



United States
Environmental Protection
Agency

Region 4 Science &
Ecosystem Support Division
and Water Management Division

EPA 904-R-07-001
September 2007

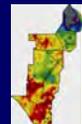
Everglades Ecosystem Assessment: Regional Environmental Monitoring and Assessment Project (R-EMAP)

A Status Report

Peter Kalla, Program Leader

Dan Scheidt, Associate Program Leader

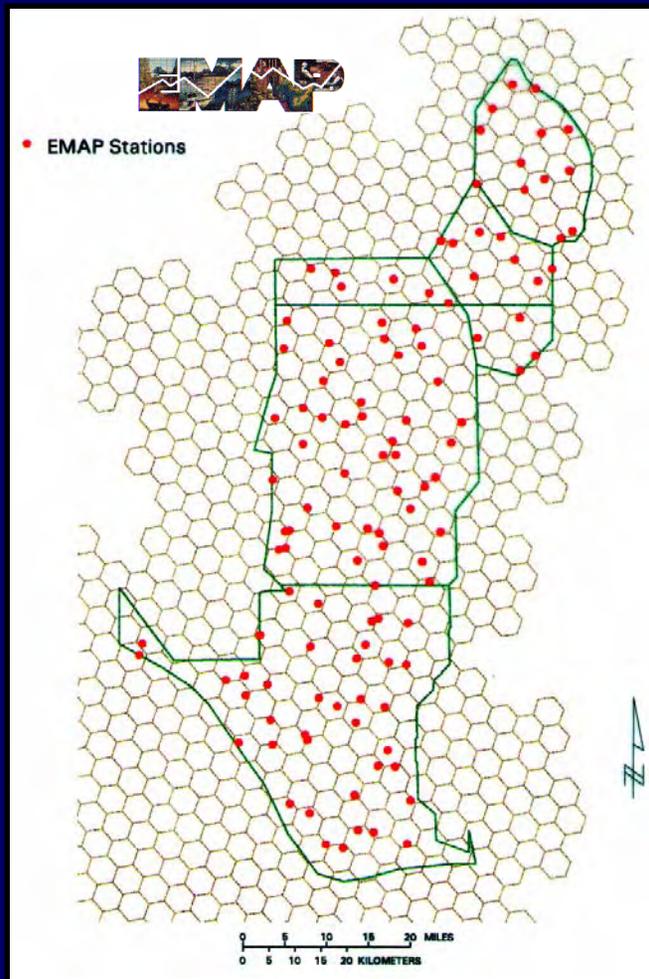
EVERGLADES ECOSYSTEM ASSESSMENT PROGRAM



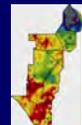


BACKGROUND

Probability-based Design

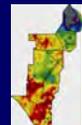


- Reviewed by National Academy of Sciences.
- Every member of a statistical population has a known chance of being selected and the samples are drawn at random.
- ***Can estimate with known confidence the status of ecological resources (% of area +/- CI)***
- Only multi-media project across entire Everglades Protection Area (EPA) with probability-based design.



Probability-based Design

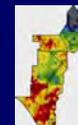
- EMAP design widely used by USEPA and states throughout the U. S. since 1990
- Estuaries, streams, rivers, lakes, wetlands, forests.
- Maine lakes, New York Harbor, California's Central Valley
- National Coastal Assessment
- Wadeable streams



Sampling Everywhere

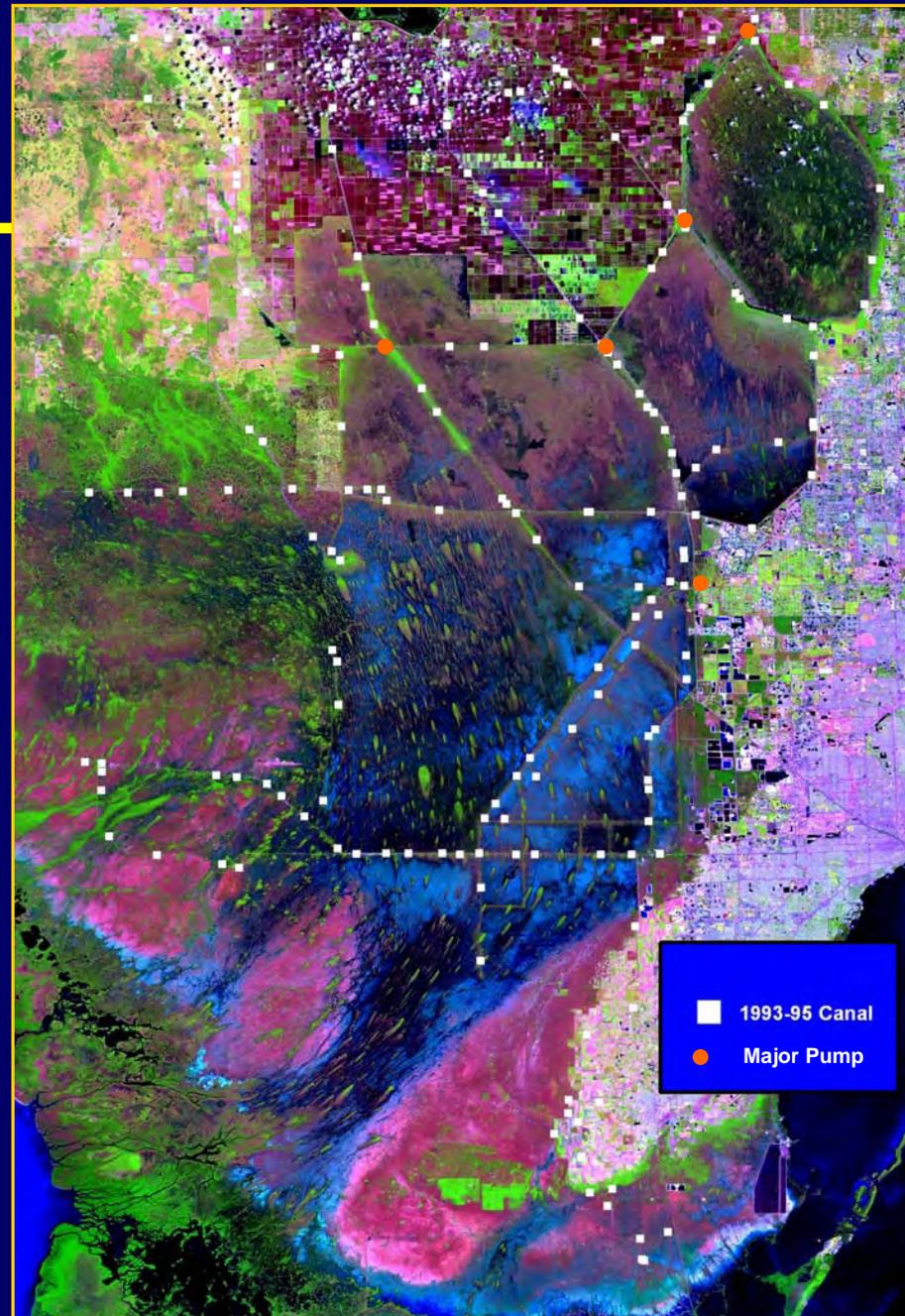


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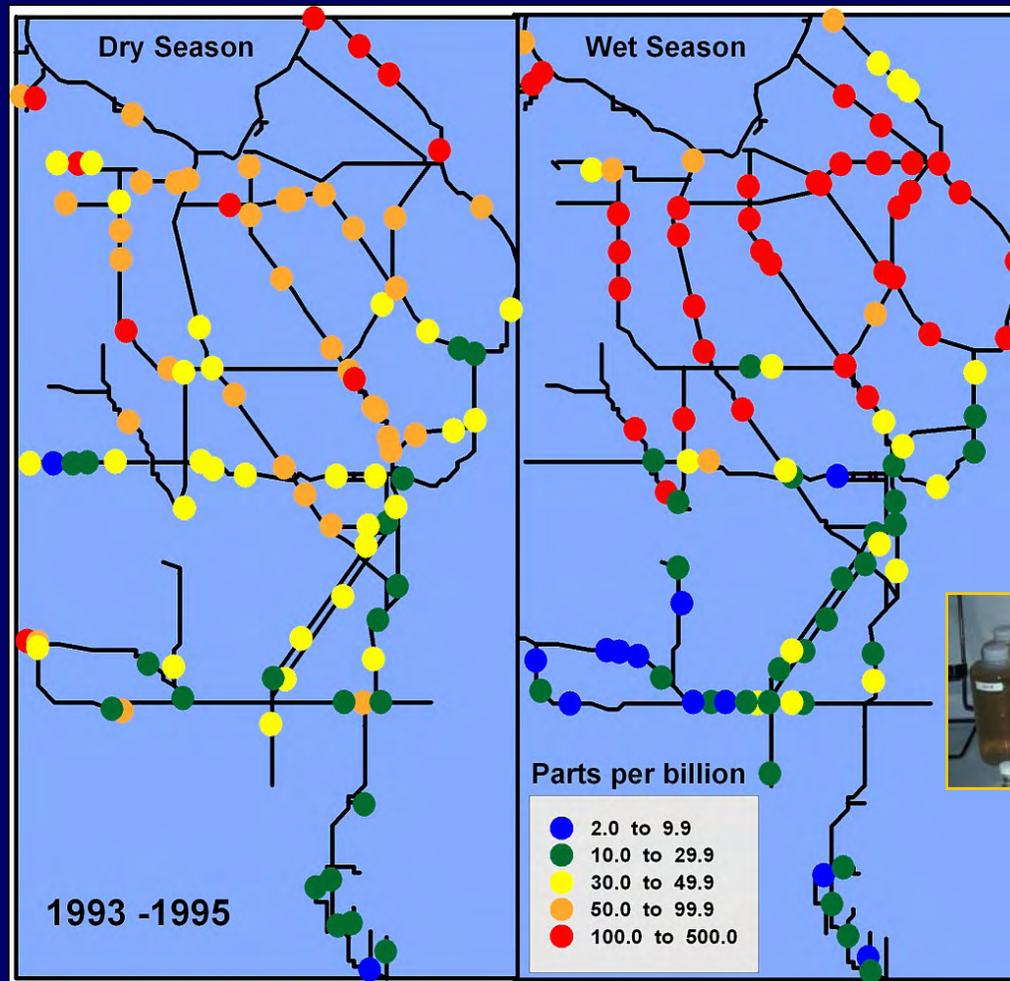


Program Initiation

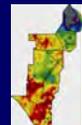
- Phase I Canals
1993-95
- 199 stations
- mercury & nutrients
- Canals a conduit
for stormwater
transport
- Distinct gradients
in P, S, C, and
conductivity



Canal Total Phosphorus



EVERGLADES ECOSYSTEM ASSESSMENT PROGRAM



Marsh Sampling 1995-2005

EMAP probability based
design

Phase I Canal = 1993-95

Phase I Marsh = 1995-96

Phase II Marsh = 1999

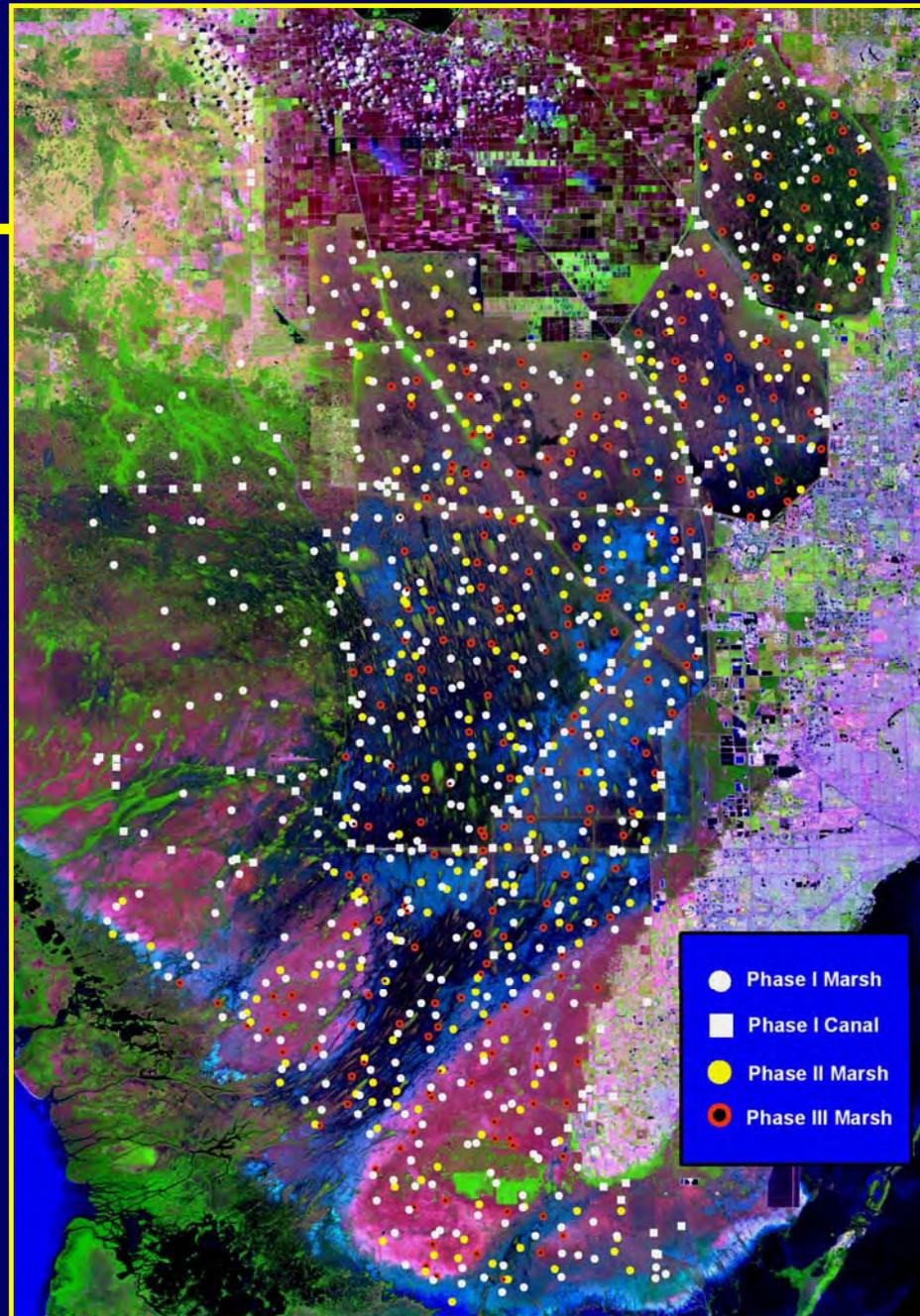
Phase III Marsh = 2005

1145 Sample Sites

~100,000 biogeochemical
data values

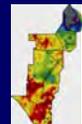
~\$6M investment to date

CERP cost ~ \$11 billion



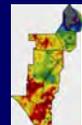
Project Data Uses: EFA

- Assess phosphorus in EPA habitats other than wet prairie.
- Assess soil TP throughout EPA, independently corroborate other sampling efforts (TP rule).
- Assess periphyton communities, cattail presence, TP throughout EPA.
- Assess mercury conditions, track response in water & fish due to atmospheric controls, TMDLs.
- Assess water quality conditions and transport throughout EPA (P, S, conductivity).
- Perform multi-variate analyses (Hg, S, C) to understand S-Hg interactions.



Project Data Uses: CERP

- Show U. S. Congress, GAO, taxpayers what they are getting for their \$11 billion.
- Pre-CERP baseline established 1995-96.
- Fill monitoring and assessment gaps while providing integrated, consistent, comparable coverage.
- Provide input to CERP conceptual models, EDEN.
- Provide input to SFWMM, ELM, CALM, ATLSS, WQ models, Hg models, S models, etc.



Everglades R-EMAP data users through 2007



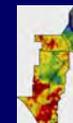
- Mercury control
- Phosphorus control
- CERP
- Water Management
- Sulfur contamination



Data users form their own conclusions.

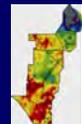


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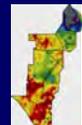
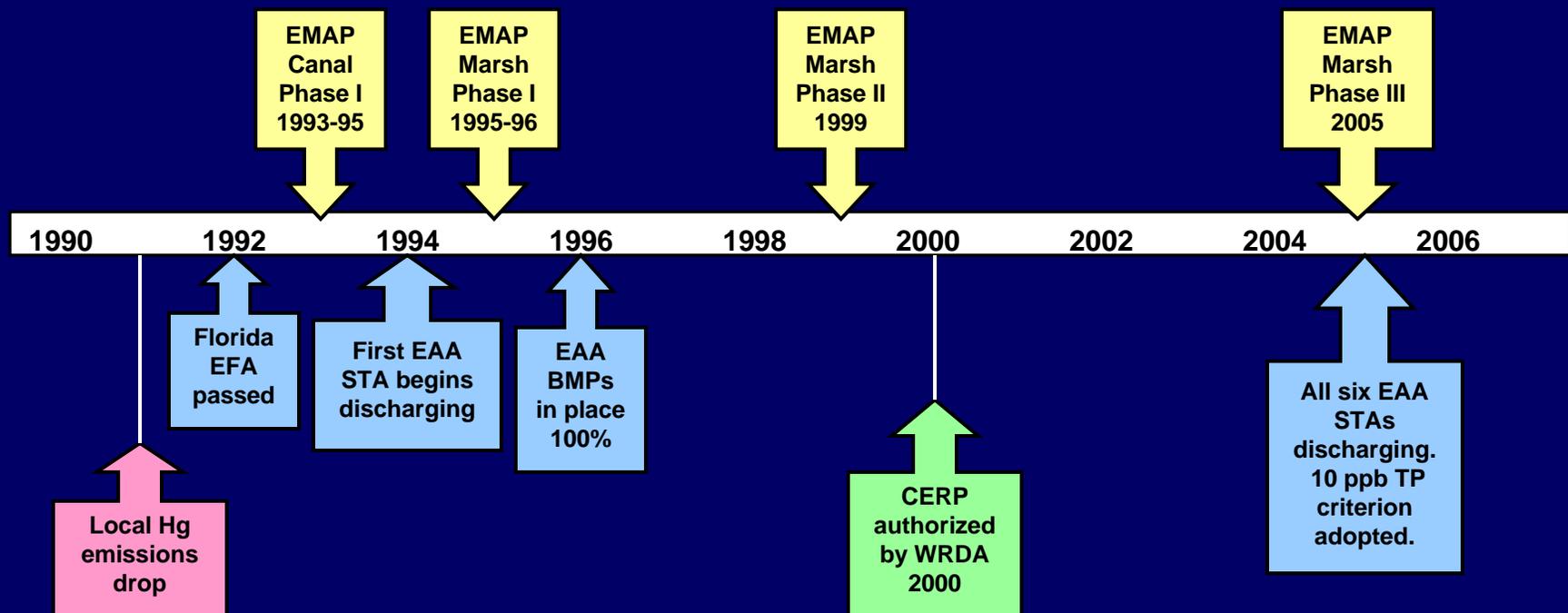


2005 Program Planning

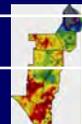
- 2003 - 04 planning input from FDEP, SFWMD, COE, USFWS, ENP, USGS, others ~ media, parameters, methods. Maximize program utility.
- P, Hg, S experts consulted.
- Coordinated with CERP MAP
 - data for 13 of 24 GE performance measures
- Independent scientific peer review of study plan.



R-EMAP Program Timeline



Phase	I	II	III
Year(s)	1995 & 1996	1999	2005
Distinguishing features	Baseline data. Multiple stressors. Big Cypress included. Canals included 1993-95.	Plant studies added. Periphyton assessment added. Canals & Big Cypress omitted.	Change detection. Food web studies added. Invasive plant survey added.
Marsh Stations	240 + 240 = 480	119 + 119 = 238	109 + 118 = 228
<i>Biogeochemical media:</i>			
Surface water	Yes	Yes	Yes
Floc	No	Yes	Yes
Pore water	No	Yes	Yes
Soil	Yes	Yes	Yes
Periphyton	Yes	Yes	Yes
Mosquitofish	Yes	Yes	Yes
<i>Macrophytic plants:</i>			
Qualitative habitat categorization	Yes	Yes	Yes
Species frequency	No	Yes	Yes
Classified vegetation mapping	No	Yes	Yes
Invasive plant survey	No	No	Yes
<i>Community ecology:</i>			
Periphyton assemblage	No	Yes	Yes
Mosquitofish food habits	No	Yes	No
Macroinvertebrate assemblage	No	No	Yes
Isotope studies	No	No	Yes



Program Elements

Chemical analytes in biogeochemical media

Surface water

Floc

Pore water

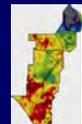
Soil

Periphyton

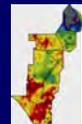
Mosquitofish

Macrophytic plants

Community ecology

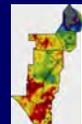


Media and Techniques



2005 Phase III Effort

- Investment ~ \$1.6M: 2005 sampling & products
USEPA OW/SFO, USEPA ORD, NPS, FDEP, COE
\$740K from outside partners
- May (dry season), November (wet season) 2005 sampling
 - 228 stations, 3000 square miles, 25,000 data points, 7 field weeks, 3 helicopters
- USEPA in-kind : additional ~\$500K
 - personnel, equipment, data interpretation, report writing
- Field crew USEPA/FIU~ 30 people
- 8 analytical labs, ~ 60 analyses
- Acknowledgements: 90 people



Collaboration



- \$160K, in-kind analytical lab support



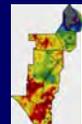
- \$280K



- \$300K

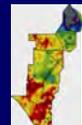


- 2007, 2008 South Florida Environment Report by FDEP and SFWMD (S, Hg, conductivity)
- 5 data requests to date (SFWMD, FDEP, USGS, Clean Water Fund)



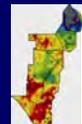
2005 QA/QC Outcome

- ~ 110 sample stations in May; 1970 containers
- ~ 120 sample stations in November; 3110 containers
- All critical analyses (P, Hg, S) done at NELAP-accredited labs
- ~ 25,000 biogeochemical data values
- 100% of analytical data were reviewed; only 2 results were rejected, others were qualified
- 99.99% of results met program data quality objectives
- Investment ~ \$100,000 contractual and 700 hours USEPA



Program Status

- **Biogeochemical Data**
 - Report released
 - multivariate analyses, data synthesis on-going
- **Macrophyte community analysis report available**
- **Periphyton lab analyses ongoing**
- **Aquatic food web: lab analyses ongoing**



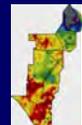


SUMMARY OF FINDINGS

Program Statistical Tools

1995/96 -- 1999 -- 2005

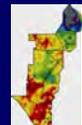
- **Weight of Evidence Approach**
 - **Box-and-whisker plot** (data distribution, changes)
 - **Krig** (spatial patterns, changes)
 - **Cumulative Distribution Function plot** (impacted area [%], +/- CI)
 - **Cumulative Distribution Function test** (Has impacted area changed over time?)
 - **z-test** (Are years different?)
 - **Multivariate analyses** (associations, causative factors)



Program Findings

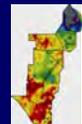
1995/96 -- 1999 -- 2005

- **General statements**
 - major findings only
 - about entire system
 - about proportion impacted
 - all changes reported are statistically significant



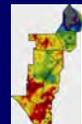
Program Findings 2005

- **Areal Extent of Stressors**
 - TP in soil: 24% of EPA > 500 mg/kg; 49% > 400 mg/kg CERP goal
 - Hg in mosquitofish: 65% > 77 ug/kg
 - Sulfate in water: 57% > 1.0 mg/L
- **Soil Thickness**
 - No further loss of soil by subsidence



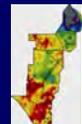
Program Findings 1995 -- 2005

- **Mercury**
 - **Bioaccumulation**
 - Mosquitofish: pronounced drop
 - **Surface water:**
 - Less methyl mercury
 - More total mercury



Program Findings 1995 -- 2005

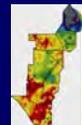
- **Sulfur**
 - Less water impacted by sulfate
 - Sulfate, sulfide contamination continue
 - Geographically, EAA remains the major source



Program Findings

1995 -- 2005

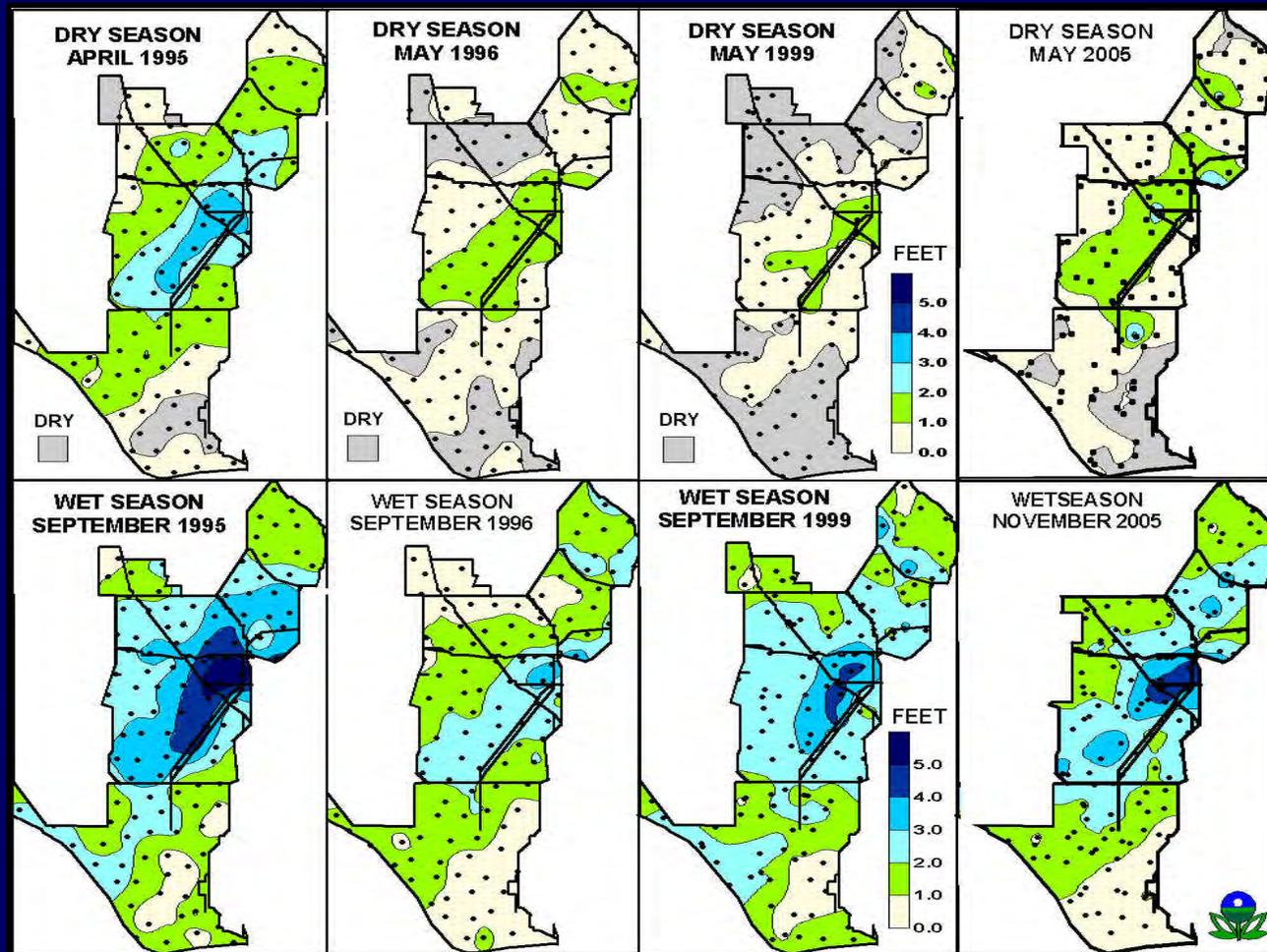
- **Phosphorus**
 - **Less in water**
 - **Contamination persists**
 - **More in soil**



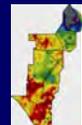


RESULTS

Krigs of Everglades Water Depth

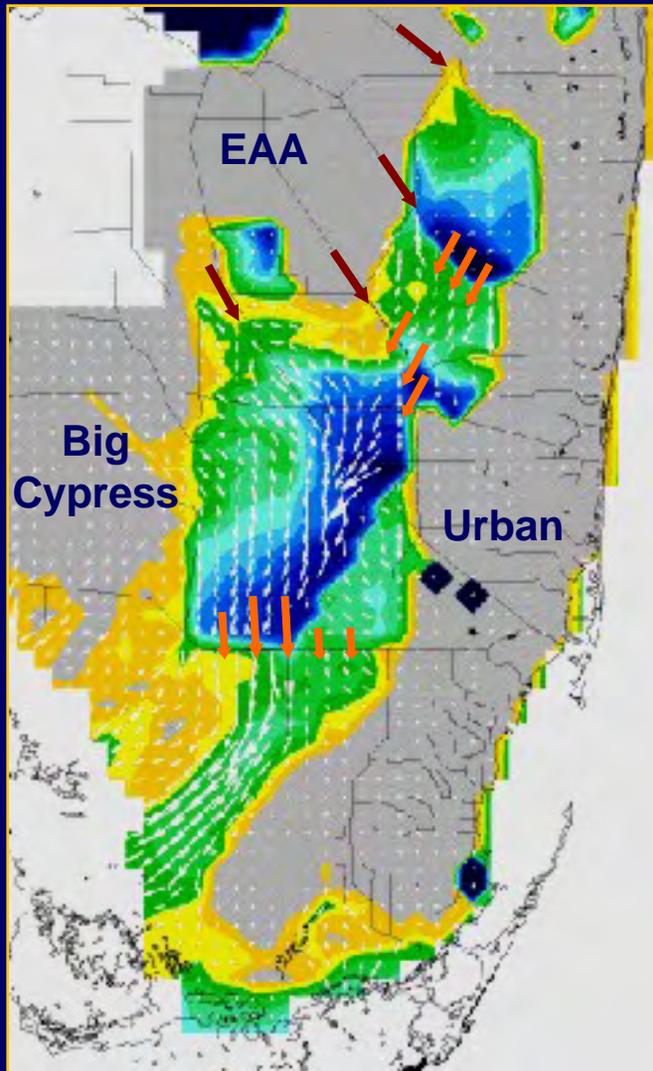


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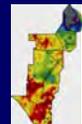


Wet Season Water Flow Vectors

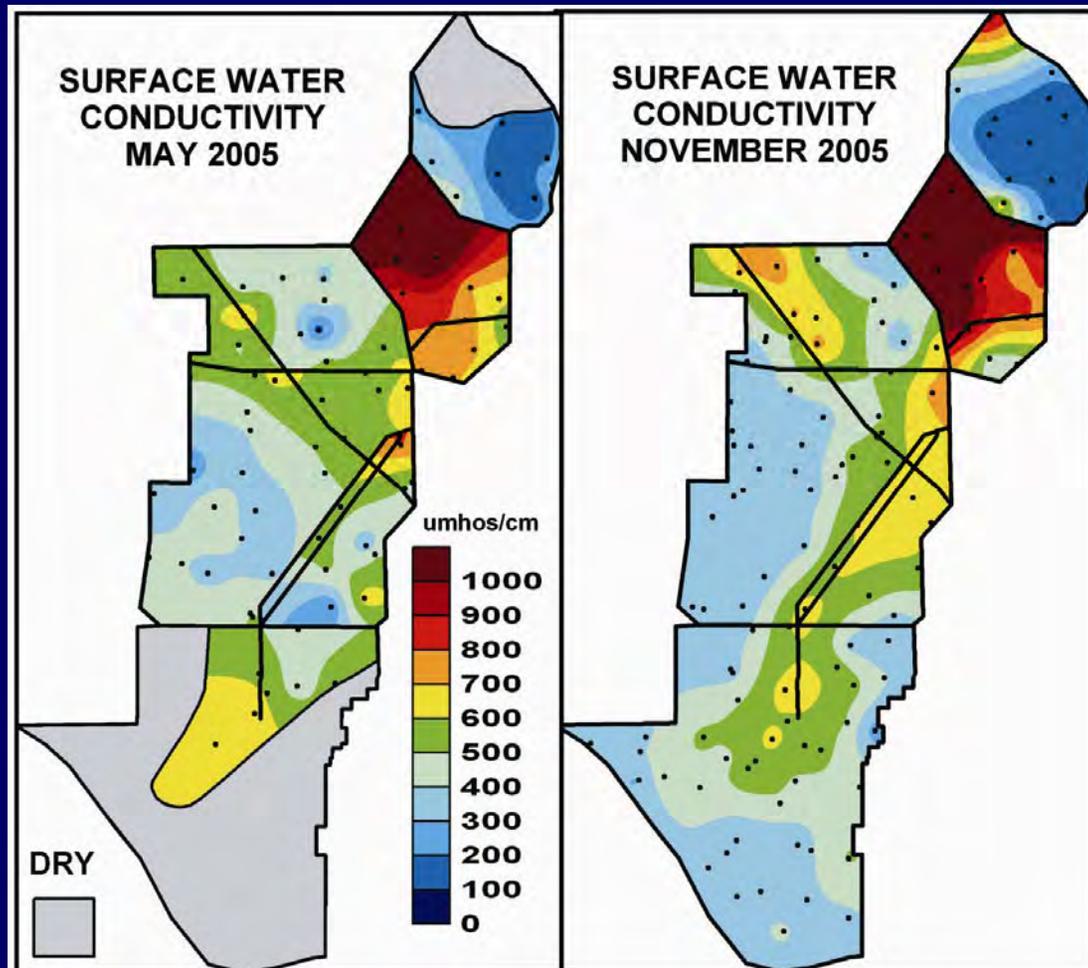
1995 Base Model



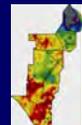
- Stormwater pumped from EAA & S-9
- Canals, levees, & ground relief dictate where water moves
- Interior portions of marsh are rain-driven
- Canals transport water great distances.
- Very flat -- marsh gradient only inches per mile



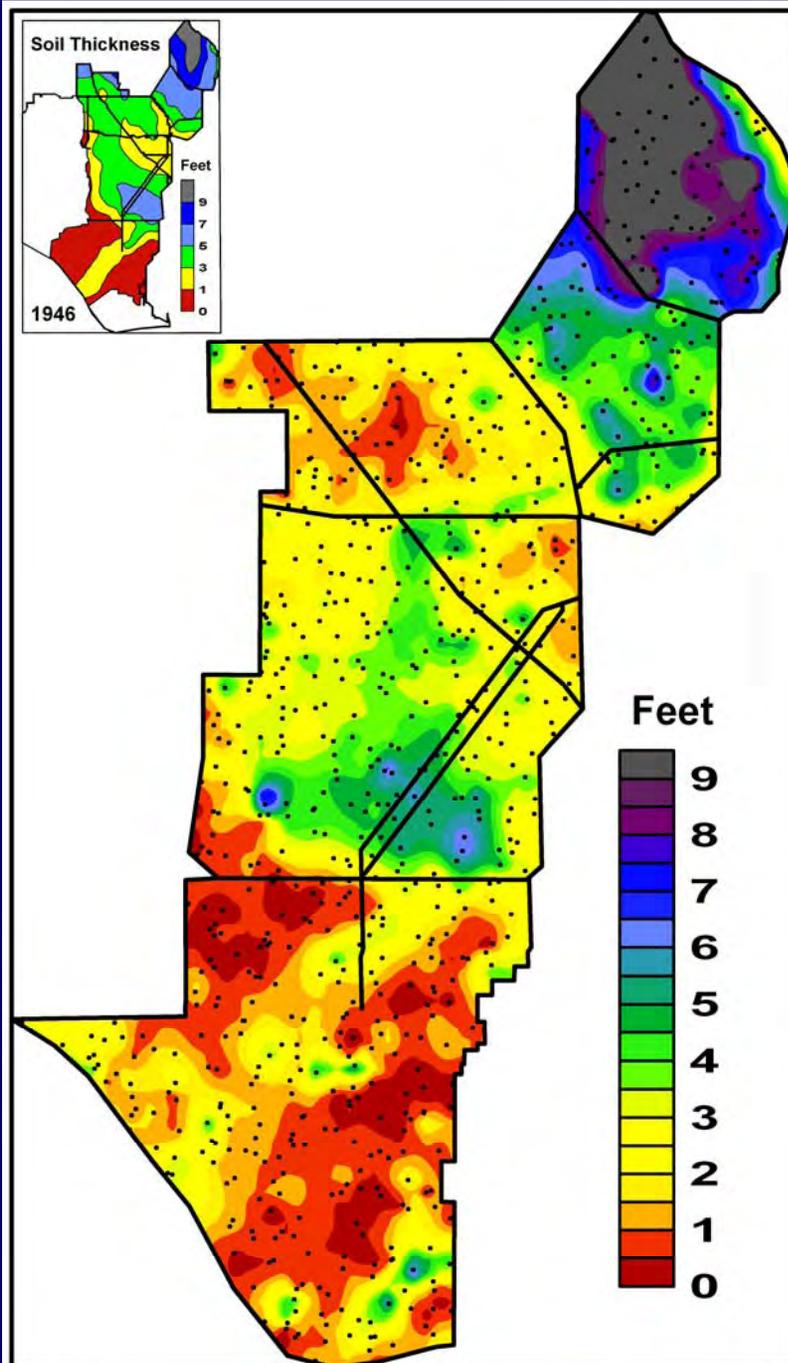
Surface Water Conductivity



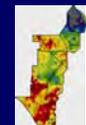
Rainfall
~ 15 umhos/cm



Soil Thickness

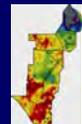


- 867 sample sites
- Pronounced soil loss from 1940s to 1995
~ N WCA3 and NE Shark Slough
- No change since 1995/96
- Still the only database since the 1940s



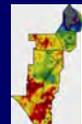
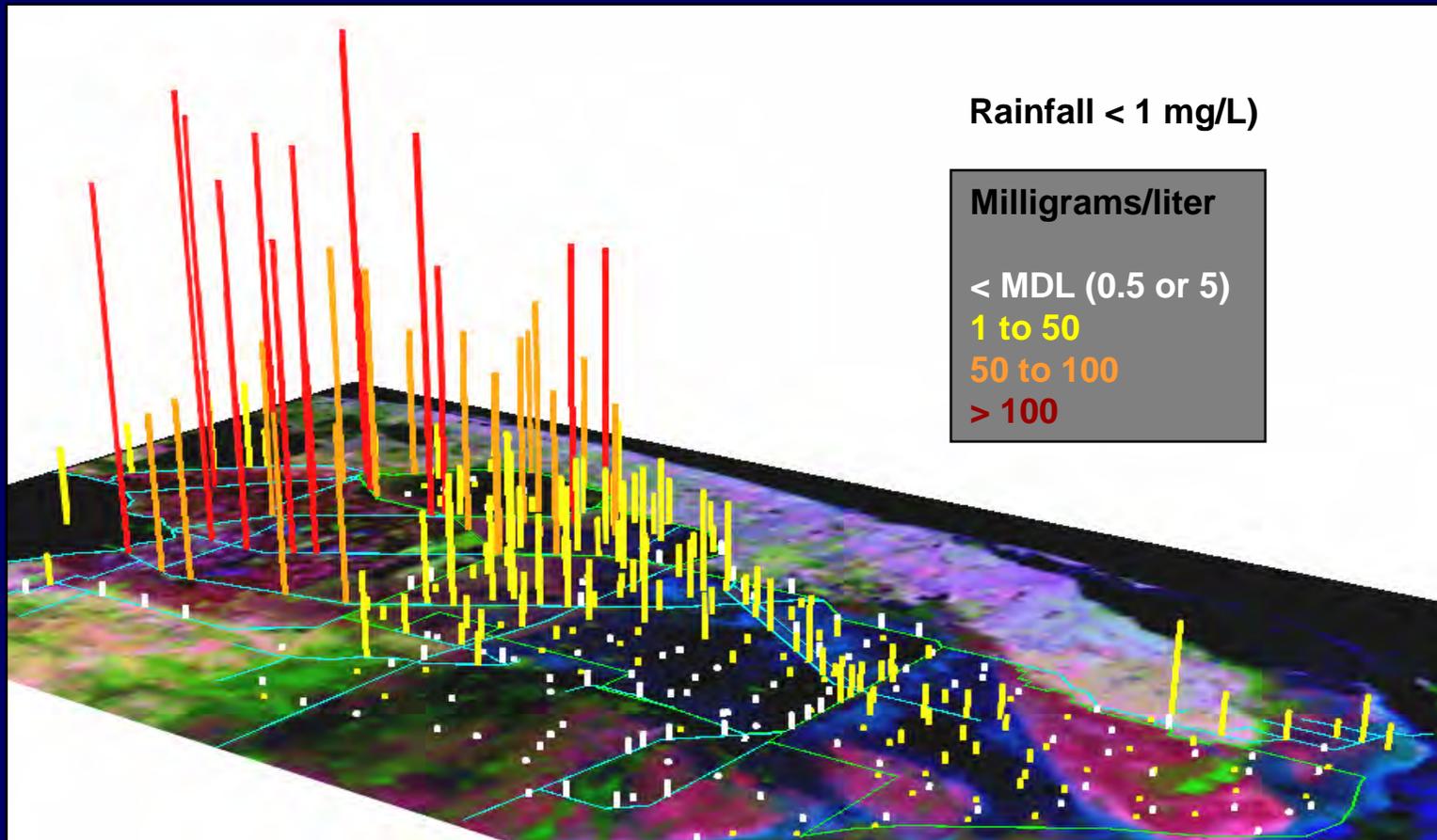
Sulfur Enrichment

- No numeric water quality criteria in Florida
- Sulfate in stormwater discharges into Everglades > 100 x background
- STAs remove minimal amount of sulfate.
- Sulfate → sulfide when anerobic
- Some sulfate enhances mercury methylation. Excess sulfide inhibits
- Sulfur can mobilize phosphorus. STAs?
- Hard water impacts Refuge biota such as periphyton
- Sulfide can be toxic to plants



Surface Water Sulfate 1993-96

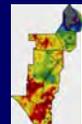
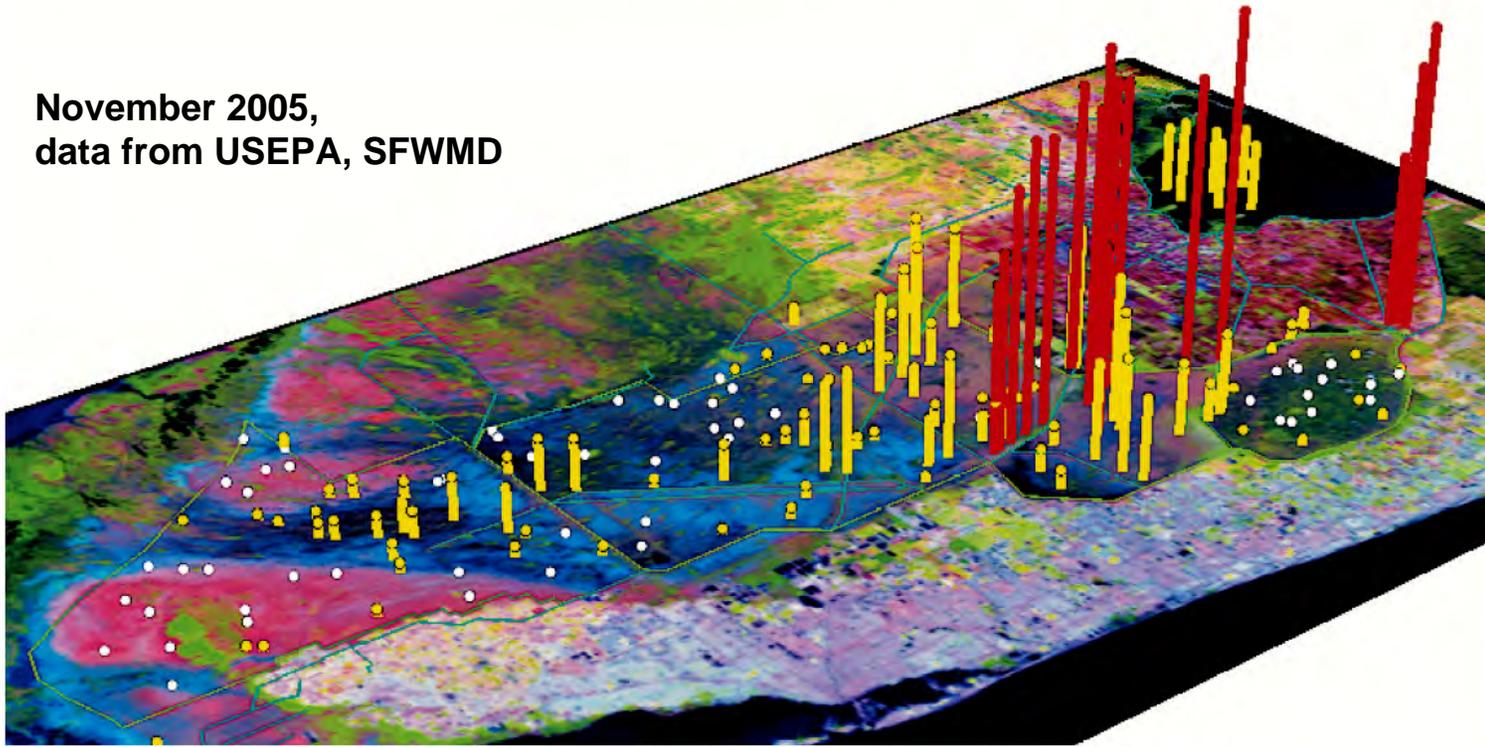
Wet Season



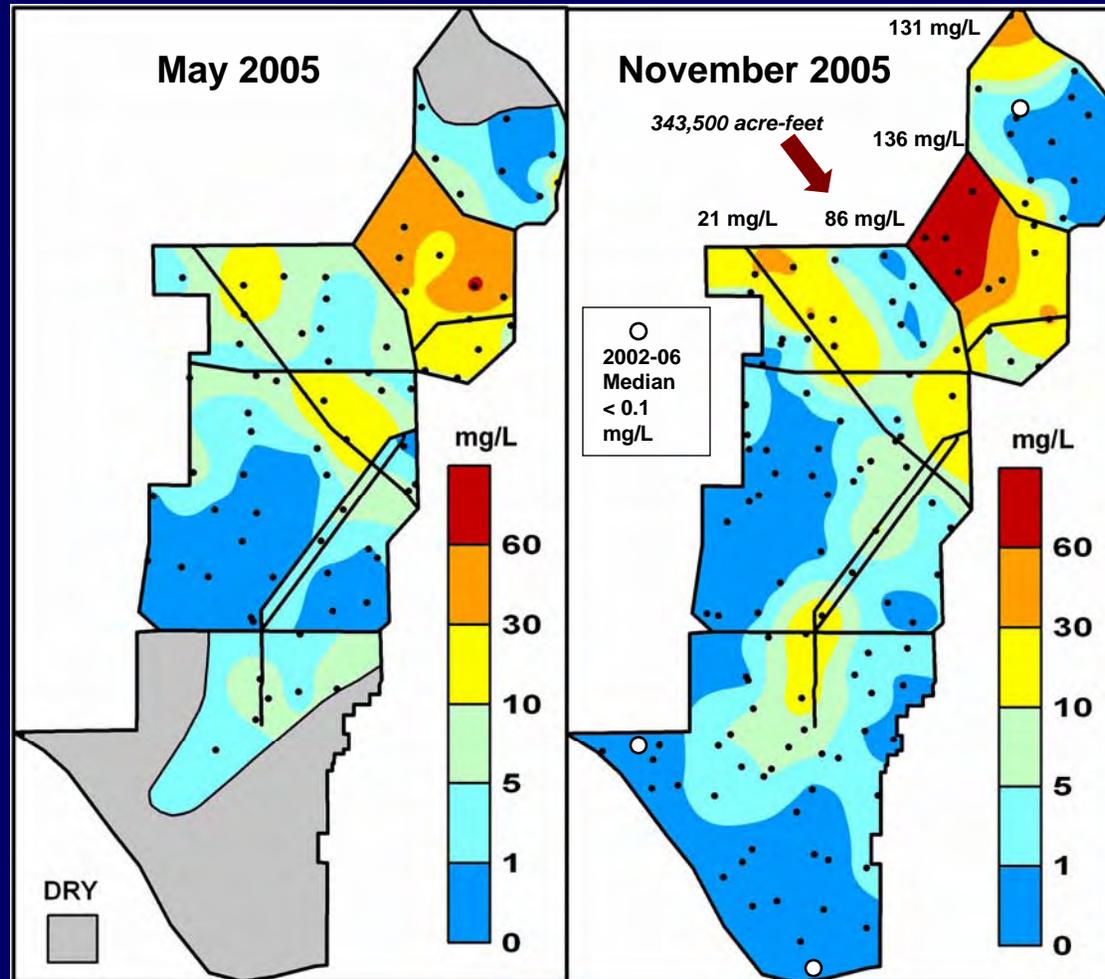
Surface Water Sulfate 2005 Wet Season

-  Sulfate > 50 mg/L
-  Sulfate 1-50 mg/L
-  Sulfate < 1 mg/L

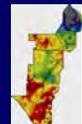
November 2005,
data from USEPA, SFWMD



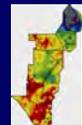
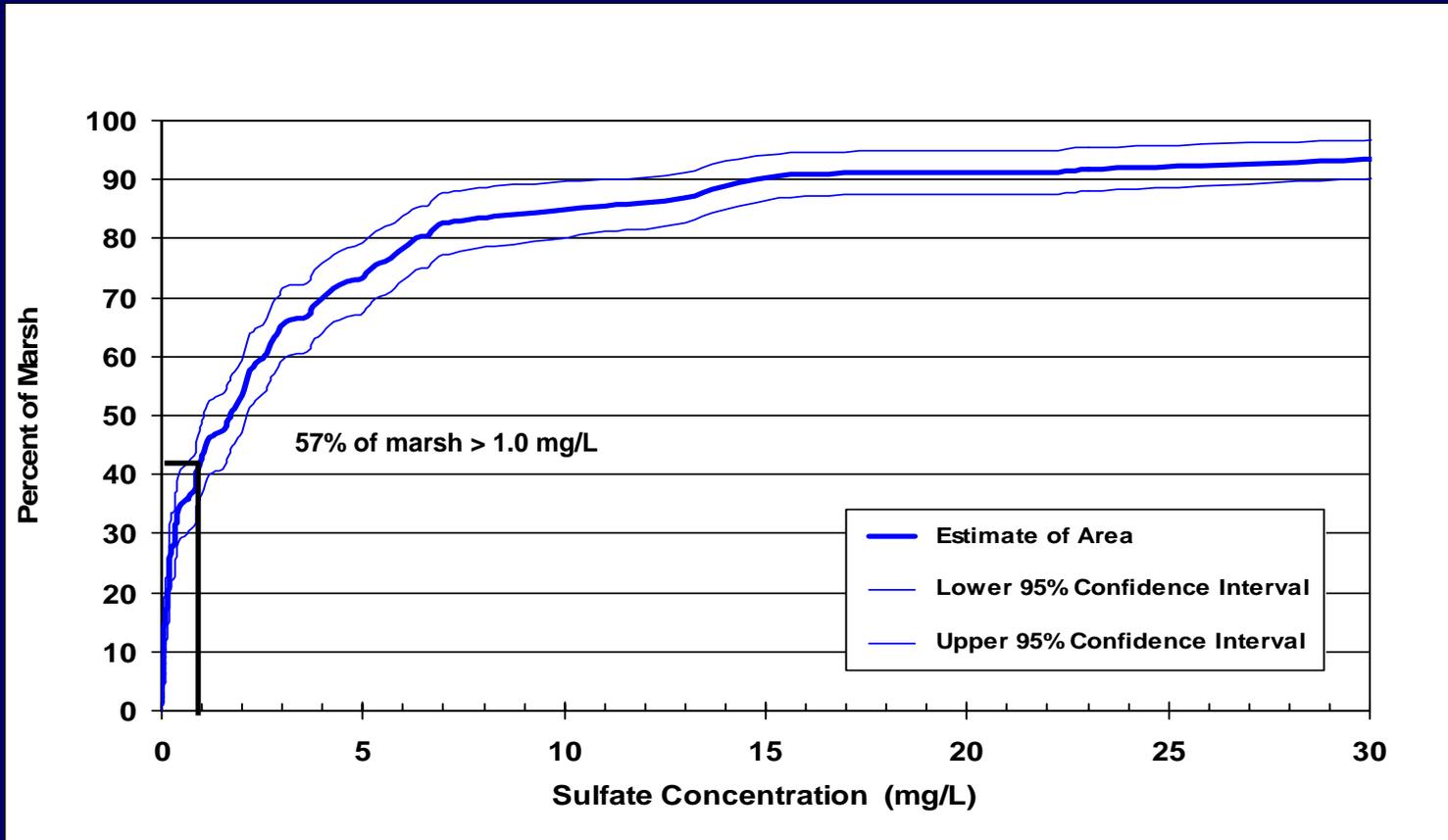
Surface Water Sulfate 2005



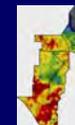
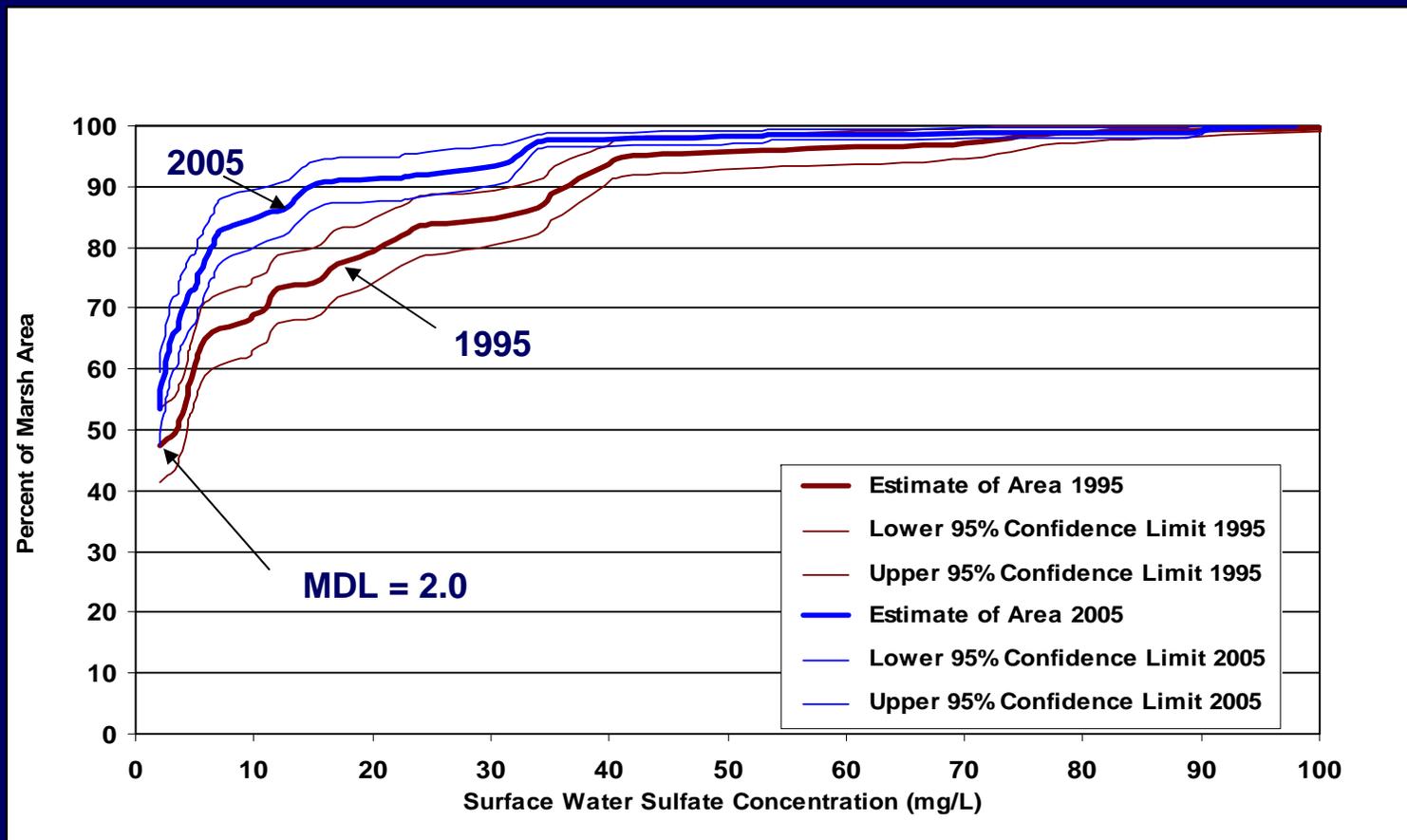
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Surface Water Sulfate 2005 Wet Season



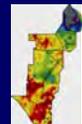
Surface Water Sulfate, 1995 & 2005 Wet Season



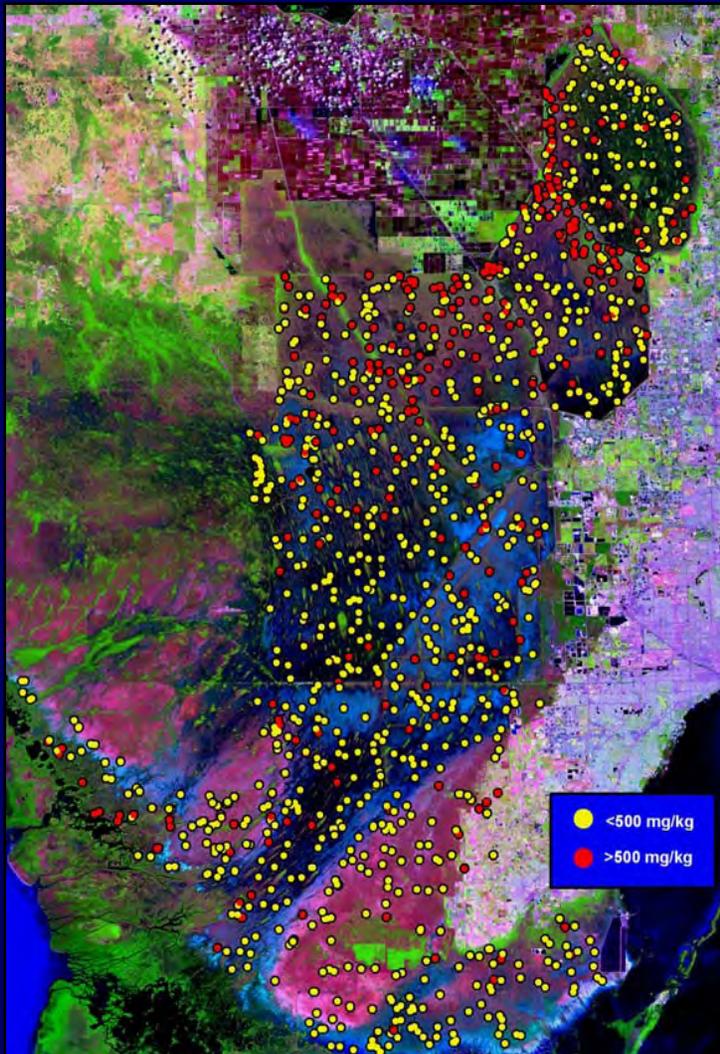
Program Findings

1995/96 -- 1999 -- 2005

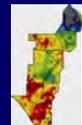
- Sulfur
 - Less water impacted by sulfate
 - 4/4 lines of evidence
 - Decline is not consistent over time
 - Year-to-year variation is apparent
 - 3.60 ↘ 2.25 ↗ 2.05 ↘ 2.00 mg/L



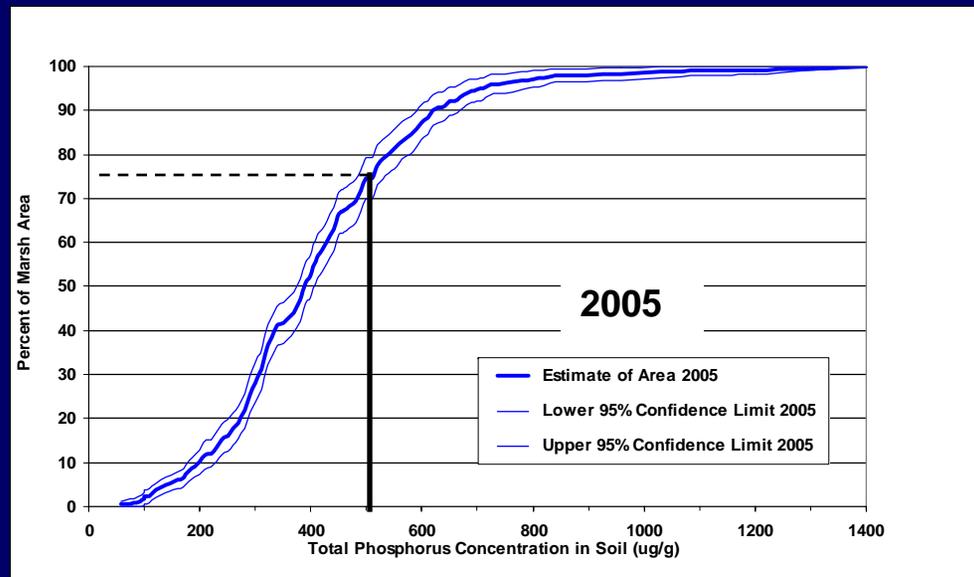
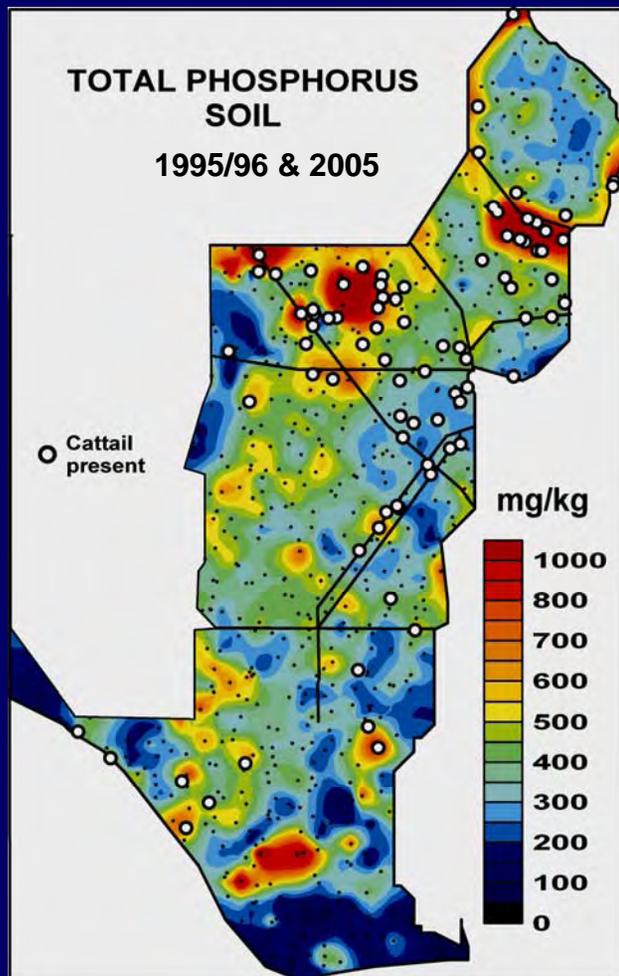
Total Phosphorus in Soil 2003-2005



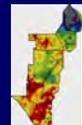
- FAC definition of P-impacted for EPA: >500 mg/kg, 0–10 cm
- N = 1270, data from USEPA, SFWMD/UF



Total Phosphorus in Soil

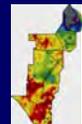
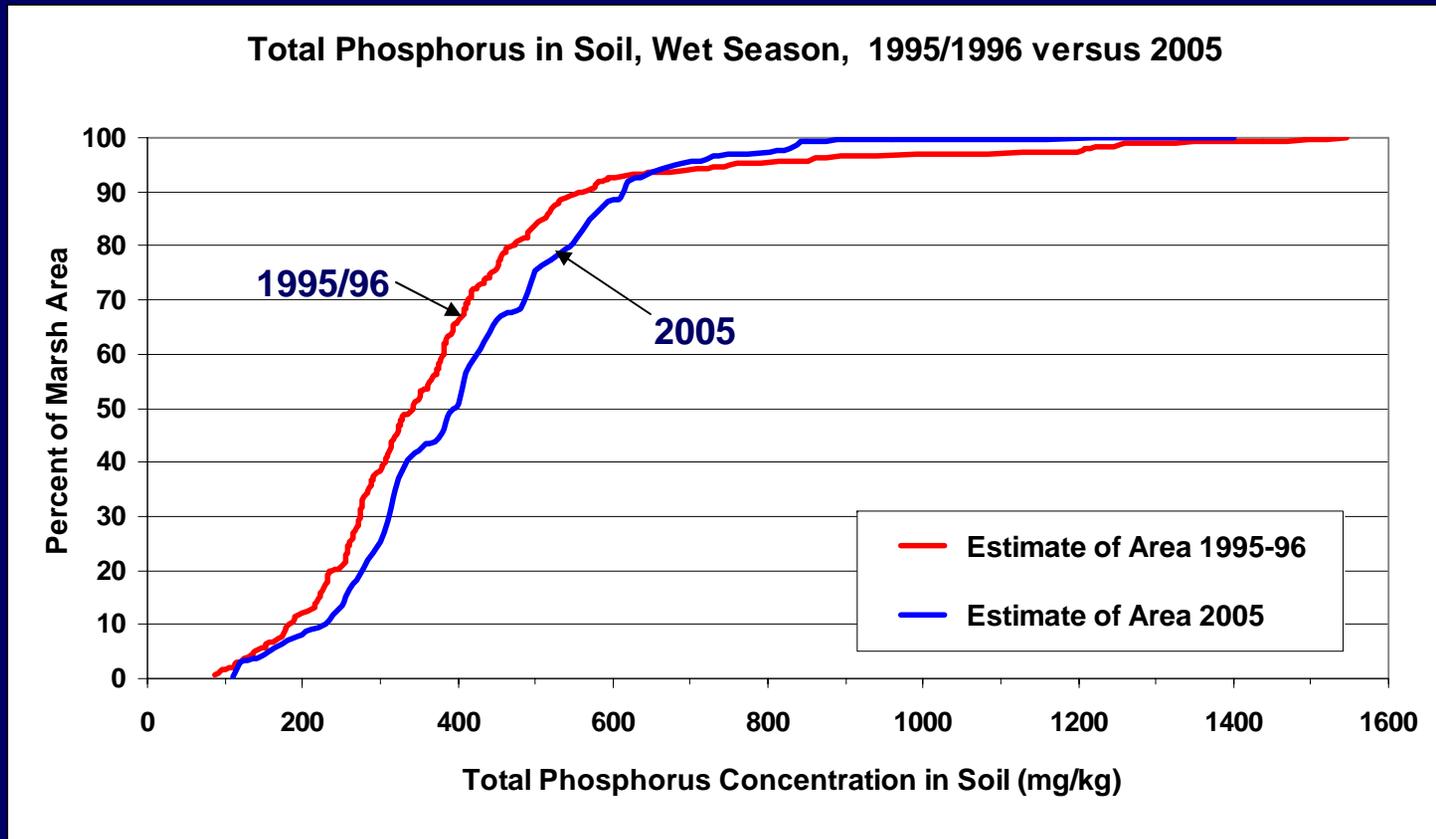


- 2005: 24 % > 500 mg/kg [= “impacted” (FDEP)], 49 % > 400 mg/kg (CERP restoration goal)
- Cattail present at 19 % of stations in 2005
- 15 % (median) increase from 95/96 to 2005



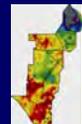
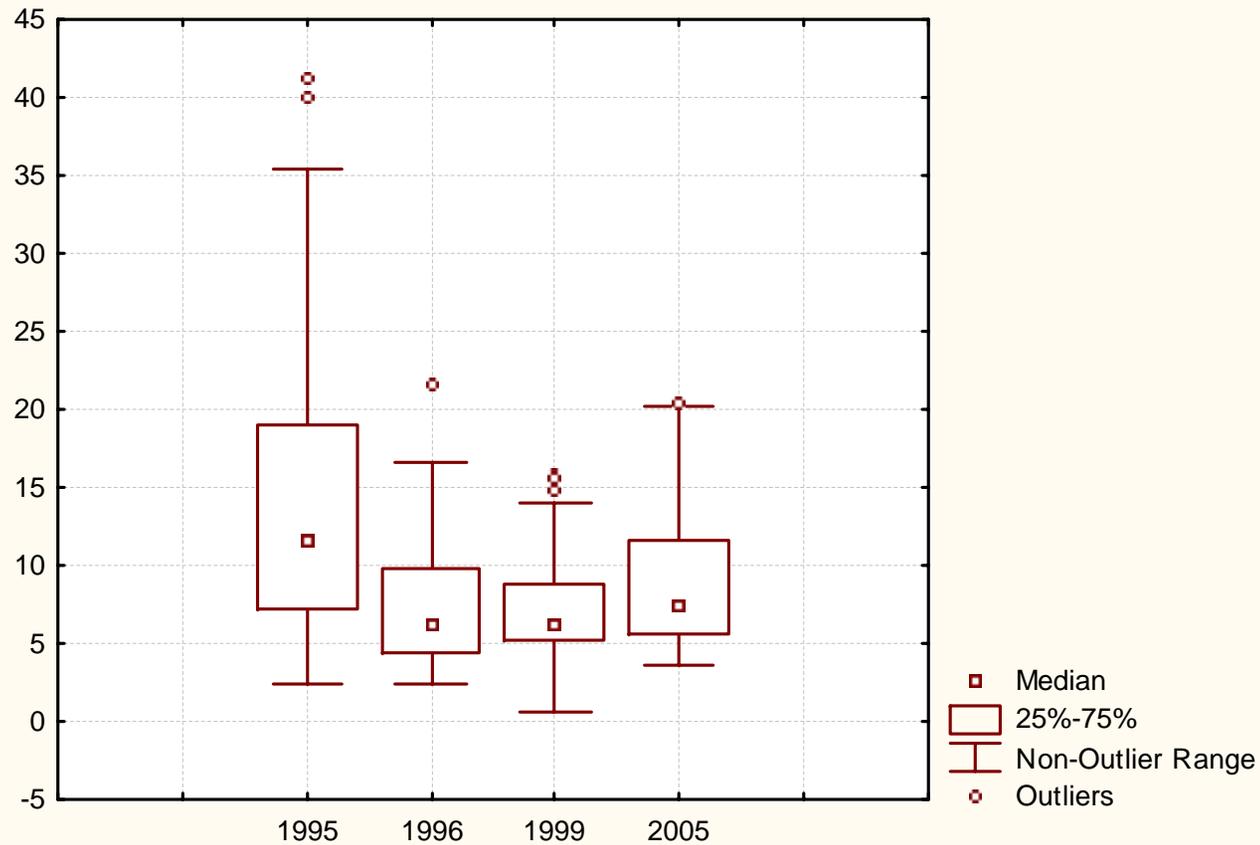
Total Phosphorus in Soil

Wet Season 1995/96 vs. 2005

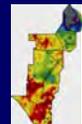
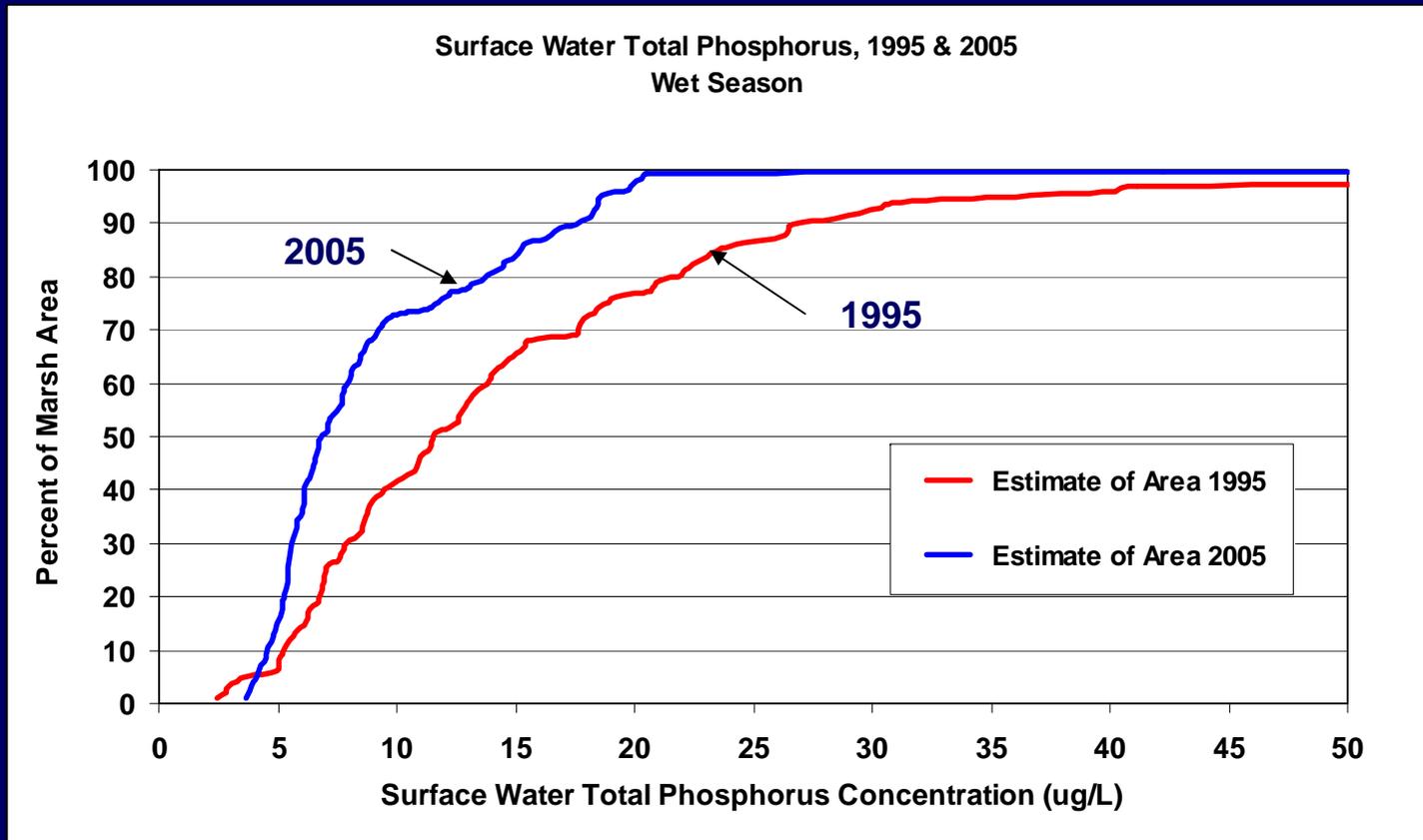


Surface Water Total Phosphorus Wet Season

Total Phosphorus in Surface Water at Everglades R-EMAP Stations,
Wet Season, by Year (extreme values omitted) (ug/l)



Surface Water Total Phosphorus Wet Season 1995 vs. 2005



Program Findings

1995/96 -- 1999 -- 2005

- Phosphorus

- Less in water

- 3/4 lines of evidence

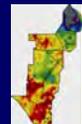
- Year-to-year variation is apparent

- 11.6 ↘ 6.2 ↘ 6.16 ↗ 7.50 ug/L

- More in Soil

- 3/4 lines of evidence

- 343 ↗ 395 mg/kg



Mercury in Largemouth Bass 1988 - 2006

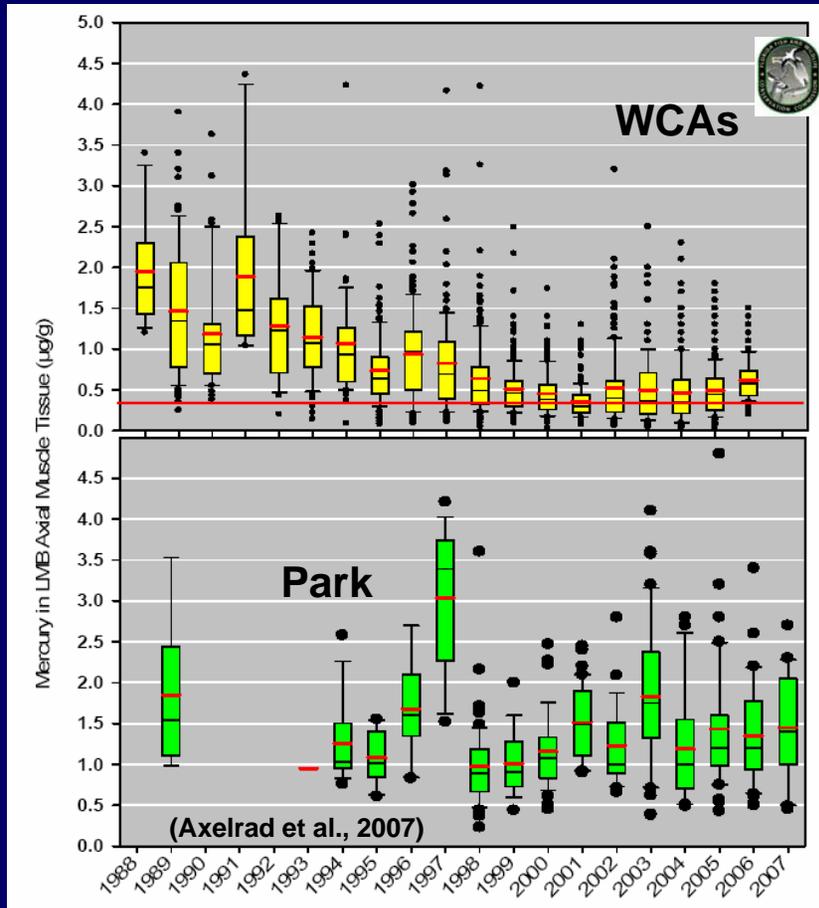
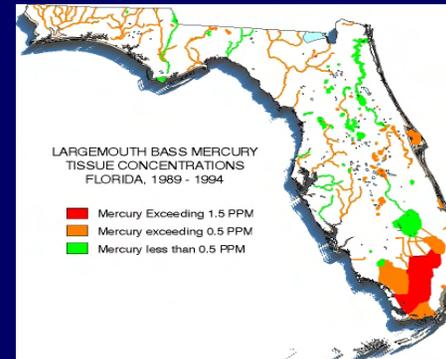
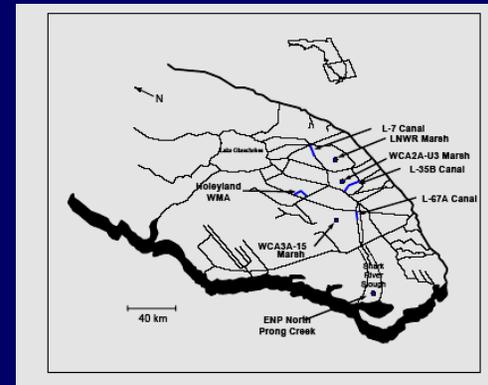


Figure 3B-2. Annual summaries of mercury concentrations in 2,529 largemouth bass collected between 1988 and 2006 from canals and marsh sites in Water Conservation Areas 1, 2, and 3 (WCA-1, WCA-2, and WCA-3) (top panel) and for 391 largemouth bass (LMB) collected between 1988 and 2007 from the Shark River Slough (at North Prong Creek and site L67F1) in the ENP (bottom panel). Mercury is reported as µg/g = mg/kg = ppm.

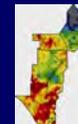


WARNING

The Florida Department of Health and Rehabilitative Services has issued a health advisory urging limited consumption of largemouth bass and warmouth caught in certain portions of the Everglades due to excessive accumulation of the element mercury.

- Fish caught in Arthur R. Marshall Loxahatchee National Wildlife Refuge (Water Conservation Area 1) should not be eaten more than once per week by adults and not more than once per month by children under 15 and pregnant women.
- Fish caught in Water Conservation Areas 2a and 3 should not be eaten at all.

For additional information, contact the Florida Department of Health and Rehabilitative Services at (405) 355-3018.



Mercury in Largemouth Bass 1988 - 2006

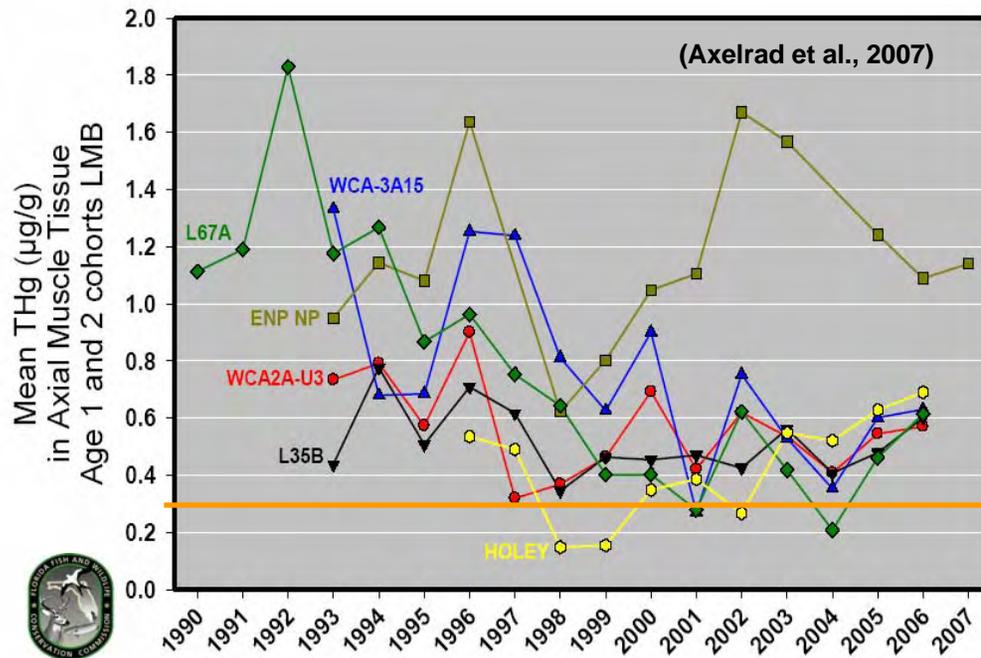
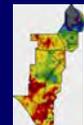


Figure 3B-10. Time series of geometric mean mercury concentrations ($\mu\text{g/g}$) for LMB (age 1-2 cohort) for six Everglades sites. Sites L-35B and L-67A are canal sites in WCA-2 and WCA-3, respectively; sites U3 and 3A-15 represent interior marsh sites located in WCA-2A and 3A, respectively. The ENP NP site is in the ENP (North Prong Creek) and site HOLEY is within the WMA.

- Mercury decreased
in great egret
Feathers
1994 to 1999 WCA3

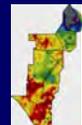
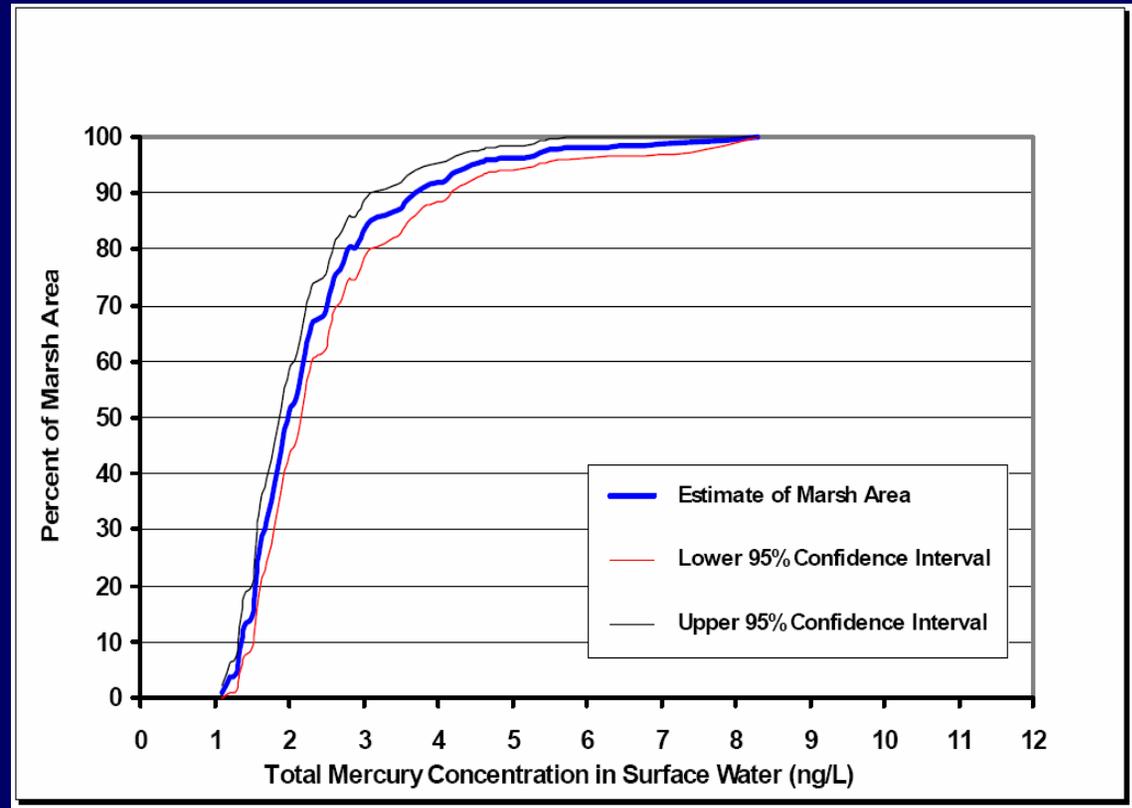
- No change in
wet deposition
1994 to 2006



Surface Water Total Mercury, 2005 Wet Season

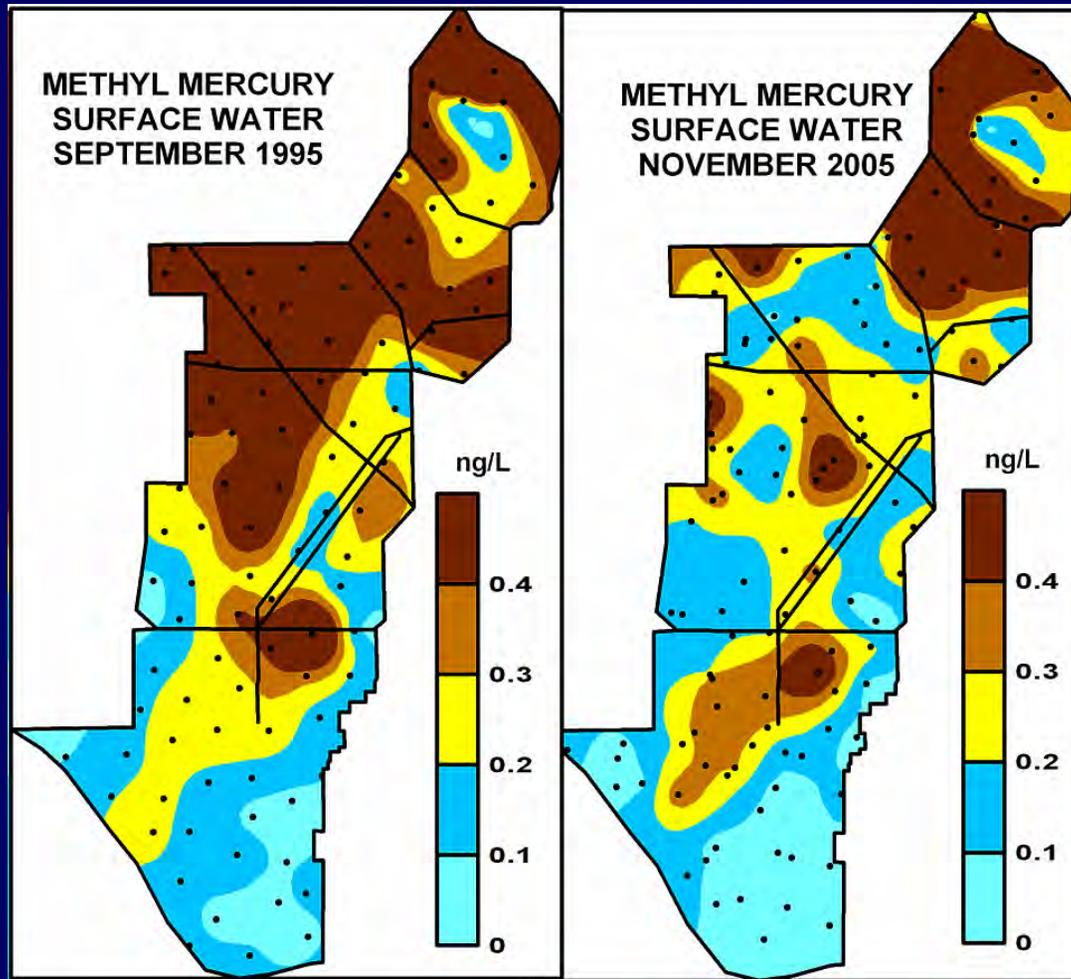
Ban on gamefish
consumption
(bass > 14 inches)

Fish contamination
persists although
100 % of
the marsh is
below the
water quality
criterion of
12 ng/L.



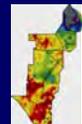
Water Methyl Mercury, 1995 & 2005

Wet Season

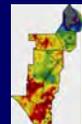
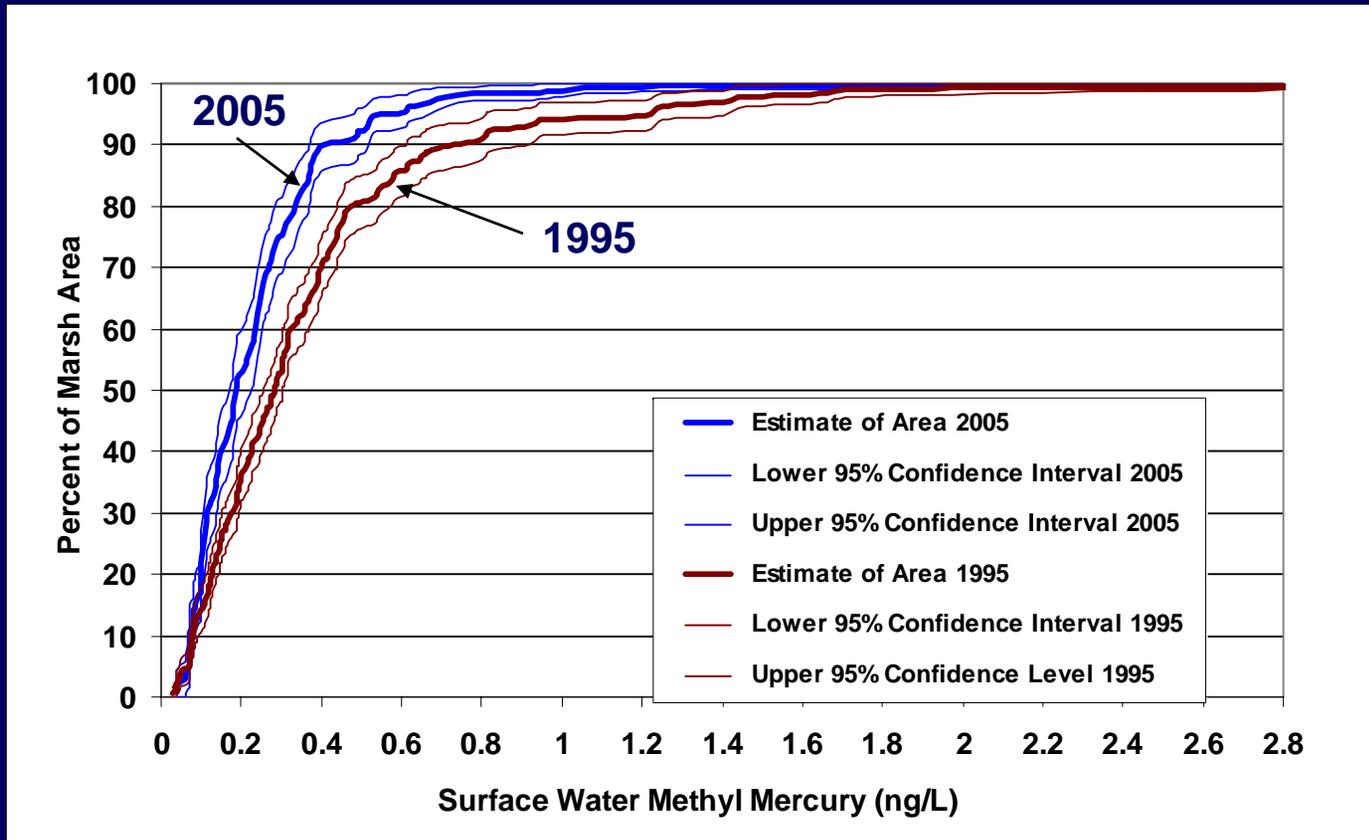


Slight drop
1995 to 1999

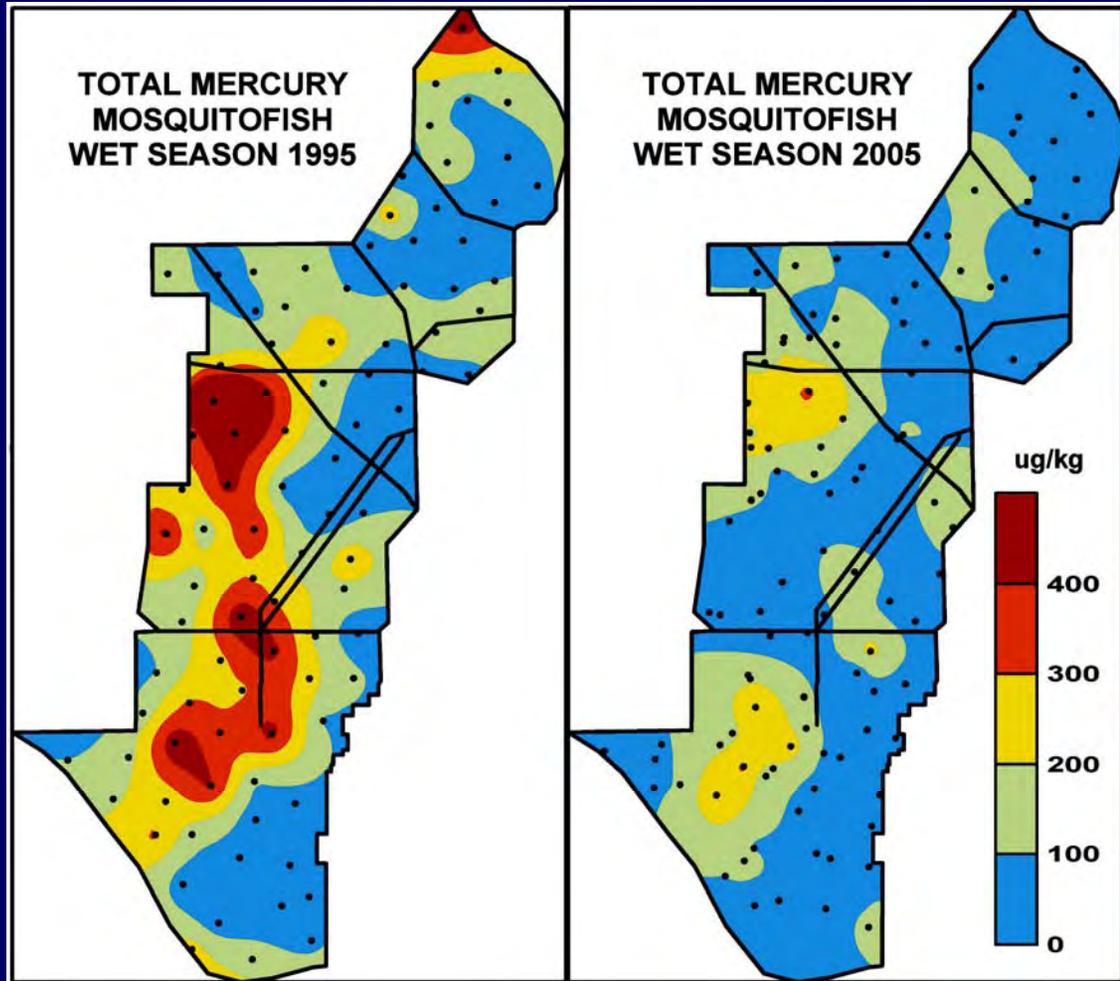
Slight increase
1999 to 2005



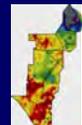
Water Methyl Mercury, 1995 & 2005 Wet Season



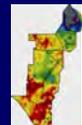
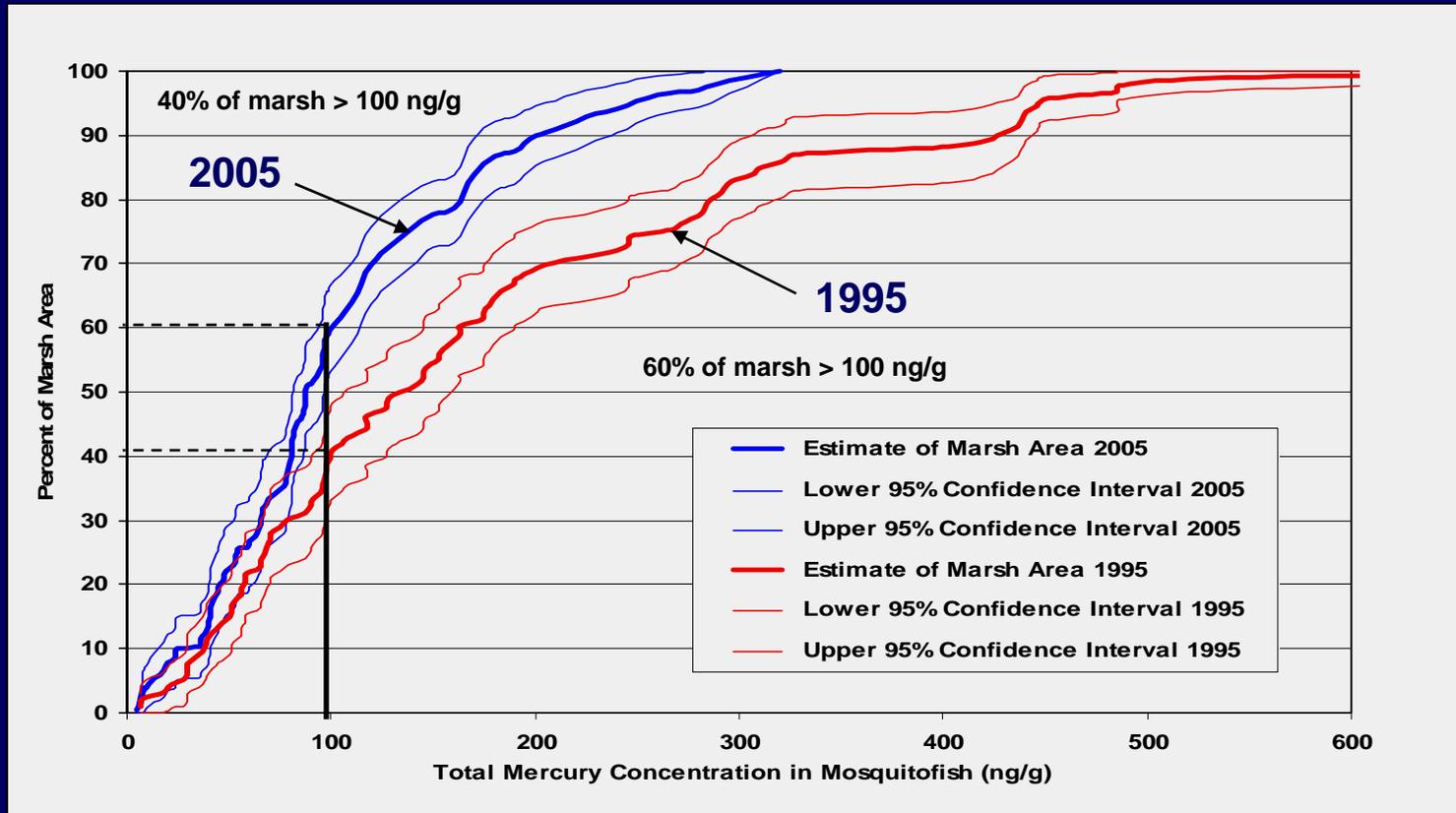
Mosquitofish Mercury, 1995 & 2005 Wet Season



EVERGLADES ECOSYSTEM ASSESSMENT PROGRAM

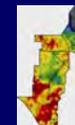
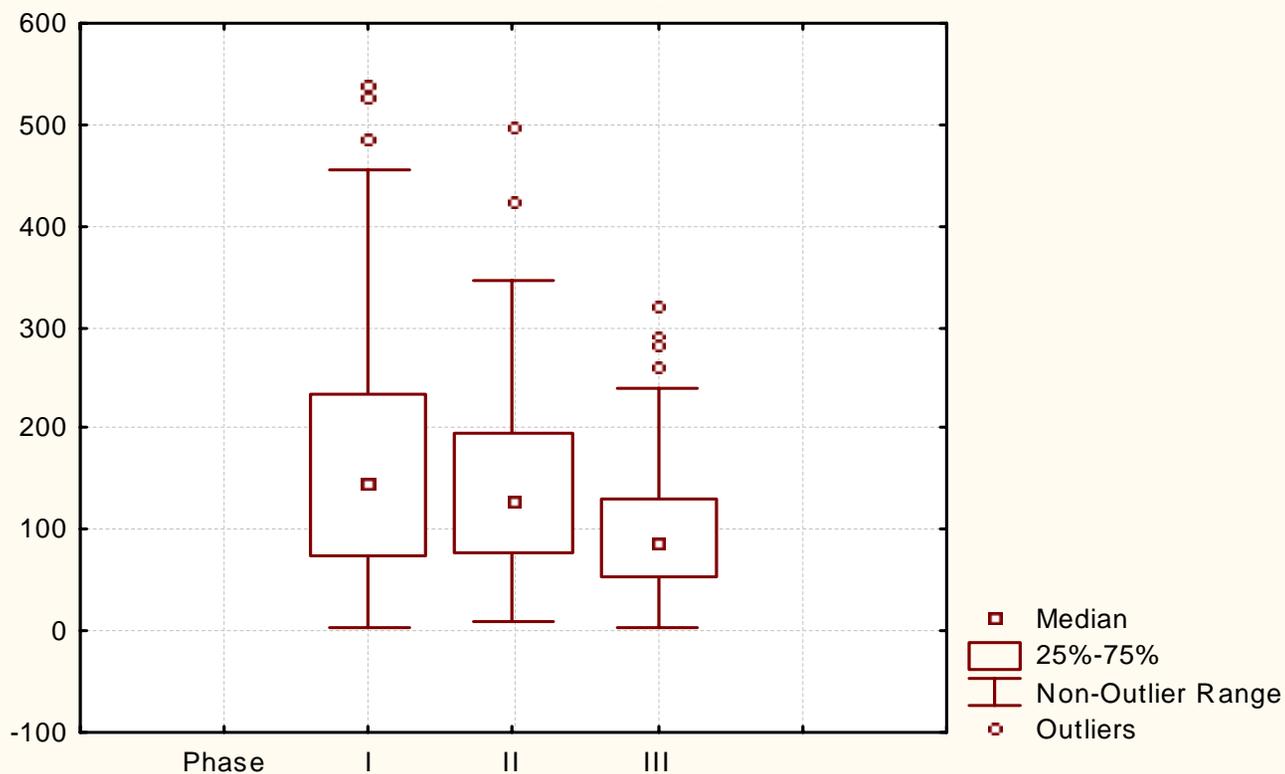


Mosquitofish Mercury, 1995 & 2005 Wet Season



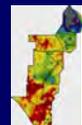
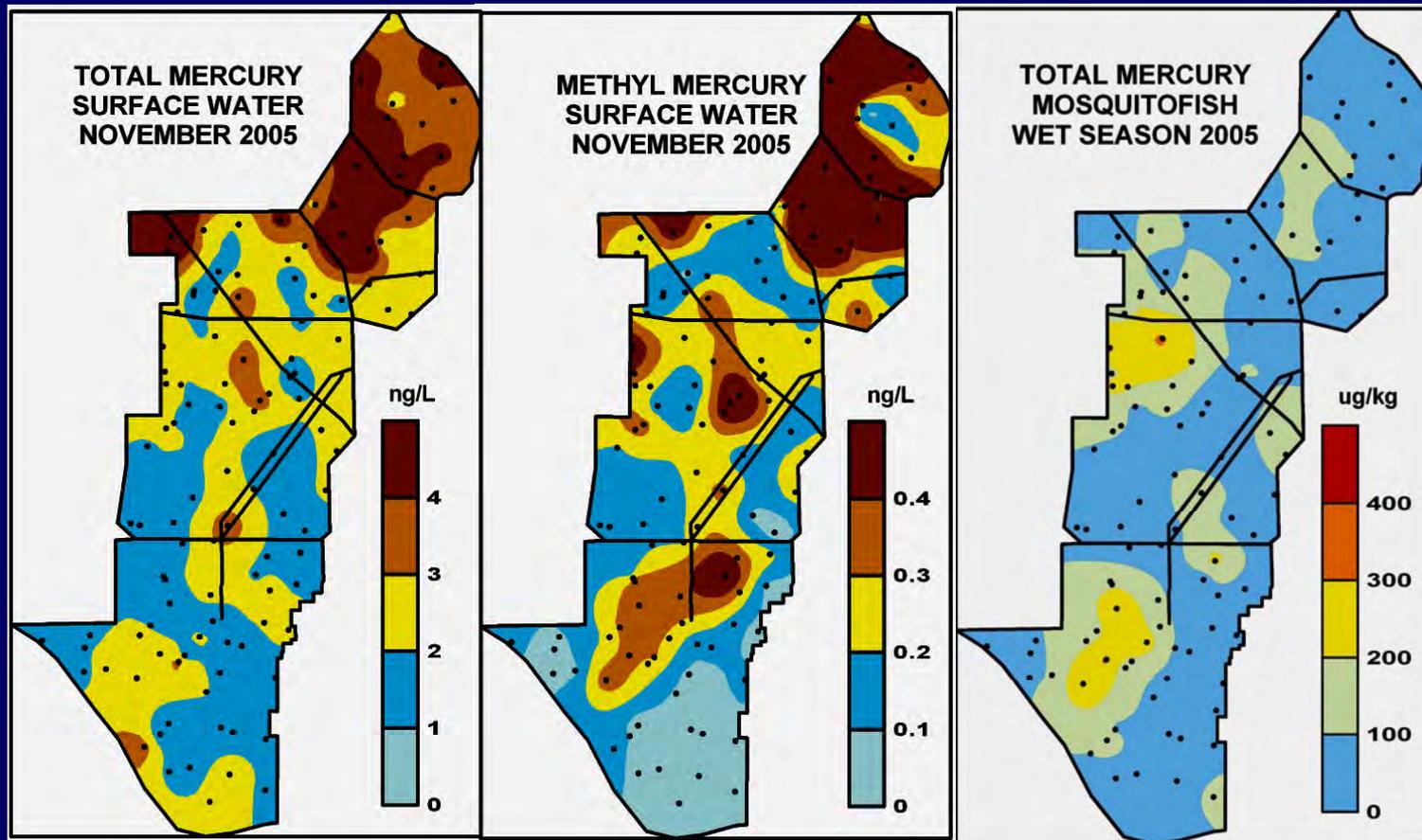
Mosquitofish Mercury 1995/96, 1999, 2005 Wet Season

Total Mercury in Mosquitofish at Everglades R-EMAP Stations in the Wet Season, by Phase (I = 1995-96, II = 99, III = 2005), with one extreme value omitted (ng/g)



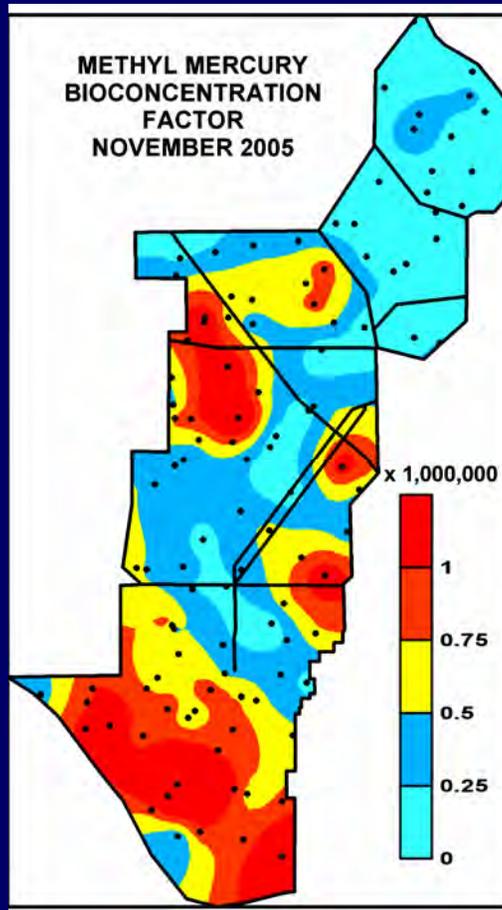
Mercury, 2005

Wet Season



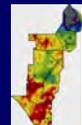
Mercury Bioaccumulation

All pathways
included

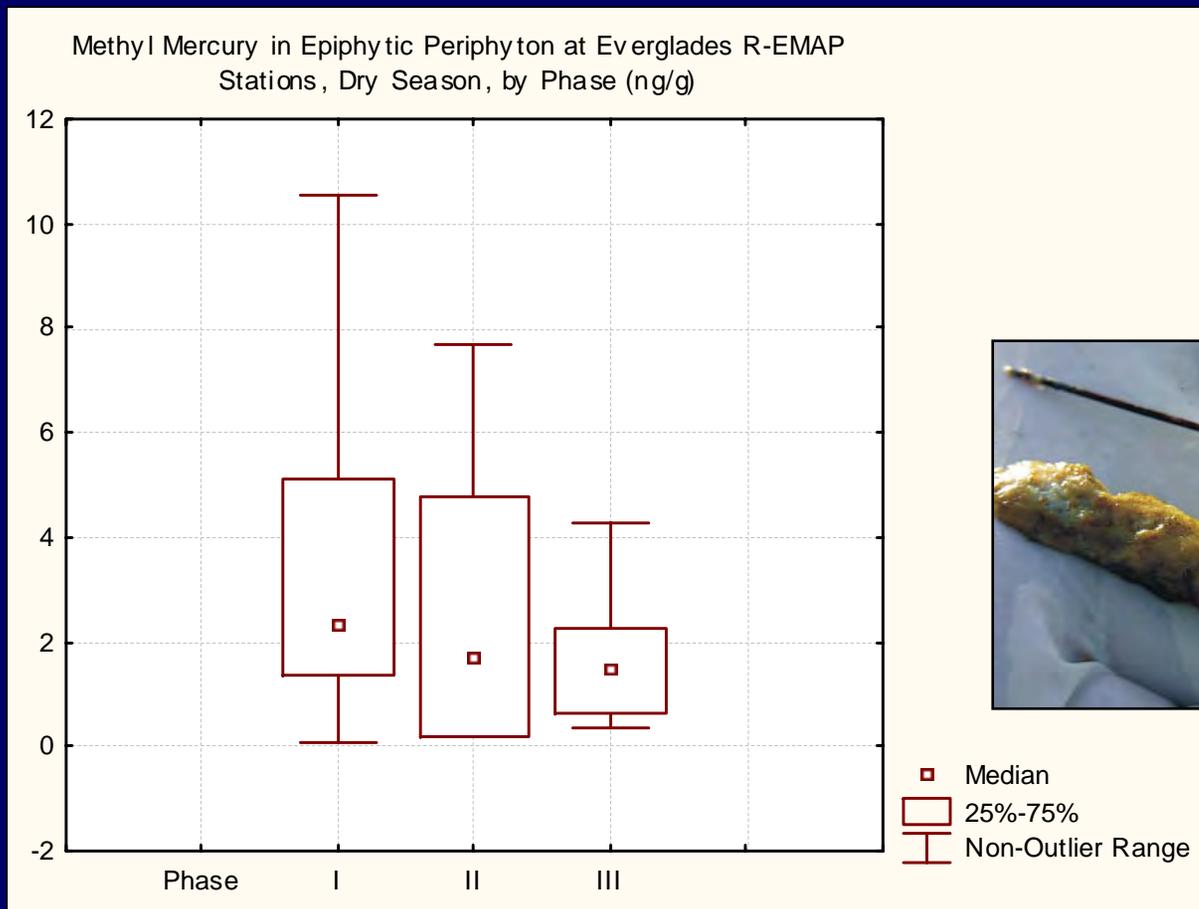


total in fish
methyl in water

Highest
BAFs
reported in
literature



Methyl Mercury in Epiphytic Periphyton Dry Season



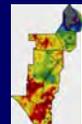
Also decreased in
floating and benthic
periphyton
growth forms



Program Findings

1995/96 -- 1999 -- 2005

- Mercury in fish and water:
 - Mosquitofish: pronounced drop
 - 4/4 lines of evidence
 - 142 ↘ 127 ↘ 87 ug/kg
 - Surface water:
 - Less methyl mercury
 - 4/4 lines of evidence
 - 0.28 ↘ 0.19 ↗ 0.21ng/L
 - More total mercury
 - 3/4 lines of evidence
 - 1.86 → 1.90 ↗ 2.20 ng/L
 - Many values at or near MDL

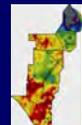




CONCLUSIONS

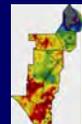
Conclusions

- **Contamination of water, soil, and fish is still extensive.**
- **Ecological condition varies with location**
 - **Rainfall-driven areas have good water quality and habitat (SW WCA3, Refuge interior)**
 - **Canals transport pollutants (P, S)**



Conclusions

- Mercury in mosquitofish has declined sharply.
- Phosphorus in soil has increased.
- No change in soil thickness.
- All other changes, in water, are subtle.
 - Slightly (0.3 ng/L) more total mercury.
 - Slightly (0.08 ng/L) less methyl mercury.
 - Slightly (0.4 mg/L) less sulfate.
 - Slightly (1.2 ug/L) less phosphate.



Next Steps

- **Further analysis is ongoing to:**
 - Explain the changes in mosquitofish
 - Relate mercury, sulfur and other parameters
- **Journal publications forthcoming**
 - Biogeochemistry, aquatic community ecology, food webs, macrophyte ecology, periphyton ecology
- **Collaborative studies**

