Ecología de las plantas acuáticas

Adonia R. Henry

Wetland Biologist, Scaup & Willet LLC

Manejo de humedales para técnicos en México

Laguna Mexicanos

4-7 March 2014

What are Aquatic Plants?

- “growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content” (Cowardin et al. 1979).

- Evolved from terrestrial plants, invading water in 50-100 separate events

- Approximately 60% of aquatic spp. have ranges on multiple continents
  - Due to moderate environmental conditions in water habitats
  - Often on certain latitudes N & S of equator, but not in between
    - Waterfowl seed dispersal

ADAPTATIONS TO GERMINATE, GROW, AND REPRODUCE IN WATER OR SATURATED SOIL THAT HAS LESS OXYGEN THAN AIR

Oxygen is critical to plant growth
because they need it to produce energy

ADAPTATIONS TO LESS OXYGEN

- Aerenchyma = tissue with large intercellular spaces
  - Enables gas exchange between air and roots
  - Passive molecular diffusion (most prevalent)
    - Gases move from area of higher concentration to lower concentration
  - Pressurized ventilation: driven by temperature and water vapor pressure diff. b/w inside of leaves and surrounding air
    - O2 in through small pores in leaves
    - Down stem to rhizomes
    - CO2 up stems of older leaves & out their large stomatal pores
      - *Nuphar lutea* (yellow water lily)
  - May be 50-60% of root area in flood-tolerant plants
  - Some invertebrates tap into this to respire
    - Coleoptera larvae (*Donacia sp.* - Chrysomelidae)
    - Diptera larvae (*Mansonia sp.* – Culicidae & *Chrysogaster sp.* – Syrphidae)

ADAPTATIONS TO LESS OXYGEN

Ludwigia palustris

- Stems
  - Elongation to access light, O2, CO2
    - *Sagittaria latifolia* (arrowhead)
- Leaves
  - Some float off long stems, spread out to access light, O2, CO2
  - Heterophylly
    - Emergent leaves ovate/elliptic/rounded
    - Submerged leaves ribbon-like/dissected
    - *Ludwigia palustris* (marsh seedbox), *Sagittaria* (arrowhead)

ADAPTATIONS TO LESS OXYGEN

- Adventitious Roots
  - Adventitious = laterally from base of main stem
    - Often in response to flooding
    - Spread into surface soil layer
    - Replace deep roots that die b/c anoxia
    - Stabilize & increase O_2 to roots
    - Aid in nutrient and water uptake
    - *Salix* (willow), *Rumex* (dock)
  - Shallow rooting
    - Roots concentrated near surface
    - Allows access to NO_{3^-} (nitrate), and O_2

Rumex crispus

- Rhizomes
  - Nutrient and carbohydrate translocation
  - Larger carbohydrate storage allows more ATP production for cell metabolism
  - *Schoenoplectus* (bulrush), *Typha* (cattail)

WHY IS OXYGEN IMPORTANT?

- Plants need oxygen to produce energy
- Active cells require 2 million molecules of ATP (energy) per second for biochemical processes
  - Aerobic Respiration
    - Optimal net yield of 36 ATP molecules per glucose molecule
- Aquatic plants have many adaptations to access oxygen in the air and water
- Many aquatic plants can produce energy without oxygen
  - Less efficient, but important adaption to tolerate periods of extended flooding
  - Anaerobic Respiration
    - Produces 2 ATP molecule per glucose molecule

TOLERANCE TO LACK OF OXYGEN

Species	Anoxia Endurance (days)	Shoot Elongation
Beaked sedge	4	None
Common rush	4-7	None
Common spike rush	7-12	None
Umbrella sedge	7-14	None
Reed switchgrass	7-21	Occasional
Common reed (*Phragmites*)	>28	None
Broadleaf cattail	>28	Frequent
Reed canary grass	>28 ?	
Three-square bulrush	>28	Frequent
Soft-stem bulrush	>90	Frequent
Hard-stem bulrush	>90	Frequent

CONTROL OF ANOXIA TOLERANT PLANTS

DRY IT OUT!

IS THIS DRY?

IF YOU CAN'T DRY IT OUT…

Can improve it, but system processes are still compromised

ANOXIA TOLERANCE TO YOUR BENEFIT

RE-FLOODING IN MOIST-SOIL

Shallow (2-5 cm) re-flooding when plants 10-15 cm

- Promotes growth of:
  - Millet
  - Sedges
  - Smartweed
- Less tolerant species:
  - Panic grass
  - Crab grass
  - Beggarticks
- Good control for cocklebur
  - Stress plant
  - Likely won't set seed

OTHER ADAPTATIONS

- Nutrient Acquisition
  - Mycorrhizae = symbiotic fungi
    - Increases P, N, K^+ available for plant, takes carbohydrates from roots
    - Occurrence decreases as water depth increases
  - N-fixing bacteria in root nodules
    - Increases nitrogen available to plant
    - *Sesbania* (legumes), *Alnus* (alder), mangroves
  - Carnivorous plants
    - Mechanism to entrap animal prey
    - Nutrients from prey assumed to ↑ fitness
    - Bladderwort (*Utricularia*)

OTHER ADAPTATIONS

- Allelopathy
  - Chemical compounds (alkaloids, terpenoids, flavonoids)
  - Root exudates
  - Leached from leaves or litter
  - Inhibit germination, growth, or chlorophyll content of other species
  - Chemicals are "expensive" to make, so may produce more under crowding stress

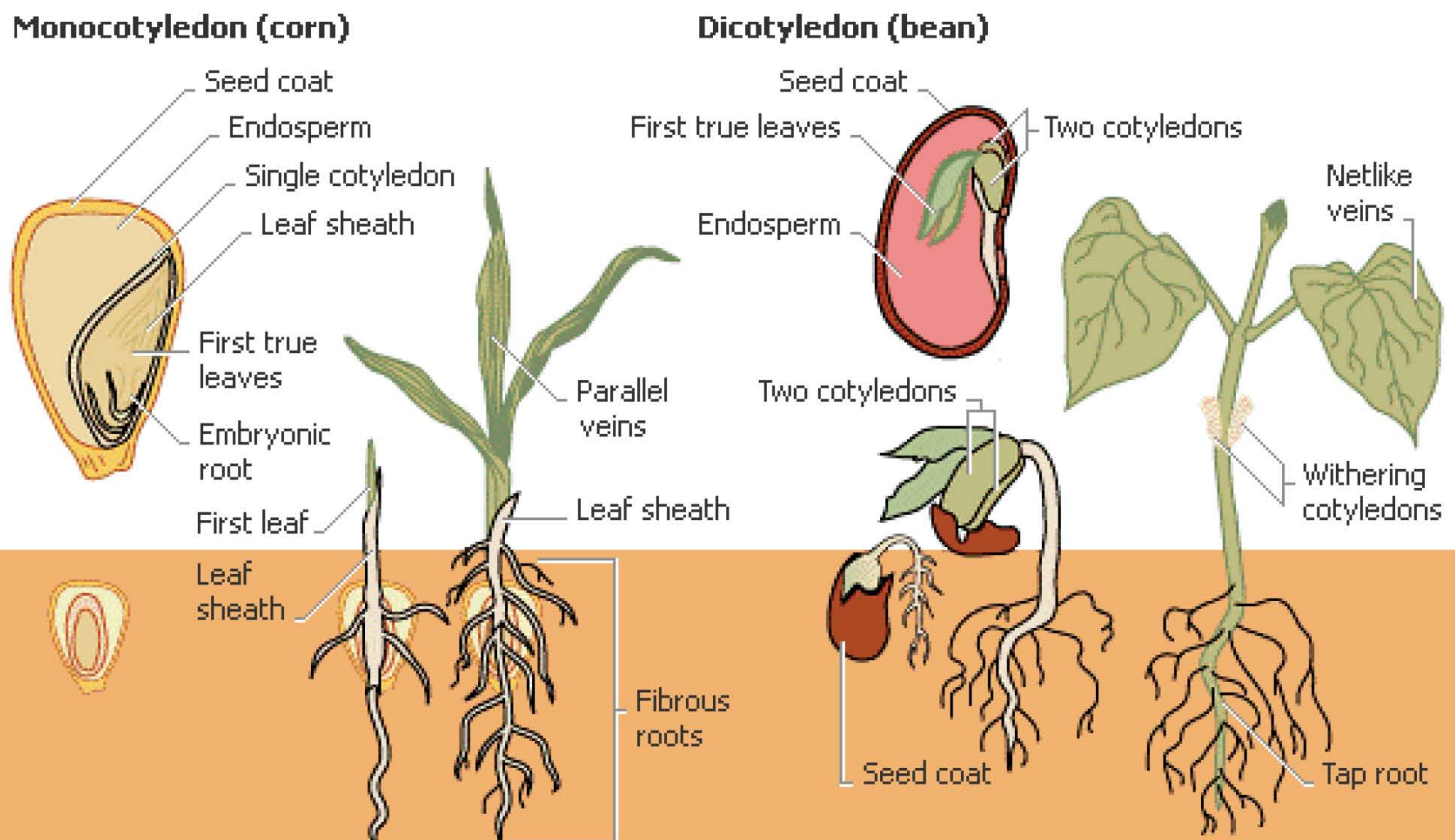
- *Typha* (cattail)
- *Cyperus* (flatsedge)
- *Eleocharis* (spikesedge)
- *Polygonum* (smartweed)
- *Nuphar* (water lotus)

Nuphar (water lotus)

FLOWERING PLANTS

Grasses & Sedges

Broad-leaved Plants



www.images.encarta.msn

GRASSES & SEDGES
(Monocots)

- Flower parts in 3’s (or multiples of)
- Leaves with parallel venation
- Basal meristematic tissue

- Other examples of monocots
  - Waterlily
  - Arrowhead

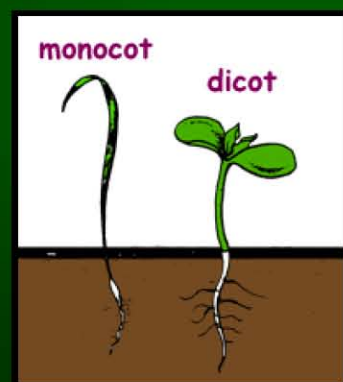
BROAD-LEAVED PLANTS
(Dicots)

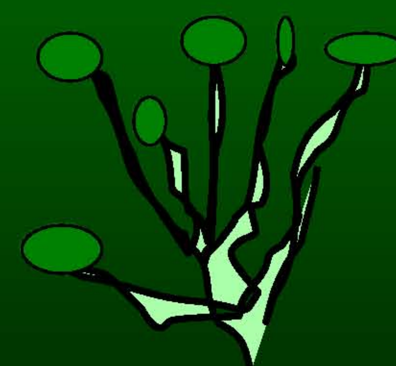
- Flower parts in 4's & 5's (or multiples of)
- Leaves with net venation
- Distal meristematic tissue

Why does it matter?

GROWING POINT AT BASE

GROWING POINT AT TIP





MONOCOTS

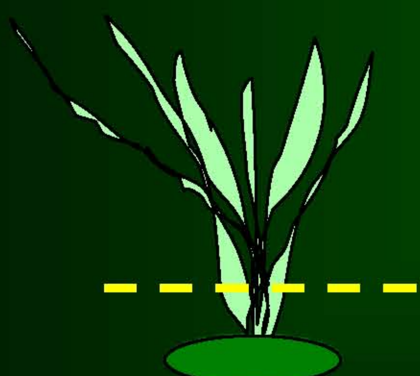
DICOTS

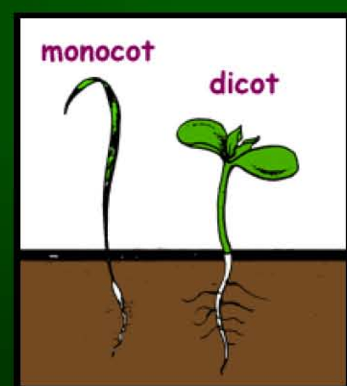
Why does it matter?

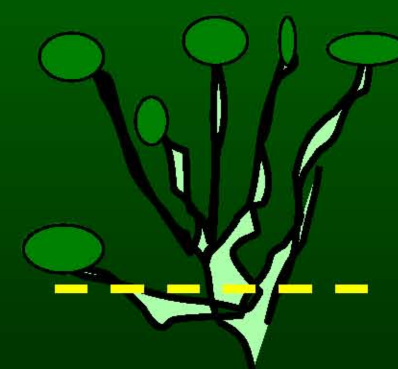
Effects of mowing

GROWING POINT AT BASE

GROWING POINT AT TIP







MONOCOTS

DICOTS

ANNUALS VS. PERENNIALS

ANNUALS

- Complete life cycle in 1 year
- Early successional species
- Colonize disturbed areas
- Reproduce by seed (prolific)
- Seeds remain viable for many years

PERENNIALS

- Survive few to many years
- Reproduce by seed, vegetatively, or sometimes both
- Store nutrients and carbohydrates in rhizomes
- Can tolerate extended flooding

ANNUALS VS. PERENNIALS

Why does it matter?

HABITAT

- Promote desirable species
- Control undesirable species
  - Perennials: Need to reduce underground biomass & nutrient reserves
  - Annuals: prevent or minimize future germination events

TIMING OF CONTROL

Annuals

Energy into growth and seed production

Prevent seeding

Mowing

Tilling/disking

Re-flooding

Perennials

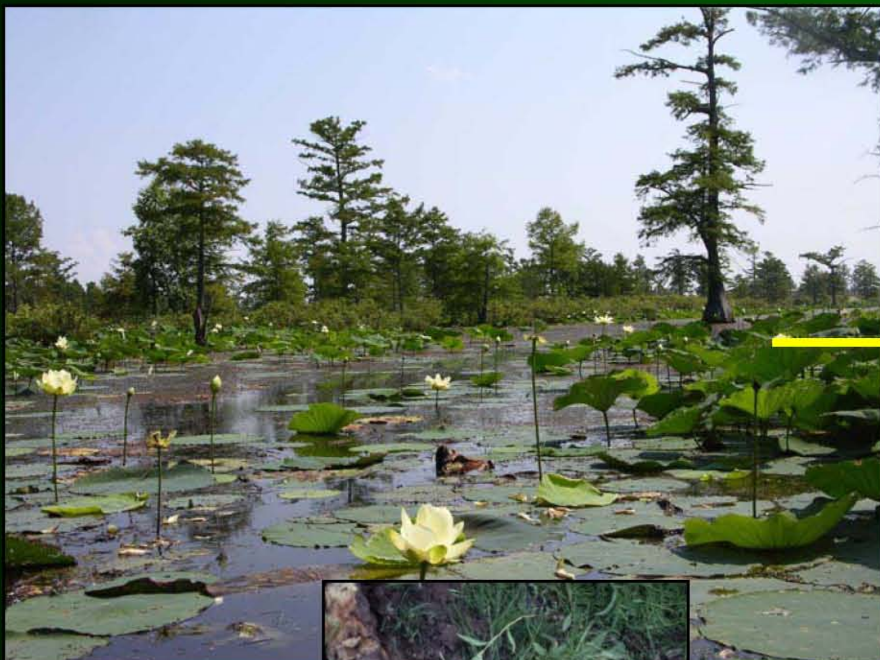
Energy into growth, seed production

Energy into rhizomes (storage for next year)

Reduce nutrient storage

May be able to reduce competitive advantage by mowing after plants flower

CONTROL OF LOTUS



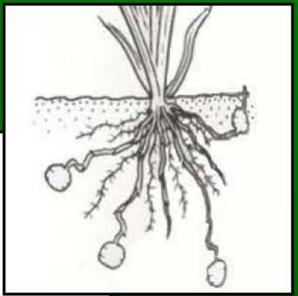
Herbicide
Drawdown
Drawdown

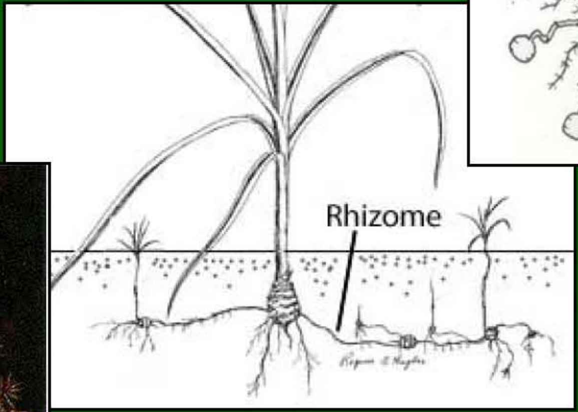
ANNUALS VS. PERENNIALS

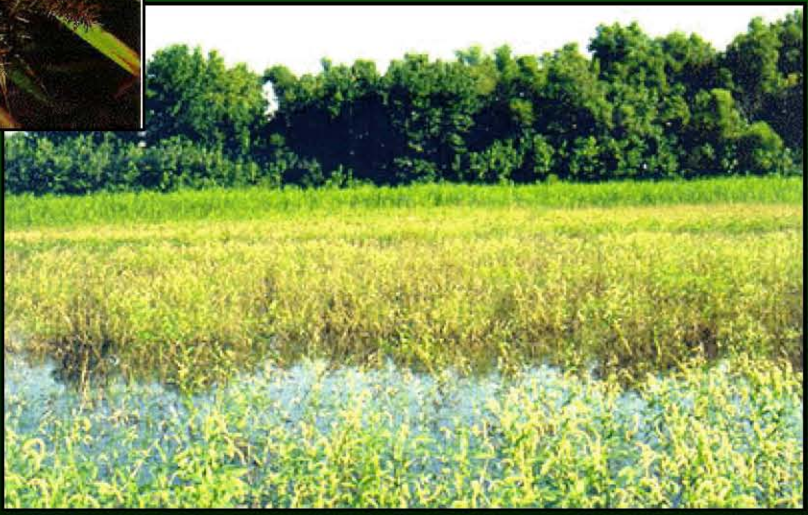
Why does it matter?

WATERFOWL FORAGE

- Where are nutrients concentrated in plants?
  - Seed production
  - Tubers/rhizomes
- Are these nutrients readily available to waterfowl?
  - Timing
  - Accessibility







Bidens spp. SEEDS

Nutrient	Low	Average	High
Energy (kcal/g)			■
Fat		■	
Ash (mineral content)		■	
Fiber (least digestible)			■
Carbohydrates (NFE)	■		
Protein			■

Bidens cernua (nodding beggartick)

Bidens frondosa (devil's beggartick)

Rumex spp.

Nutrient	Low	Average	High
Energy (kcal/g)		■	
Fat	■		
Ash (mineral content)		■	
Fiber (least digestible)			■
Carbohydrates (NFE)	?	?	?
Protein	■		

Rumex salicifolius (willow dock)

Rumex aquaticus (western dock)

TUBERS

Sagittaria spp.

Nutrient	Low	Average	High
Energy (kcal/g)		■	
Fat		■	
Ash (mineral content)		■	
Fiber (least digestible)	■		
Carbohydrates (NFE)			■
Protein			■

Sagittaria latifolia (arrowhead)

Chufa flatsedge

Nutrient	Low	Average	High
Energy (kcal/g)		■	
Fat		■	
Ash (mineral content)	■		
Fiber (least digestible)	■		
Carbohydrates (NFE)			■
Protein	Depends on time of year		

Native to lower 48

Roots

- From annuals and perennials
- High in protein - new growth most nutritious
- Tremendous potential for biomass

Leaves

- From annuals and perennials
- Most nutritious early in growing season or just after establishment

LEAVES

Duckweed

Nutrient	Low	Average	High
Energy (kcal/g)		■	
Fat	■		
Ash (mineral content)		■	
Fiber (least digestible)		■	
Carbohydrates (NFE)			■
Protein			■

Lemna minor (common duckweed)

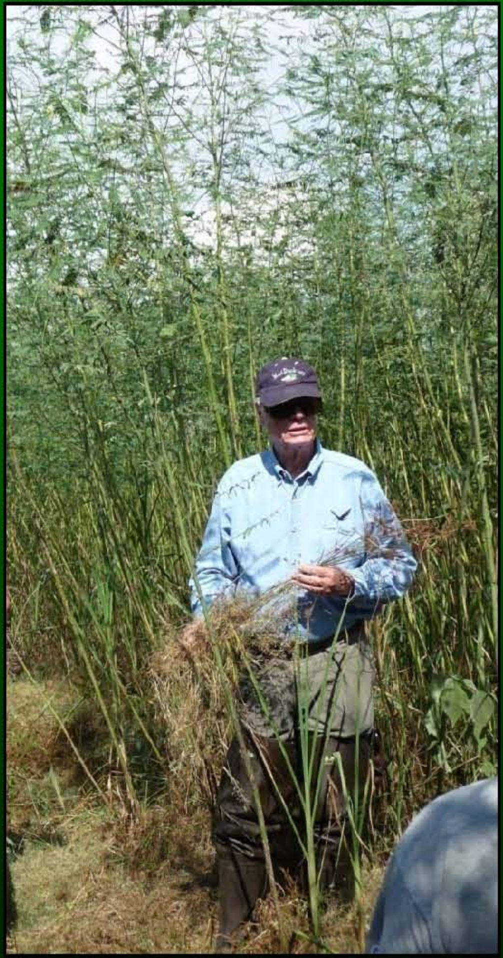
Washington Dept. of Ecology

AVAILABILITY OF PLANT FOODS

- Habitat structure
- Water depth

Habitat Use by Waterbirds

No. of Species	Water Depth
34	<4 in
24	2-10 in
19	> 10 in



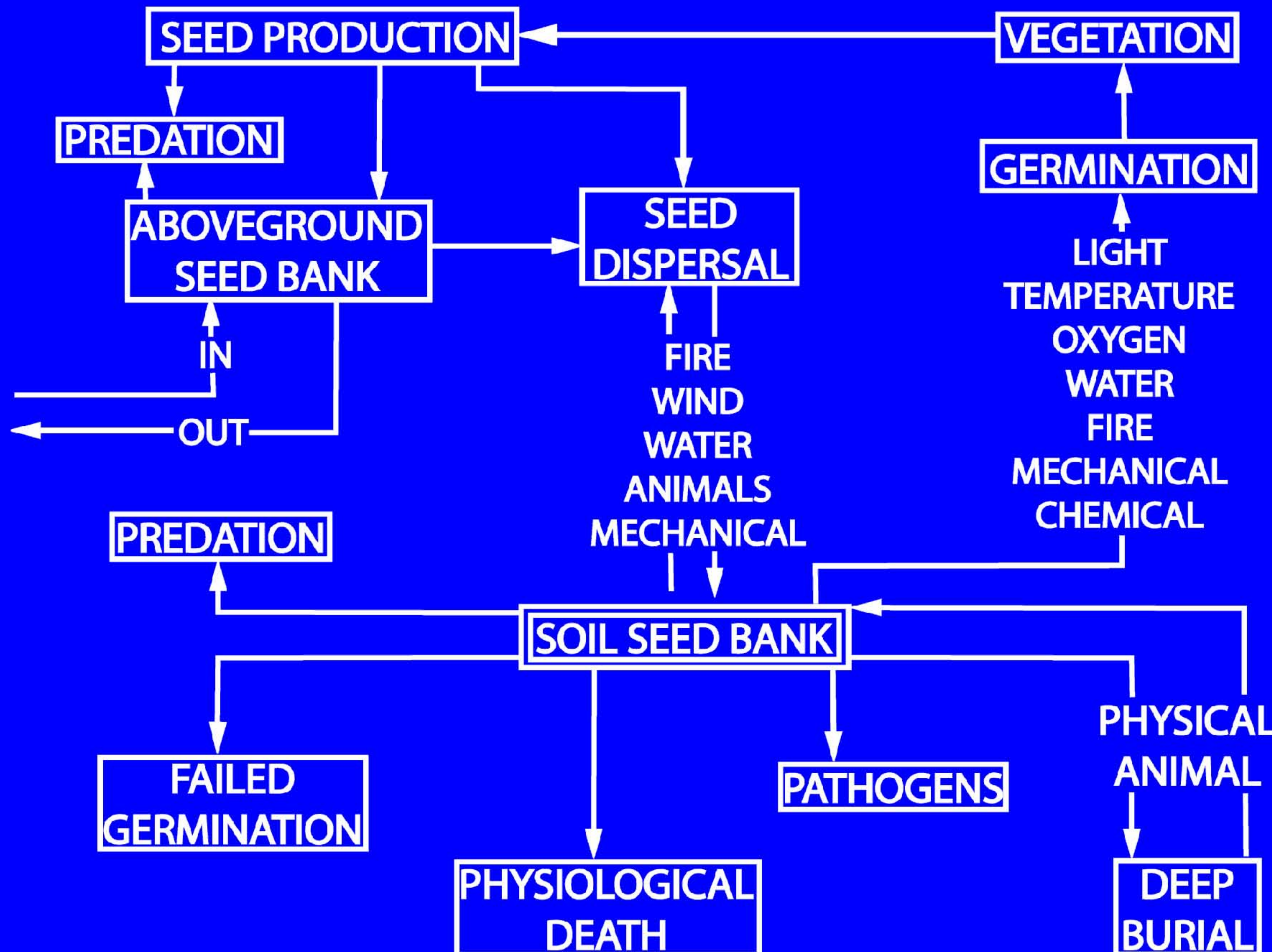
VEGETATION STRUCTURE

- Nesting
  - Tall or short robust plants
  - Protection from wind
  - Protection from water fluctuation
  - Materials for nests
- Courtship
  - Isolation of the individual from flocks
  - Predator protection
- Microclimate
  - Moderation of ambient temperature
  - More favorable energy balance
- Invertebrates
  - High vegetation complexity is best for high invertebrates
  - Submerged structure very important

SEED BANK

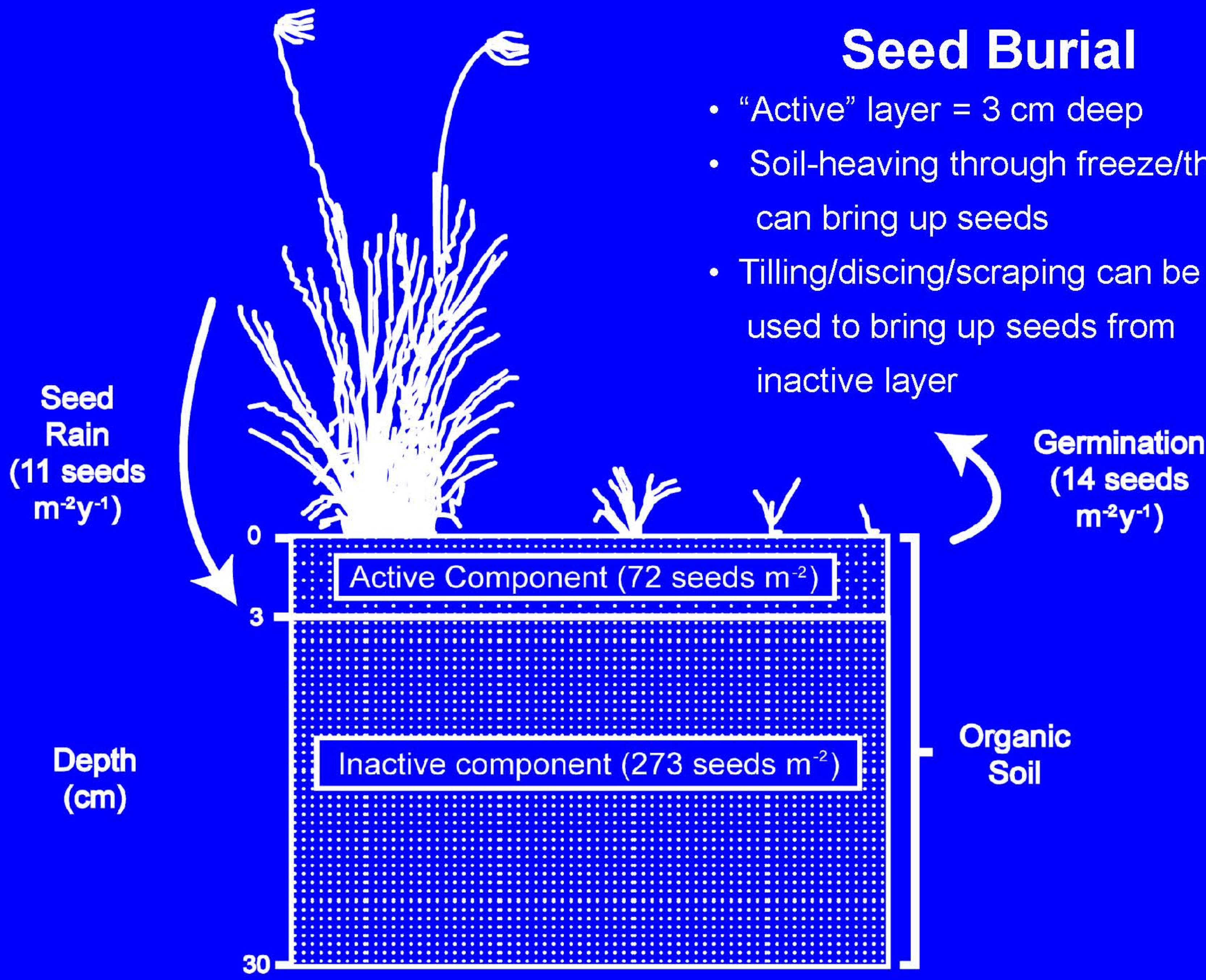
SEED BANK

All viable seeds and/or propagules
present on or in the
soil and associated litter


SEED PRODUCTION
VEGETATION
PREDATION
GERMINATION
ABOVEGROUND SEED BANK
SEED DISPERSAL
LIGHT
TEMPERATURE
OXYGEN
WATER
FIRE
MECHANICAL
CHEMICAL
IN
OUT
FIRE
WIND
WATER
ANIMALS
MECHANICAL
PREDATION
SOIL SEED BANK
PHYSICAL
ANIMAL
FAILED GERMINATION
PATHOGENS
PHYSIOLOGICAL DEATH
DEEP BURIAL

Seed Burial

- "Active" layer = 3 cm deep
- Soil-heaving through freeze/thaw can bring up seeds
- Tilling/discing/scraping can be used to bring up seeds from inactive layer



Species	Age (years)	Naturally Preserved	Natural Field Conditions	Location
Lupinus arcticus (Arctic Lupin)	10,000	+		Yukon Territory
Chenopodium album (Lambsquarters)	1,700	+		Scandinavia
Spergula arvensis (Corn spurry)	1,700	+		Manchuria, Tokyo, Great Britain
Nelumbium nucifera *(Indian lotus)*	100 – 3,000	+		Argentina
Canna compacta	550	+		Michigan
Rumex crispus (Curled dock)	80		+	Michigan
Oenothera biennis (Evening primrose)	80		+	Michigan
Amaranthus retroflexus (Redroot pigweed)	>30		+	Michigan
Setaria media (Bristlegrass)	>30		+	Michigan
Agrostis vulgaris (Colonial bentgrass)	<10		+	Virginia
Grindelia squarrosa (Curlycup gumweed)	<10		+	Virginia

Size & Diversity of Wetland Seed Banks

WETLAND TYPE	DENSITY (x/m^2)	RANGE (x/m^2)	SPECIES RICHNESS	LOCATION	REFERENCE
FRESH	29,753	10,875 - 36,230	45	IOWA	VAN DER VALK AND DAVIS (1978)
FRESH	110,000	42,000 - 255,000	50	IOWA	VAN DER VALK AND DAVIS (1979)
TEMPORARY	17,943	11,455 - 24,430	21	NEW JERSEY	MCCARTHY (1987)
BRACKISH	3,577	93 - 8,253	34	MANITOBA	PEDERSON (1981)
LAKESHORE	10,089	1,862 - 19,798	41	ONTARIO	KEDDY AND REZNICEK (1982)
RIVERINE SWAMP	2,576	759 - 4,392	59	SOUTH CAROLINA	SCHNEIDER AND SHARITZ (1986)
SALT	191	50 - 430	3	UTAH	KADLEC AND SMITH (1984)

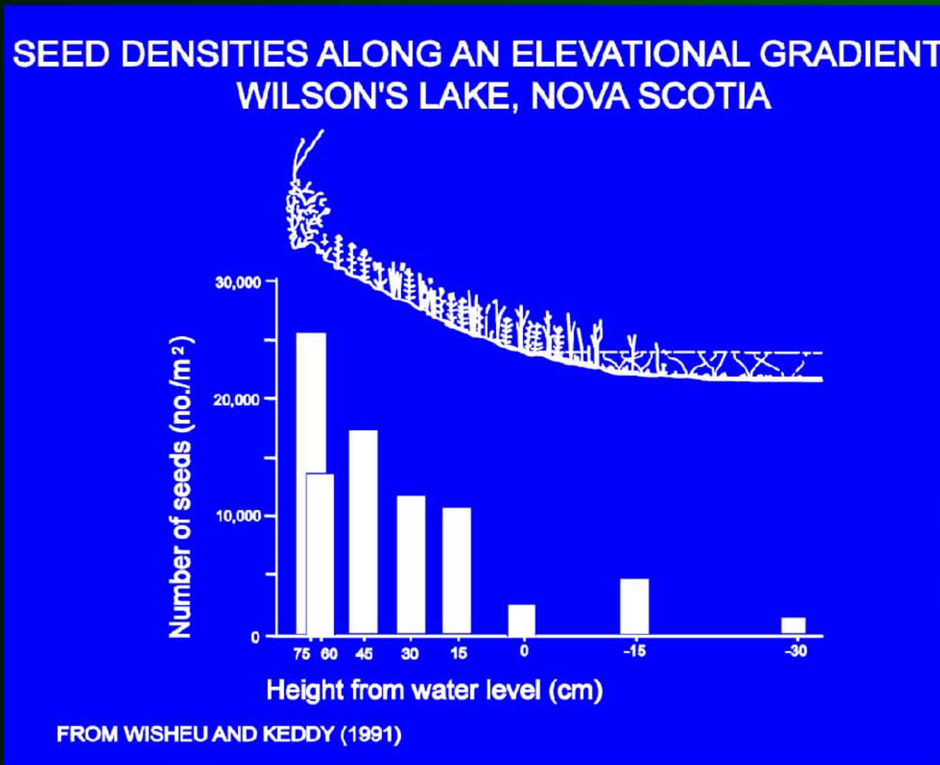
ADAPTED FROM LECK (1989)

Seed Bank & Standing Veg. Species Diversity

Wetland type	Seed Bank	Veg	Total	Location	Reference
Fresh	45+	34	48	Iowa	Van Der Valk & Davis (1978)
Temporary	21	29	31	New Jersey	McCarthy (1987)
Brackish	29+	18	35	Manitoba	Pederson (1981)
Lakeshore	41	45	50	Ontario	Keddy & Reznicek (1982)
Riverine Swamp	59	49	73	S Carolina	Schneider & Sharitz (1986)
Salt	9	14	15	Utah	Kadlec & Smith (1984)

DISTRIBUTION OF SEED BANKS

Wilson's Lake vs. Playa Wetlands



- Relatively uniform seed density along elevation gradient
  - Short linear gradient with a flat bottom
  - Seed dispersal may be accentuated by frequent rise and fall of water levels
  - Wind may distribute seeds during dry phases

Using Seed Banks to Your Benefit

Success depends on:

1. Presence of seeds of preferred species
2. Suitable conditions for germination and establishment of preferred spp.
3. Absence of seeds of unwanted species, or these seeds are uncommon

4. Conditions for germination and establishment of unwanted species are not met

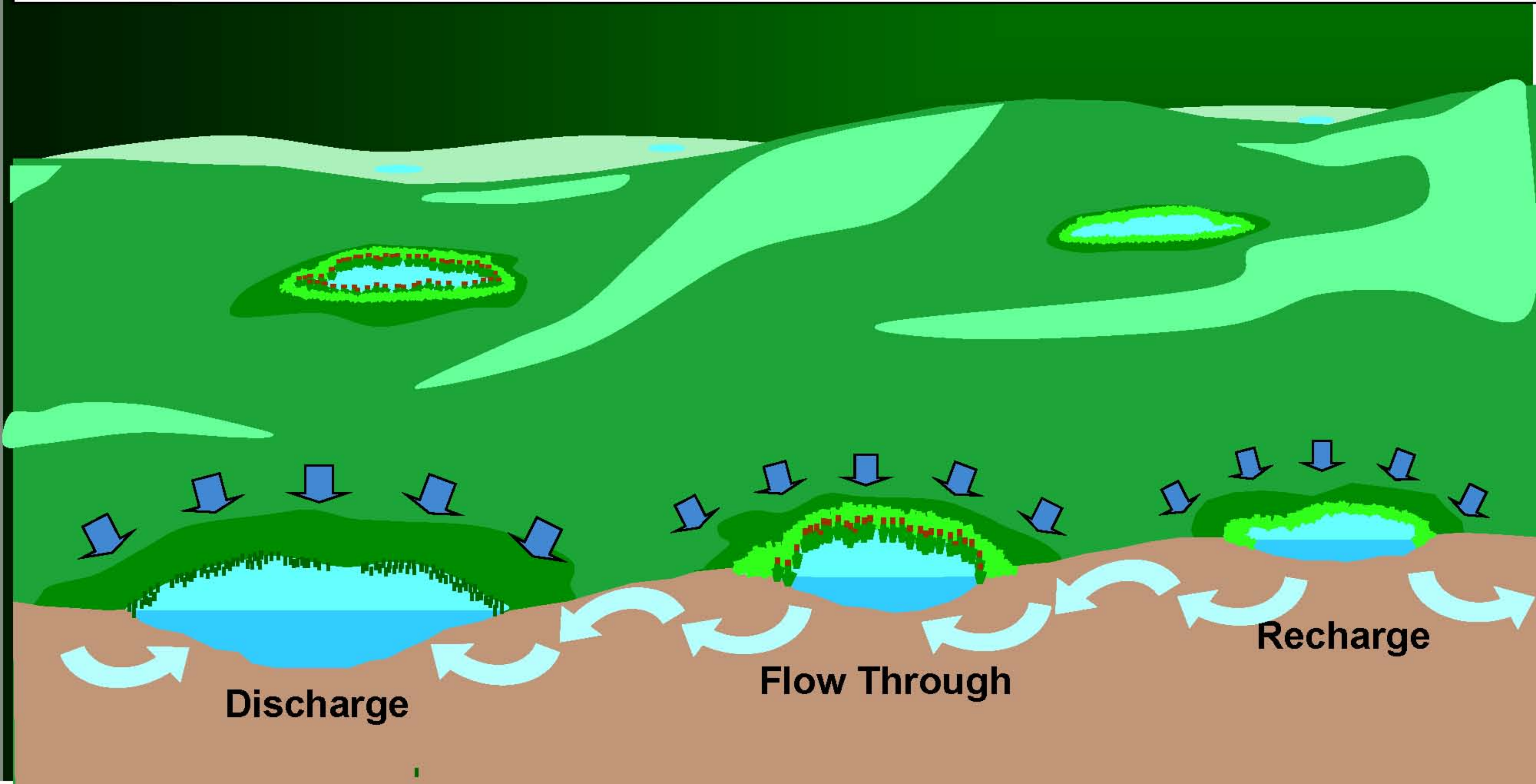
WHAT TO CONSIDER

Influences on Aquatic Plant Communities

- Position in Landscape
- Climate & Hydrology
- Soils
- Light
- Temperature
- Water chemistry

Wetlands in the Landscape...

Relationship with Hydrology



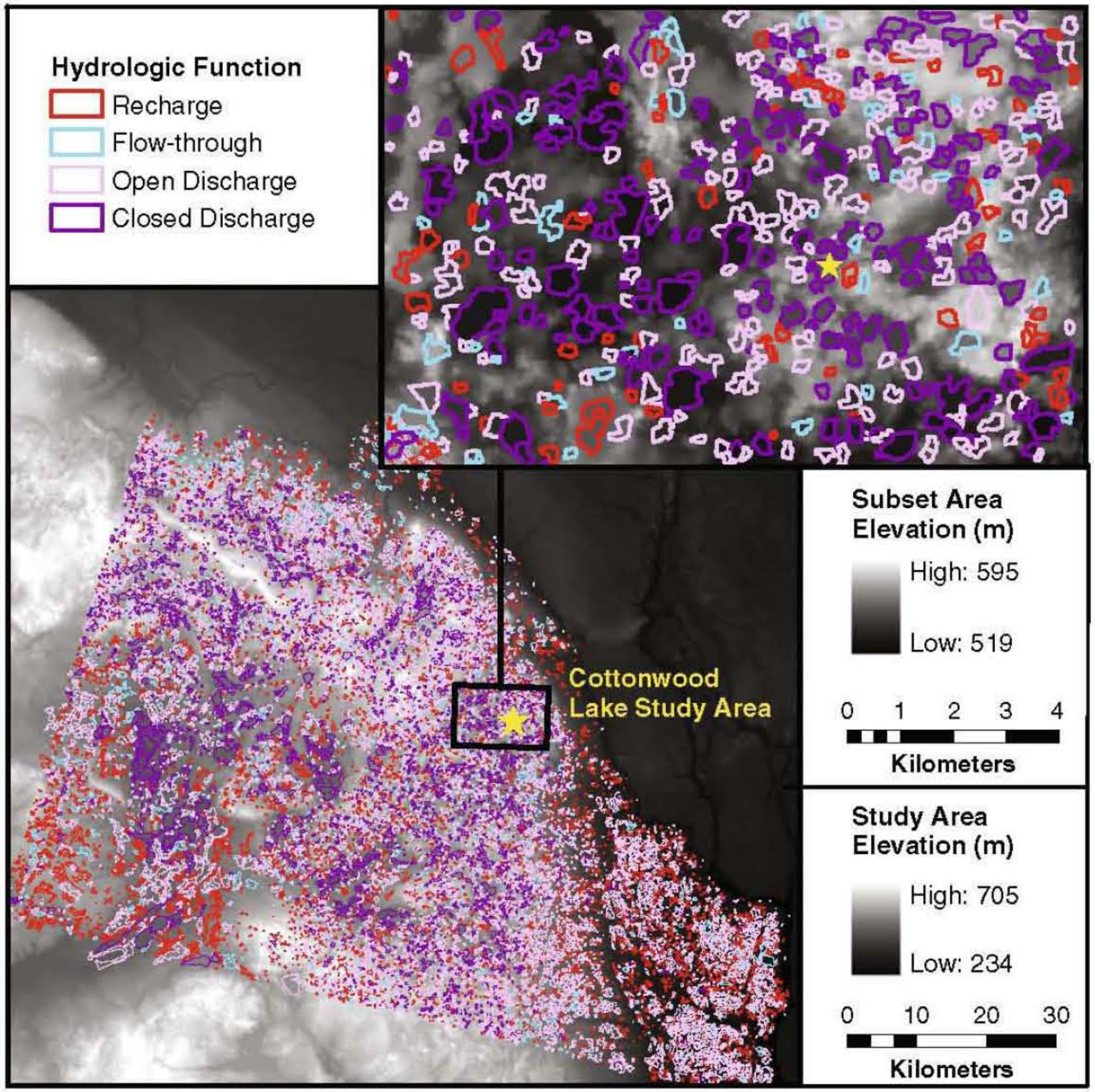


Fig. 5 Classification of hydrologic function in the Missouri Coteau and a subset area containing CLSA

Carex utriculata
(northwest territory sedge)

Juncus arcticus (syn; *J. balticus*)
(mountain rush)

Hordeum jubatum
(foxtail barley)

Carex diandra
(lesser panicled sedge)

Distichlis spicata
(saltgrass)

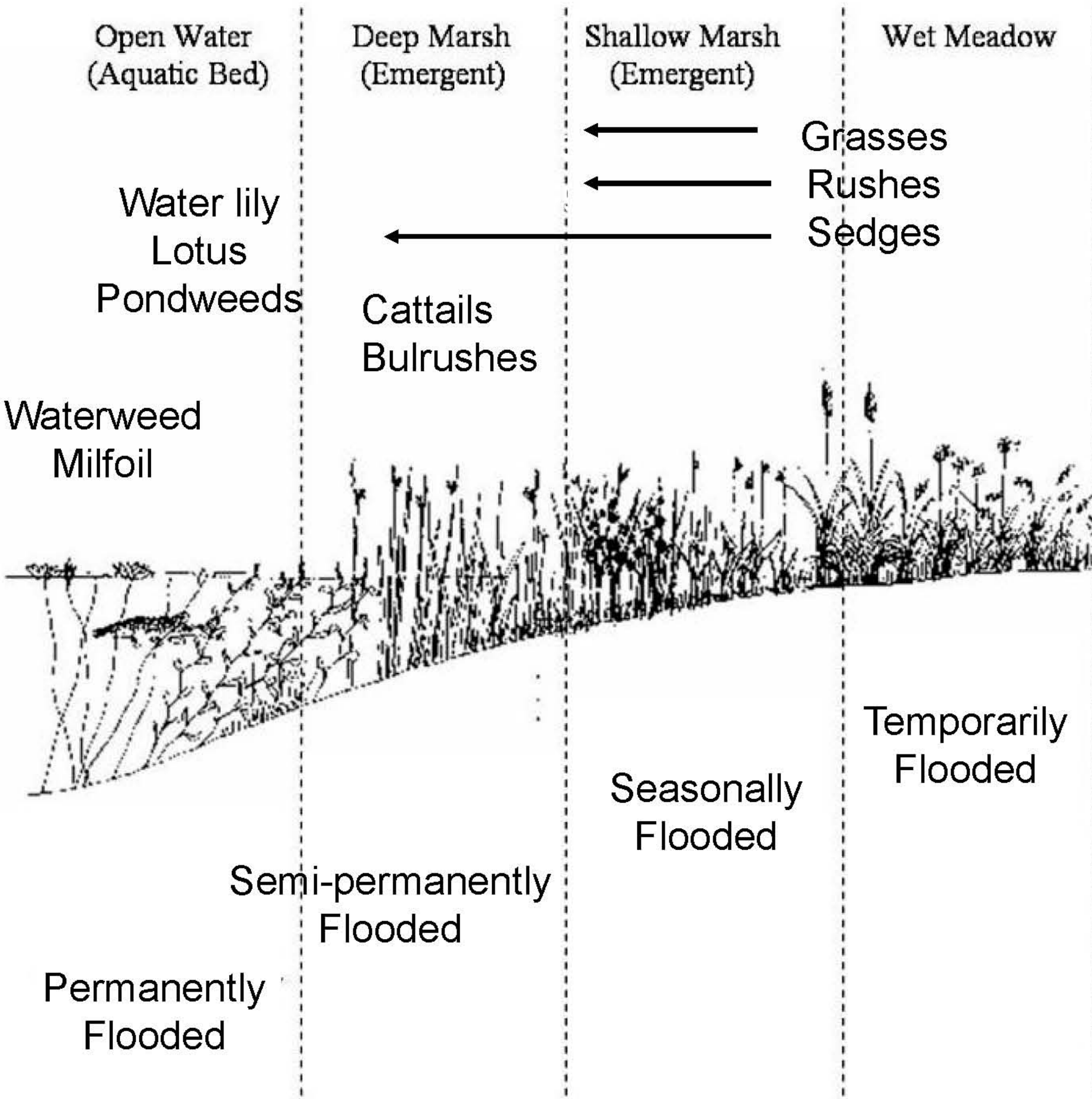
Suaeda sp. (seepweed)
Salicornia rubra (red swampfire)

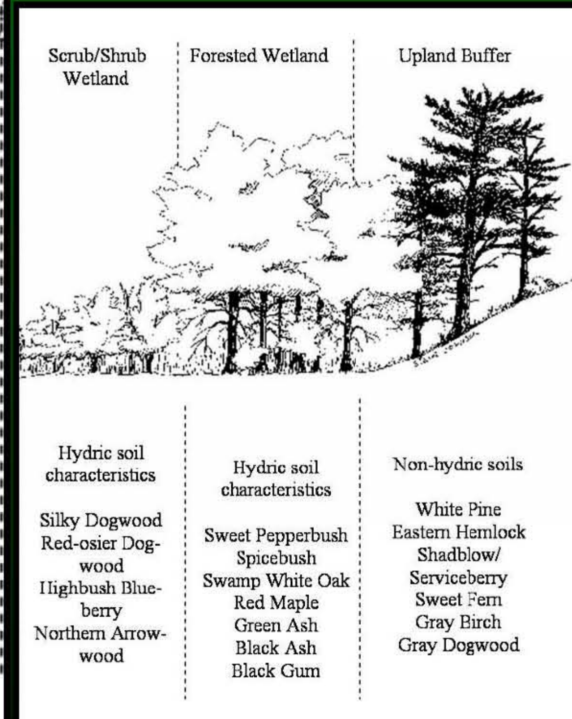
increasing salinity

CLIMATE AND HYDROLOGY

- Intra-annual (timing of hydrologic inputs)
  - Early vs. late
  - Duration of inputs
- Inter-annual (wet vs. dry year)
- Inter-decadal (e.g., 1930s US drought; 1950s US and Mexico drought)
- Other weather conditions
  - Above or below average temperatures
  - Wind

HYDRO-PERIOD





Seed Bank & Climatic Conditions

Carolina Bays

Carolina Bay	Species in Seed Bank	1999 Vegetation (Wet)	2002 Vegetation (Dry)	Seed Bank never in Vegetation
SRS Bay 3	80	21	32	61 (76%)
SRS Bay 31	55	15	29	39 (71%)
SRS Bay 78	63	21	18	48 (76%)
SRS Bay 176	67	24	32	41 (61%)
Average	66	20	28	47 (71%)

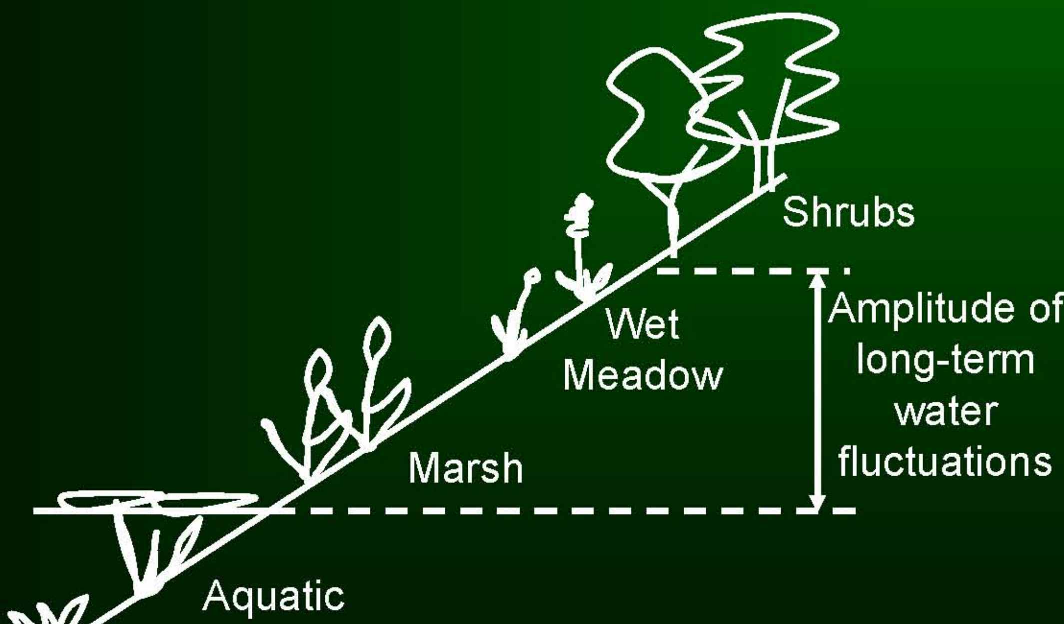
DYNAMIC WATER VS. STABLE WATER

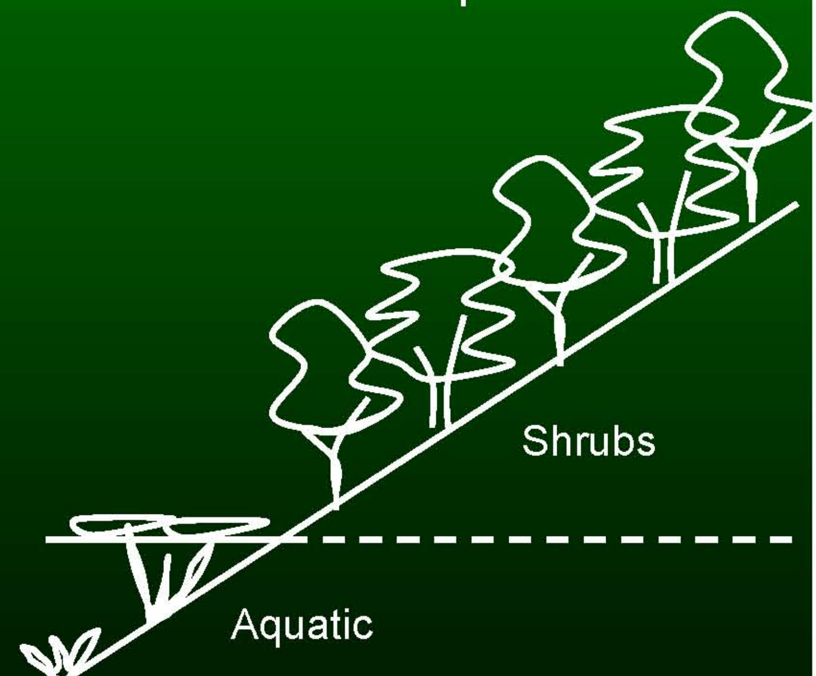
DYNAMIC WATER

- Increases plant spp. & community diversity
- Increase habitat interspersion (e.g., emergent veg and water)
- Increase niches available for waterbird foraging and nesting

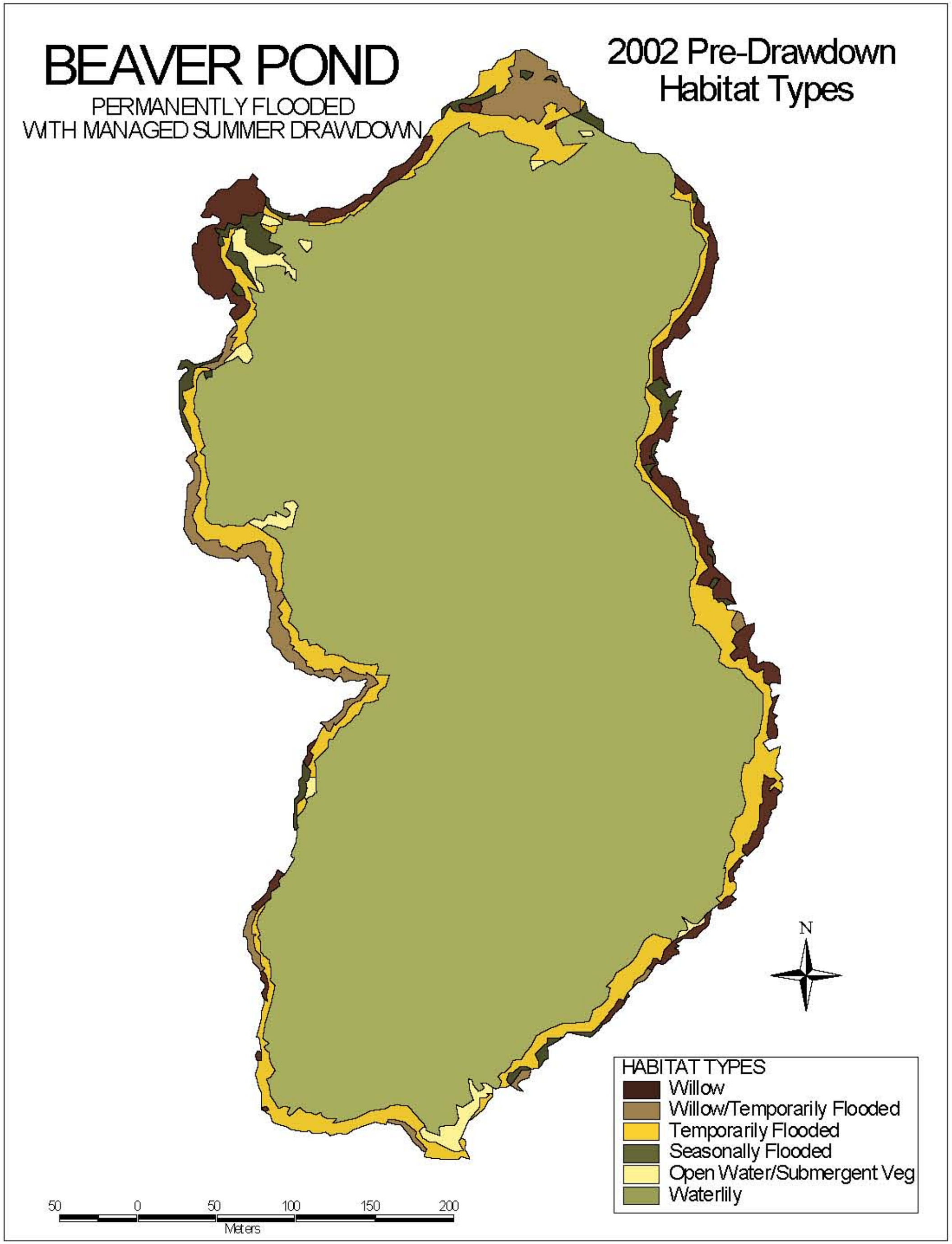
STABLE WATER

- Allow monospecific vegetation stands &/or one structural type
- Increase # and dominance of exotic/aggressive perennials
- Reduce or eliminate wet meadow and/or marsh zone
- Decrease fungal or pollinator mutualistic relationships



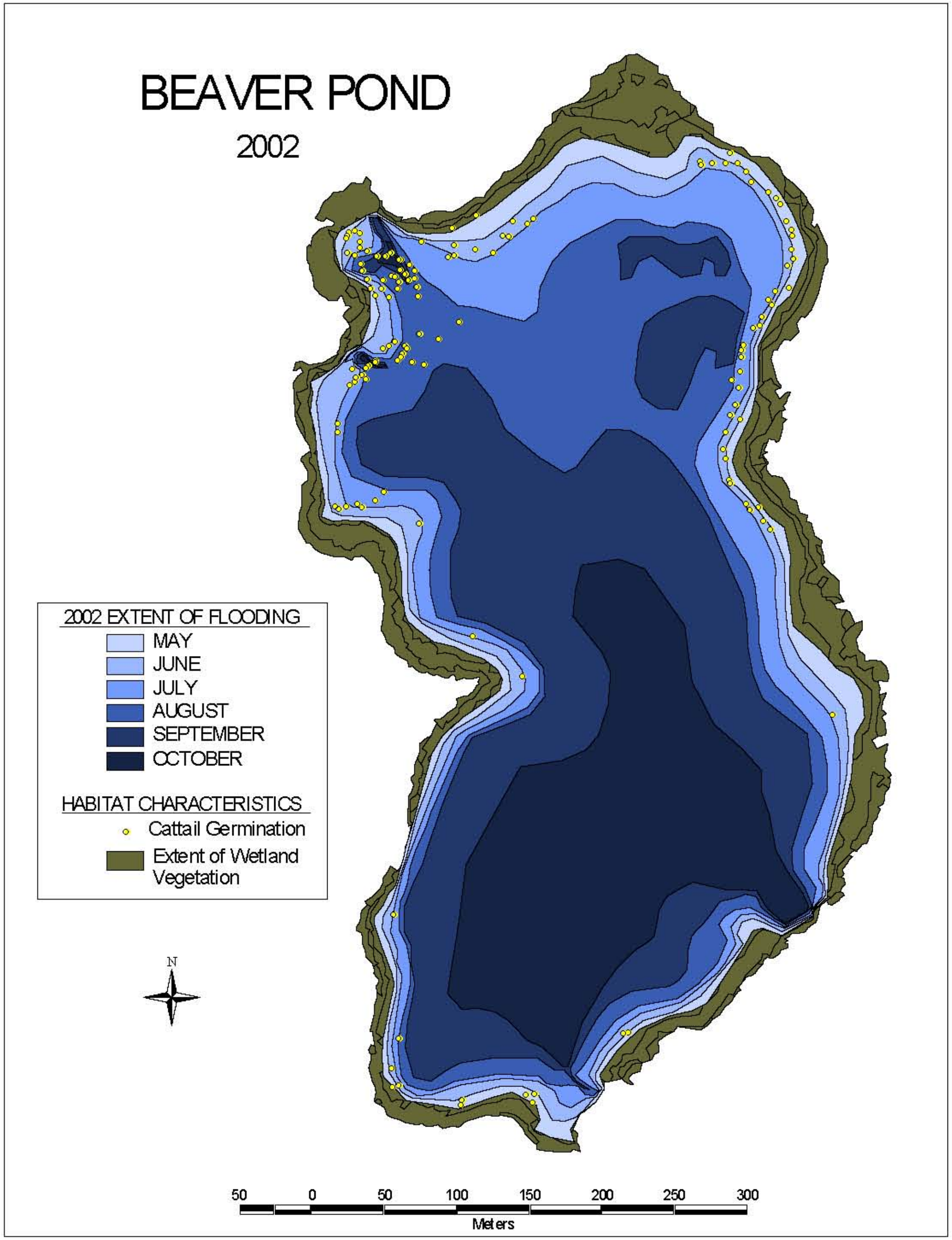


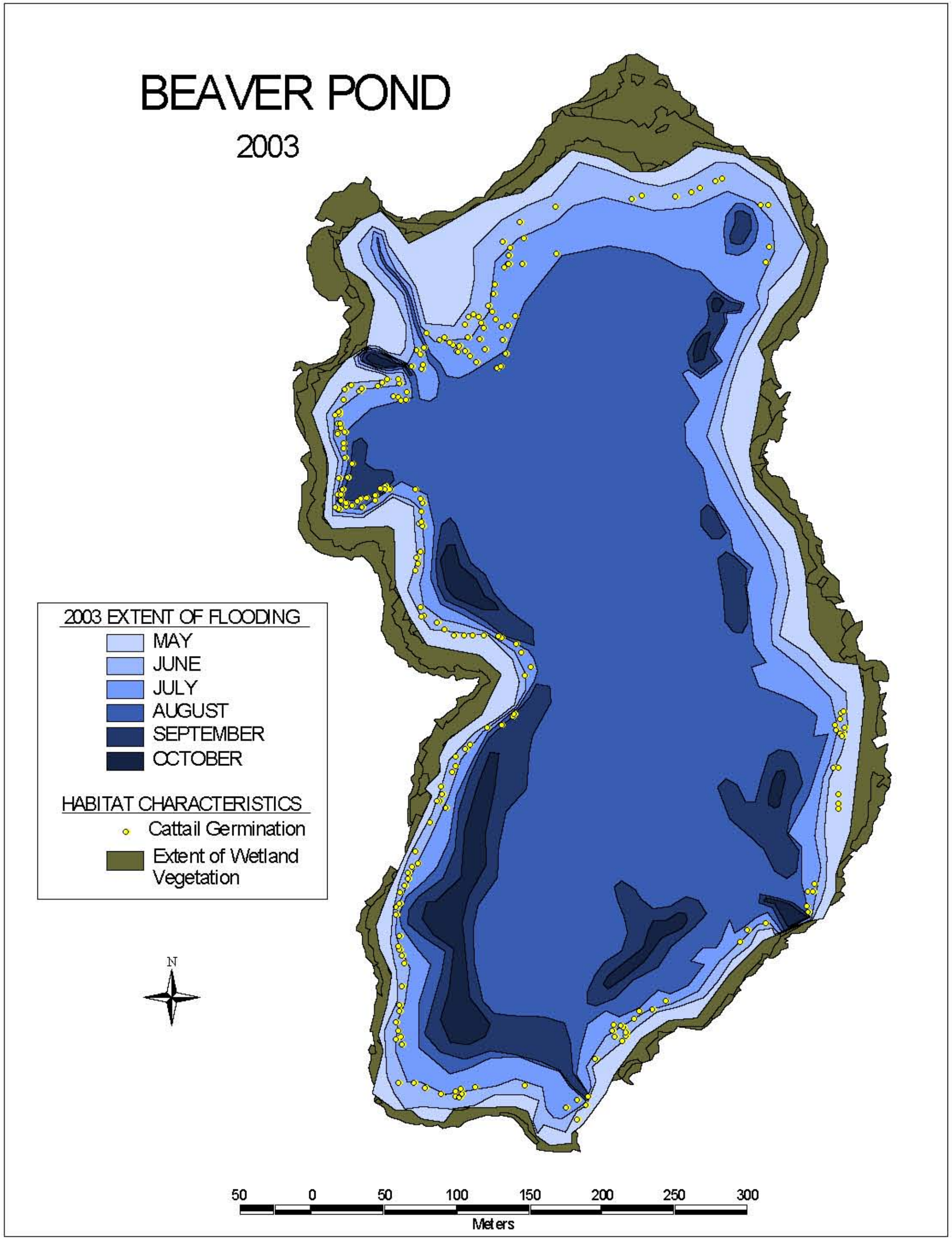
Adapted from Cronk & Fennessy 2001



STABILIZED WETLAND DRAWDOWN RESPONSE

GERMINATION REPONSE TO DRAWDOWN Year 1





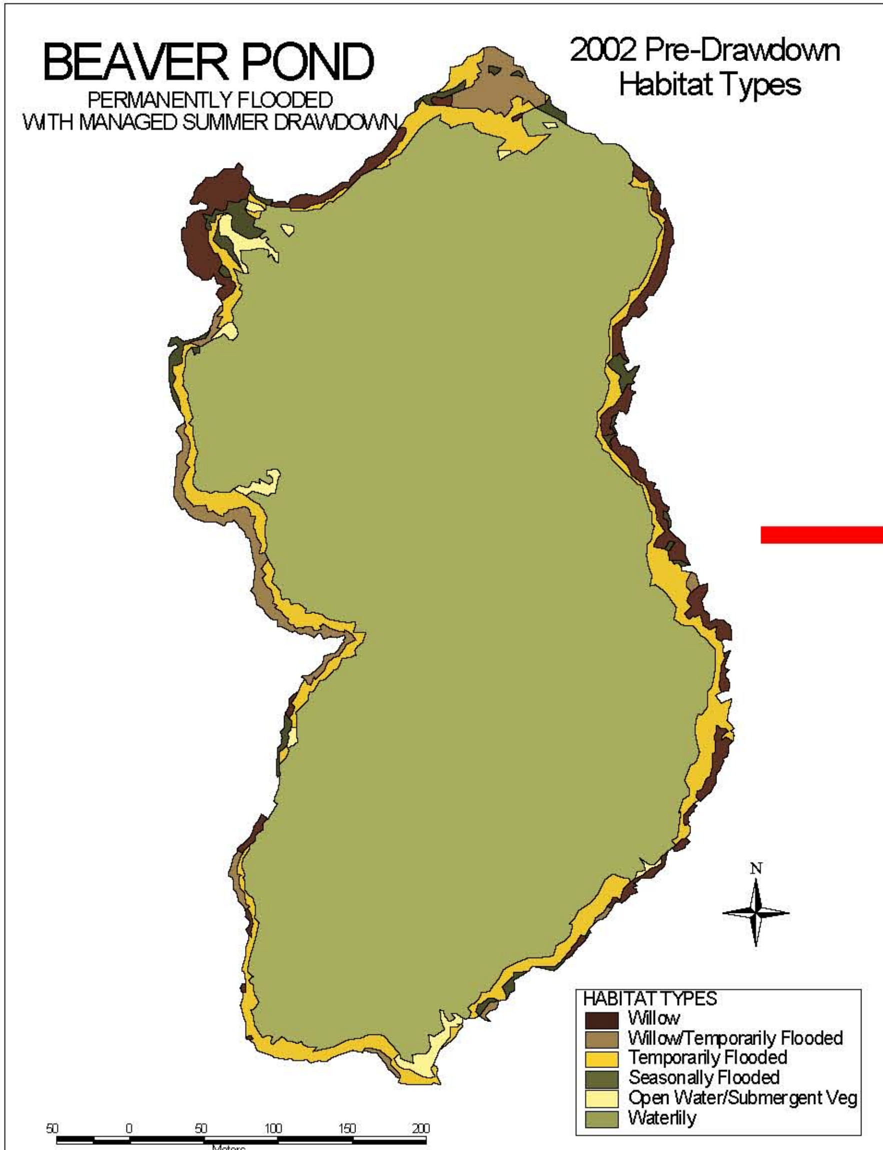
GERMINATION RESPONSE TO DRAWDOWN Year 2

Key Factors Observed
Soil temperature
Soil moisture
Organic matter

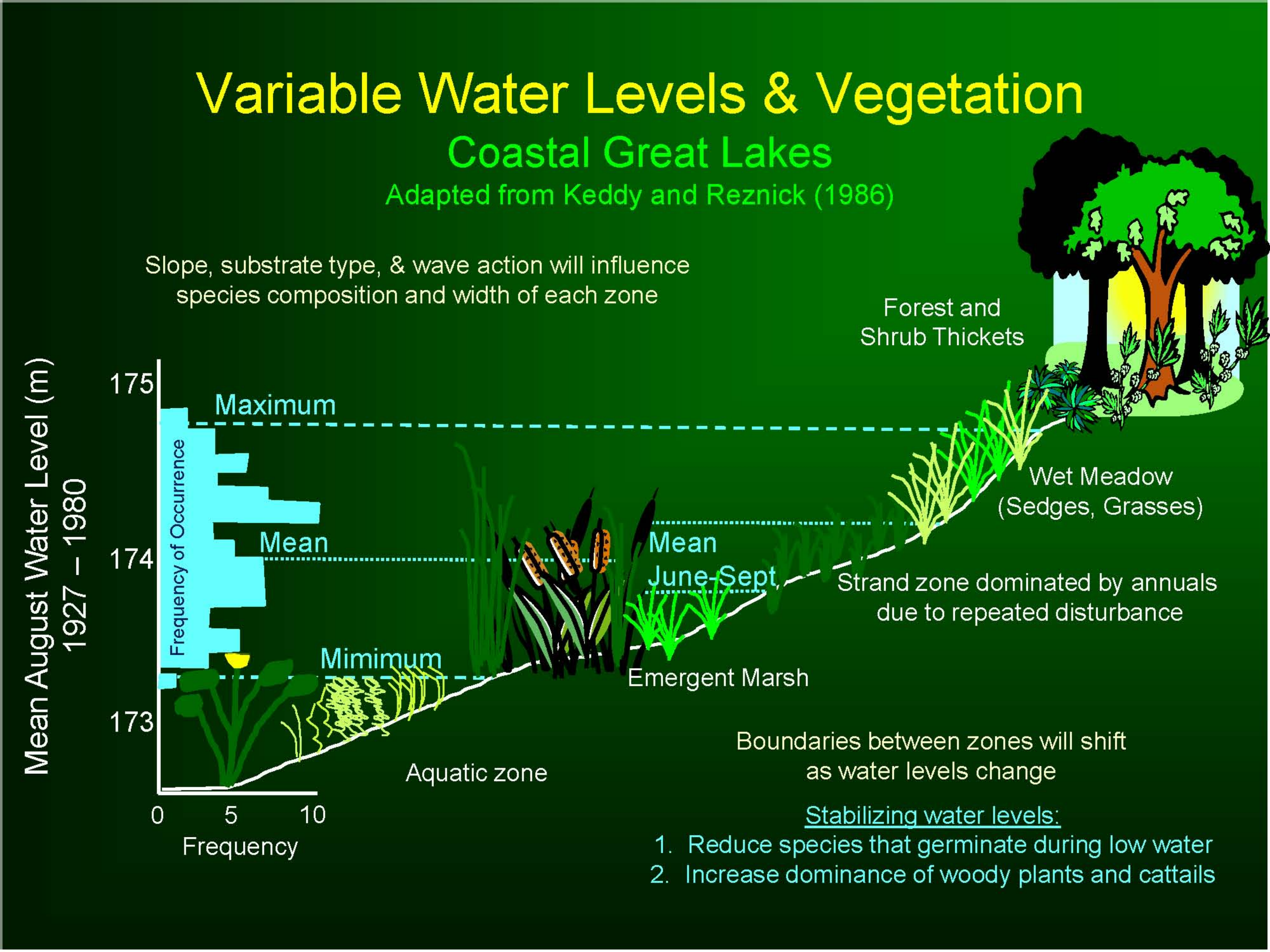
Cattails – warm saturated
Sedges – cooler saturated

High organic matter dried out quickly and seedlings died.

AFTER 2 YEARS




11 years of "natural" water fluctuations at Beaver Pond
= substantial increase in emergent vegetation
= interspersion of cattail, spikerush, baltic rush & sedges


Variable Water Levels & Vegetation
Coastal Great Lakes
Adapted from Keddy and Reznick (1986)
Slope, substrate type, & wave action will influence
species composition and width of each zone
Forest and
Shrub Thickets
Mean August Water Level (m)
1927 – 1980
175
174
173
Maximum
Mean
Mimimum
Frequency of Occurrence
0
5
10
Frequency
Wet Meadow
(Sedges, Grasses)
Mean
June-Sept
Strand zone dominated by annuals
due to repeated disturbance
Emergent Marsh
Aquatic zone
Boundaries between zones will shift
as water levels change
Stabilizing water levels:
1. Reduce species that germinate during low water
2. Increase dominance of woody plants and cattails

SOIL

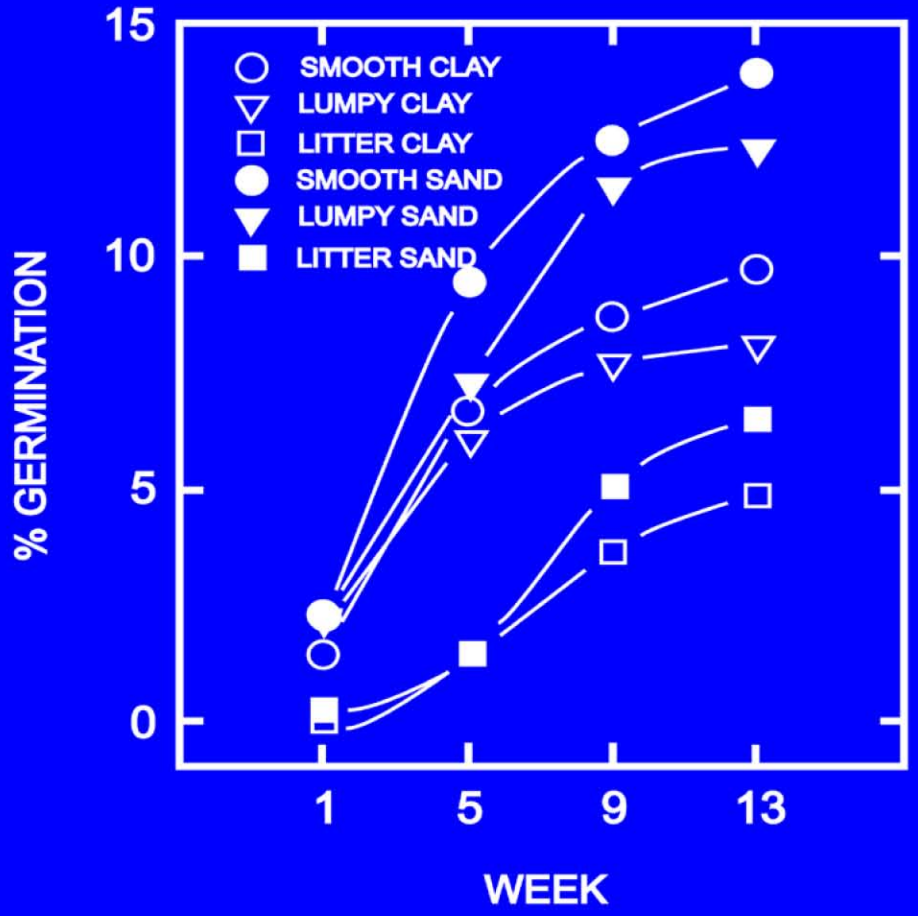
SOIL

SOIL

- Soil temperature
- Soil moisture and texture
  - Capillary fringe
    - Pull water higher with tighter pores
      - Sand = 0-3 in.
      - Silt = 0.5-5 ft.
      - Clay = 5-10 ft.
  - Shrink/swell capacity of clays can result in a variety of niches for germination
- Organic content

Variable Germination Depending on Soil Type

Boltonia = white doll's daisy



Germination of *Boltonia decrens* at 4-week inetervals over a 13-week period on smooth clay (open circle), smooth sand (filled circle), lumpy clay (open triangle), lumpy sand (closed triangle), litter-covered clay (open box), and litter-covered sand (closed box).

FROM SMITH ET AL. 1995

SOIL TEMPERATURE

- Soil Stratigraphy
- Soil Texture
- Soil Color
- Organic Content

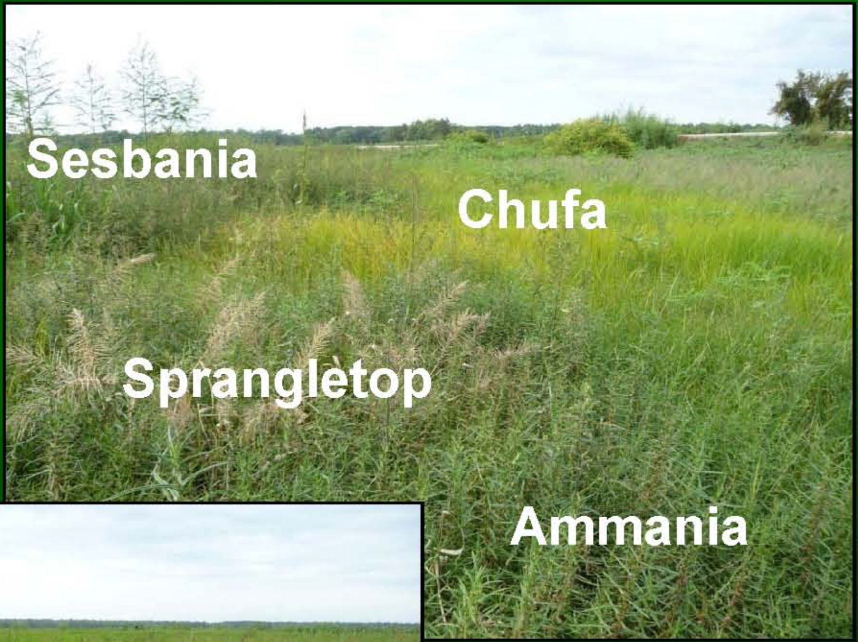
MOIST-SOIL DRAWDOWN REPONSE

Early Succession (after disturbance)

Early Drawdown	Mid Drawdown	Late Drawdown
+ Big-seeded smartweed		
+ Nodding smartweed		
	+ Beggarticks	+ Beggarticks
	- Cocklebur	- Cocklebur
		+ Sprangletop
		+ Panic grass
		+ Crab grass
		+ Ammania
		- Sesbania
+ Redroot sedge	+ Redroot sedge	+ Redroot sedge
+ Millet (colonum)	+ Millet (crus-galli)	+ Millet (walteri)
- Purple loosestrife	- Purple loosestrife	- Purple loosestrife

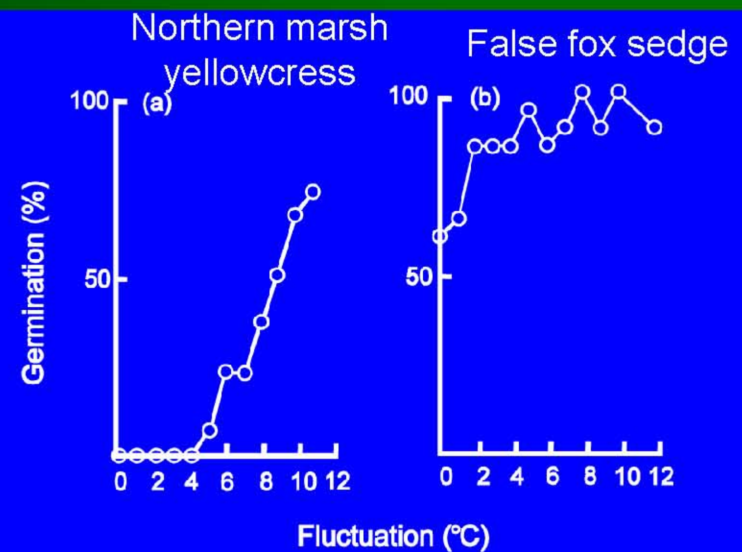
DRAWDOWN REPONSE

Variability will result from differences in soils, topography, and climate



SOIL TEMPERATURE FLUCTUATIONS

An increase in soil temperature fluctuations can incite germination.



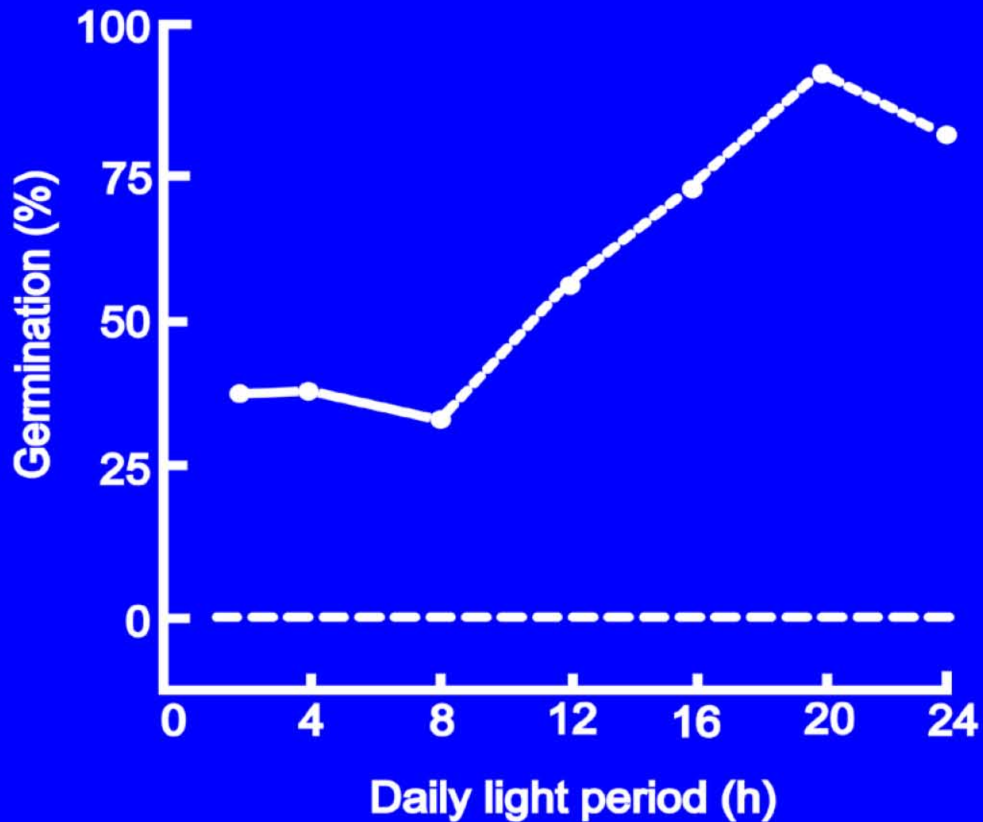
Germination responses diurnal temperature fluctuations with an 18h photoperiod. (a) Rorippa islandica (b) Carex otrubae (after Thompson and Grime, 1983)

From Fenner (1985)

LIGHT

- Most important factor for submerged plant distribution
  - Some species will grow under ice if light is adequate
- Amount of light determined by:
  - Water depth: <50% incident natural sunlight penetrates 1 m of pure water
  - Time of day/year - most light reflected when “long light”, i.e. sunrise/sunset and winter months
  - Shading by vegetation
  - Heavy periphyton can reduce plant productivity
  - Suspended solids, dissolved organic and inorganic compounds can scatter light & absorb heat

Photo Period



Response of seeds of birch (Betula pubescens) to various photo periods. Temperature during the tests was 15° C. Dotted line, dark control (from Bewley and Black 1982, after Black and Wareing, 1955).

From Fenner (1985)

WATER CHEMISTRY

- Conductivity (total dissolved salts)
- Salinity
- pH
- Dissolved oxygen
- Nutrients
- Pollutants

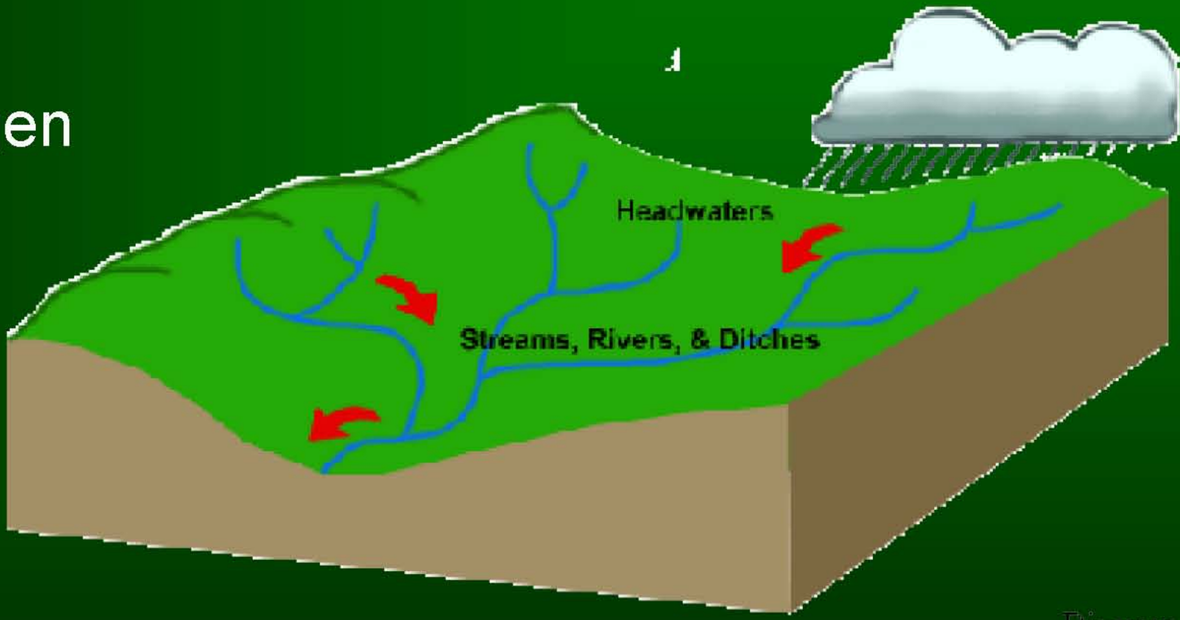


Diagram: KJ

MANAGEMENT

- Many tools available to control pests and promote native beneficial plants

- Need to understand your system
  - Biotic Factors
  - Abiotic Factors

- Need to understand growth characteristics of plants present
  - Create conditions favorable for good species
  - Implement effective control for invasive species

- NO COOKBOOK ANSWER!!

MONITOR
HAVE PATIENCE

Disturbance and Wetland Succession

DISTURBANCE - Natural or managed

(drawdown, tilling, etc)

Mud flats

Moist-soil

↓

"OPEN MARSH"

Deep Water center & Ring of emergents

Annuals / Emergents

↓

Perennials

↓

Floating

↓

Submergents

- IF NO DISTURBANCE:
  - Lower Seed Production
  - More Perennials
  - More Woody Vegetation

EQUIPMENT USED TO MIMIC HISTORICAL ECOLOGICAL DISTURBANCE

Weller (1978)

DRAWDONS

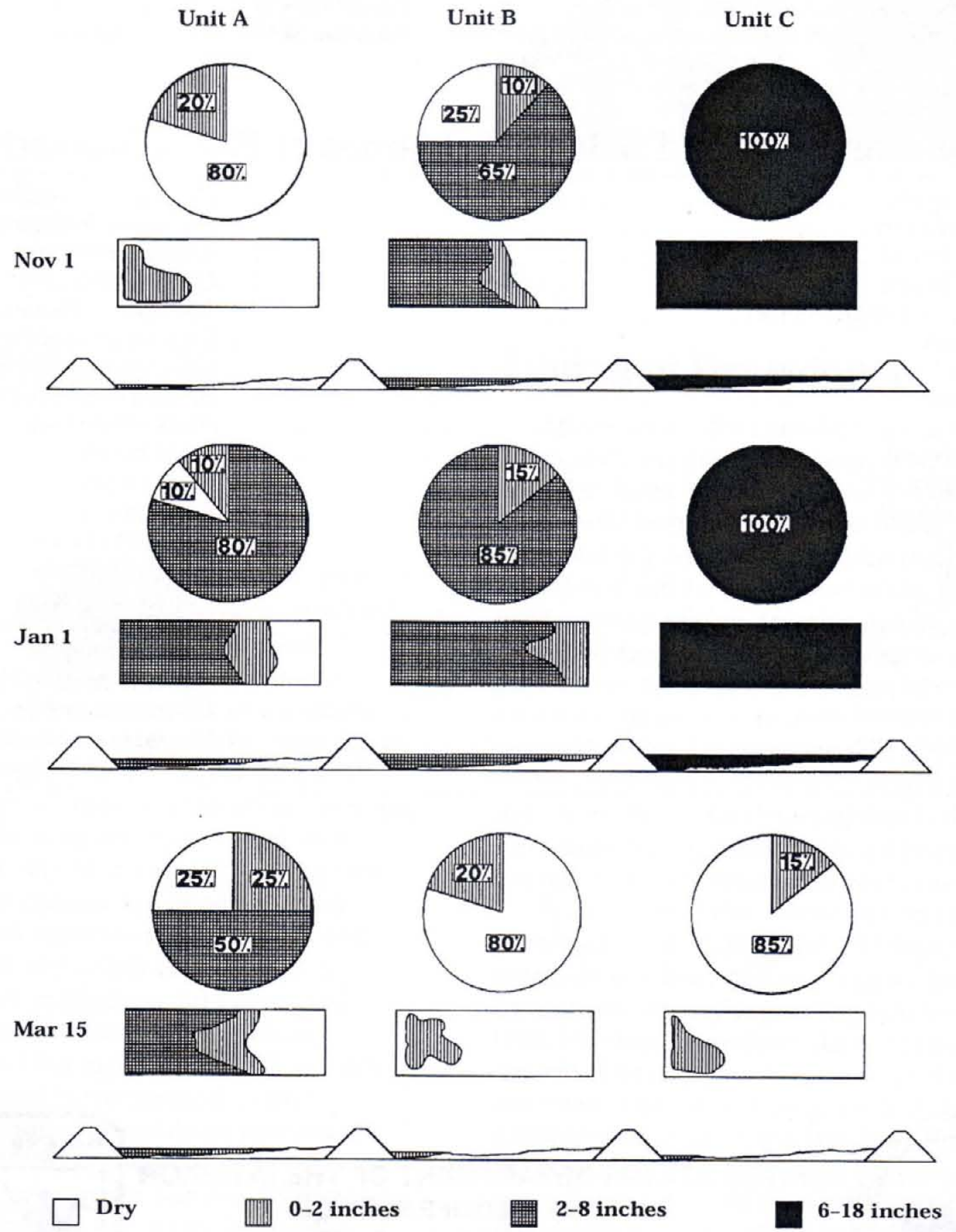
RE-FLOODING OR FLOOD-UP

- Increase water levels SLOWLY
- Release of Nitrogen & Phosphorus into water
  - Available for plants and inverts
- Perennials often persist/come back quickly
  - Mechanisms to survive water fluctuations
- Must understand water budget before flood/drawdown

SPATIAL & TEMPORAL VARIABILITY

Management units
- Drawdown
- Very shallow flooding
- Shallow flooded
- Deeper water for divers
- Rotate among units

Restoration design
- Historical flooding regimes
- Historical records
- Multiple hydroperiods



LAST THOUGHTS

- Combination of management strategies may be needed to achieve desired results.
  - May take more years
- Know your system
  - Climatic variability
  - Position in landscape, substrates
  - Ecology of plant species present and/or desired
- Get in the field throughout entire growing season

VARIABILITY IS KEY TO SUCCESS!

Stability is "...deadly to a marsh system..." (Weller 1978)

OR

QUESTIONS?