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Wetland Ecology – Basic Principles

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Wetland Ecology

- Primary & Secondary Succession
- Disturbance
- Ecological Thresholds
- Ecological Dynamics
- Resistance/Resilience (sensitivity)
- Intensity & Duration of Disturbance

Ecology

Ecology – the study of relationships between organisms and their environment.

Ecology attempts to better understand the complex interactions:

- Between organisms, and
- ***Organisms relationship with abiotic components and their environment***

Ecological Succession

Ecological succession is a reasonably predictable process of changes that occur over time in an ecosystem.

- Ecosystems change over time, especially after disturbances, as new species move in, populations change, and species die out.

Two types of succession:

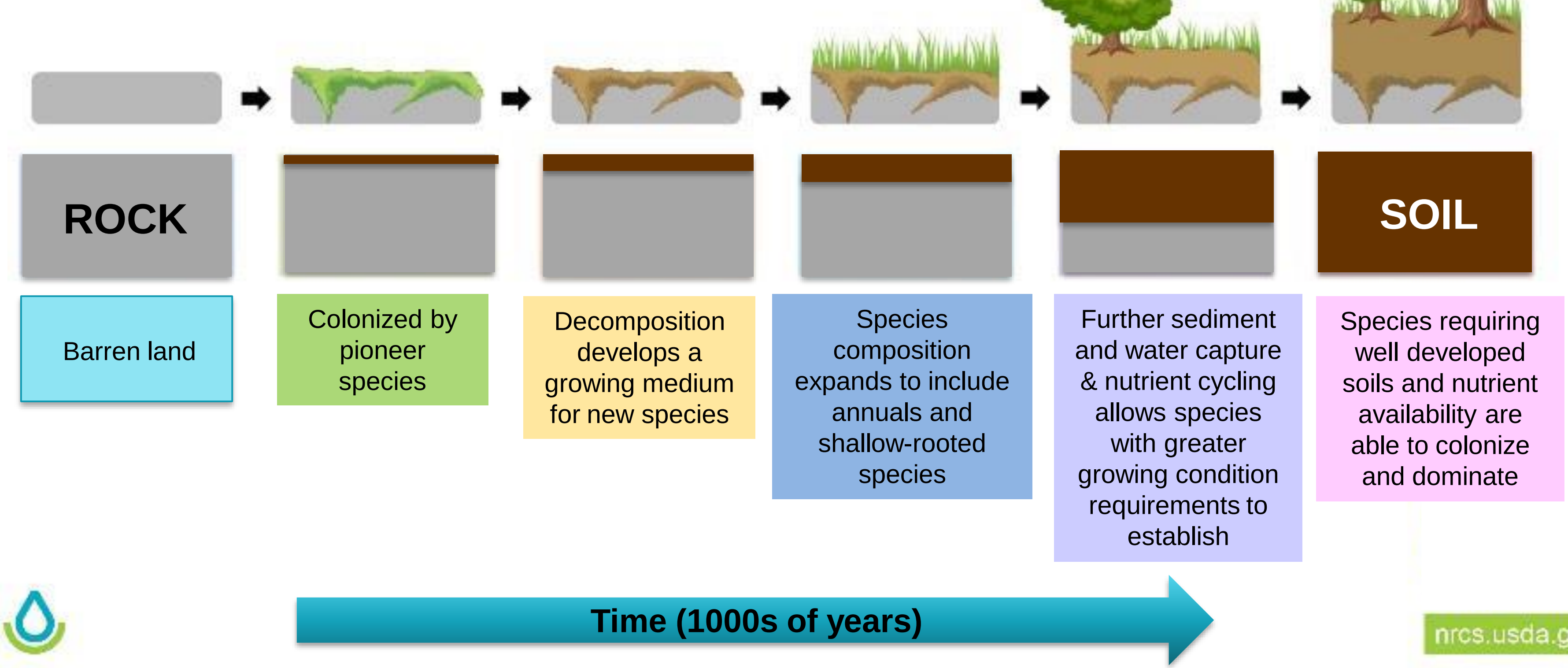
- Primary Succession
- Secondary Succession

Primary Succession

The process of establishment and development of an ecosystem in an uninhabited environment.

Primary succession is most often described using upland examples that occur in areas that begin as rock that slowly over 1000s of years becomes an established community.

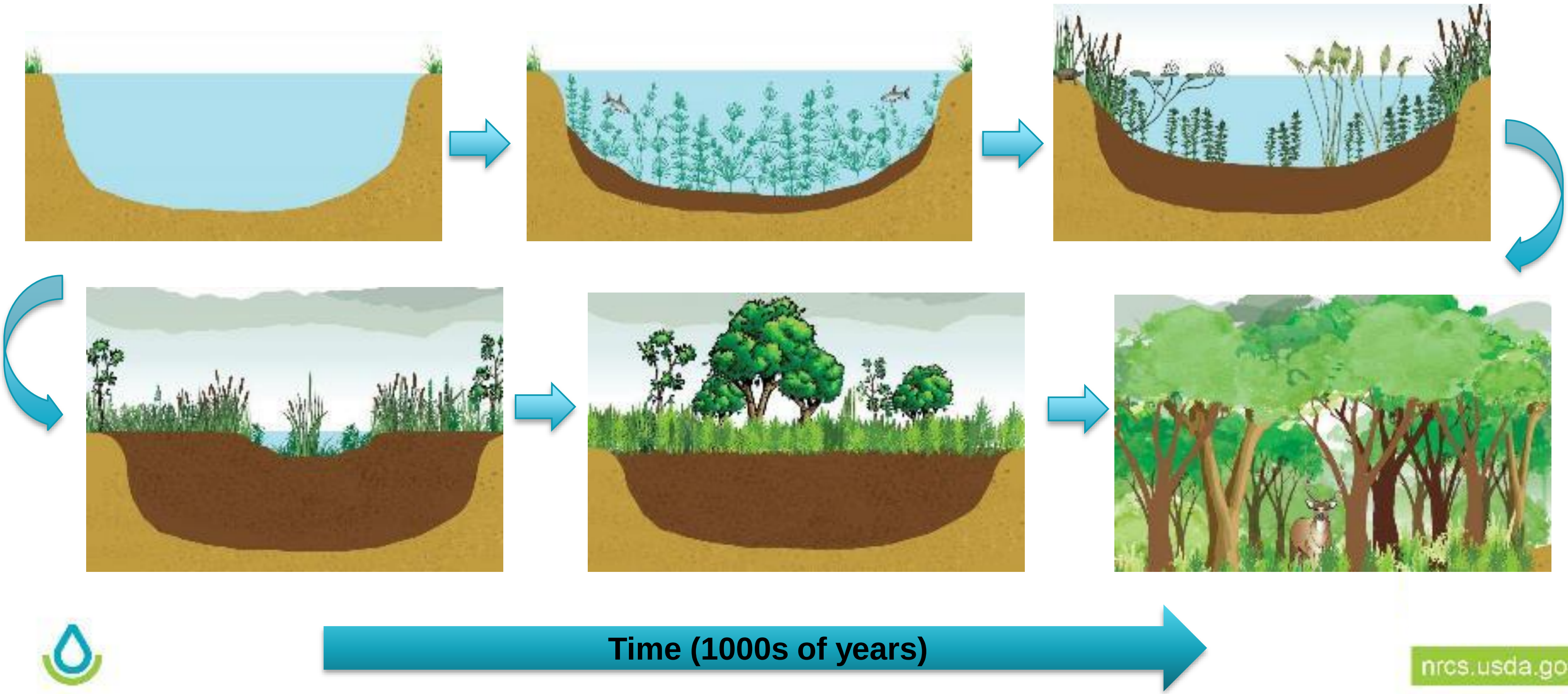
Examples: Glacial retreat, or hardened lava flows



Primary Succession

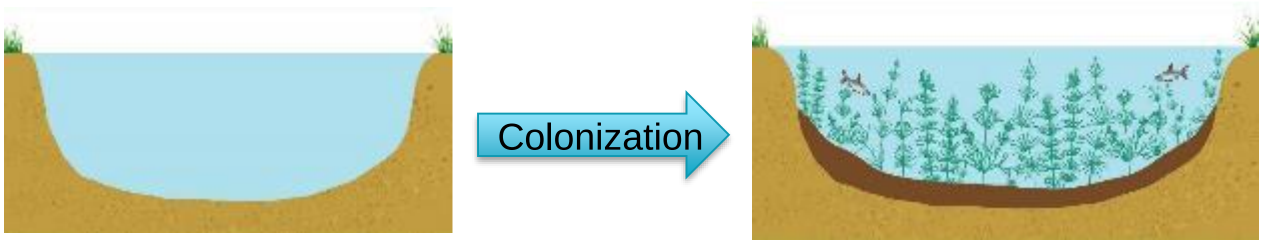
Primary succession concepts in water are generally thought about as a continuum, not necessarily distinct 'wetland types'; however it really depends on the environment that defines the site created

Ex: Pond → Marsh → Wet Meadow → Shrubby Swamp → Forest Swamp → Upland Forest



Primary Succession

Pioneer Species – the first species to colonize the uninhabited area. In general these species are highly adaptable to total submersion and limited resources (light or nutrients) for growth.

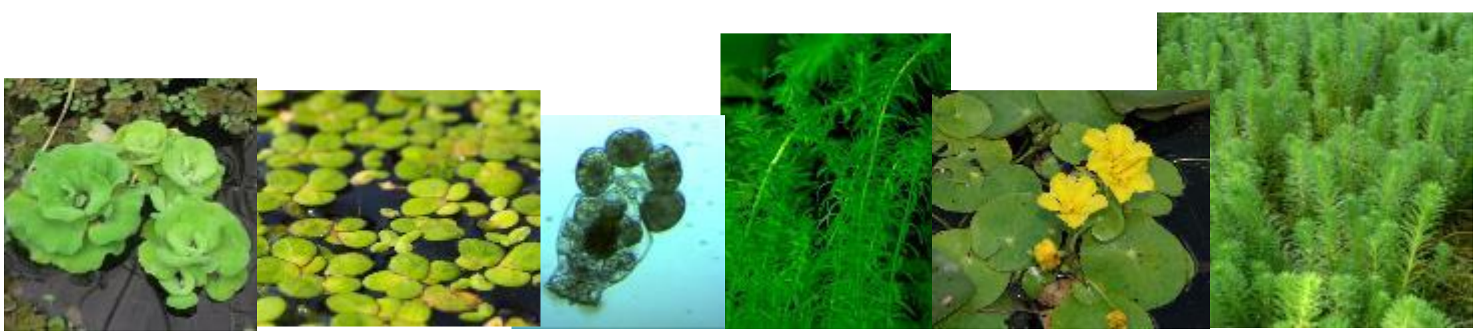


As pioneer species grow, occupy space, and decompose they:

- Capture sediment
- Create and capture nutrients
- Facilitate the development of better growing conditions for other species to colonize.

The type of pioneer species depends on:

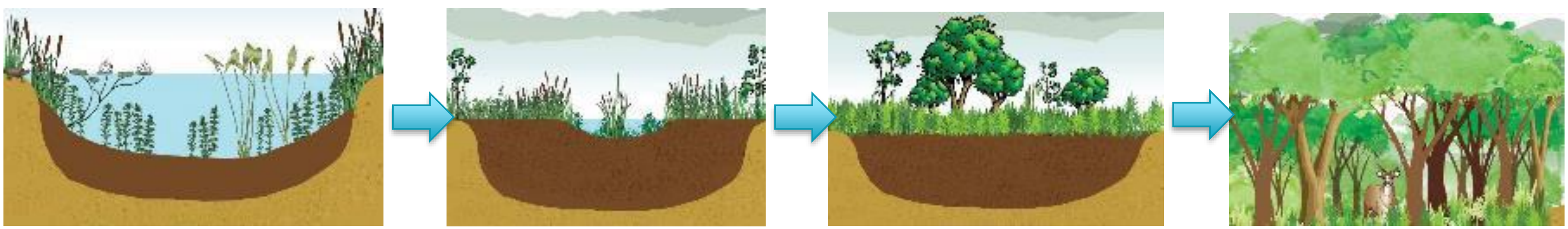
- Source water
- Degree of water fluctuation
- Climate (cold vs. hot, wet vs. dry)
- Surrounding vegetation (seed source)
- Size/Extent of the area (deep vs. shallow, wide vs. narrow)



Primary Succession

What Determines the Successional Development of a Wetland?

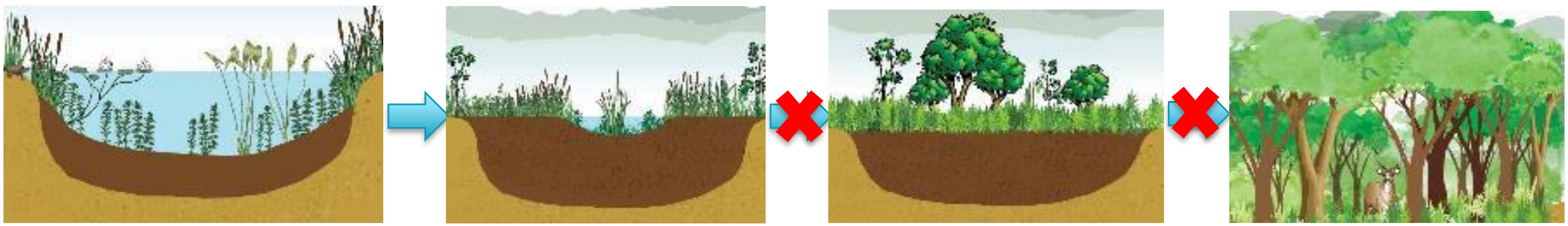
- Water Source (snow melt, rainfall, groundwater, etc.)
- Timing/Duration/Fluctuation of Water (continuous, seasonal, one-time event, etc.
- Landscape Position (bottomlands, depressions, slopes, etc.)
- Parent Material (volcanic, granitic, etc.)

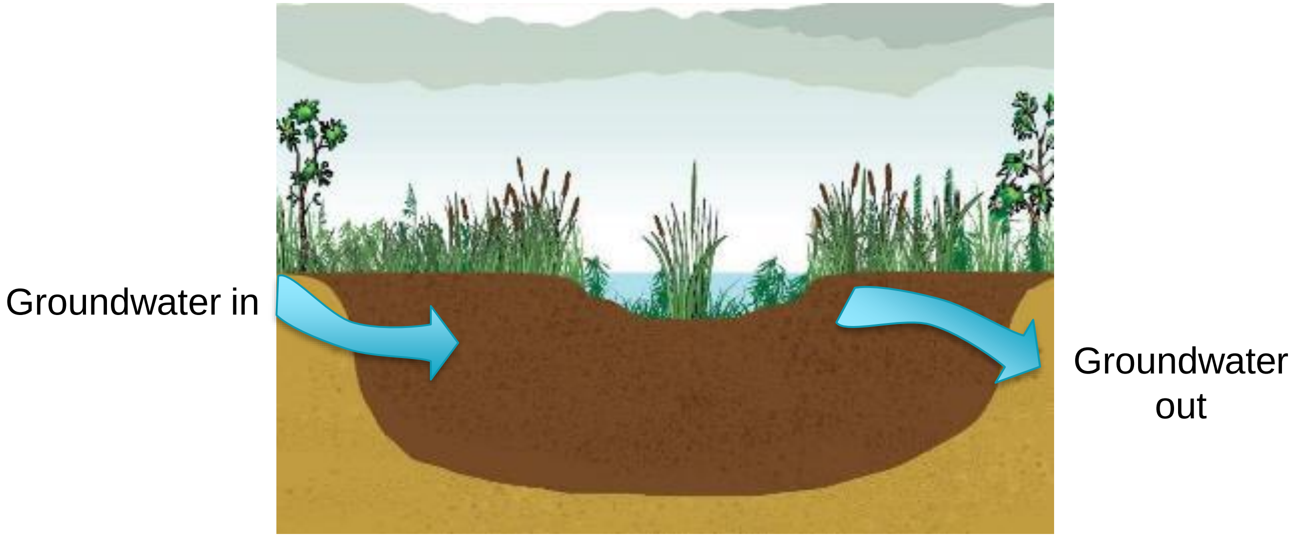


As an isolated pond or lake that is not receiving enough yearly water inputs, the sedimentation (and evaporation in more arid environments) continues to reduce water depth and increases vegetation infill.

Primary Succession

If instead the site receives some sort of yearly water inputs, it may reach a stable, self-regulating condition where inputs and outputs maintain the site as a specific wetland type instead of continuing towards complete soil infill and total water loss.





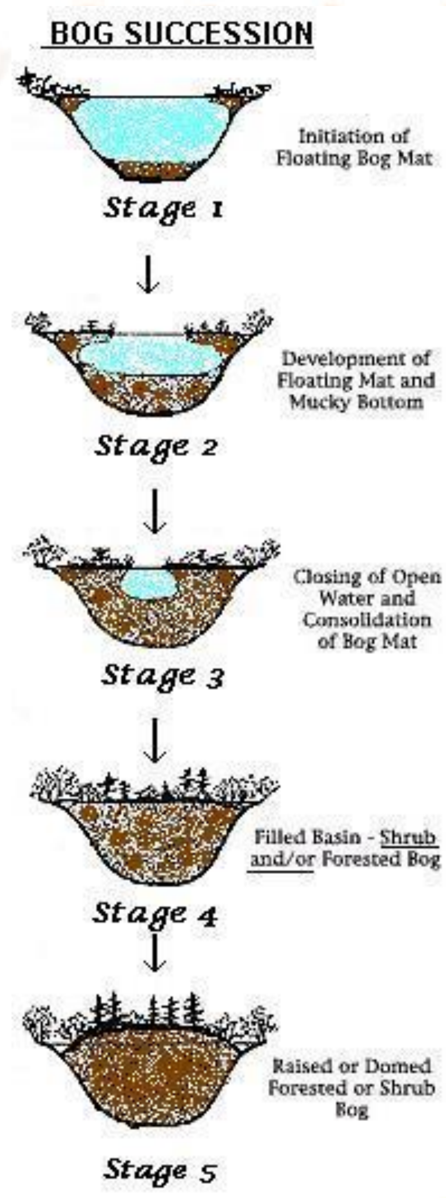
Primary Succession

Late-seral ("mature") or reference community is the conceptual linear end point to primary succession and represents an assemblage of species that are relatively stable and self-regulating.

Species are best adapted to the area

The biotic and abiotic characteristics are at equilibrium

Represent the community that is most resistant and/or resilient to common natural disturbances

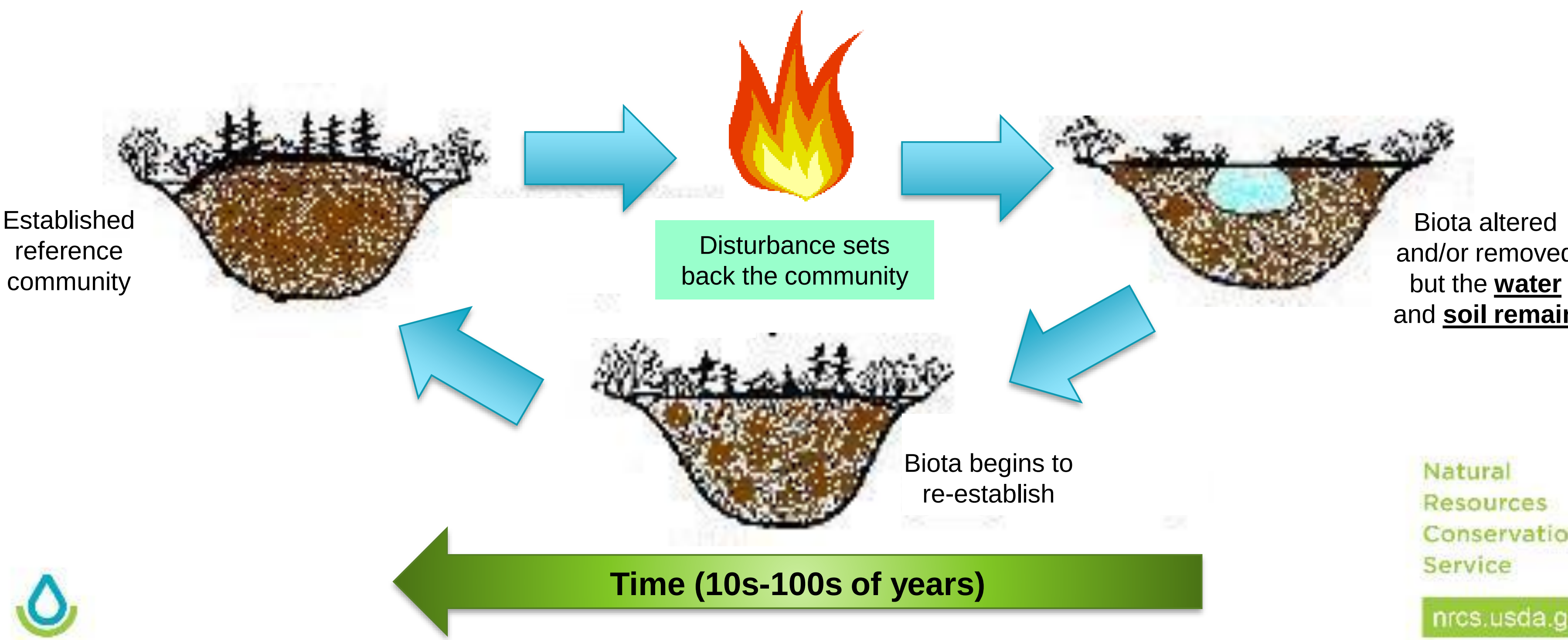


Secondary Succession

A series of changes that occur to an already existing ecosystem after a disturbance.

- The already existing ecosystem is reduced or drastically changed, however key abiotic properties remain reasonably unchanged.

Disturbance - an event or force, of nonbiological or biological origin, that brings about mortality to organisms and changes in their spatial patterning in the ecosystems they inhabit.



Secondary Succession

Reference community

Flood

Freshly scoured gravel beds

Time

Pioneer species community

Time

Early-seral herb community

Time

Mid-seral shrubs and young trees community

Time

Dynamic environment that is adapted to flooding disturbance and moves through different assemblages of species to return to a stable, self-sustaining late-seral community

Primary vs. Secondary Succession

Primary Succession

Conceptually starts in open waters

Soil is formed through the process

Pioneer species facilitate soil development

Conceptual linear trajectory towards stable reference community

Disturbances are primarily processes like glacial retreat or lava flows

Takes thousands of years

Both result in a trajectory toward a stable, self-regulating community that is in equilibrium with the biotic and abiotic characteristics of the ecosystem

Secondary Succession

Water and soil relationships are already developed

Soil has already formed

Pioneer species facilitate recovery post-disturbance

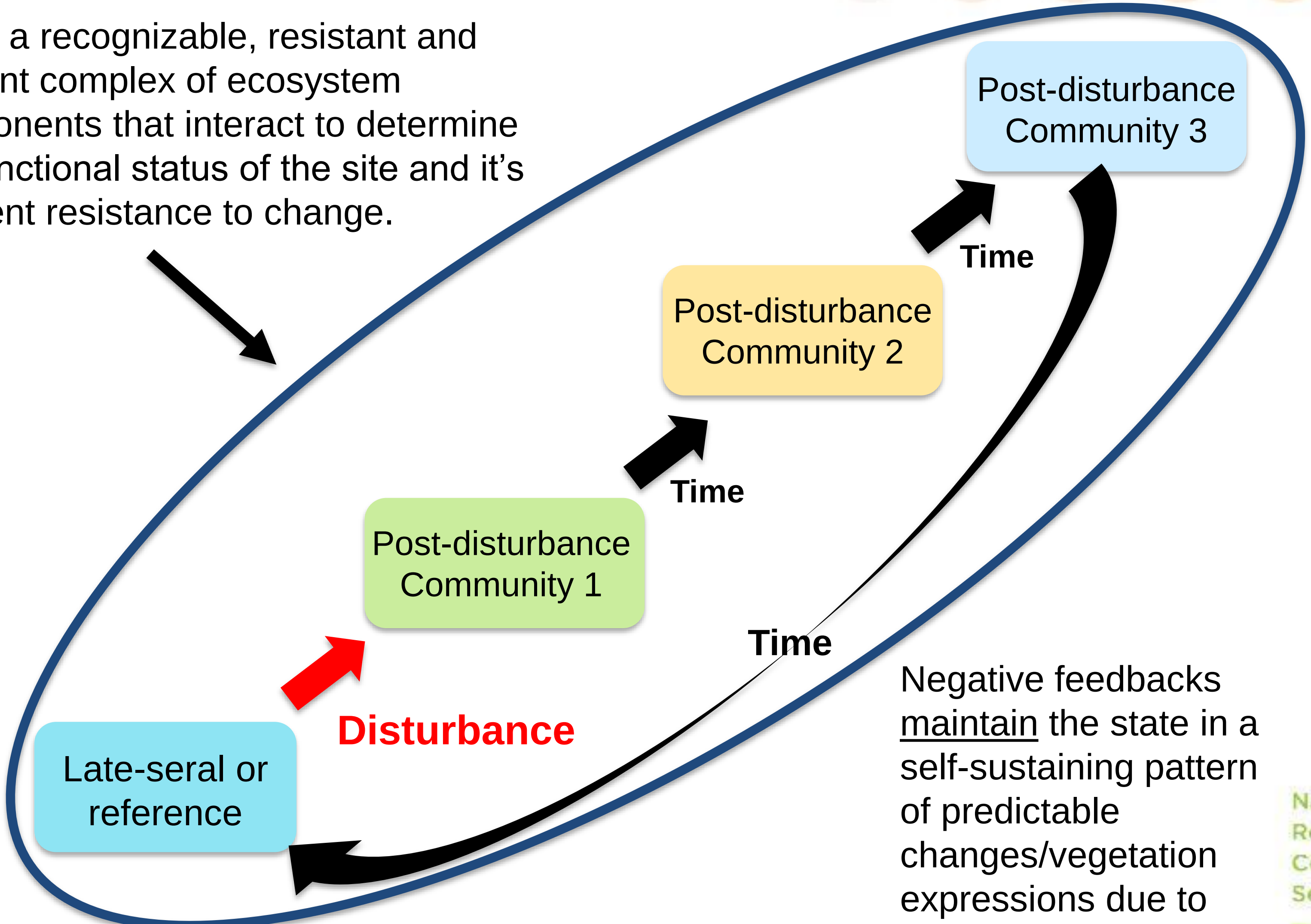
Not always a linear trajectory back towards the reference community (depends on the type of disturbance)

Disturbances are primarily disruptive to the water and vegetation

Takes only years to several decades

Ecological Equilibrium

State: a recognizable, resistant and resilient complex of ecosystem components that interact to determine the functional status of the site and it's inherent resistance to change.

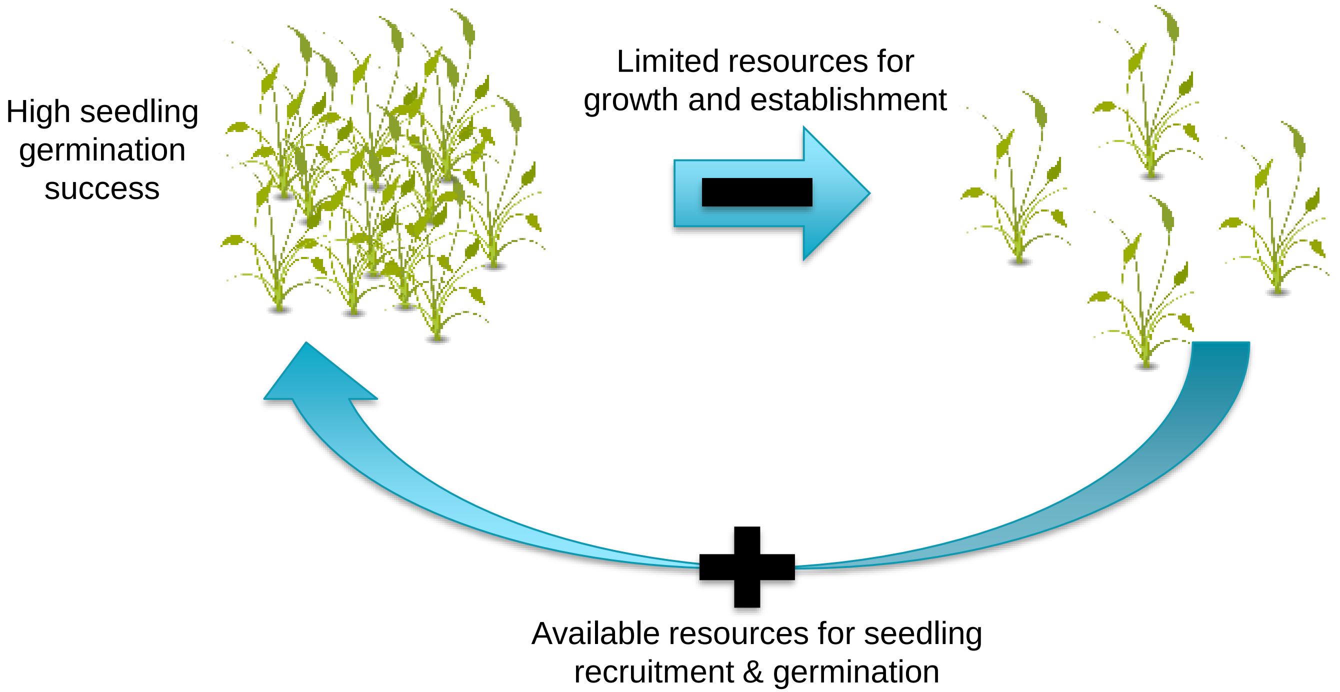


Negative feedbacks maintain the state in a self-sustaining pattern of predictable changes/vegetation expressions due to disturbance over time

Ecological Equilibrium

Negative feedbacks – where the state of one element has an effect on another element, essentially keeping things in a stable cycle of inputs and outputs

Example: Self-thinning, when the vegetation becomes too dense, too many individuals vying for limited resources, some of the individuals die out leaving room for the growth of the surviving individuals. This results in a “stable” cover of individuals.



Ecological Equilibrium

Negative Feedback Loop – Typha x glauca invasion

Typha germinates and establishes

↓

Typha density & litter mass significantly increases

↓

Significant decreases in plant species richness and diversity

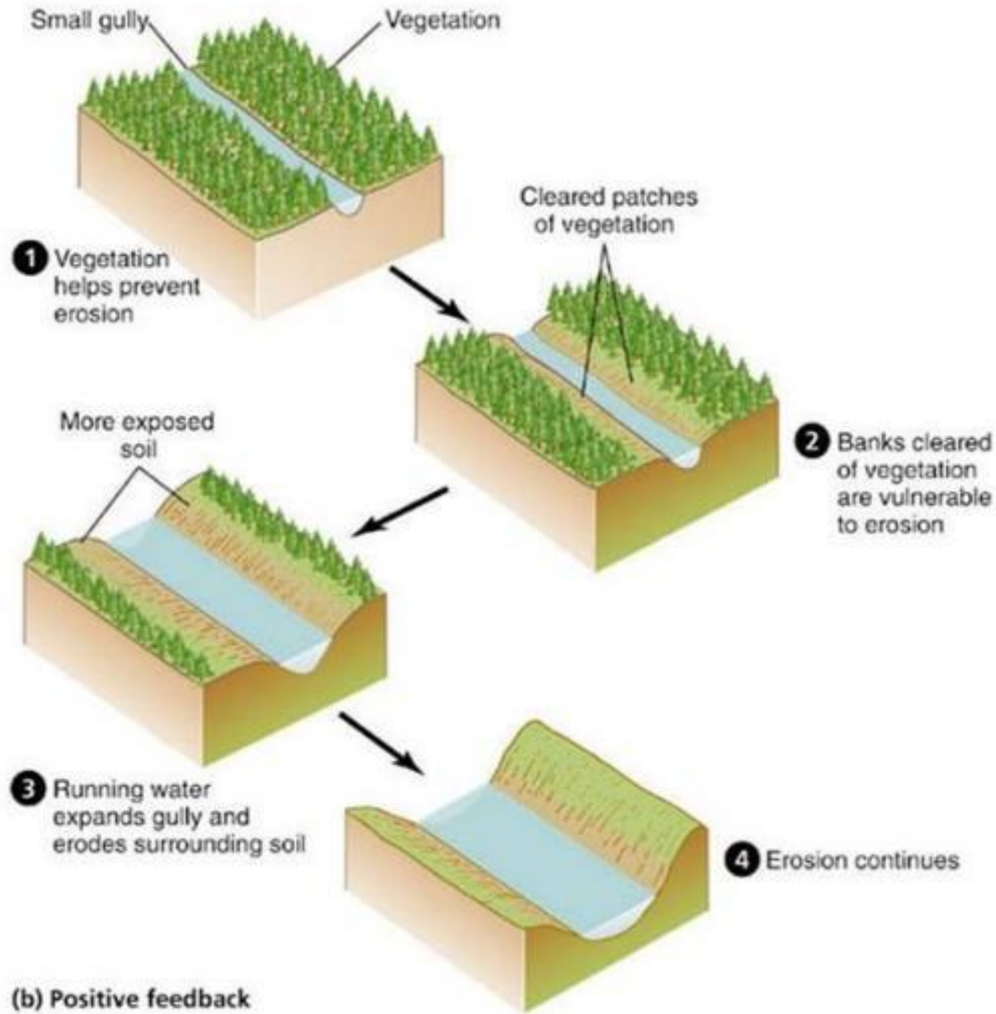
↓

Significant increases in soil organic matter and litter layer depth

Ecological Equilibrium

Positive feedbacks – output acts as input that moves the system further in the same direction. This magnification of effects can sometimes to "destabilize" the system.

Example: Gully erosion

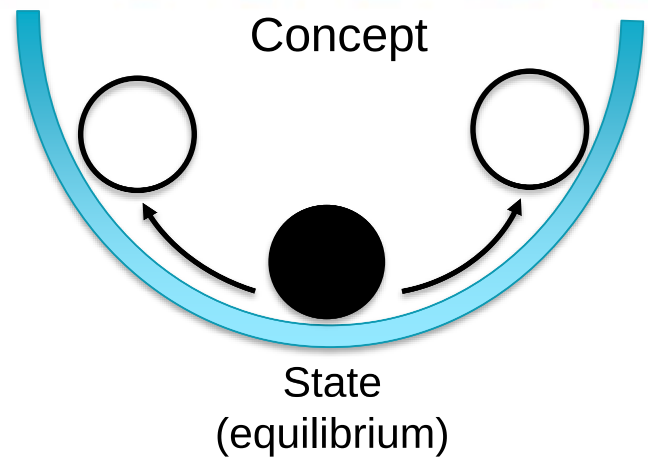


(b) Positive feedback

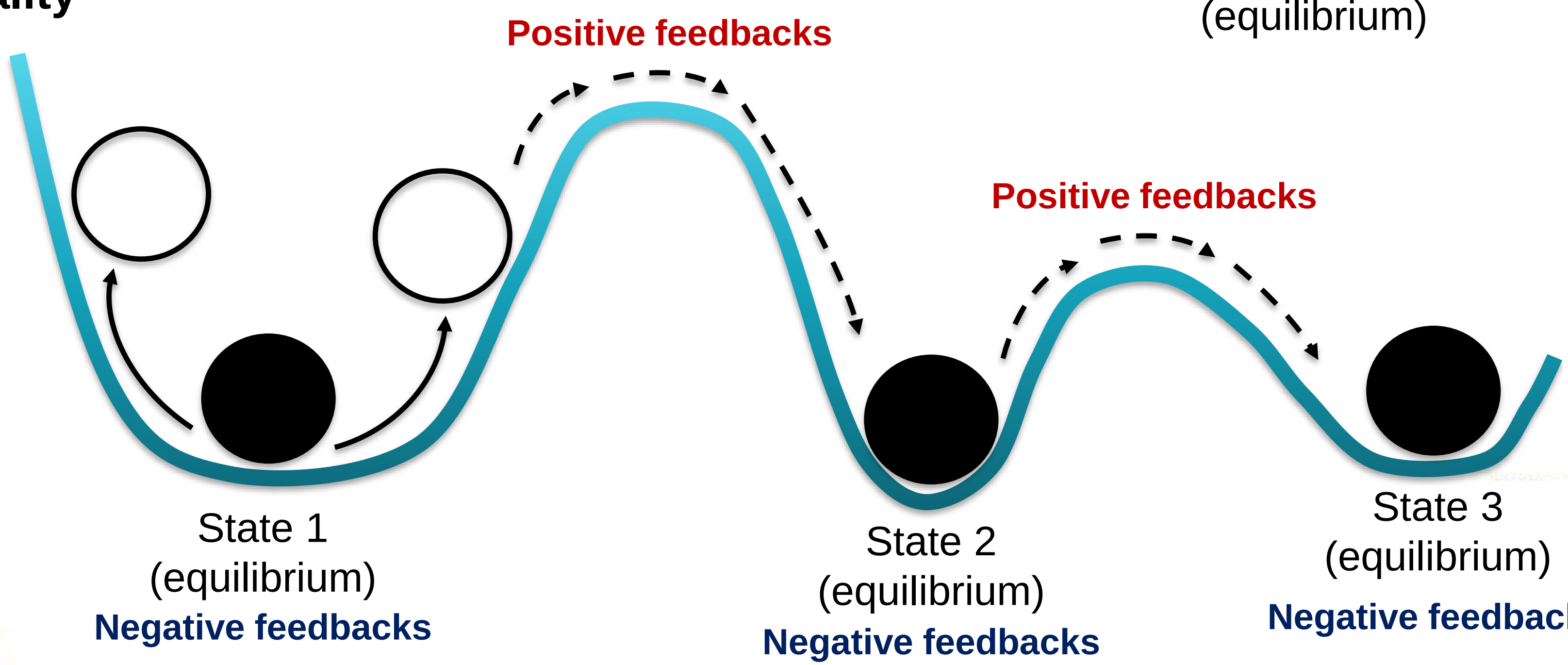
Ecological Equilibrium

Nature is complex and humans have significant impact on nature

- Leads to a reality where in many ecosystems there are multiple trajectories that a site has the potential to follow depending on the timing, intensity, duration and type of disturbance or management that occurs.



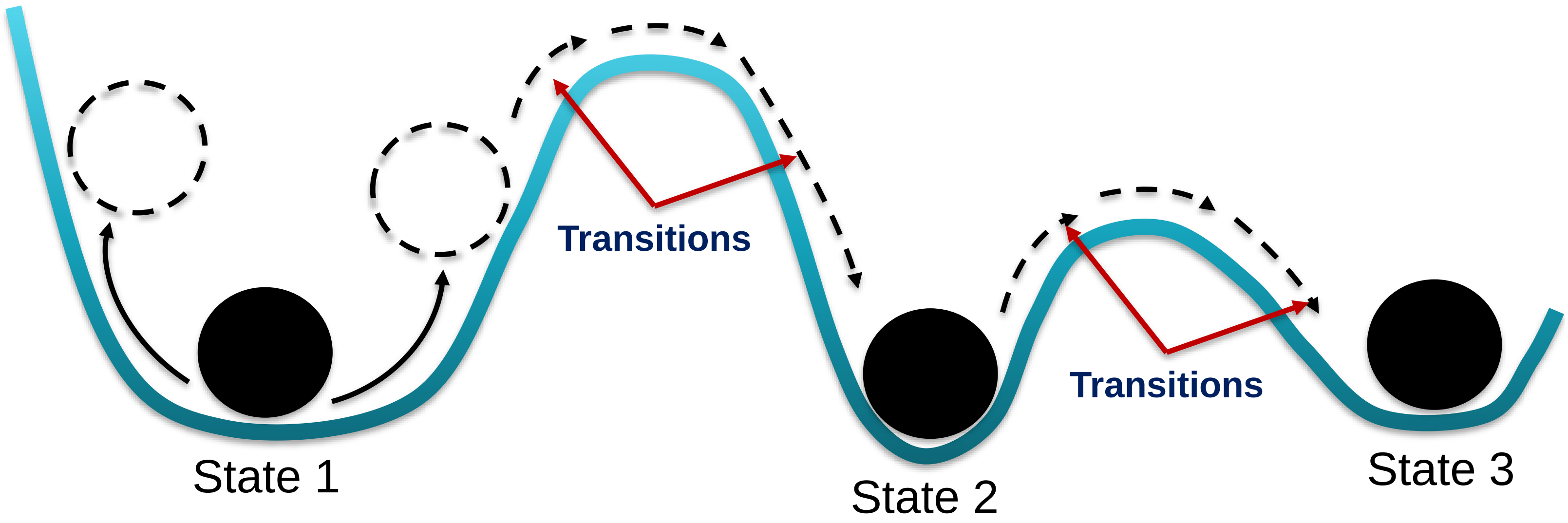
Reality



Ecological Equilibrium

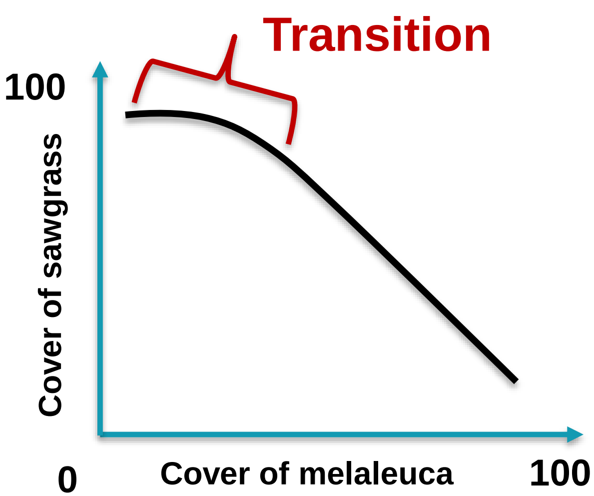
Transition – the trajectory of change to a state

- Change is precipitated by natural events, management actions, or both
- The feedbacks begin to change from negative to positive in one or more of the state's primary ecological processes toward the point when self-repair is no longer possible



Ecological Equilibrium

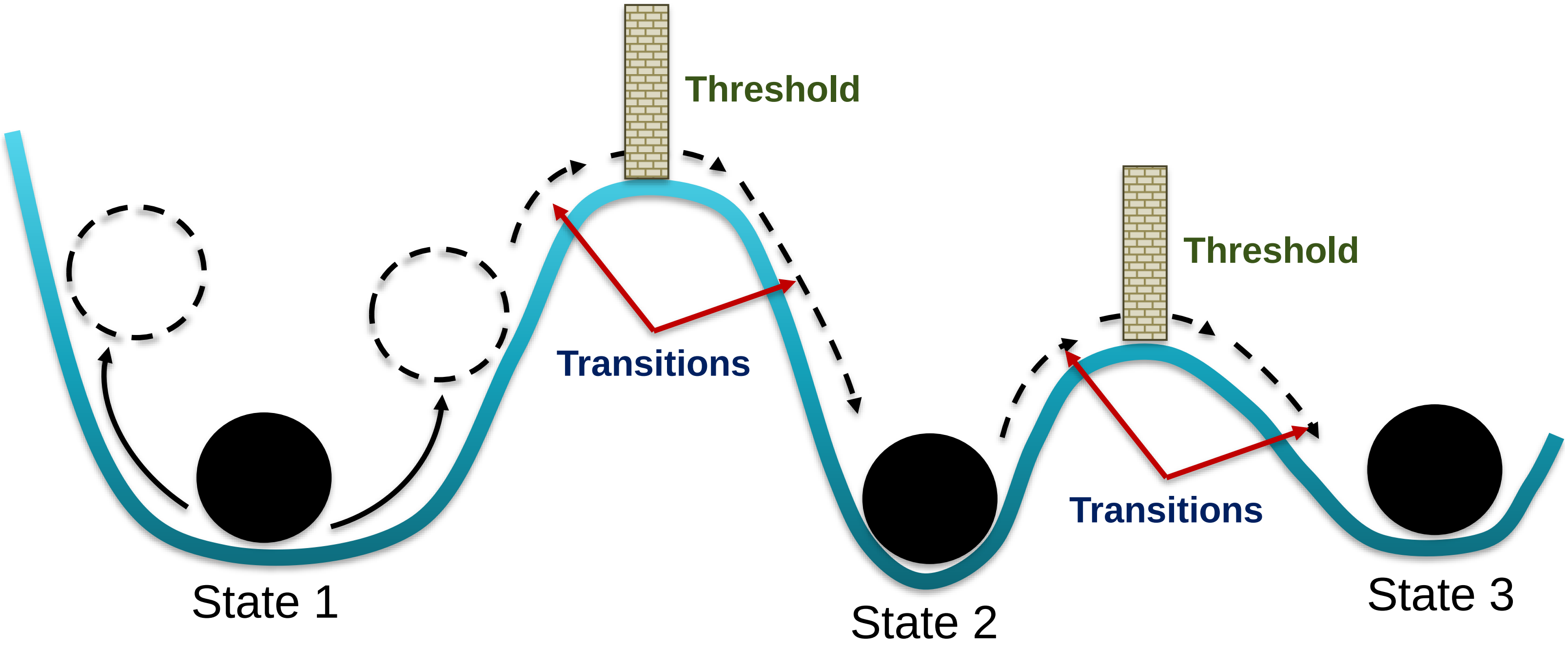
Transition:



Ecological Thresholds

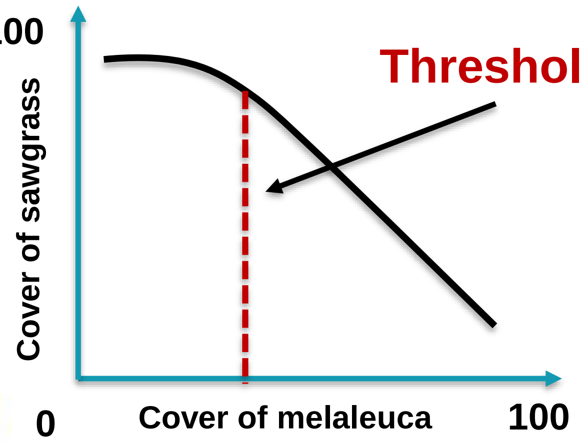
Threshold – boundary in space and time between two states

- Point when the positive feedbacks take over entirely
- System naturally isn't able to go back, requires significant human inputs to repair the feedback mechanisms that maintained the state.



Ecological Equilibrium

Threshold:



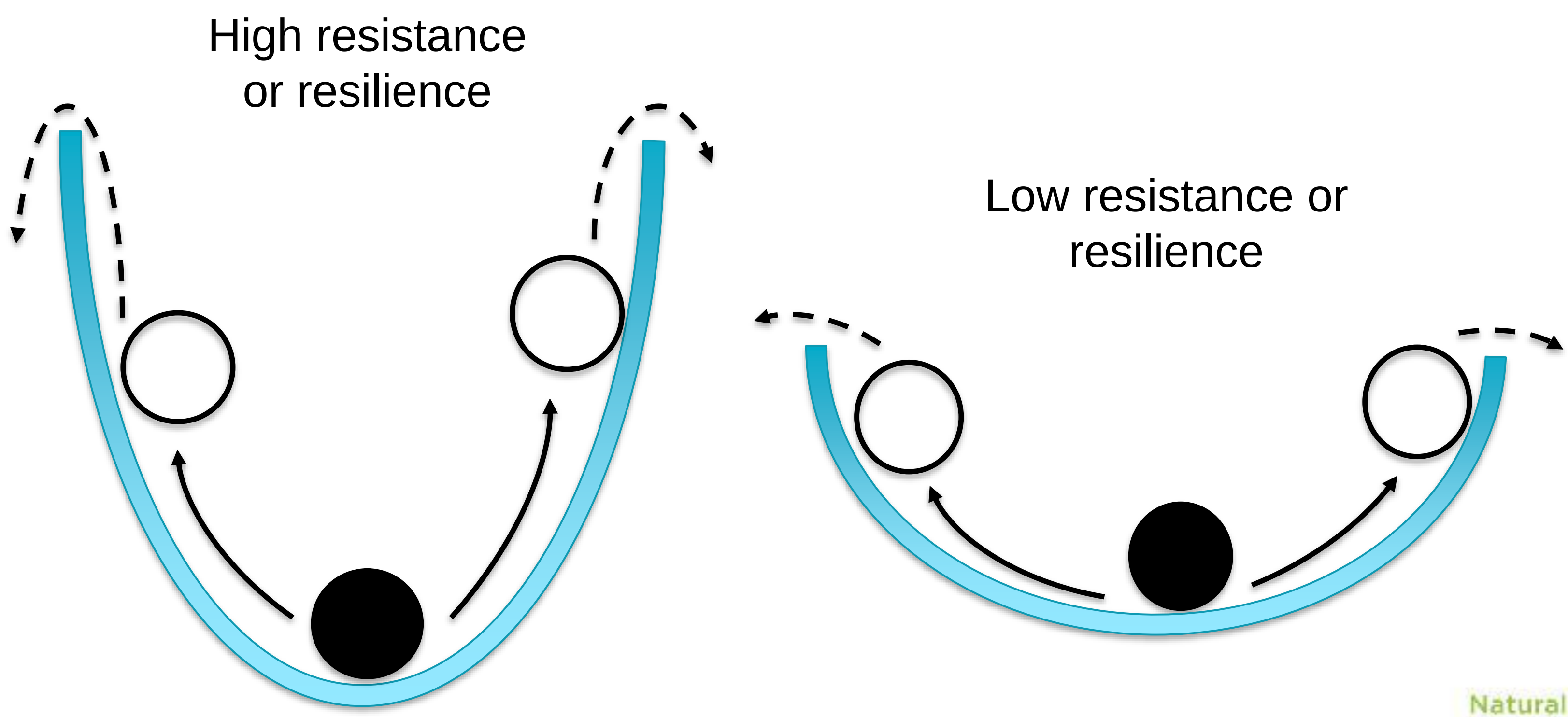
Resistance & Resilience

Resistance – the ecosystem's ability to maintain it's structure and function over long periods of time despite disturbance pressures.

Resistance & Resilience

Resilience – the ecosystem's ability to return it's structure and function over long periods of time due to the changes caused by disturbances.

Resistance & Resilience



Ecological Dynamics in Wetlands

Wetland dynamics are complex and require an understanding of the type of wetland being evaluated:

Static variables that relate to wetlands:
- Landscape position
- Geology/Soils
- Vegetation

Changing variables that relate to wetlands:
- **Hydrology (timing, frequency, duration, water movement)**
- **Disturbance types (natural & man-made)**

Ecological Dynamics in Wetlands

Spring to Fall

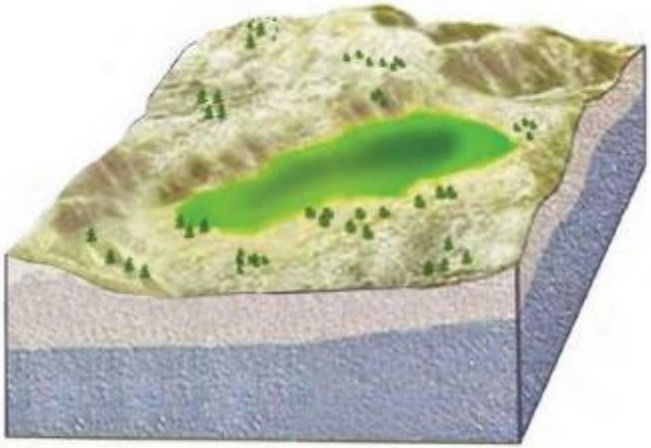
Fall to Spring

Ecological Dynamics in Wetlands

Tide comes in

Tide goes out

Ecological Dynamics in Wetlands

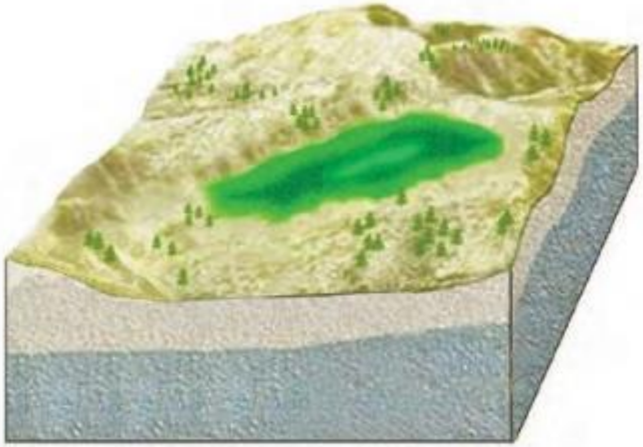


Occasional and seasonal and/or precipitation-dependent

Water table fluctuates a lot

Constant and groundwater-dependent

Water table fluctuates very little



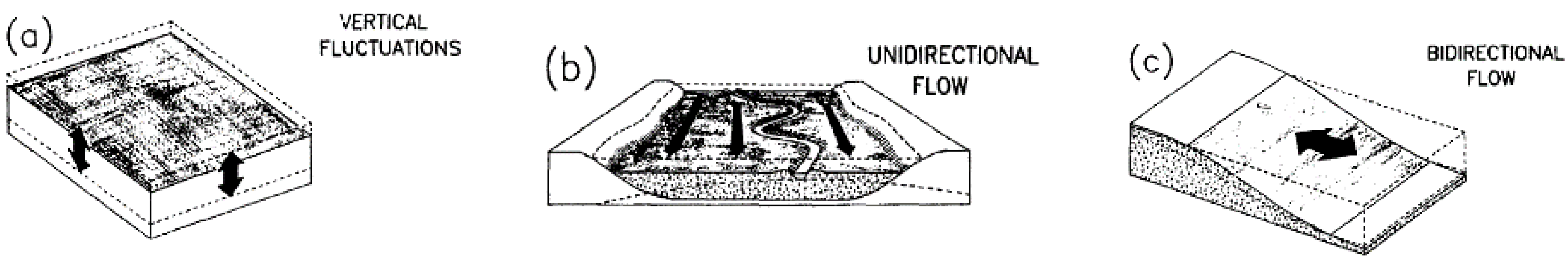
Ecological Dynamics in Wetlands

Basin wetland

Riverine wetland

Ecological Dynamics in Wetlands

- **Water Movement - Hydrodynamics refers to the direction of flow and strength of water movement. These prevalent directions of water movement correspond, respectively, to the geomorphic setting categories (i.e., depressional, riverine, and fringe)**
  - Vertical fluctuation - vertical fluctuations of the water table that result from evapotranspiration and subsequent replacement by precipitation or groundwater discharge into the wetland
  - Unidirectional flow - unidirectional flows that range from strong channel-contained currents to sluggish sheet flow across a floodplain
  - Bi-directional flow - bidirectional, surface or near-surface flows resulting from tides or standing waves (seiches)



Ecological Dynamics in Wetlands

Energy and Power as a Disturbance in Wetlands

- Energy – energy provides the capability to do a specific amount of work, such as move soil or sediment particles a given distance
- Power – power is the amount of energy expended over time, to keep those sediment or soil particles moving

Examples -

- Flowing water
- Wave action
- Raindrop impact
- Shallow overland sheet flows

Ecological Dynamics in Wetlands

The general unit of measure for power within an ecosystem is watts per square meter (W/m2) or watts/meter (W/m) of shoreline length.

- Rainstorm precipitation – generally produces 1 W/m2
- Streamflows – generally produce 10 to greater than 1000 W/m2
  - Lower values will occur on lower slopes, slower water types
  - Higher values will occur on steeper slopes, high velocity water types
- Waves – generally vary considerably, generated by wave height & frequency of wave occurrence
  - Almost no power from waves in small ponds
  - High power values on ocean beaches

Ecological Dynamics in Wetlands

Low slope vs. steep slope

Small waves vs. big waves

Gentle rains vs. heavy downpours

Ecological Dynamics in Wetlands

Alterations to the Water Source:

- **Natural alterations**
  - Drought
  - Too much rain or snow
  - Sediment deposits cut off water source
- **Man-made alterations**
  - Channels
  - Dikes
  - Levees
  - Roads
  - Irrigation
  - Dams
  - Other

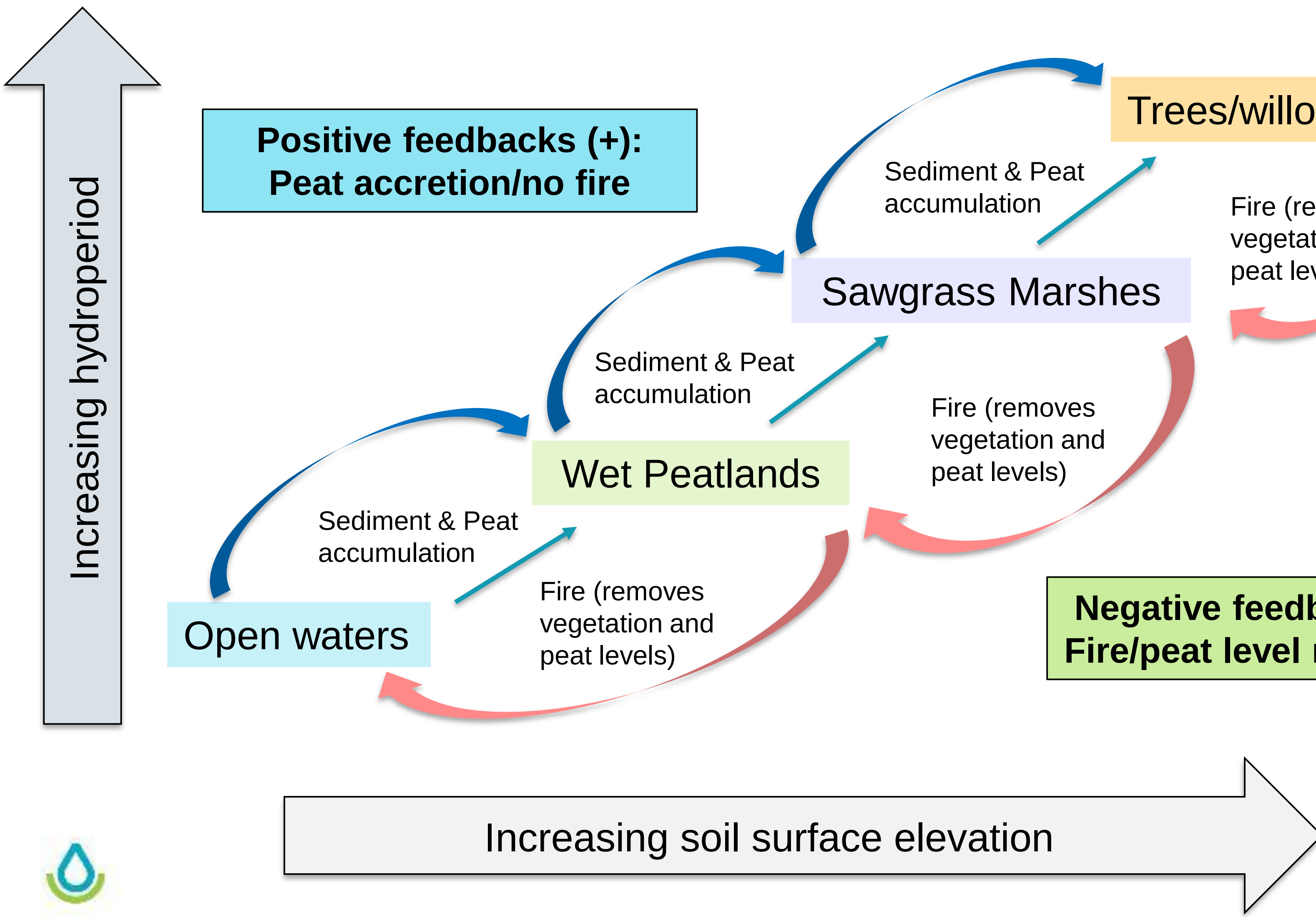
Ecological Dynamics in Wetlands

Everglades – Example

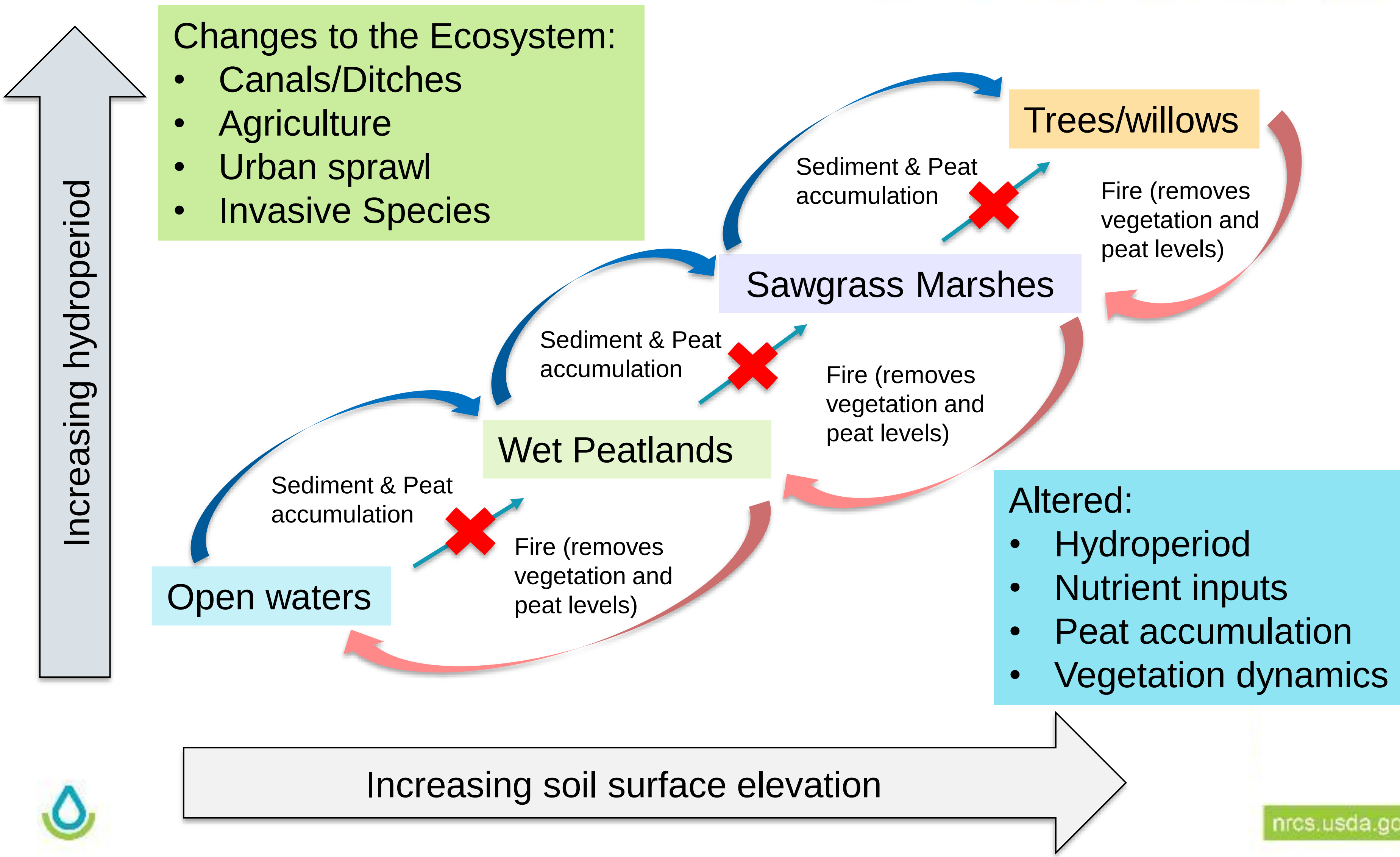
Oligotrophic (low nutrient) wetland – Everglade fresh water marshlands

- Self-regulated over thousands of years to:
  - Limited amounts of phosphorus
  - Water sources (precip/groundwater)
  - Annual wet/dry cycles
  - Decadal fire cycles
- Resulted in a mosaic:
  - Small islands of nutrient dense tree islands
  - Open sawgrass marshes and wet prairies

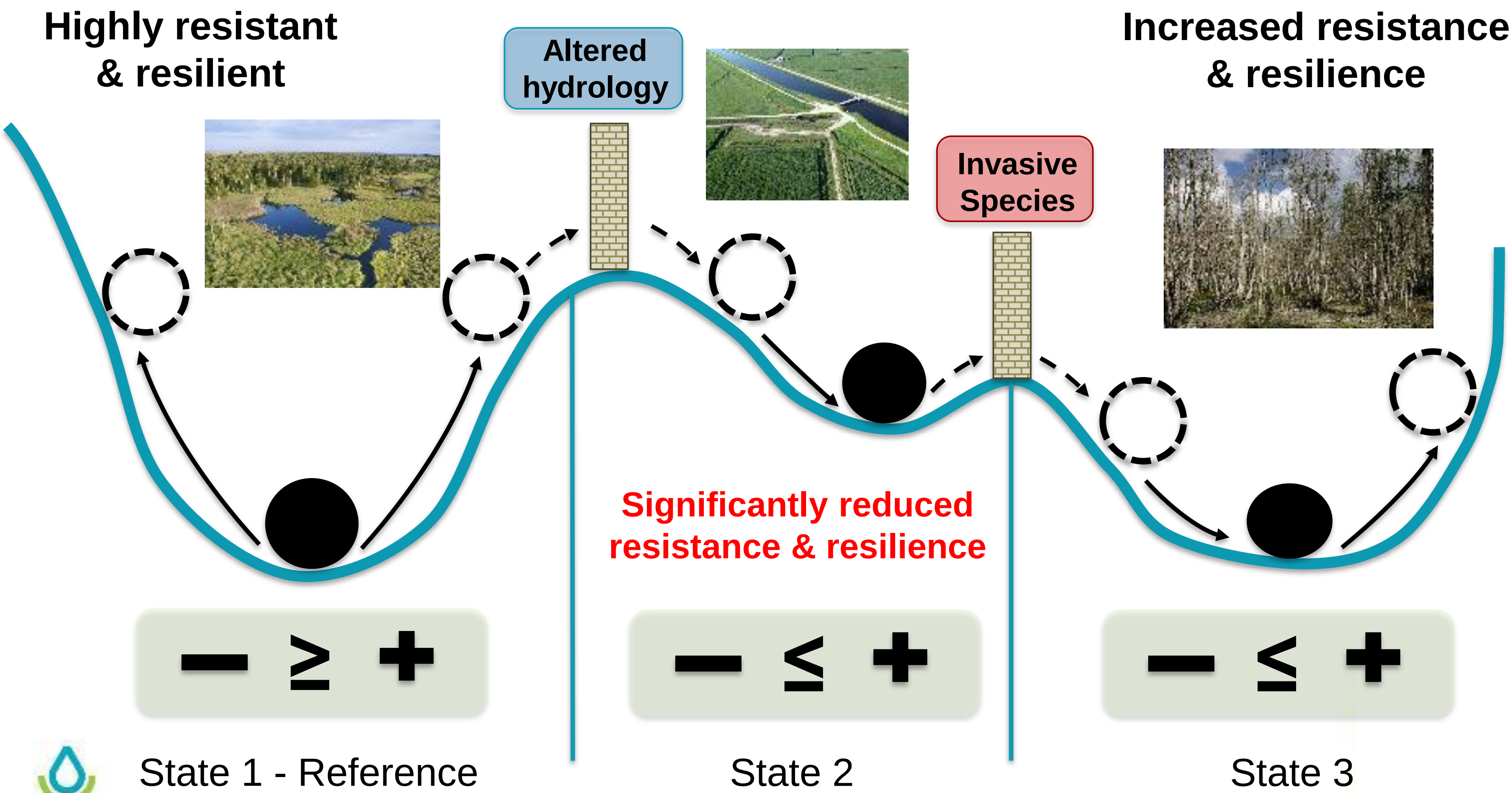
Everglades – Example



Everglades – Example



Everglades – Example



Ecology in Wetlands

- ✓ Understanding successional processes, thresholds and transitions, resistance and resilience concepts, and ecological dynamics is key to understanding wetland ecology and dynamics.
- ✓ The kind of wetland, the natural dynamics of the wetland and how disturbances impact the processes of the wetland all inform the individual what the road map should look like for successful management or restoration of wetlands.