Primer on Restoration Ecology

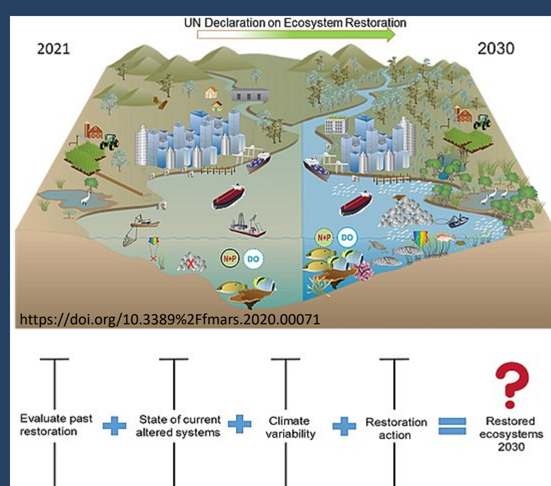

McFadden National Wildlife Refuge in SE Texas

Paul R. Gagnon, Ph.D.
Wetland Ecologist, USACE IWR

1

Brief Course Outline

1. Restoring to what?
   a. The way things were
   b. The way things are
   c. The way things are heading
2. Plant's eye view – plant dynamics and ecological succession
3. Important lessons from restoration ecology



https://doi.org/10.3389%2Ffmars.2020.00071

2

Large Populations Shaped the Pre-Columbian Environment

- Estimates of 62 million people in the New World
  https://doi.org/10.1016/j.quascirev.2018.12.004
- Modern-day USA heavily inhabited before 1492

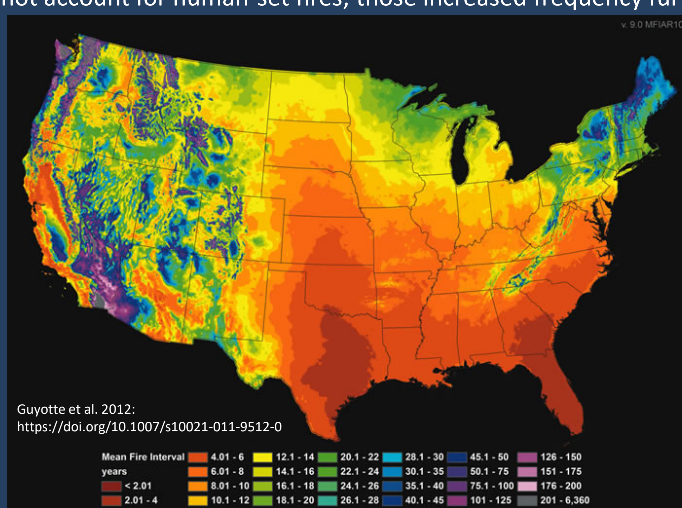
George Catlin: Ball-play of the Choctaw--Ball Up

- “The Great Dying:” 1492-1600
- Estimates of 90% mortality of Native Americans
- Smallpox, influenza, measles, massacres…
- Native cultures & populations fragmentary before settlers even moved west

3

There Was a LOT of Fire Before It Was the USA

- Fire Frequency 1650-1850 in Modern Day USA
- Based on physio-chemical model of climate and vegetation
- Does not account for human-set fires; those increased frequency further



Guyotte et al. 2012:
https://doi.org/10.1007/s10021-011-9512-0

4

Massive Continent-Scale Hydrological Modifications


Wikimedia Commons
A Dutch ditch

- Agricultural ditching and draining following European arrival in Midwest and elsewhere
  - Local scale action, watershed-wide affects
  - Flood pulse is earlier, more pronounced
- Levee building 19th – 20th Century
  - River valleys cut off from flood pulses
  - Deeper, longer flooding inside levees

Aerial view of a tile drainage system


http://www.omafra.gov.on.ca/english/engineer/facts/10-091.htm


USACE MVD

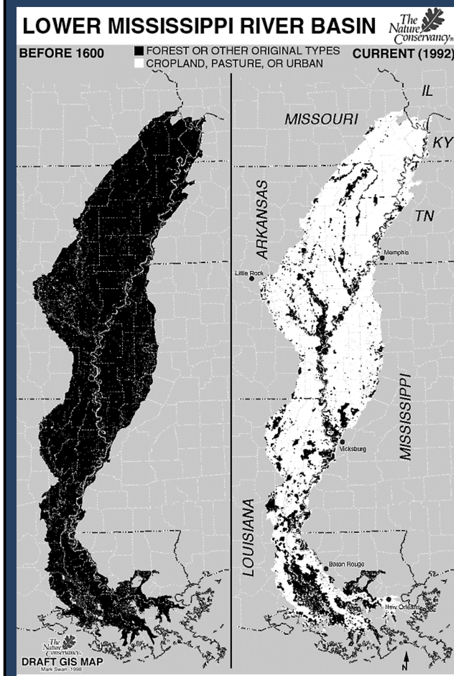
5

Why Is Restoration Necessary Anyway?

"Never has a concerted effort to drain, dike, levee, fill or otherwise alter wetlands on a national scale been undertaken so efficiently and so effectively than that which was facilitated by the US government in the 19th & early 20th centuries" (Somerville & Pruitt 2010).


Lake Drummond at Great Dismal Swamp National Wildlife Refuge in Virginia; Rebecca Wynn/USFWS; Wikimedia Commons

6



Wetlands Conversion & Habitat Fragmentation

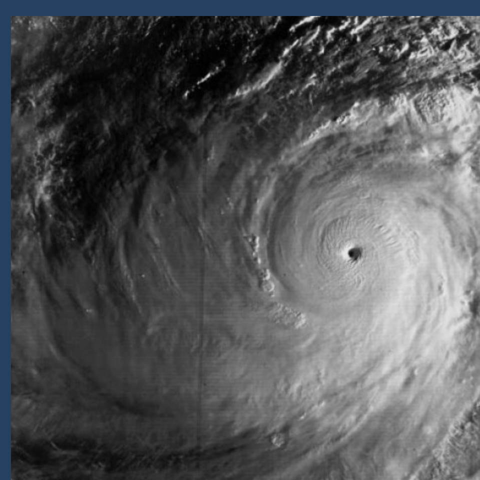
- By the 1970s, half of all wetlands in the lower 48 were filled or drained
- Productive farmland when drained
- Result is habitat fragmentation
- Remaining patches too small to support certain species
- Urban and rural development continues apace

So Here We Are…

7

Disturbances Common in Restoration Sites

Flooding
Hurricanes
Tornados
Ice or ice storms
Fires
Drought
Landslides/avalanches
Earthquake (e.g., New Madrid)
Herbivory
Disease
Toxins
Habitat Fragmentation
Targeted over-harvest
Eutrophication (nutrient pollution)

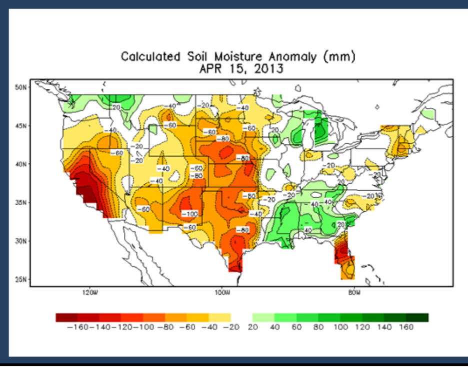


8

Components of Disturbance

There are 4 components of disturbance (Keddy 2010):

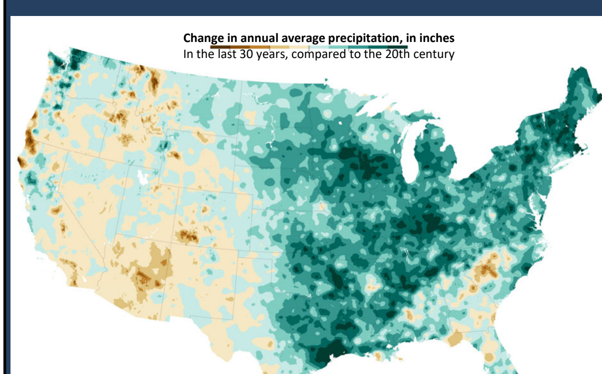
1. **Intensity** – how much damage per unit time
2. **Duration** – how long damage continues
3. **Frequency** – how often damage recurs
4. **Area** – spatial extent over which damage occurs



9

The Way Things Are Heading

- Increasing intensity of severe storms, tornados, hurricanes, droughts, heatwaves
- Changing rainfall patterns: wetter in the east, drier in the west
- Increasing severity of wildfires
- Sea level rise and resulting "coastal squeeze"



NYT: These Maps Tell the Story of Two Americas: One Parched, One Soaked
NOAA: National Centers for Environmental Information

Wikimedia Commons

Wikimedia Commons

10

Recap

- North America was heavily influenced by human inhabitants before Europeans arrived.
- Since European settlement there has been drastic changes to:
  - fire regimes
  - hydrological regimes
  - habitat connectivity
- The current and historical "normals" always involved dynamism – perceptions of stability are an artifact of limited human time scale
- Looking forward: climate change, severe weather, sea level rise
- Picking a restoration target will be challenging and… arbitrary
- Good luck. Choose carefully!

11

Plant's Eye View of Restoration:

Plant Dynamics and Ecological Succession

Ecological succession – the idea that a predictable assemblage of species will first colonize following an ecological disturbance, followed by a (predictable?) progression of changing species assemblages (until arrival of "climax" assemblage?)

- Idea first popularized by **Clements** in the early 20th Century
- Was and is widely taught, to the point of being dogma in ecology

12

Succession According to Gleason

Gleason's idea (1926) was that succession is more complex, less deterministic.

Much greater role of chance factors

Old fields dominated ecologists' perceptions about succession in 20th century.

Only rarely do disturbances initiate directional species replacement.

Instead, those species already present normally regenerate (Platt & Connell 2003).

Founder effects and site history extremely important in predicting succession

13

The Soil Seed Bank

Soil Seed Banks – buried reserves of viable seeds

- Seeds stored in the soil can strongly influence what plants regenerate during restoration.
- Sapling banks – advanced regeneration may be more important than seeds in some forested systems.

Dispersal limitation – there are limits to where seeds can disperse.

- Important in determining what plants will appear following disturbance
- Some seeds disperse more easily than others.

14

Natural Disturbance and Regrowth

- Disturbance removes biomass
- new resources become available: e.g., light, space, various nutrients.
- Densities > 1000 seeds m^{-2} common in coastal & prairie marshes in SE USA
- Densities > 10,000 seeds m^{-2} common in wet meadows (Keddy 2010)
- Heat or smoke from fire, increased light, temperature fluctuations can trigger germination.
- Some species adapted for regeneration post-disturbance

15

Tracy's sundew *(Drosera filiformis* var. *tracyi)*

Competition in Plant Communities

- All plants require the same basic resources
- Water & sunlight
- N-P-K, micronutrients
- They all depend on the same basic means of procuring them.
- Therefor plants compete with other plants.

16

Restoration Lessons from Ecology Theory

Island Biogeography:

- Restoration sites as "islands" in fragmented landscape
- Large sites should have more different habitats than small sites.
- Large sites should typically support more species.
- Sites near existing habitat blocks attract and sustain more species.
- Desired species may have particular niches that must be incorporated or built.

Succession:

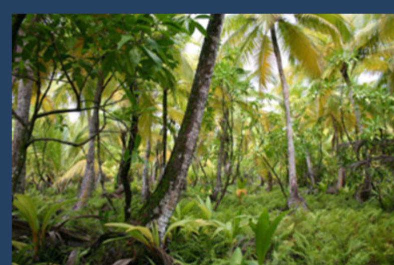
- The more degraded the site, the more prep necessary.
- Some early dominants can persist indefinitely (founder effects).
- Introduce woody plants if desired, as they may or may not arrive (dispersal limitation).

17

Restoration Lessons from Ecology Theory

Competition/Facilitation:

- Some plants benefit from facilitators, especially in degraded sites.
- Tipping balance away from dominant competitors is a challenge
- Conditions necessary for mature plants may differ from those for regeneration.



Stress/disturbance:

- Systems naturally experiencing extremes have high resilience.
- Diverse communities can be more resilient than those with few species.

18

Recap

- The idea that one assemblage of organisms will predictably follow another after a disturbance is often inaccurate.
- Oftentimes instead:

  Biotic Assemblage = (Founder Effects) × Stochasticity

  where: Stochasticity = disturbances + (site idiosyncracies)
- Soil seedbanks can be your friend (or enemy) for restoration.
- Seeds are limited in where they can disperse, so they might need help getting to your site.
- Plants compete; you might not like the winners.
- Predicting where your restoration will end up is… tricky

19

Important lessons from restoration ecology: wetlands case studies

Eutrophication

N accumulates in wetlands & aquatic systems

Four main consequences (Keddy 2010):

1. Fertilizer eliminates nutrient limitation
   a) Increased vegetative growth reduces species richness.
   b) Small-stature plants, carnivorous plants and evergreens endangered.
2. Plants growing faster with more N taste better to herbivores, whose populations increase.
3. In shallow water, floating algae increases, killing macrophytes.
4. As algae dies, decomposition consumes O_2 -> hypoxia

20

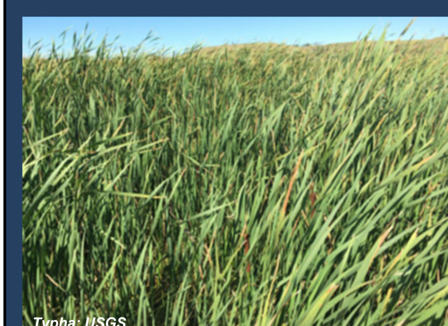
Eutrophication – a Big Deal for Wetland and Aquatic Systems

- Our industrial age = siltified, eutrophied rivers
- Industrial agriculture radically altered nutrient cycles
- Nitrogen in agriculture not from natural sources
- Haber-Bosch process fixes inert atmospheric N_2 into bioavailable ammonia/nitrates for fertilizer and explosives
- Alchemy of Air (Hager 2009) – good read!
- Nobel Prize, averted mass starvation, half the green revolution
- Bioavailable N is now drastically increased
- Industrially fixed N 1980-1990 more than all industrial fertilizer applied previously ever (Vitousek 1997)

21

Nutrient Removal vs. Biodiversity

- Productivity enhanced by nutrients; not species richness
- High species diversity often not possible in eutrophied systems.
- Monodominance or very low diversity is the rule in eutrophied systems (Bedford et al. 1999; Zedler 2006).
- Nutrient removal wetlands and biodiversity wetlands are incompatible.
- Agricultural wetlands are prone to invasion by reed canary grass, phragmites, typha, etc.



- Restored wetlands for biodiversity should be located upstream of eutrophied water, or with a nutrient-removal buffer.
- Low fertility locations best for biodiversity restorations, but wetlands are sinks; sometimes eutrophication unavoidable.

22

Restoring Stressed Systems


Naturally meandering river within its floodplain
Kissimmee River in Florida


Channelized; deposited dredged material destroying wetlands

- Removal of the stress-causing agent usually essential
- Removing the stress-causing agent may not be enough
- System could have changed, e.g., new invasive species may be present
- Founder effects!
- Some degraded systems are virtually un-save-able given scarce resources

23

Invasive Species in Restoration

- Invasive species are the rule rather than the exception.
- Many of the most invasive of plants are wetland species.
- Invaders will likely require sustained, repeated attention.
- Ounce of prevention worth pound of cure.
- Invasions caught early are much easier to combat.
- For some species, once they have attained a particular density, it can be extremely difficult to eliminate them.


Phragmites at Farmington Bay, Utah; NovelFeynman

24

Nutrient Limitation and Diversity

Big related questions:

1) what are the limiting nutrients?
2) how are increased nutrients from human sources affecting wetlands?

- N is typically most limiting in terrestrial systems.
- In wetlands, N can accumulate, and P is often limiting, or both N&P.
- The most species-rich wetlands are not the most productive ones.
- Wetlands with the highest NPP typically have lower species-richness than some others.
- Highly productive wetlands often end up dominated by single or few species.
- Agricultural runoff has documented effects – as NPP increases with N & P pollution, species richness declines as rare & uncommon species get outcompeted, and (oftentimes), invasives form monodominant stands

25

Reestablishing Plants

- Establishment requirements for different plants vary greatly.
- Some plants need full sun, mineral soil.
- Some need shade, constant moisture, nurse plants.
- Rhizomes vs. seeds vs. cuttings etc.
- Genotypes matter:
  - *Spartina alterniflora* is highly clonal
  - some genotypes greatly outperformed others (Seliskar et al. 2002)
- Goal is to establish a **self-regulating system**
- Easier said than done
- Easiest for nutrient-capture projects: nail the hydrology, add nutrients – done!!
- Where the goal is high species richness, eutrophication and invasive species a constant, long-term threat
- Lengthy monitoring windows, adaptive management become essential


Spartina alterniflora: Wikimedia Commons

26

Difficult-to-Restore Wetlands

Lag: Some wetlands take a very long time to "mature:"

- Forested wetlands
- Peatlands

Other difficult-to-restore wetlands:

- Formerly species-rich wetlands may be overrun with monodominant invaders
- Wetlands for which background conditions have changed (e.g., loss of pollinators, altered disturbance regime, habitat fragmentation of landscape matrix, increased nutrient loads from non-point sources, etc.)
- Temporarily flooded sites are hard to get just right – slightly too lengthy or too brief flooding, major implications for biota

27

Compensatory Mitigation Success Rate?

Study by Turner et al. (2001)*:

- For every 100-ha of wetlands permitted to be filled, 178-ha of mitigated wetlands required as compensation.
- Of these 178-ha required, only 134-ha actually get built.
- Of these 134-ha built, only 77-104 ha would develop as required, thereby complying with permitting regulations.
- Of these 77-104 ha developing as required, only 16-19 ha would pass requirements for functional equivalency.

* Turner, R. E., Redmond, A. M., & Zedler, J. B. (2001). Count it by acre or function—mitigation adds up to net loss of wetlands. *National Wetlands Newsletter*, *23*(6), 5-6.

28

Do Restored Wetlands Do What They're Supposed To?

- Much debate about how well restoring wetlands works
- What we know about restoring high-functioning wetlands:
  - High habitat & topographic heterogeneity necessary for biodiversity.

Hydrological features:

- Slowed water flow by increase water friction – sinuosity, organic soils, other permeable substrates
- Shallow pockets of standing water for denitrification
- Some deep pools for slowing water so it drops its sediments (phosphorous).

Watershed scale restoration can be most effective:

- Focus on headwater restoration, denitrification for improved water quality.
- Focus on creating large catchments for flood control, timing of emptying and flooding control structures
- Focus on full watershed heterogeneity for biodiversity, large blocks and connecting corridors, niches of desired target species.

29

Restoration Policy Definitions and Concepts

Section 404 of the Clean Water Act (via USEPA)**:**

1. **Restoration** – site manipulation with the goal of returning natural/historic functions to a *former or degraded* aquatic resource. Two subcategories:
   a) **Re-establishment** – site manipulation with the goal of returning natural/historic functions to a former aquatic resource. This rebuilding of a *former* aquatic resource yields a *gain in aquatic resource area and functions*.
   b) **Rehabilitation** – site manipulation with the goal of repairing natural/historic functions to an *existing, degraded* aquatic resource. Yields a *gain in aquatic resource function, but not resource area*.
2. **Establishment** – (creation) site manipulation to develop an aquatic resource that at a *novel, upland site*. Yields a *gain in aquatic resource area and functions*.
3. **Enhancement** – site manipulation to heighten, intensify, or improve a specific aquatic resource function(s). Yields a *gain of selected aquatic resource function(s)* but may cause a *decline in others*. Yields *no gain in aquatic resource area*.
4. **Preservation** – protection to maintain aquatic resources by implementing appropriate legal and physical mechanisms. Yields *no gain in aquatic resource area or functions*.

30

Recap

Field of Dreams Hypothesis*: **If you build it, they will come**
Translation: "If you get the hydrology right, you're done."

Not so fast…

If you build it, they **MIGHT** come.
IF they come, they might **STAY**.


Restoring sheetflow with native plantings; NPS Kings Canyon

- If you get hydrology right, restoration has a chance.
- For stream restoration, this might suffice.
- For nutrient capture wetlands, this might suffice.
- For high biodiversity sites, the following may be essential:
  - more help establishing desired species
  - long term monitoring
  - adaptive management to fight invasive species

*Palmer, M. A., R. F. Ambrose, and N. L. R. Poff. 1997. Ecological theory and community restoration ecology. Restoration Ecology 5:291–300.

31

Teaser for My Next Section Later Today


Bottomland hardwood forest in Tensas Parish, LA; photo by Virginia Velez-Thaxton

Why Hydrology Is So Important: A Wetland Ecology Case Study

32