R-EMAP: Phosphorus and sulfur landscape patterns and temporal trends

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R-EMAP Sampling 1993-2005

EMAP probability-based design

Canal = 1993-95
Marsh = 1995-96; 1999; 2005

1145 Distinct Sample Sites, 990 marsh sites

~ biogeochemistry (~100,000 data values); periphyton; macrophytes; community ecology

~$6M investment to date; CERP > $11 billion
R-EMAP program timeline & restoration milestones

- **1990**: EMAP Canal Phase I (1993-95)
- **1992**: EMAP Marsh Phase I (1995-96)
- **1994**: EMAP Marsh Phase II (1999)
- **1996**: EMAP Marsh Phase III (2005)
- **1998**: First EAA STA begins discharging
- **2000**: EAA BMPs in place 100%
- **2002**: All six EAA STAs discharging.
- **2004**: 10 ppb TP criterion adopted for EPA.
- **2006**: CERP authorized by WRDA 2000
PHOSPHORUS
Soil sampling

- 3 inch inner diameter clear polycarbonate core
- 0 – 10 cm soil
- Separate soil, floc, benthic periphyton
- Triplicate cores at all sites
Total Phosphorus in Soil 2003-2005

- N = 1270
  - USEPA R-EMAP
  - UF/SFWMD Everglades Soil Mapping Project
  - STA 404 permit transects

- Florida definition of P-impacted for Everglades: >500 mg/kg, 0–10 cm
Total Phosphorus in Soil

- Cattail present at 19% of stations in 2005

(Scheidt and Kalla 2007)
867 sample sites
Only database since the 1940s
\( \sim 25.1\% \pm 2.0\% \) of the EPA has soil < 1 foot, \( 36.1\% \pm 2.1\% \) > 3 feet.
Median 2.3 feet
From 1946 to 1996 northern WCA3A lost 39\% to 69\% of its soil.
Soil subsidence associated with dry conditions, decreasing organic content, vegetation change.
No change since 1995/96
Peat fire risk (SFWMD 2002):
Total Phosphorus in Soil
Wet Season 1995/96 vs. 2005

Can estimate with known confidence the status of ecological resource: 2005
24.5 ± 6.4% has soil TP > 500 mg/kg

(Scheidt and Kalla 2007)
R-EMAP Findings in the EPA

• Soil Phosphorus
  – 1995-96 impacted area
    • 16.3 (± 4.1%) > 500 mg/kg FAC
    • 33.7 (± 5.4 %) > 400 mg/kg CERP restoration goal.
  – 2005 impacted area
    • 24.5 (± 6.4%) > 500 mg/kg FAC
    • 49.3 (± 7.1%) > 400 mk/kg CERP goal
Increasing Soil Phosphorus

- EPA 2005 soil TP distribution (median 390 mg/kg) > 1995-96 TP distribution (median 343 mg/kg). Significant increase.
  - [P < 0.05, Wald, mean Eigenvalue, Satterthwaite]
- WCA 2 1990 vs. 1998
  - (UF/SFWMD Grunwald et al. 2004)
- WCA 3 1992 vs. 2003
  - (UF/SFWMD Bruland et al. 2007)
- WCA1 WCA2 1989 vs. 1999
  - (FIU Childers et al. 2003)
ECP Basins:
- STA-1E
- STA-1W (incl. L-8)
- STA-2
- STA-3/4
- STA-5
- STA-6

ESP Basins:
- ACME Basin “B”
- North Springs Improvement District
- North New River Canal (G-123)
- C-11 West
- L-28 Feeder Canal

WY05-07 geomean inflow TP ug/L (SFER 2008)
Excess P into the Everglades

- WY 06: 63% TP from EAA removed
  - STAs retained 177 mt
  - EAA BMPs retained 117 mt
- 169 mt TP discharged into WCAs 1, 2, and 3
- If discharges equivalent to 10 ppb: 42 mt
- Excess TP 169 – 42 = 127 mt
SULFUR
Sulfur Enrichment in the Everglades

- No numeric quality criteria in Florida, but FAC requires that substances “which injure, are chronically toxic to, or produce adverse physiological or behavioral response in humans, plants or animals – none shall be present.”
- Sulfate $\rightarrow$ sulfide when anaerobic
- Sulfide toxic to plants
- Some sulfate enhances mercury methylation. Excess sulfate, sulfide inhibit
- Sulfur can mobilize phosphorus
- Mineralization can impact Refuge soft water biota such as periphyton
Sulfur Enrichment in the Everglades

- Surface water sulfate varies spatially depending upon proximity to EAA and the relative contribution of rain water, stormwater and groundwater.
- Sulfate in stormwater discharges into Everglades up to 500 x marsh background. Seasonal.
Random probability-based locations

Seasonality, gradients.
- Eastern EAA highest

Conductivity, C, P have similar pattern

(Scheidt et al., 1999)
Surface Water Sulfate 1993-96

Wet Season

Rainfall < 1 mg/L

Milligrams/liter

< MDL (0.5 or 5)
1 to 50
50 to 100
> 100

(Scheidt and Kalla 2007)
Surface Water Sulfate 2005
Wet Season

November 2005, data from USEPA R-EMAP, SFWMD DBHYDRO

(Scheidt and Kalla 2007)
Sulfide - Sulfate November 2005

SULFIDE POREWATER NOVEMBER 2005

SULFATE SURFACE WATER
343,500 acre-feet

21 mg/L 86 mg/L
131 mg/L 136 mg/L

Rainfall 0.7 mg/L

(Scheidt and Kalla 2007)
Surface Water Sulfate 2005
Wet Season

57% of EPA marsh > 1.0 mg/L CERP restoration goal
Surface water sulfate

• 2005: 57.3 ± 6.0% of EPA exceeded 1.0 mg/L CERP restoration goal. Background < 0.2 mg/L.

• 1995: 66.1 ± 7.0% exceeded 1.0 mg/L. Significant drop.

• Less stormwater. Stormwater inflow in 60 days prior to 2005 sampling 1/2 1995 sampling.
Mercury, 2005
Wet Season

**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 2 should not be eaten at all.

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**METHYL MERCURY**
**SURFACE WATER**
**NOVEMBER 2005**

**TOTAL MERCURY**
**MOSQUITOFISH**
**WET SEASON 2005**

**METHYL MERCURY**
**BIOACCUMULATION FACTOR**
**NOVEMBER 2005**

- 77 ug/kg predator protection level

**Concentration Levels:**
- 0 ug/kg
- 0.1 ug/kg
- 0.2 ug/kg
- 0.3 ug/kg
- 0.4 ug/kg
- 0.5 ug/kg
- 0.75 ug/kg
- 1 ug/kg

**Bioaccumulation Factor Levels:**
- 0 x 1,000,000
- 0.25 x 1,000,000
- 0.5 x 1,000,000
- 0.75 x 1,000,000
- 1 x 1,000,000
Sulfur: Pearson Correlation Coefficients

\[ p < 0.0006 \]

- SW sulfate
  - SW MeHg (0.65)
  - BAF (-0.47); MeHg Peri B (0.87)
- PW sulfide
  - SW THg (0.51), MeHg (0.61), SW Sulfate (0.77); PW sulfate (0.81)
  - BAF (-0.63); MeHg Peri B (0.80), THg Peri E (0.88); THg Peri B (0.68)
WCA 2 Hydropattern restoration

(CH2MILL, Inc and Goforth, Inc 2008)
Sulfate & WCA 2 Hydropattern Restoration

- Significant increase (p<0.05) at all sampling locations. [4 – 12 mg/L vs. 52 – 78 mg/L]
- Farthest site 6 miles.
- CERP restoration goal 1 mg/L
- STAs remove little sulfate
- Ecological effects?
- Risks vs. benefits:
  - Hydropattern restoration vs. TP vs. S enrichment vs. Hg

(Garrett and Ivanoff, 2008)
WCA 3A Hydropattern Restoration

Soil Thickness
~ 1-2 feet

Soil TP
> 500 mg/kg

Cattail presence
2003-05

Ecological risks vs. benefits: Soil loss/fire risk vs. TP enrichment, cattail expansion, habitat decline vs. S enrichment vs. Hg

Adapted from CH2M HILL, Inc and Goforth, Inc 2008
Closing thought

• R-EMAP program helps satisfy CERP, EFA monitoring objectives
  – Baseline variability, status and trends, responses, associations.
• 25% of EPA is P-impacted.
• 57% of EPA has sulfate > CERP restoration goal.
• 65% of EPA had mosquitofish Hg exceeding 77 ug/kg predator protection level
R-EMAP 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, ie, 24.5 ± 6.4% has soil TP > 500 mg/kg, 2005)
- Only multi-media program across entire Everglades Protection Area (EPA) with probability-based design.