Nutrient Standards for Protection of Coral Reef Ecosystems

Brian E. Lapointe, Ph. D.

Center for Coastal Research

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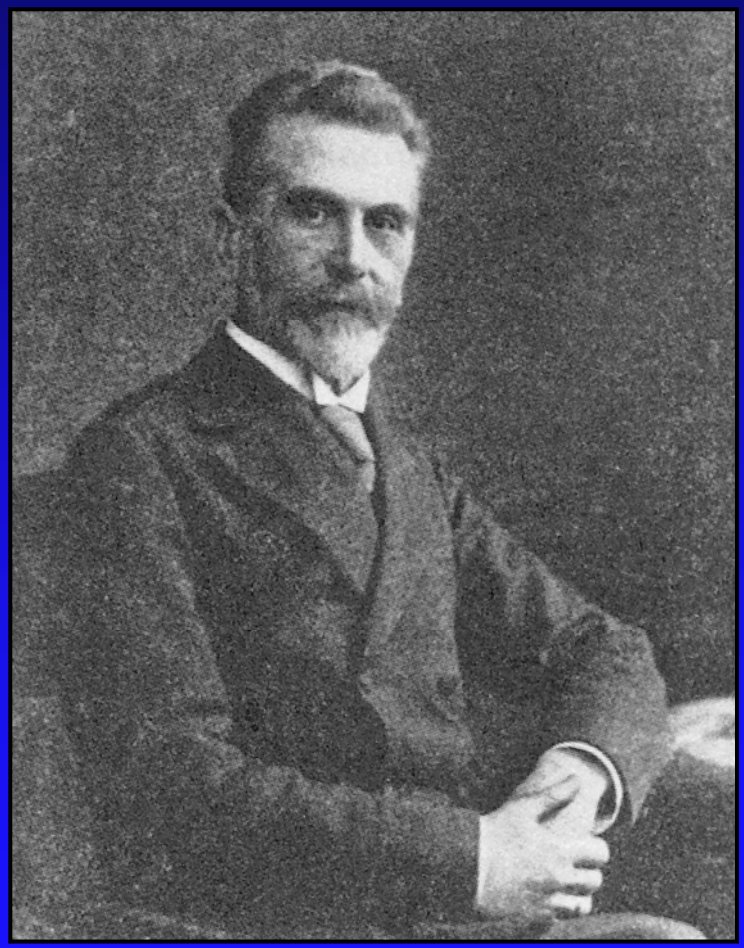
Ft. Pierce, FL

Studies of Nitrogen Enrichment Began Over a Century Ago…

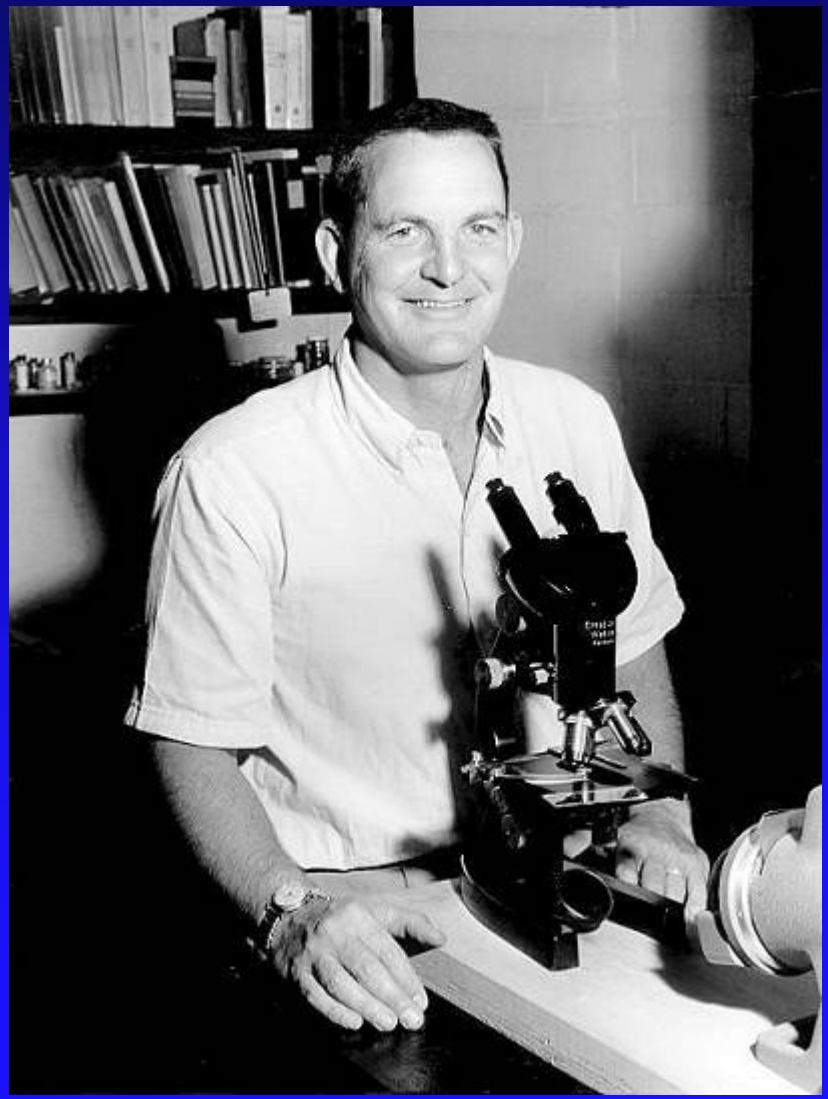


Karl Brandt

"Denitrifying bacteria in the ocean remove the excess of nitrogen compounds and it is they that restore the prevailing equilibrium of nature's household."

(Brandt, 1899)

Dr. John Ryther: Seminal Work on Nitrogen Enrichment and Harmful Algal Blooms



Biological Bulletin 106: 198-209 (1954).

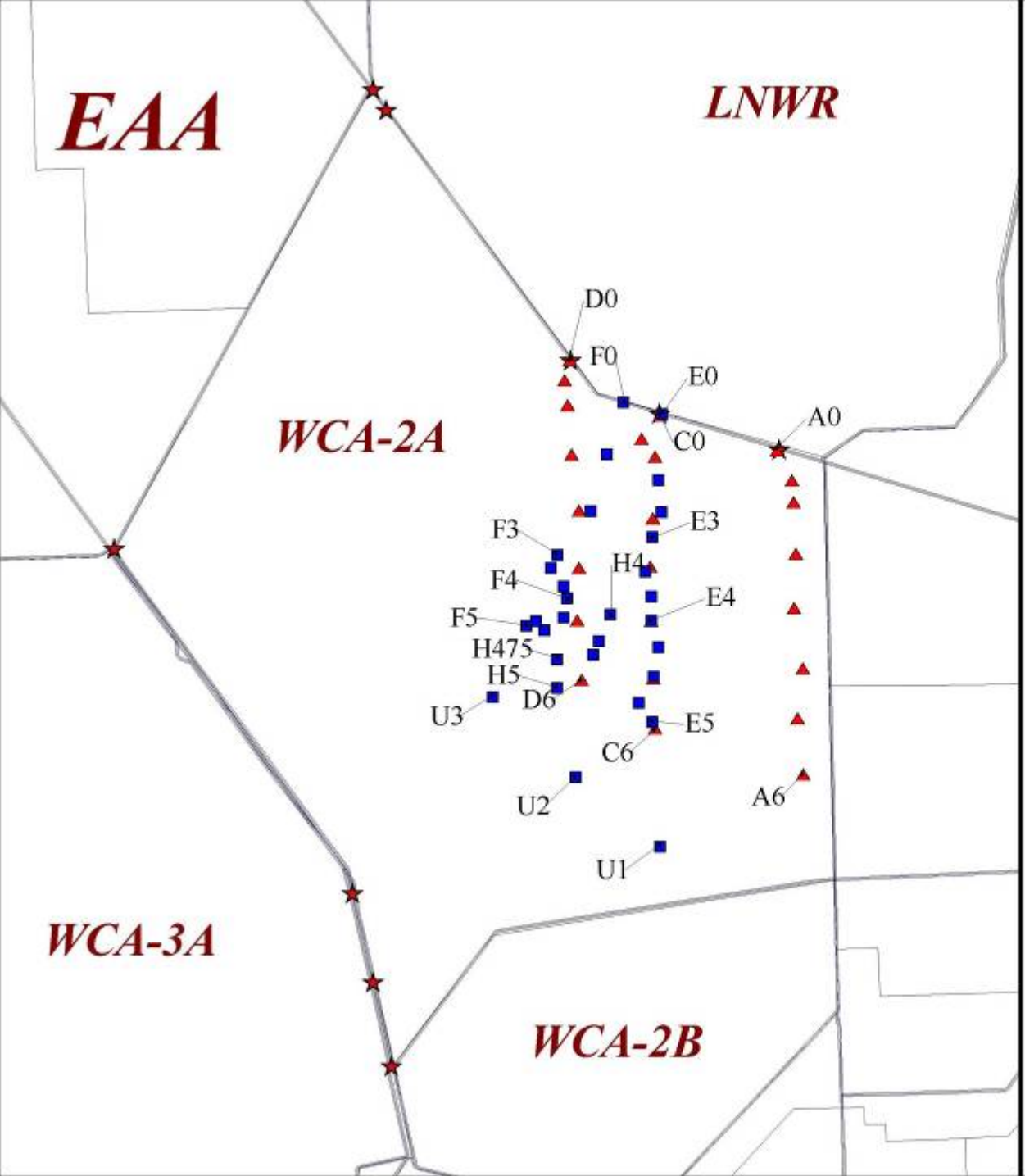
THE ECOLOGY OF PHYTOPLANKTON BLOOMS IN MORICHES BAY AND GREAT SOUTH BAY, LONG ISLAND, NEW YORK[1]

JOHN H. RYTHER

Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

Imbalance Determination: Nutrient Threshold Research in South Florida's Everglades

- Using best available information, determine the "normal structure and function" of the aquatic system in areas least affected by humans (reference conditions).
- By sampling across nutrient gradients, determine where significant departures from the reference conditions occur using multiple lines of evidence
- Determine causation through analysis of mesocosm & flume studies



Gradient Monitoring Sites in WCA-2A

N

2 0 2 4 6 Kilometers

2 0 2 4 6 Miles

- SFWMD Transect Site
- Duke Gradient Site
- Water Control Structure
- Canal

DEPARTMENT OF ENVIRONMENTAL PROTECTION
FLORIDA

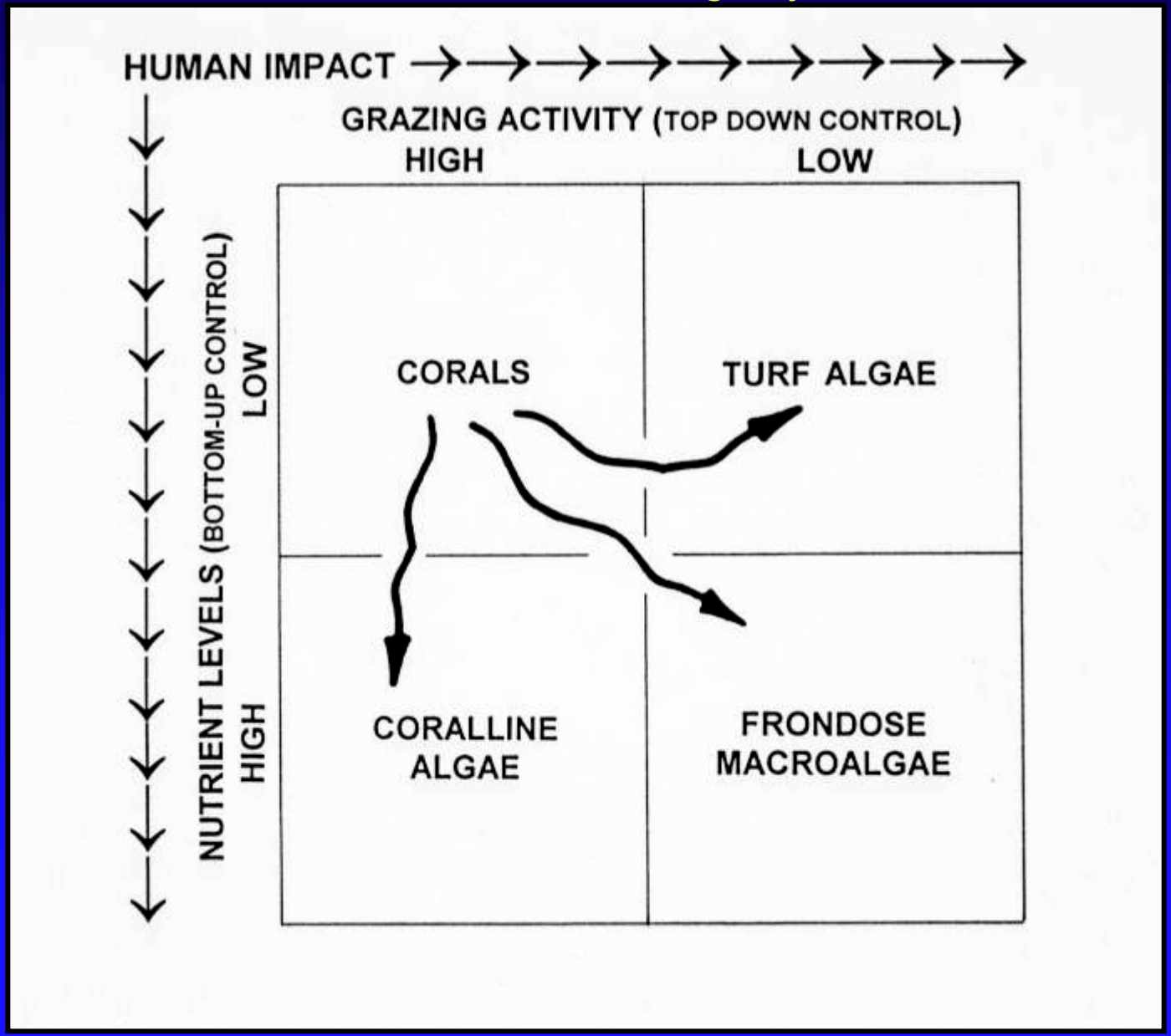
Summary of Findings

Examined relationships between various measures of the structure and function of Everglades biological communities and P-enrichment. Examples of changes in biological communities observed with increasing P-enrichment include:

- Microbial:
  - Decreased production of alkaline phosphatase
  - Increased metabolic rates
- Periphyton:
  - Calcareous blue-green taxa eliminated
  - Abundance of pollution and phosphorus sensitive taxa decrease
  - Pollution tolerant taxa increase
- Macrophytes:
  - Increased spatial distribution of cattail
  - Loss of native sawgrass and slough vegetation
- Macroinverebrates:
  - Altered invertebrate community structure (may be related to changes in D.O., food, habitat)
- Dissolved Oxygen:
  - Depressed dissolved oxygen regime (lower daily average and daily minimum).

Relative Dominance Model

Littler, M. M. and D. S. Littler. 1984. *Prog. Phycol. Res.* 3:323-364



Effects of Nutrients on Coral Reefs

Microbial:

- **increased metabolic rates**
- **increased coral diseases**

Scleractinean corals:

- **biochemical alteration of symbiosis**
- **increased zooxanthellae biomass**
- **increased respiration (CO_2)**
- **decreased calcification**

Macroalgae/turfs:

- **increased growth, reproduction, and spatial distribution**
- **appearance of indicator species**
- **alteration of biogeochemical cycles**

Invertebrates:

- **increased growth of herbivores (sea urchins)**
- **increase in corallivores (COT)**

Fish Assemblages:

- **decreased diversity and relative abundance**
- **increase in herbivores**

Dissolved Oxygen

- **Altered diel DO concentrations and cycles**

Nutrient Gradient Research on the Belize Barrier Reef: 1985-1990

R/V Cape Hatteras

Table 2. Water column nutrient concentrations (μM) at four sites on the Belizean Barrier Reef. Values represent means ± 1 SE (n = 2). U.D. = Undetectable; N/A = Not Available.

Location	System	Sampling Area	Date	Ammonium	Nitrate/ Nitrite	SRP	N:P
Man-of-War Cay	Mangrove Bird Rookery	W	2/24/88	1.26±0.08	2.25±0.25	1.29±0.01	2.8±0.21
		N	2/24/88	4.08±0.18	16.2±0.25	7.18±0.12	2.8±0.00
		S	2/24/88	1.92±0.10	1.17±0.02	1.18±0.01	2.6±0.00
		E	2/24/88	0.60±0.01	0.69±0.06	0.30±0.01	4.3±0.10
		W 10m	6/27/89	2.99±0.27	14.6±2.05	3.95±0.16	4.5±0.31
		N 10m	6/27/89	3.74±0.34	20.1±2.81	4.45±0.18	5.4±0.37
		S 10m	6/27/89	1.56±0.14	0.46±0.06	0.10±0.00	21.0±1.47
		E 10m	6/27/89	1.02±0.09	0.35±0.05	U.D.	N/A
		W 100m	6/27/89	0.25±0.02	0.19±0.03	U.D.	N/A
		N 100m	6/27/89	0.22±0.02	0.26±0.04	U.D.	N/A
		S 100m	6/27/89	0.33±0.03	0.17±0.02	0.28±0.01	1.8±0.13
		E 100m	6/28/89	0.17±0.02	0.20±0.03	0.37±0.01	1.0±0.07
		W	5/30/90	0.36±0.02	0.21±0.15	0.09±0.02	6.3±0.11
		N	5/30/90	0.58±0.30	0.67±0.00	0.24±0.00	6.4±0.00
		S	5/30/90	0.18±0.11	0.84±0.11	0.09±0.01	11.9±0.70
		E	5/30/90	0.45±0.17	0.16±0.00	0.06±0.00	7.3±0.00
		Mean		1.21	3.63	1.56	5.7
		Std. Error		0.26	1.31	0.48	1.0
Twin Cays	Mangrove	W	2/20/88	0.83±0.07	0.74±0.10	0.17±0.01	9.3±0.65
		N	2/20/88	0.26±0.02	0.16±0.02	0.17±0.01	2.5±0.18
		S	2/20/88	0.44±0.04	0.27±0.04	0.08±0.01	8.8±0.08
		E	2/20/88	0.69±0.06	0.74±0.10	0.09±0.01	15.8±1.9
		W	6/27/89	U.D.	0.38±0.05	0.19±0.0	N/A
		N	6/27/89	U.D.	0.15±0.02	0.15±0.0	N/A
		S	6/27/89	0.12±0.01	U.D.	U.D.	N/A
		E	6/27/89	0.14±0.01	0.08±0.01	U.D.	N/A
		Mean		0.41	0.36	0.14	9.1
		Std. Error		0.10	0.02	0.03	2.4
Tobacco Reef	Coral Reef	W	6/27/89	0.22±0.02	U.D.	0.09±0.00	N/A
		N	6/27/89	0.60±0.05	U.D.	0.09±0.00	N/A
		S	6/27/89	0.60±0.05	U.D.	0.06	N/A
		E	6/27/89	0.30±0.03	U.D.	0.08±0.00	N/A
		Mean		0.43	U.D.	0.08	N/A
		Std. Error		0.09	U.D.	0.01	N/A
Curlew Cay	Coral Reef	W	5/30/90	U.D.	U.D.	U.D.	N/A
		N	5/30/90	U.D.	U.D.	U.D.	N/A
		S	5/30/90	0.14±0.01	U.D.	U.D.	N/A
		E	5/30/90	U.D.	U.D.	U.D.	N/A
		W	5/30/90	U.D.	U.D.	U.D.	N/A
		N	5/30/90	U.D.	U.D.	U.D.	N/A
		S	5/30/90	0.18±0.02	U.D.	U.D.	N/A
		E	5/30/90	U.D.	U.D.	U.D.	N/A
		Mean		<0.10	U.D.	U.D.	N/A
		Std. Error		0.04	U.D.	U.D.	N/A

Proposed Thresholds:
DIN: 1 μM, SRP: 0.1 μM

Lapointe, B. E., M. M. Littler, and D. S. Littler. 1993. Modification of benthic community structure by natural eutrophication: the Belize Barrier Reef. ***Proceedings of the 7th International Coral Reef Symposium*****, Guam 1: 323-334.**

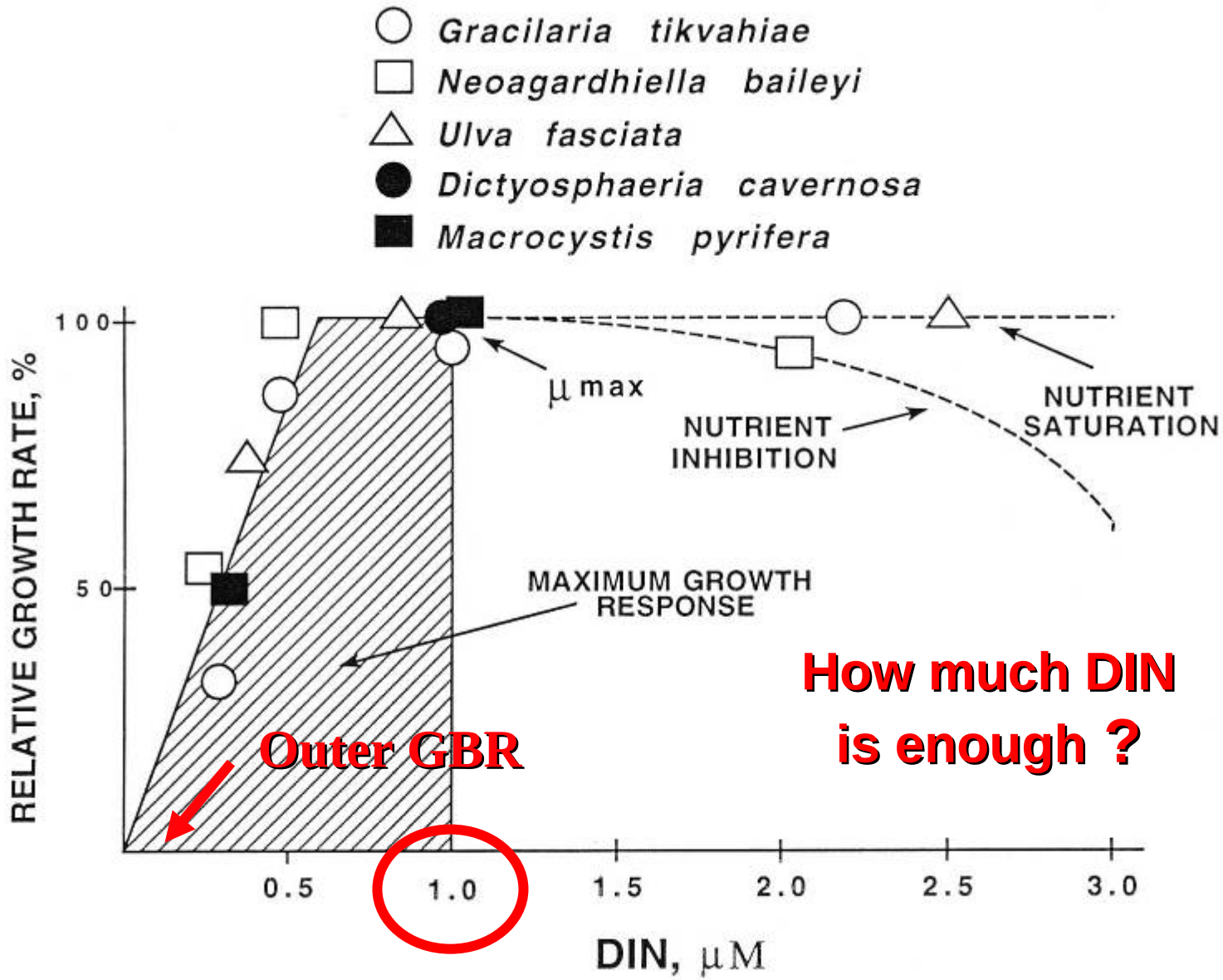
Nutrient Threshold Research Down Under: Australia's Great Barrier Reef

Daydream Island

Proposed Nutrient Thresholds:
DIN: 1 µM
SRP: 0.2 µM
Chl *a*: 0.5 µg/l

Bell, P.R.F. 1992. Eutrophication and Coral Reefs-Some Examples in the Great Barrier Reef Lagoon. *Water Research 26*, 553-568.

DIN Thresholds: Macroalgal HABs on Coral Reefs



Lapointe, B. E. 1999 *L&O* 44(6):1586-1592

South Florida

St. Lucie, Martin, Palm Beach, Broward, and Dade counties

Everglades Agricultural Area

Shark River Slough

Taylor Slough

Florida Bay

Florida Keys

Land-Based Nutrient Enrichment and Coastal Eutrophication in the Florida Keys:1989-1990

Florida Keys Land & Sea Trust

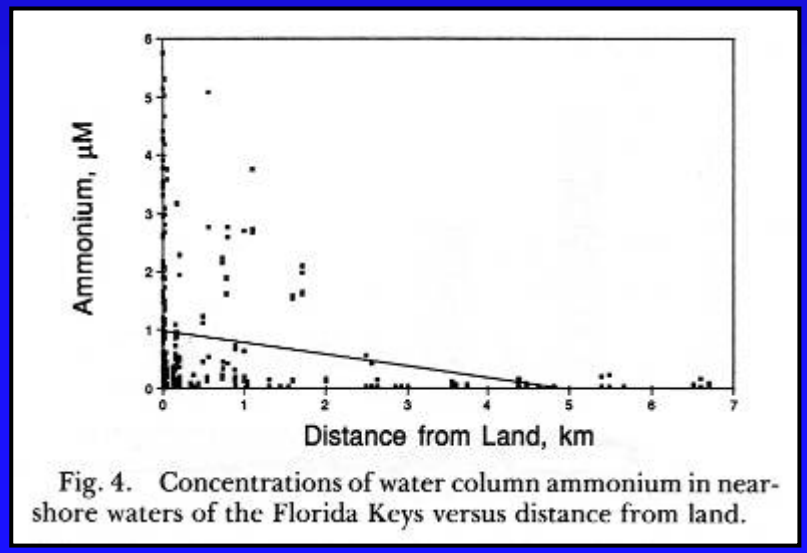


Fig. 4. Concentrations of water column ammonium in nearshore waters of the Florida Keys versus distance from land.

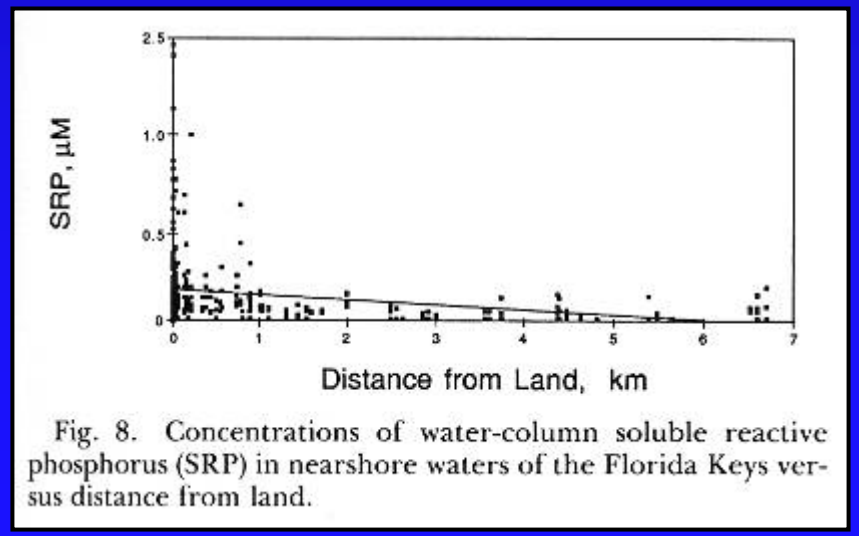
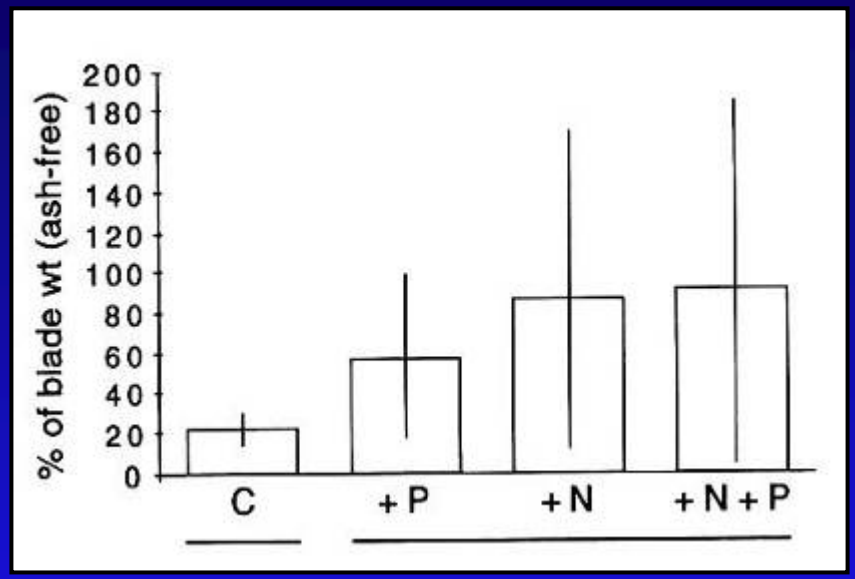


Fig. 8. Concentrations of water-column soluble reactive phosphorus (SRP) in nearshore waters of the Florida Keys versus distance from land.

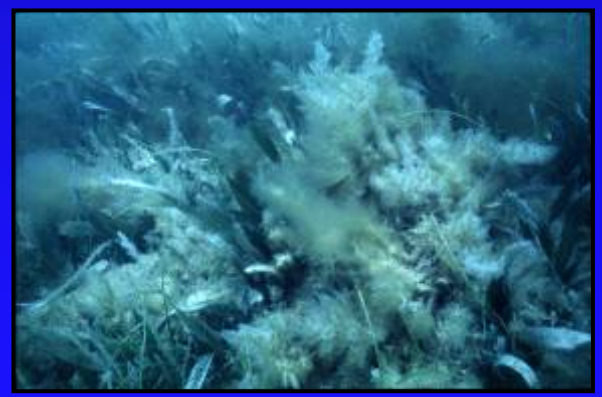
Effects of Nutrient Enrichment on Growth and Productivity of Seagrasses: 1990-1994

David Tomasko



Thalassia testudinum

Seagrass epiphytes



Macroalgal HABs

Florida Keys National Marine Sanctuary Act-1990

The Key West Citizen
Vol. 111 No. 46 16 Pages Key West, Fla., Monday, Feb. 24, 1992 25 Cents

Marine sanctuary

Panel: Water quality is top local concern

By Marilyn J. Tarnowski
Citizen Staff Writer

MARATHON — A 22-person advisory panel has agreed that water quality is the single most important issue underpinning the management plan being prepared for the nascent Florida Keys National Marine Sanctuary.

The same panel also found available research and data are scant and inadequate for informed decision-making about what affects marine life and ecology in the Keys.

The group is chartered with advising the National Oceanic and Atmospheric Administration of user-group concerns within the sanctuary. In a two-day session last week in Marathon, the advisory panel reviewed a near-final report that summarizes existing research and known quantities related to the water-quality of the sanctuary and adjacent waters.

The management-plan writing project now moves into a second phase: A Water Quality Steering committee comprised of NOAA, the federal Environmental Protection Agency, and state and local agencies, will develop water quality monitoring and research programs.

The advisory panel, said member George Barley of Orlando, cautioned the Water Quality Steering Committee that its first report may give the impression that ample information is available on water-quality impacts.

"We don't agree there's adequate data," Barley said.

Barley said his committee advocated research and monitoring for water entering the sanctuary and what effect deep sea salty water and freshwater runoff from the Everglades has on sanctuary ecology.

"The South Florida Water management district says it is monitoring the situation, but we are skeptical about that," Barley said.

In 1991, Congress funded $390,000 for Phase I work, the compilation of existing data released earlier this month and reviewed by the user groups last week. For 1992, the federal government has funded $625,000 for the development of research and water quality monitoring projects, the heart of Phase II.

In addition, a Gulf of Mexico Project will add $50,000 for demonstration water quality projects, EPA Regional Administrator Greer Tidwell said.

The user groups also advocated a so-called ecosystem approach to research and monitering, which would identify pollution sources in local and adjacent waters. The water concerns must not stop at sanctuary boundries, Mark Robertson of The Nature Conservatory said. Tidwell said that enlarged scope was already planned.

The advisory committee advocated active pursuit of new technology appropriate to each of the several sources of water degradation.

"This group is the community's link in the development of the management plan," Billy Causey, manager of the sanctuary project, said Thursday after an information session at Buccaneer Lodge.

"Now that all of the public scoping meetings have been held, time is tighter now. The advisory council is here to convey the wishes of the constituencies," he said. The entire management plan must be finished by June 1993.

The Florida Keys National Marine Sanctuary was created by Congress Nov. 16, 1990, to be managed by the NOAA within the Department of Commerce. Legislation included a first-time mandate that the program include water quality program administered in conjunction with the EPA.

Summer 1992: Hypersalinity Hypothesis Promoted

Ron Jones, FIU

Florida Bay outflow in Upper Keys

FLORIDA

The Miami Herald

SECTION B
TUESDAY, SEPTEMBER 29, 1992

Decline of corals blamed on water

DAN KEATING
Herald Staff Writer

The federal government is putting up million to help the water quality ound the Florida Keys coral reef — but cientists are pointing their fingers at the erglades as the greatest source of water oblems.

Researchers say the lack of freshwater w into Florida Bay causes a surge of er-salty water that damages the Keys f, the third longest barrier coral reef in world and the only one on the North erican Continent.

"The 'Florida Bay water' hypothesis is at present the best hypothesis to explain the decline of corals in the Florida Keys," said Jim Porter, a University of Georgia researcher who has been at the forefront of reef research.

In a meeting at Hawk's Cay, the Environmental Protection Agency was scheduled Monday night to release its assessment of water quality in the Florida Keys National Marine Sanctuary. It will summarize the current condition, lay out a plan for monitoring and research and specify other actions to be taken.

Congress has appropriated $1 million for the coming year for water quality improvement and research. Half of that money is dedicated to an unspecified program to find innovative ways of improving sewage treatment in the Keys.

Led by George Barley, the chairman of the sanctuary's advisory committee, many scientists are already calling for action.

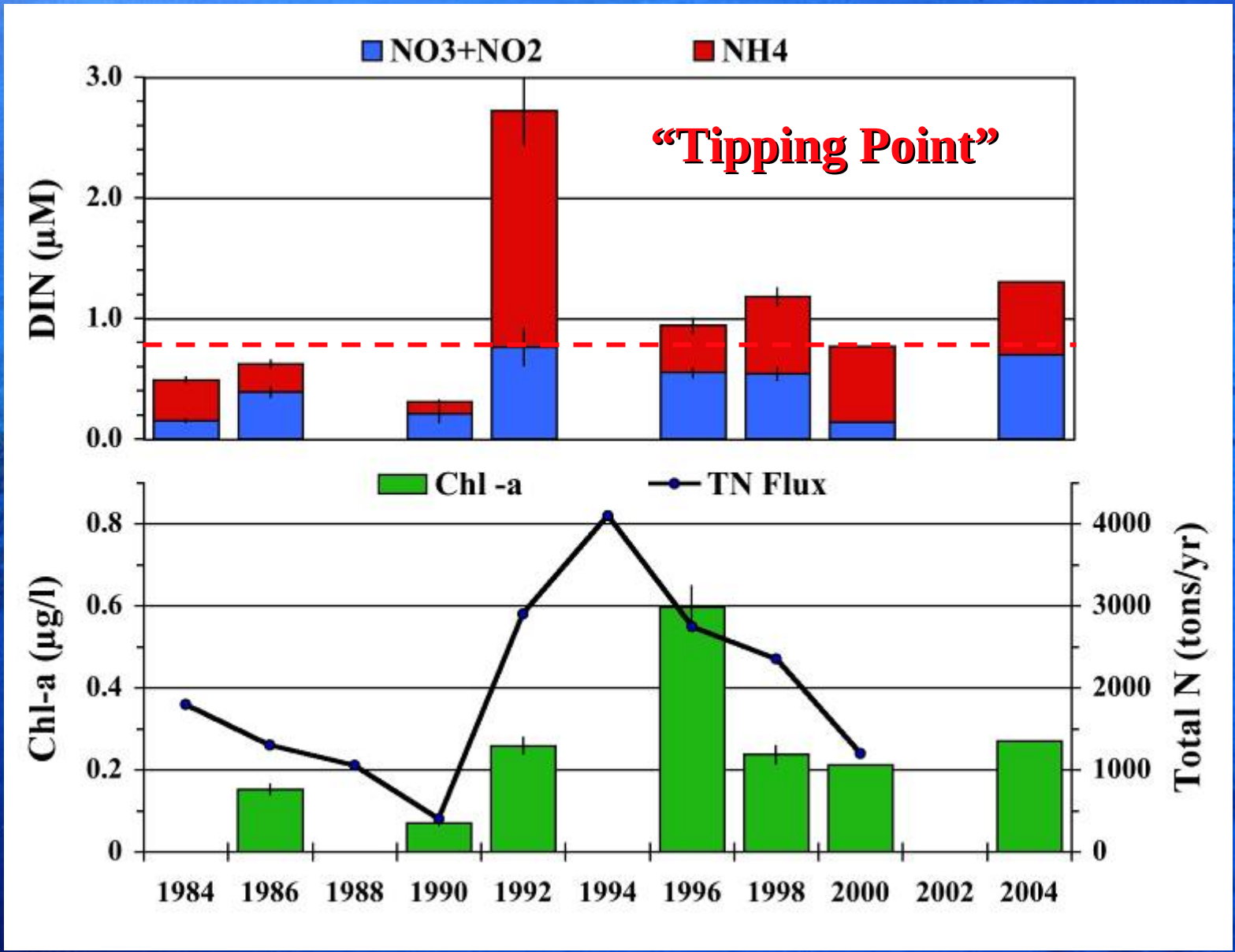
Until the last year, water quality problems in the Keys were generally described as nutrient pollution coming from septic tanks, cesspools and neighborhood sewage treatment plants. Research has shown severe pollution around several keys and subdivisions.

But scientist J. Zieman of the University of Virginia and Barley have shifted the attention and most of the scientific consensus to look north, to Florida Bay, to explain the water problems in the Keys. Zieman cites the die-off of thousands of acres of sea grass in the bay, large blooms of algae throughout the region, coral bleaching and other marine problems.

"These are highly unlikely to be random, simultaneous events," he said.

Scientists meeting to finalize the EPA study generally agreed, he said, "that the issue of restoring fresh water to Florida Bay and the Everglades was the leading problem."

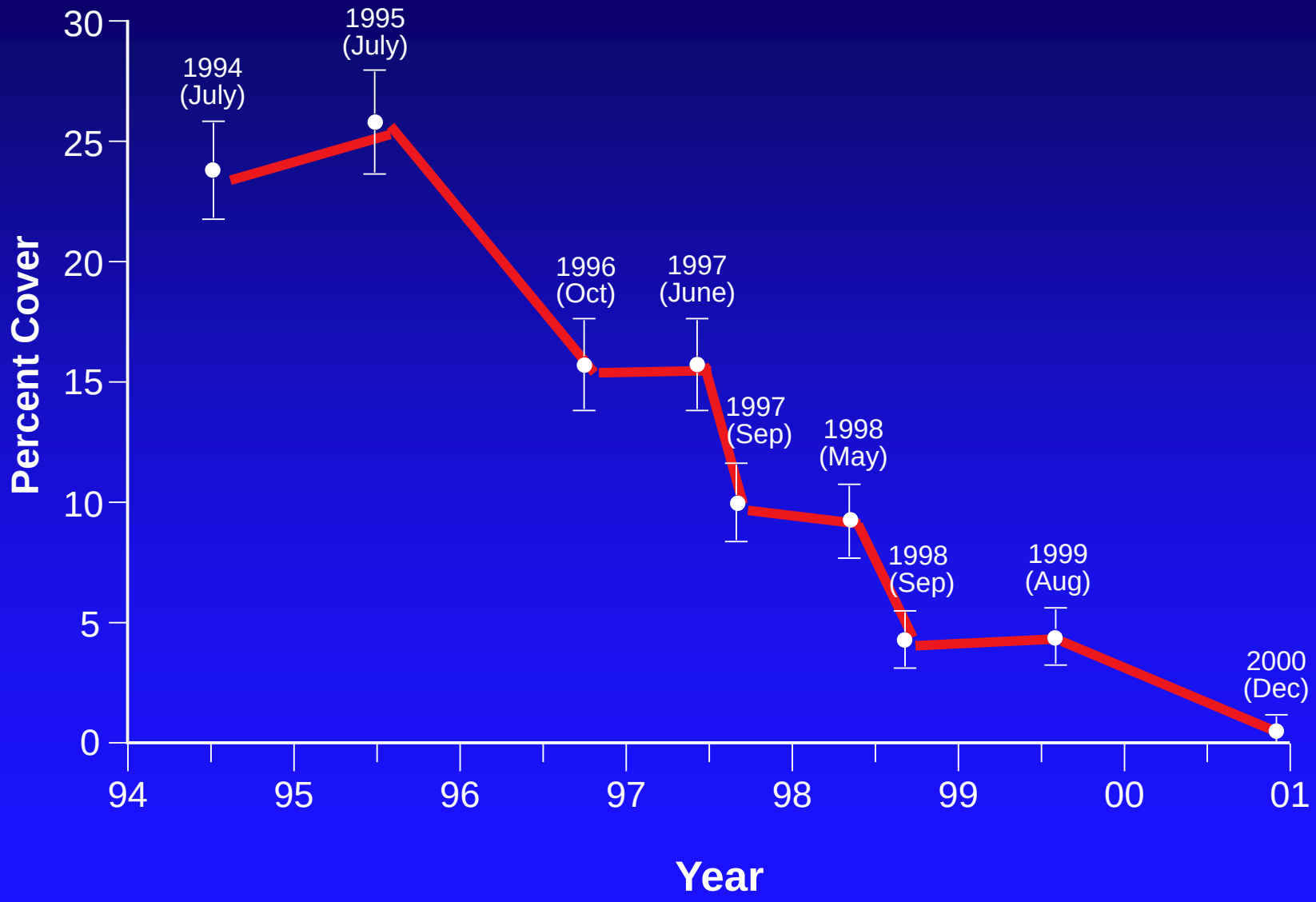
Looe Key Water Column Nutrients 1984-2004

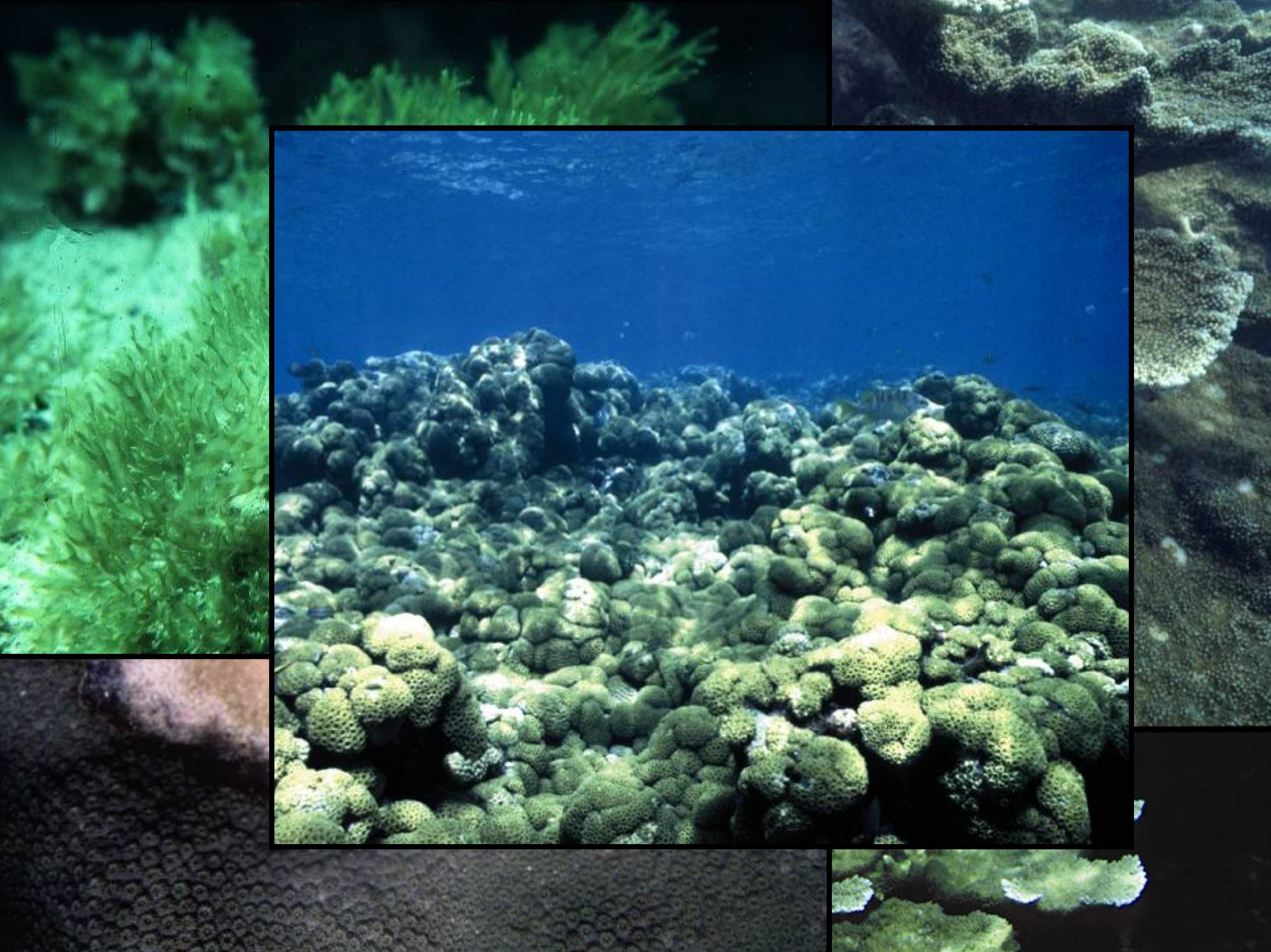


Acropora palmata (Lamarck, 1816)

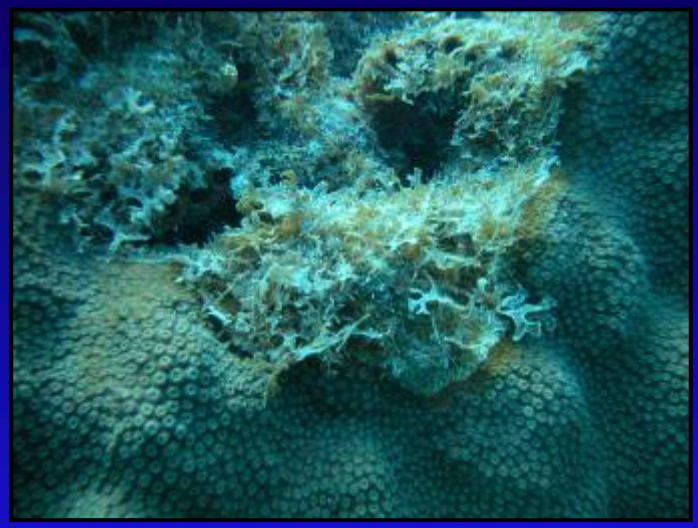
Eastern Dry Rocks Reef, Key West, FL

(1994-2000)



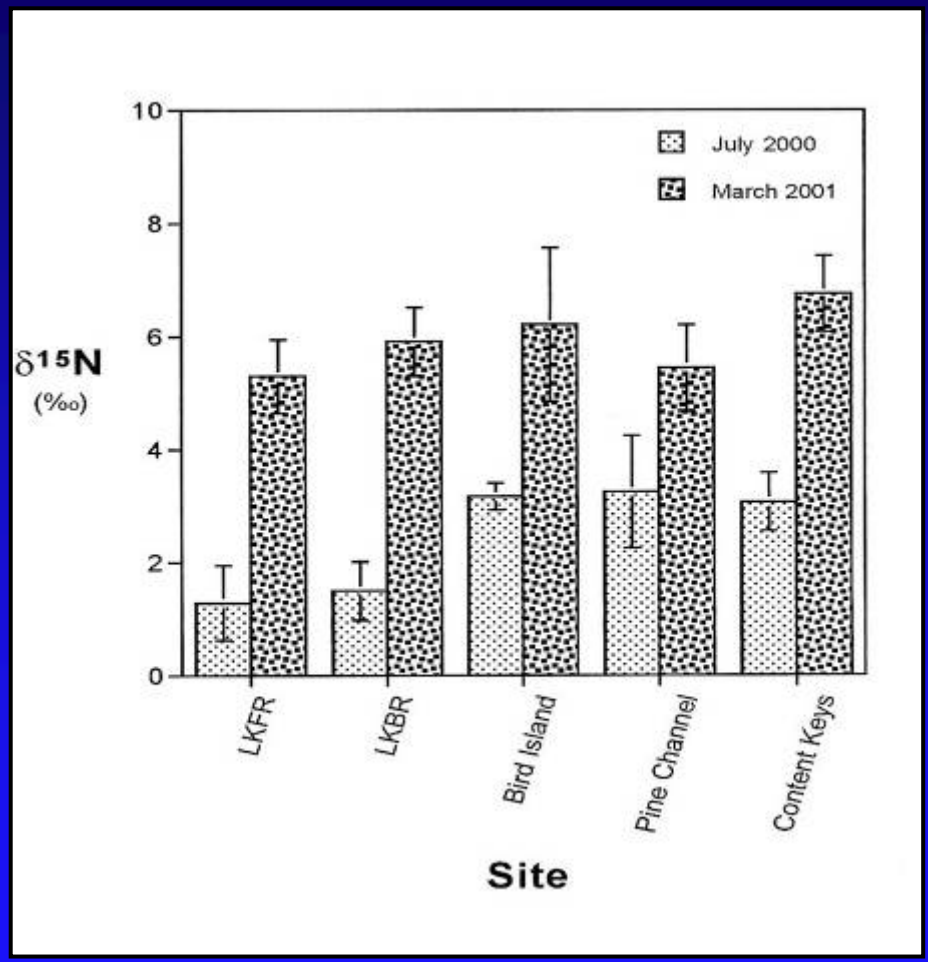


“Fingerprinting” Nitrogen Sources Using Stable Nitrogen Isotopes in Macroalgae: 1996 - Present



Looe Key, October 20, 2006

Little Palm Island, October 21, 2006



Lapointe et al. 2004. JEMBE 308:23-58.

Biologist downplays pollution's role in spoiling coral reefs

By CYRIL T. ZANESKI
Herald Staff Writer

The decline in numbers of algae-eating fish and sea urchins is fouling Florida's coral reefs far more than pollutants in the water, according to findings of a Georgia

Mark Hay of the Georgia Insti[tute] of Technology said Wednes[day] at his experiments off the Florid[a] Keys strongly suggest that sewage a[nd] storm water spewing from the c[row]ded coastline are not responsi[ble] for the algae smothering some [reefs].

Everybody says d[evelop]ment and nutrients in t[he] Florida K[eys] are to blame, but we see ing[] the same impacts in reefs [] whe[re] including some remo[te] sites [] way from developed areas throug[hout] the Caribbean," Hay told ab[out] 500 scientists and resource [m]anagers Wednesday at Fort Lauderdale's Radisson Bahia Mar hotel. "There's something else going on out there."

Scientists are only starting to learn how to look for culprits behind what many say is a worldwide epidemic of coral diseases and degradation.

[Th]eir search brought them to the [in]ternational conference on reef assessm[ent] and restoration. Nova Southeaster[n] University's National Coral Reef In[sti]tute is hosting the three-day gather[ing] which has drawn scientists and government officials from 31 countries.

Scientists are only starting to learn how to look for culprits behind what many say is a worldwide epidemic of coral diseases and degradation.

[Ja]mes D. Thomas, the reef institute research director, said the confere[nce] is aimed at challenging some lo[ng]-standing scientific beliefs and fo[rce] researchers to come up with fres[h] ideas.

"[Ri]ght now, all we [do] them to be doing [is] watching re[efs] die," Thomas said. "We need to get to the next level. We need to know what groups of animals or plants we should be looking at to tell us [what] is happening before the reefs die and [give] managers how they can make bette[r] decisions."

Along with 140 pre[sen]tations of research results, the con[fer]ence includes workshops in which scientists — who are known for intense arguments among themselves — might work to resolve disputes.

"That should be very interesting," Thomas said.

There is no disputing that the world's coral reefs are in crisis. Among the many possible reasons: epidemics of mysterious diseases, overfishing, a changing global climate and pollution.

Alarmed by the declining health of the reefs and a lack of information about them, the Clinton administration last year formed a federal task force to steer research and formulate strategies for protecting reefs and the [] environment that sustains them.

Hay, a biologist at the Georgia Institute of Technology, led off the conference with his controversial suggestion that nutrients from sewage may not be the smoking gun that environmental activists and researchers maintain that it is.

"Some of the few things we really 'know' about reefs appear to be wrong," Hay said bluntly in a summary of his research written for the conference.

As a result, he added, a lot of money and energy may be chasing the wrong problems while ignoring more damaging factors.

Hay has been conducting experiments along the Keys since 1997. He uses cages to exclude algae-eating stoplight parrotfish from live corals growing on concrete blocks to test the importance of plant-eating animals. And he built a simple mechanism to apply fertilizers directly to corals to test the role nutrient pollution may be playing in the degradation of the reefs.

The fertilizer had no impact in spurring algal growth on the mature corals, he said.

"Perhaps," he said, "nutrients are overrated in reef studies."

It is possible, he conceded, that the waters are already so overfertilized that the nutrients he added were irrelevant. But he gives the latter theory less weight because algal growth on Florida's reefs is comparable to that seen in areas much farther from developed coasts.

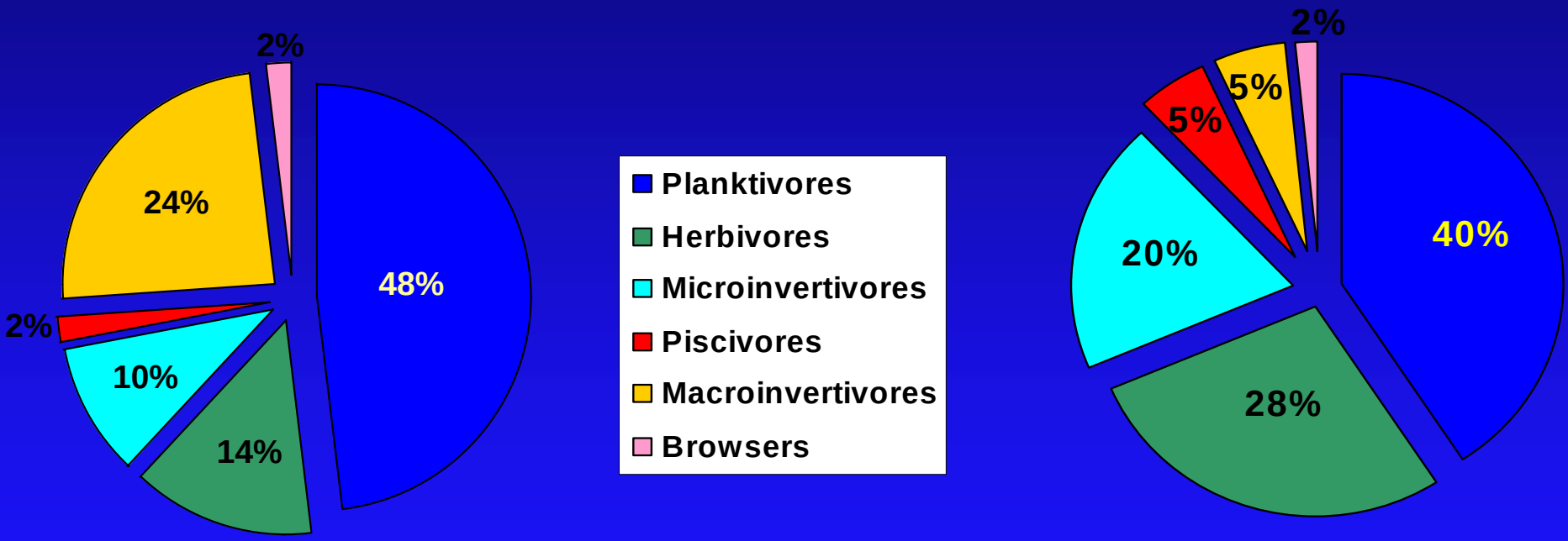
Meanwhile, parrotfish cleaned algae from the reef in a couple of days. The problem is that prolific algae eaters, including the sea urchin, have vanished in recent years and the reefs have grown shaggy with weedy algae.

MIAMI HERALD
15 APRIL, 1999

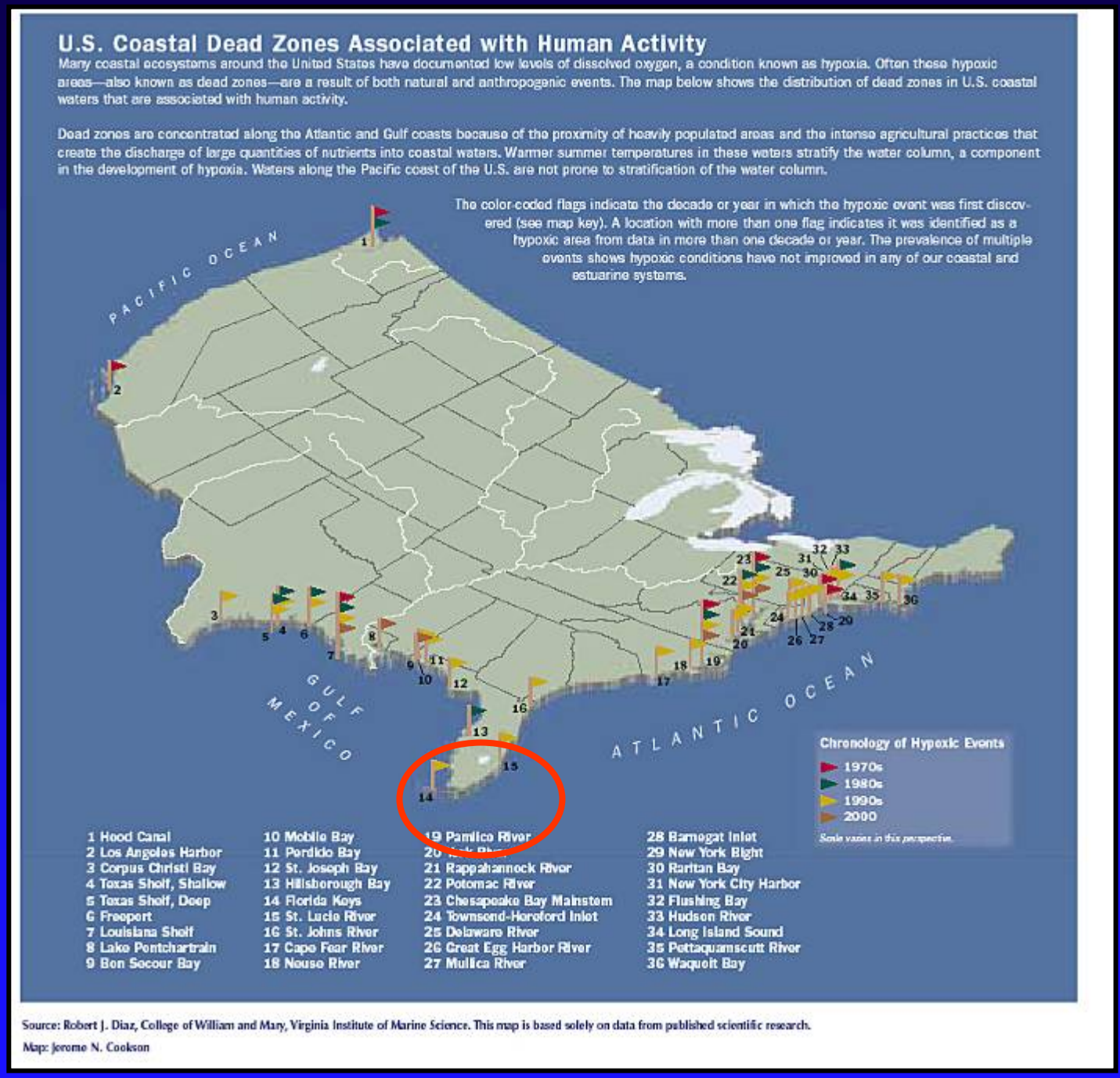
"experiments off the Florida Keys strongly suggest that sewage and storm water spewing from the crowded coastline are not responsible for the algae smothering some reefs."

Trophic Distribution of Fish Assemblages in the Looe Key Sanctuary Protection Area

Percent Total of Individuals, 1984[1] versus Percent Total of Individuals, 2002



1. Adapted from Bohnsack, et.al, 1987.



Source: Robert J. Diaz, College of William and Mary, Virginia Institute of Marine Science. This map is based solely on data from published scientific research.

Map: Jerome N. Cookson

Pew Oceans Commission Report - 2003

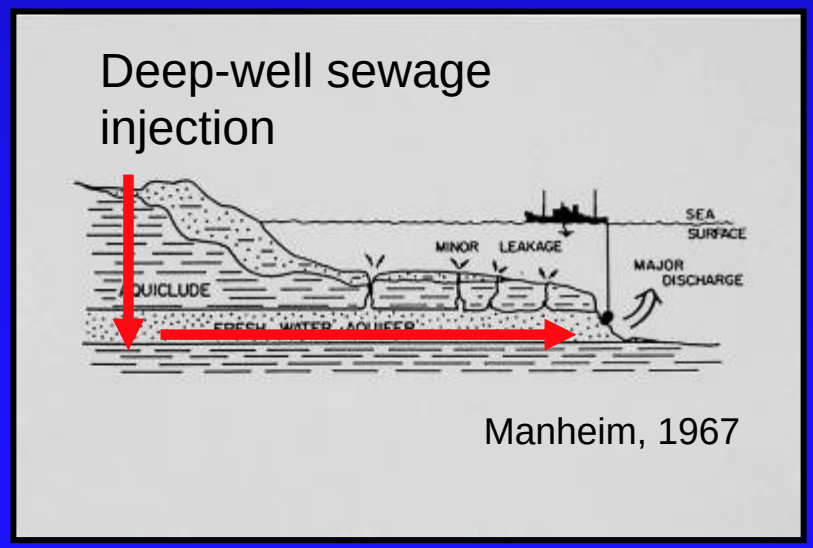
Sea urchins bloom in FL Bay in 1996 !

DON'T FORGET YOUR
KEYS

Human Sources of Nutrient Input to Coastal Southeast Florida

Ocean Outfalls
(~400 MGD)

Surface Water Inlet Discharge



Submarine Groundwater Discharge
(~500 MGD)

Invasive Macroalgal Blooms on Southeast Florida Coral Reefs

"Invasional Meltdown"

1990

Codium isthmocladum

⬇

1997

Caulerpa verticillata

C. racemosa

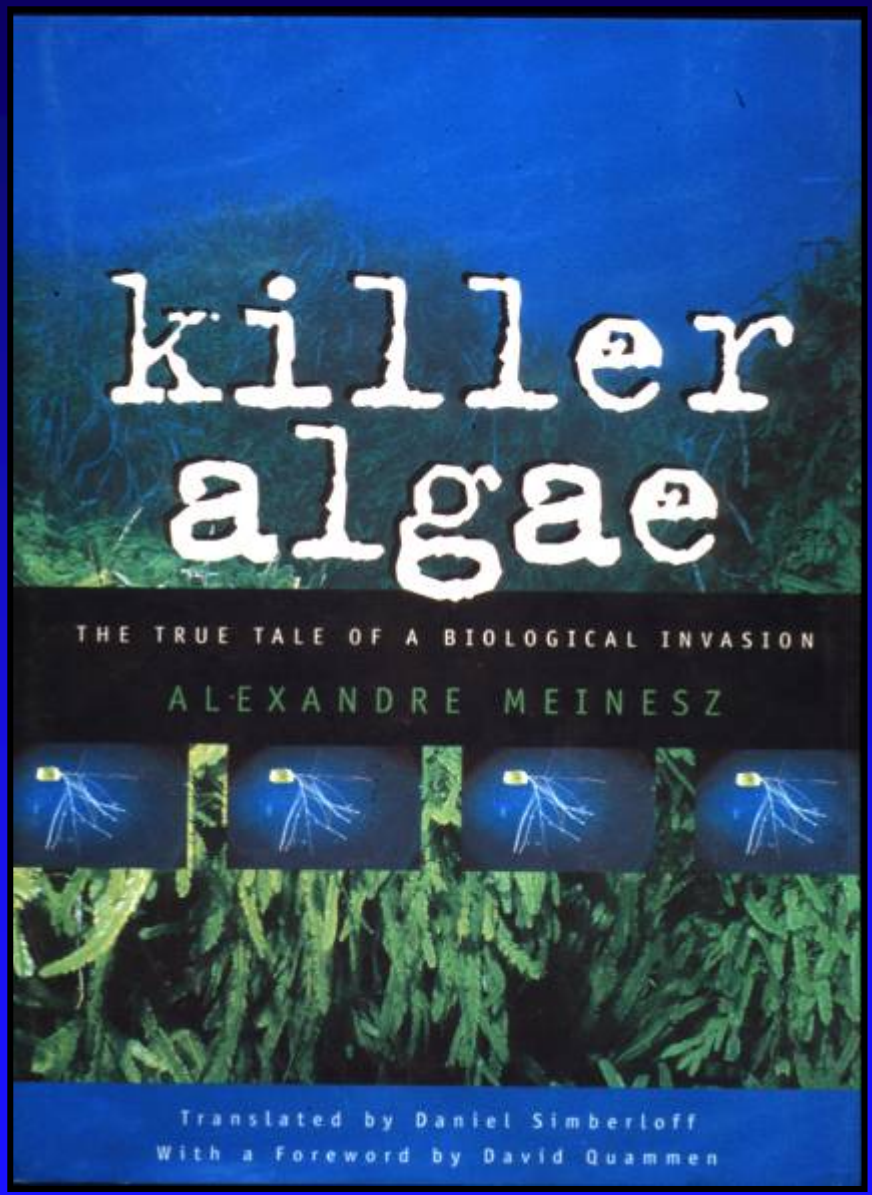
⬇

2001

Caulerpa brachypus

(Pacific native)

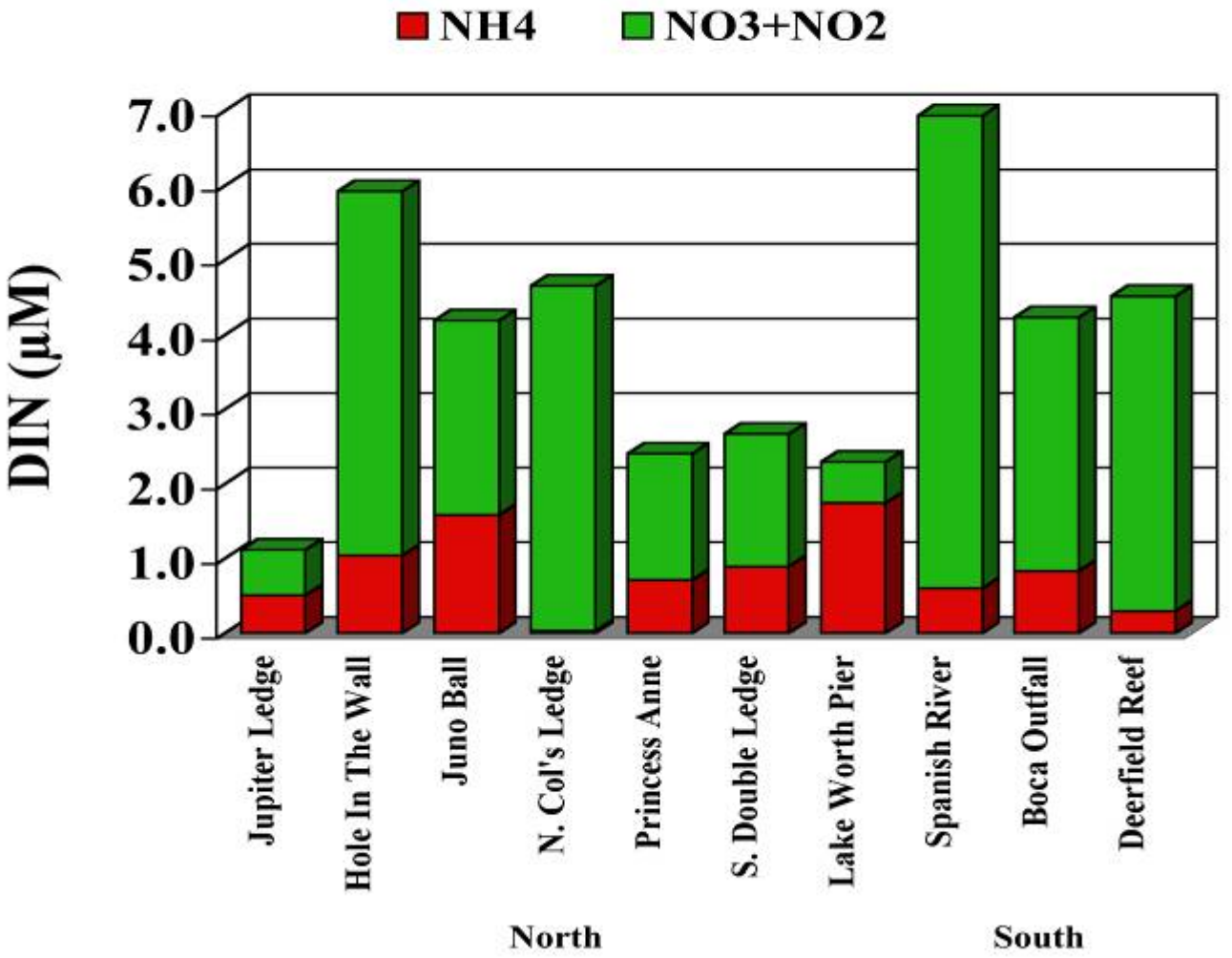
Nutrient Pollution and Invasive Species



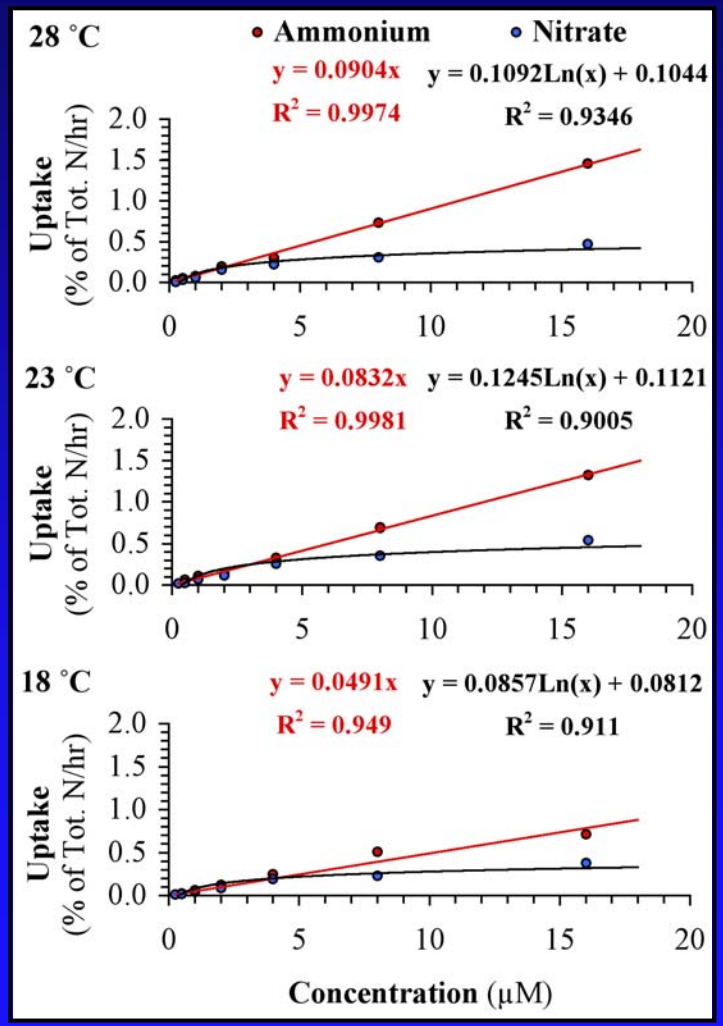
Caulerpa taxifolia in the Mediterranean Sea

www.jadran4you.com/ caulerpa.htm

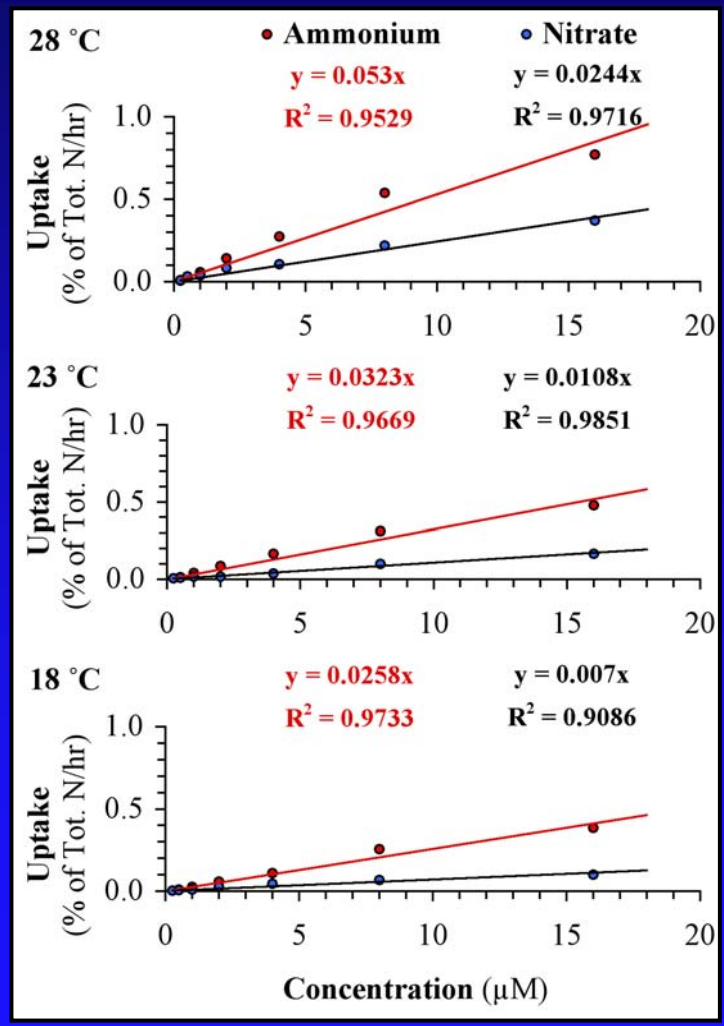
DIN on SE Florida Coral Reefs: Summer, 1996



Preferential Uptake of Ammonium vs. Nitrate by *Caulerpa brachypus and Codium isthmocladum*

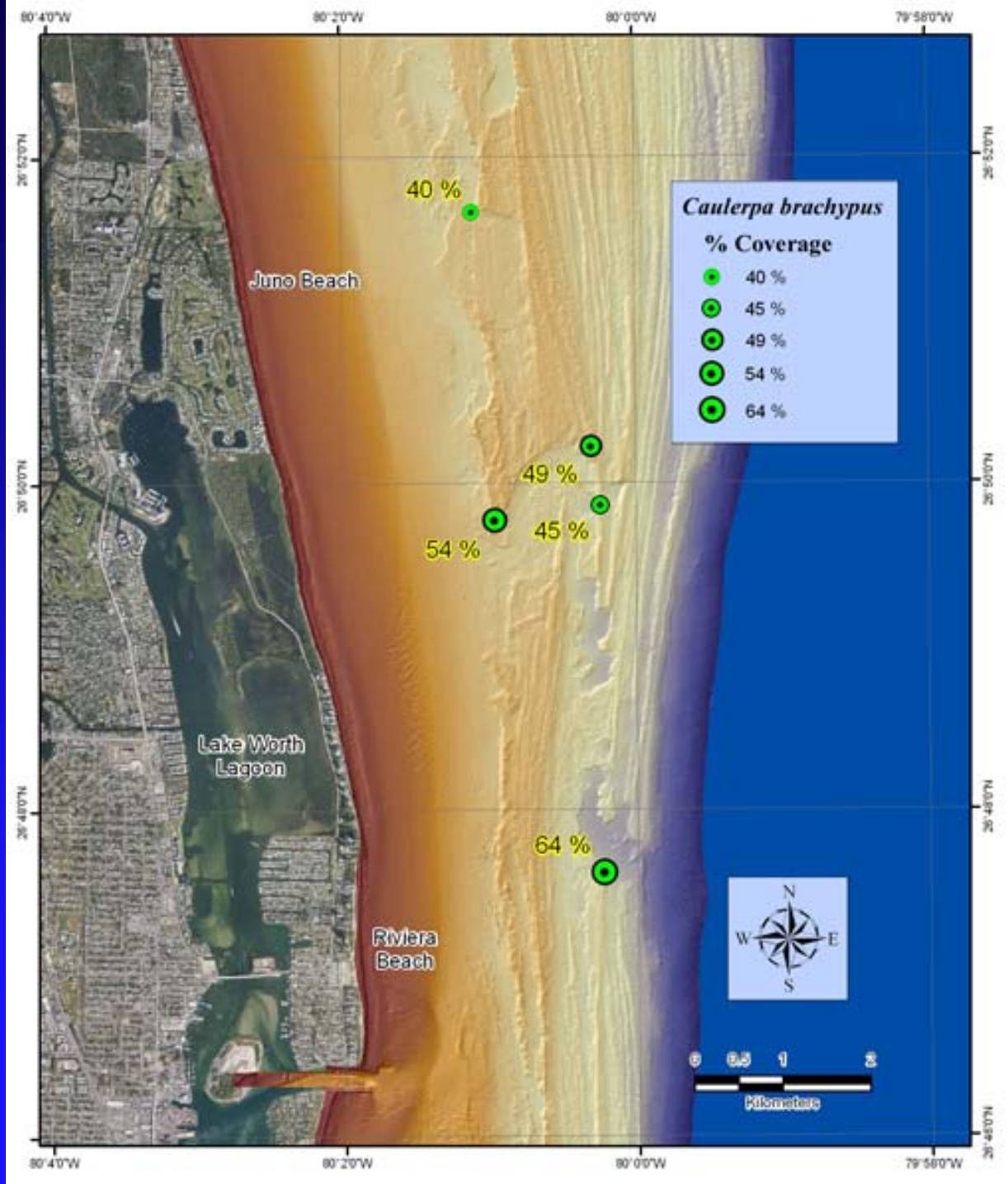


C. brachypus

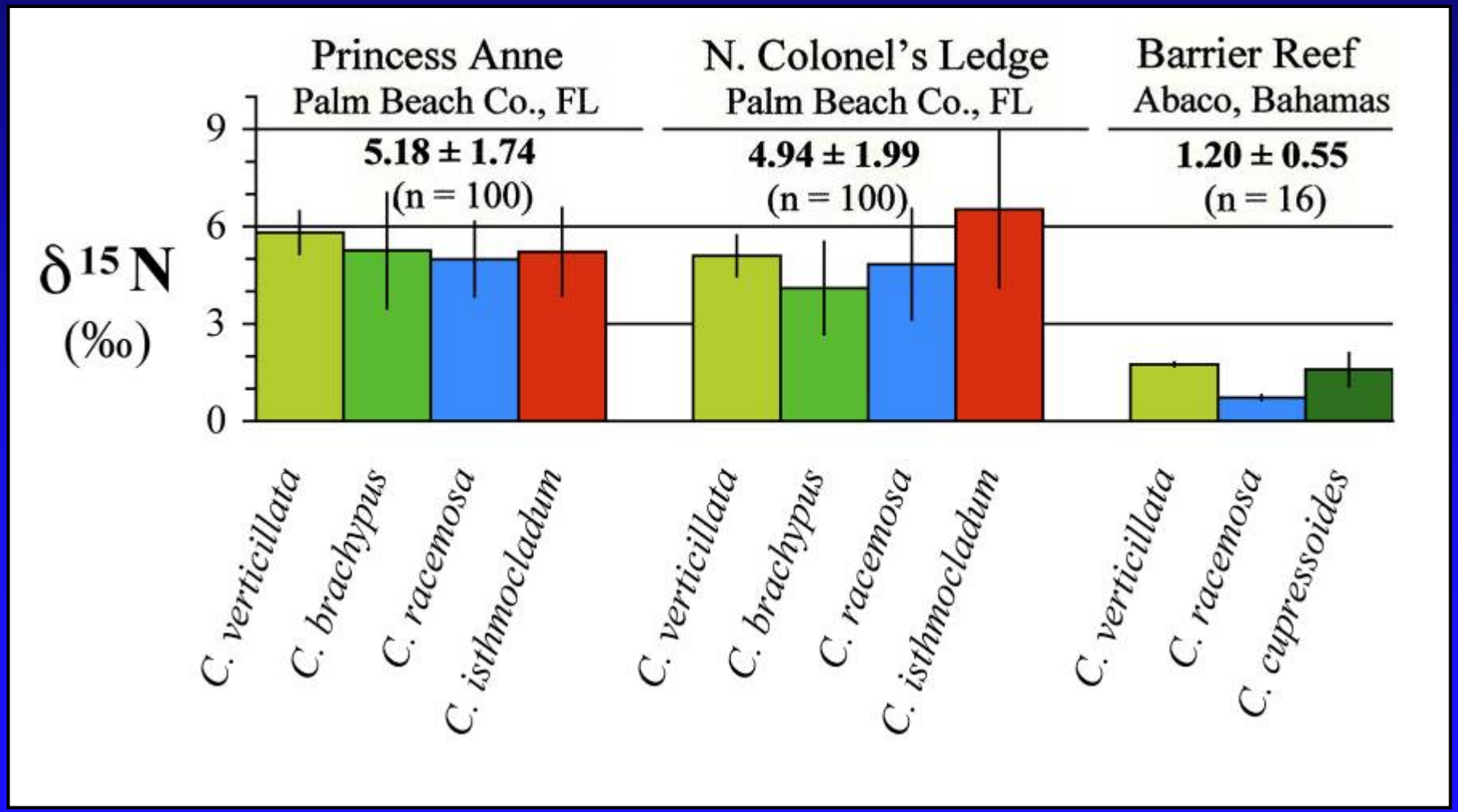


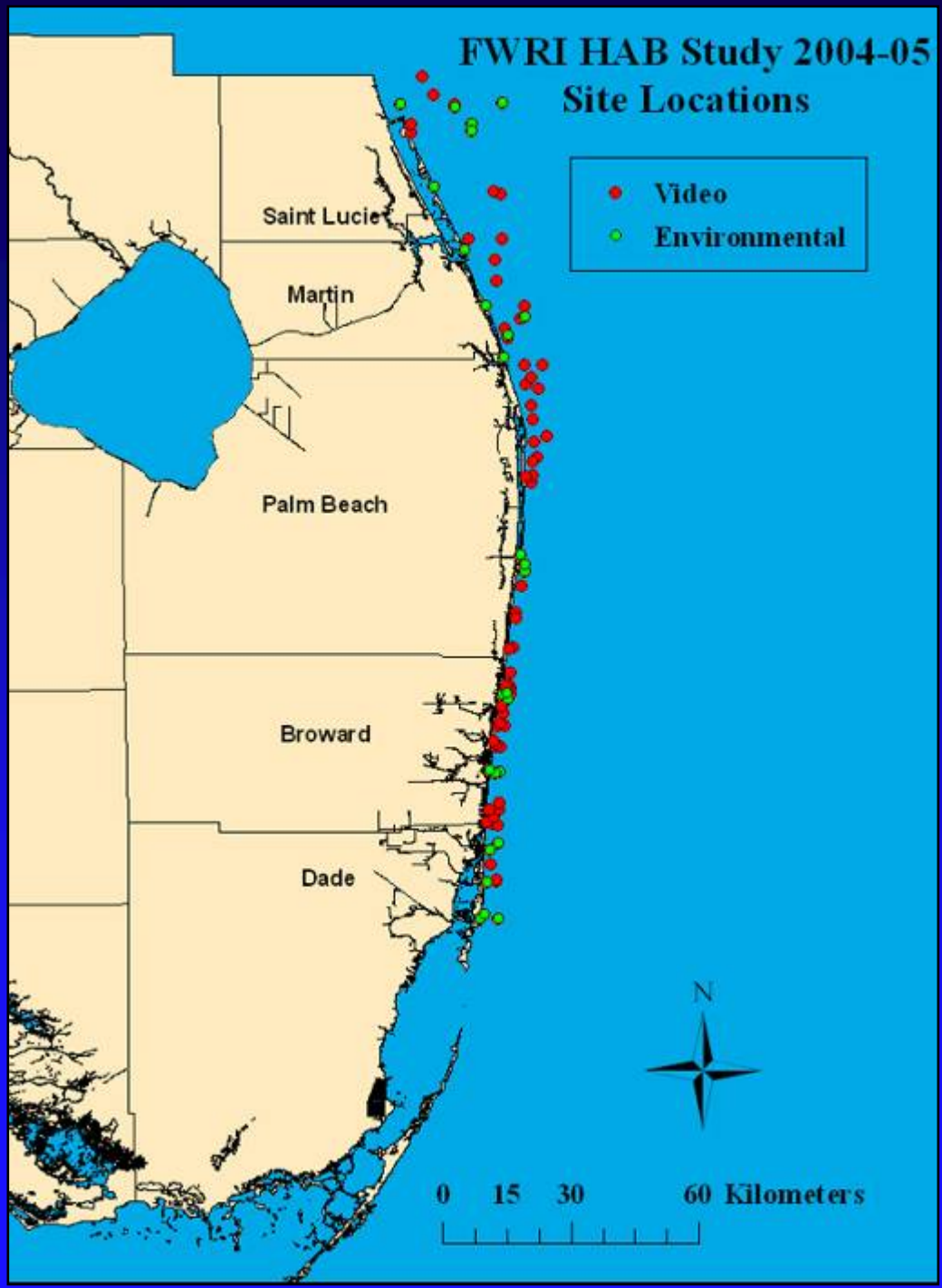
C. isthmocladum

% Coverage of *Caulerpa brachypus* forma *parvifolia* (Harvey) Cribb August 2004



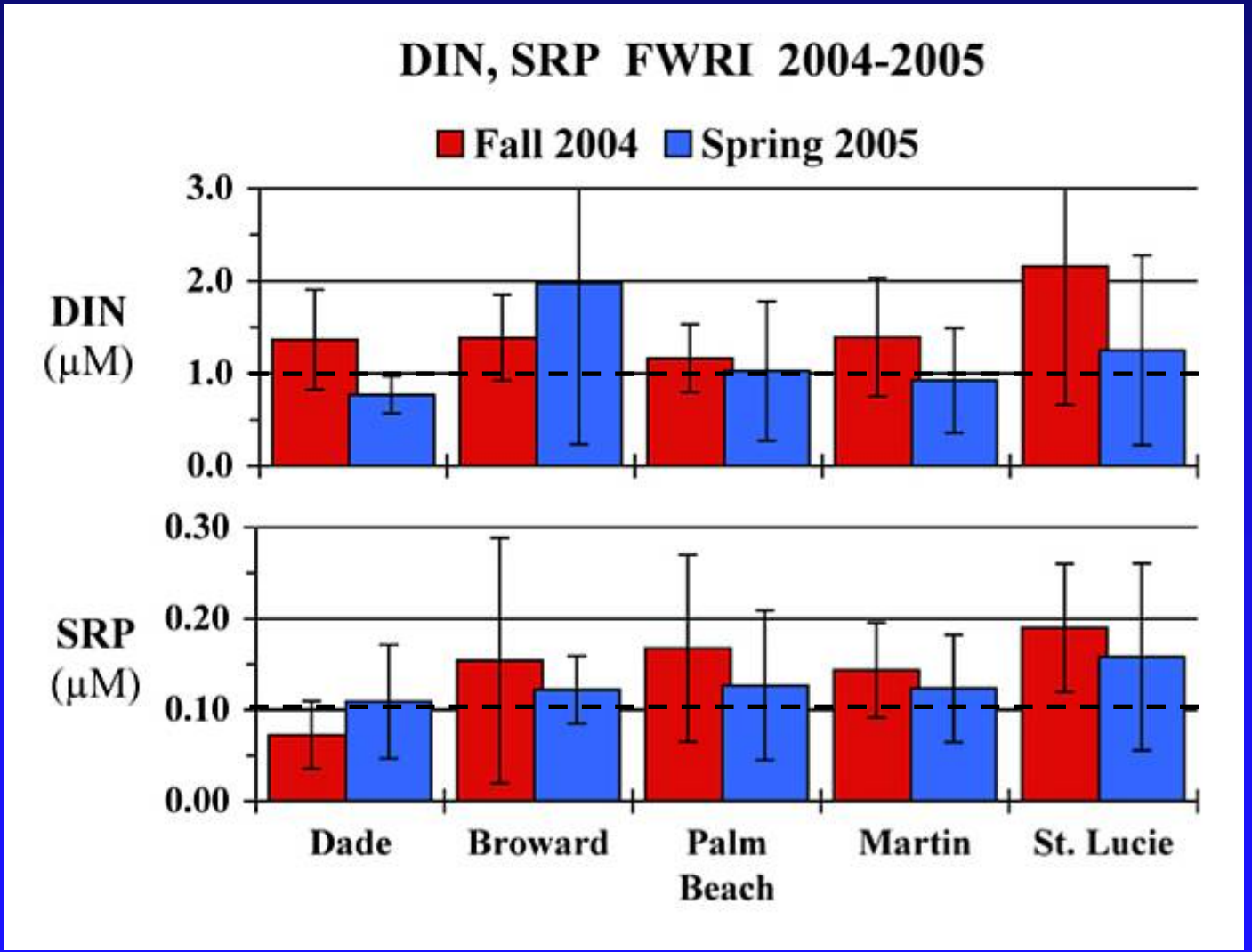
Macroalgal HABs in SE FL Supported by Sewage Nitrogen ?




FWRI HAB Study 2004-05
Site Locations
Video
Environmental
Saint Lucie
Martin
Palm Beach
Broward
Dade
N
0 15 30 60 Kilometers

Dissolved Inorganic Nutrients

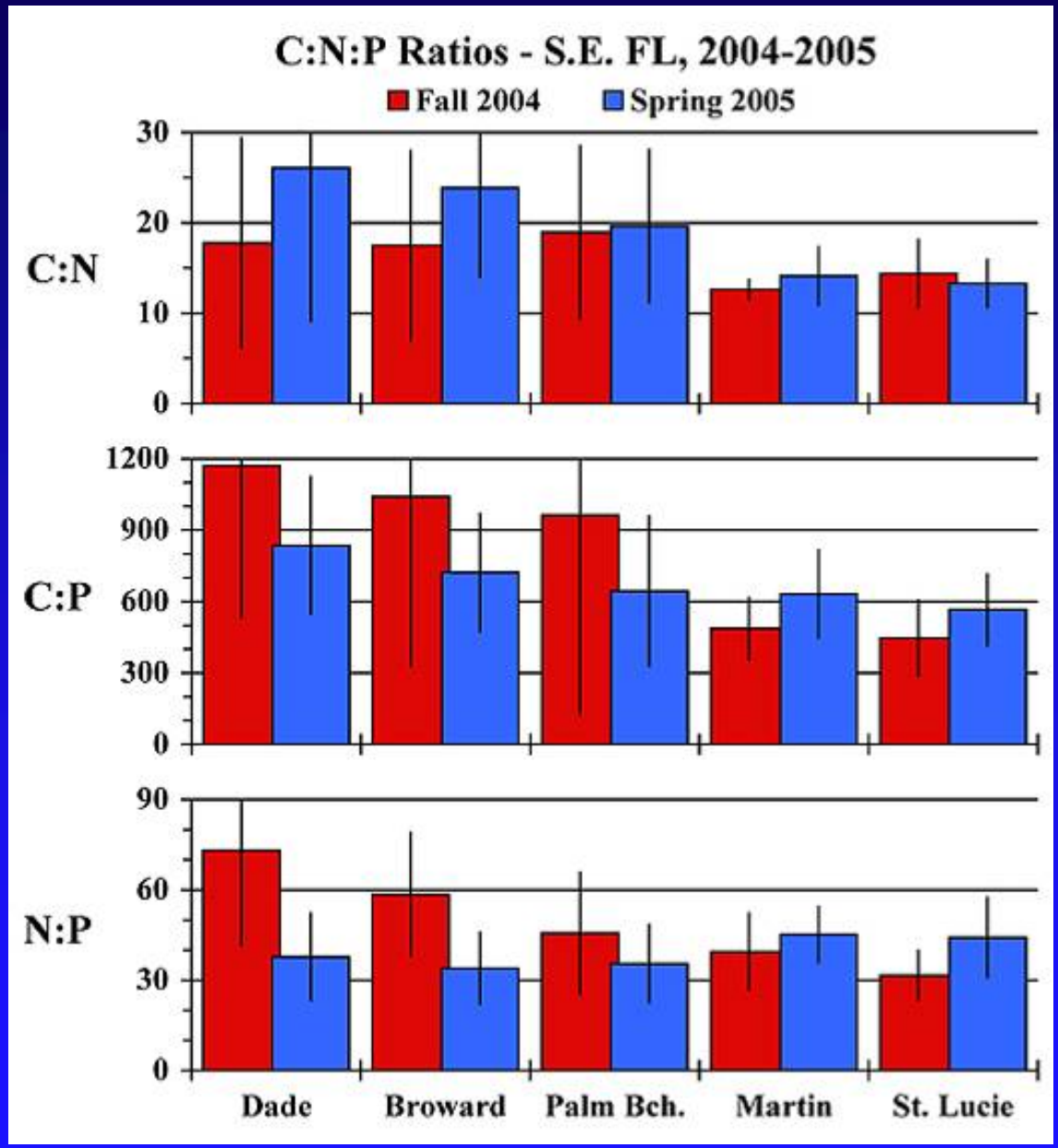
Dissolved Inorganic Nitrogen - DIN
Soluble Reactive Phosphorus - SRP



Macroalgal Tissue Nutrients

Carbon:Nitrogen: Phosphorus Ratios

- C:N ratios > 15:1 indicate N limitation
- C:P ratios > 700:1 indicate P limitation
- N:P ratios > 35:1 indicate P limitation



Latitudinal Changes in Macroalgal HABs on SE FL Coral Reefs

Lyngbya

Dictyota menstrualis

Codium isthmocladum

Caulerpa racemosa

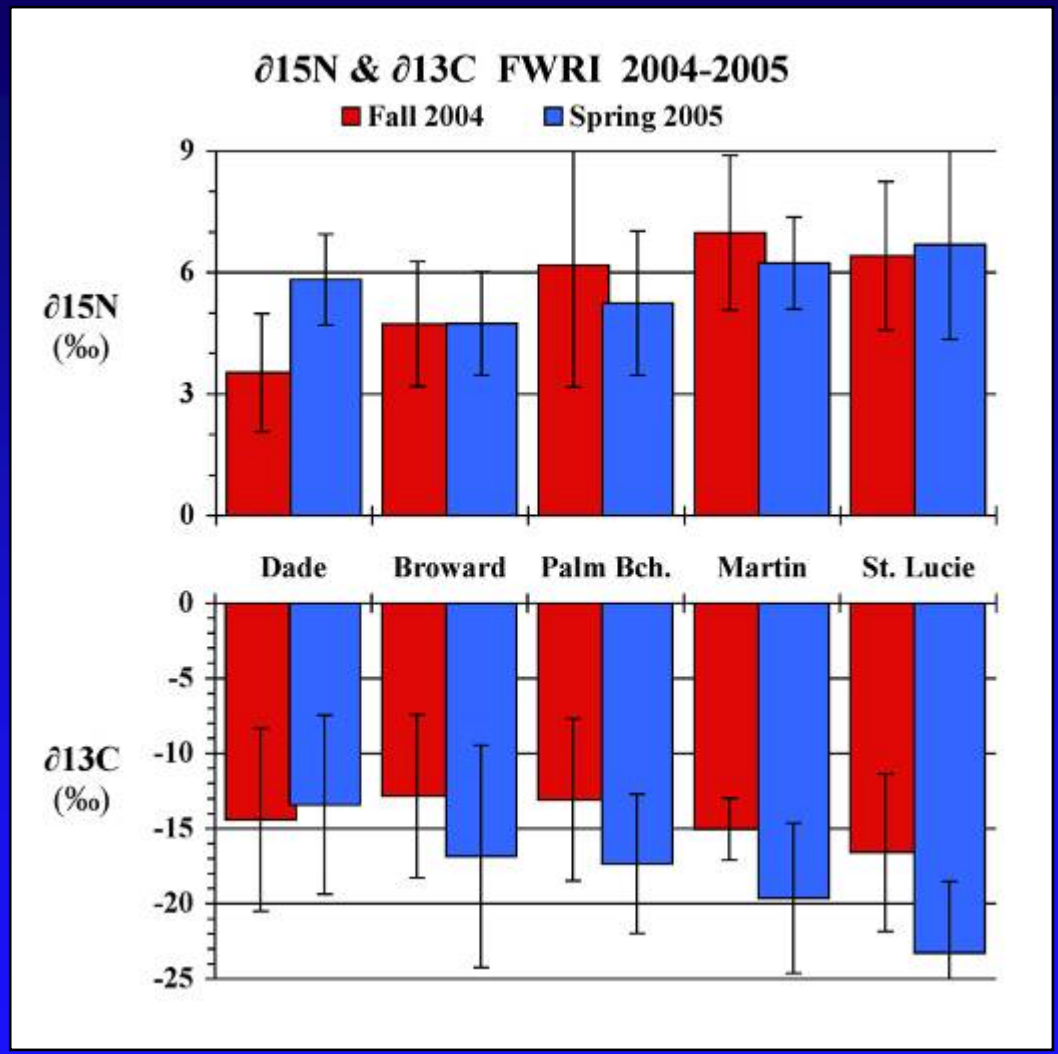
Stable Carbon and Nitrogen Isotopes in SE FL Macroalgae

$\delta^{15}N$ Source Values (o/oo)

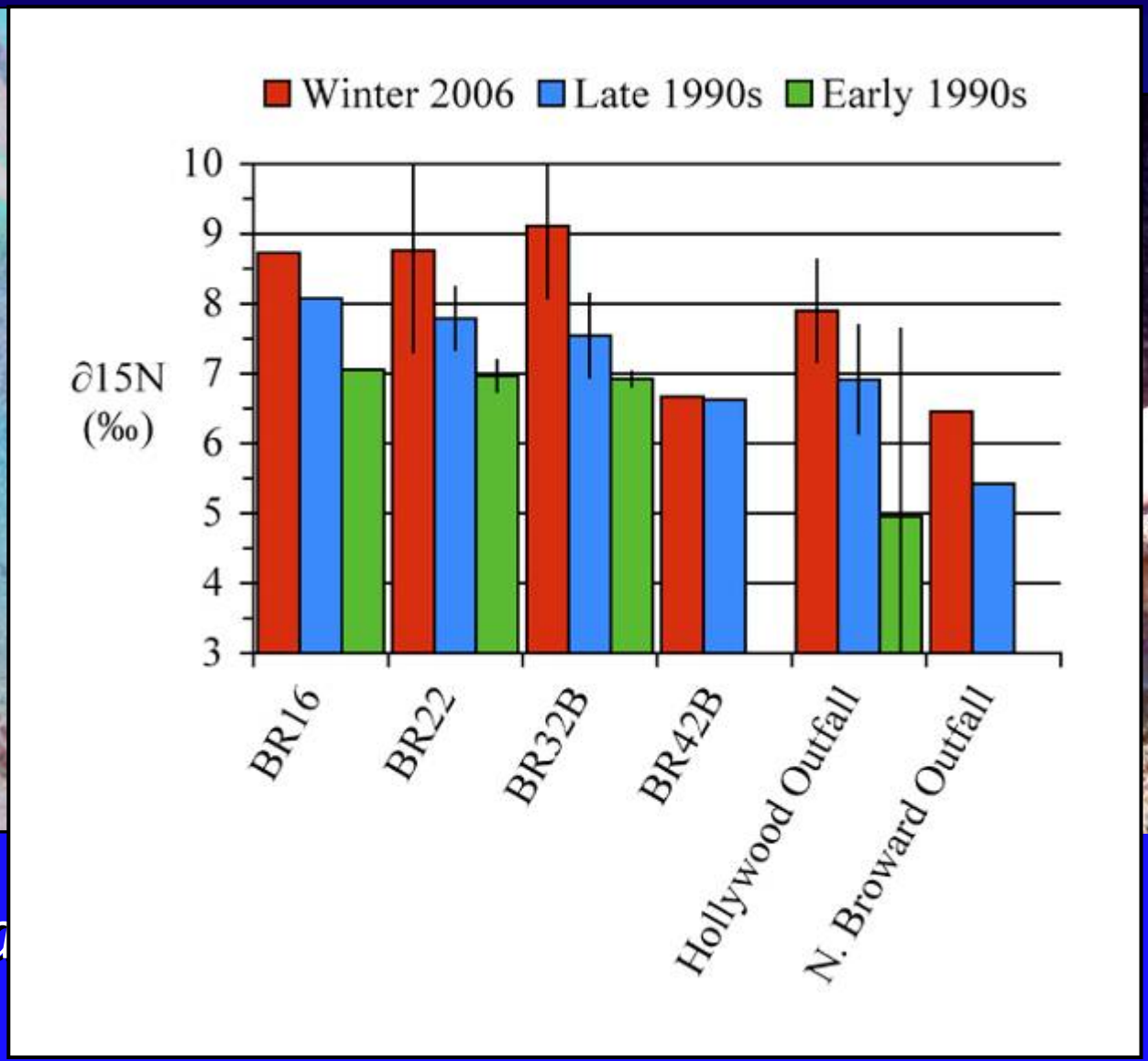
Peat	+ 1 to + 3
Fertilizers	- 3 to + 3
Sewage	+ 3 to + 12
N-Fixation	0 to + 1.0
Upwelling	+ 4.7

$\delta^{13}C$ Source Values (o/oo)

Marine carbonate	0
Atmospheric CO_2	-8
Aquatic Plants	-10 to - 50
CAM Plants	- 10 to - 32

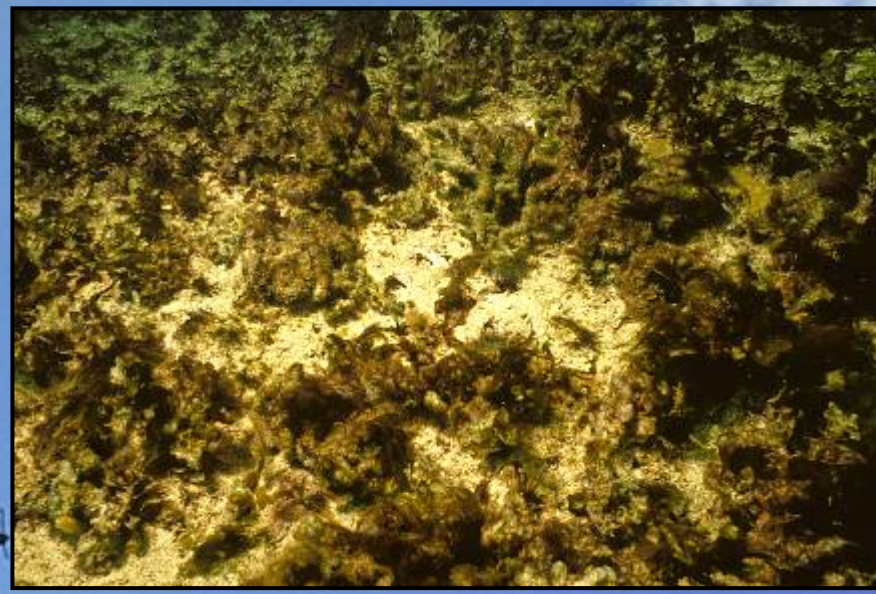


Using Octocorals to Hindcast Sewage Pollution on SE Florida Reefs

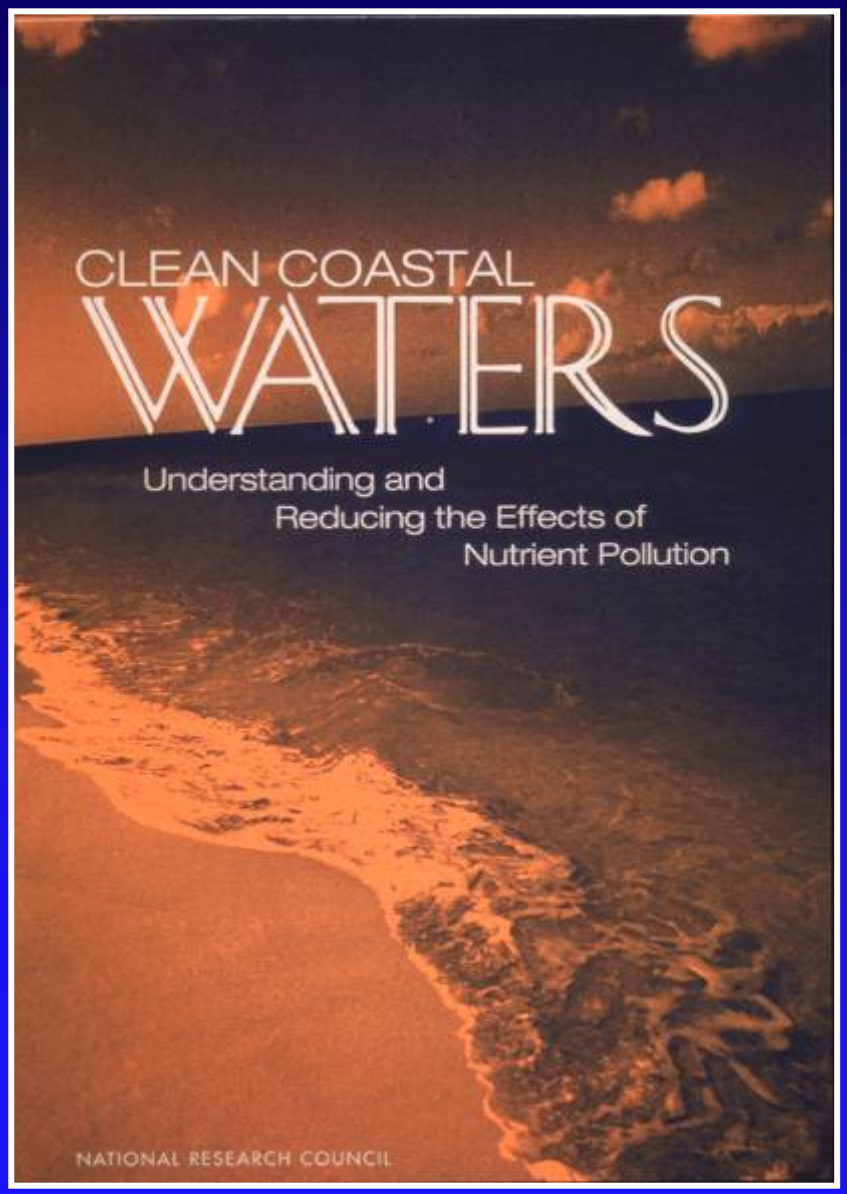


Plexa bands

Experimental Evidence of Nutrient Pollution: The Wreck of the *Arimora*, Egg Island, Bahamas



U. S. National Academy of Sciences

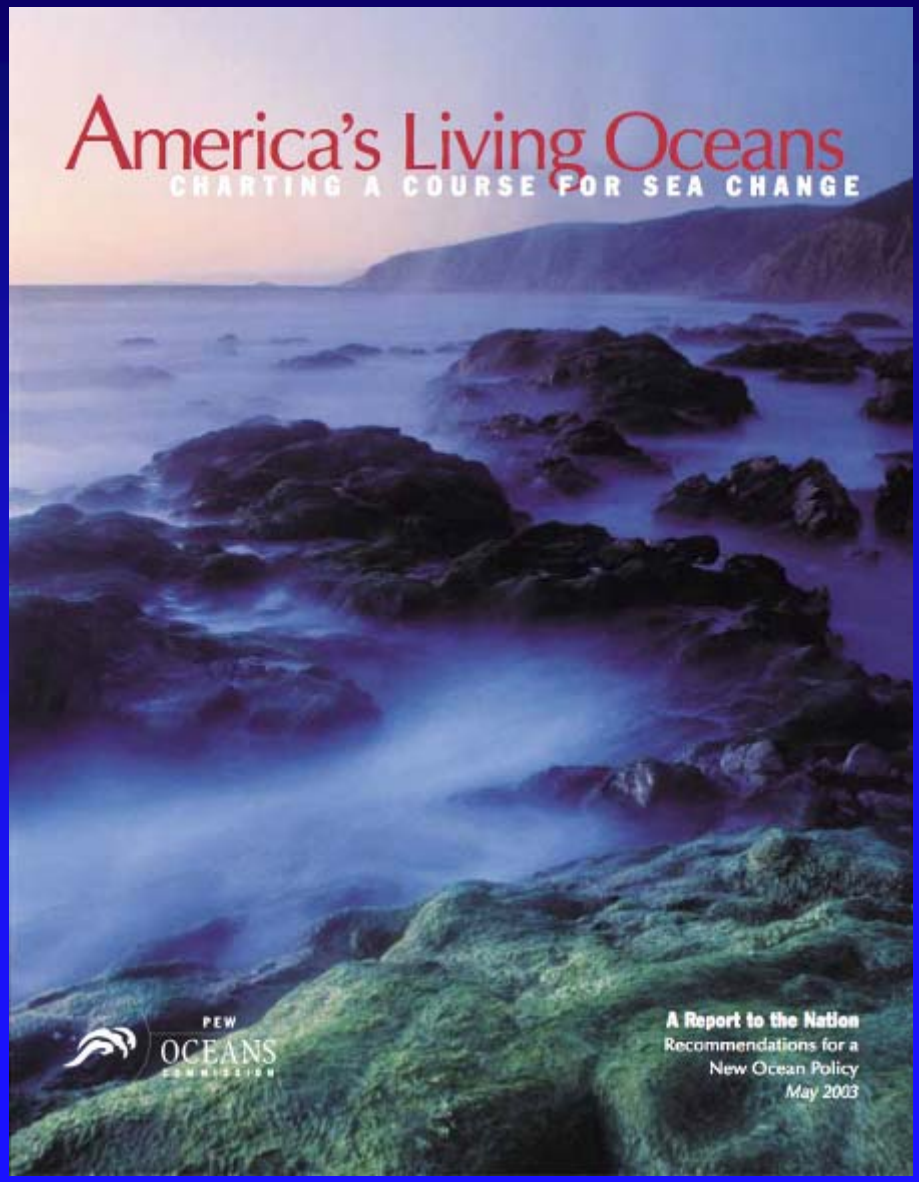


"The fundamental driving force is the accumulation of nitrogen and phosphorus in fresh water on its way to the sea."

Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution.
(NRC, 2000)

The Pew Charitable Trusts

PEW OCEANS COMMISSION



Chapter Five
CLEANING COASTAL WATERS

"EPA and the states should establish water quality standards for nutrients, especially nitrogen, as quickly as possible."

"For too long our oceans have been dumping grounds."

State of Hawaii Water Quality Standards for Open Coastal Waters[1]

Constituent	Geometric Mean Not to Exceed the GivenValue:	Not to Exceed the GivenValue More than 10% of the Time:	Not to Exceed the GivenValue More than 2% of the Time:
Total Nitrogen (µM)	10.7	17.8	25.0
Ammonium (µM)	0.25	0.61	1.07
Nitrate + Nitrite (µM)	0.36	1.0	1.79
Total P (µM)	0.65	1.29	1.94
Chl a (µg/l)	0.30	0.90	1.75
Turbidity (NTU)	0.50	1.25	2.00

1: HAR 11-54.6

What Are Ambient Nutrient Concentrations in SE Florida ?

2004-06	n	Ammonium (µM)	Nitrate (µM)	DIN (µM)	TDN (µM)
Dade	24	0.39 ± 0.46	0.59 ± 0.28	0.97 ± 0.57	11.91 ± 3.65
Broward	153	0.17 ± 0.66	0.81 ± 0.41	0.98 ± 0.74	11.63 ± 3.24
Palm Beach	143	0.08 ± 0.30	0.76 ± 0.75	0.84 ± 0.82	10.89 ± 4.09
Mean	320	**0.21 ± 0.15**	**0.72 ± 0.12**	**0.93 ± 0.08**	**11.48 ± 0.524**

2004-06	n	SRP (µM)	TDP (µM)
Dade	24	0.09 ± 0.05	0.20 ± 0.07
Broward	153	0.15 ± 0.10	0.31 ± 0.17
Palm Beach	143	0.11 ± 0.07	0.24 ± 0.11
Mean	320	**0.12 ± 0.03**	**0.25 ± 0.05**

What Are Ambient Nutrient Concentrations in SE Florida ?

	SEFLOE II Ambient				HBOI / FFWCC	
	Hollywood		N. Broward		Broward 2004-06	
	n	Mean (µM)	n	Mean (µM)	n	µM ± 1 SD
Ammonium	8	**6.4**	28	**6.4**	153	< **0.21** ± 0.66
Nitrate	9	**7.9**	1	**11.4**	153	**0.81** ± 0.41
DIN	-	**14.3**	-	**17.8**	153	**0.98** ± 0.74
Total Phophorus	6	**2.9**	17	**2.6**	153	**0.31** ± 0.17

	Miami-Dade North		Dade Co. 2004-05	
	n	Mean (µM)	n	µM ± 1 SD
Ammonium	4	**47.1**	24	**0.39** ± 0.46
Total Kjeldahl N	14	**51.4**	24	**11.32** ± 3.74

SEFLOE II report prepared by Hazen & Sawyer, 1994

S.E. FL Ocean Outfall Sewage Effluent Nitrogen Concentratons

Sampling	Site	n	Ammonium (µM)	Nitrate (µM)	TDN (µM)
Fall 2005	N. Broward	3	685.6 ± 156.7	85.4 ± 6.5	842.1 ± 77.1
	Delray	3	943.1 ± 202.1	99.8 ± 22.7	1117.1 ± 241.0
	Hollywood	3	729.3 ± 118.4	119.2 ± 24.6	985.2 ± 147.4
	Mean	9	786.0 ± 137.8	121.4 ± 17.0	1021.5 ± 137.5
Winter 2006	Delray	3	531.7 ± 51.7	170.3 ± 21.1	843.8 ± 81.1
	Boca Raton	3	257.7 ± 10.3	128.0 ± 3.6	534.6 ± 7.0
	N. Broward	3	1519.6 ± 36.0	116.3 ± 1.5	1694.2 ± 66.9
	Hollywood	3	843.6 ± 7.9	130.7 ± 0.6	1133.7 ± 31.7
	Mean	12	788.1 ± 543.2	136.3 ± 23.5	1051.6 ± 493.3
	Grand Mean	**21**	**787.2 ± 392.2**	**121.4 ± 26.8**	**1021.5 ± 359.7**

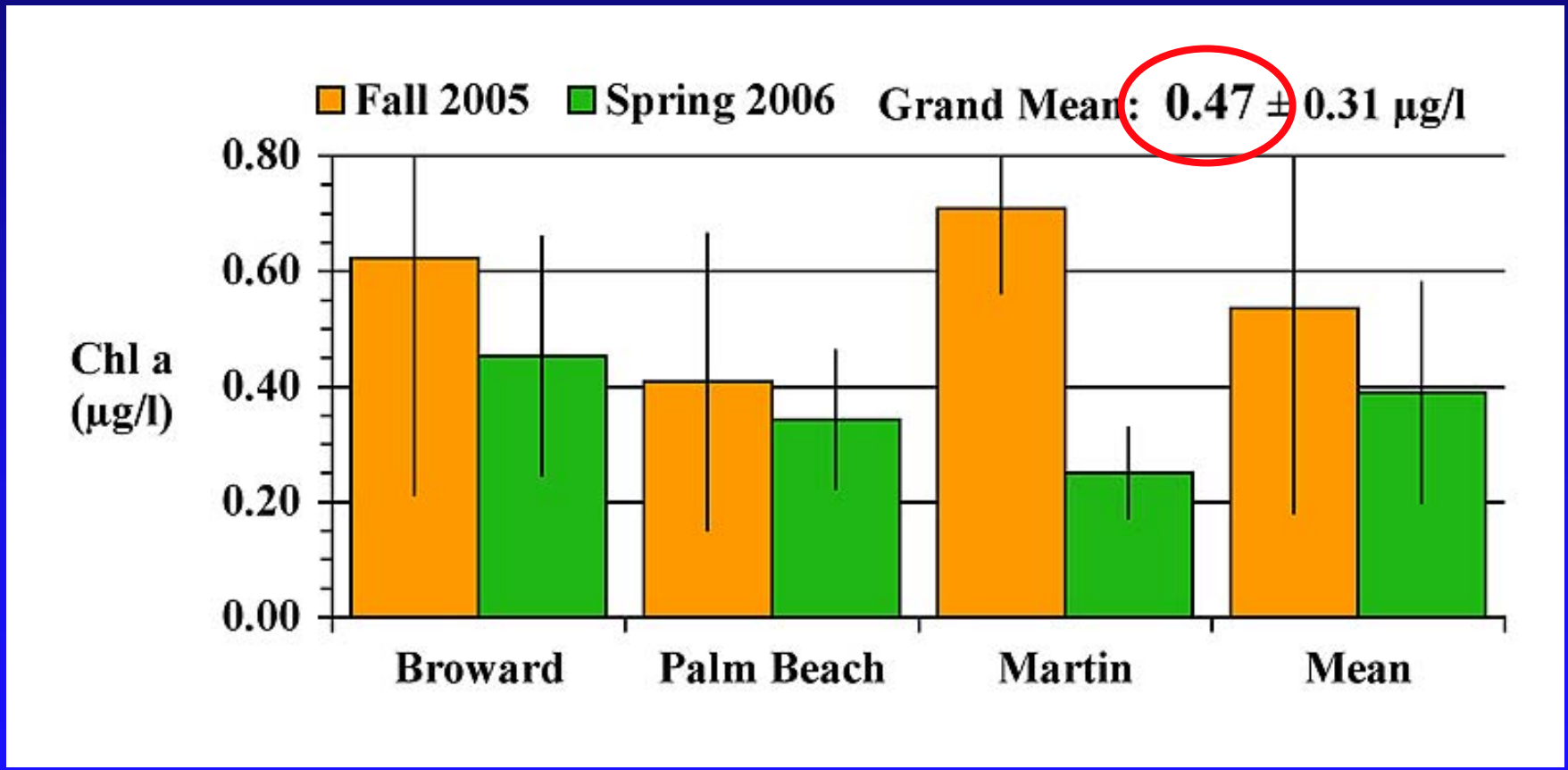
S.E. FL Ocean Outfall Sewage Effluent $\delta^{15}N$ Values

Sampling	Site	n	$\delta^{15}NH_4$ (‰)	$\delta^{15}NO_3$ (‰)
Fall 2005	N. Broward	4	13.54 ± 1.86	0.59 ± 2.24
	Delray	4	15.42 ± 4.60	3.66 ± 0.69
	Hollywood	2	12.35 ± 0.39	3.98 ± 0.08
	Mean	10	13.77 ± 1.55	2.74 ± 1.87
Winter 2006	Delray	2	13.62 ± 0.30	15.61 ± 0.51
	Boca Raton	4	21.32 ± 0.192	10.68 ± 0.89
	N. Broward	2	21.52 ± 0.421	15.34 ± 0.87
	Hollywood	2	14.32 ± 2.423	4.14 ± 1.82
	Mean	10	15.73 ± 4.316	7.09 ± 5.37
	Grand Mean	**20**	**16.01 ± 3.811**	**7.71 ± 6.1**

S.E. FL Ocean Outfall Sewage Effluent Phosphorus Concentratons & TDN:TDP

Sampling	Site	n	SRP (µM)	TDP (µM)	TDN:TDP Ratio
Fall 2005	N. Broward	3	41.5 ± 8.7	42.6 ± 8.9	20.3 ± 4.2
	Delray	3	65.1 ± 12.7	69.2 ± 15.0	16.1 ± 0.1
	Hollywood	3	15.1 ± 1.5	19.7 ± 2.6	50.0 ± 3.2
	Mean	9	30.6 ± 25.0	33.8 24.8	33.8 ± 18.5
Winter 2006	Delray	3	28.1 ± 2.2	31.0 ± 2.3	27.2 ± 0.7
	Boca Raton	3	21.9 ± 1.4	25.4 ± 2.1	21.1 ± 1.4
	N. Broward	3	30.1 ± 0.3	34.6 ± 0.9	49.0 ± 0.7
	Hollywood	3	12.6 ± 0.1	14.0 ± 0.1	81.2 ± 3.1
	Mean	12	23.2 ± 7.8	26.2 ± 9.0	44.6 ± 27.2
	Grand Mean	**21**	**30.6 ± 18.0**	**33.8 ± 18.3**	**37.9 ± 23.5**

S.E. Florida Chlorophyll *a* Concentrations 2005-06



Millenium Ecosystem Assessment: 2005

- Involved 1,300 environmental scientists from 95 countries, 22 National Academies of Science

- Concluded that excessive nutrient loading into freshwater and marine ecosystems is one of the biggest problems

- This issue is where they found the biggest “disconnect” between a major problem related to ecosystem services and the lack of policy action in response

- Specifically cited nutrient enrichment from terrestrial sources as an example of a “tipping point”that caused Jamaica’s coral reefs to be overgrown by macroalgae

Summary

- Nutrient enrichment of coastal waters is supporting the trend of increasing eutrophication and decline of coral reefs worldwide

- In South Florida, nutrient concentrations vary as a function of wastewater loading and stormwater runoff

- Spatial pattern in nutrient concentrations and algal blooms a function of physical & geochemical controls

- Nutrient standards similar to those adopted in Hawaii would provide engineers with an ecologically relevant "endpoint" for dilution models

Thank You !

How You Can Help Support Water Quality Research in Florida

DAVIS COVE

Davis R.

NORTH NEGRIL

Orange Bay

North Negril R.

Orange R.

LOGWOOD

FISH RIVER

LONG BAY

Great Morass

N. SILVER SPRING

S. SILVER SPRING

SPRING FIELD

South Negril R.

SOUTH NEGRIL

Negril

Negril Lighthouse

IRONSHORE

New Savanna R.

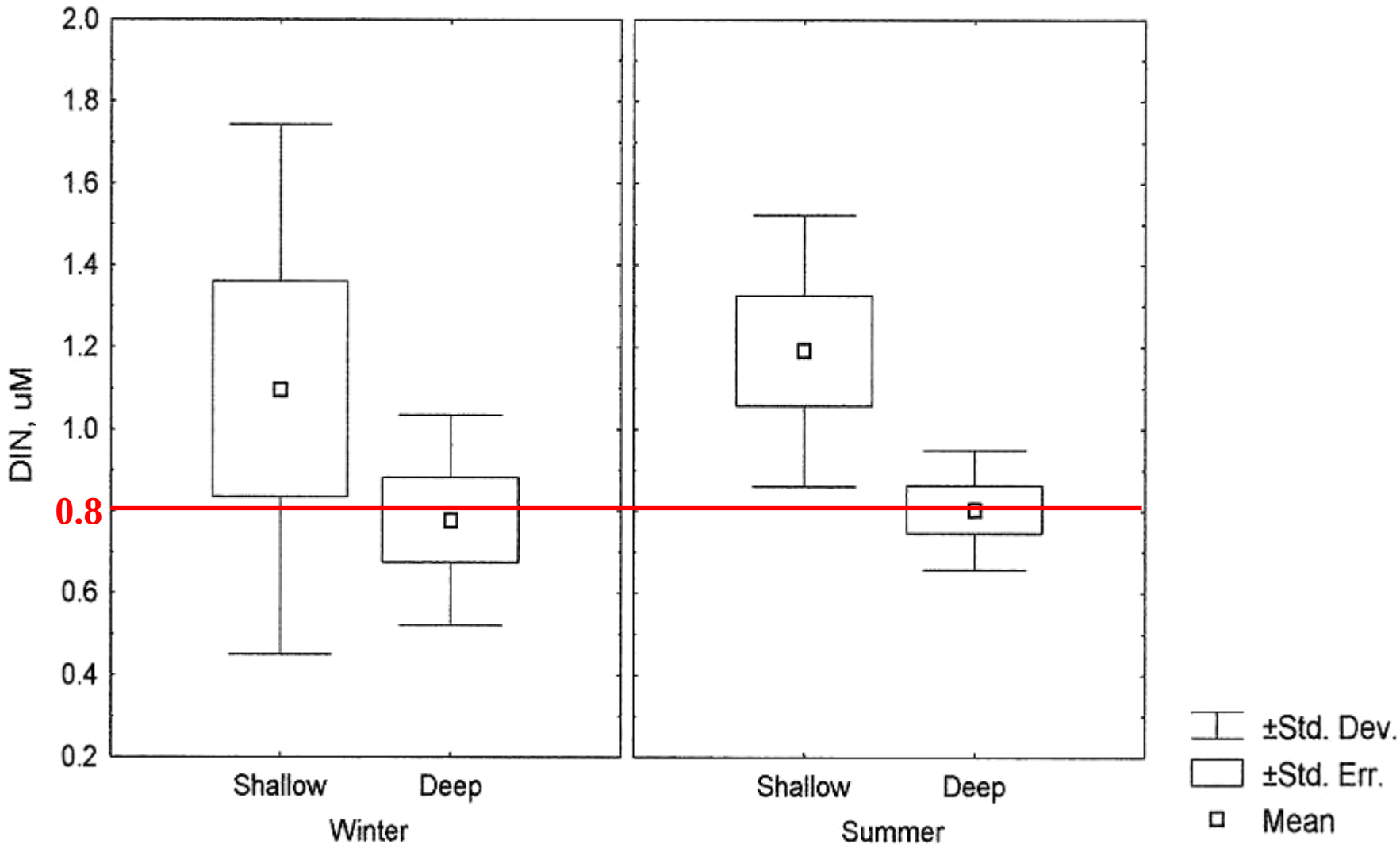
LITTLE BAY

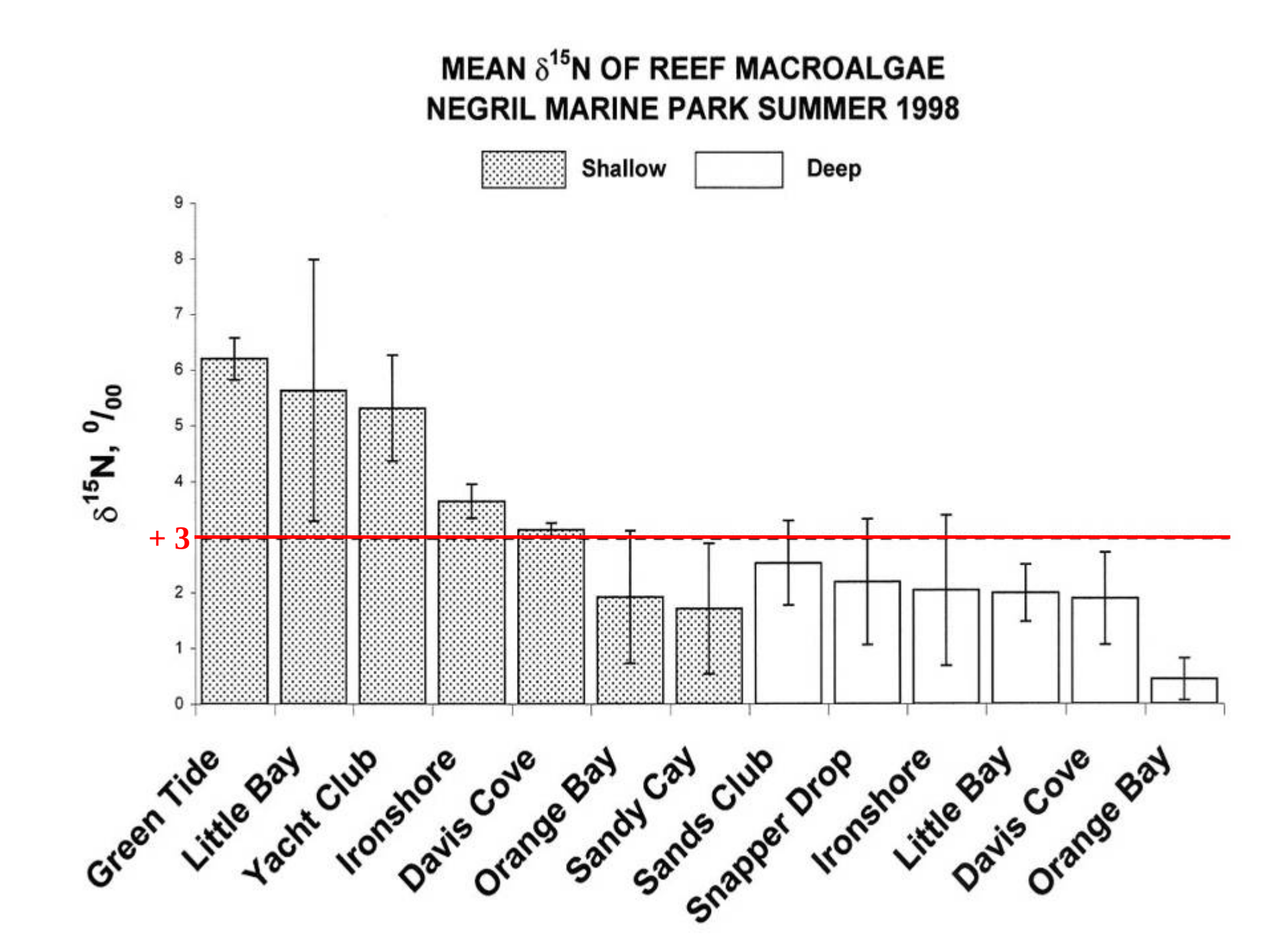
St. John's Point

Urban Growth Centres
Limestone Forest
Morass, Wetlands & Mangrove
Canefields
Pasture
Mixed Agriculture
Aquafer Recharge
Woodland & Forest

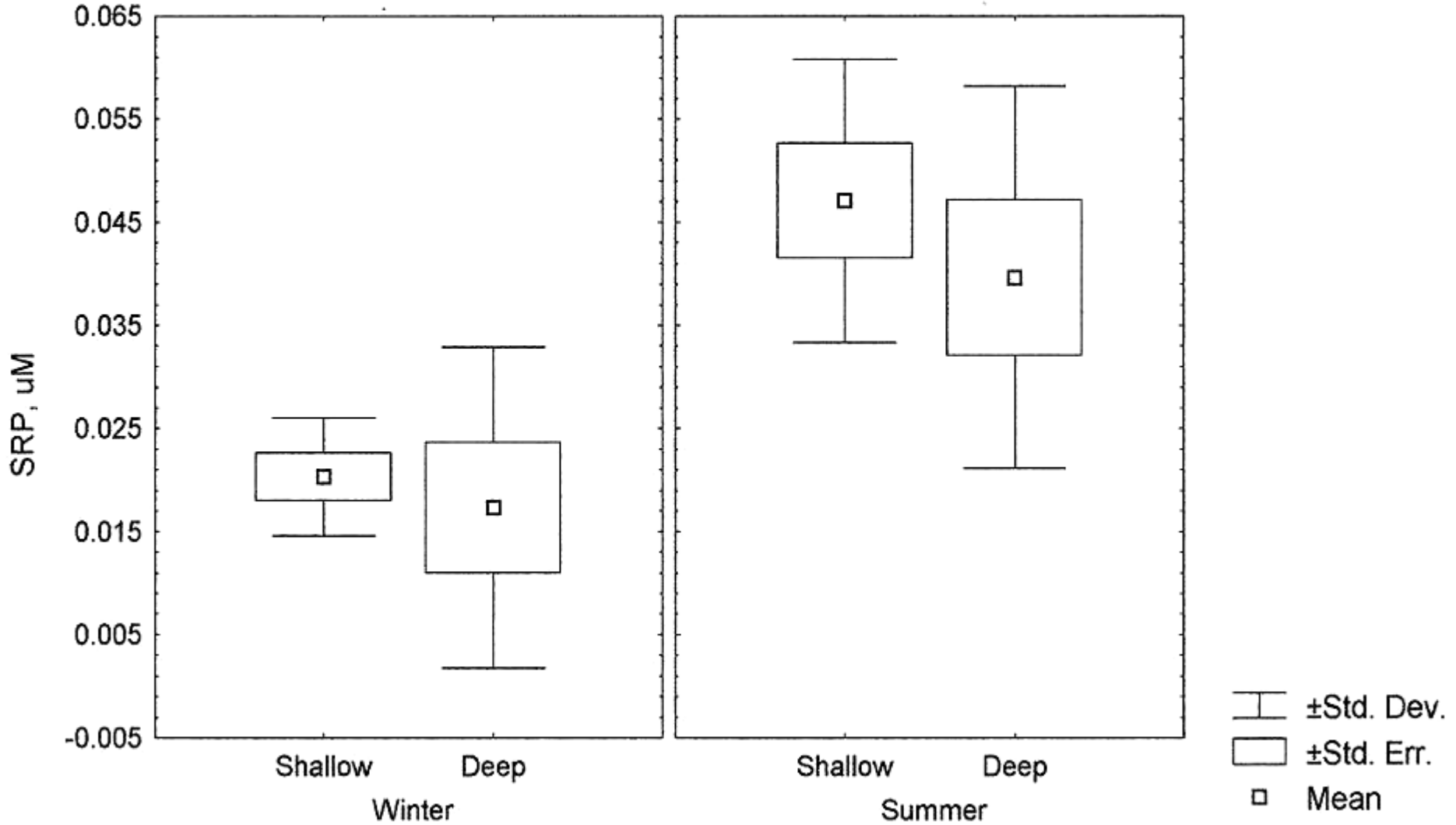
Monitoring Sites
Negril Marine Park
Rivers & Ponds
Roads
Watershed Boundary
EPA Boundary

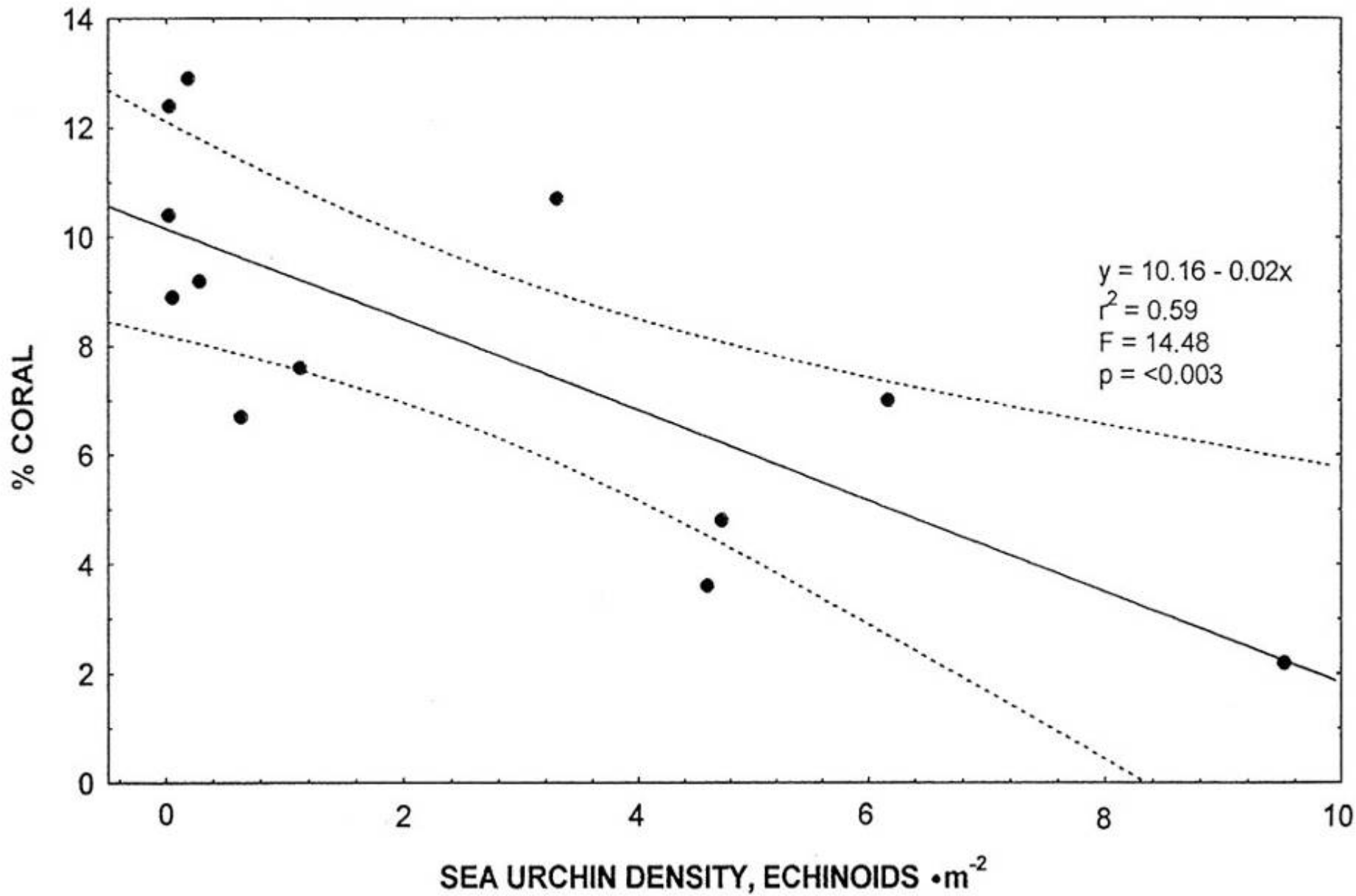
0 1 2 3 4 5km


MEAN SEASONAL DIN IN SHALLOW AND DEEP REEFS
NEGRIL MARINE PARK 1998
DIN, uM
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Shallow
Deep
Winter
Shallow
Deep
Summer
±Std. Dev.
±Std. Err.
Mean

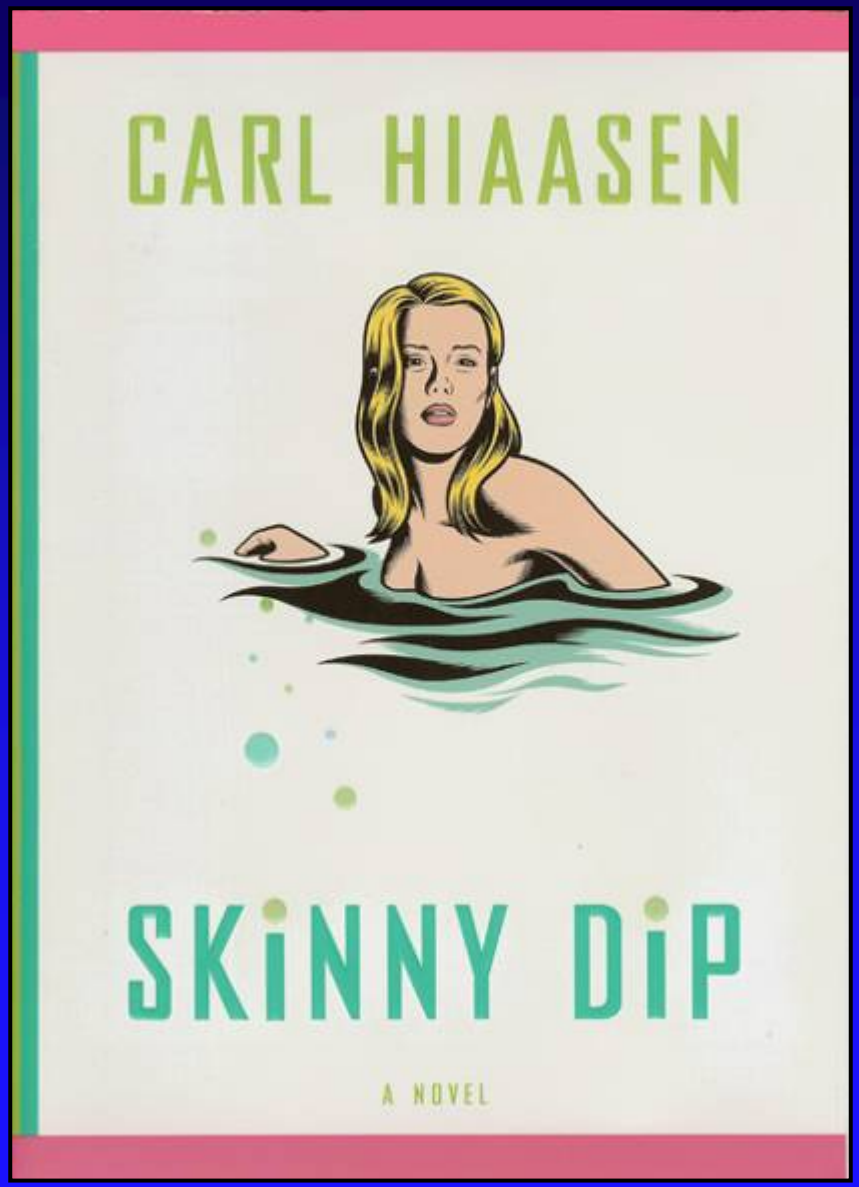

MEAN δ15N OF REEF MACROALGAE
NEGRIL MARINE PARK SUMMER 1998
Shallow
Deep
δ15N, 0/00
9
8
7
6
5
4
3
2
1
0
+ 3
Green Tide
Little Bay
Yacht Club
Ironshore
Davis Cove
Orange Bay
Sandy Cay
Sands Club
Snapper Drop
Ironshore
Little Bay
Davis Cove
Orange Bay

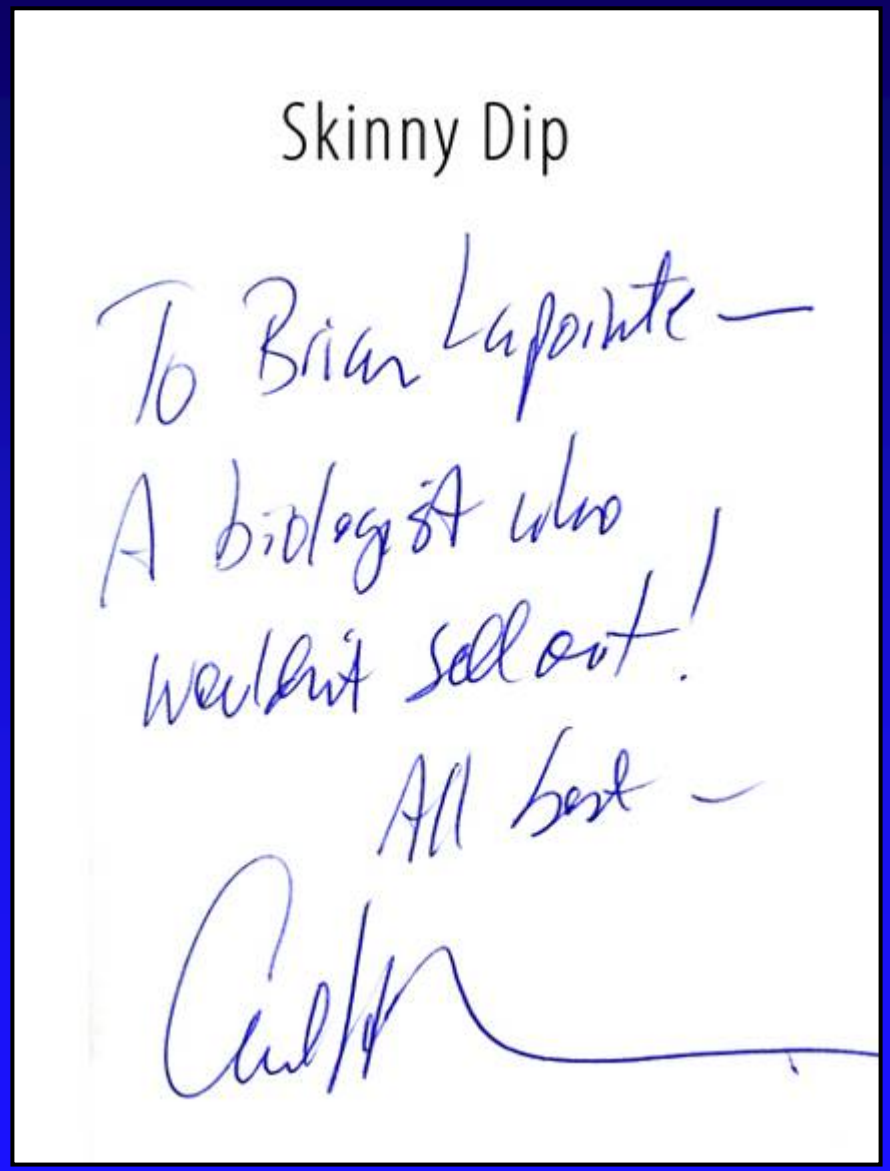
MEAN SEASONAL SRP IN SHALLOW AND DEEP REEFS
NEGRIL MARINE PARK 1998




SEA URCHIN DENSITY VS CORAL COVER IN THE NEGRIL MARINE PARK 1998
% CORAL
SEA URCHIN DENSITY, ECHINOIDS •m-2
y = 10.16 - 0.02x
r2 = 0.59
F = 14.48
p = <0.003
0
2
4
6
8
10
12
14

“Biostitutes” in South Florida





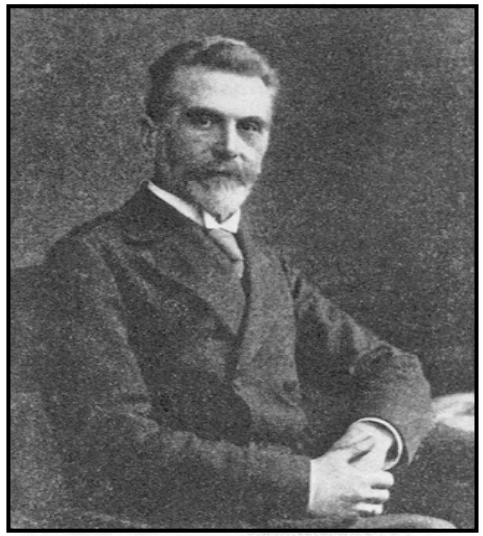
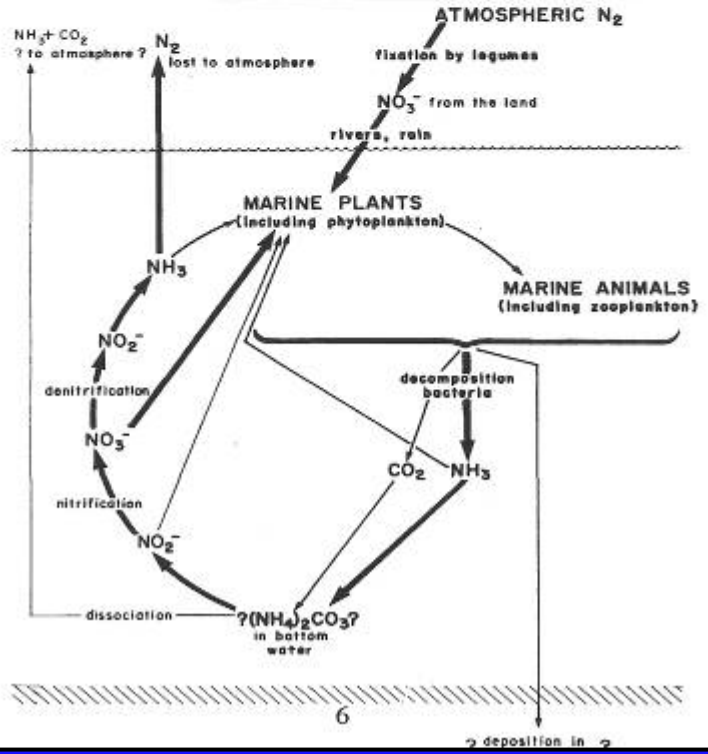
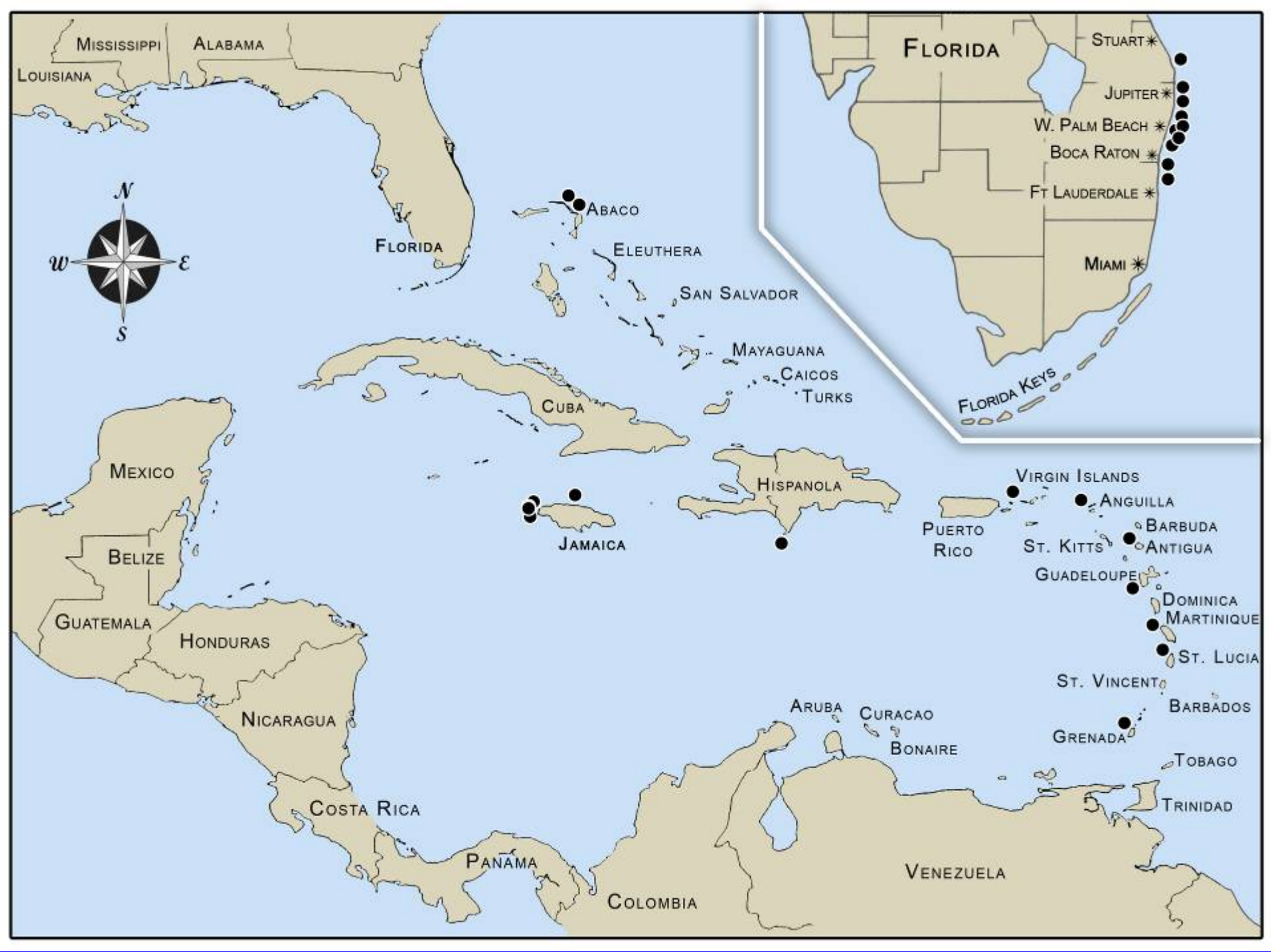


FIGURE 2.1 Karl Brandt, professor of zoology and director of the Zoological Institute at Kiel from 1888 until 1922. From Reibisch 1931, with permission of the Conseil International pour l'Exploration de la Mer.




Mississippi
Alabama
Louisiana
N
W
E
S
Florida
Abaco
Eleuthera
San Salvador
Mayaguana
Caicos
Turks
Cuba
Hispanola
Jamaica
Mexico
Belize
Guatemala
Honduras
Nicaragua
Costa Rica
Panama
Colombia
Venezuela
Aruba
Curacao
Bonaire
Puerto Rico
Virgin Islands
Anguilla
Barbuda
Antigua
St. Kitts
Guadeloupe
Dominica
Martinique
St. Lucia
St. Vincent
Barbados
Grenada
Tobago
Trinidad
Florida
Stuart
Jupiter
W. Palm Beach
Boca Raton
Ft Lauderdale
Miami
Florida Keys

Nutrient Pollution: Effects on Optical Properties of Coastal Waters in the Florida Keys

Charles Yentsch

Increasing Chl *a*

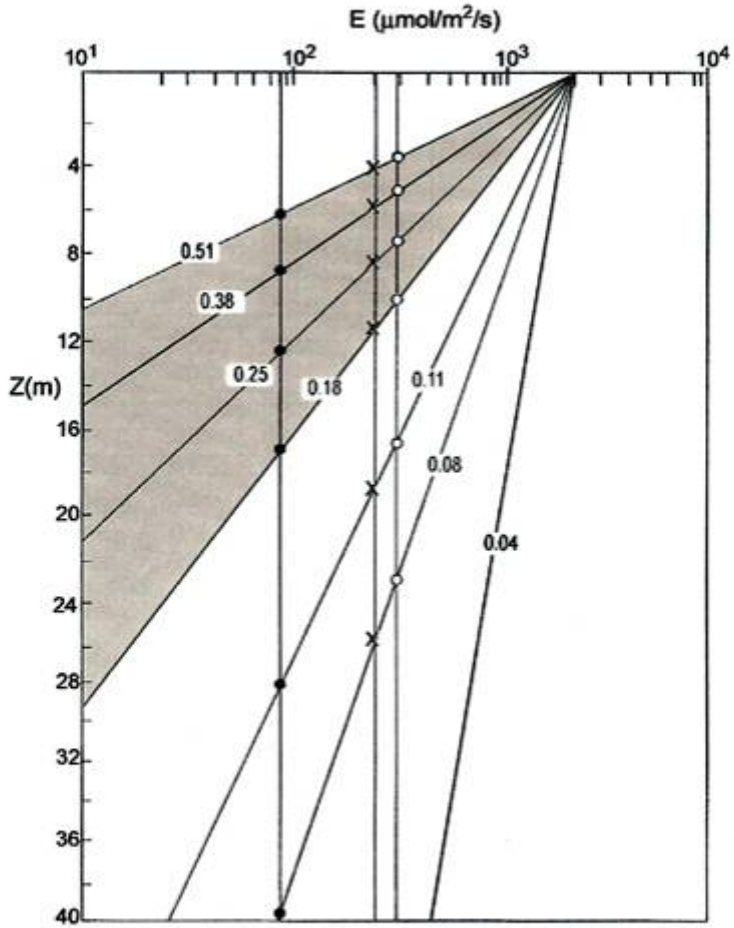


Fig. 5. Nomograph for the relationship of light irradiance (E in μmol/m²/s) on a log scale vs. depth (Z in m) on a linear scale. So-called coastal waters are heavily shaded; so-called clear oceanic waters are lightly shaded. The lines for the amounts of irradiance at depth are fitted with values for attenuation for water types. The compensation intensity when extended with depth intersects water masses of different K values and defines the compensation depth. These depths are shown for zooxanthellae alone as black dots. Crosses and clear dots represent the observed compensation depths of Chalker (1981).

SUNDAY
Los Angeles Times
JULY 30, 2006

ALTERED OCEANS

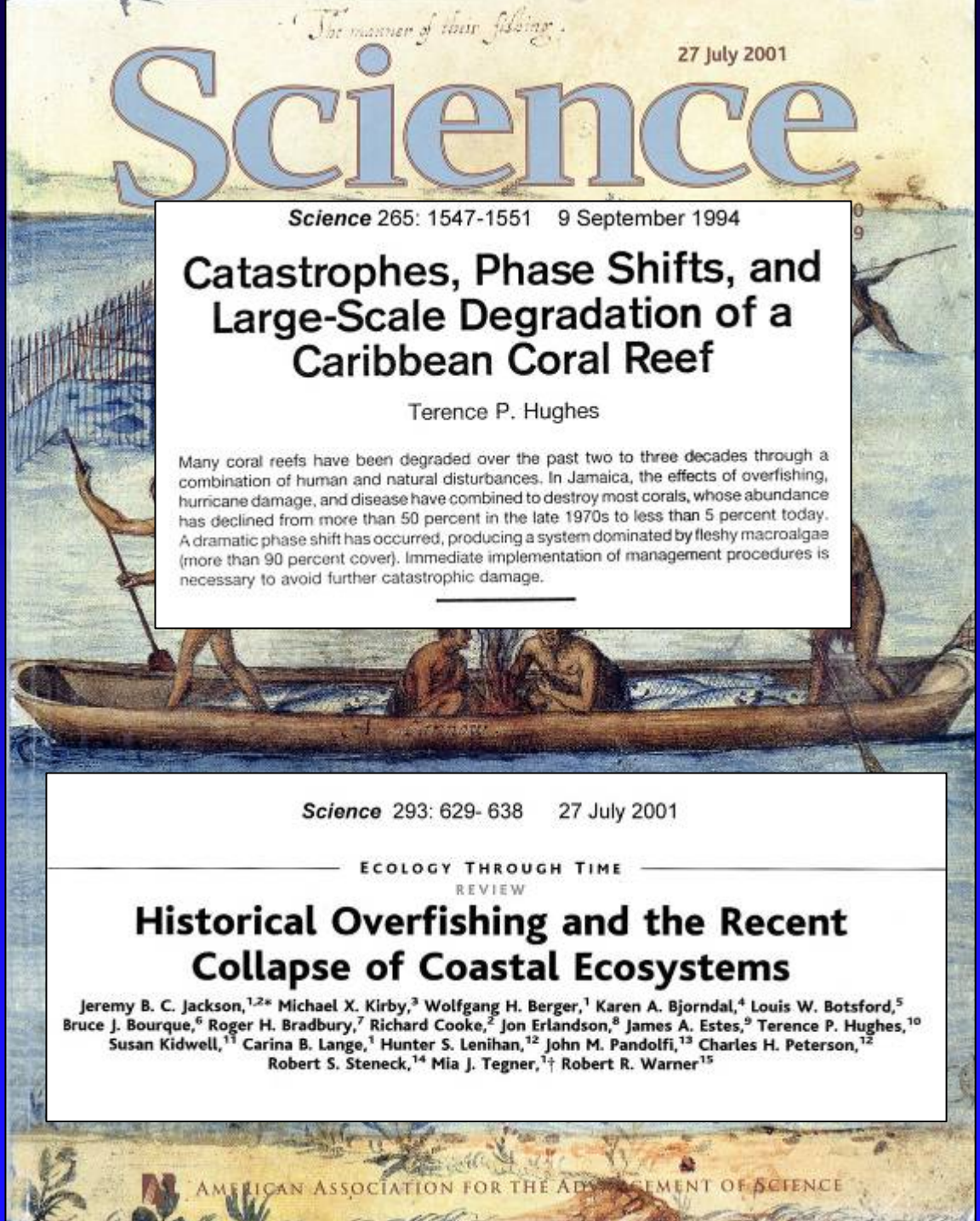
A PRIMEVAL TIDE OF TOXINS

Runoff from modern life is feeding an explosion of primitive organisms. This 'rise of slime,' as one scientist calls it, is killing larger species and sickening people.

RICK LOOMIS Los Angeles Times

By KENNETH R. WEISS
Times Staff Writer

The Future is in Your Hands !



Science 265: 1547-1551 9 September 1994

Catastrophes, Phase Shifts, and Large-Scale Degradation of a Caribbean Coral Reef

Terence P. Hughes

Many coral reefs have been degraded over the past two to three decades through a combination of human and natural disturbances. In Jamaica, the effects of overfishing, hurricane damage, and disease have combined to destroy most corals, whose abundance has declined from more than 50 percent in the late 1970s to less than 5 percent today. A dramatic phase shift has occurred, producing a system dominated by fleshy macroalgae (more than 90 percent cover). Immediate implementation of management procedures is necessary to avoid further catastrophic damage.

Science 293: 629- 638 27 July 2001

ECOLOGY THROUGH TIME

REVIEW

Historical Overfishing and the Recent Collapse of Coastal Ecosystems

Jeremy B. C. Jackson,[1,2*] Michael X. Kirby,[3] Wolfgang H. Berger,[1] Karen A. Bjorndal,[4] Louis W. Botsford,[5] Bruce J. Bourque,[6] Roger H. Bradbury,[7] Richard Cooke,[2] Jon Erlandson,[8] James A. Estes,[9] Terence P. Hughes,[10] Susan Kidwell,[11] Carina B. Lange,[1] Hunter S. Lenihan,[12] John M. Pandolfi,[13] Charles H. Peterson,[12] Robert S. Steneck,[14] Mia J. Tegner,[1†] Robert R. Warner[15]

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE