Patterns of Inorganic Nitrogen Flux from Northern Florida Bay Sediments

David Rudnick, Stephen Kelly and Chelsea Donovan
Everglades Department
South Florida Water Management District

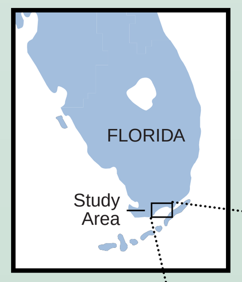
Jeffrey Cornwell and Michael Owens
Horn Point Environmental Laboratory
University of Maryland
Cambridge, Maryland

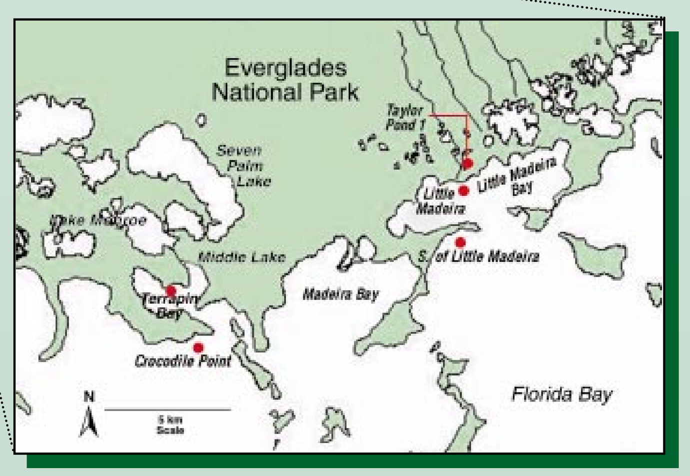
Introduction

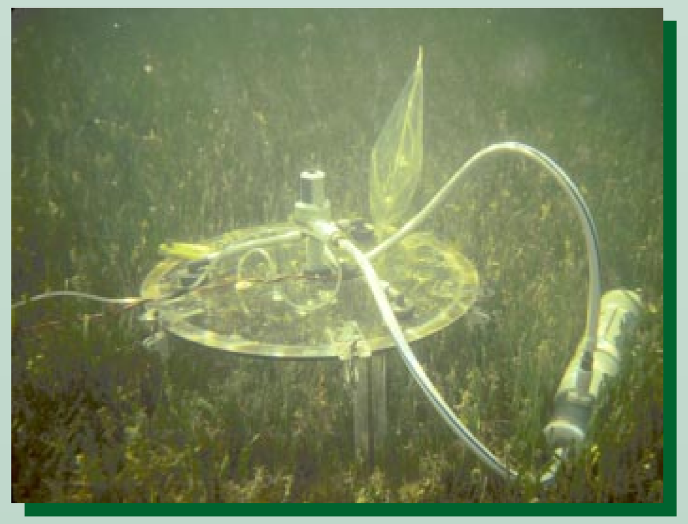
The availability of nitrogen in Florida Bay for the production of algal blooms may be dependent upon rates of decomposition of organic matter in Bay sediments and the resultant release of inorganic nitrogen from these sediments. As part of a program to understand the ecosystem-level effects of the hydrological restoration of Florida Bay and the Everglades, we measured benthic fluxes of dissolved oxygen and nutrients near the northern coast of Florida Bay, including ponds within the mangrove ecotone. Five sites along north-south transects through Little Madeira Bay and Terrapin Bay were measured seasonally using in situ chambers from May 1996 through September 1998 and measured less frequently since then. Both dark chambers and clear chambers were used to estimate fluxes during day and night.

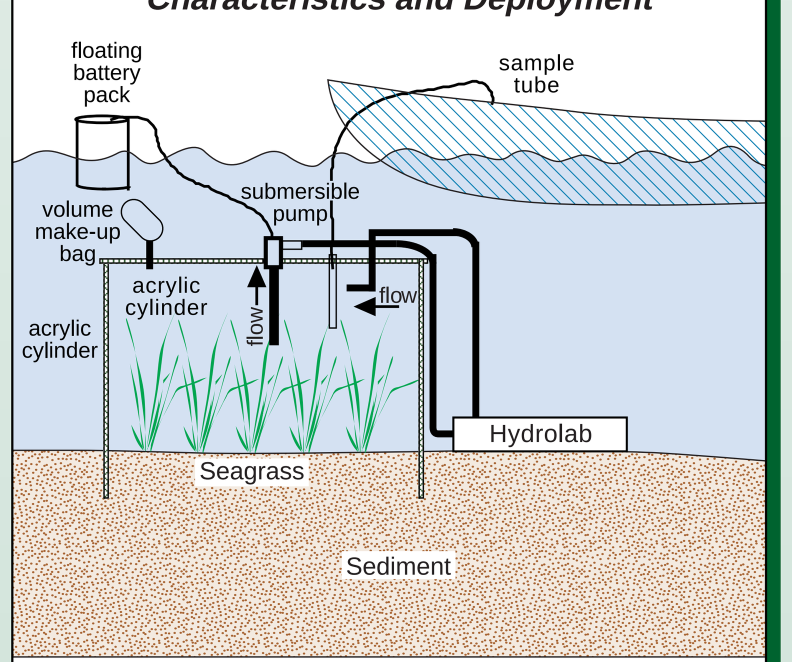
Site Description

	Pond	East		West	
	Taylor Pond 1	**Little Madeira Bay**	**South of Little Madeira**	**Terrapin Bay**	**Crocodile Point**
Water depth (m)	0.7	0.9	1.3	0.8	0.9
Salinity range (ppt)	0.2-33	5-33	9-33	7-37	16-43
Sediment					
% inorg. C	6.9	9.2	10.3	7.5	7.3
% org. C	6.6	2.6	1.3	3.6	3.8
% N	0.62	0.25	0.13	0.32	0.36
% P	0.028	0.007	0.005	0.011	0.010
Sediment C:N:P (molar)	635:49:1	3389:79:1	5312:57:1	1758:64:1	1882:80:1
Dominant vegetation	*Ruppia*	*Thalassia*	*Thalassia*	*Halodule*	*Thalassia*
Above ground vegetation biomass (g/m^2)	15	40	11	10	43
Setting	4 ha mangrove pond	open water near creek	open water	large cove	open water









Benthic Chamber Characteristics and Deployment

In situ benthic chamber characteristics

- Material: clear acrylic and opaque acrylic
- Shape: cylinder with removable top
- Diameter: 60 cm
- Height: 25 cm
- Mixing: continuous, variable speed submersible pump
- Replicates: 4 clear, 4 opaque

Methods

Sampling

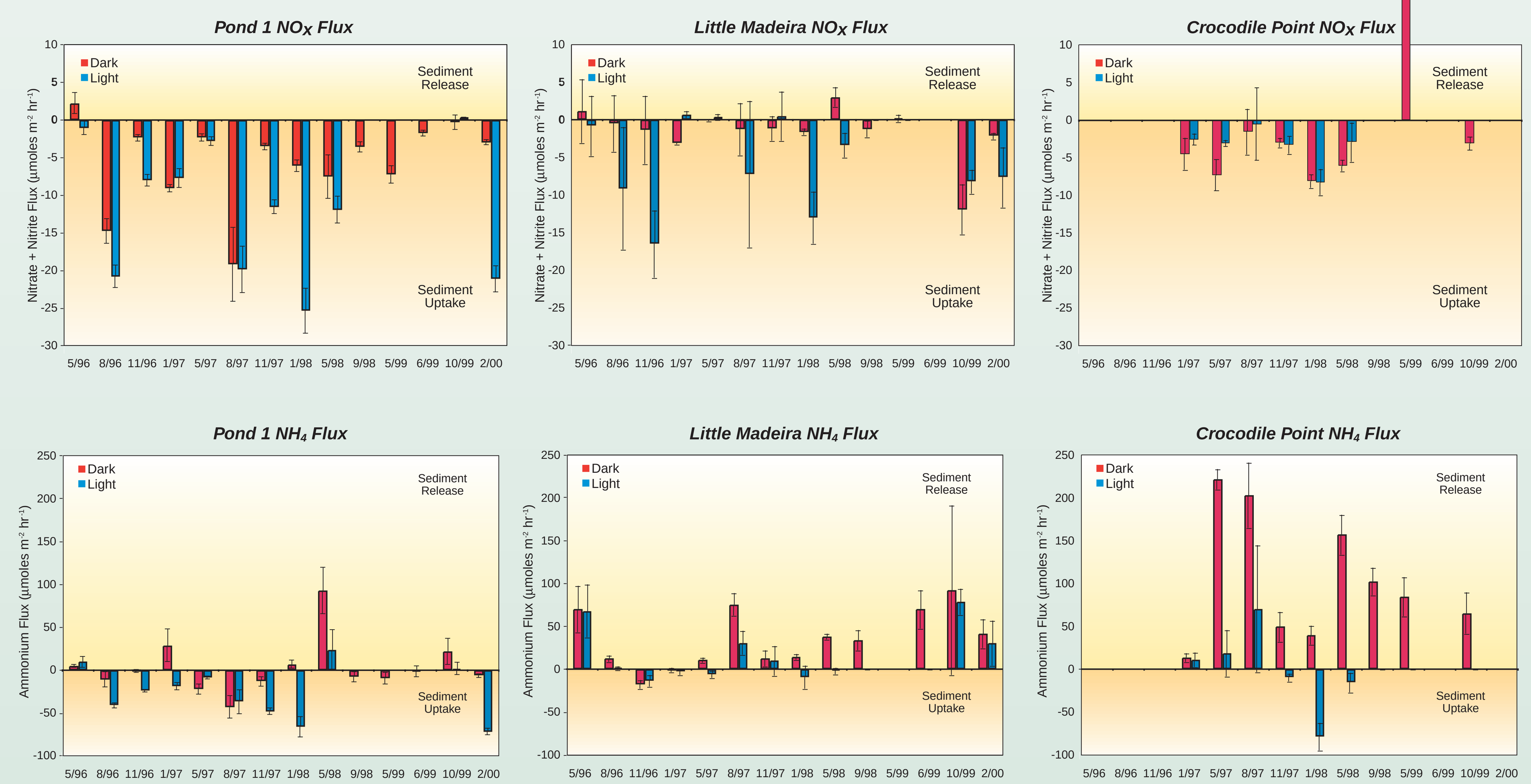
- **Four replicate light and dark benthic chambers per site**
- **Water column controls**
- **Measurements from 5/96 - 9/98 and measured less frequently since then (to 2/00)**
- **Four bay sites along north bay coast (2 east, 2 west)**

Measurements

- **Hydrolab: continuous O_2, pH, temperature, salinity**
- **Dissolved nutrient analysis: N_2 - N, NO_2, $NO_3 + NO_2$, SRP, NH_4, TDKN, TDP, DOC**
- **Particle analysis: chlorophyll a, suspended solids**
- **Sediment analysis: loss on ignition, total C, N, P**
- **Vegetation analysis: above ground dry weight, C, N, P**

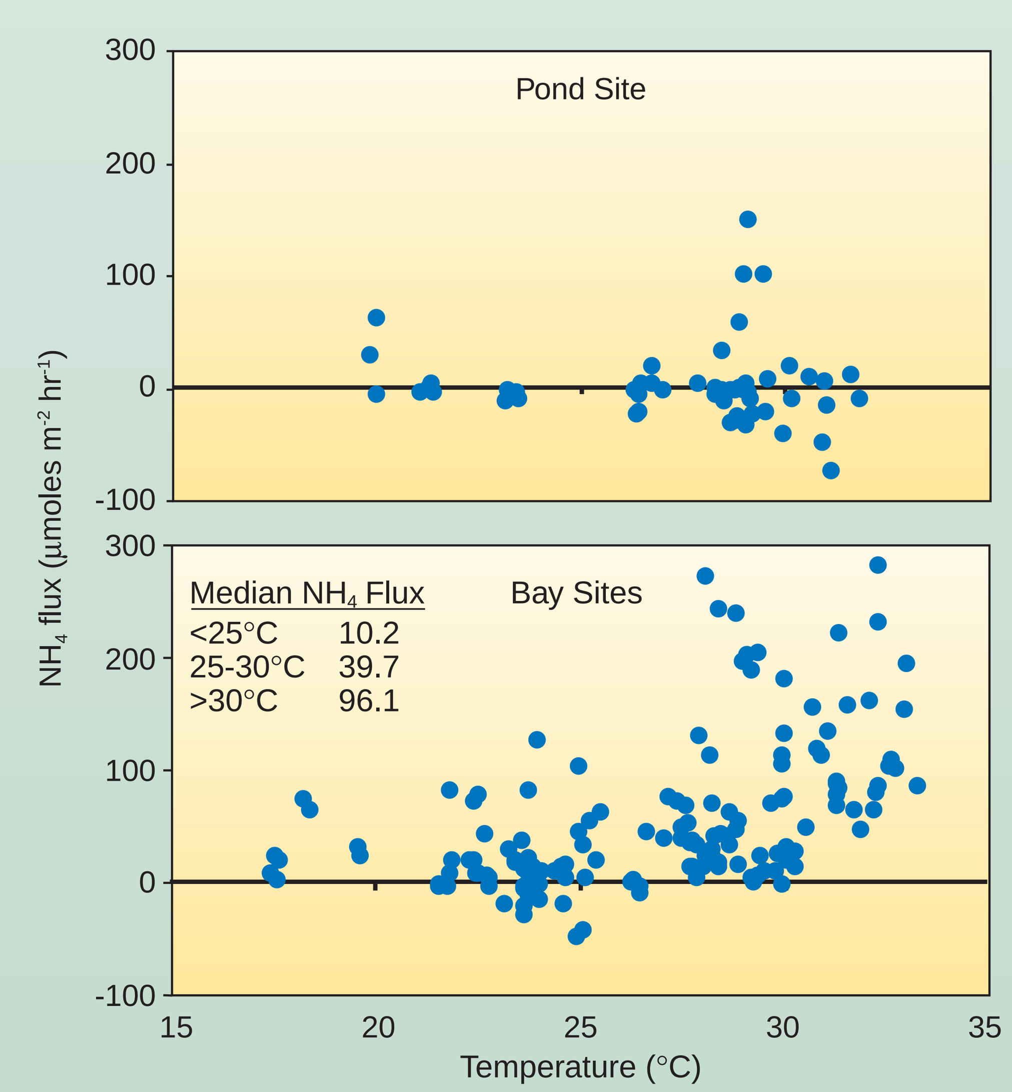
Results

Dissolved Inorganic Nitrogen Flux



Mean benthic fluxes (± SE) from 5/96-2/00.
A negative flux corresponds to sedimentary uptake and a positive flux corresponds to sedimentary release. Ammonium release from the sediment was apparent at the eastern and western sites, whereas ammonium uptake occurred in Pond 1. Nitrate + nitrite sediment uptake occurred at all sites under both light and dark conditions, and was almost always higher in the light except at the western sites. P fluxes were near zero (0.07 µmoles m^{-2} h^{-1} ± 0.07) at all sites in the light and dark (data not shown).

Ammonium flux temperature relations



Ammonium release from the sediment at the Bay sites was strongly correlated to temperature. Fluxes were 5 to 10 times higher when temperatures were >30°C than when they were <25°C. There was no correlation between temperature and ammonium flux at the Pond site.

Time weighted mean net 24 hour fluxes

	(5/96-5/98)			(1/97-5/98)	
	Taylor Pond 1	**Little Madeira Bay**	**South of Little Madeira**	**Terrapin Bay**	**Crocodile Point**
	µmoles m^{-2} d^{-1}				
Dissolved Oxygen	697	20,645	5249	14,057	18,960
Nitrate + Nitrite	-235	-72	-37	-31	-102
Ammonium	-230	350	514	958	1422
P:R	1.1	1.6	1.3	1.5	1.5

Time weighted mean daily fluxes show Pond 1 as a nitrogen sink while the Bay sites were a net source of ammonium with fluxes at western sites higher than eastern sites.

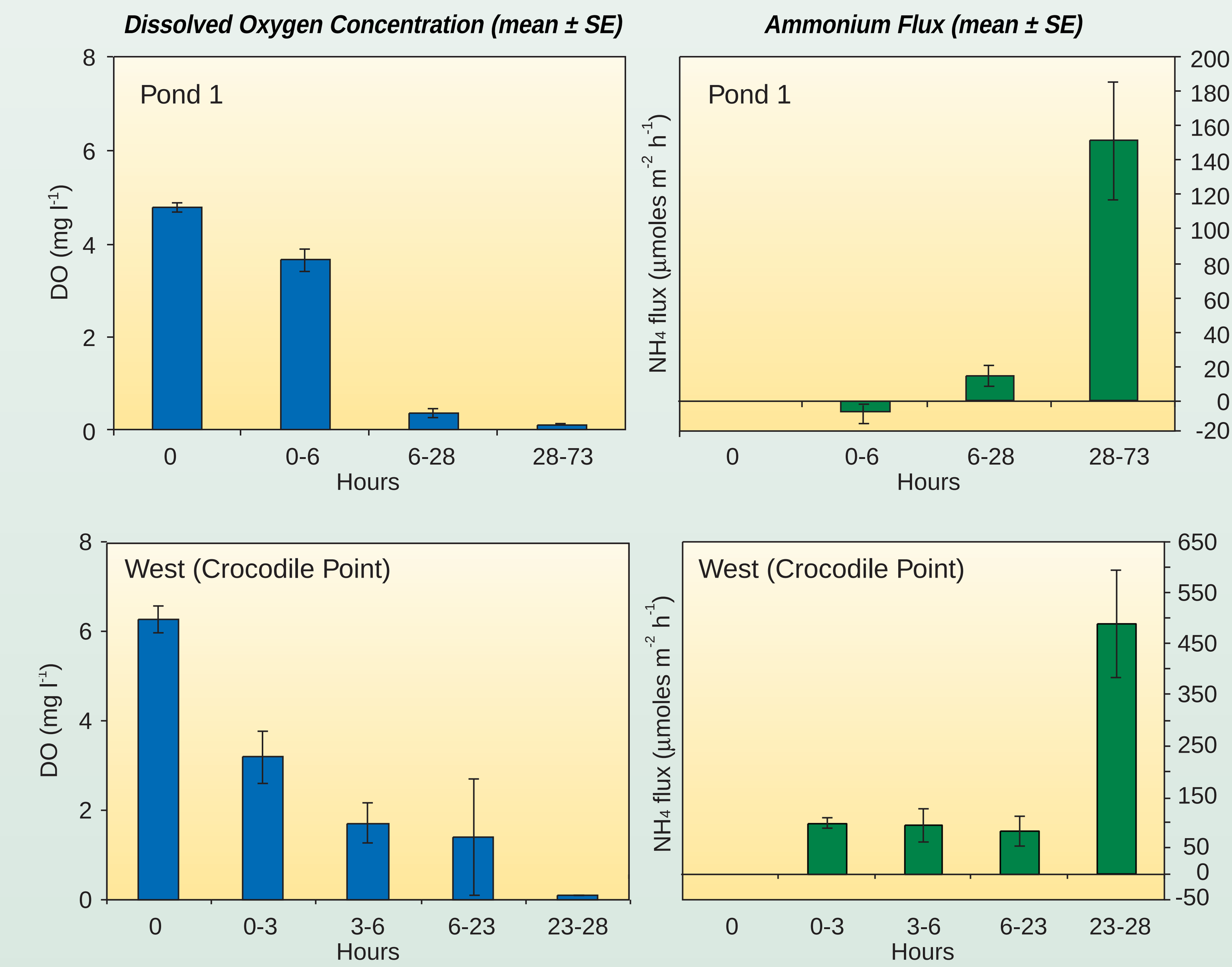
Dark fluxes (May 1996-February 2000)

	Pond 1	East	West
Median O:N (O_2 uptake: NH_4 release)	-49	47-124	51-57
Median O_2 flux (µmoles m^{-2} h^{-1})	-1780	-2322	-3149
Expected NH_4 flux* (µmoles m^{-2} h^{-1})	89-270	116-352	157-477
Median NH_4 flux (µmoles m^{-2} h^{-1})	-1.8	38	59

* Based on oxygen uptake and decomposition of organic matter sources seagrass C:N = 20, algal C:N = 6.6

Median O:N molar ratios deviate greatly from ratios expected from the decomposition of seagrass or algal detritus. The release of ammonium from sediments was far less than expected, based on measured oxygen uptake rates in the dark at all sites.

Anoxia Experiment



An anoxia experiment conducted in September 1998 shows a very high ammonium release occurring at all sites immediately after oxygen depletion. Ammonium release from anoxic Crocodile Point sediments was 3 to 4 times higher than from anoxic Little Madeira (data not shown) and Pond 1 sediments.

N_2 Flux Measurements (October 1999)

		Pond 1		East (Little Madeira Bay)		West (Crocodile Point)	
		Dark	**Light**	**Dark**	**Light**	**Dark**	**Light**
		µmoles m^{-2} h^{-1}					
N_2- N	median	137	25	190	27	319	—
	mean (± SE)	139 (30)	25	195 (87)	65 (46)	375 (66)	—
NH_4	median	17	2.4	71	66	59	—
	mean (± SE)	22 (15)	2.4 (7.5)	92 (99)	79 (15)	66 (24)	—
O_2	median	-364	2002	-1568	-430	-1110	—
	mean (± SE)	-434 (119)	2002	1431 (431)	-630 (666)	-1083 (157)	—
Temp (°C)							
	mean (± SD)	28.7 (0.3)	29.1 (0.3)	28.8 (0.9)	29.1 (0.9)	23.6 (0.2)	—

Median N_2 fluxes showed release from the sediments in the light and dark with dark fluxes 5-7 times higher than light fluxes. Dark N_2 fluxes were 3-5 times higher than NH_4 fluxes at the Bay sites and 8-10 times higher than Pond 1 fluxes. NH_4 release from the sediment exceeded the N_2 release only at the eastern site in the light. This corresponds to low ambient DO (~3 mg l^{-1}) and was preceded by a seagrass die off 2 months earlier.

Conclusions

- Northern Florida Bay sediments were found to be a dissolved inorganic nitrogen source over an annual cycle while a basin mangrove pond was found to be a dissolved inorganic nitrogen sink.
- N regeneration rates were surprisingly low. Possible causes are:
  - rapid coupled nitrification and denitrification
  - algal and seagrass uptake
  - N immobilization within sediments
  - high C/N of organic matter sources
- Nitrogen availability in Florida Bay is strongly influenced by oxygen availability at the sediment water interface and the processes of coupled nitrification and denitrification.
- The importance of coupled nitrification and denitrification is indicated by:
  - direct measurement of N_2 flux shows high sediment release, relative to the ammonium flux
  - the magnitude of sedimentary nitrogen release is very low relative to oxygen uptake
  - the sensitivity of ammonium fluxes to temperature
  - high ammonium flux under anoxic conditions
- We propose that the seasonality of algal blooms may be dependent on ammonium releases from the sediment, with high releases at times of low oxygen availability and high temperature because coupled nitrification-denitrification is inhibited.