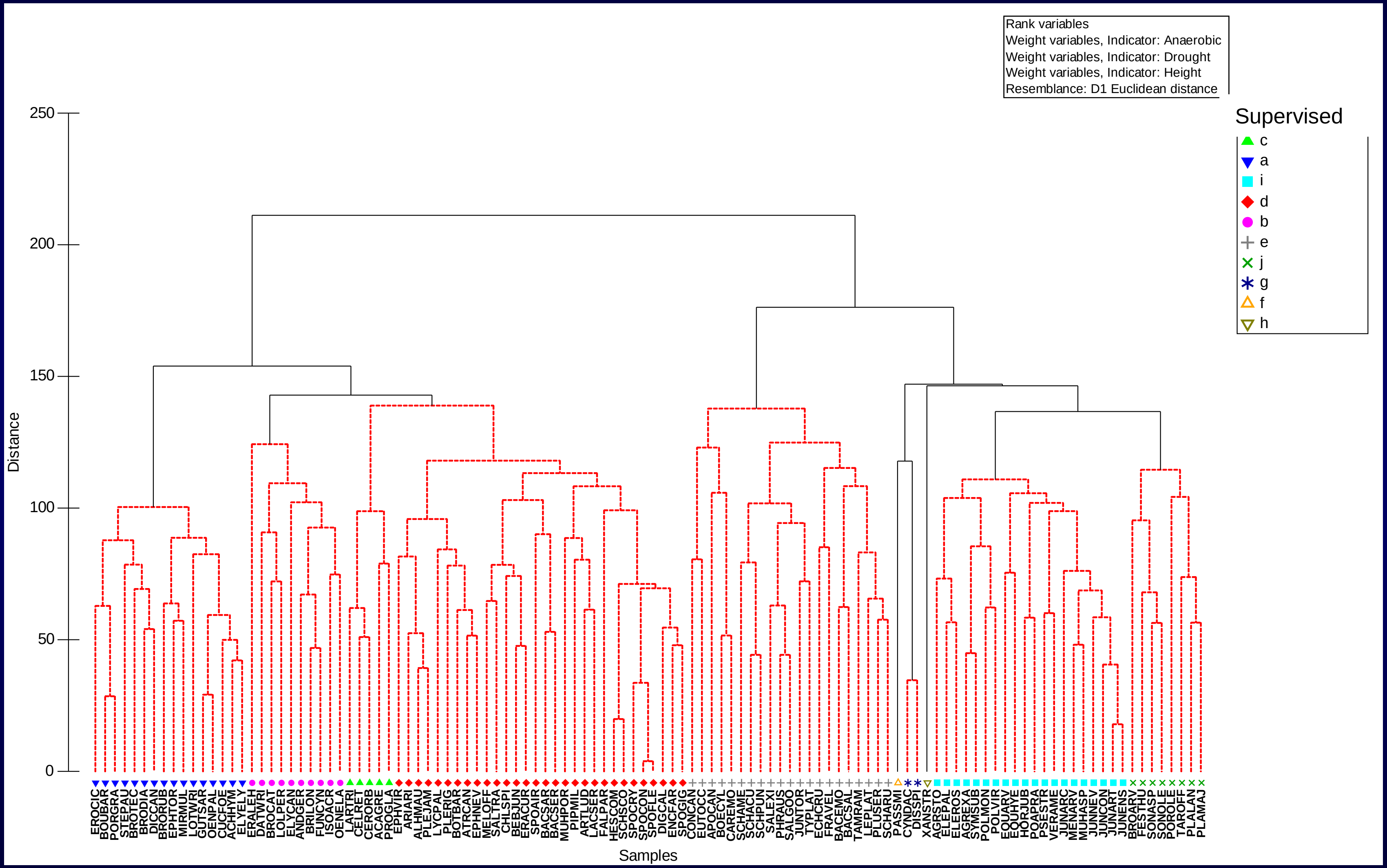
Unsupervised Classification



Preliminary results, do not cite (Sarr et al., in prep.)

Cluster Analysis Results (Dendrogram)

Supervised Classification



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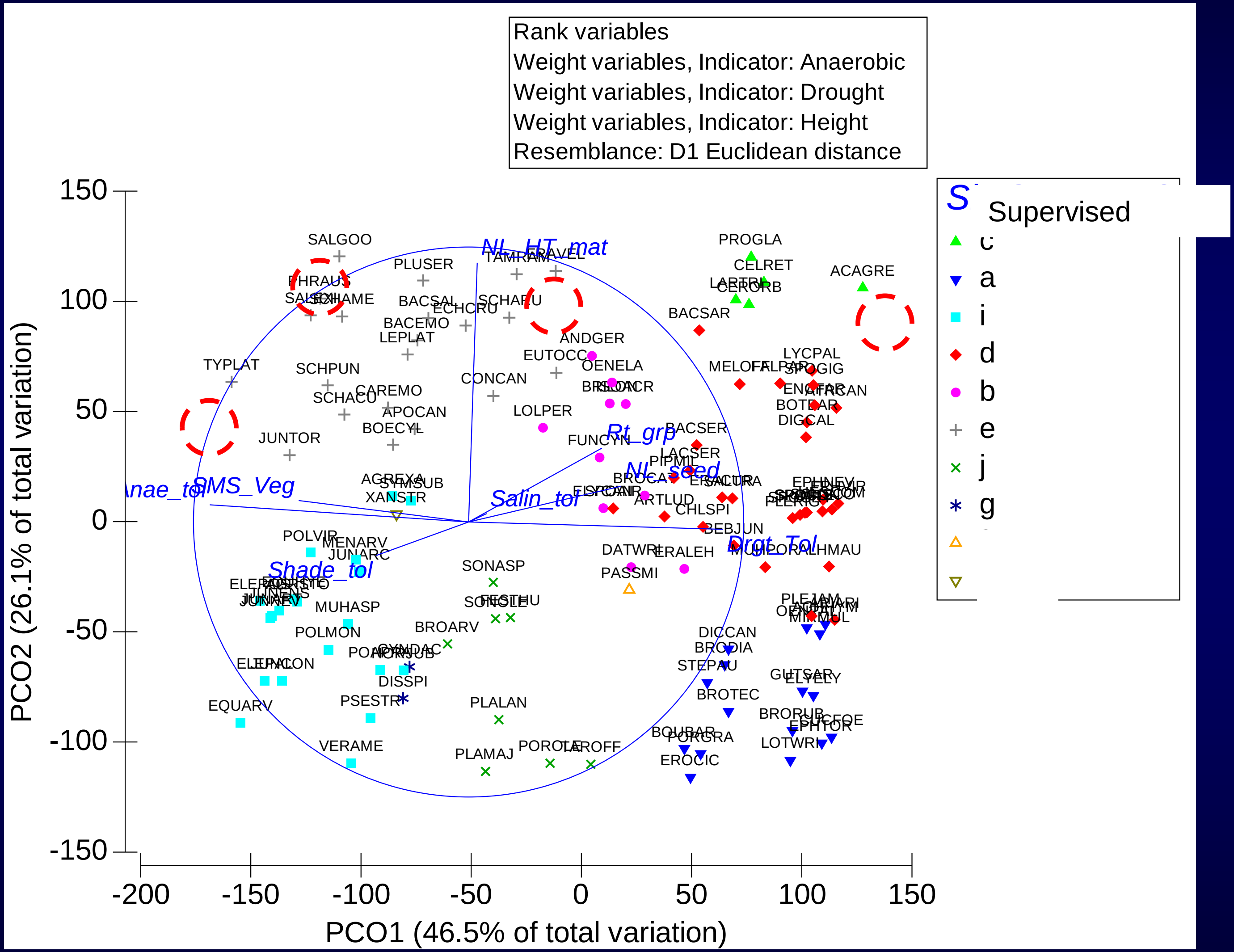
Cluster Analysis Results

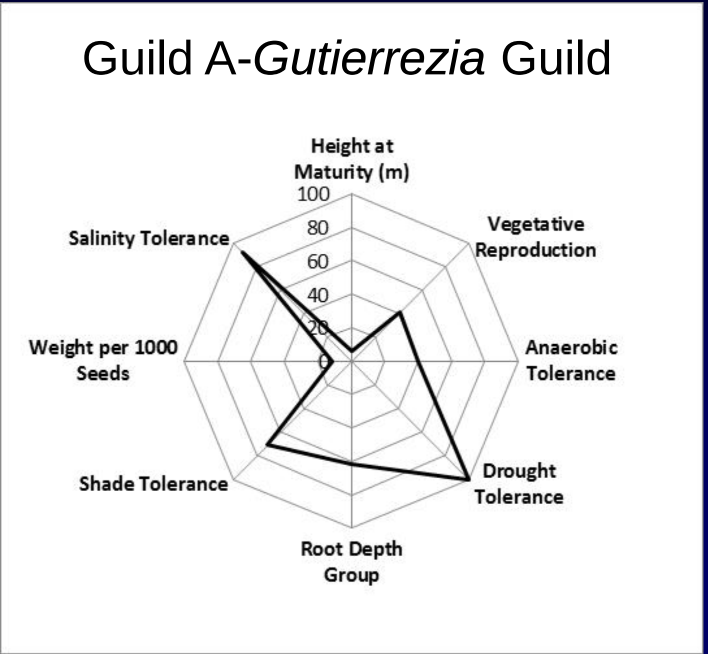
Supervised Classification



Preliminary results, do not cite (Sarr et al., in prep.)

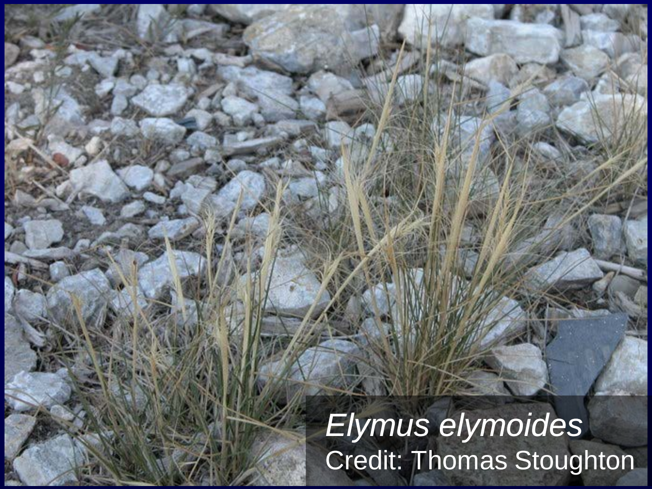
Guild Descriptions

Guild A-*Gutierrezia* Guild



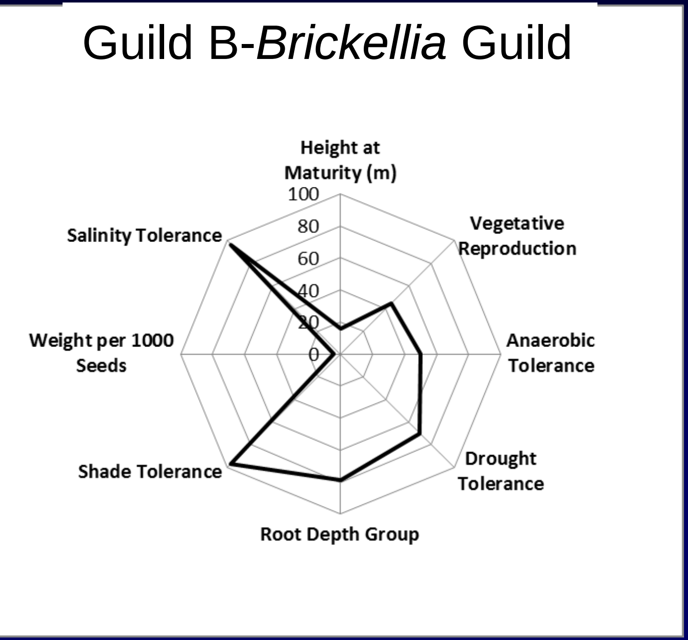
Guild A: This medium sized (n=16 species) guild consists of low statured, relatively deep rooted, nonclonal shrubs, forbs, and graminoids with low flood tolerance and high drought tolerance. Characteristic species include *Gutierrezia sarothrae, Stephanomeria pauciflora, Oenothera pallida, Achnatherum hymenoides, Elymus elymoides,* and *Bromus* spp.


Gutierrezia sarothrae
Credit: Robert Sivinsky


Elymus elymoides
Credit: Thomas Stoughton

Preliminary results, do not cite (Sarr et al., in prep.)

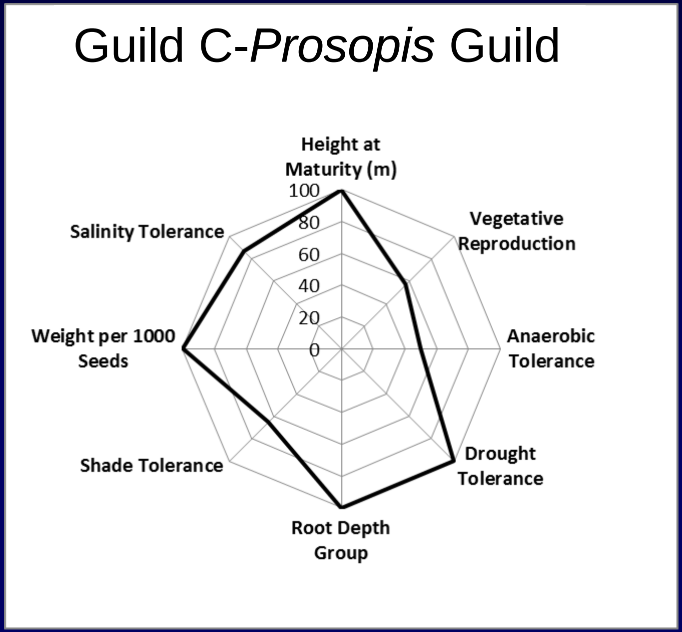
Guild Descriptions Guild B-*Brickellia* Guild



Guild B: This medium sized (n=10 species) guild is composed of a mixture of medium statured but deep rooted shrubs, robust forbs, and graminoids of medium to high drought tolerance and medium flood tolerance. Species include shrubs, such as *Isocoma acradenia* and *Brickellia longifolia*, rank forbs, such as *Datura wrightii* and *Oenothera elata*, and graminoids, such as *Andropogon gerardii*, *Elymus canadensis*, and *Lolium perenne*.

Preliminary results, do not cite (Sarr et al., in prep.)

Guild Descriptions Guild C-*Prosopis* Guild



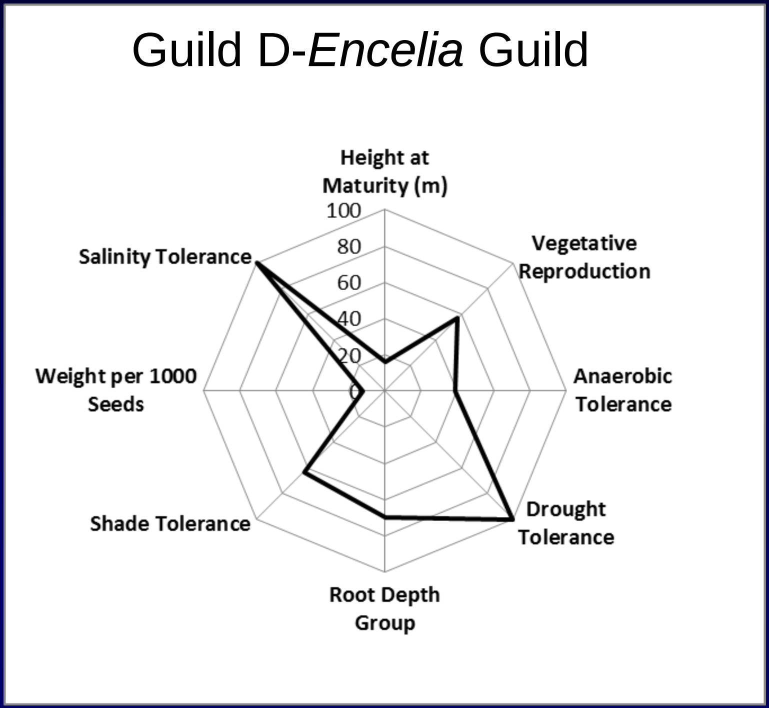
Prosopis glandulosa
Credit: Robert Sivinsky

Guild C: This small (n=5 species) guild consists of large seeded, deep rooted, and robust trees and shrubs characterized by high drought tolerance, and low flood tolerance. Species include *Prosopis glandulosa*, *Acacia greggii, Celtis reticulata, Cercis orbiculata,* and *Larrea tridendata.*

Celtis reticulata
Credit:Zoya Akulova

Preliminary results, do not cite (Sarr et al., in prep.)

Guild Descriptions Guild D-*Encelia* Guild



Guild D: This large (n=30 species) guild consists of medium sized shrubs and graminoids characterized by high drought tolerance, and low flood tolerance. Species include shrubs such as *Baccharis sarathroides, Fallugia paradoxa, Encelia farinosa, Ephedra spp., Lycium pallidum,* and graminoids such as *Achnatherum hymenoides, Aristida arizonica, Bouteloua* spp., and *Sporobulus* spp.

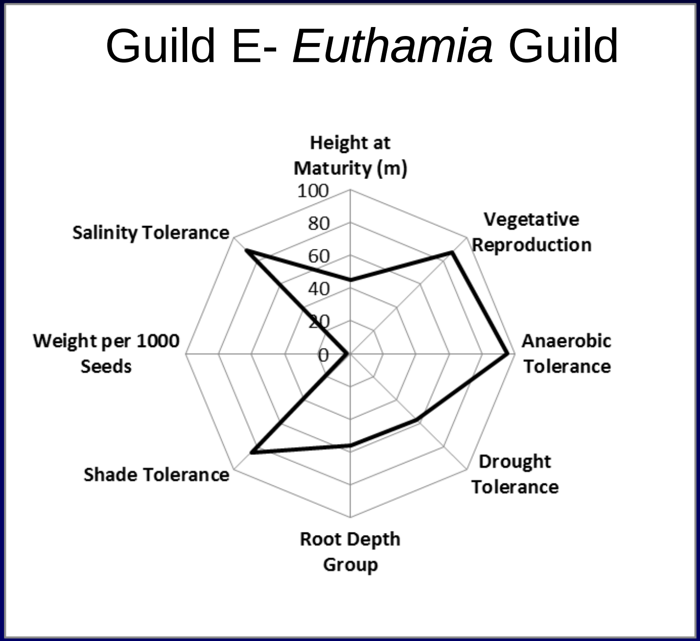
Baccharis sarathroides

Encelia farinosa
Credit: Christopher L. Christie

Sporobolus cryptandrus
Credit: Steve Matson

Preliminary results, do not cite (Sarr et al., in prep.)

Guild Descriptions Guild E-*Euthamia* Guild



Euthamia occidentalis
Credit: Aaron Arthur

Phragmites australis

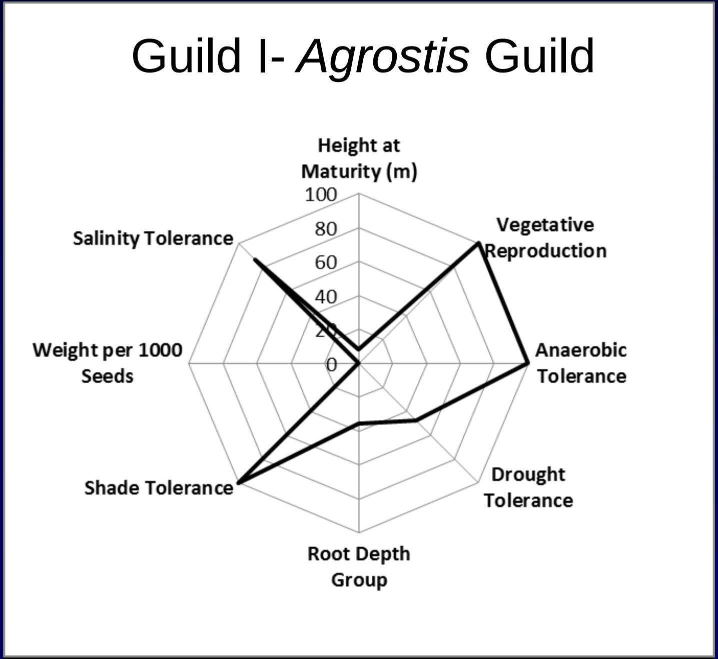
Guild E: This large (n=21 species) guild consists of robust trees, shrubs, forbs, and graminoids characterized by low drought tolerance, high flood tolerance, a tendency toward vegetative reproduction, and smaller seed sizes. Notable species include the trees *Salix goodingii, Tamarix ramossissima,* and *Fraxinus velutina*, shrubs such as *Salix exigua, Euthamia occidentalis, Baccharis emoryi, B. salicifolia,*forbs such as *Conyza canadensis* and *Apocynum cannabinum,* and robust graminoids such as *Typha latifolia, Schoenoplectus spp., Phragmites australis, Schedonorus arundinaceus,* and *Carex emoryi.*

Tamarix spp.

Salix gooddingi
Credit: Neal Kramer

Preliminary results, do not cite (Sarr et al., in prep.)

Guild Descriptions   Guild I-*Agrostis* Guild



Guild I: This large (n=20 species) guild consists of low statured forbs, and graminoids characterized by low drought tolerance, high flood tolerance, a strong tendency toward vegetative reproduction, and small seed sizes. Notable species include forbs such as *Veronica americana, Mentha arvensis, Equisetum* spp. and a diverse suite of largely clonal graminoids, including *Agrostis stolonifera, Eleocharis* spp., *Juncus* spp., *Polypogon monspeliensis*, *P. viridis*, and *Poa pratensis*.

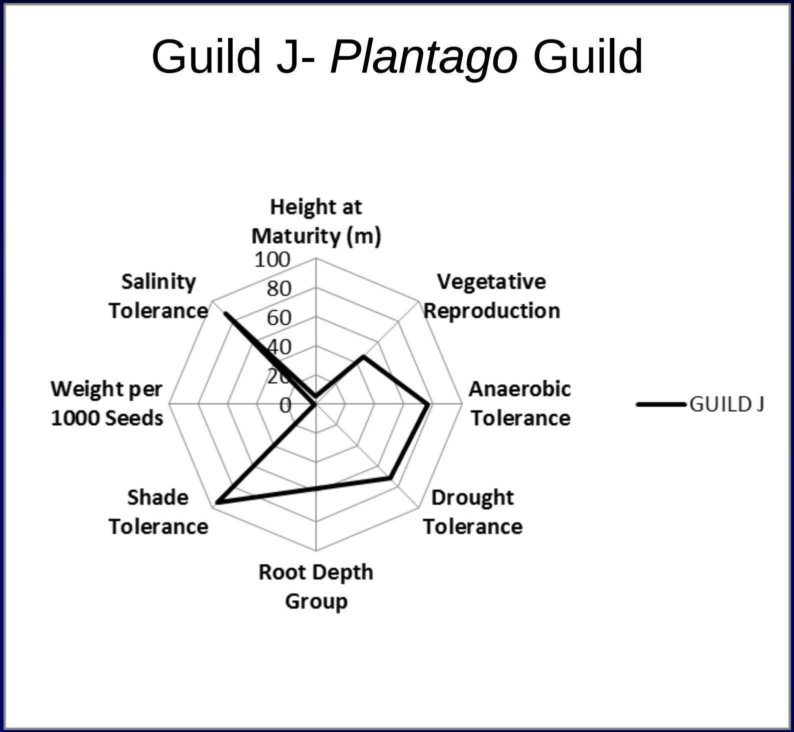
Agrostis stolonifera
Credit: Louis-M. Landry


Mentha arvensis
Credit: Louis-M. Landry

Preliminary results, do not cite (Sarr et al., in prep.)

Guild Descriptions

Guild J-*Plantago* Guild



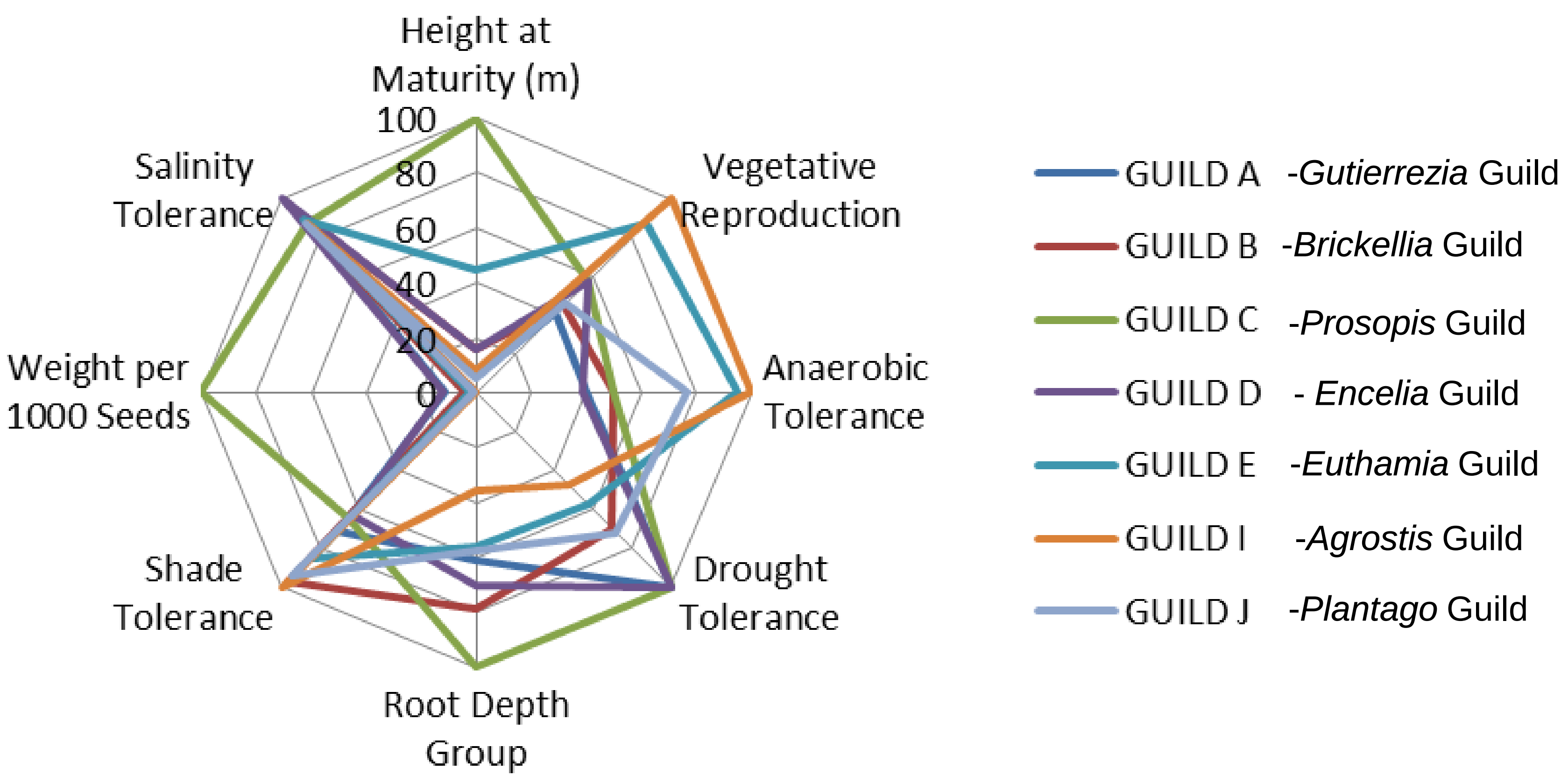
Guild J: This medium sized (n=8 species) guild is composed of a mixture of small statured, small seeded forbs and graminoids of intermediate drought and flood tolerance. Species include the forbs *Plantago major, P. lanceolata*, *Taraxacum officinale*, and *Sonchus* spp., as well as the graminoids *Festuca thurberiana* and *Bromus arvensis*.

Plantago major
Credit: Barry Breckling

Sonchus oleraceus
Credit: Neal Kramer

Preliminary results, do not cite (Sarr et al., in prep.)

Guild Characteristics



Preliminary results, do not cite (Sarr et al., in prep.)

Application: Riparian Guilds As a MonitoringTool

- A major challenge in most ecological monitoring efforts is high variation and low statistical power to detect change, due to low detection probabilities. This is especially true for many animal species, or spatially rare plant species.
- One solution is to increase sample numbers or increase the size of individual samples. Sample quadrat ($1m^2$) vs. site ($27m^2$)
- Other solutions include selection of indicator species (common species that predict rarer species)
- Since our guilds contain between 5 and 30 plant species, guilds have the potential to increase detection probabilities

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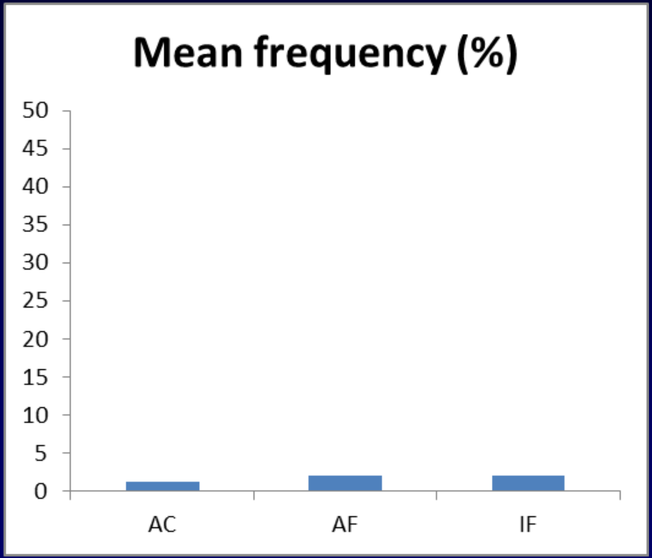
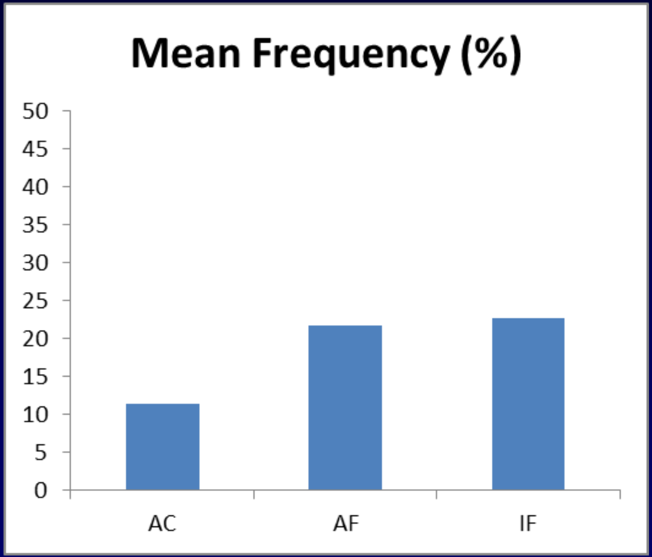
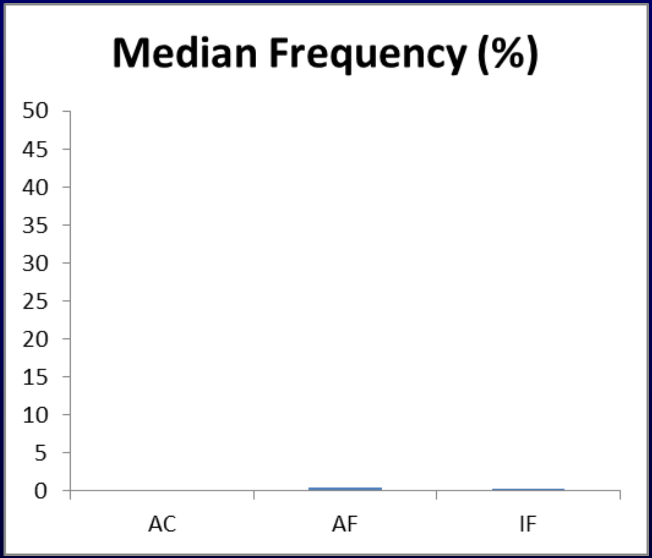
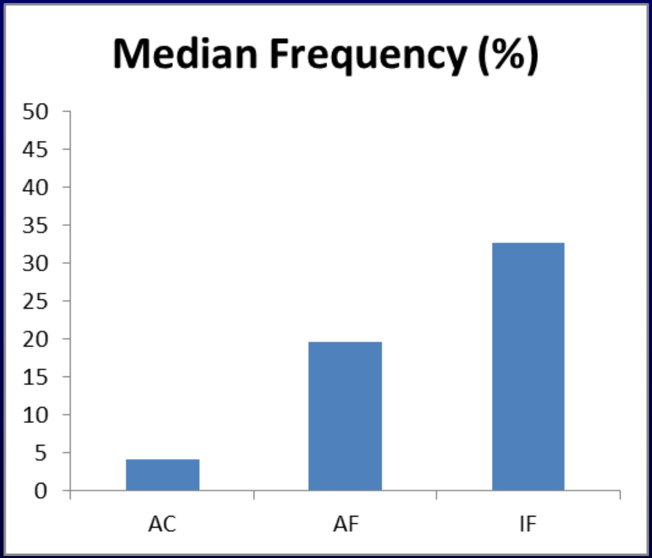
Preliminary results, do not cite (Sarr et al., in prep.)

Application: Guilds As a Monitoring Tool









INDIVIDUAL SPECIES

GUILDS

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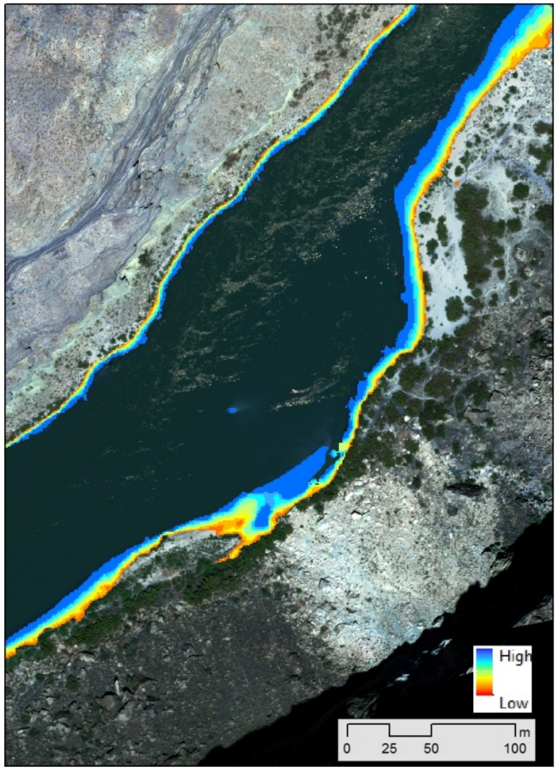
Preliminary results, do not cite (Sarr et al., in prep.)

Application: Riparian Guilds As a Modeling Tool

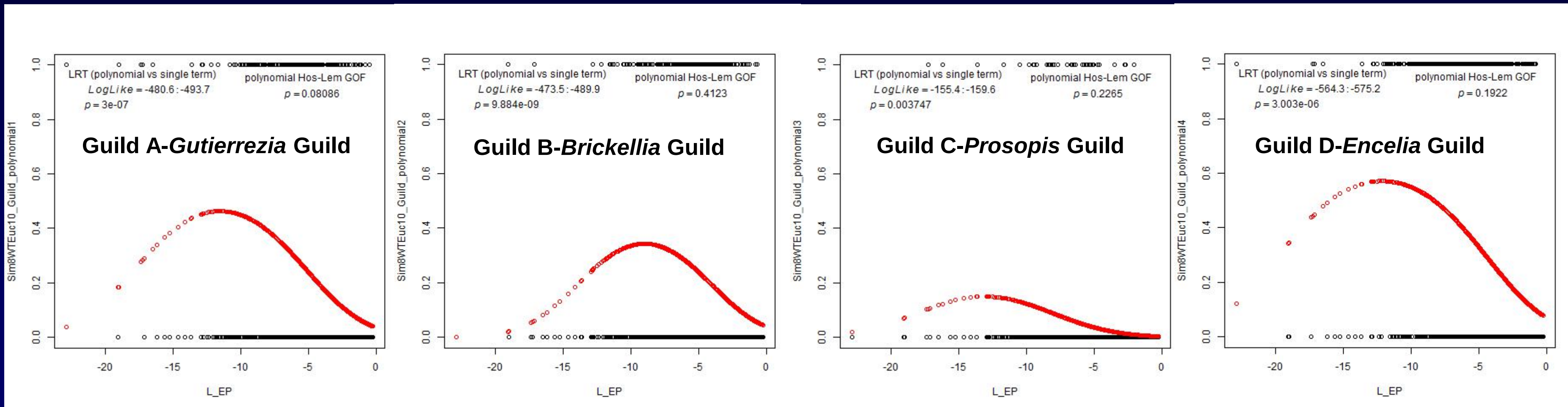
- Using logistic regression, we modeled the presence of each guild as a function of flow exceedance (amount of the time from 1985-2013 a site was inundated)
- We chose best models based using log-linear or polynomial equations
- Once the best models were selected, we used GIS to develop spatial grids of guild probability at a geomorphically complex sandbar site (Kwagunt Marsh)

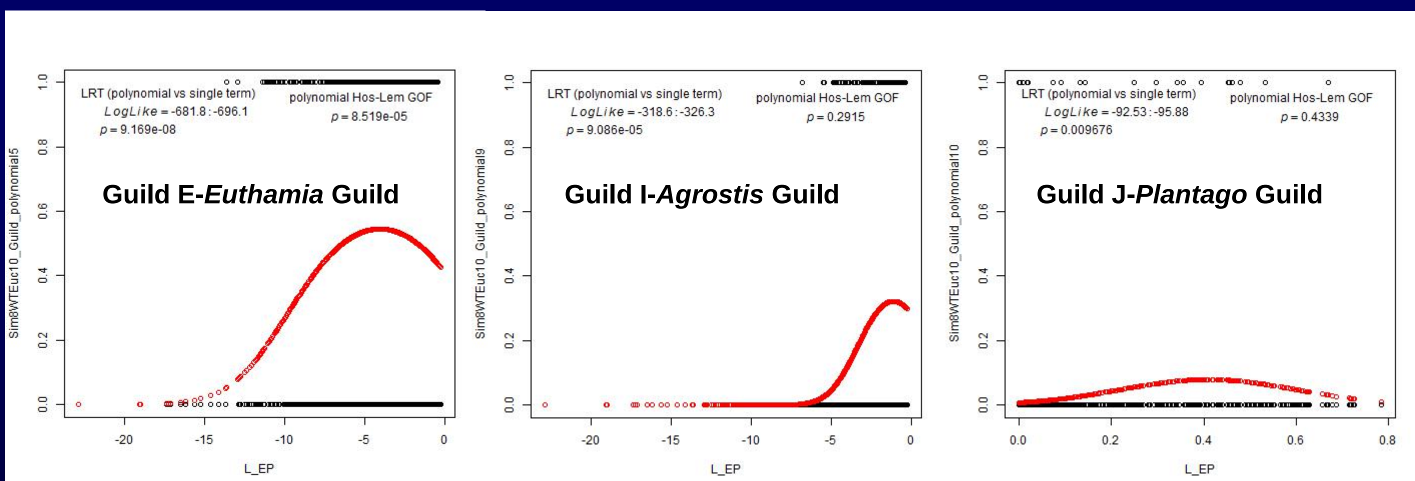
Forecasting Consequences of Alternate Flow Regimes



Preliminary results, do not cite (Sarr et al., in prep.)

Supervised Guilds Models





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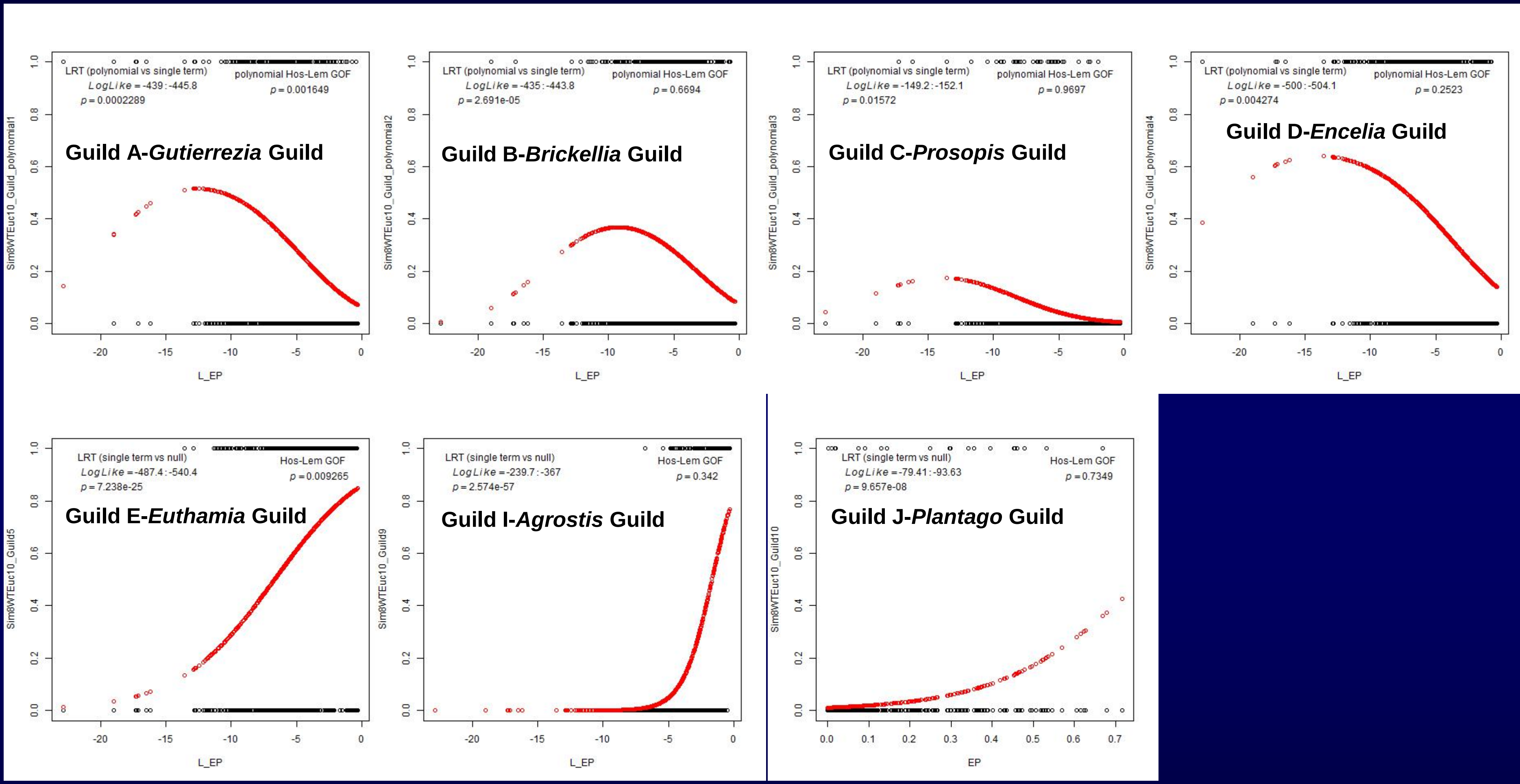
Preliminary results, do not cite (Sarr et al., in prep.)

Supervised Guilds Models (no zeros)



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Preliminary results, do not cite (Sarr et al., in prep.)

Application: Riparian Guilds As a Modeling Tool

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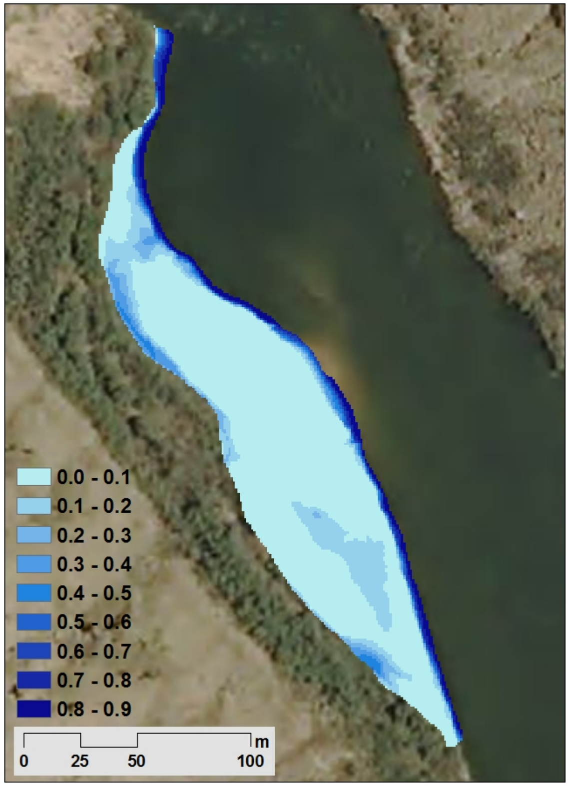
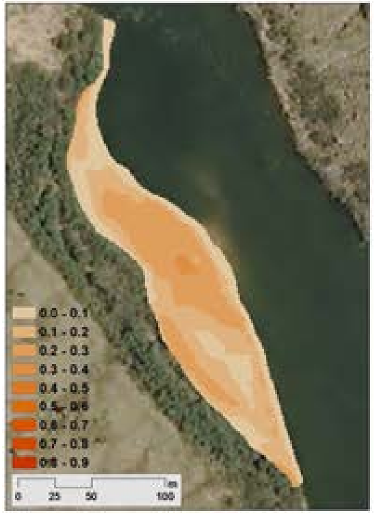
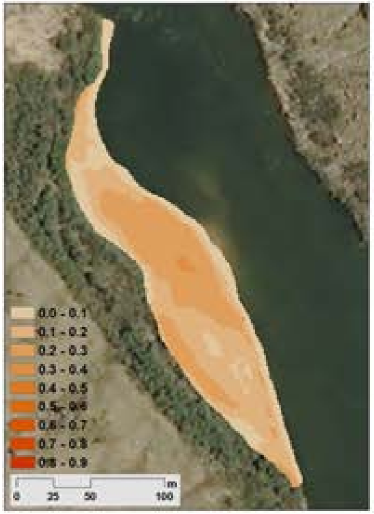


Kwagunt Marsh sandbar site. a) surface elevation, b) modeled exceedance probability (proportion of time that a given location is inundated, based on 1985-2013 flow data).

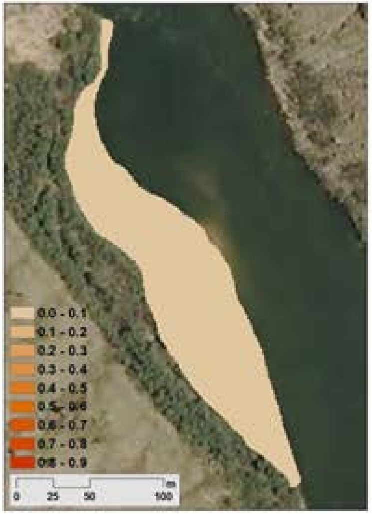
Preliminary results, do not cite (Sarr et al., in prep.)



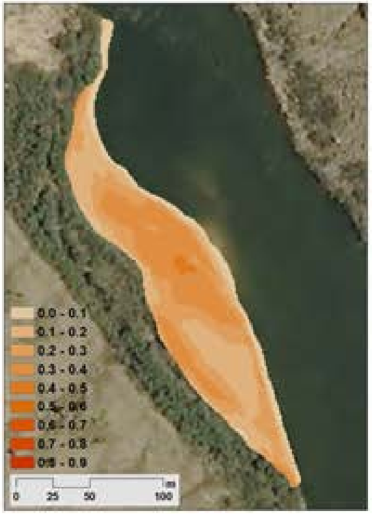
Guild A-*Gutierrezia* Guild



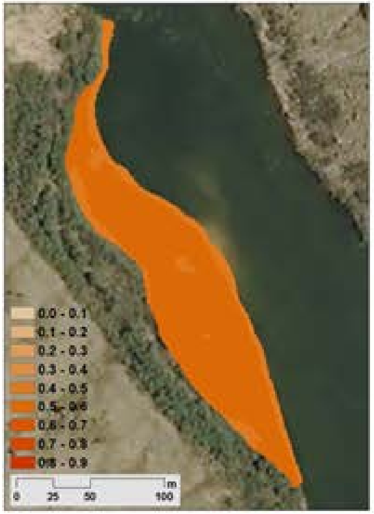
Guild B-*Brickellia* Guild



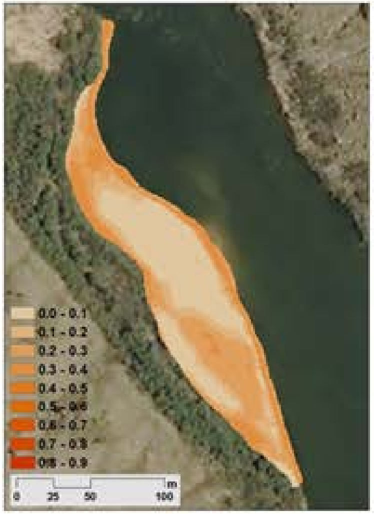
Guild C-*Prosopis* Guild



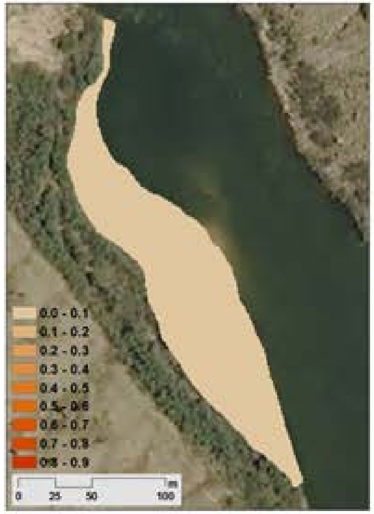
Guild D-*Encelia* Guild



Guild E-*Euthamia* Guild



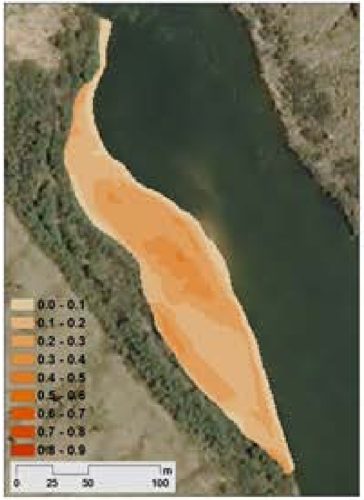
Guild I-*Agrostis* Guild



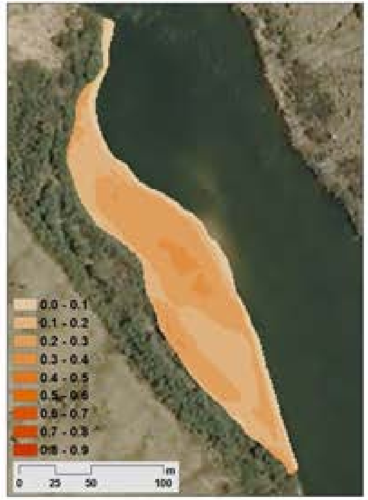
Guild J-*Plantago* Guild

Preliminary results, do not cite (Sarr et al., in prep.)

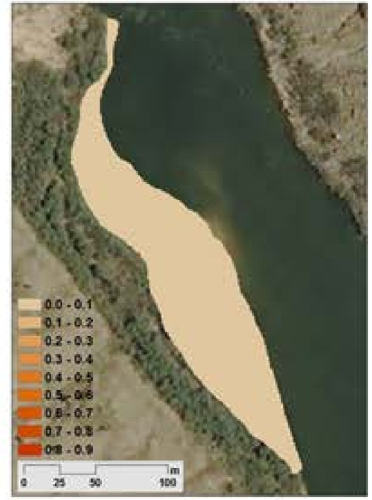
Modeled probabilities of occurrence for the guilds A-J from complete dataset(note that guilds F, G, and H had less than three species, and are not included). All probabilities are given in deciles from 0.0 to 0.9.



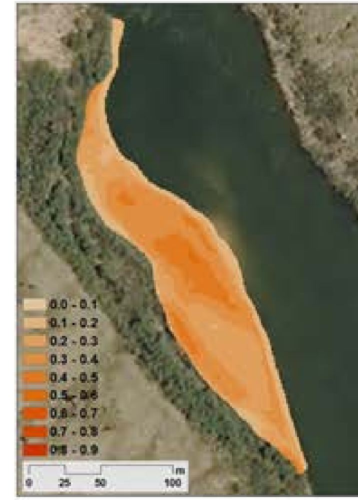
Guild A-*Gutierrezia* Guild



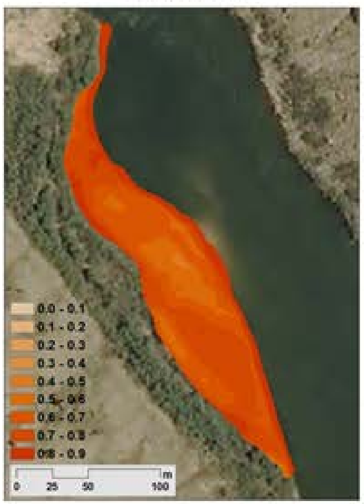
Guild B-*Brickellia* Guild



Guild C-*Prosopis* Guild



Guild D-*Encelia* Guild



Guild E-*Euthamia* Guild

Guild I-*Agrostis* Guild

Guild J-*Plantago* Guild

Preliminary results, do not cite (Sarr et al., in prep.)

Modeled probabilities of occurrence for the supervised guilds A-J with empty samples excluded (note that guilds F, G, and H had less than three species, and are not included). All probabilities are given in deciles from 0.0 to 0.9.

Riparian Guilds in Grand Canyon-Initial Findings

- Classification process is challenging, and we need to settle on a best approach, but we are making great progress
- It appears to be a sound approach to aggregating species for riparian vegetation monitoring
- Can also have strong application to alternative modeling scenarios.
- Could possibly be improved by making linkages to theoretical and other forms of vegetation analysis

Monitoring Riparian Vegetation in Grand Canyon: Next Steps

- Conduct modeling analyses of alternate flow scenarios (2015)
- Retrospective analysis of geomorphic and vegetation change on subsample of NAU sandbars (2015-2017)
- Conduct power analyses and floristic analyses of monitoring data (2015)
- Formalize monitoring protocol (2015-2016)
- Ask Emily more questions at her poster!

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Questions?
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