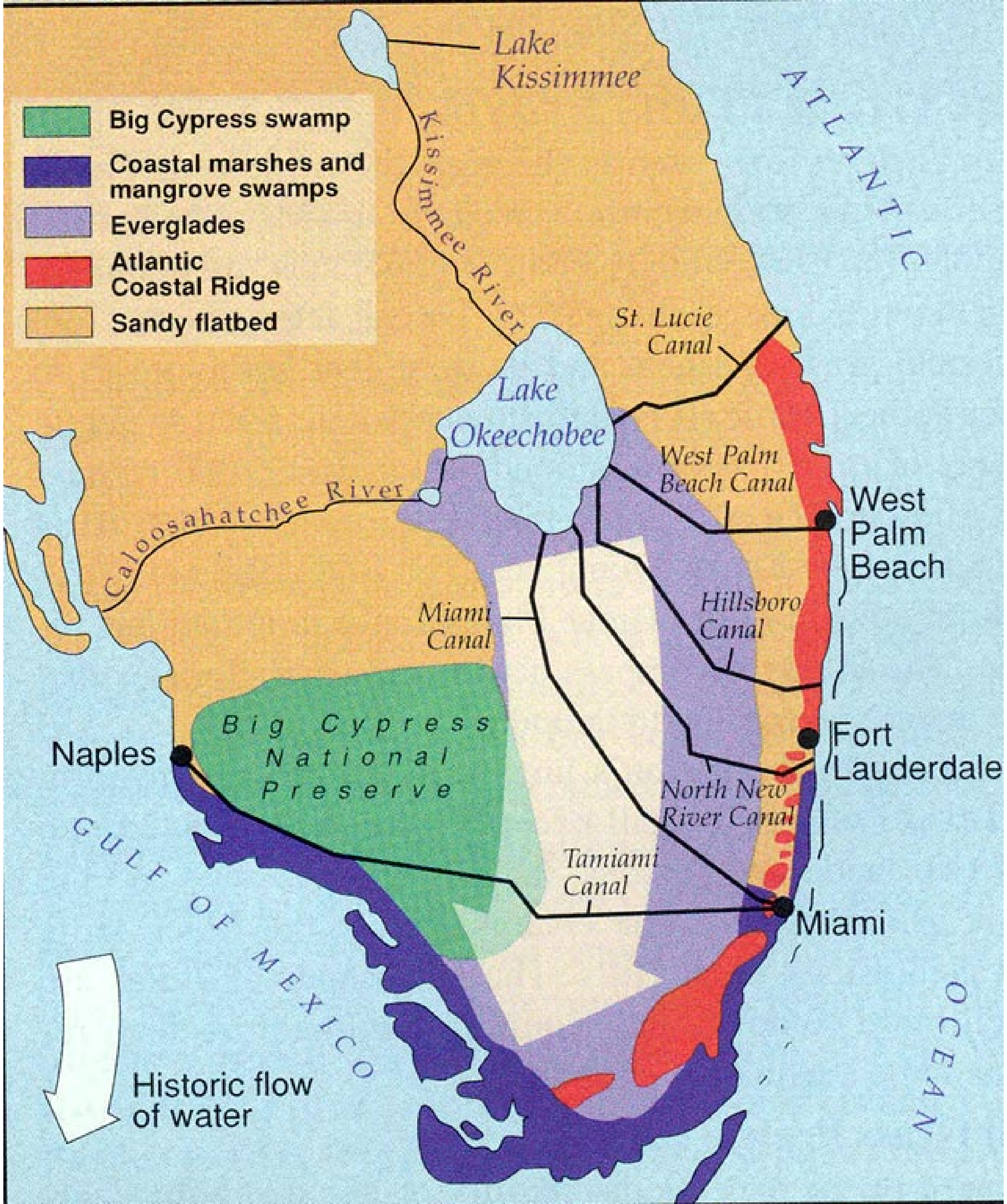
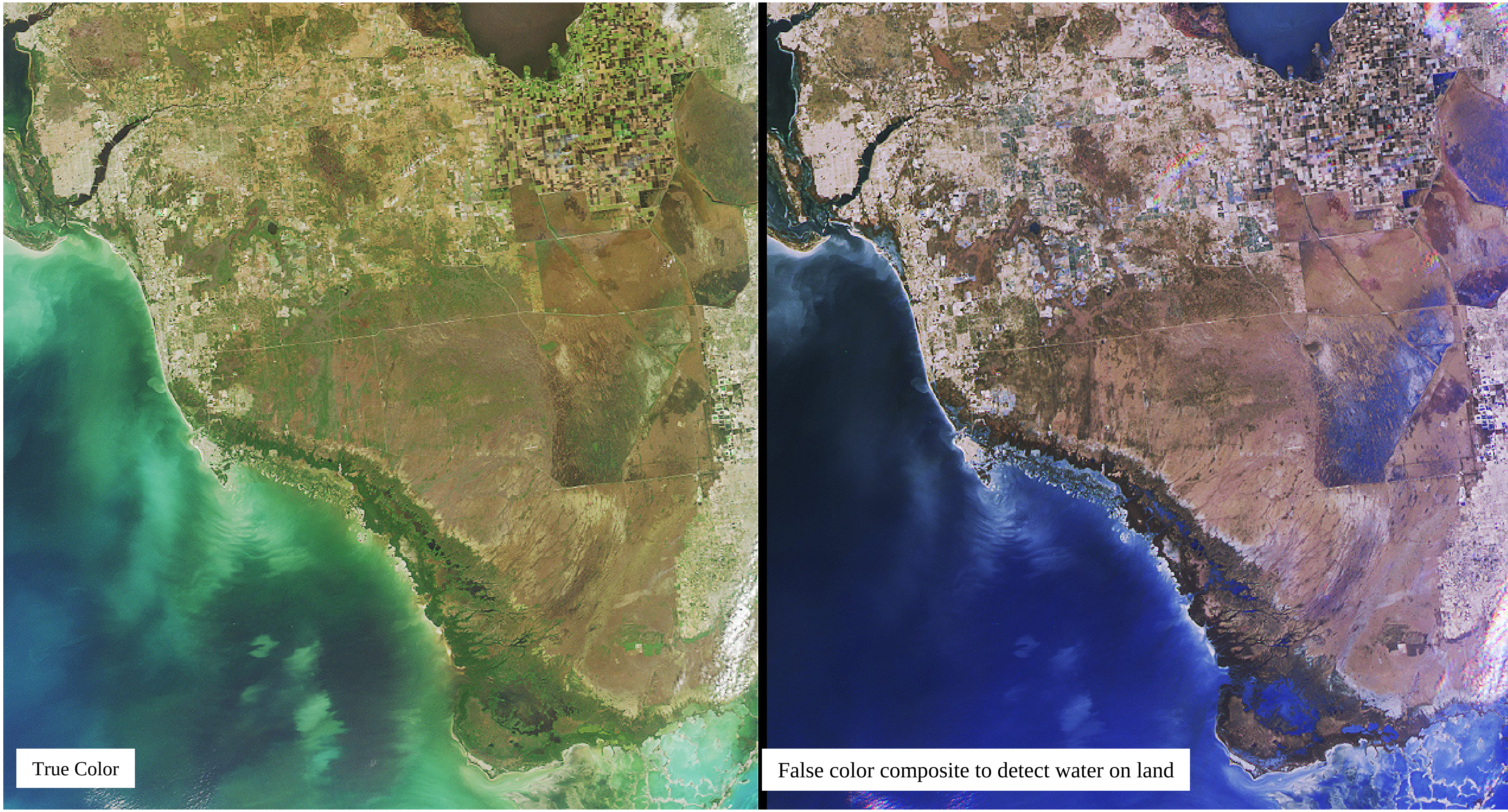
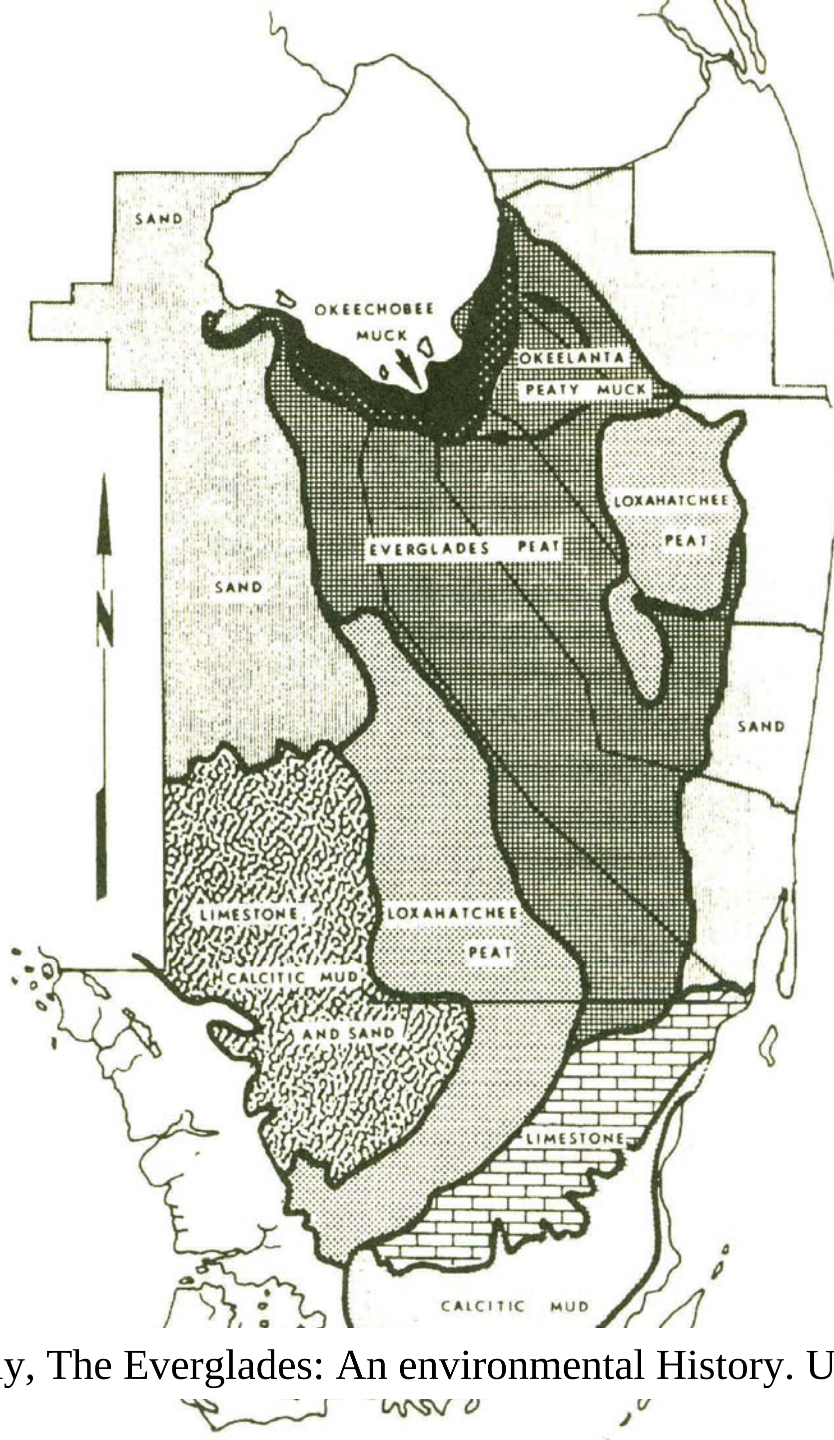
Phosphorus Biogeochemistry in the Everglades

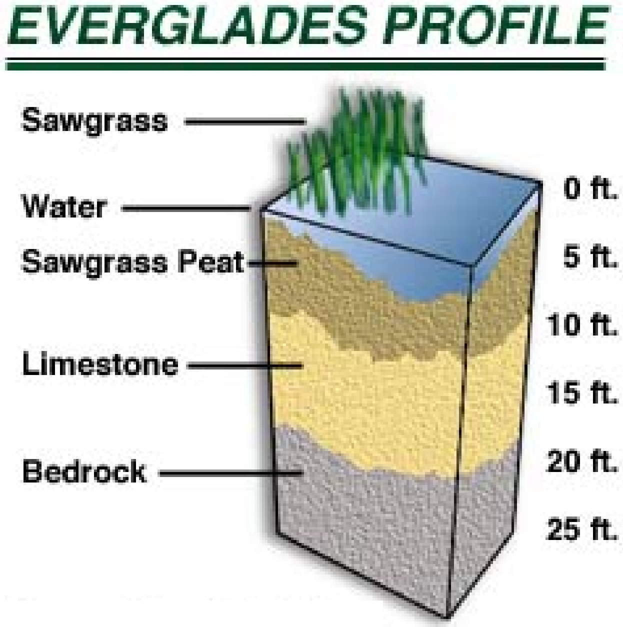

Lake Kissimmee
Big Cypress swamp
Coastal marshes and mangrove swamps
Everglades
Atlantic Coastal Ridge
Sandy flatbed
Kissimmee River
ATLANTIC
St. Lucie Canal
Lake Okeechobee
Caloosahatchee River
West Palm Beach Canal
West Palm Beach
Hillsboro Canal
Miami Canal
Big Cypress National Preserve
Naples
Fort Lauderdale
North New River Canal
GULF OF MEXICO
Tamiami Canal
Miami
OCEAN
Historic flow of water



Florida’s Everglades is a region of broad, slow-moving sheets of water flowing southward over low-lying areas from Lake Okeechobee to the Gulf of Mexico. In places this remarkable ‘river of grass’ is 80 kilometers wide. These images from the Multi-angle Imaging SpectroRadiometer show the Everglades region on January 16, 2002. Each image covers an area measuring 191 kilometers x 205 kilometers.



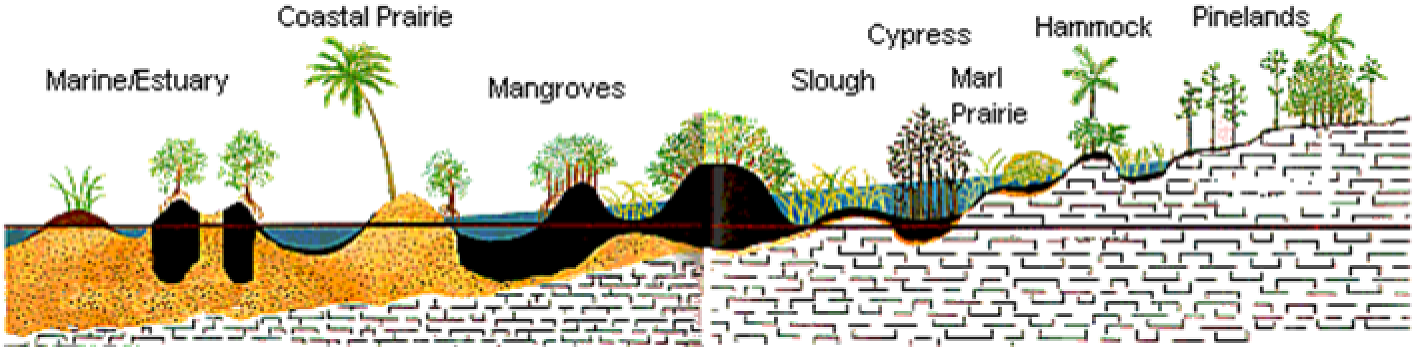
From: David McCally, The Everglades: An environmental History. University Press of Florida. 1999



EVERGLADES PROFILE
Sawgrass
Water
Sawgrass Peat
Limestone
Bedrock
0 ft.
5 ft.
10 ft.
15 ft.
20 ft.
25 ft.

The Everglades is unique:

1. Habitat heterogeneity (e.g., tree islands, prairies, etc);
2. Large spatial extent;
3. Distinctive hydrologic regime (e.g., small and graduate elevation gradient, little external water input, wet-dry cycle, etc.); and
4. A high degree of P-limitation for the less disturbed areas (Limestone, little external input, peat accumulation, etc.).


Coastal Prairie
Marine/Estuary
Mangroves
Slough
Cypress
Marl
Prairie
Hammock
Pinelands

sloughs: main routes of moving water through the Everglades.

Taylor Slough
courtesy U.S. Geological Survey

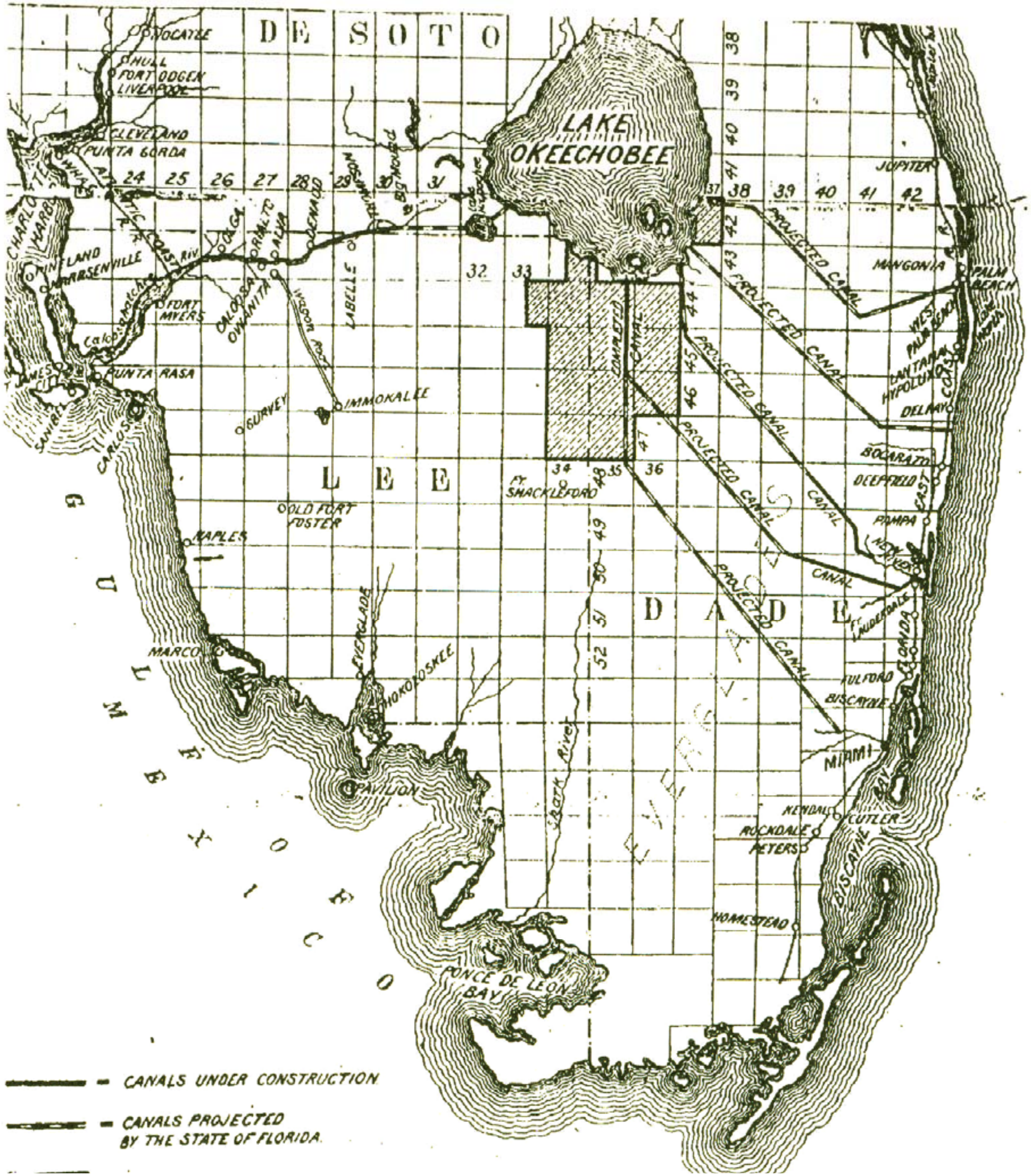
pinelands: dominated by slash pines, this habitat has the richest diversity in the Everglades.




The wet-dry cycle

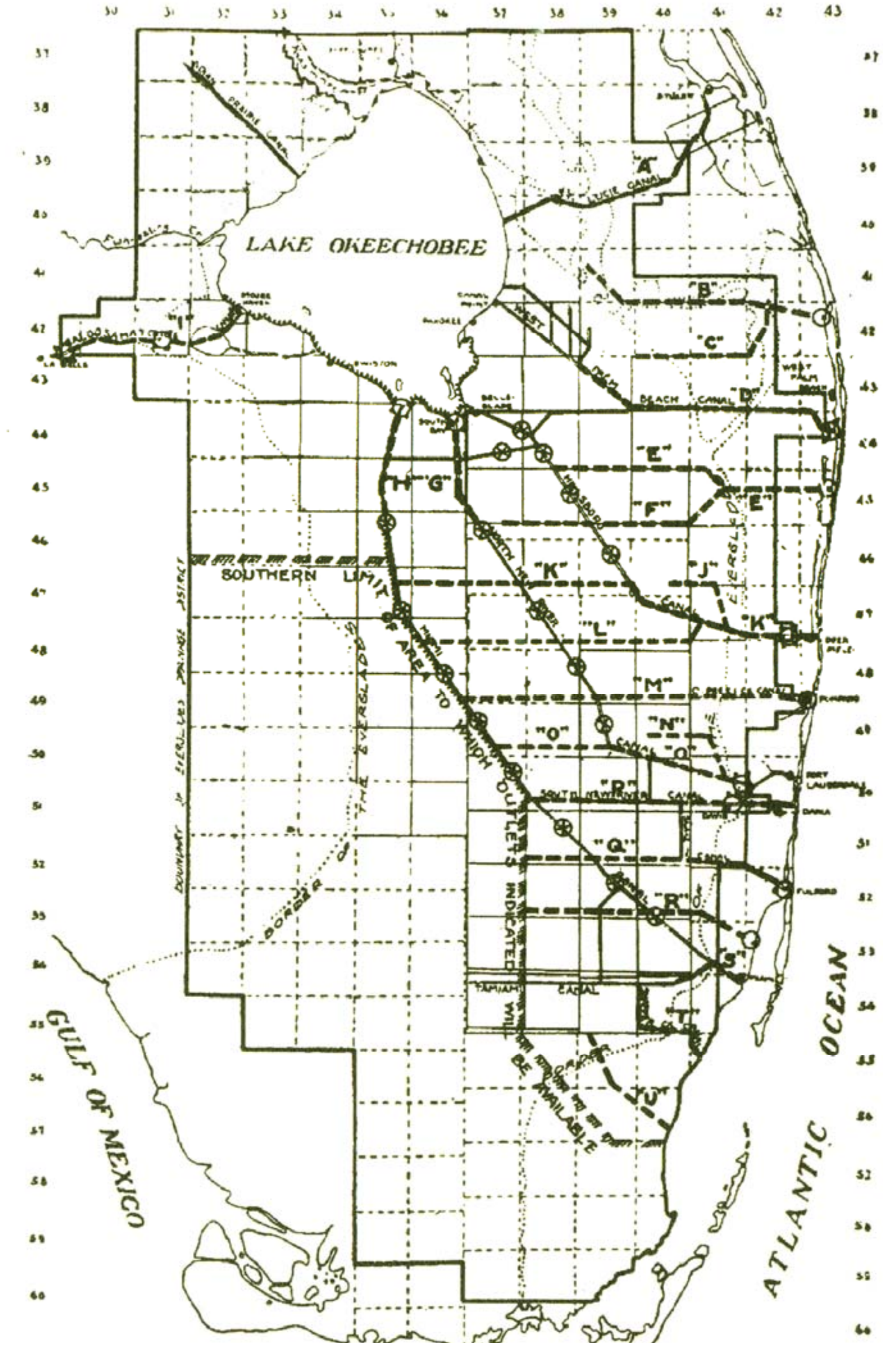
Draining the Everglades

Canals built or to be built in 1912



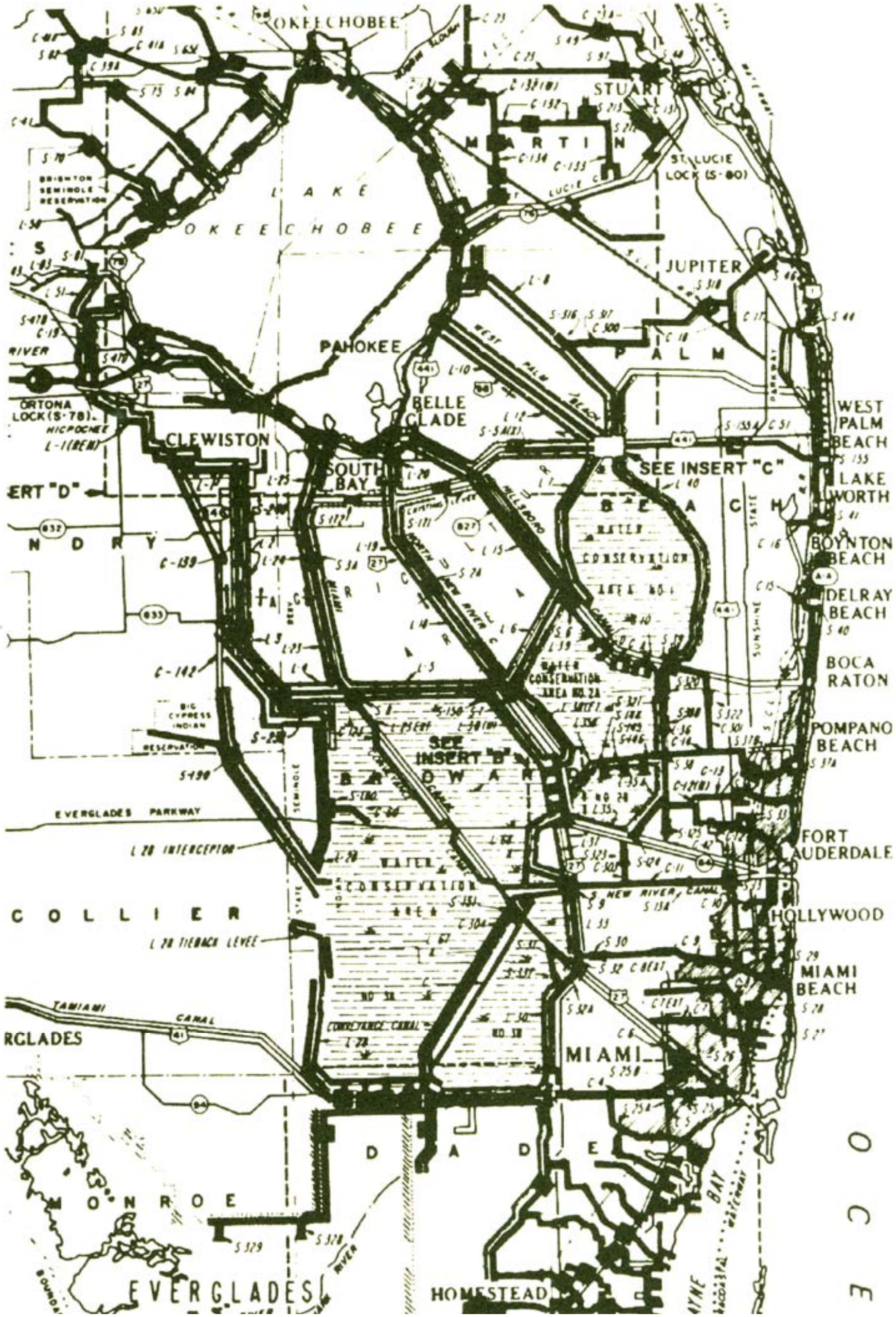
From: David McCally, The Everglades: An environmental History. University Press of Florida. 1999

Canals built during 1913-1928



From: David McCally, The Everglades: An environmental History. University Press of Florida. 1999

Comprehensive water control system put in during 1950s



From: David McCally, The Everglades: An environmental History. University Press of Florida. 1999

What has happened to the Everglades after these hydrologic alterations?

1. Accelerated agricultural development
2. Establishment of urban areas
3. Much increased accessibility
4. Less water level fluctuation, reduced wet-dry cycles
5. Accelerated decomposition of SOM/peat materials
6. Sharp decline of nesting birds, less nutrient input from bird droppings

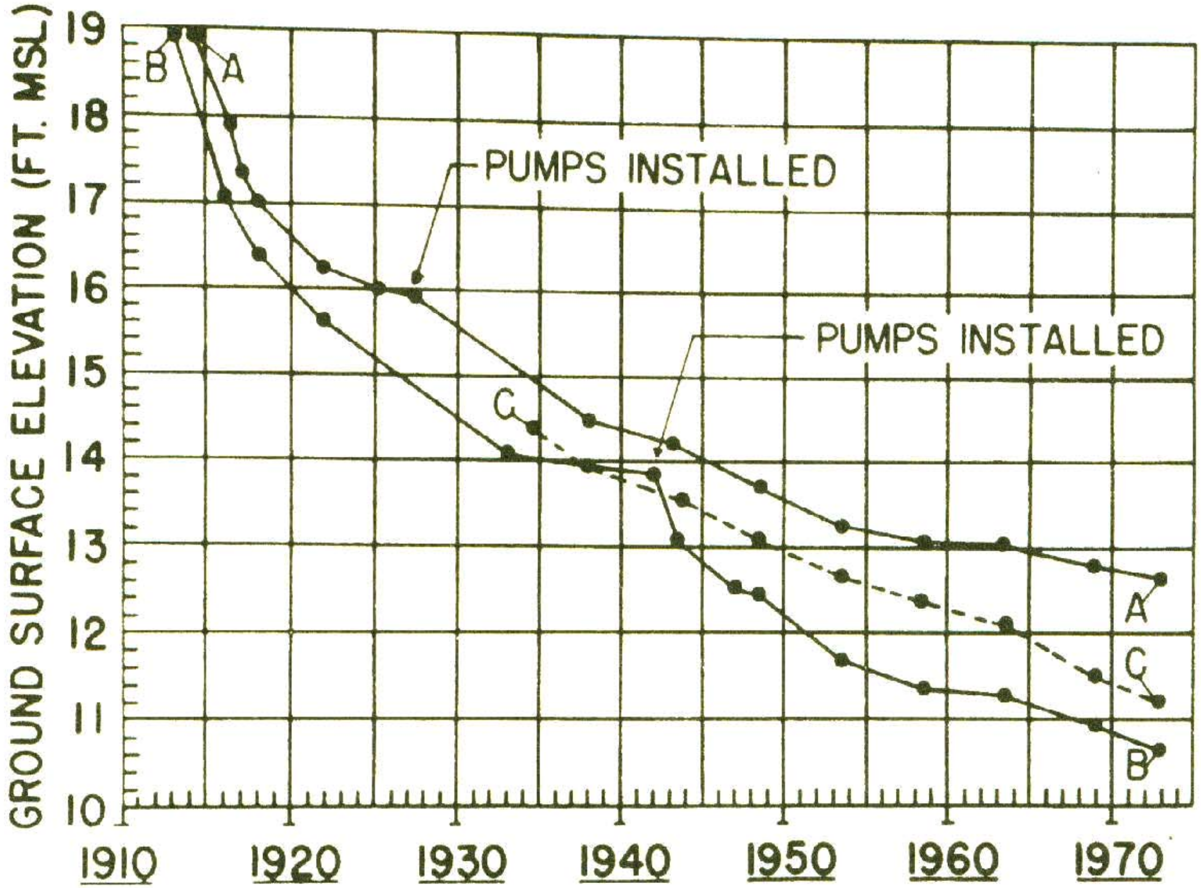


Figure 6.3. Sequence of subsidence in the Everglades. Source: John C. Stephens, "Subsidence of Organic Soils in the Florida Everglades—A Review and Update," in *Environments of South Florida Present and Past II,* Patrick J. Gleason, ed. (Miami: Miami Geological Society, 1984), fig. 2, p. 383. Reprinted with permission.

From: David McCally, The Everglades: An environmental History. University Press of Florida. 1999

Fixation and Mobilization of Phosphorus

Phosphorus is easily fixed by chemical reactions with Ca^{2+}, Mg^{2+}, Fe^{2+} ,Al^{3+} etc. Phosphorus fixation is pH-dependent, and is the process that removes P from active pools. Both too high and too low of pH values can resulted in P fixation, for example:

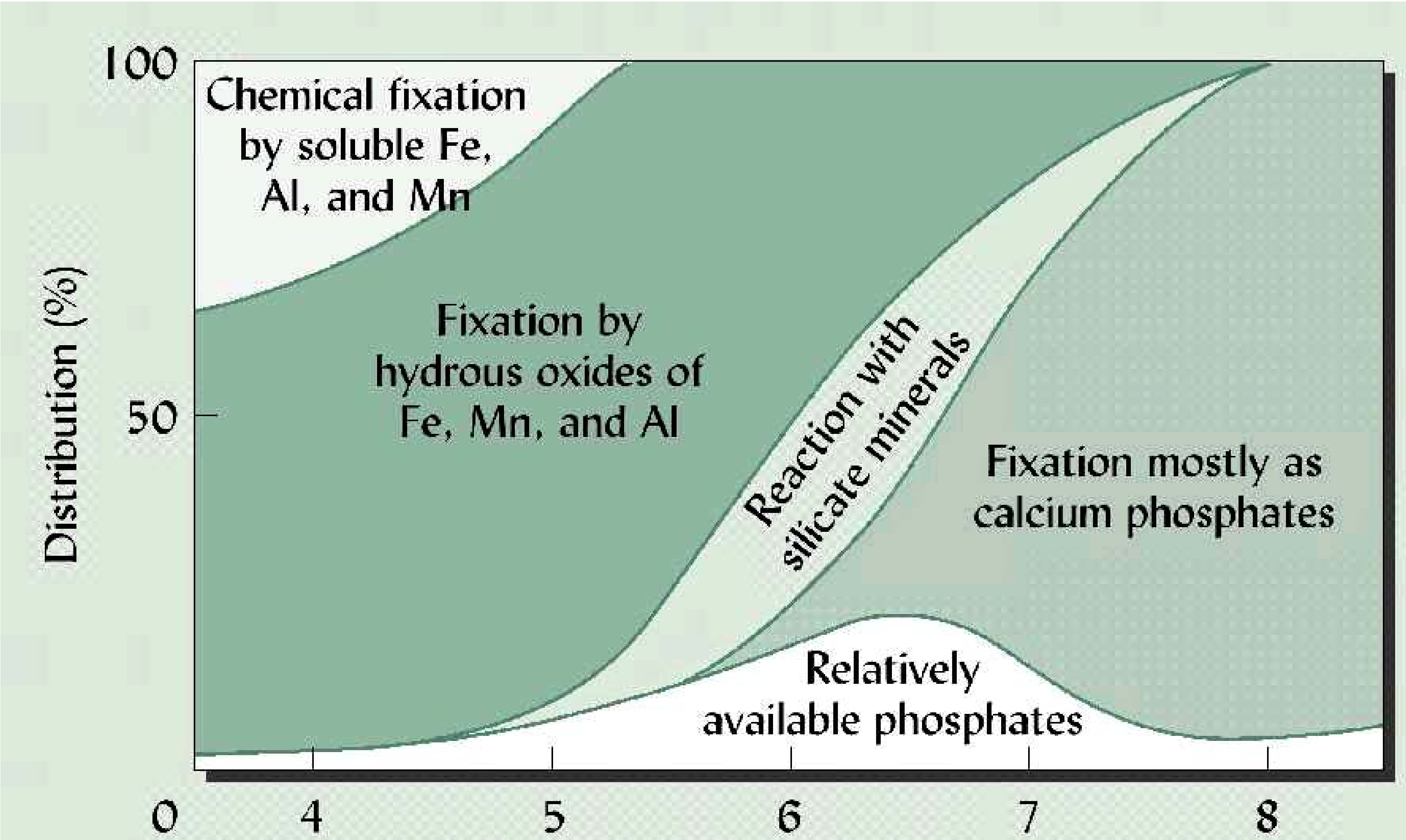
$$2PO_4^{3+} + 3Ca^{2+} \text{ (or } Mg^{2+}, Fe^{2+} \text{ etc) --> } Ca_3(PO_4)_2$$

This is solely a chemical process.

Although the total P content of soils is large, in most soils only a small fraction is available to biota, primarily because of chemical fixation.

Microbes play a crucial role in the transforming process from organic P to inorganic P, and in mobilizing chemically-fixed P (mycorrhizal roots and other rhizosphere activities).

Chemical P fixation is pH-dependent.



pH

Phosphorus enrichment near EAA

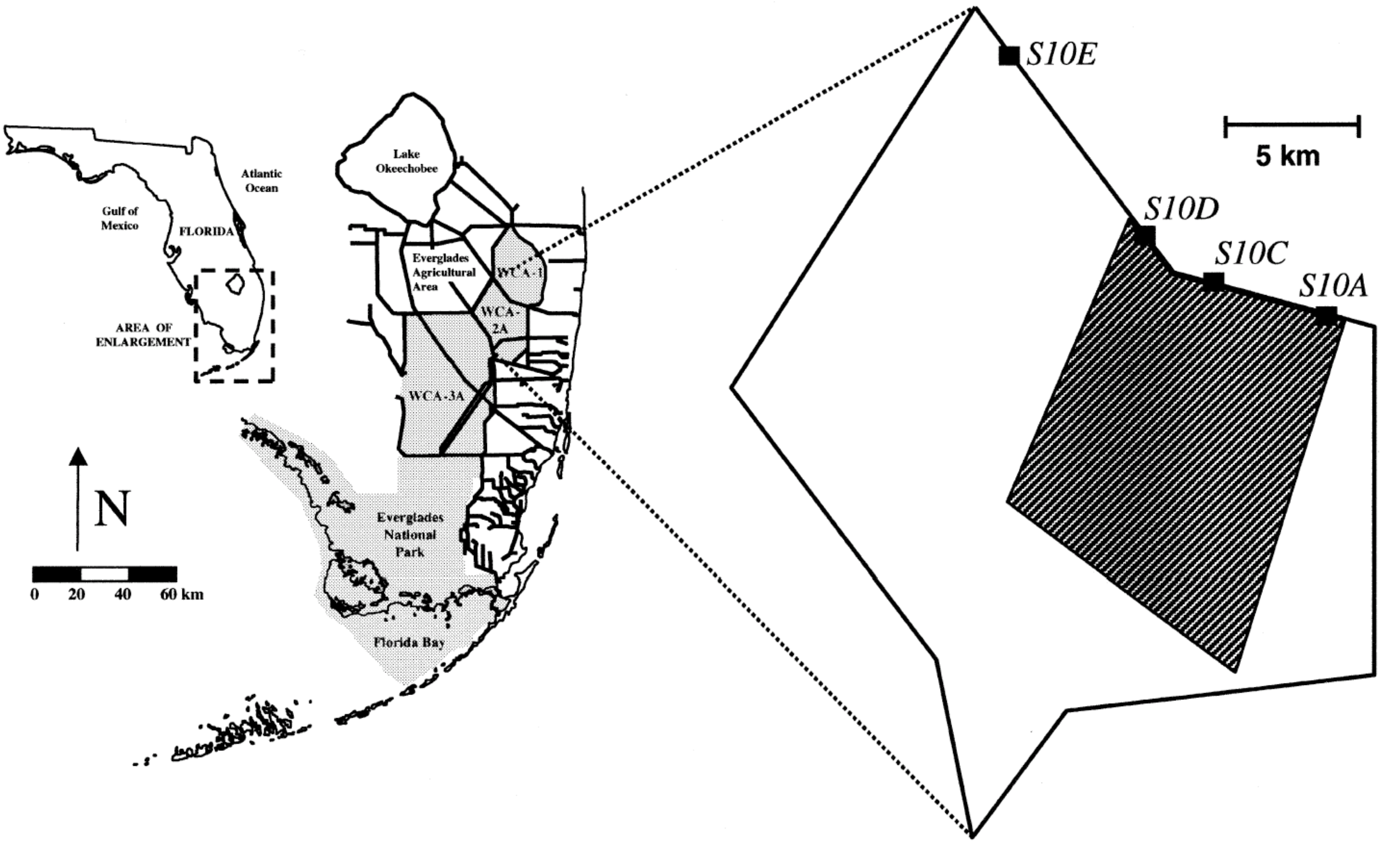


Figure 1. Location of WCA-2A within the remnant Everglades (shaded area). System of canals and levees is shown as a network of solid black lines. Diagram of WCA-2A shows inflow structures and the sampling area within the marsh (hatched area).

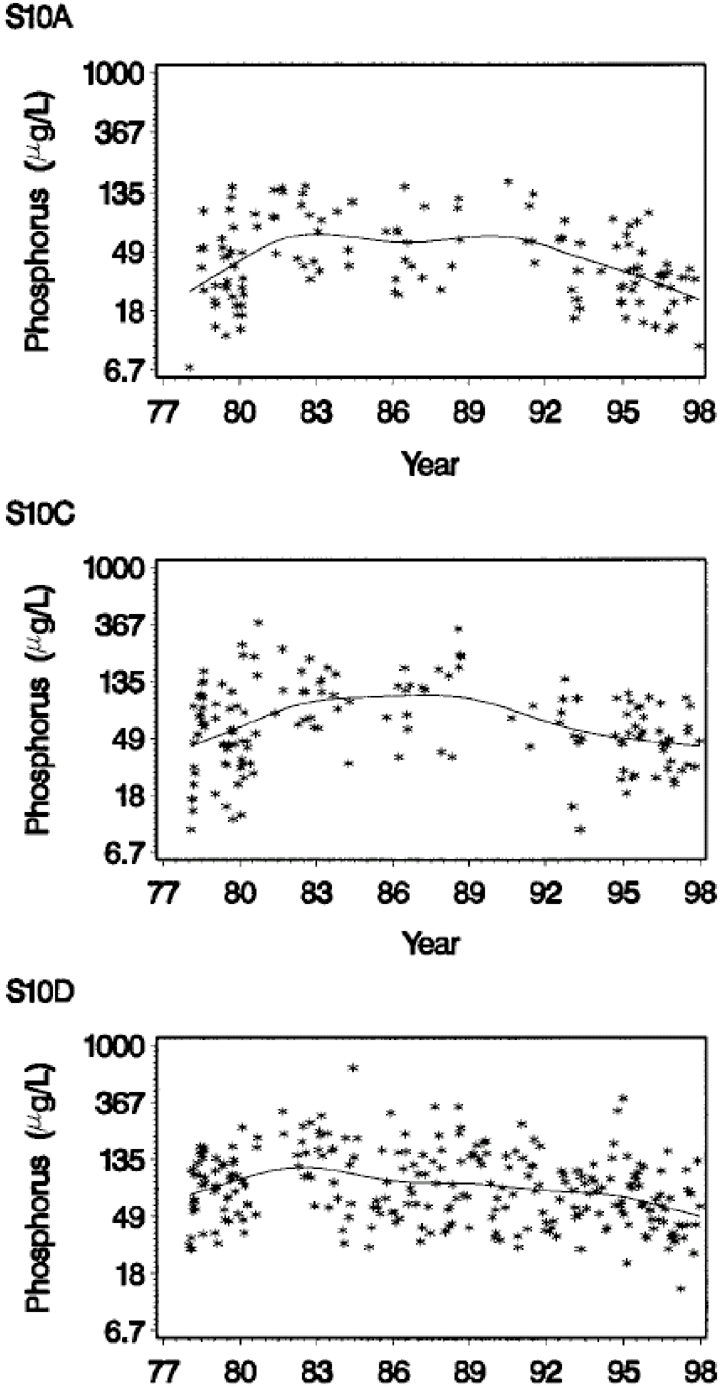


Figure 4. Temporal changes in TP concentration (log scale) for canal waters entering WCA-2A through the three S10 inflow structures. Lines show the smoothed fit to the data collected for each structure. (Smith and McCormick 2001. Environ. Monitoring & Assessmnt 68:153-176)

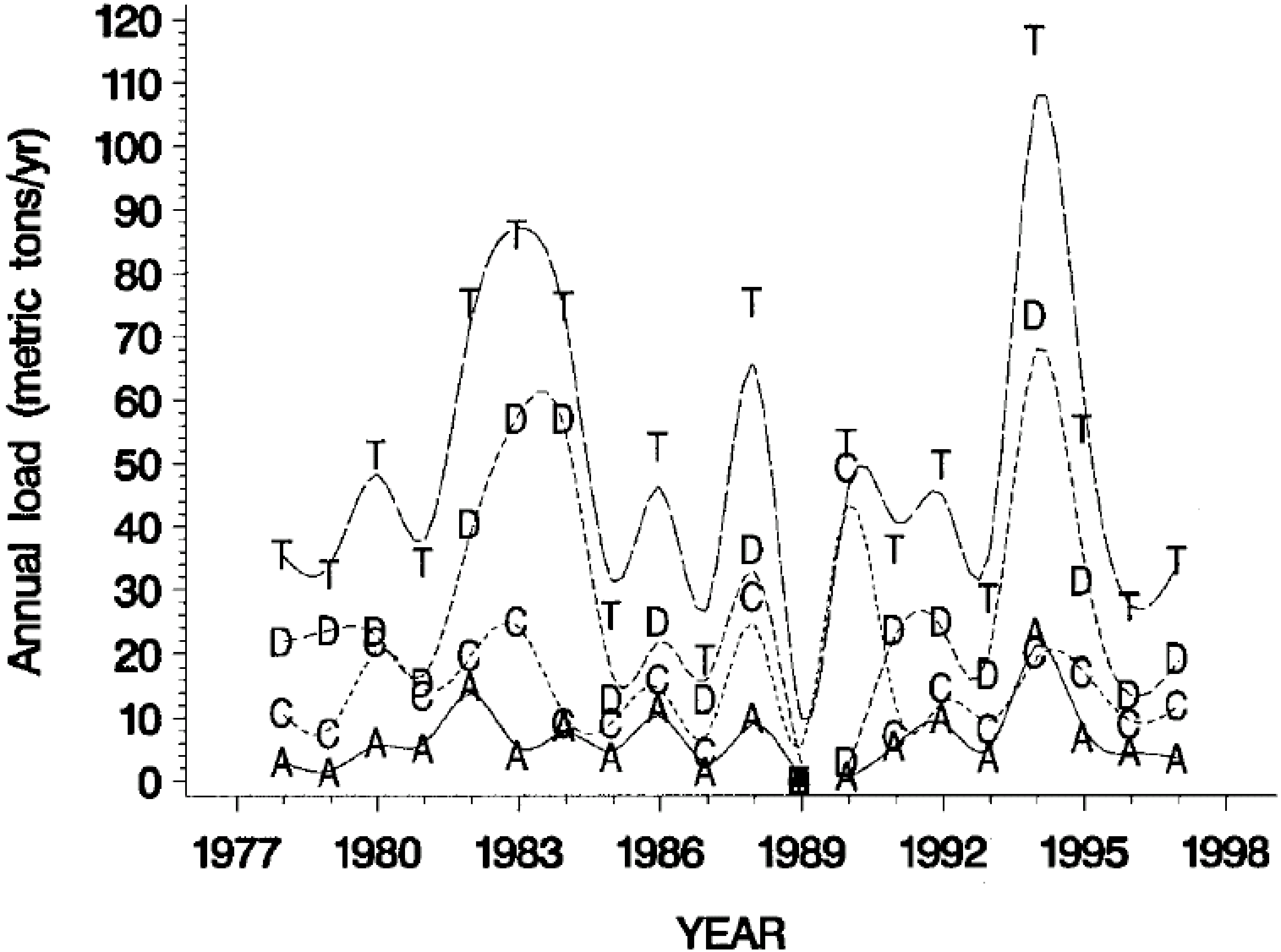


Figure 5. Changes in annual TP load entering the study area as canal inflows during the period of record. Load is presented for three structures (labeled A, C and D) and the total of the three (T). Lines show the smoothed fit. (Smith and McCormick 2001. Environ. Monitoring & Assessmnt 68:153-176)

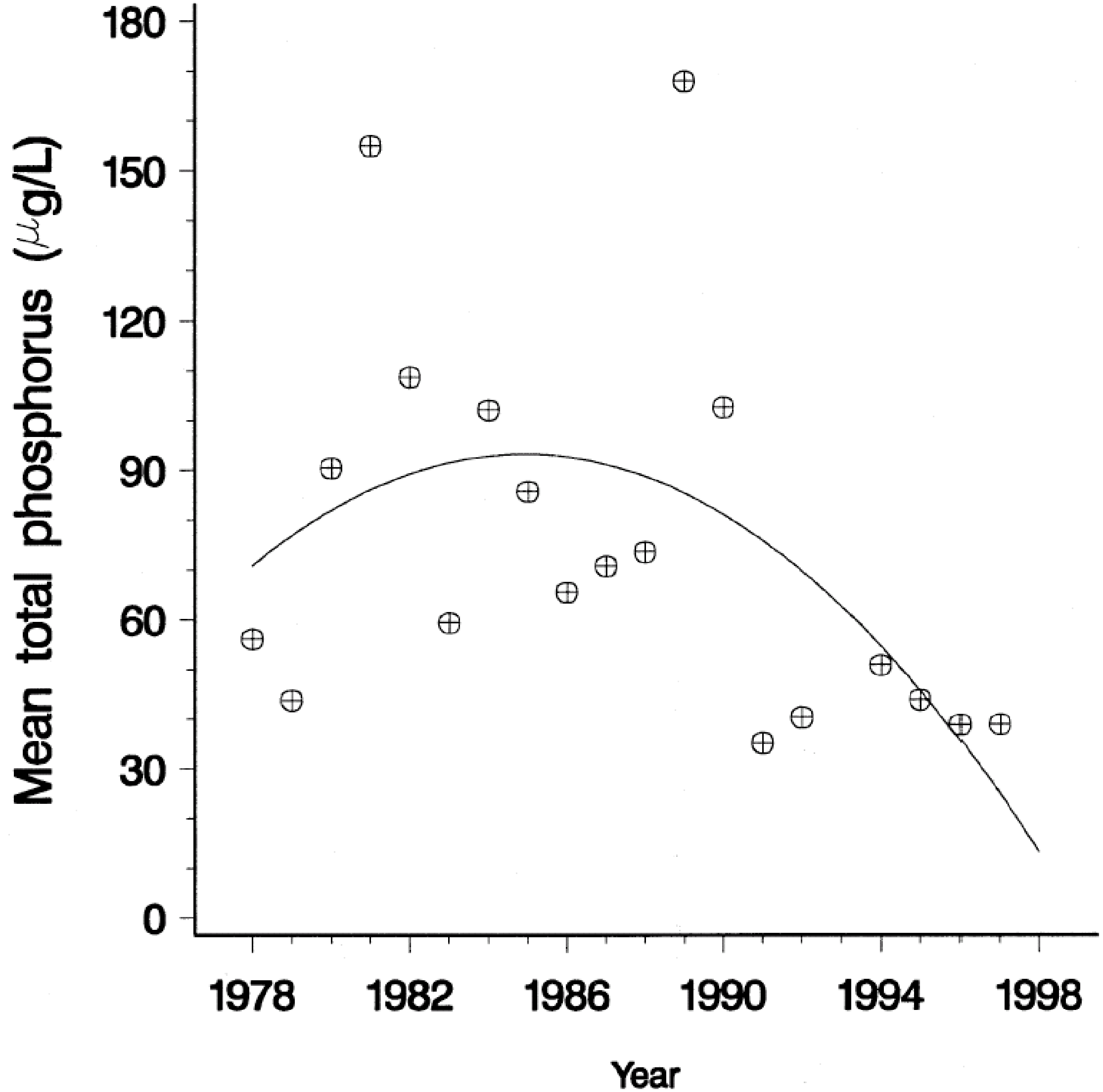


Figure 6. Changes in annual mean water-column TP during the period of record considered in this study. The line shows the best-fit quadratic regression model (R2 = 0.70, F = 20.18, p = 0.0001 for log-transformed TP); the linear model was not statistically significant. (Smith and McCormick 2001. Environ. Monitoring & Assessmnt 68:153-176)

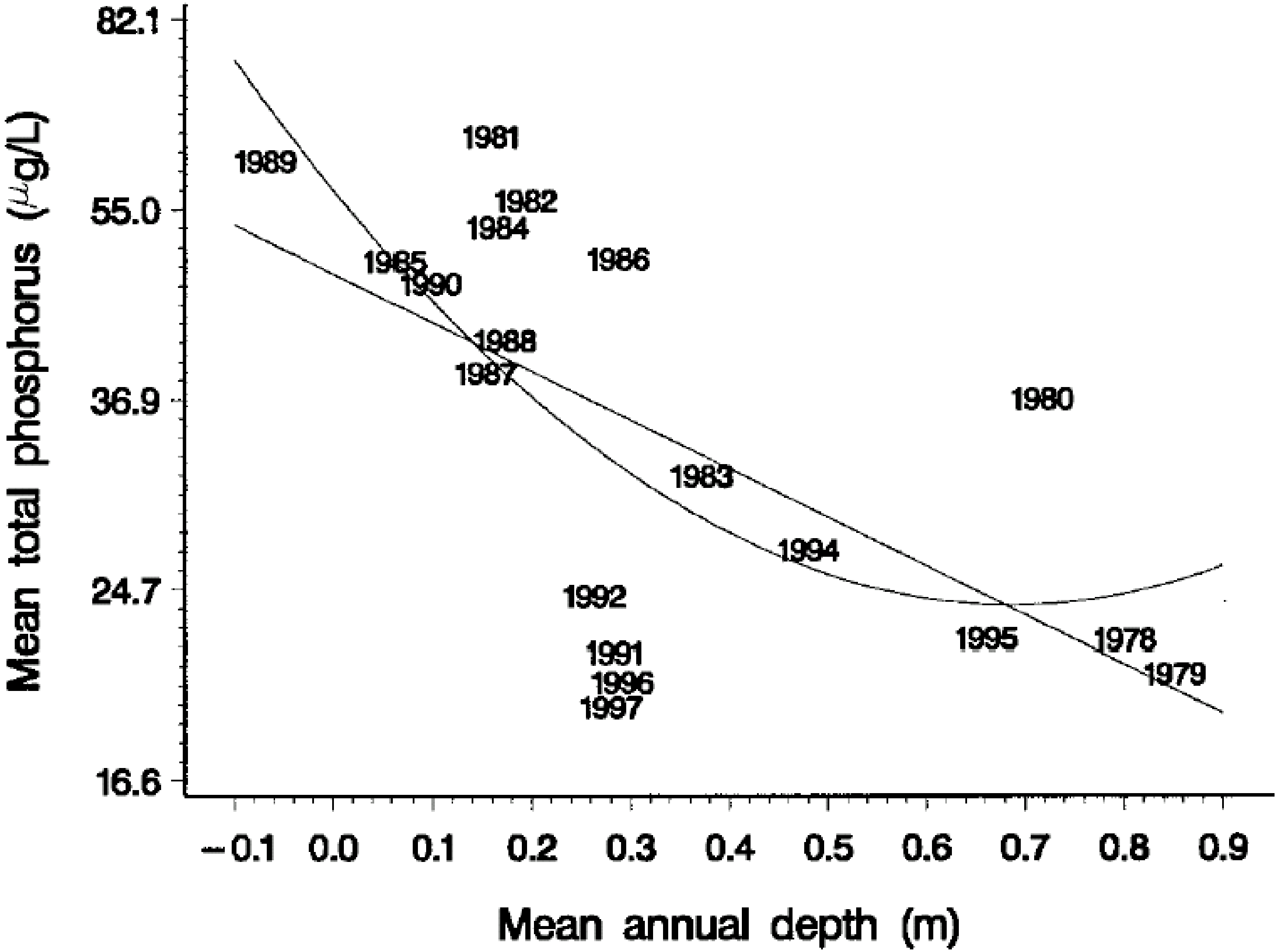


Figure 7. Variation in annual mean log water-column TP concentration in relation to annual mean depth. Lines show best-fit linear (R2 = 0.37, F = 11.75, p = 0.0032 for log-transformed TP) and quadratic (R2 = 0.49, F = 7.74, p = 0.0045, for log-transformed TP regression models. (Smith and McCormick 2001. Environ. Monitoring & Assessmnt 68:153-176)

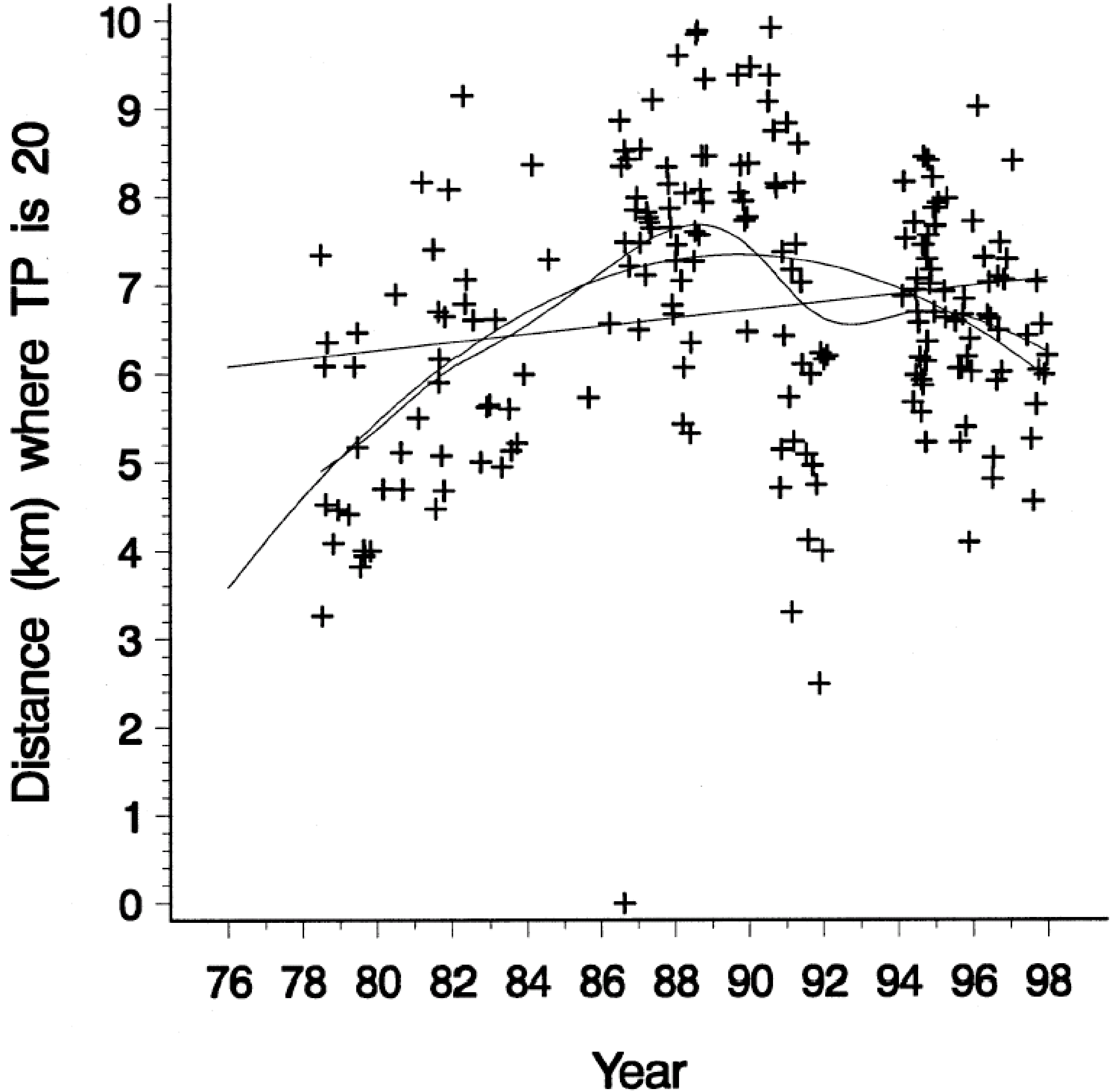
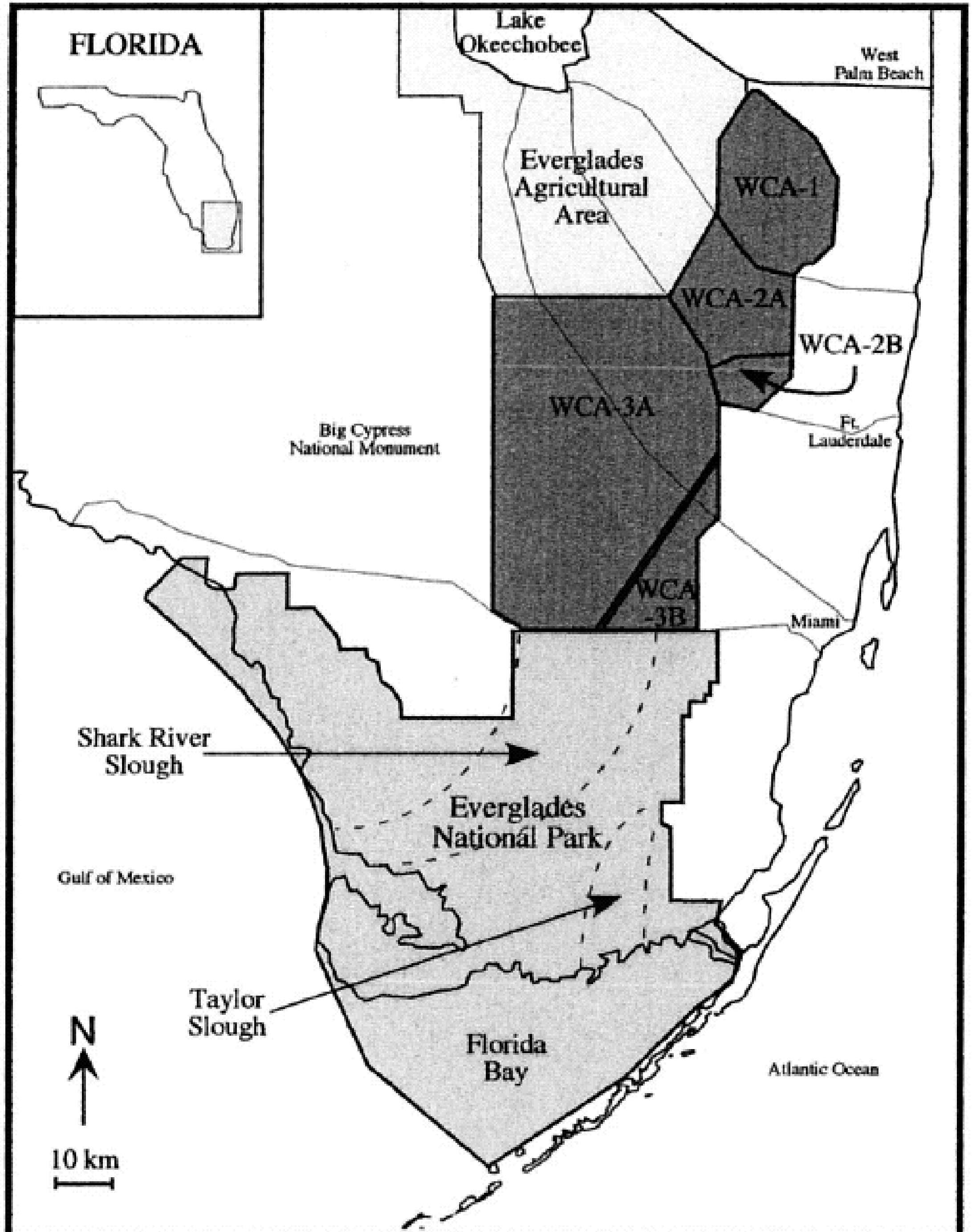
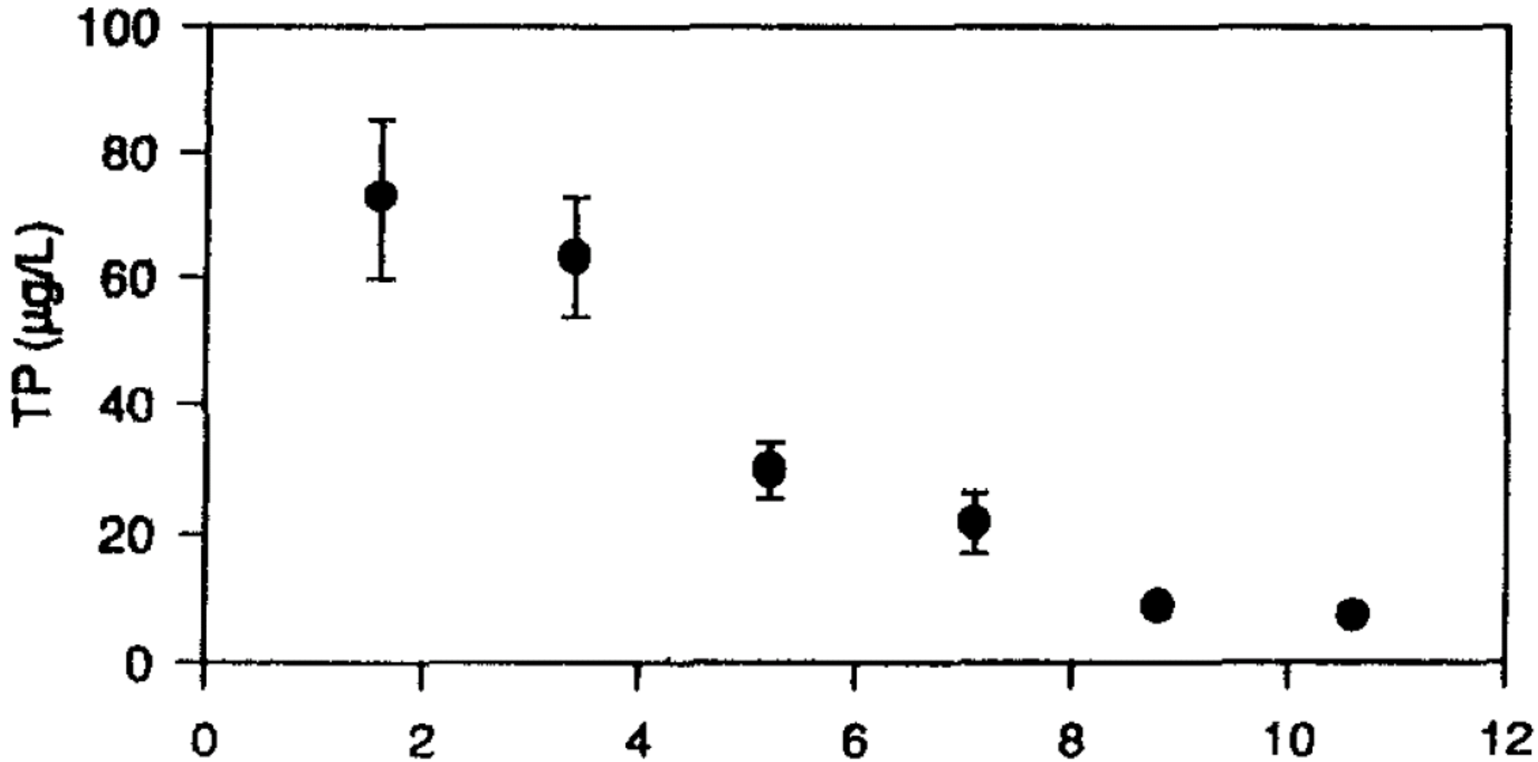


Figure 9. Estimated distance from canal inflows where water-column TP is 20 g L−1 on each sampling date. Curves are plotted for the best-fit linear and quadratic regression and for the smoothed fit. (Smith and McCormick 2001. Environ. Monitoring & Assessmnt 68:153-176)

What cause the P-enrichment in the Everglades?

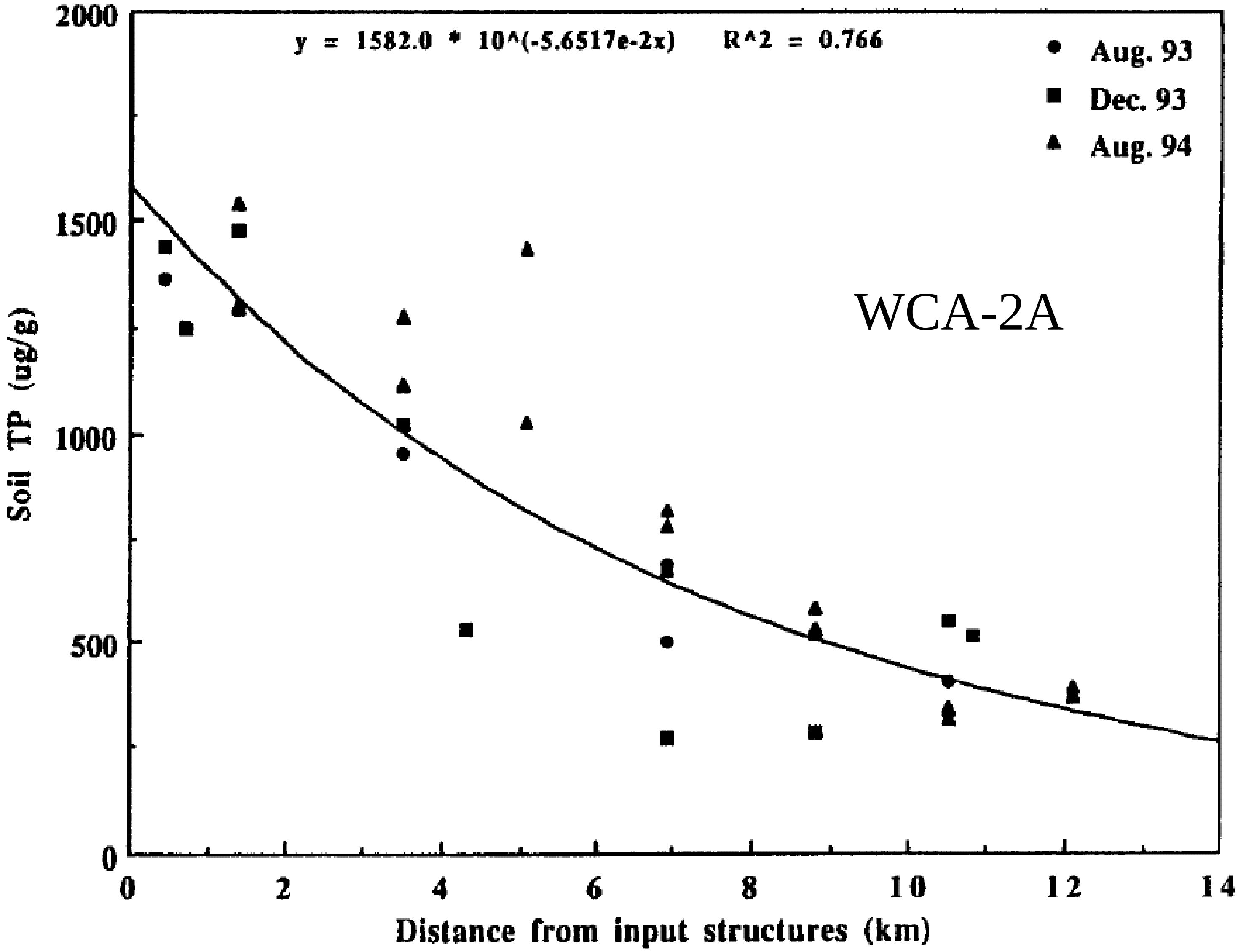
From: Noe et al. 2000. Ecosystem 4:603-624





Distance from input structures (km) for WCA-2A

From: Vaithiyanathan & Richardson 1997. The Sci. of Total Environ. 205:81-95



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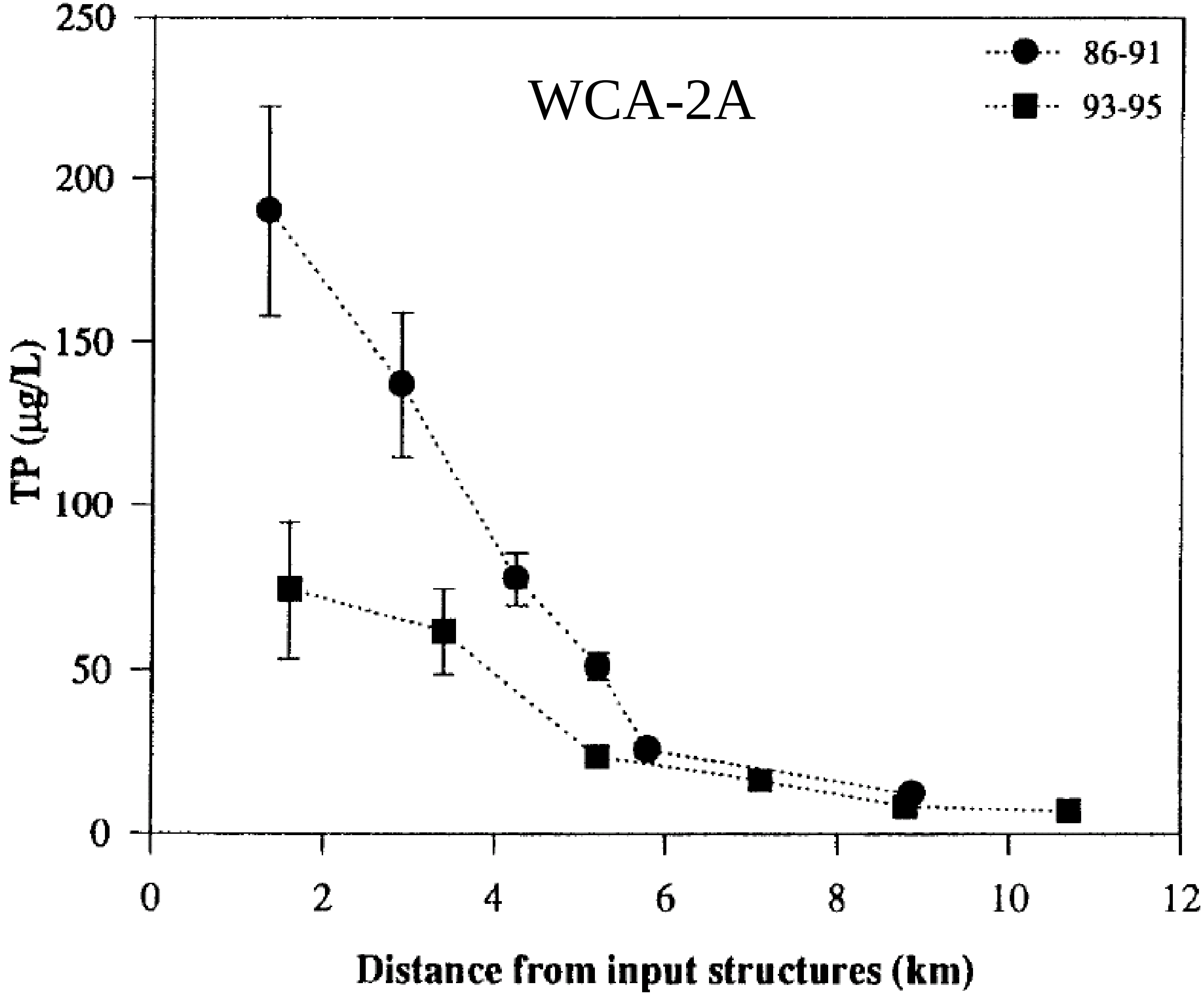

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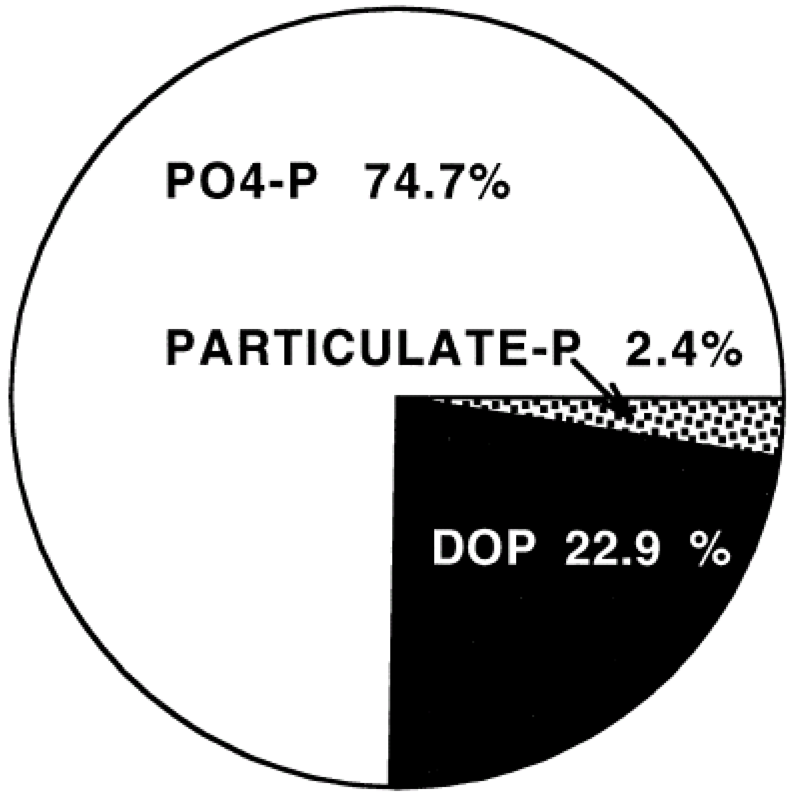


Figure 4. Average proportion of particulate, dissolved organic, and dissolved inorganic P (PO4-P) in surface water in three plots in the un-enriched (southern areas) of Water Conservation Area 2A over the sampling period. Total P concentration was 30 g L^{-1} (± 16 SD). (Qualls & Richardson 2002. Biogeochemistry 62(2):197-229)

Phosphorus enrichment, drainage, agricultural activities, and urban development has resulted in:

1. Saw grass (*Cladium jamaicense*) being replaced by cattails (*Typha spp.*);

2. Periphyton mats (a community of cyanobacteria/algae, bacteria, microfauna) being reduced by the shading of Typha, which may form a positive feedback on P-enrichment because periphyton is more effective in removing P from the water;

3. P-enrichment also change the composition of periphyton mats from original cyanobacteria-dominated production to green algae-based production;

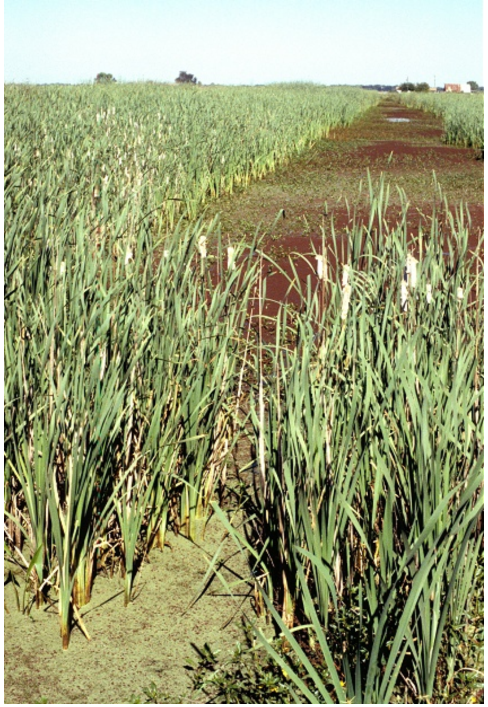
4. An increase in secondary production (e.g., fish);

5. But the number of nesting birds has declined by 90% or more since 1930s;

Therefore, human development has changed the Everglades ecosystem to a very different one.

Cladium jamaicense Crantz
Saw Grass
Cyperaceae: **Sedge Family**

Typha latifolia



Family: Typhaceae
(Cattail family)

Typha domingensis

Typha angustifolia

Table 2. Meta-analysis of Published Data for the Everglades and Other Wetlands

Component	Bedford and Others 1999	Everglades			
		Typha	*Typha/Cladium*	*Cladium*	Slough/Wet Prairie
Water TP	—	76.1 ± 38.8 (5)[a]	42.3 ± 36.2 (5)[a]	10.8 ± 4.8 (5)[b]	10.4 ± 2.5 (8)[a]
Water N:P	—	94.1 ± 52.6 (4)[ab]	228.0 ± 221.1 (4)[bc]	542.0 ± 774.8 (3)[c]	377.6 ± 164.0 (7)[c]
Periphyton TP	—	2885.0 ± 3049.4 (2)[a]	898.0 ± 2884.3 (2)[b]	242.8 ± 337.1 (3)[c]	242.8 ± 120.1 (6)[c]
Periphyton N:P	—	—	86.0	165.0	151.7 ± 50.2 (4)
Soil TP	900 ± 590 (109)	1402.9 ± 165.6 (15)[a]	947.3 ± 230.5 (10)[b]	533.2 ± 94.0 (20)[c]	467.1 ± 116.1 (10)[c]
Soil TP load	—	0.60 ± 0.31 (4)[a]	0.38 ± 0.98 (2)[a]	0.09 ± 0.04 (10)[b]	—
Soil N:P	47.1 ± 1.3 (109)	49.0 ± 10.3 (10)[a]	77.6 ± 20.5 (6)[a]	144.6 ± 30.2 (12)[b]	213.0 ± 80.1 (4)[c]
Macrophyte TP	1400 ± 200 (65)	1509.3 ± 214.6 (3)[a]	515.0 ± 346.7 (4)[b]	193.3 ± 32.7 (7)[c]	396.5 ± 2268.0 (2)[bc]
Macrophyte N:P	32.9 ± 3.8 (48)	16.7 ± 9.0 (3)[a]	40.2 ± 21.8 (4)[b]	76.7 ± 26.2 (7)[c]	62.2 ± 53.3 (3)[bc]

Mean ± 95% confidence interval (CI) is presented with the sample size (number of studies) in parentheses for TP concentration ($\mu g\ L^{-1}$ or $\mu g\ g^{-1}$), molar N:P ratio, and annual soil TP load ($g\ m^{-2}\ y^{-1}$).
Different letters indicate that a significant difference ($\alpha < 0.05$) exists among Everglades habitats, as determined by Tukey's post hoc tests.
Summary statistics are calculated from the analysis by Bedford and others (1999) of nutrient concentrations in temperate North American wetlands. Macrophyte N:P data from Bedford and others (1999) only include values from peat-based wetlands.
The mean is presented when $n = 1$; — dashes indicate that data was not found in the literature.
Bolded cells indicate that the 95% CI of a parameter in the Everglades and in temperate North American wetlands (Bedford and others 1999) do not overlap.

From: Noe et al. 2000. Ecosystem 4:603-624

The ultimate question:

How can we balance the need for development with the need of maintaining healthy natural ecosystems?