The Ohio State University
WILMA H. SCHIERMEIER
OLENTANGY RIVER
WETLAND RESEARCH PARK

Identification and enhancement of the ecosystem services from created and restored wetlands

Olentangy River Wetlands to the Florida Everglades to the Planet

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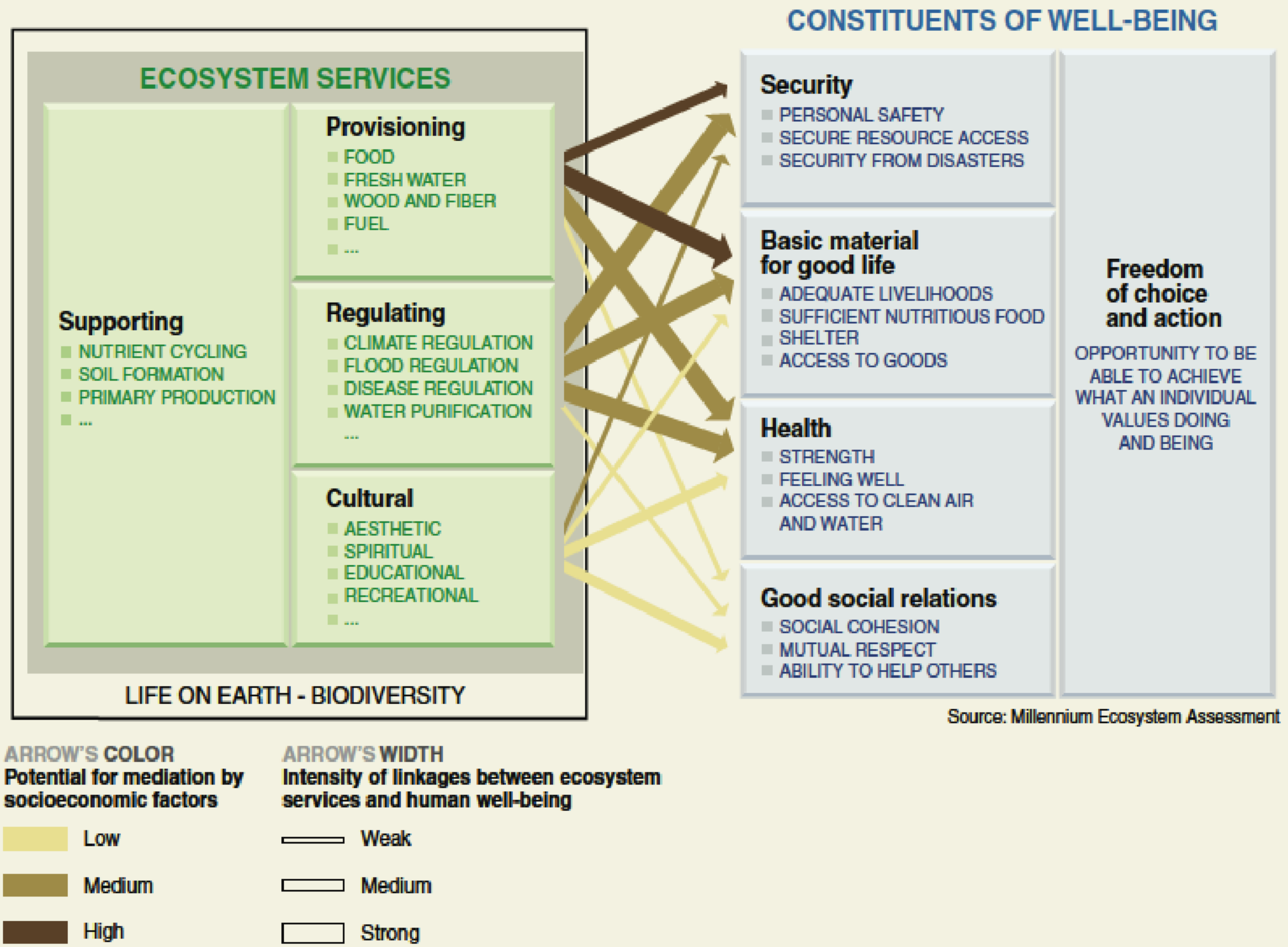
Outline

- Ecosystem Services and Ecological Engineering
- Olentangy River Wetlands—Ecosystem development and nutrient retention in the Mississippi-Ohio-Missouri (MOM) River Basin
- Florida Everglades—Phosphorus retention by wetlands at low concentrations
- The Planet—Carbon sequestration and methane emissions in wetlands
- Conclusions

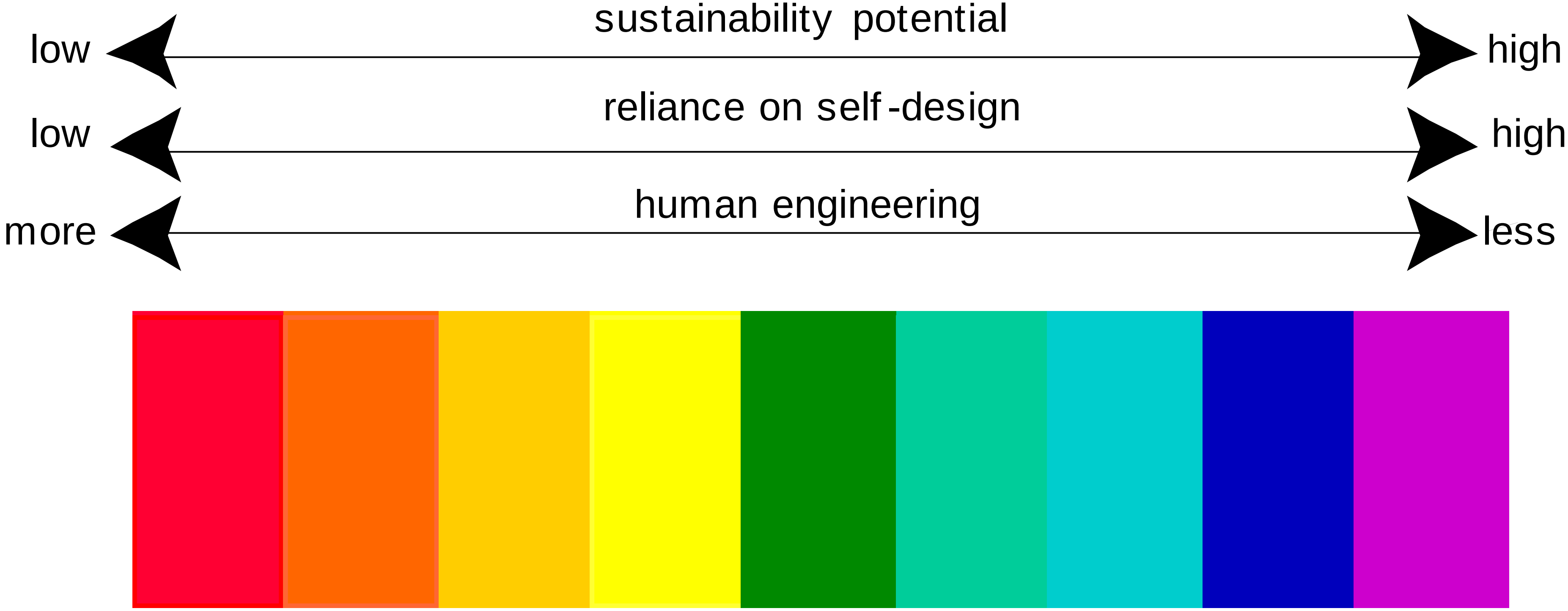

CONSTITUENTS OF WELL-BEING
ECOSYSTEM SERVICES
Supporting
NUTRIENT CYCLING
SOIL FORMATION
PRIMARY PRODUCTION
...
Provisioning
FOOD
FRESH WATER
WOOD AND FIBER
FUEL
...
Regulating
CLIMATE REGULATION
FLOOD REGULATION
DISEASE REGULATION
WATER PURIFICATION
...
Cultural
AESTHETIC
SPIRITUAL
EDUCATIONAL
RECREATIONAL
...
LIFE ON EARTH - BIODIVERSITY
Security
PERSONAL SAFETY
SECURE RESOURCE ACCESS
SECURITY FROM DISASTERS
Basic material for good life
ADEQUATE LIVELIHOODS
SUFFICIENT NUTRITIOUS FOOD
SHELTER
ACCESS TO GOODS
Health
STRENGTH
FEELING WELL
ACCESS TO CLEAN AIR AND WATER
Good social relations
SOCIAL COHESION
MUTUAL RESPECT
ABILITY TO HELP OTHERS
Freedom of choice and action
OPPORTUNITY TO BE ABLE TO ACHIEVE WHAT AN INDIVIDUAL VALUES DOING AND BEING
Source: Millennium Ecosystem Assessment
ARROW'S COLOR
Potential for mediation by socioeconomic factors
Low
Medium
High
ARROW'S WIDTH
Intensity of linkages between ecosystem services and human well-being
Weak
Medium
Strong

Millennium Ecosystem Assessment "Regulating" ECOSYSTEM SERVICES related to wetlands

- Climate regulation
- Flood regulation
- Water purification

Ref: Millennium Ecosystem Assessment, 2005

The Spectrum of Ecological Engineering



Biosphere 2

Biomanipulation

Prairie Restoration

Soil Bioremediation

Wetland Creation

Wetland Restoration

Solar Aquatics

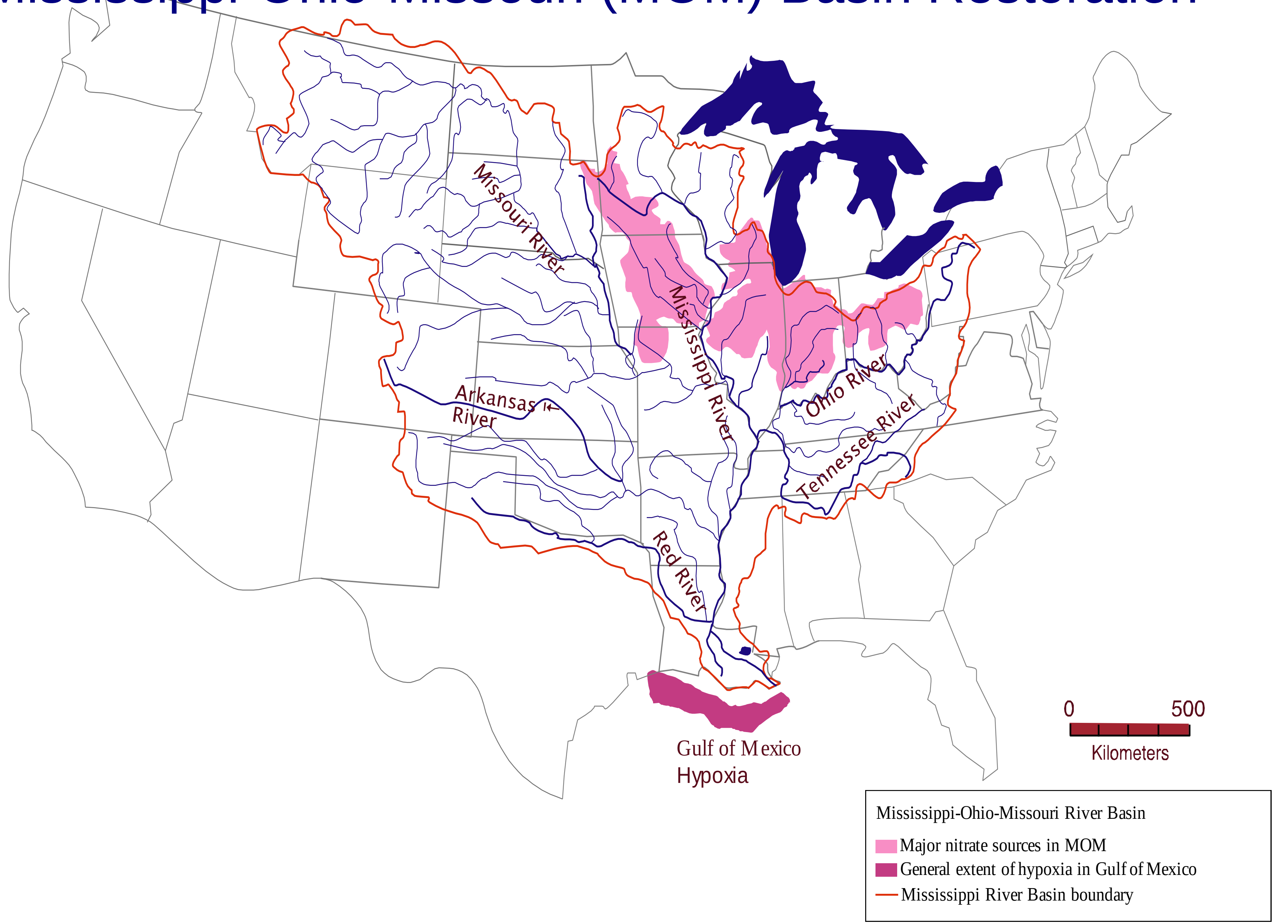
Wastewater Wetlands

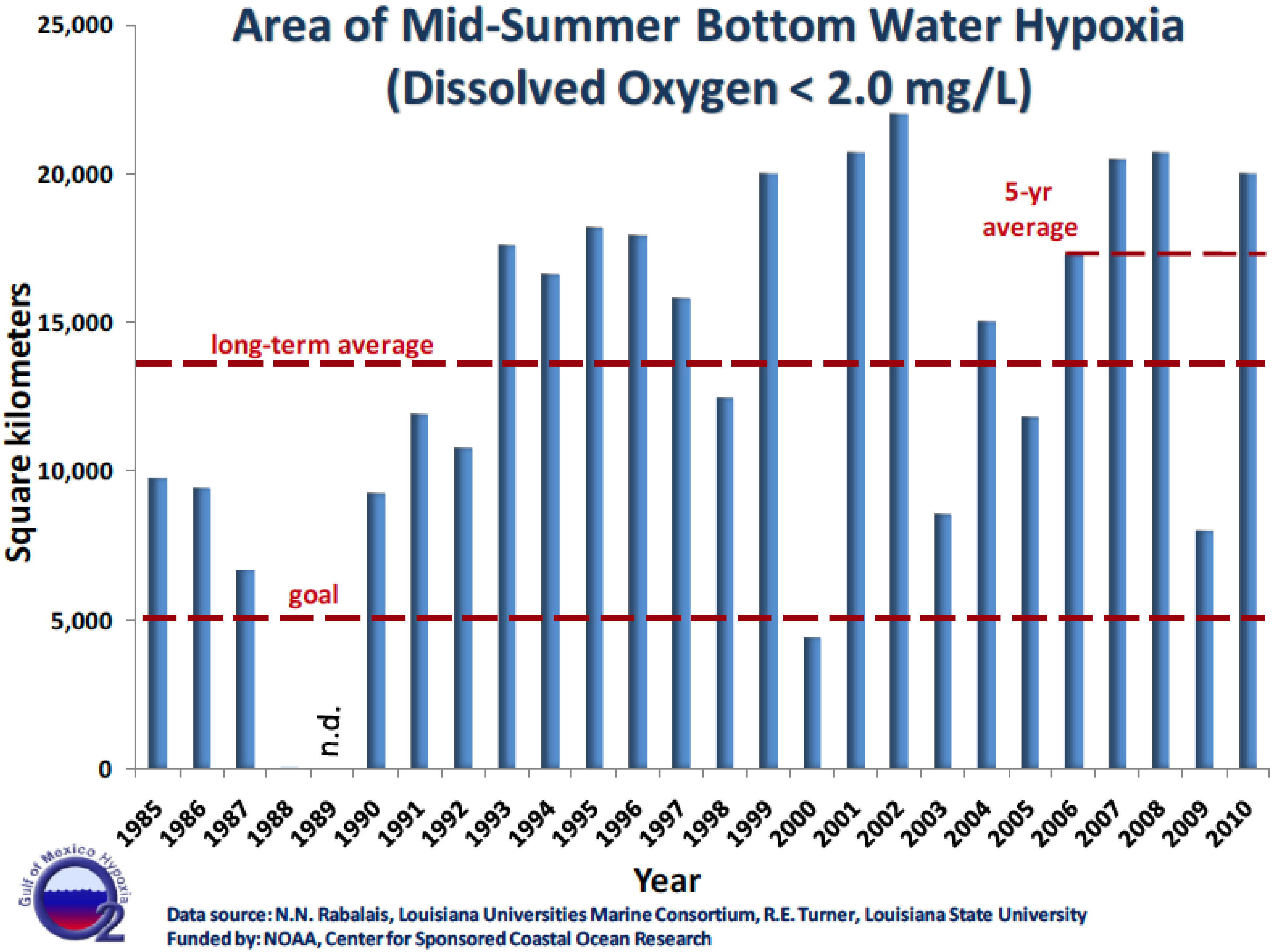
Mineland Restoration

Agroecological Engineering

The Mississippi-Ohio-Missouri River Basin
and
The Olentangy River Wetlands

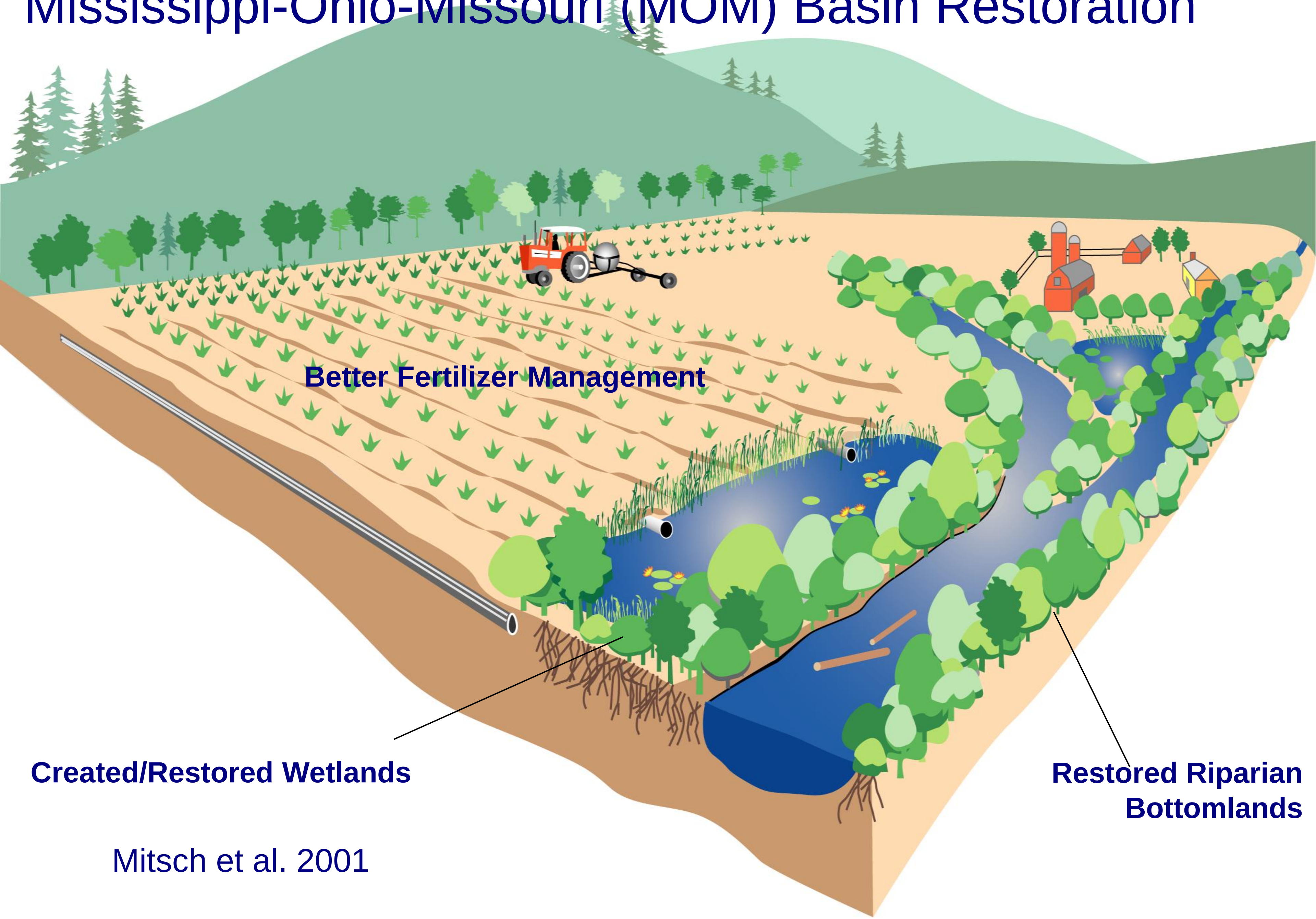
Mississippi-Ohio-Missouri (MOM) Basin Restoration





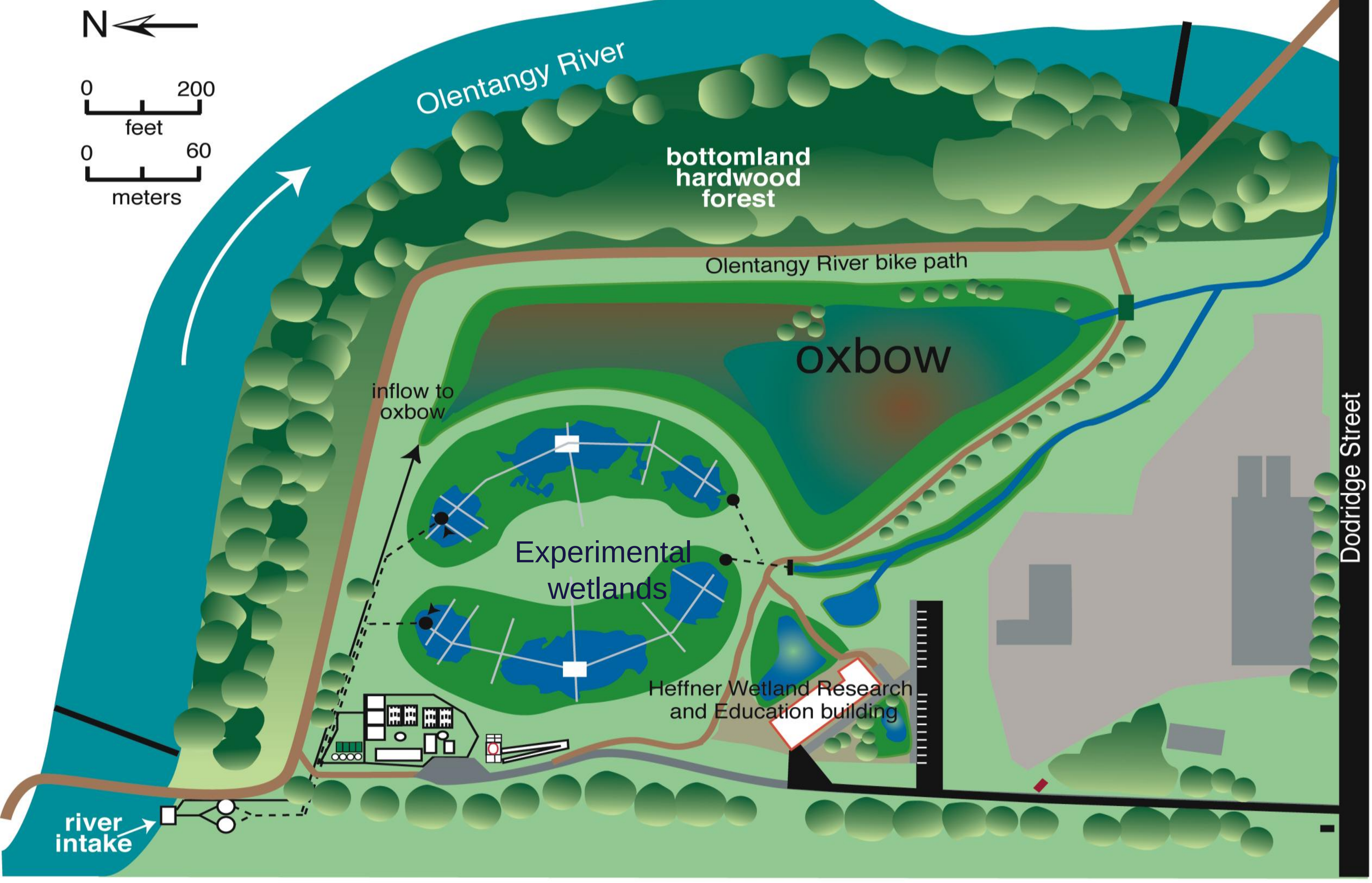
Time series of bottom-water hypoxic area since 1985. Landmarks for Hypoxia Action Plan indicated with red dashed lines.

Mississippi-Ohio-Missouri (MOM) Basin Restoration



Mitsch et al. 2001

Wilma H. Schiermeier Olentangy River Wetland Research Park at The Ohio State University



Wilma H. Schiermeier Olentangy River Wetland Research Park at The Ohio State University

Ramsar

CONVENTION ON WETLANDS

(Ramsar, Iran, 1971)

This is to certify that

Wilma H. Schiermeier Olentangy River Wetland Research Park

has been designated as a

Wetland of International Importance

and has been included in the
List of Wetlands of International Importance
established by Article 2.1 of the Convention.
This is site No.: 1779

Date of designation *18 April 2008*

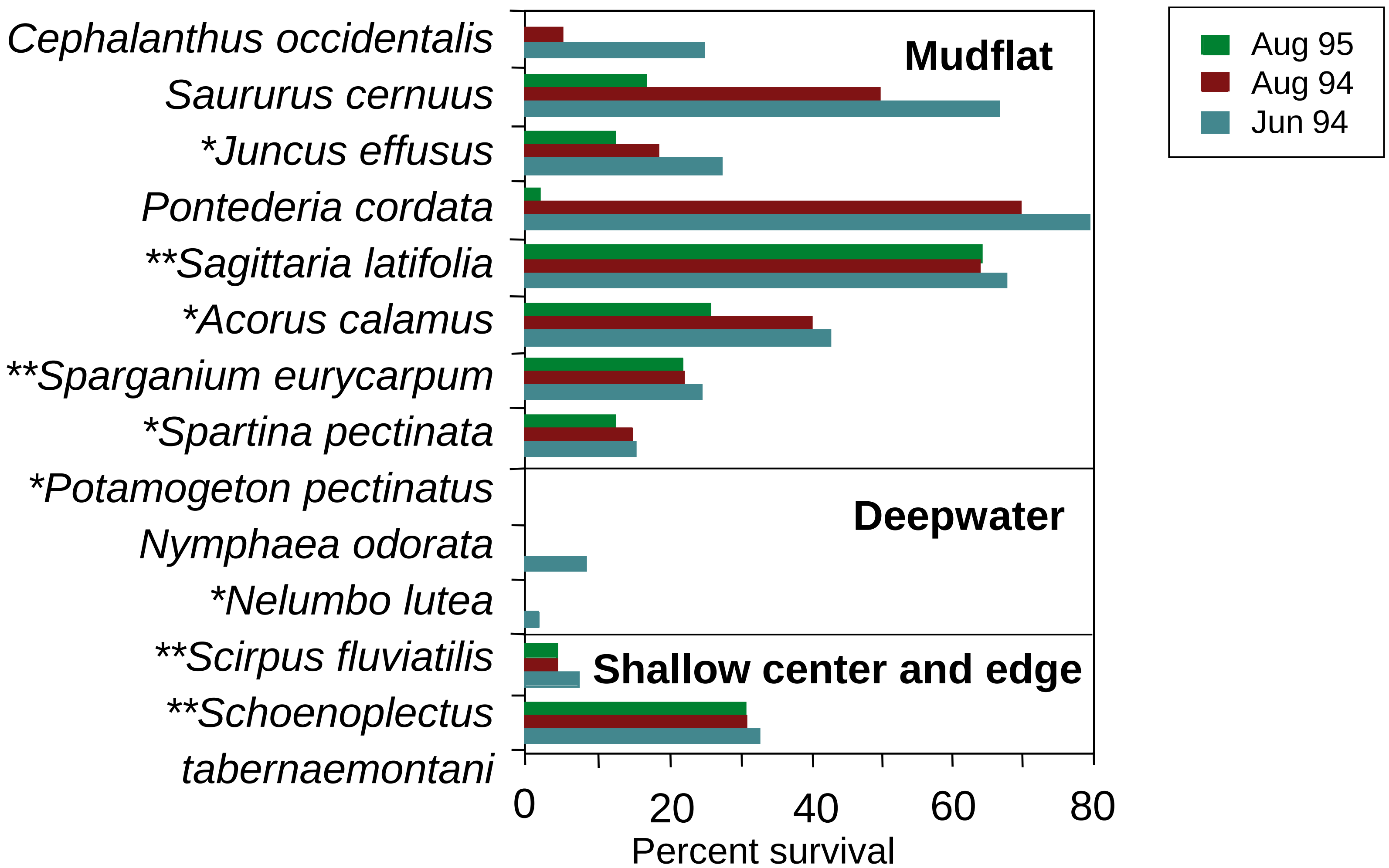
Secretary General
Convention on Wetlands

Whole ecosystem experiment

1994 - 2010

Planting May 1994

Original Planting in experimental wetland 1

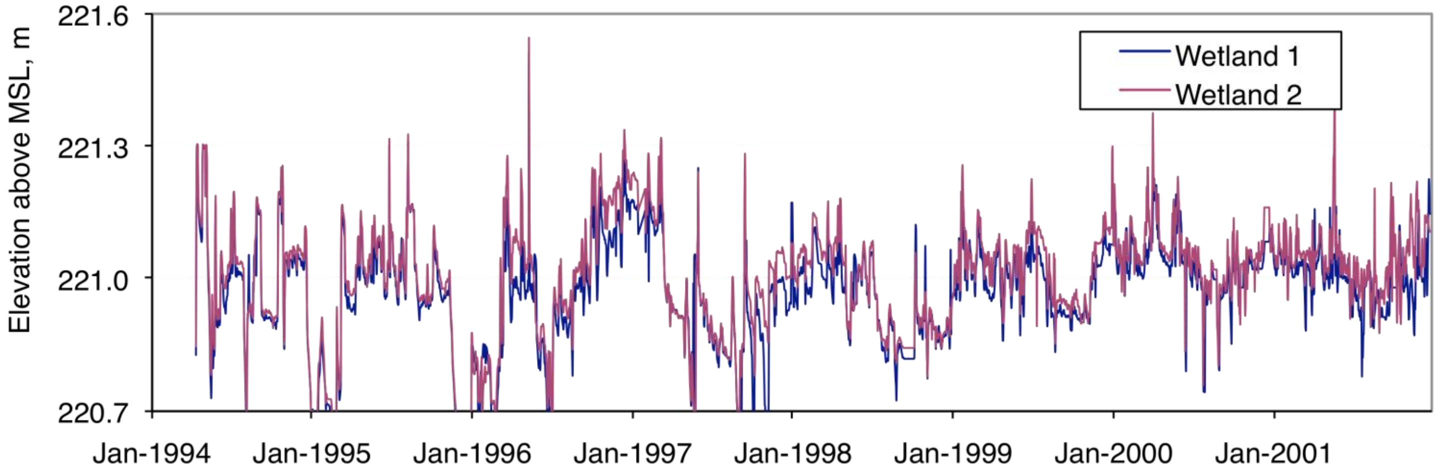


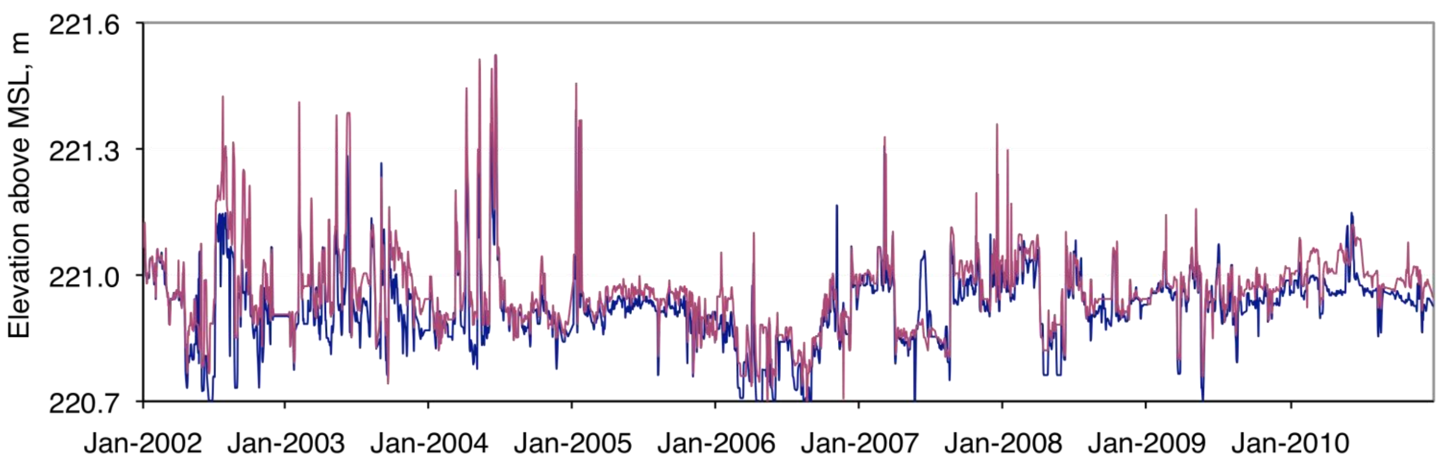
* present in 2010

**abundant in 2010

HYDROLOGY

- **Identical inflows of river water (approx 30 m/yr) have been maintained for both wetlands for 17 years.**
- **Inflows are programmed to relate to the river flow. Inflows to the wetlands pulse when there are river pulses.**





Olentangy River Wetland Research Park
At The Ohio State University

1995 (year 2)

2008 (year 15)

Mitsch et al. 2012. BioScience 62: 237-250

Changes in the upper 8 to 10 cm of soil in the planted (W1) and unplanted (W2) experimental wetlands

1993 and 1995 data from Nairn (1996); 2004 data from Anderson et al. (2005) and Anderson and Mitsch (2006); 2008 data from Bernal and Mitsch (in prep.) Numbers are averages± std error (number of samples).

YEAR	Wetland age, yr	Bulk Density, g cm^{-3}		Percent of soil samples with chroma less than or equal to 2	Soil Carbon, g-C/kg soil	
		W1	W2		W1	W2
1993	-1	1.3±0.01 (19)	1.29±0.01 (21)	0 %	16 ± 0.1(19)	16 ± 0.2 (21)
1995	1	1.0±0.01 (19)	0.73±0.01 (21)	78%	20 ± 0.3 (19)	20 ± 0.3 (21)
2004	10	0.53 ±0.02 (33)	0.49±0.03 (36)	100%	39 ± 1.0 (22)	38± 2.0 (24)
2008	15	0.60±0.02 (13)	0.72±0.01 (18)	100%	41 ± 1.8 (5)	49± 0.8 (18)

Mitsch et al. 2012. BioScience 62: 237-250

PLANT RICHNESS

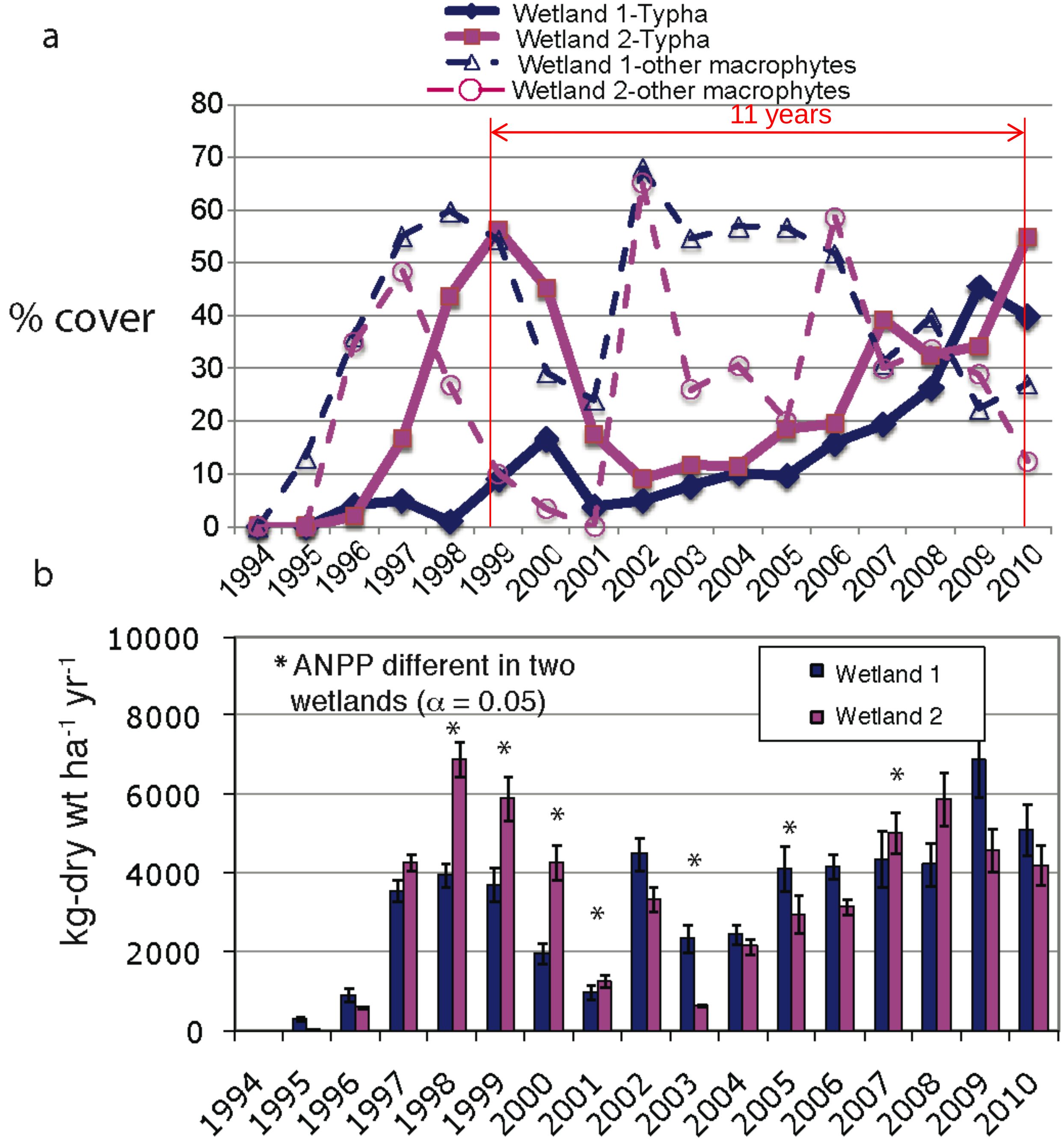
Number of plant species in the planted (W1)* and unplanted (W2) wetlands

	1996		1998		2010	
	W1	W2	W1	W2	W1	W2
Total # of species	72		99		117	
# species, each wetland	67	56	96	87	98	95
Total # wetland species (OBL+FACW)	44		57		63	
# wetland species, each wetland	43	31	56	46	54	48
Total # planted wetland species*	9	1	9	2	9	2
Total # of woody species	5	7	15	15	18**	21**
Total # of invasive species**	1	1	4	4	7**	9**

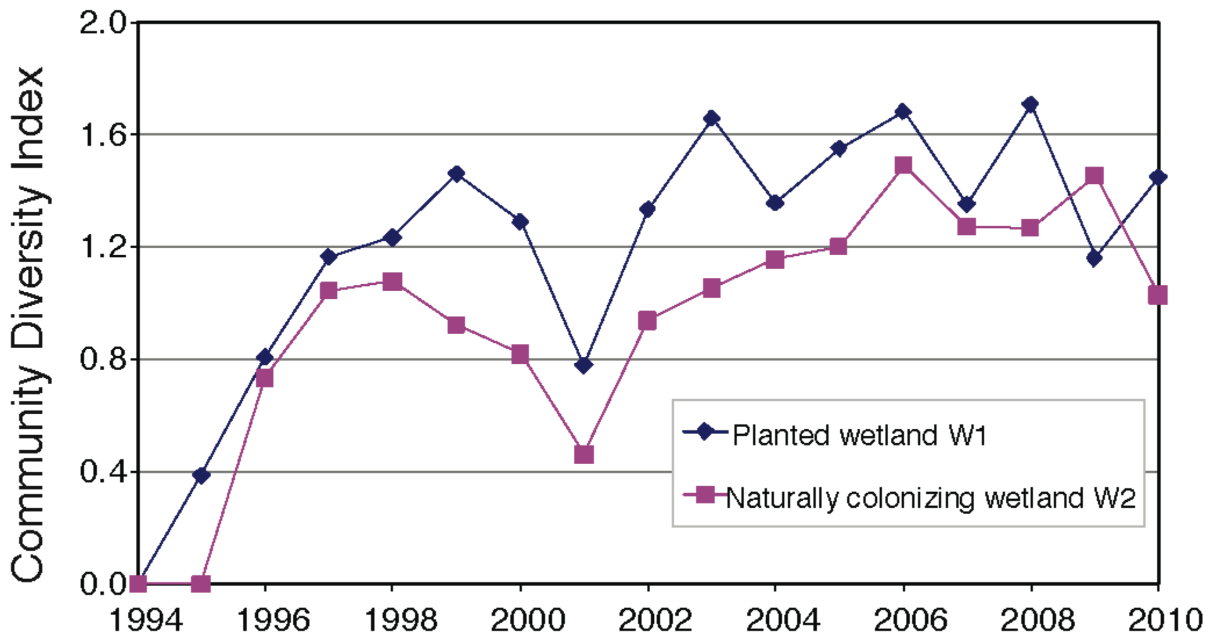
* from 13 species planted in wetland 1 (W1) in May 1994 (see Mitsch et al. 1998)

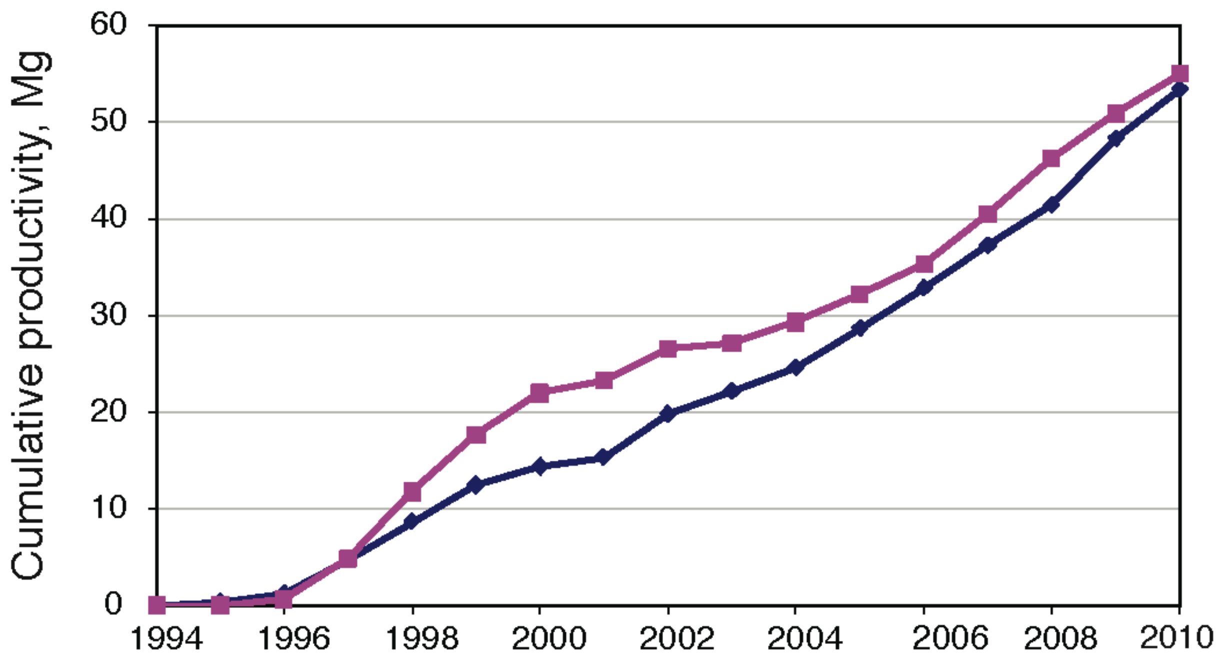
** 2008 data

VEGETATION COMMUNITIES AND PRODUCTIVITY



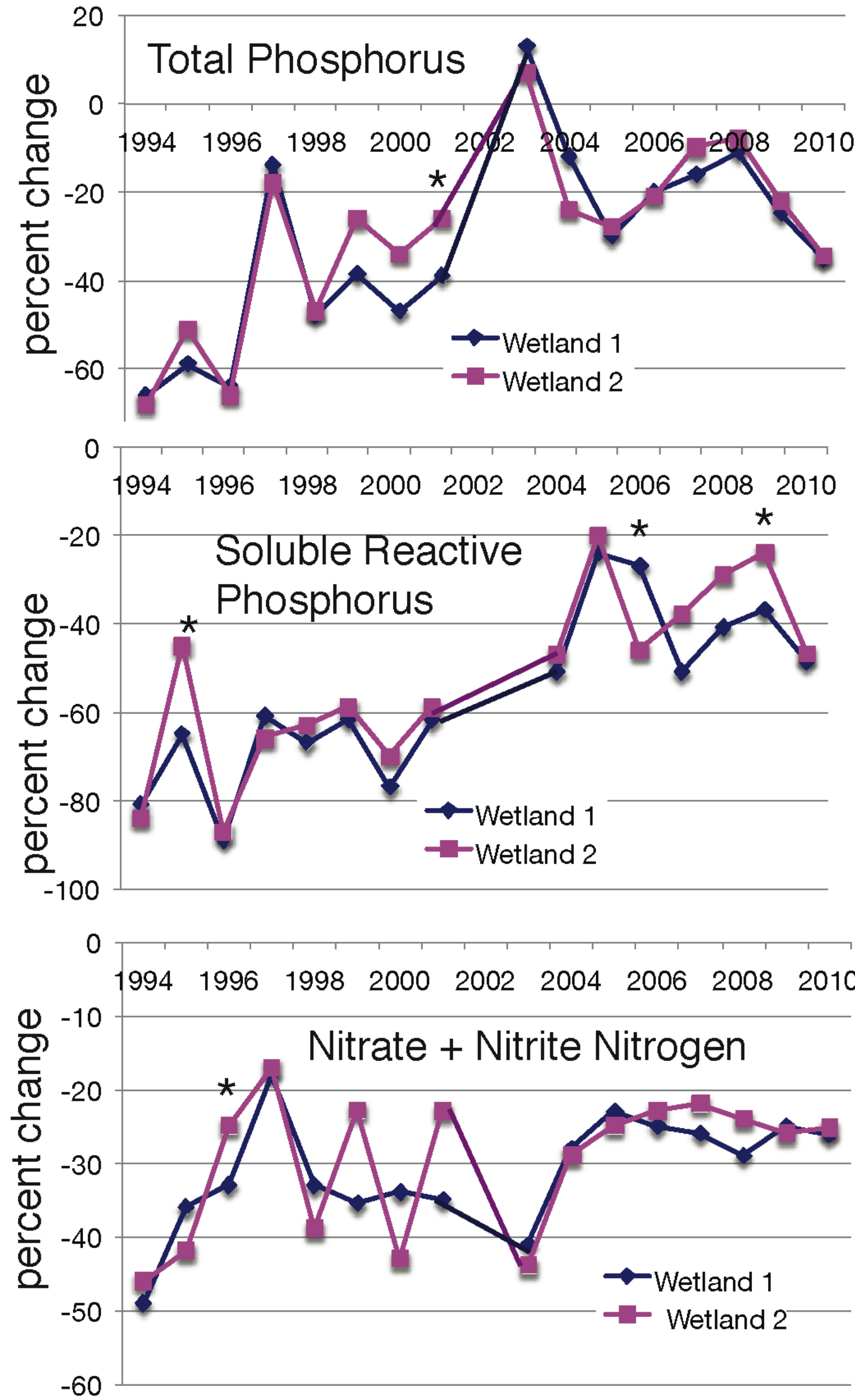
PLANT COMMUNITY DIVERSITY AND ACCUMULATED PRODUCTIVITY





NUTRIENT RETENTION

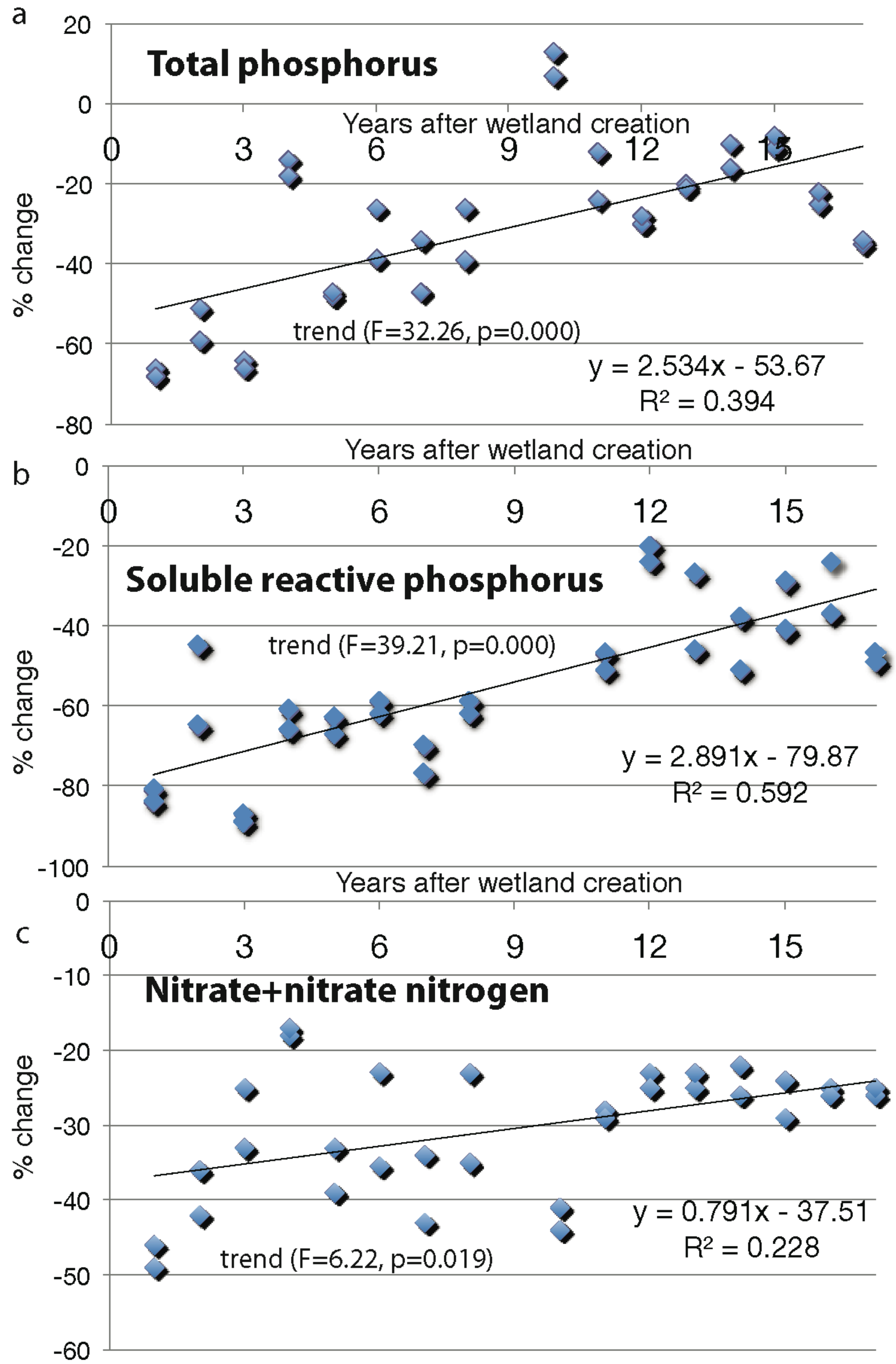
Percent change of total phosphorus, soluble reactive phosphorus,, and nitrate-nitrogen in the planted (blue) and unplanted (red) experimental wetlands



* Statistical difference between outflow concentrations (α = 0.05) of two wetlands only 5 times out of 47 possible chances (10.6%)

NUTRIENT RETENTION TRENDS

Percent change of total phosphorus, soluble reactive phosphorus, and nitrate-nitrogen in both experimental wetlands



Strong trends for decreasing TP and SRP retention over time; recent (last 6 years) nitrate-nitrogen retention is in steady state.

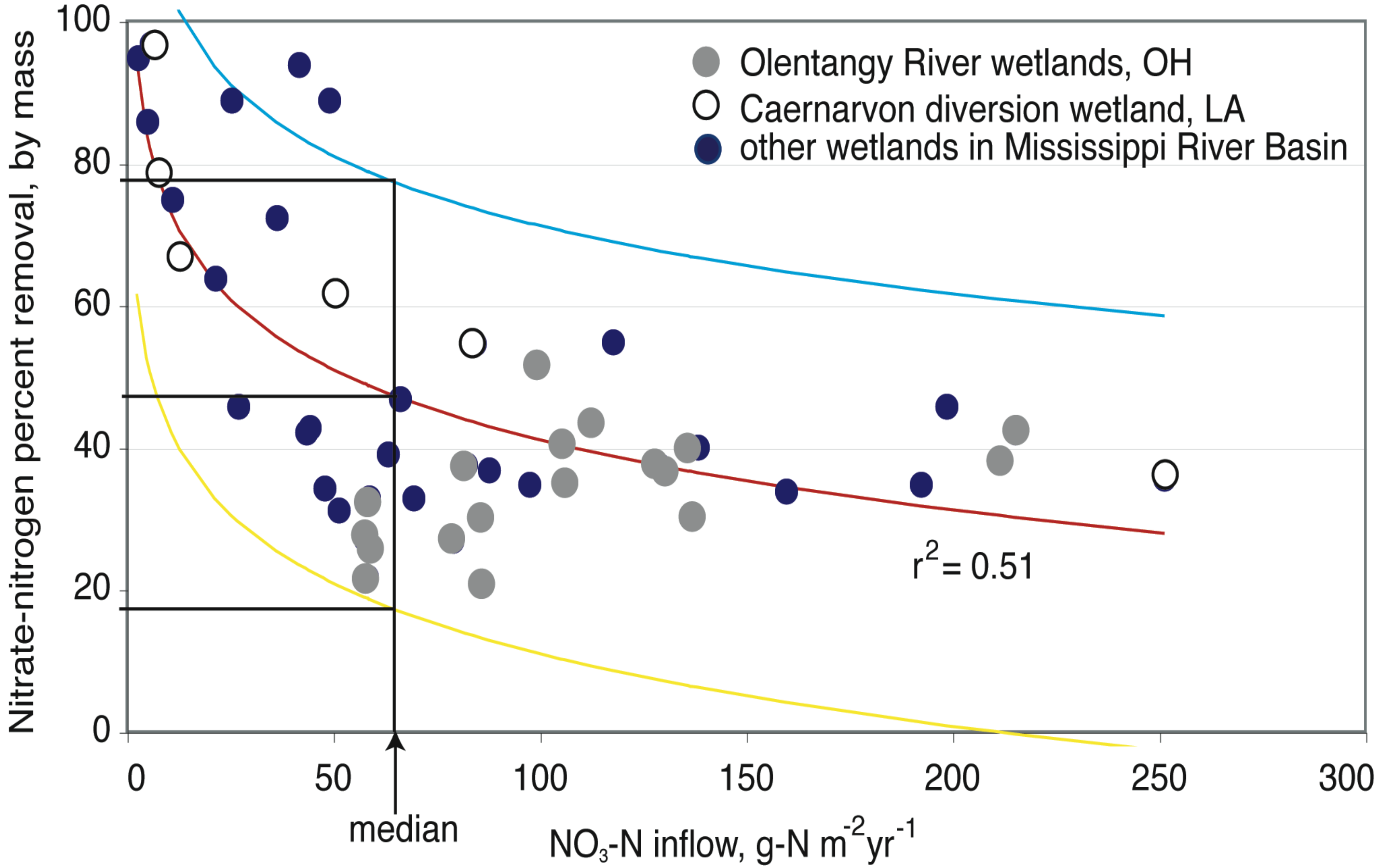
NITROGEN BUDGET AND DENITRIFICATION

Denitrification rates are low and have consistently been less than 10% of the nitrogen retention in these wetlands

Denitrification data from Hernandez and Mitsch (2007) and Song et al. (2012).

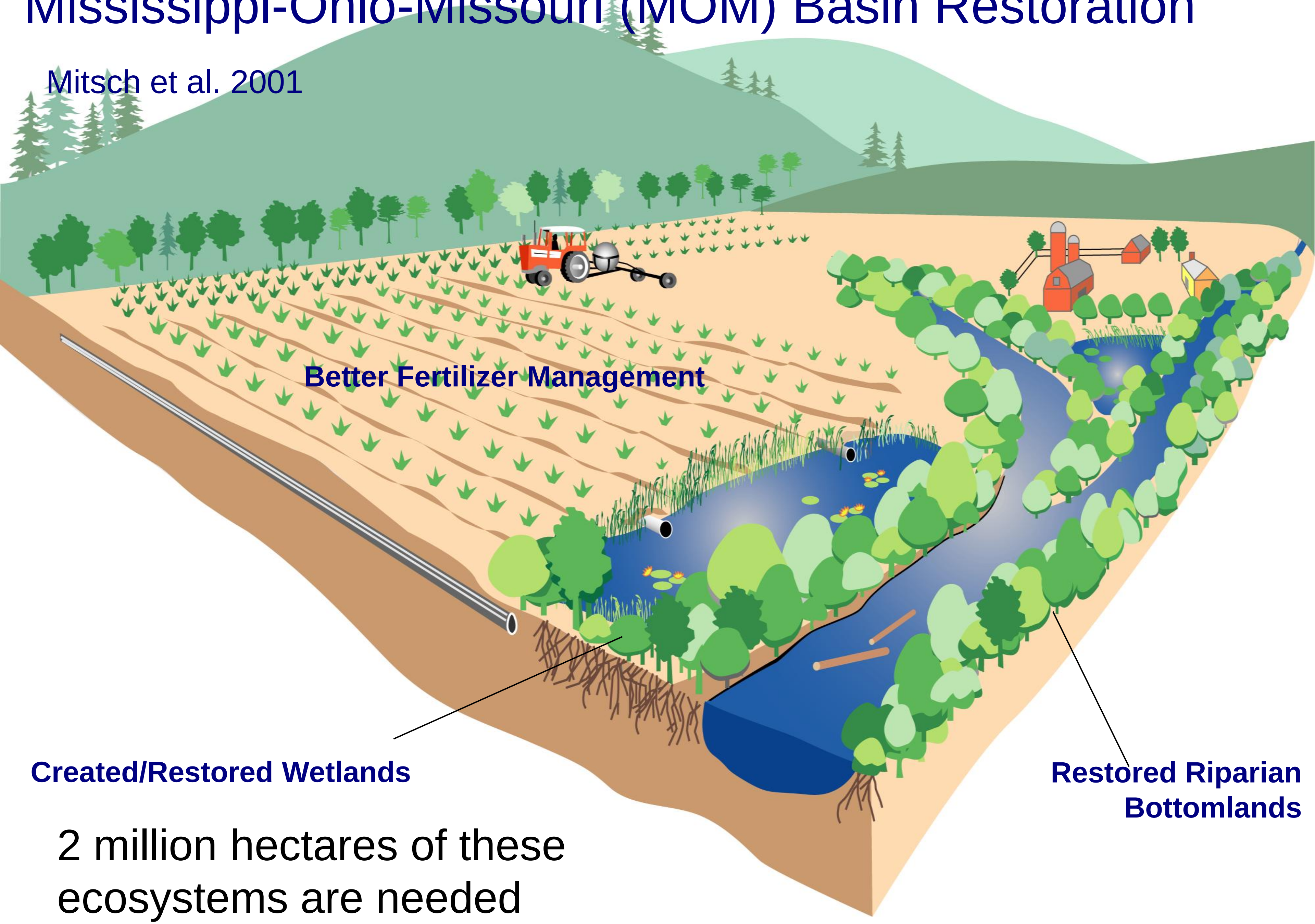
	Wetland 1 2004	Wetland 2 2004	Wetland 1 2005	Wetland 2 2005	Both wetlands 2008
Hydrologic conditions	Artificial spring pulses	Artificial spring pulses	Flood pulses suppressed	Flood pulses suppressed	Normal river conditions
Overall denitrification, g-N m^{-2} per year	2.5	2.7	1.7	2.3	1.8
Nitrogen accumulation in soil, g-N m^{-2} per year	16	17			
Nitrogen surface inflow, g-N m^{-2} per year	107	108	98	92	139
Nitrogen surface outflow from wetland, g-N m^{-2} per year	69	80	44	37	56
Nitrogen retention in wetland, g-N m^{-2} per year	38	28	54	55	83
Percent nitrogen removal	35.5	25.9	55.1	59.8	59.7
% nitrogen retention due to denitrification	6.6	9.6	3.1	4.2	3.0
% nitrogen retention in soil sequestration	42	61	-	-	-

Mississippi-Ohio-Missouri (MOM) Basin Restoration



Mississippi-Ohio-Missouri (MOM) Basin Restoration

Mitsch et al. 2001

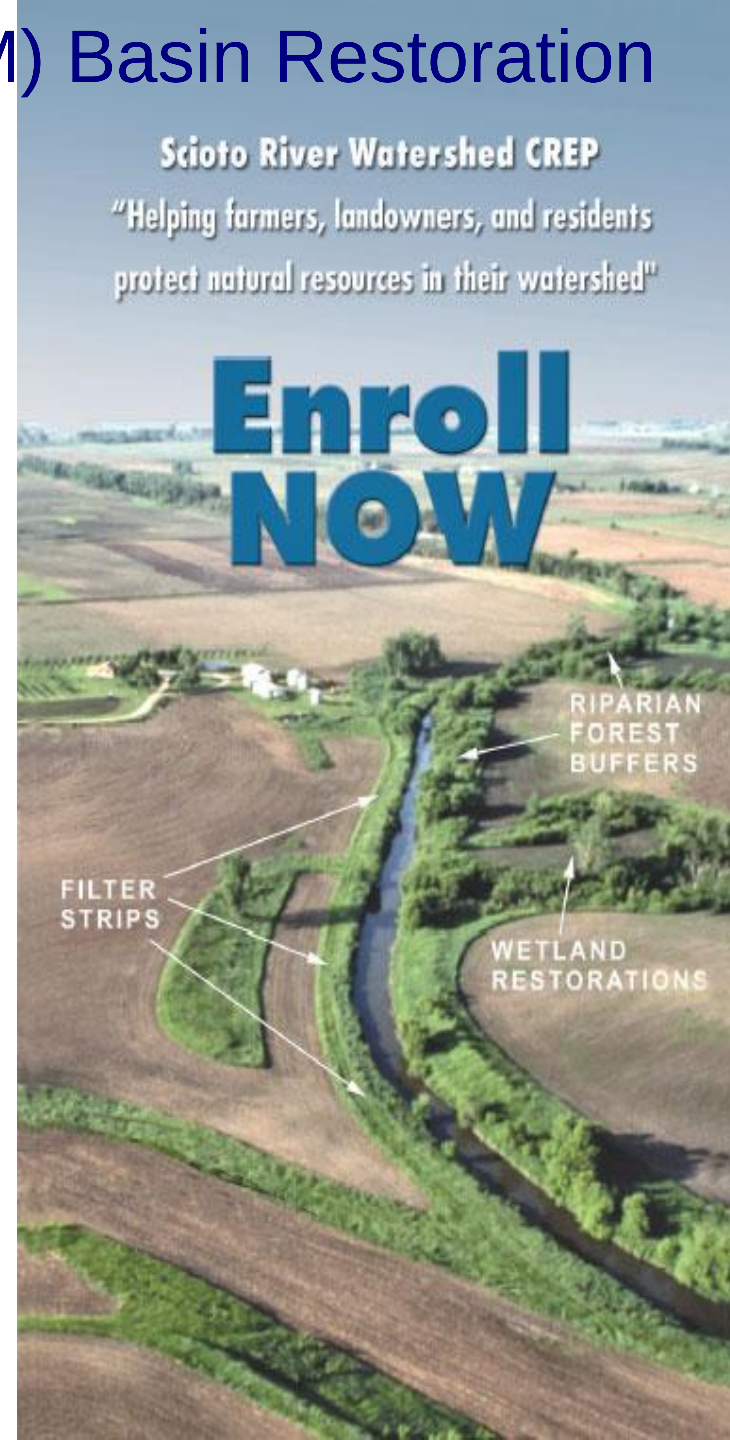


2 million hectares of these ecosystems are needed

Mississippi-Ohio-Missouri (MOM) Basin Restoration

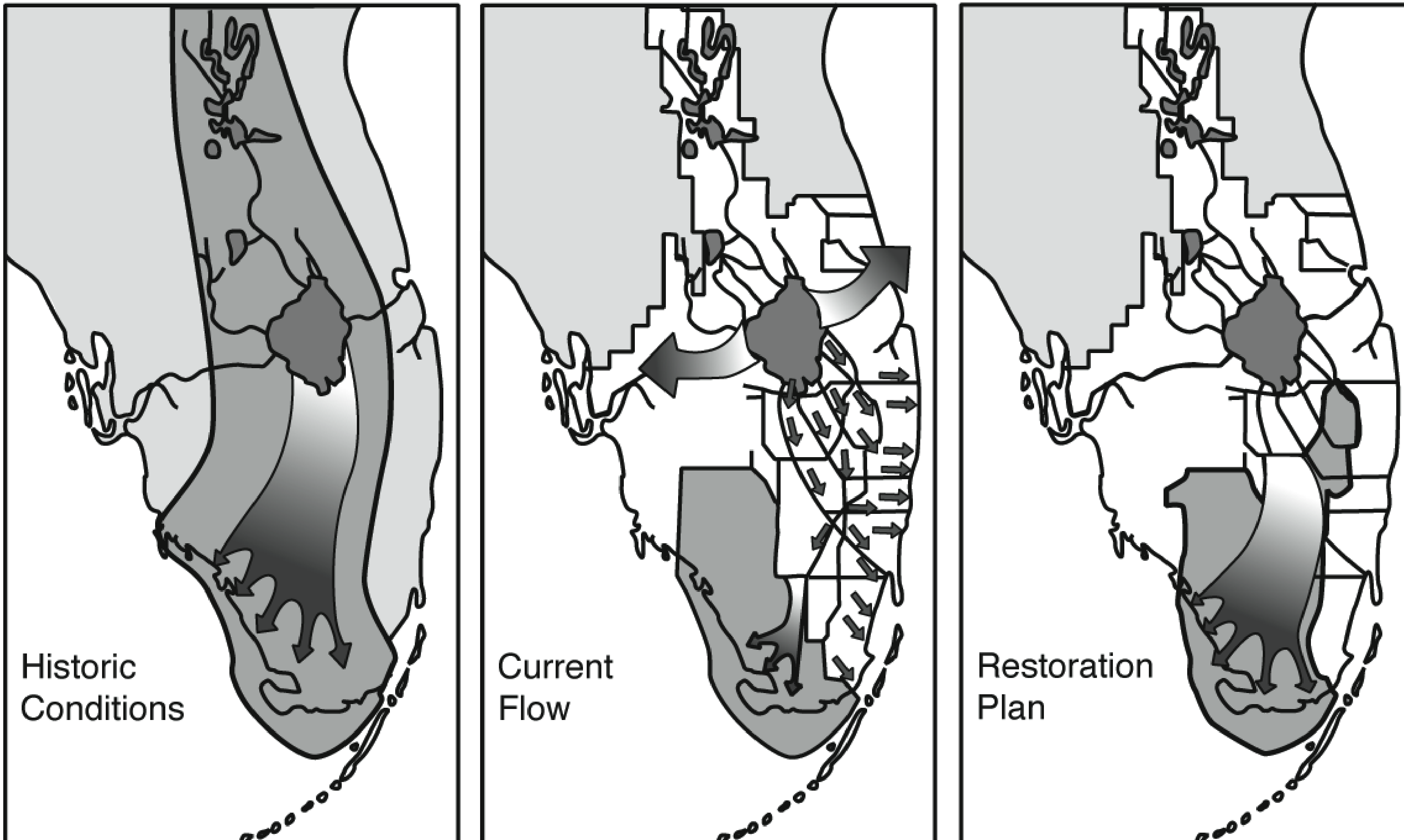
Goal is to create 28,000 ha of riparian systems and wetlands in one watershed in Ohio

OHIO



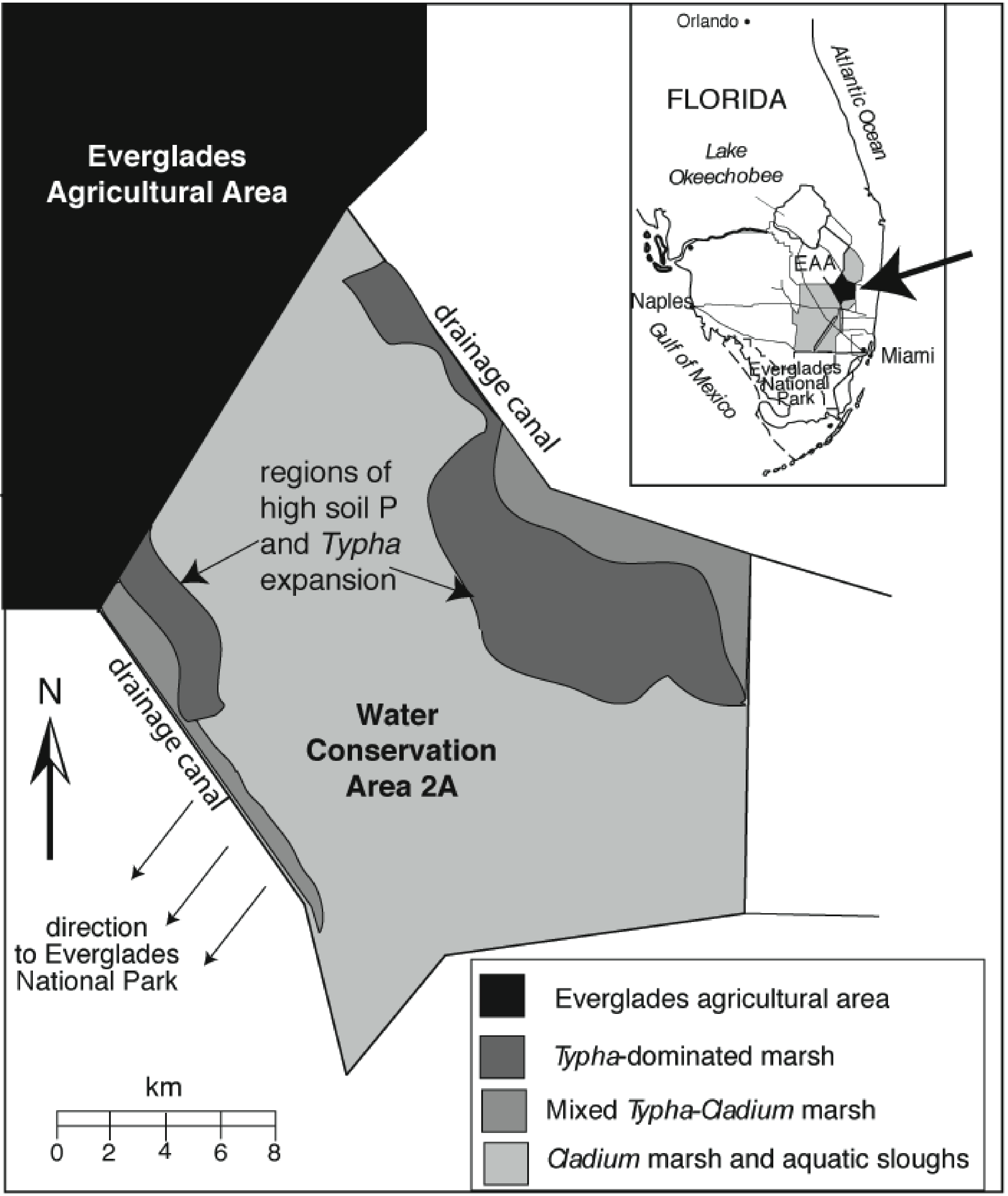
The Florida Everglades

Restoring the Florida Everglades

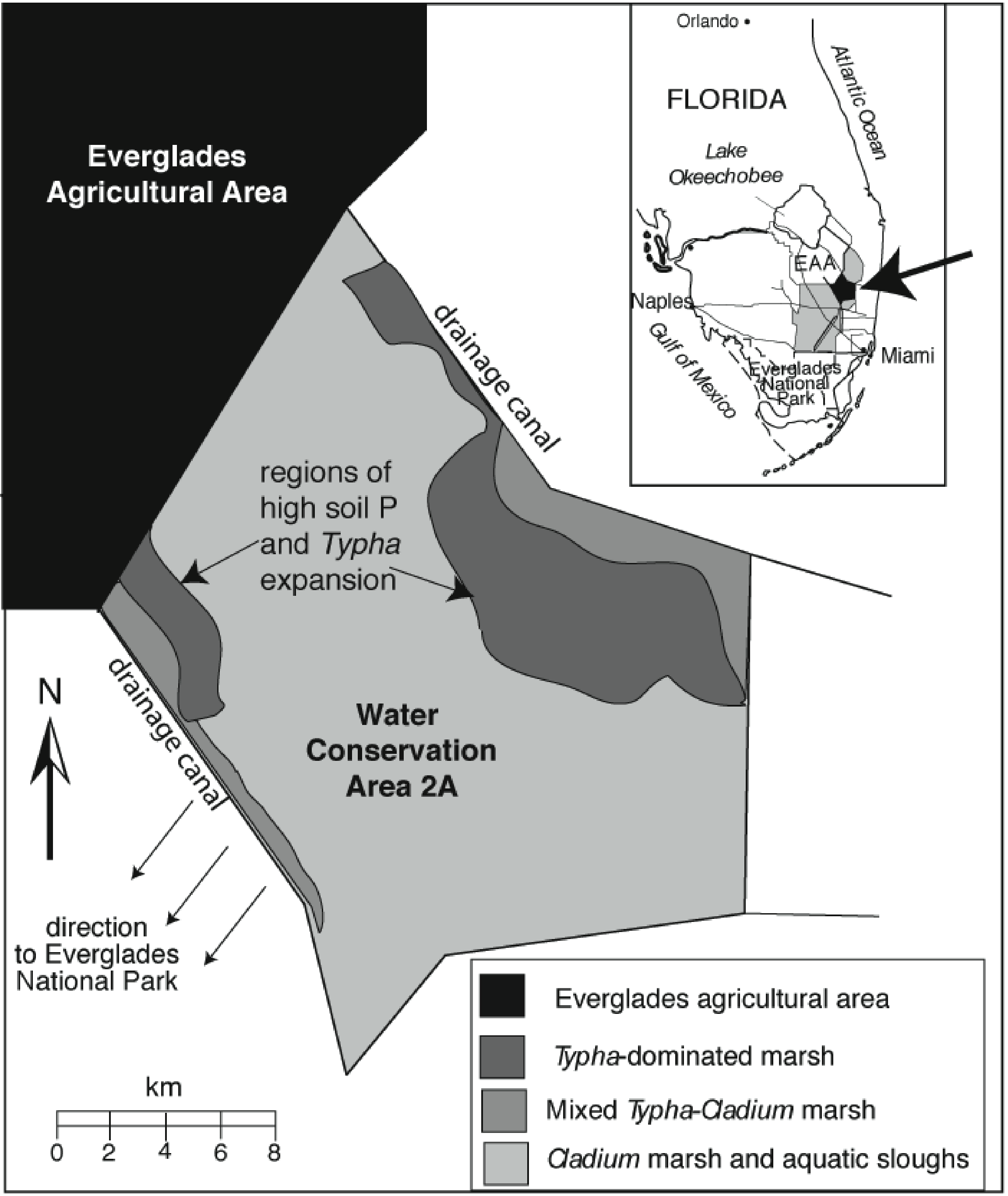


Water quality and the Florida Everglades

- The Everglades “river of grass” is considered to be an **oligotrophic** system primarily dependent on rain water
- Excessive nutrients, particularly phosphorus from the sugar farms in the EAA are loading major amounts of nutrients to the water conservation areas (WCAs) north of Everglades National Park.
- The nutrients are causing the Everglades to switch from sawgrass (*Cladium jamaicense*) to cattail (*Typha latifolia and T. domingensis*)
- Current directives are requiring that the total phosphorus concentration of storm water drainage be limited to 10 ppb (µg-L), the approximate concentration of phosphorus in rainfall.

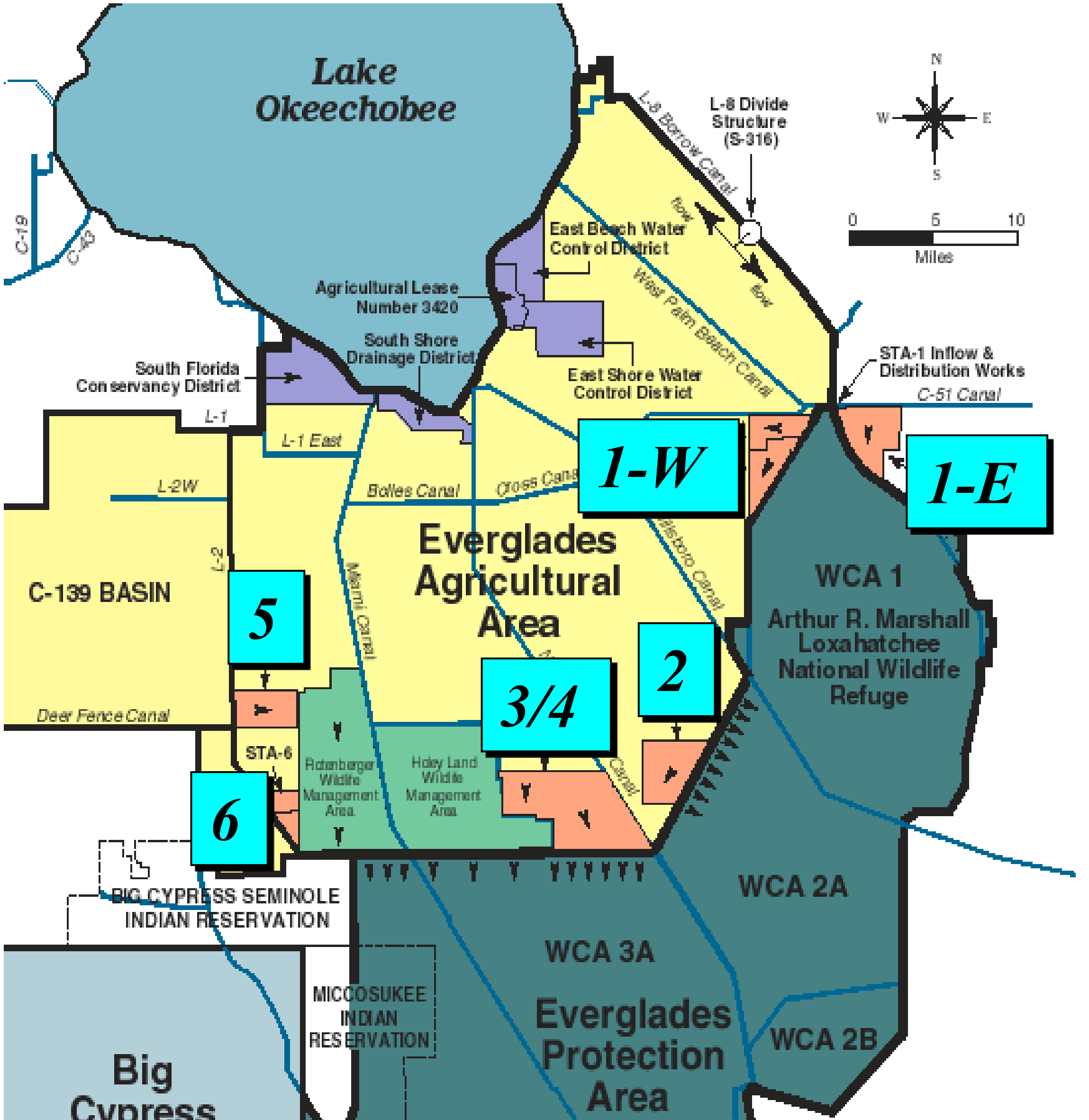

Everglades Agricultural Area
Orlando
FLORIDA
Atlantic Ocean
Lake Okeechobee
EAA
Naples
Gulf of Mexico
Miami
Everglades National Park
drainage canal
regions of high soil P and Typha expansion
drainage canal
N
Water Conservation Area 2A
direction to Everglades National Park
km
0 2 4 6 8
Everglades agricultural area
Typha-dominated marsh
Mixed Typha-Cladium marsh
Cladium marsh and aquatic sloughs


Cladium jamaicense
sawgrass


Everglades Agricultural Area
drainage canal
regions of high soil P and *Typha* expansion
drainage canal
N
Water Conservation Area 2A
direction to Everglades National Park
km
0 2 4 6 8
Orlando
FLORIDA
Atlantic Ocean
Lake Okeechobee
EAA
Naples
Gulf of Mexico
Miami
Everglades National Park
Everglades agricultural area
Typha-dominated marsh
Mixed *Typha*-*Cladium* marsh
Cladium marsh and aquatic sloughs


Typha domingensis
cattail

Stormwater Treatment Areas (STAs) upstream of Everglades

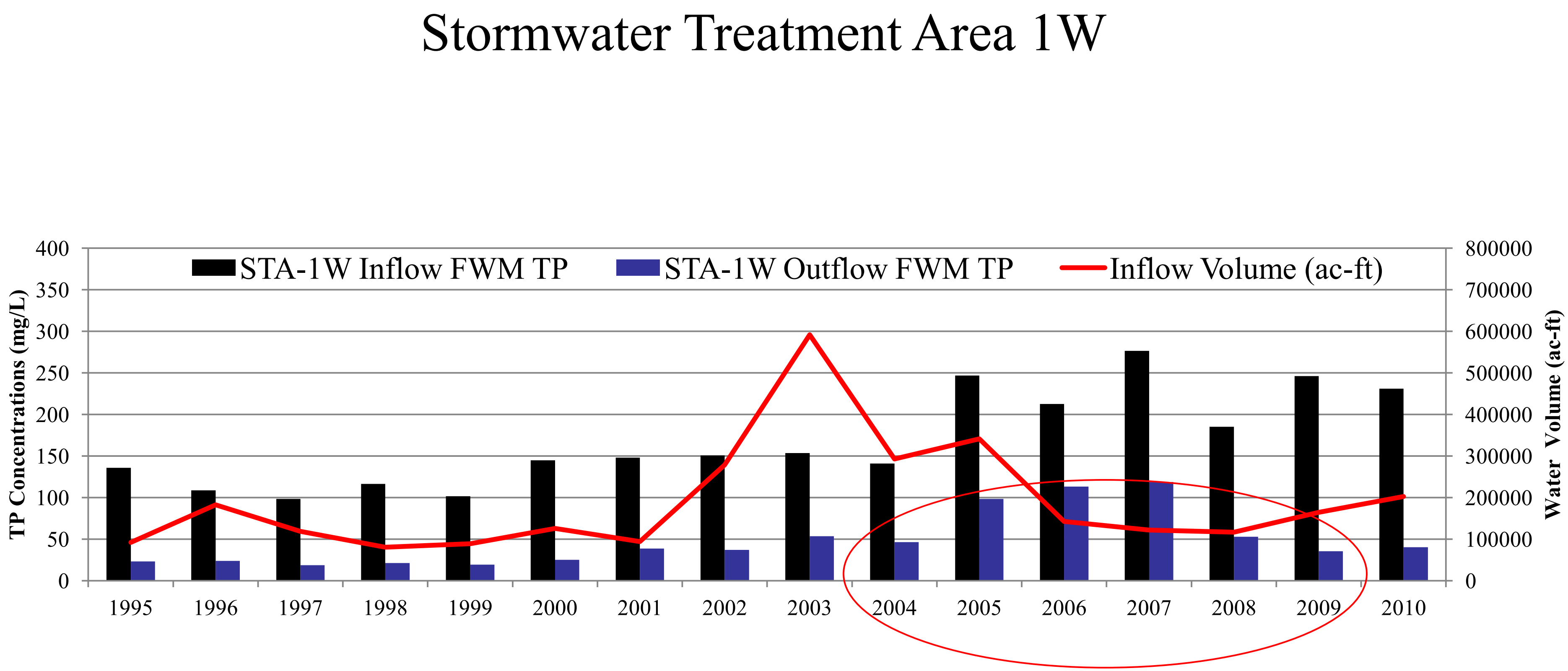


Treatment Wetland	Area, ha
STA-1-E	2078
STA-1W	2700
STA-2	2603
STA-3/4	6698
STA-5	1664
STA-6	352
TOTAL	**16095**

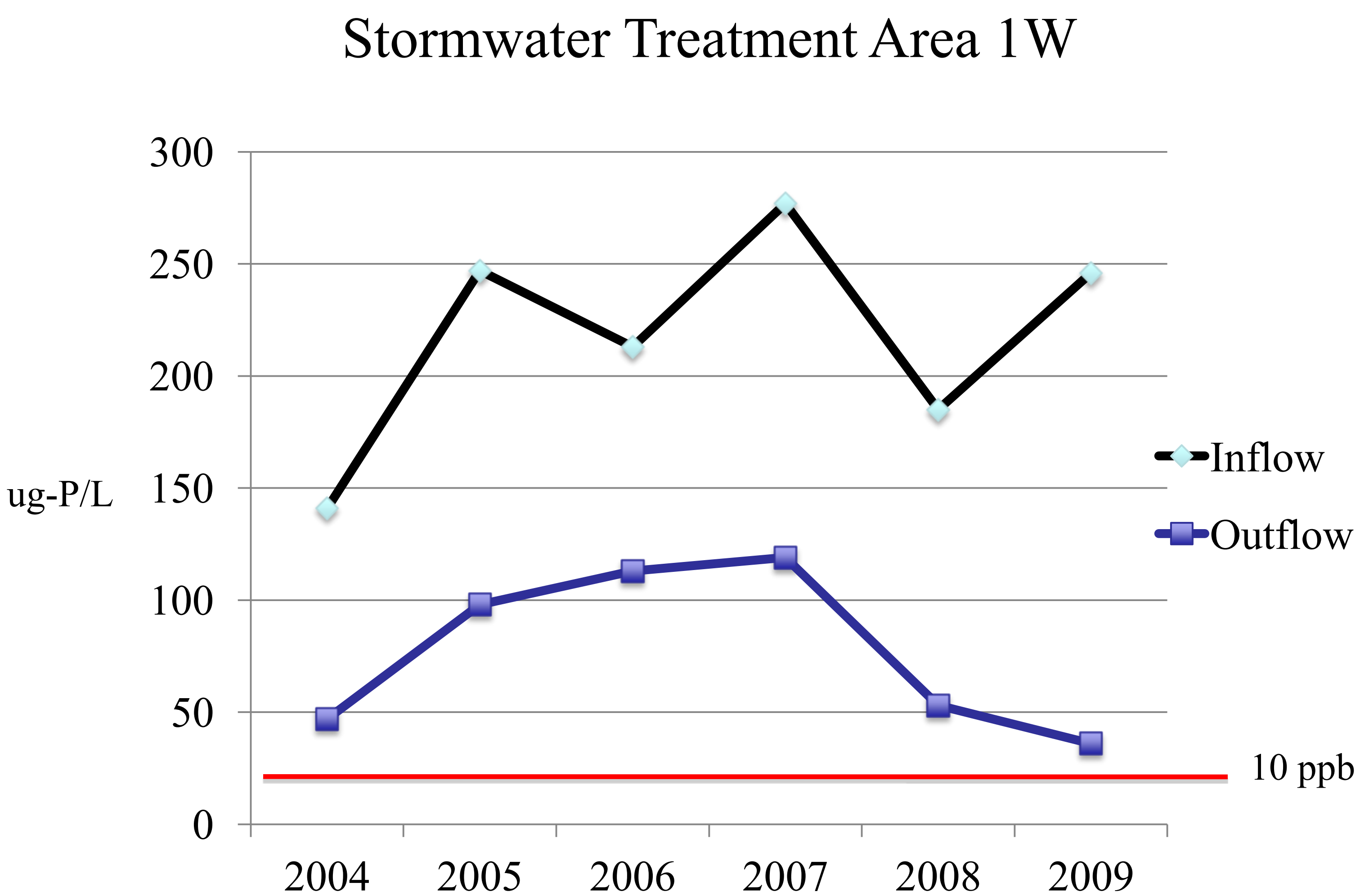
Newman and Chimney, 2004

Stormwater Treatment Areas (STAs) upstream of Everglades

Stormwater Treatment Areas (STAs) upstream of Everglades

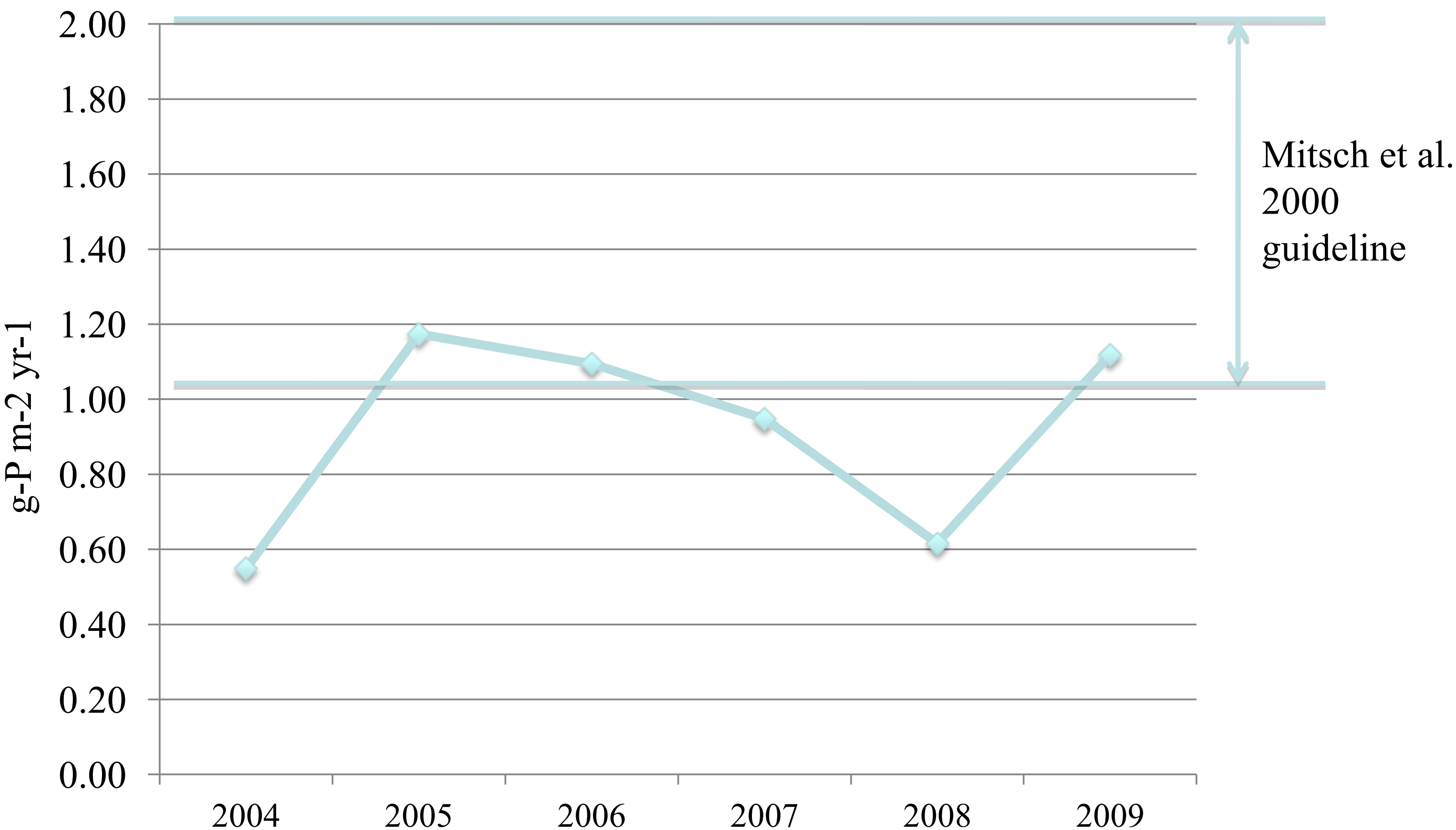


Stormwater Treatment Areas (STAs) upstream of Everglades



Stormwater Treatment Areas (STAs) upstream of Everglades

P retention rate by Stormwater Treatment Areas (all 6 STAs)



Stormwater Treatment Area (STA) mesocosm experiment

Ohio State University Wetlanders in the Florida Everglades, March 2011

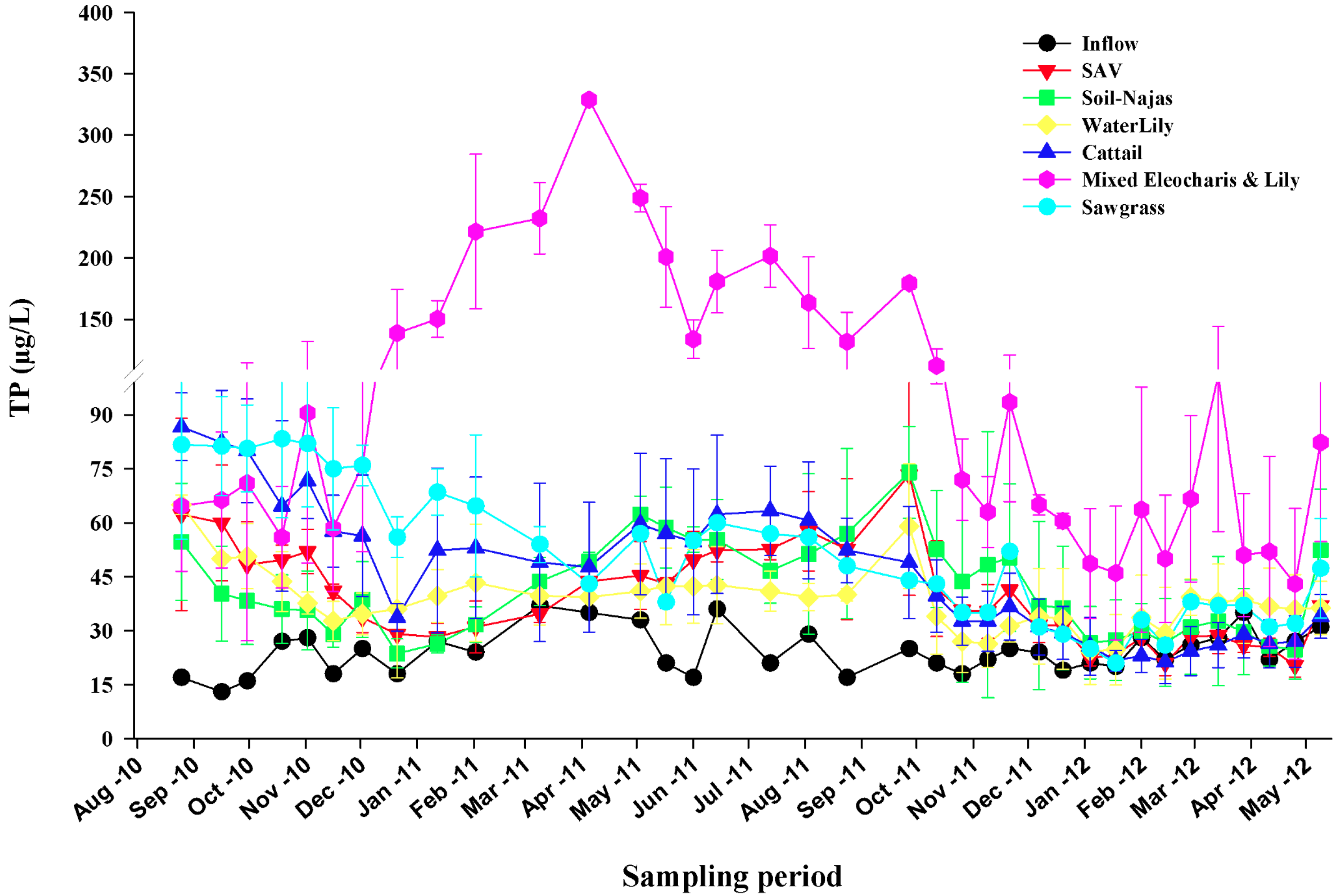
Stormwater Treatment Area (STA) mesocosm experiment

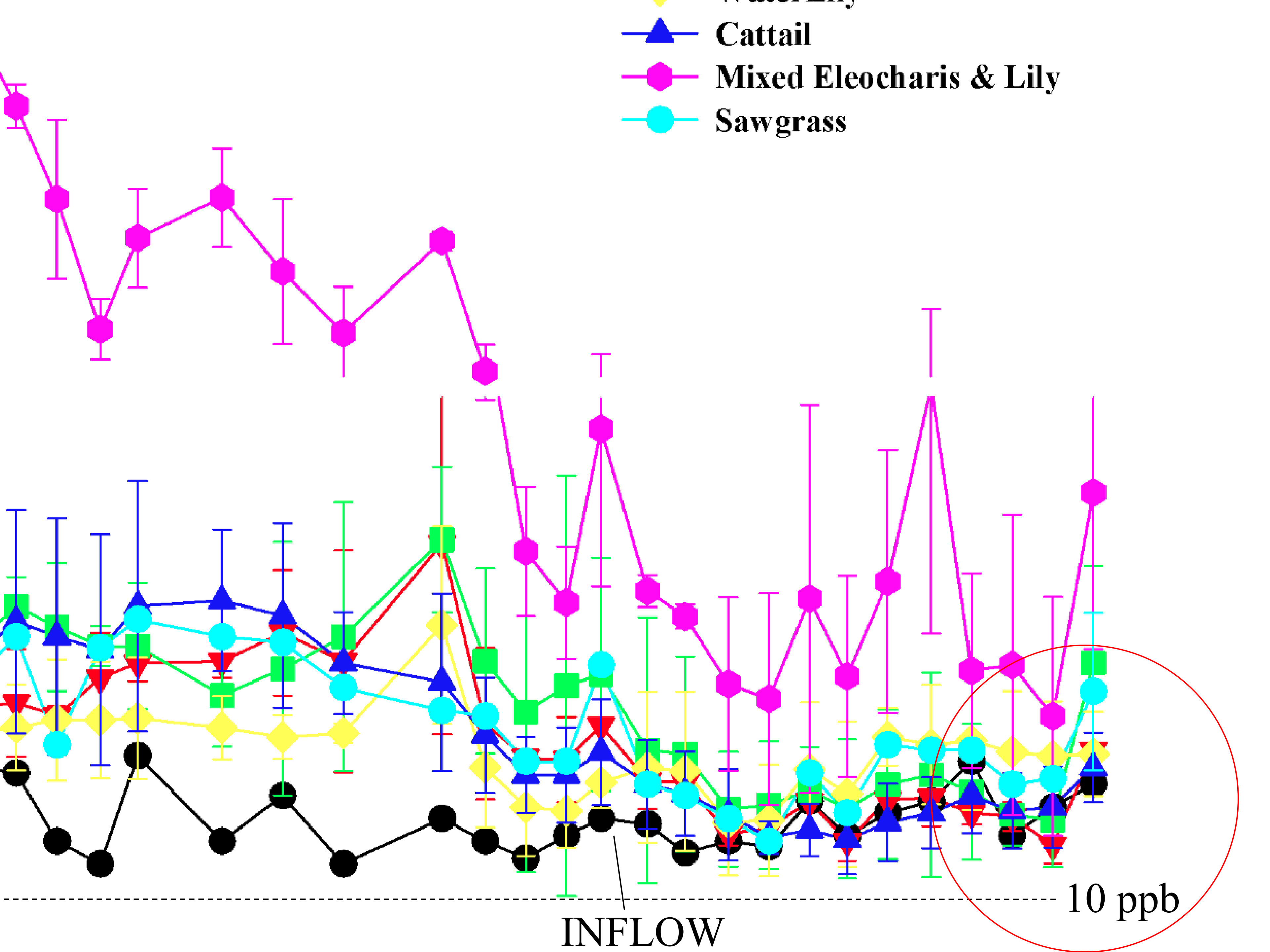




Stormwater Treatment Area (STA) mesocosm experiment

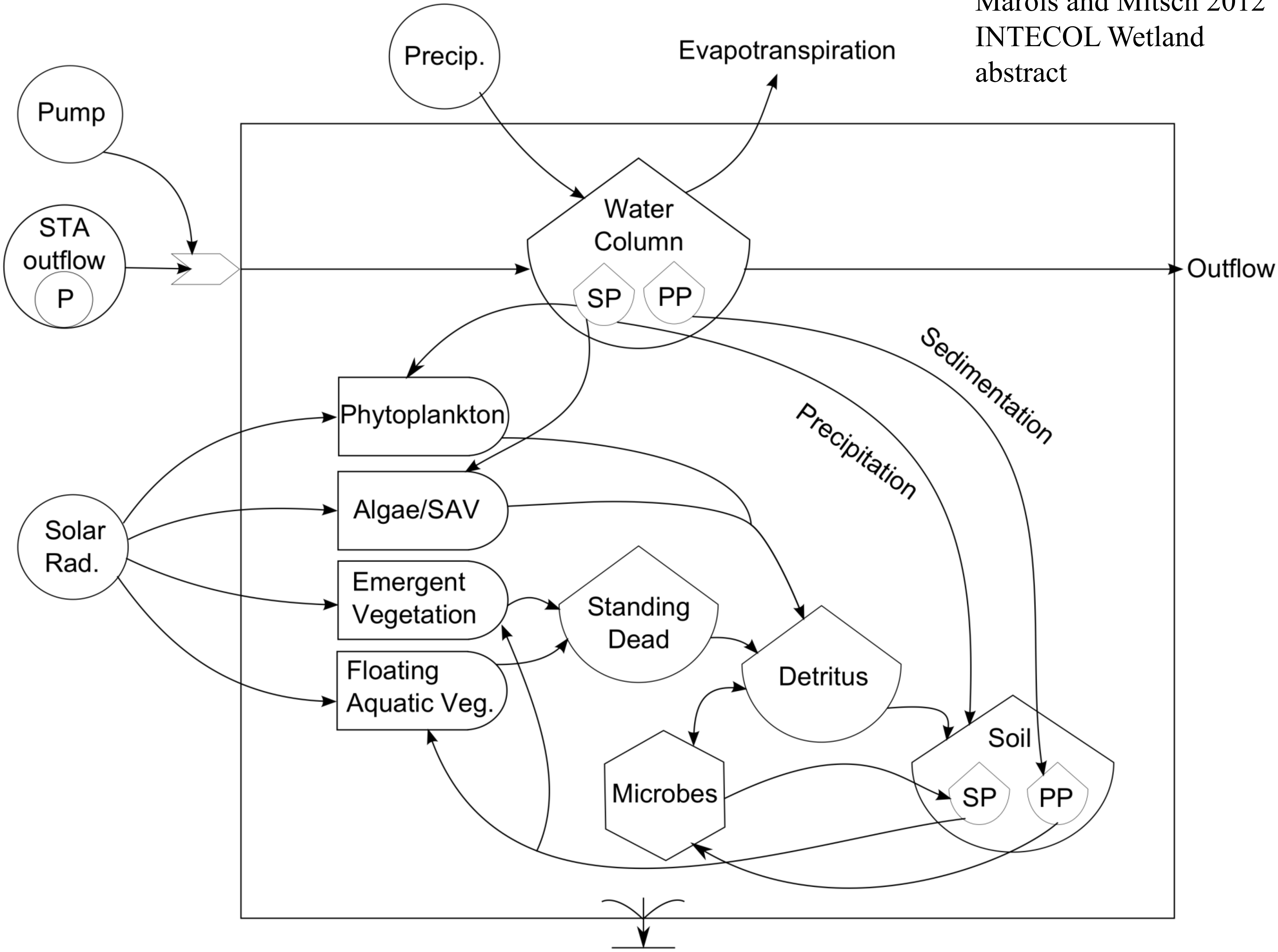
Pattern of outflow phosphorus concentrations in cattail (*Typha domingensis)*, lily (*Nymphaea odorata*), and submersed aquatic vegetation (SAV) treatments





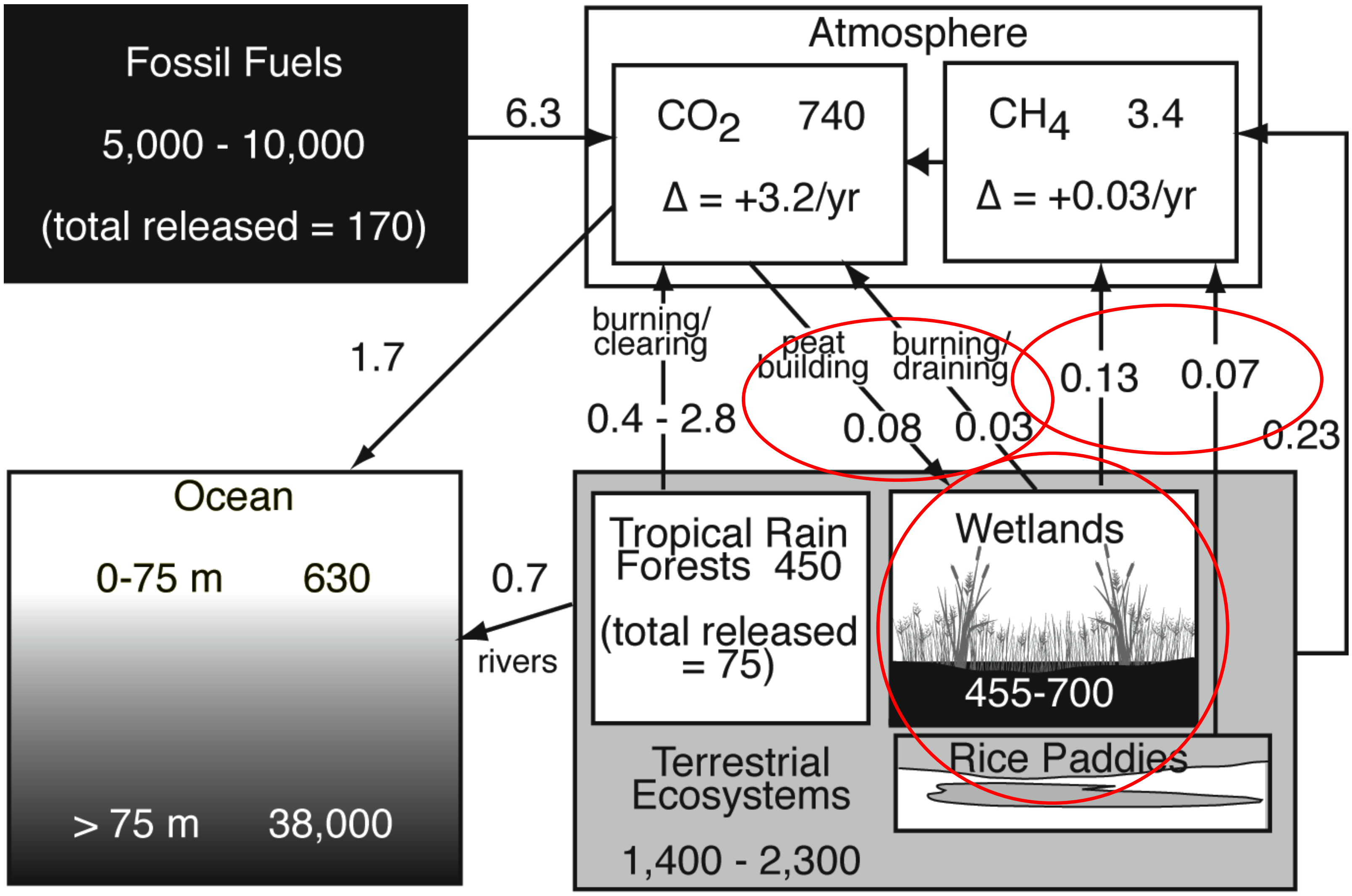
Cattail
Mixed Eleocharis & Lily
Sawgrass
10 ppb
INFLOW

Marois and Mitsch 2012
INTECOL Wetland
abstract



The Planet

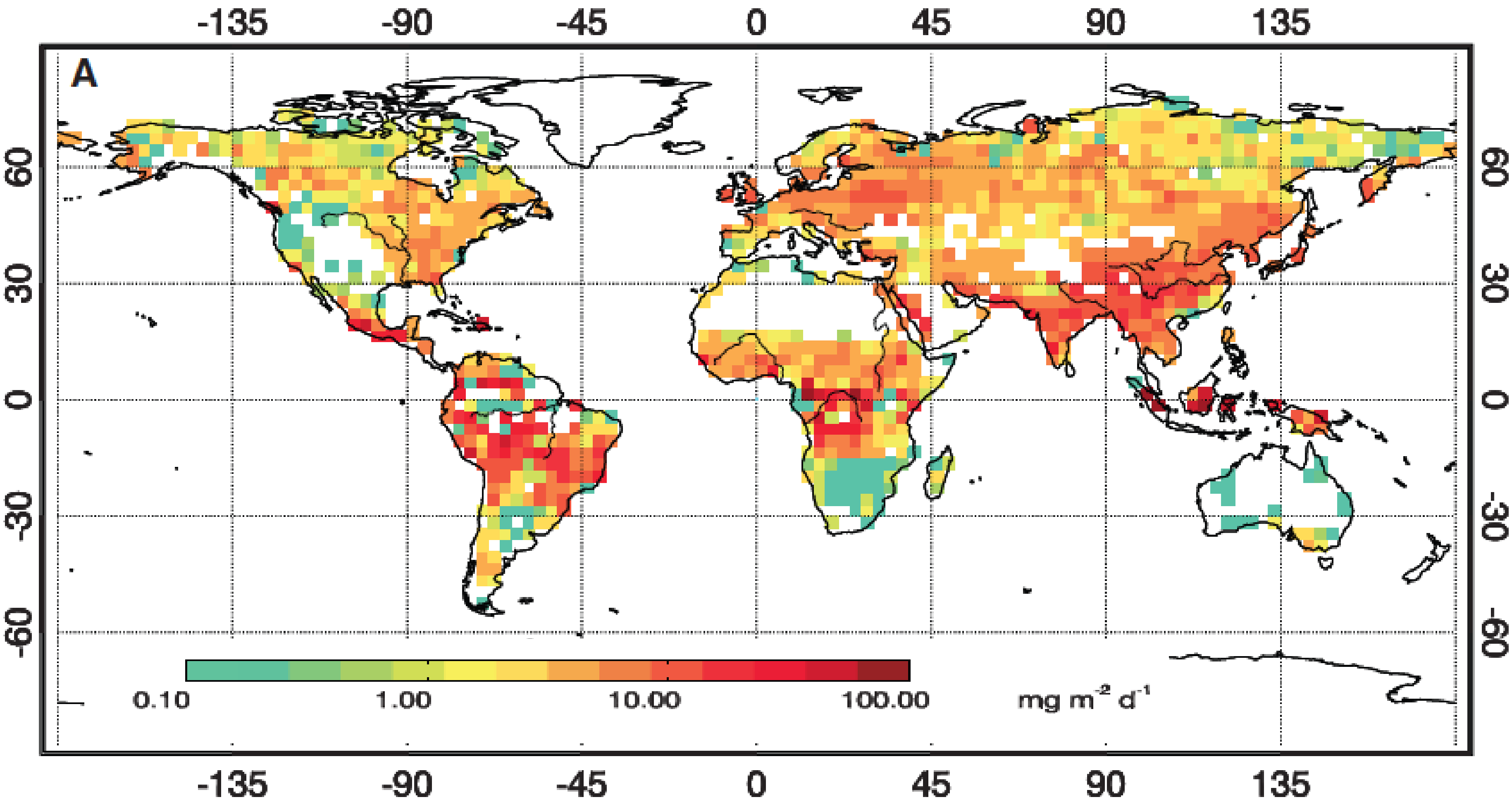
Old Global Carbon Budget with Wetlands Featured



Pools: Pg (=10^{15} g) Fluxes: Pg/yr

Source:Mitsch and Gosselink, 2007

Bloom et al./ *Science* (10 January 2010) suggested that wetlands and rice paddies contribute **227 Tg of CH_4** and that 52 to 58% of methane emissions come from the tropics. They furthermore conclude that an increase in methane seen from 2003 to 2007 was due primarily due to warming in Arctic and mid-latitudes over that time.



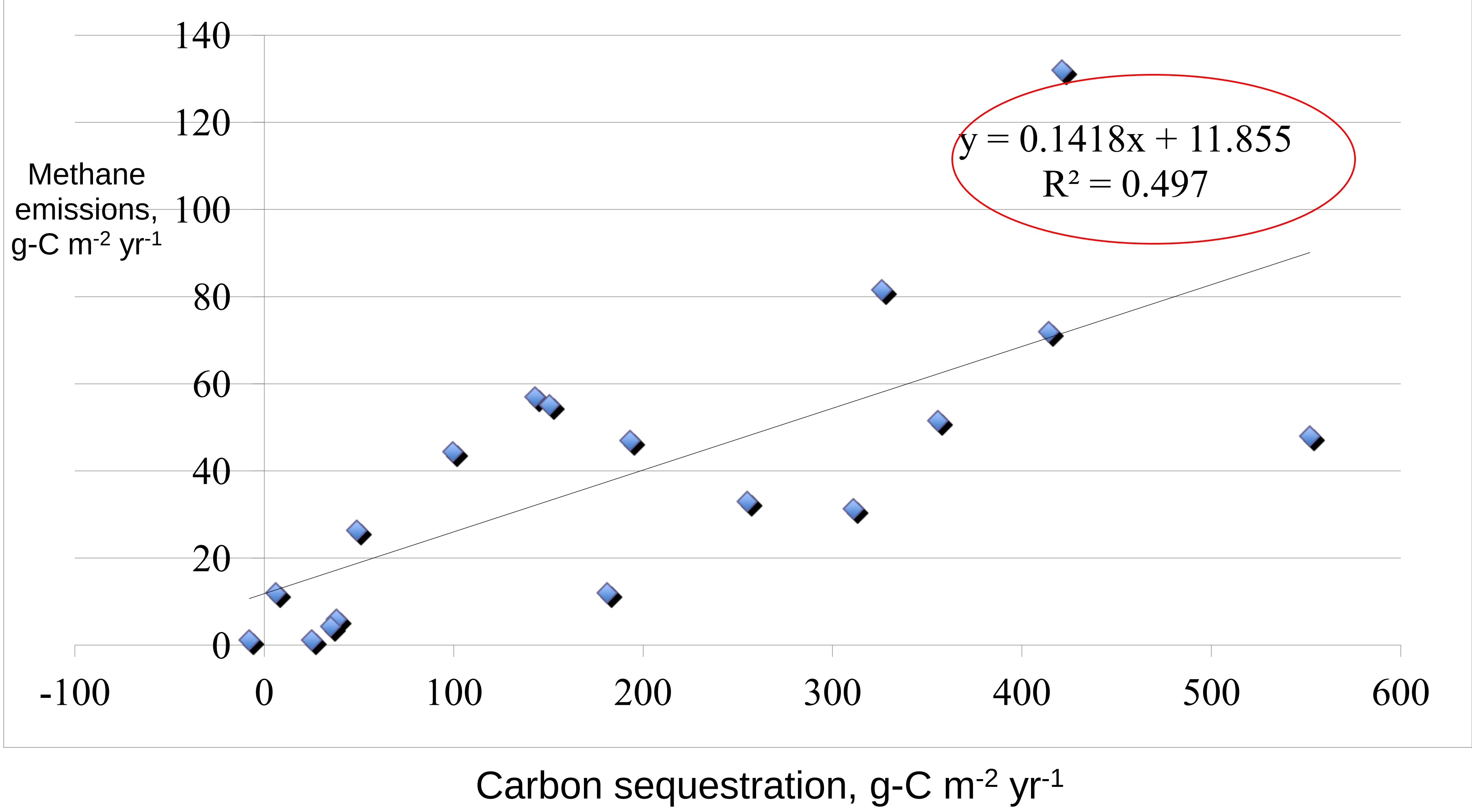
Bloom et al. 2010 Science 327: 322

Wetlands offer one of the best natural environments for sequestration and long-term storage of carbon….

…… and yet are also natural sources of greenhouse gases (GHG) to the atmosphere.

Both of these processes are due to the same anaerobic condition caused by shallow water and saturated soils that are features of wetlands.

Comparison of methane emissions and carbon sequestration in 18 wetlands around the world

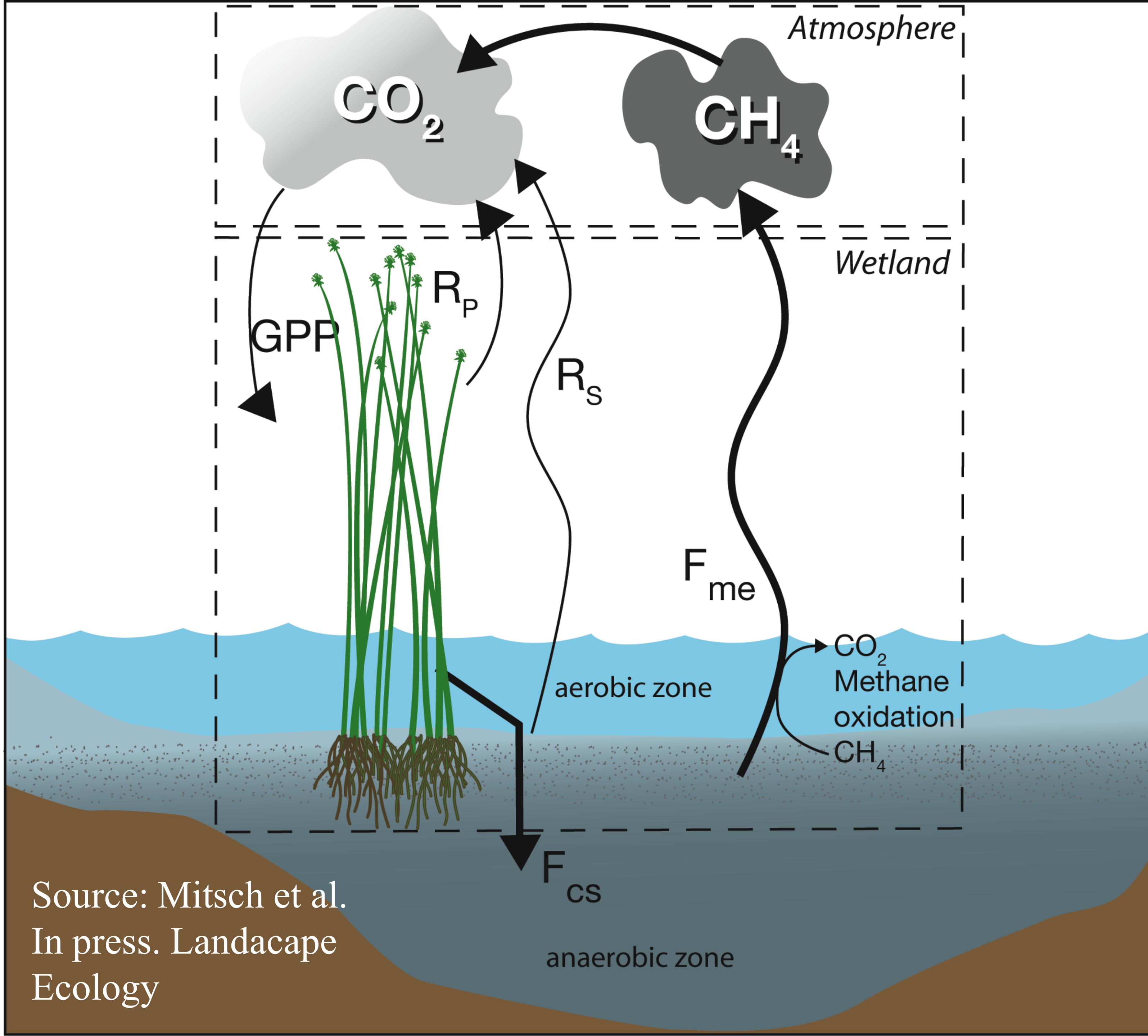


- On average, methane emitted from wetlands, as carbon, is 14% of the wetland’s carbon sequestration.

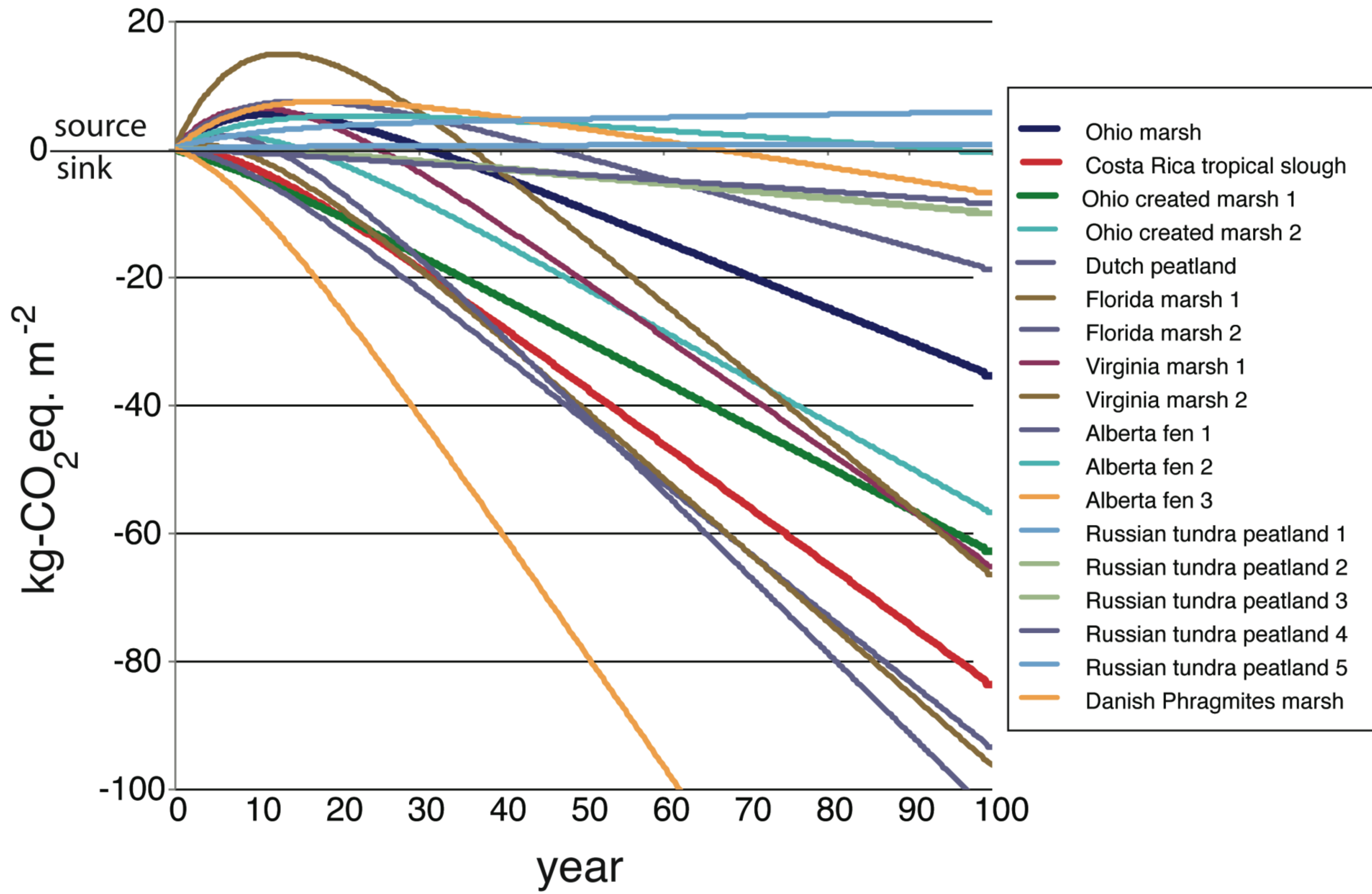
- This 7.1:1 (sequestration/methane) carbon ratio is equivalent to 19:5 as CO_2 /CH_4

- The standard global warming potential (GWP_M) used by the International Panel on Climate Change (IPCC, 2007) and others to compare methane and carbon dioxide is now 25:1

- It could be concluded from this simple comparison that the world’s wetlands are net sources of radiative forcing on climate.



Source: Mitsch et al.
In press. Landacape
Ecology


20
0
source
sink
-20
-40
-60
-80
-100
kg-CO2eq. m-2
0
10
20
30
40
50
60
70
80
90
100
year
Ohio marsh
Costa Rica tropical slough
Ohio created marsh 1
Ohio created marsh 2
Dutch peatland
Florida marsh 1
Florida marsh 2
Virginia marsh 1
Virginia marsh 2
Alberta fen 1
Alberta fen 2
Alberta fen 3
Russian tundra peatland 1
Russian tundra peatland 2
Russian tundra peatland 3
Russian tundra peatland 4
Russian tundra peatland 5
Danish Phragmites marsh

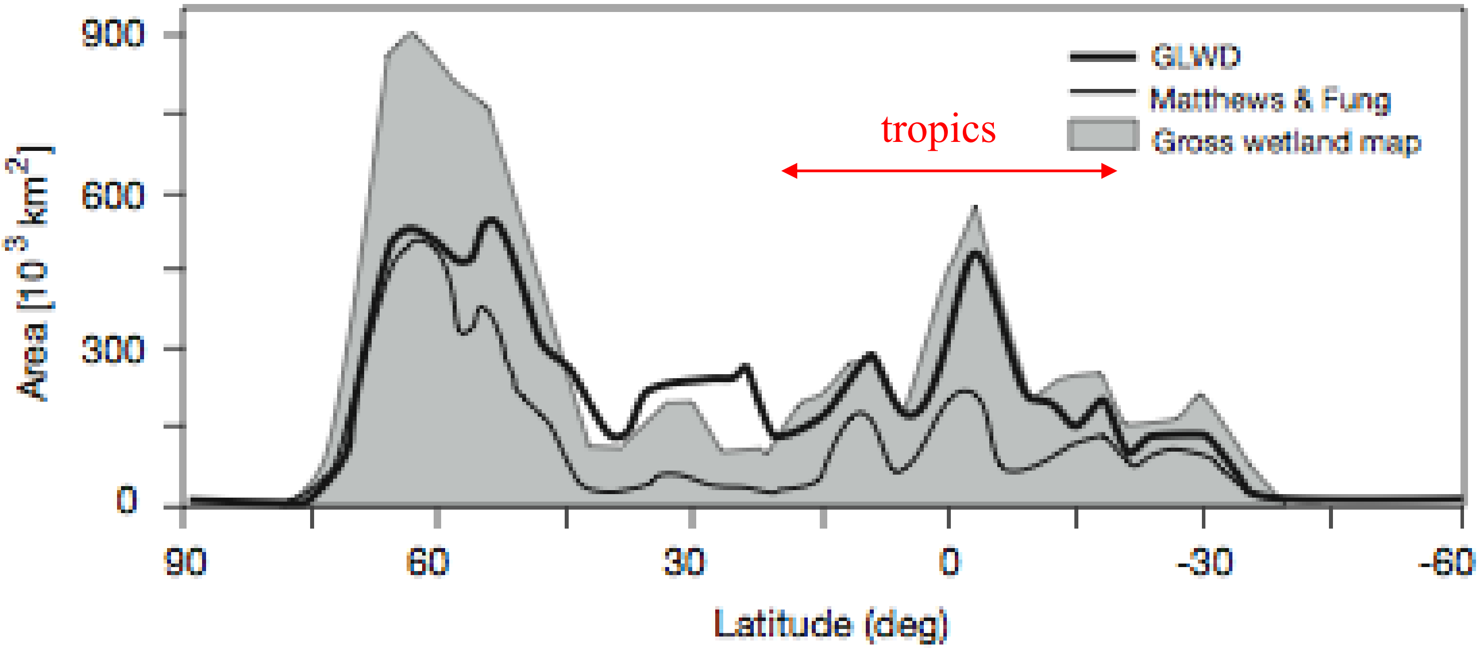
Net carbon retention after 100 simulated years for 21 wetlands

Wetland	**Latitude, degrees N**	**Carbon-neutral years, yr**	**Carbon retention, g-C m^{-2} yr^{-1}**
TROPICAL/SUBTROPICAL WETLANDS (n = 6)	10 - 30	0 - 255	194
TEMPERATE WETLANDS (n = 7)	37 - 55	0 - 36	278
BOREAL WETLANDS (n = 8)	54 - 67	0 – 95*	29

* two boreal wetlands could never be carbon neutral as they were sources of CO_2

Source: Mitsch et al. In press. Landscape Ecology

Wetland area of the world (thousand km^2 by latitud

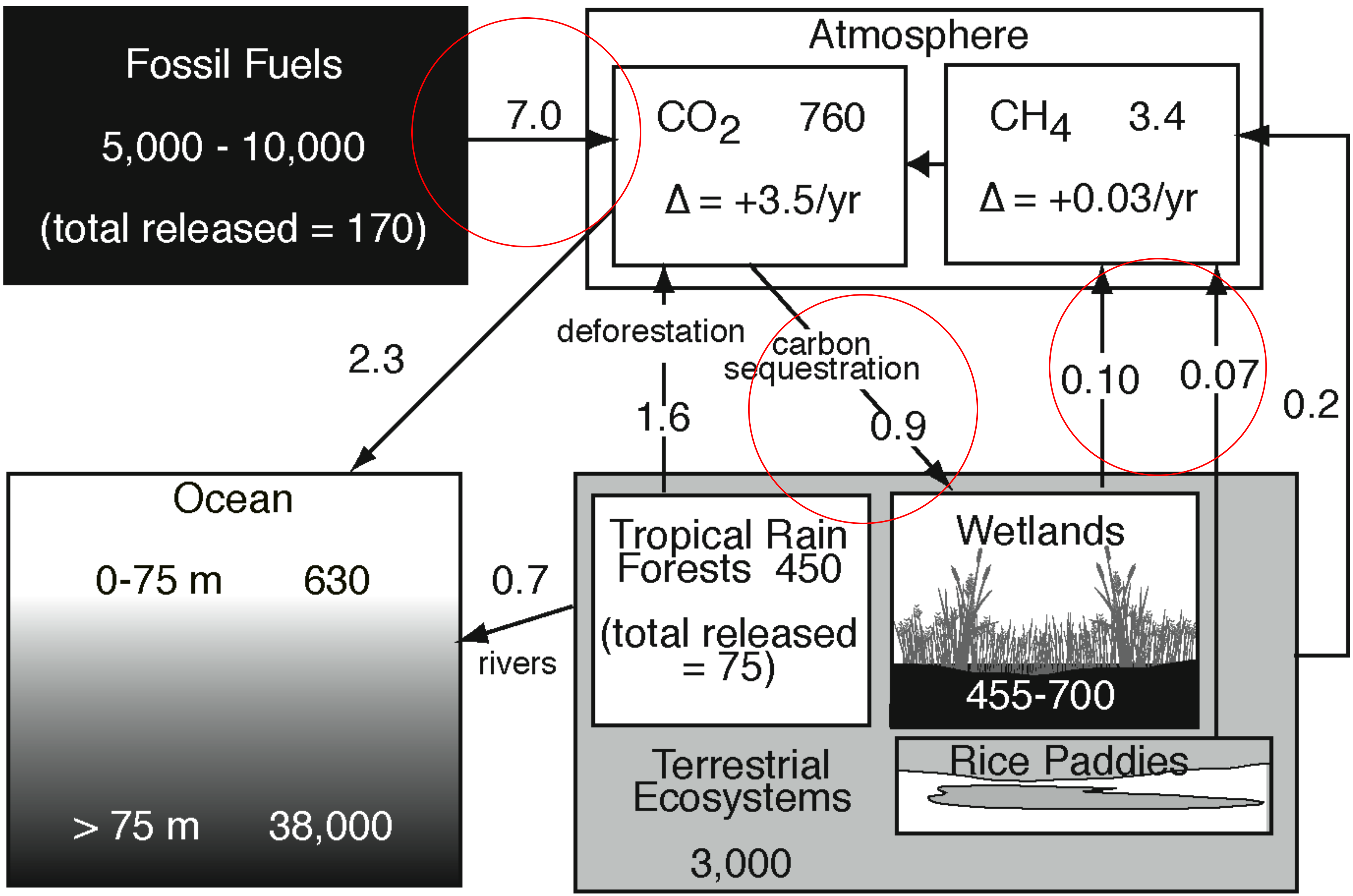


Source: Mitsch and Gosselink,
Lehner and Döll (2004)

Global carbon sequestration by wetlands

Wetland	Net carbon retention, g-C m^{-2} yr^{-1}	Estimated Area*, x 10^6 km^2	Carbon retention, Pg-C/yr
TROPICAL/SUBTROPICAL WETLANDS	194	2.9	0.56
TEMPERATE WETLANDS	278	0.6	0.16
BOREAL PEATLANDS	32	3.5	0.11
TOTAL		**7.0**	**0.83**

Source: Mitsch et al. In press. Landscape Ecology



Pools: Pg (=10^{15} g) Fluxes: Pg/yr

Conclusions

- Created freshwater wetlands can regulate, with some management, significant amounts of nitrogen and phosphorus on a sustainable basis.
- However nutrient retention in created and restored wetlands has not been validated for long periods. Our studies in Ohio indicate reduced phosphorus retention over 15 years with high particulate P but sustainable nitrate retention.
- The STAs in Florida have been effective in keeping significant amounts of phosphorus from entering the Everglades, some for a decade. They remain the most reasonable approach to solve this problem.

Conclusions

- Achieving 10 ppb phosphorus concentrations from treatment wetlands is problematic. Achieving concentrations of 20 to 30 ppb consistently is a more reasonable goal in the Florida Everglades, given the continued input of nutrients at much higher concentrations.
- A more appropriate goal for these wetlands is retention of 1 g-P m^{-2} yr^{-1} overall. To expect more in the long run might invite disappointment.

Conclusions

- Our phosphorus mescosm experiment in Florida will eventually show phosphorus retention after the initial efflux that probably resulted from the phosphorus-rich soils used for the study. Three years is a minimum amount of time for this study to provide useable results.
- It is likely that the submerged aquatic vegetation (SAV) mesocosms will show the best nutrient removal at low inflow concentrations of phosphorus. This is consistent with what has been seen in the full-scale treatment wetlands (STAs) at higher concentrations.

Conclusions

- Most wetlands, if evaluated with the simple 25:1 methane : carbon dioxide ratio used by climate change policy makers, are net sources of radiative forcing and hence bad for climate.
- Most wetlands are net sinks of radiative forcing on climate well within 100 to 200 years when the decay of methane in the atmosphere is factored in.

Conclusions

- The world's wetlands, despite being only about 7% of the terrestrial landscape or <2% of the globe, could be net sinks for a significant portion (as much as 1 Pg/yr) of the carbon released by fossil fuel combustion.
- Wetlands can and should be created and restored to provide nutrient retention, carbon sequestration and other ecosystem services without great concern of creating net radiative sources on climate.


The Ohio State University
20
1991 - 2011
Wilma H. Schiermeier
Olentangy River Wetland
Research Park
40
Ramsar
1971-2011
Thank you!
http://swamp.osu.edu

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