Blooms of Cyanobacteria in South Florida: Environmental Causes and Human Health Consequences

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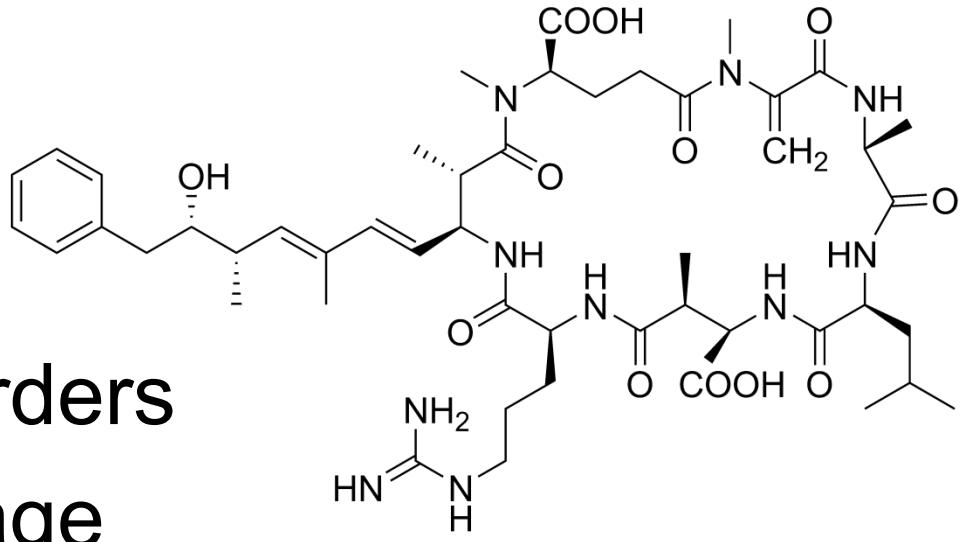
Microcystin



- Animal deaths
- Gastrointestinal disorders
- Long term liver damage
- Tumor promoter
- Linked to liver and colorectal cancer

Anthropocentric view of secondary compounds

odoriferous

distasteful

skin irritation

gastrointestinal disorder

neurological

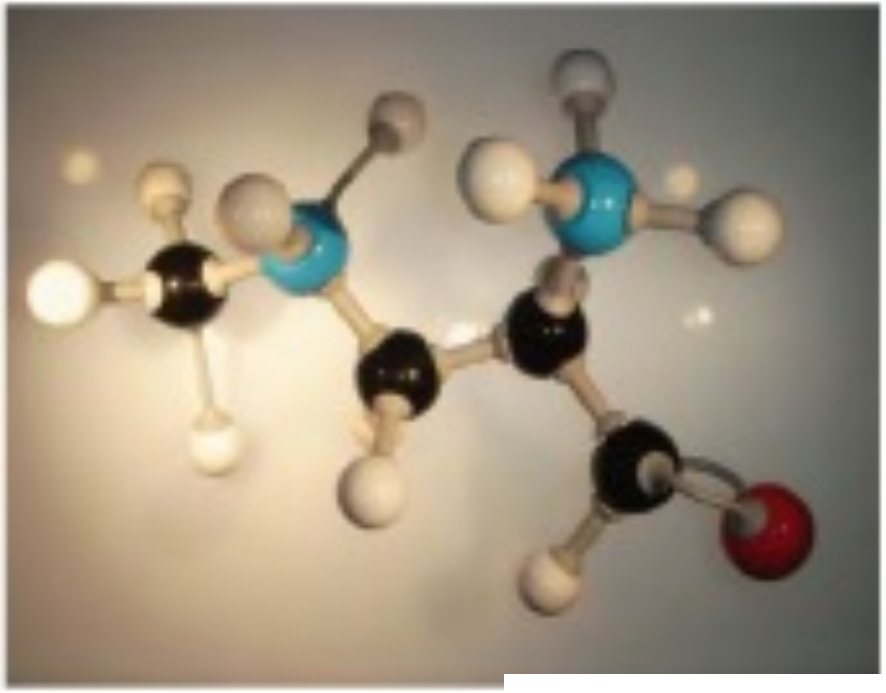
liver damage

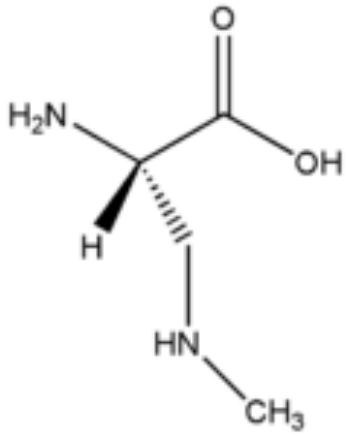
neurodegenerative

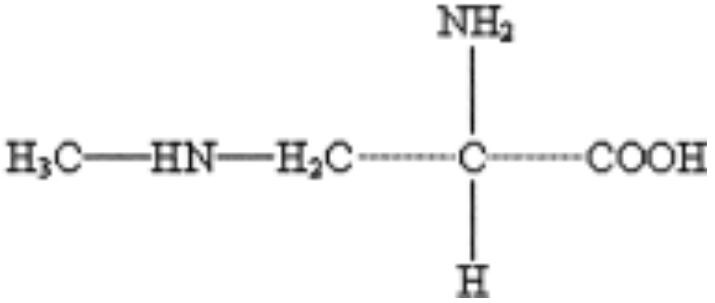
cancer

BMAA

Beta-N-methylamino-L-alanine







Neurodegenerative diseases

- Alzheimer's disease
- Parkinson's disease
- Amyotrophic Lateral Sclerosis (ALS)

Tangle Diseases

Alzheimer's 1-5% genetic

ave. 1% of population

Parkinson's 5-15% genetic

ave. 0.3% of population

ALS 5% genetic

ave. 0.01-0.02% of population

Huntington's 100% genetic

ave. 0.05-0.01% of population

Table 1 BMAA in the superior frontal gyrus tissue of patients in Guam and Canada[1]

Diagnosis at death	Nationality	Age at death	Gender	FreeBMAA (μg/g)	ProteinBMAA (μg/g)
PDC	Chamorro	60	M	ND	1190
PDC	Chamorro	69	M	6.7	644
ALS	Chamorro	68	F	10.1	610
PDC	Chamorro	77	M	7.0	736
PDC	Chamorro	60	M	9.1	149
PDC	Chamorro	67	F	3.3	433
Alzheimer's disease	Canadian	–	–	3.4	220
Alzheimer's disease	Canadian	–	–	9.7	264
Metastic cancer	Canadian	39	F	ND	ND
Heart failure	Canadian	62	M	ND	ND
Cancer of the esophogus	Canadian	69	M	ND	ND
COPD	Canadian	80	M	ND	ND
Lymphoma	Canadian	60	F	ND	ND
Cancer of the thyroid	Canadian	86	F	ND	ND
Heart failure	Canadian	89	M	ND	ND
Cancer of the pancreas	Canadian	76	M	ND	ND
COPD	Canadian	89	M	ND	ND
Heart failure	Canadian	71	F	ND	ND
Acute heart attack	Canadian	80	F	ND	ND
Chronic heart failure	Canadian	87	F	ND	ND
Aortic aneurysm	Canadian	85	F	ND	ND

[1] Paraformadlehyde fixed tissues were provided by Dr Patrick L. McGeer of the University of British Columbia, Vancouver, BC, Canada.

ND = below limits of detection; the limits of detection and the limits of quantification were 0.0001 and 0.013 μmol respectively. COPD = chronic obstructive pulmonary disease.

Diagnosis	Age at death	Gender	BMAA (ug/g) in frontal cortex	BMAA (ug/g) in temporal cortex
ALS	55	M	91	87
ALS	59	M	185	61
ALS	65	M	158	112
ALS	65	F	135	205
ALS	66	M	102	63
ALS	67	F	86	77
ALS	67	F	118	57
ALS	70	M	225	161
ALS	70	M	256	221
ALS	74	F	238	187
ALS	77	M	182	189
ALS	79	M	89	31
ALS	83	M	115	52
Alzheimer's	66	M	ND	85
Alzheimer's	67	F	182	140
Alzheimer's	67	M	24	18
Alzheimer's	76	M	41	10
Alzheimer's	80	M	191	157
Alzheimer's	81	F	217	180
Alzheimer's	81	M	228	98
Alzheimer's	81	M	172	158
Alzheimer's	84	F	56	40
Alzheimer's	87	F	155	114
Alzheimer's	87	M	188	101
Alzheimer's	90	F	61	46
Huntington's	47	M	ND	ND
Huntington's	54	M	ND	ND
Huntington's	59	M	ND	ND
Huntington's	62	F	ND	11
Huntington's	66	F	ND	ND
Huntington's	69	M	ND	ND
Huntington's	77	M	ND	ND
Huntington's	85	F	ND	ND
Control	46	M	ND	ND
Control	54	M	ND	ND
Control	67	M	ND	ND
Control	68	F	ND	ND
Control	68	M	36	ND
Control	70	M	ND	ND
Control	78	F	ND	ND
Control	81	M	ND	ND
Control	83	F	ND	ND
Control	85	M	ND	ND
Control	85	F	ND	45
Control	87	M	ND	ND

Caloosahatchee River

Sample	Species	Scientific Name	Average total BMAA (μg/g)
LB31	paper pondshell mussel	*Utterbackia imbecillis*	261
LB28	oyster	*Crassostra virginica*	305
JC4	bowfin	*Amia calva*	554
JC5	bowfin	*Amia calva*	2559
JC7	alligator gar	*Atractosteus spatula*	2140
JC8	alligator gar	*Atractosteus spatula*	857
JC9	alligator gar	*Atractosteus spatula*	1207
JC1	largemouth bass	*Micropterus salmoides*	1130
JC2	largemouth bass	*Micropterus salmoides*	2388

Florida Bay

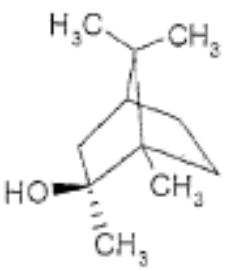
Sample	Species	Scientific Name	Average total BMAA (μg/g)
MC1	pink shrimp	*Panaeus duorarum*	1499
MC2	pink shrimp	*Panaeus duorarum*	2951
JL2	grey snapper	*Lutjanus griseus*	ND
JL4	grey snapper	*Lutjanus griseus*	ND
JL1	grey snapper	*Lutjanus griseus*	20
JL3	grey snapper	*Lutjanus griseus*	53
JL5	grey snapper	*Lutjanus griseus*	188

Biscayne Bay

Sample	Species	Scientific name	Average total BMAA (ug/g)
NH34	pink shrimp	*Panaeus duorarum*	55
NH14	pink shrimp	*Panaeus duorarum*	181
NH28	pink shrimp	*Panaeus duorarum*	942
NH17	blue crab	*Callinectes sapidus*	ND
NH24	blue crab	*Callinectes sapidus*	30
NH31	blue crab	*Callinectes sapidus*	357
NH4	blue crab	*Callinectes sapidus*	4979
NH16	blue crab	*Callinectes sapidus*	6976
NH11	band tail puffer	*Sphoeroides spengleri*	ND
NH29	band tail puffer	*Sphoeroides spengleri*	455
NH18	least puffer	*Sphoeroides parvus*	194
NH10	least puffer	*Sphoeroides parvus*	6823
HN30	scraw led cow fish	*Acanthostracion quadricornis*	441
NH23	sea bream	*Archosargus rhomboidalis*	857
NH39	sea bream	*Archosargus rhomboidalis*	2349
NH37	sailors choice grunt	*Haemulon parra*	242
NH7	sailors choice grunt	*Haemulon parra*	722
NH32	bluestriped grunt	*Haemulon sciurus*	ND
NH1	bluestriped grunt	*Haemulon sciurus*	1723

Indian River Lagoon

Sample	Species	Scientific Name	Average total BMAA (μg/g)
H-0541-TX	bottlenose dolphin	*Tursiops truncatus*	474
H-0630-TX	bottlenose dolphin	*Tursiops truncatus*	335
H-0636-TX	bottlenose dolphin	*Tursiops truncatus*	675
H-0717-TX	bottlenose dolphin	*Tursiops truncatus*	295
H-0720-TX	bottlenose dolphin	*Tursiops truncatus*	114
H-0805	bottlenose dolphin	*Tursiops truncatus*	ND



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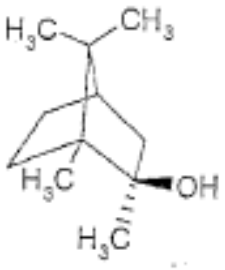

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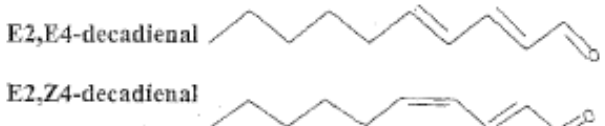
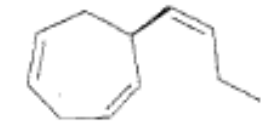
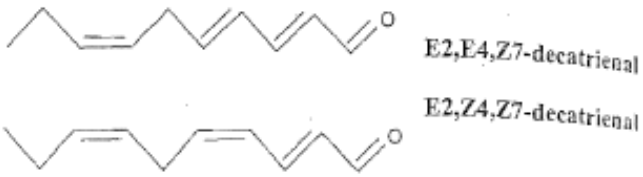
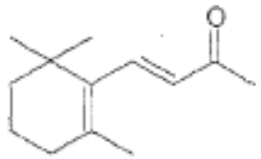




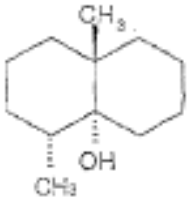
6S-[Z1-butenyl]-1,4-cycloheptadiene (**ectocarpene**)



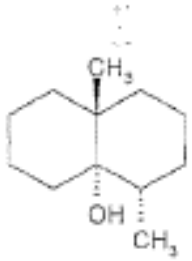
1,3E,5Z-octatriene (**fucoserratene**)



β-ionone



(+) **geosmin**



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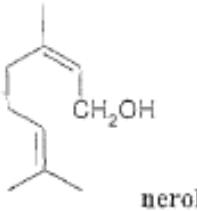
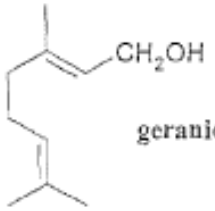
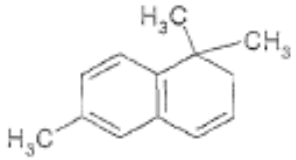


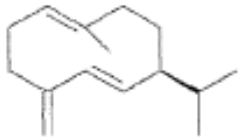
nerol



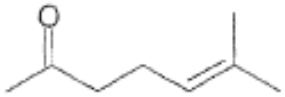
geraniol



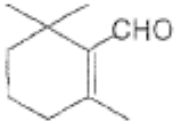
1,2-dihydro-1,1,6-trimethylnaphthalene



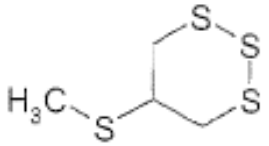
germacrene-D



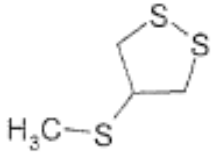
6-methyl-5-hepten-2-one



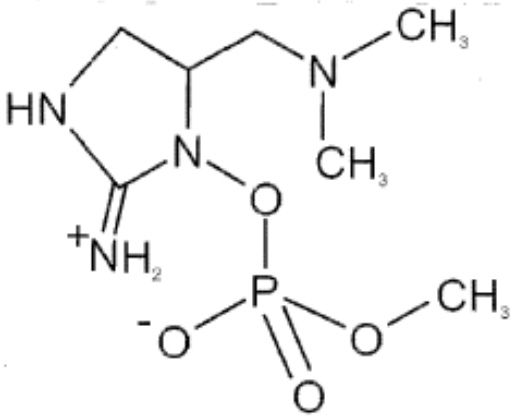
β-cyclocitral



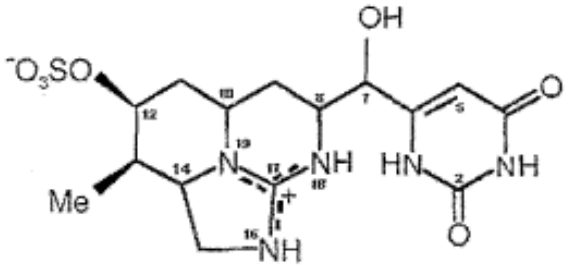
5-methythio-1,2,3-trithiane



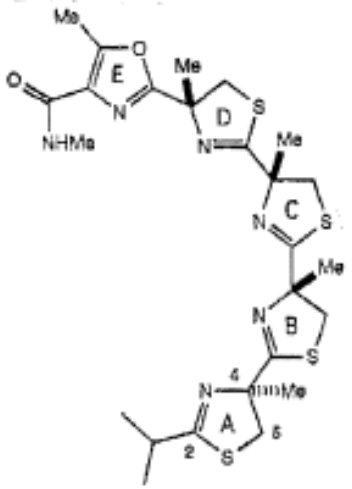
4-methylthio-1,2-dithiolane



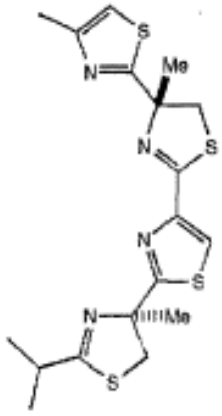
Anatoxin-a(s)



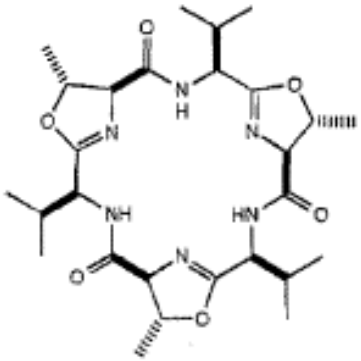
Cylindrospermopsin



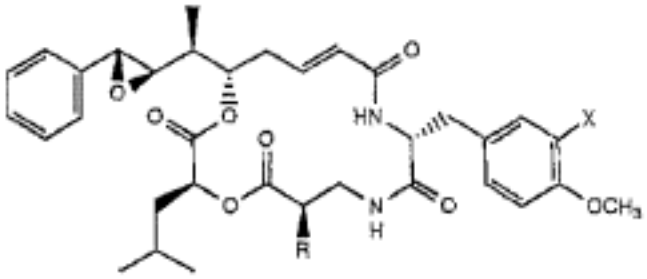
tantazole B



didehydromirabazole A

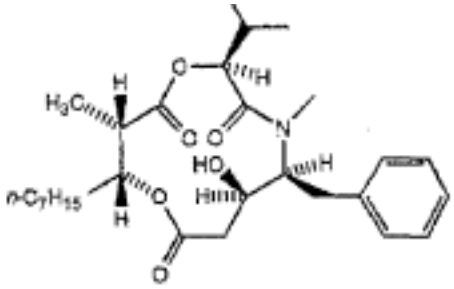


westiellamide

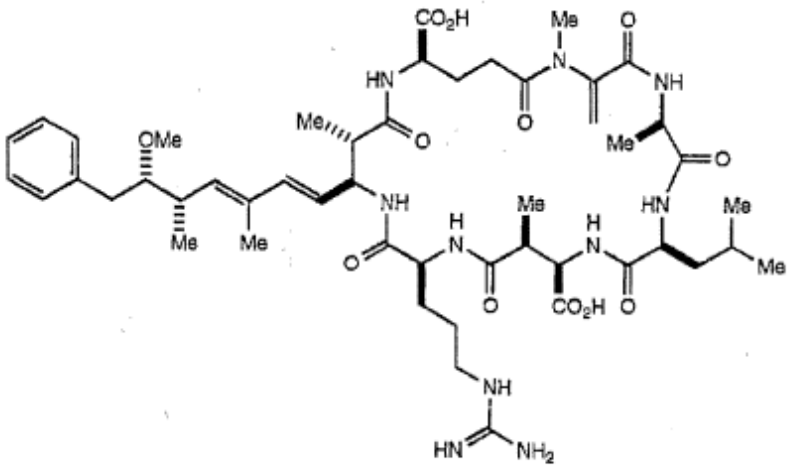


cryptophycin-1 X = Cl; R = CH_3

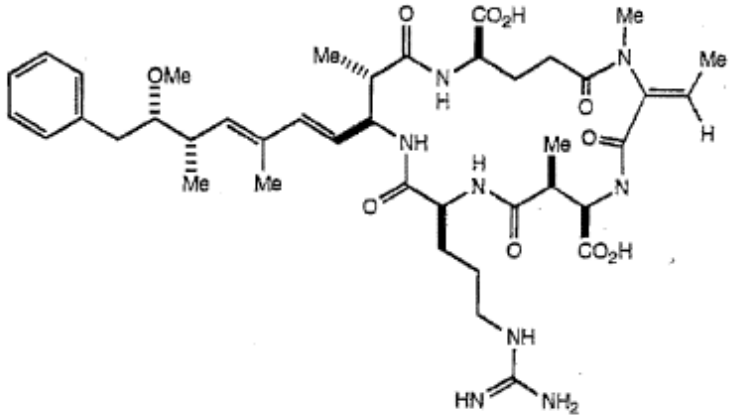
arenastatin A X = H; R = H



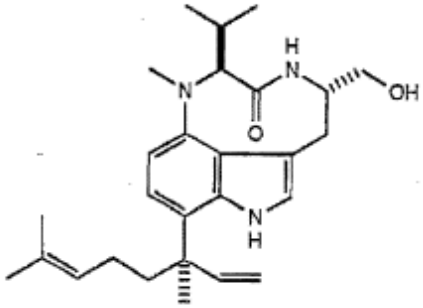
hapalosin



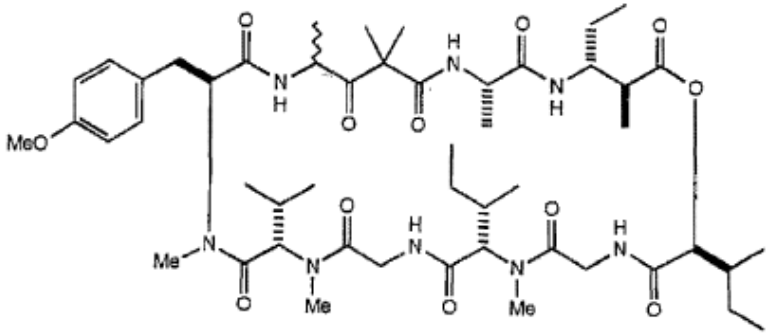
microcystin-LR



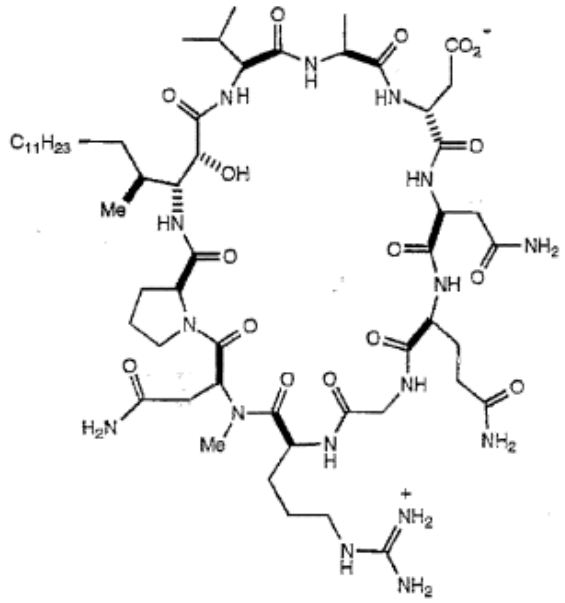
nodularin



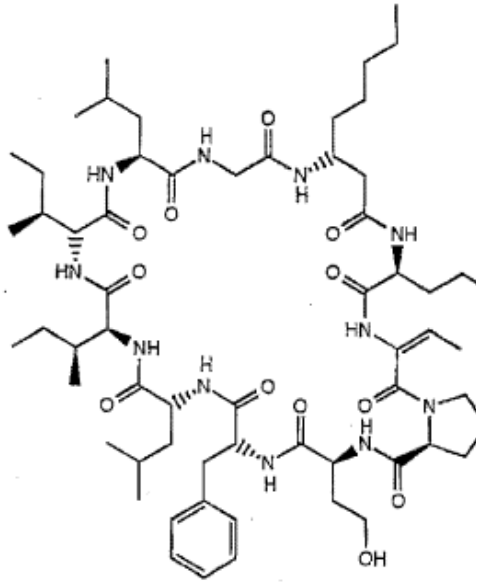
lyngbyatoxin A



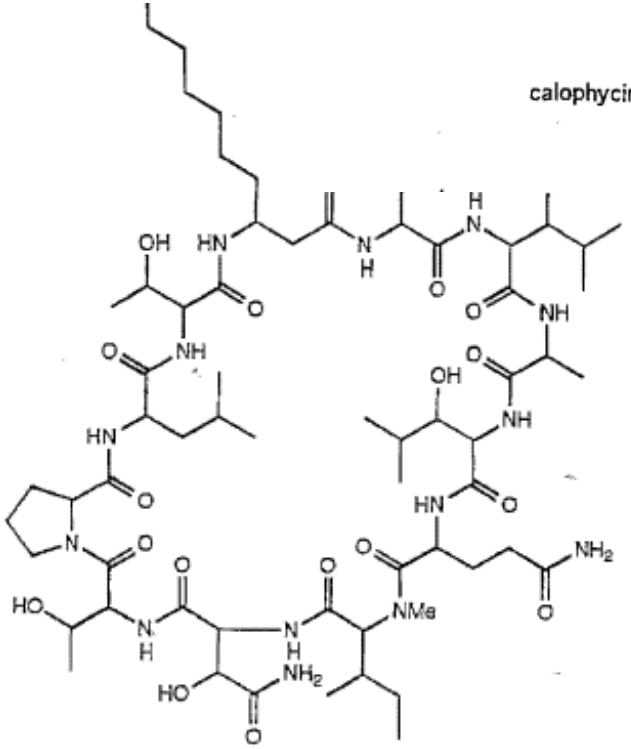
majusculamide C



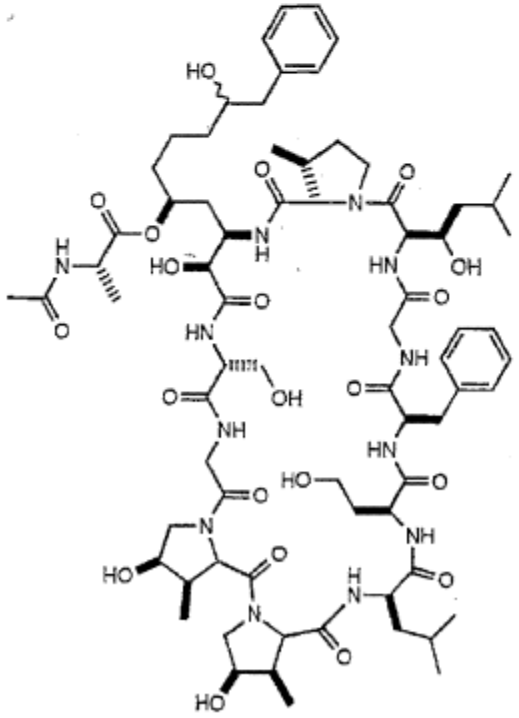
calophycin



laxaphycin A



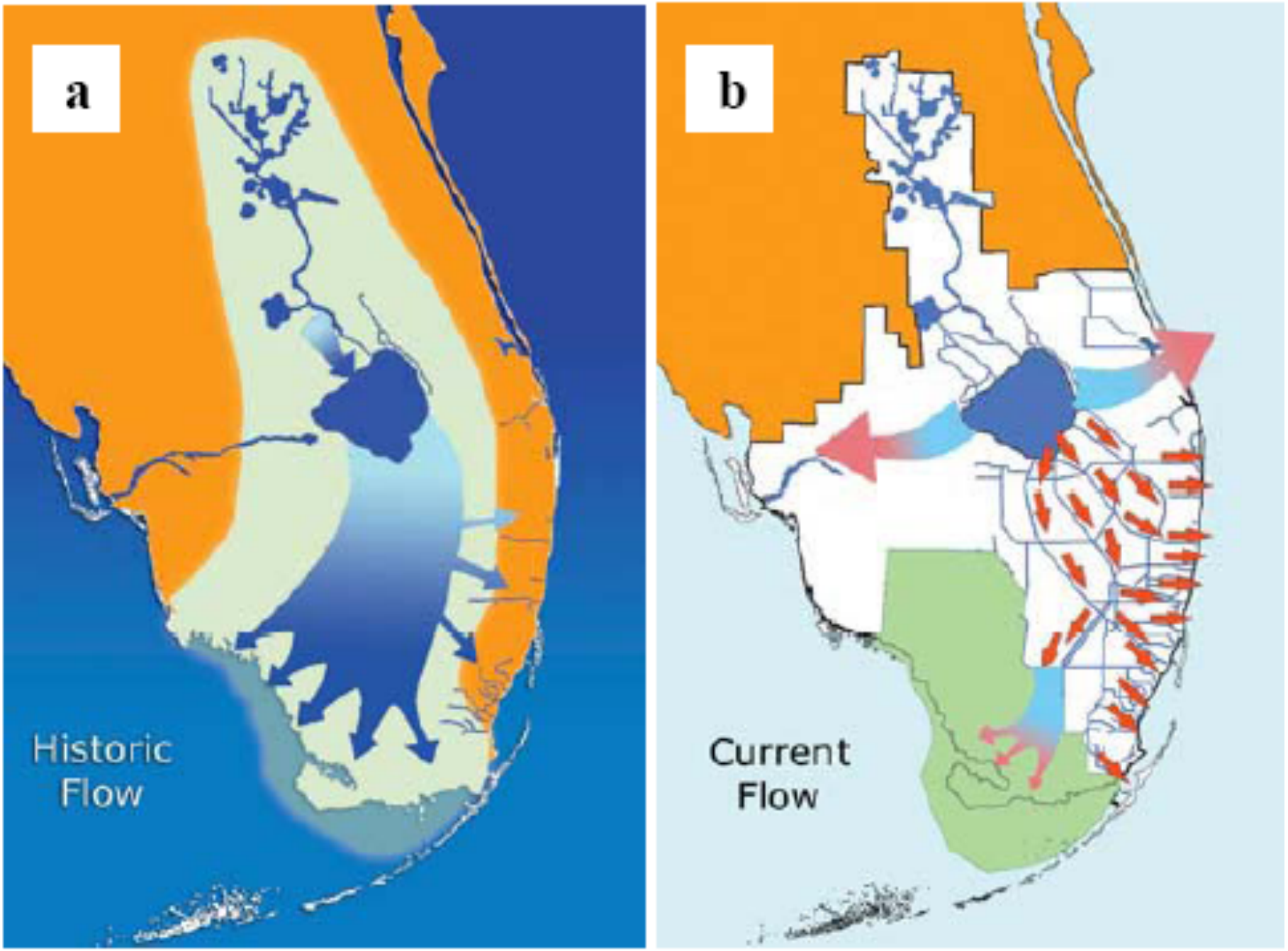
laxaphycin B

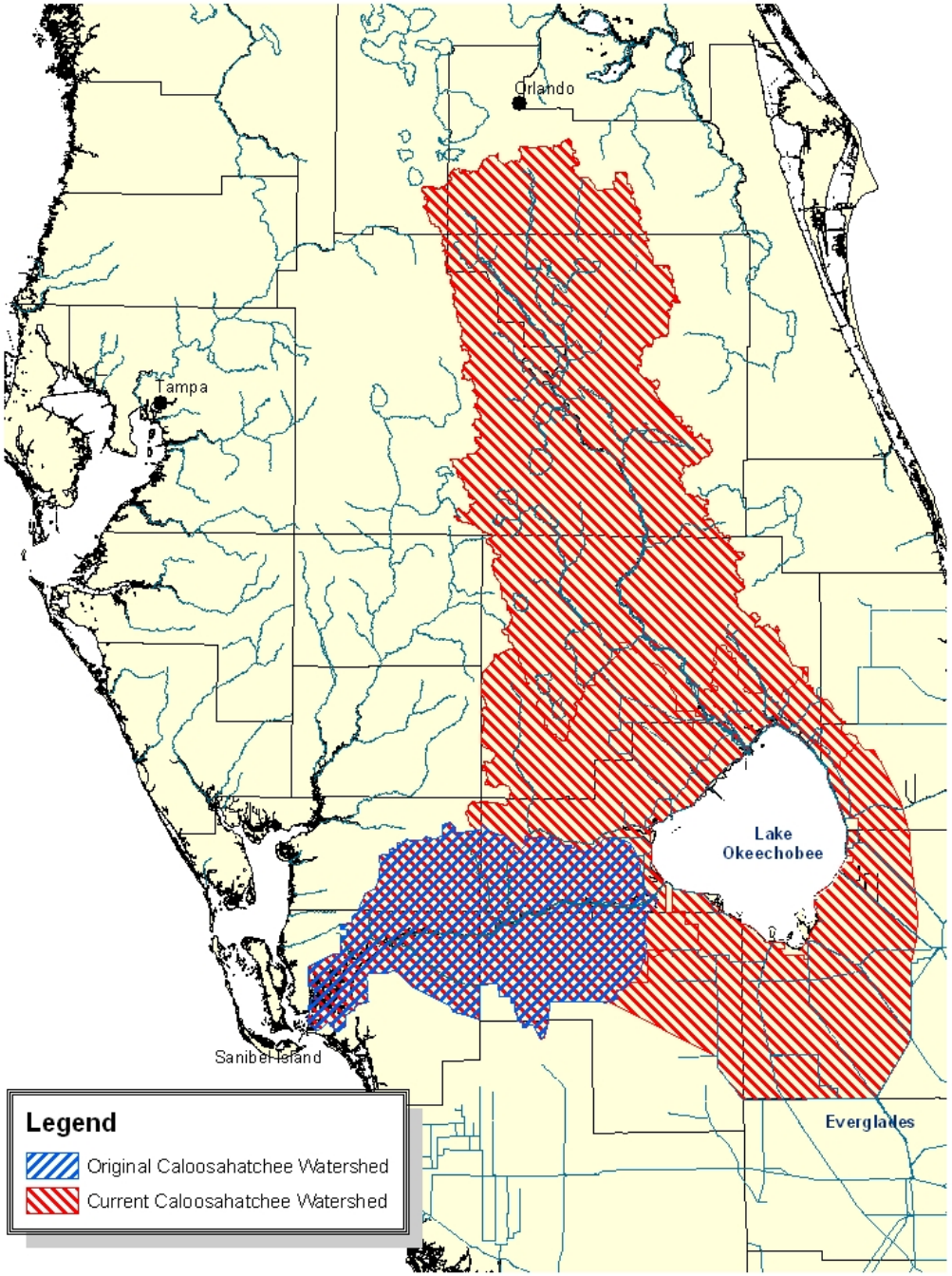


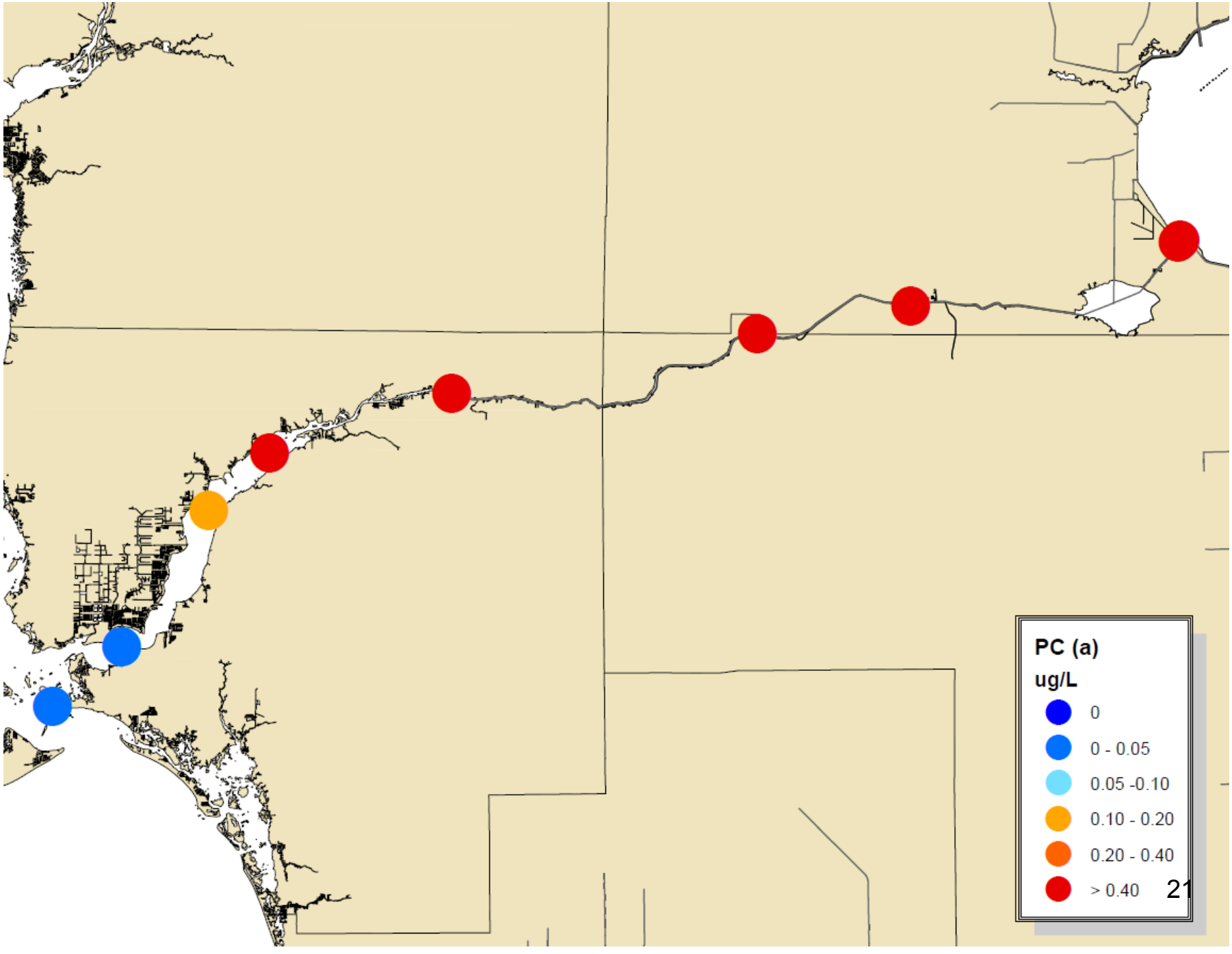
scytonemin A

"There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know."

~Donald Rumsfeld

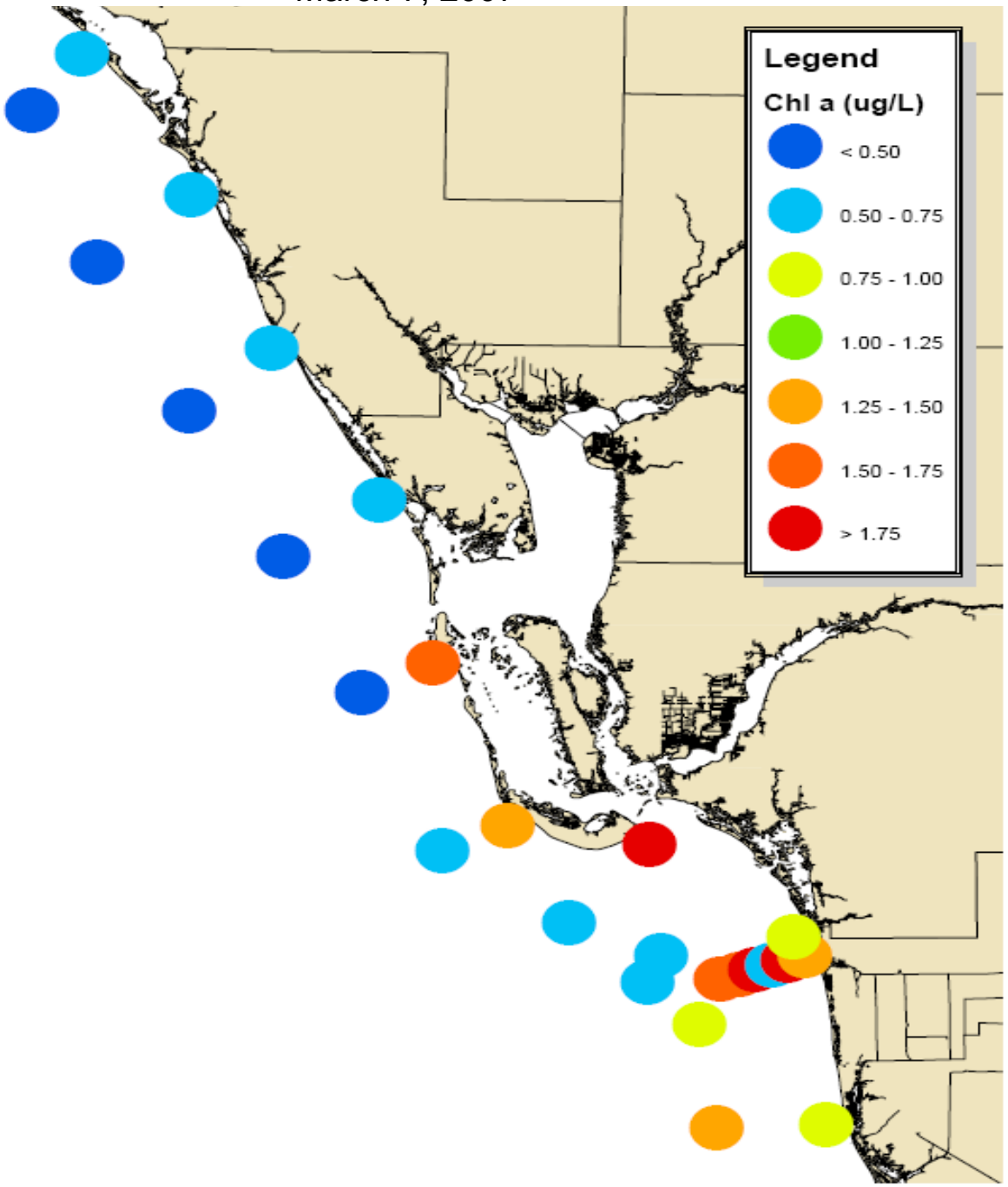

a
Historic
Flow
b
Current
Flow


Orlando
Tampa
Lake
Okeechobee
Sanibel Island
Everglades
Legend
Original Caloosahatchee Watershed
Current Caloosahatchee Watershed

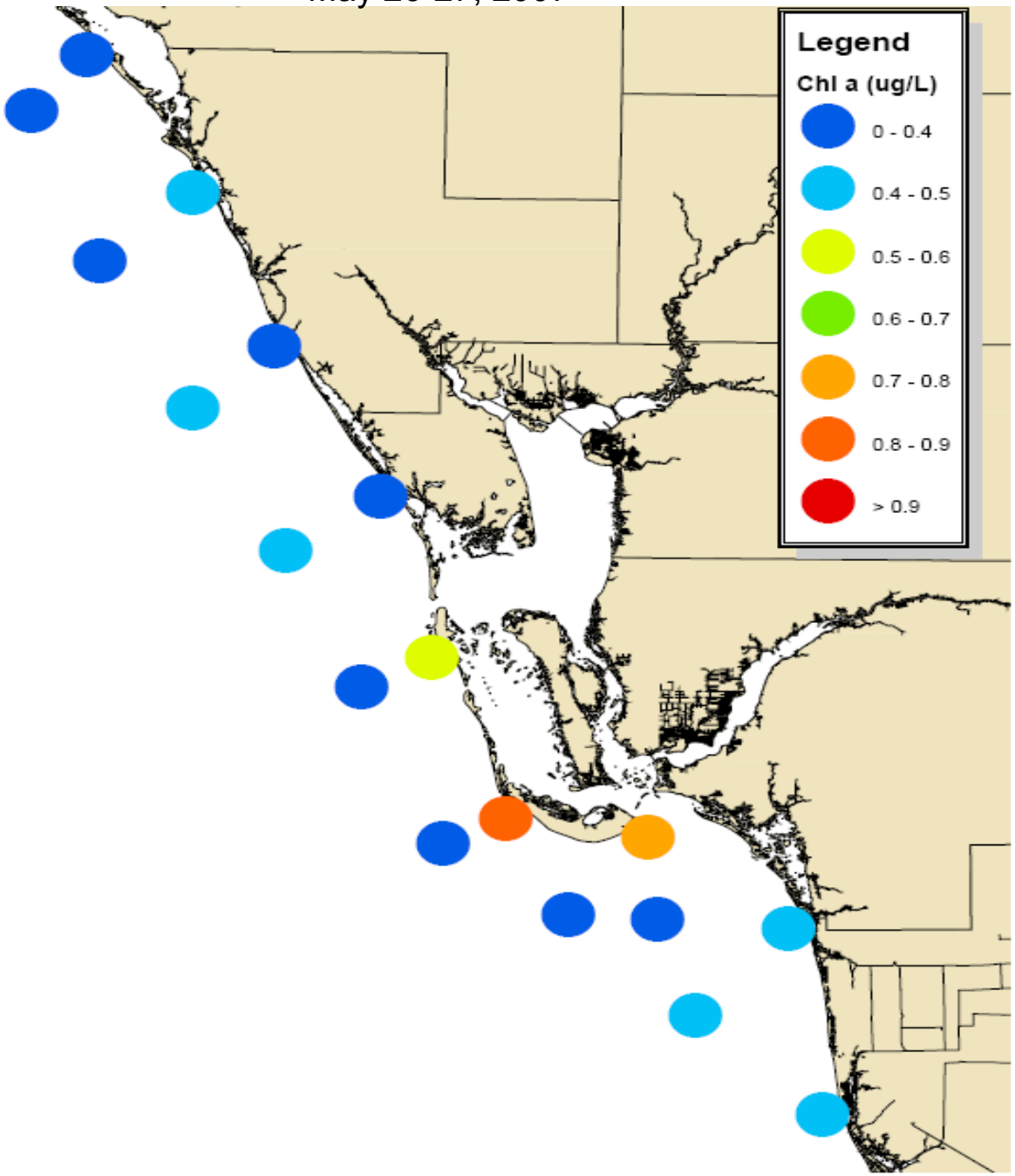

PC (a)
ug/L
0
0 - 0.05
0.05 -0.10
0.10 - 0.20
0.20 - 0.40
> 0.40

Caloosahatchee 2008

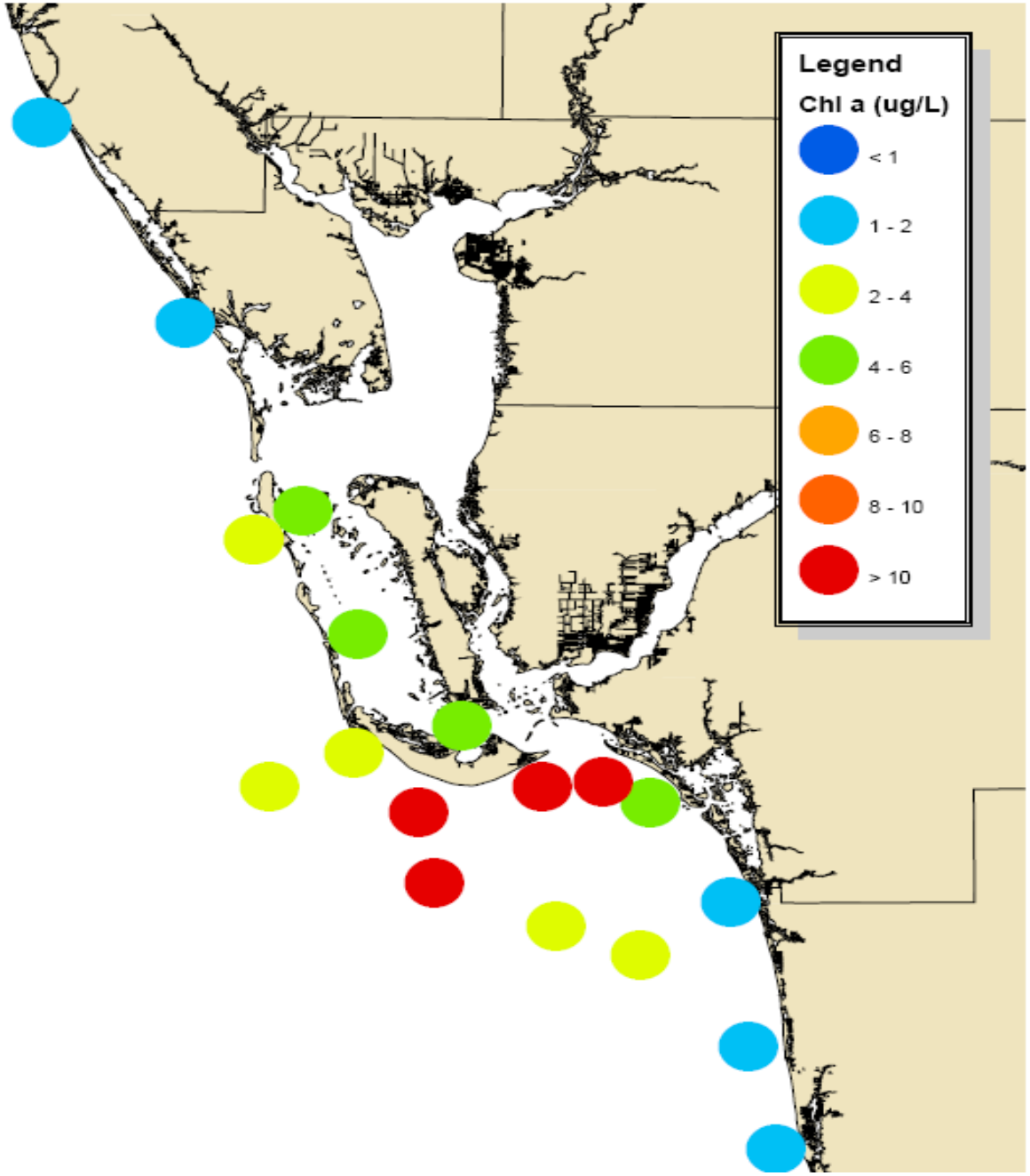
March 7, 2007

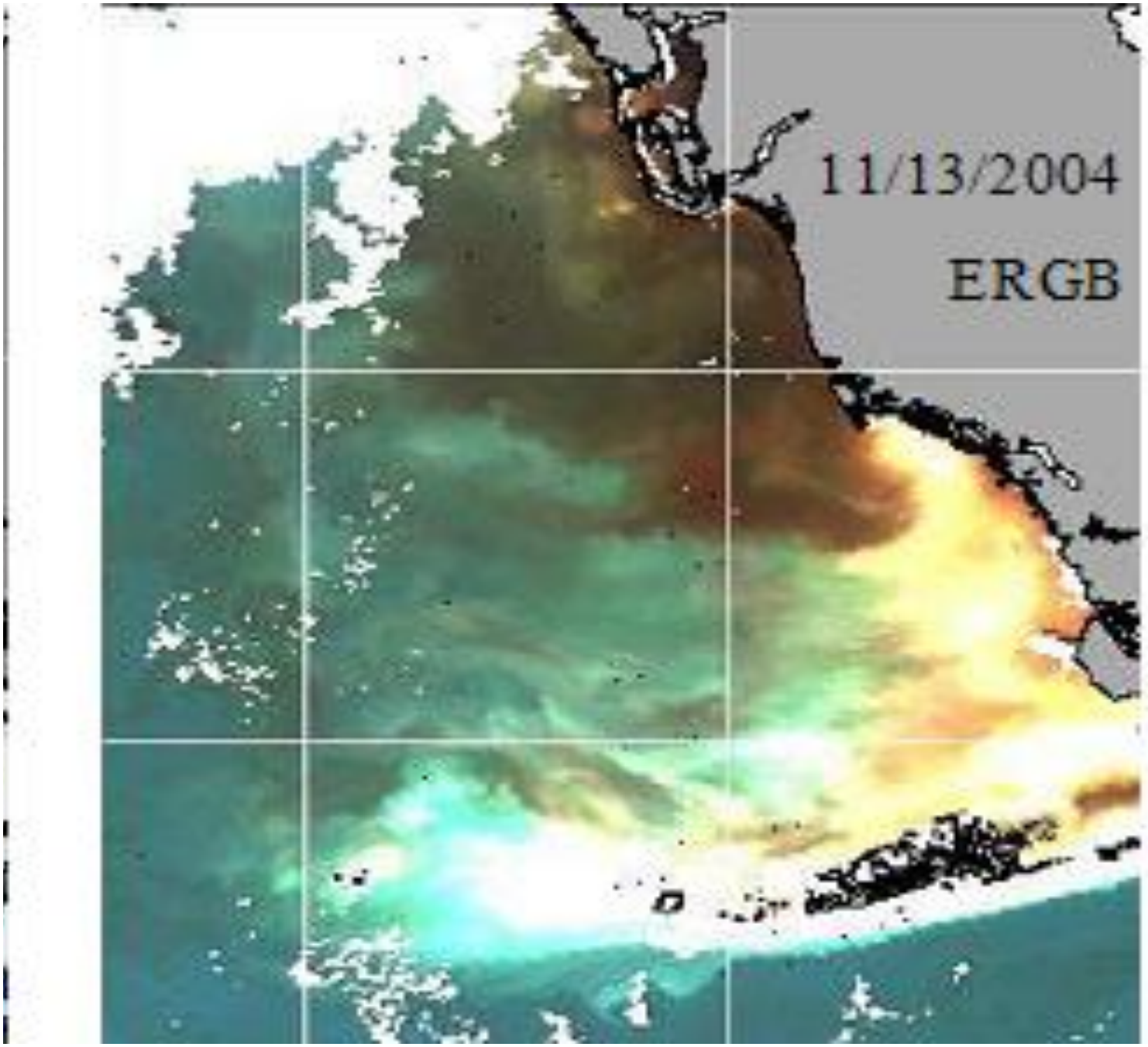


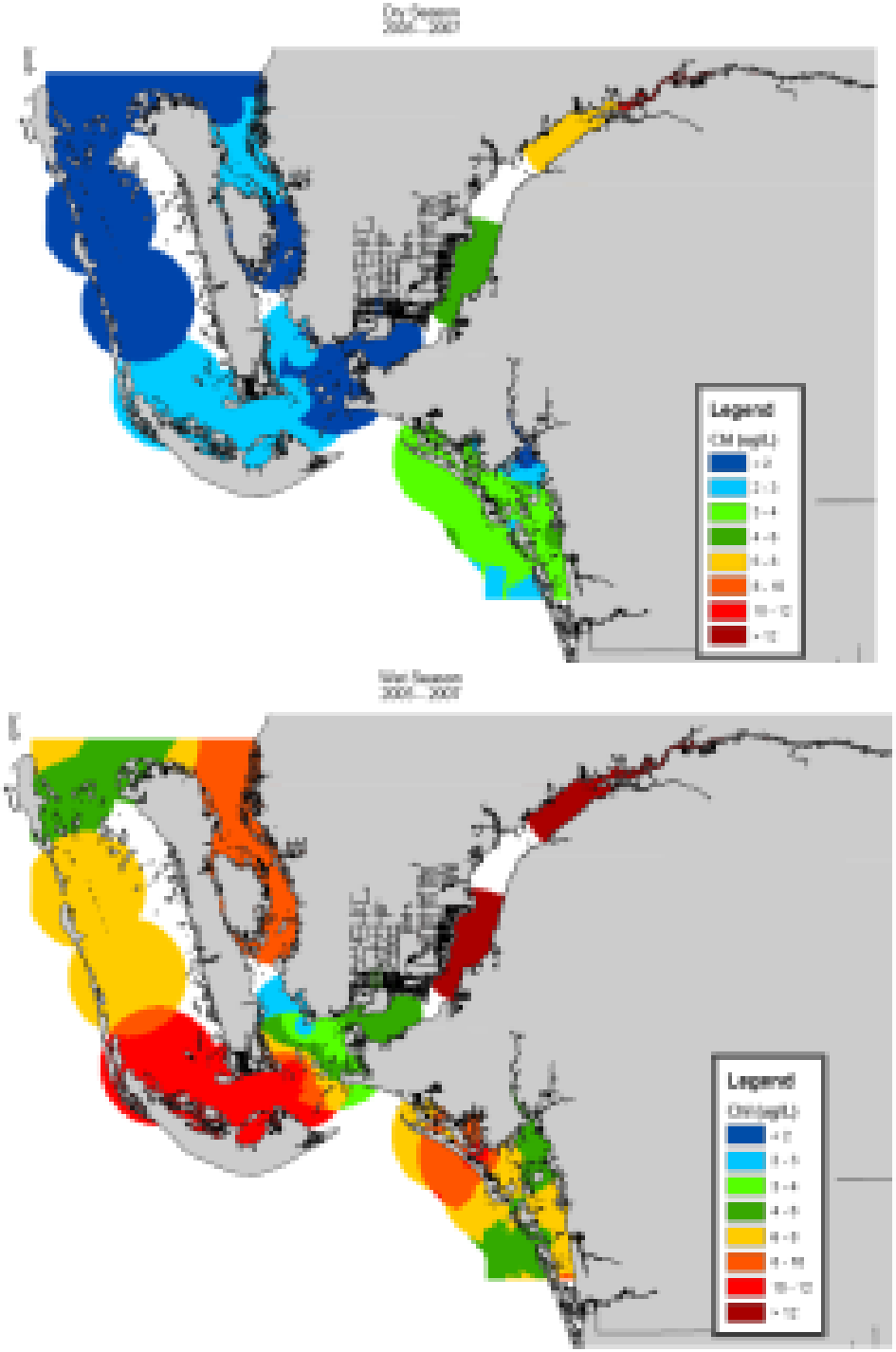
May 26-27, 2007



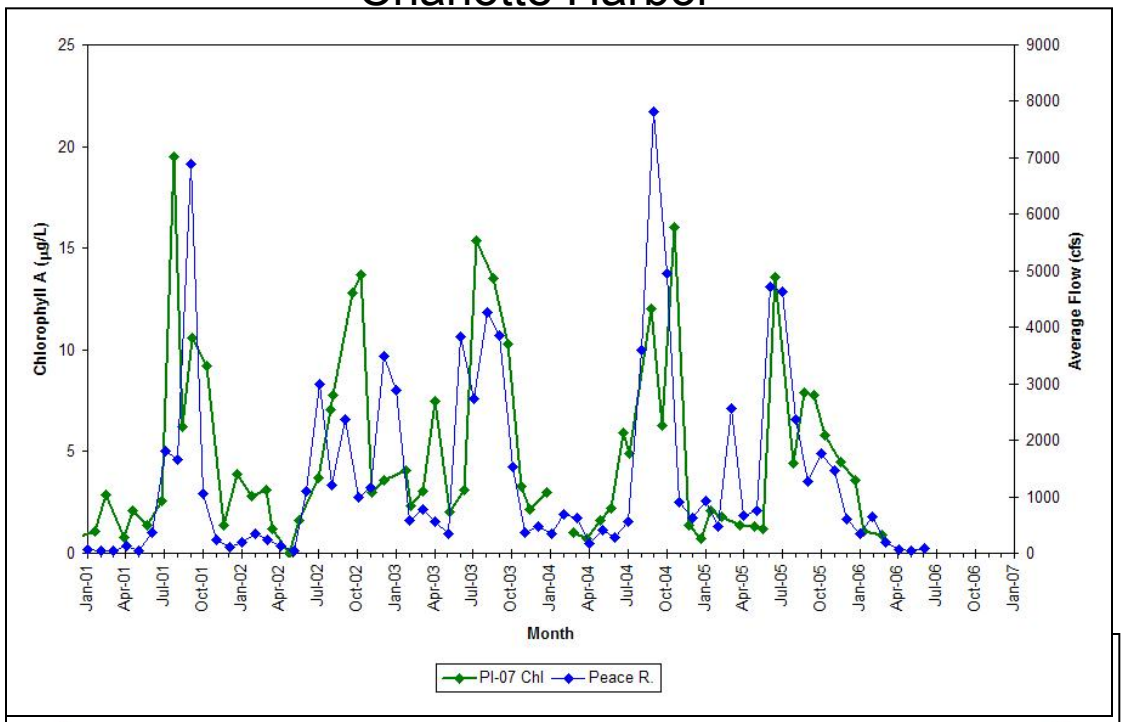
October 21-26, 2007

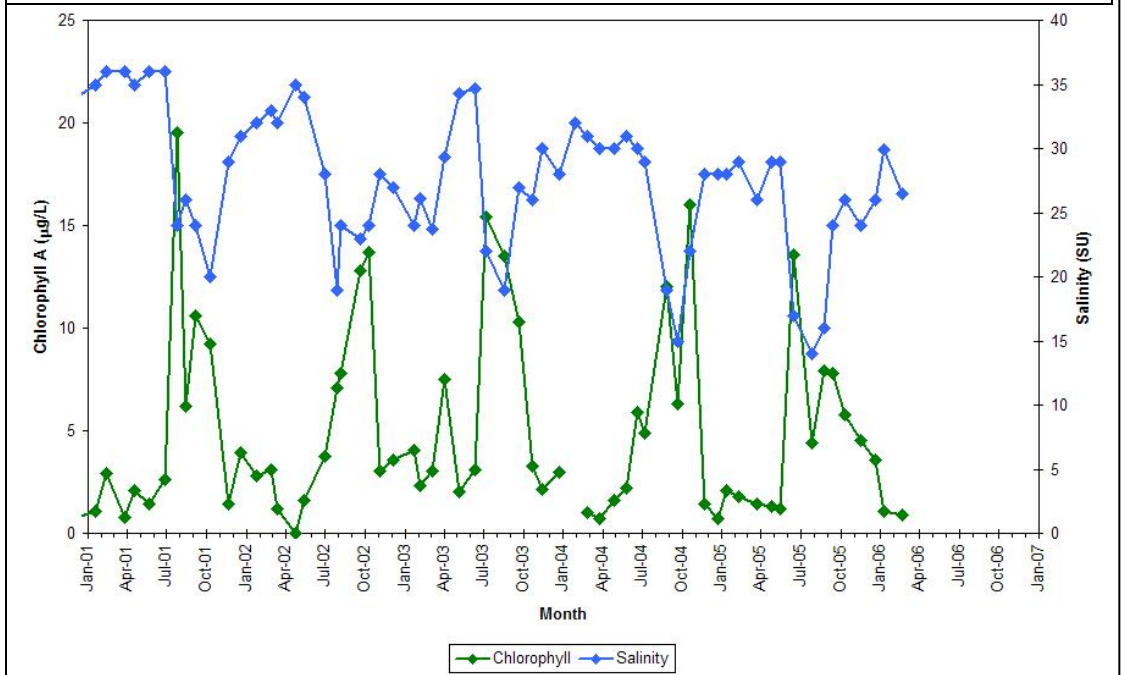



11/13/2004
ERGB

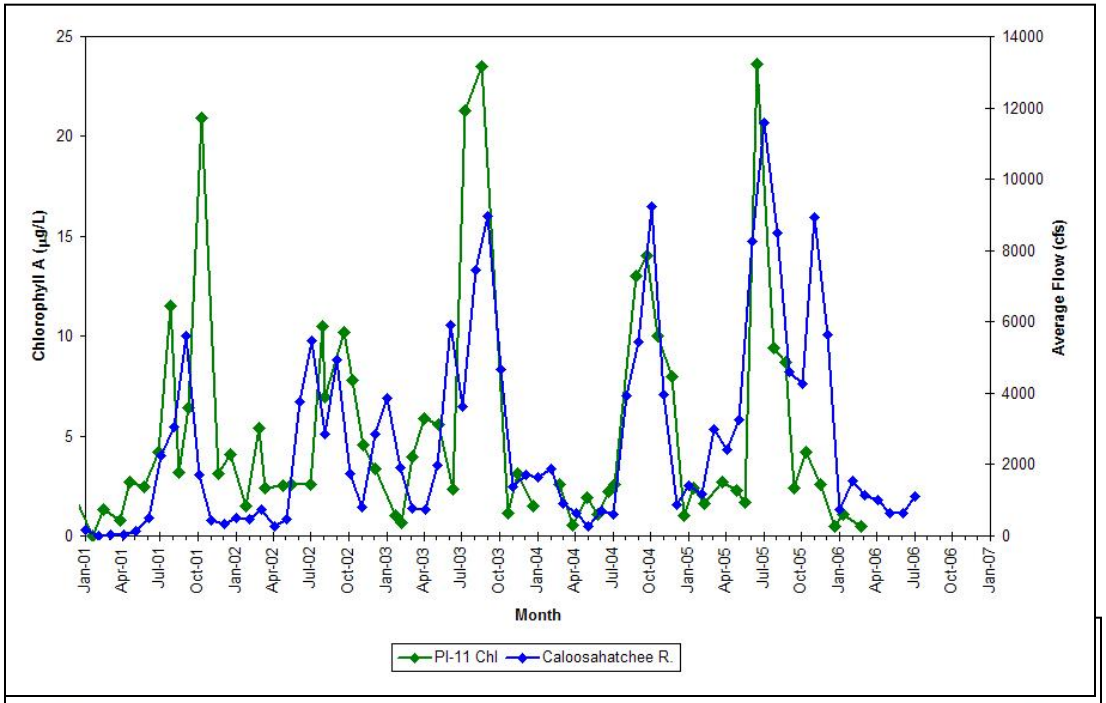

Legend
Legend

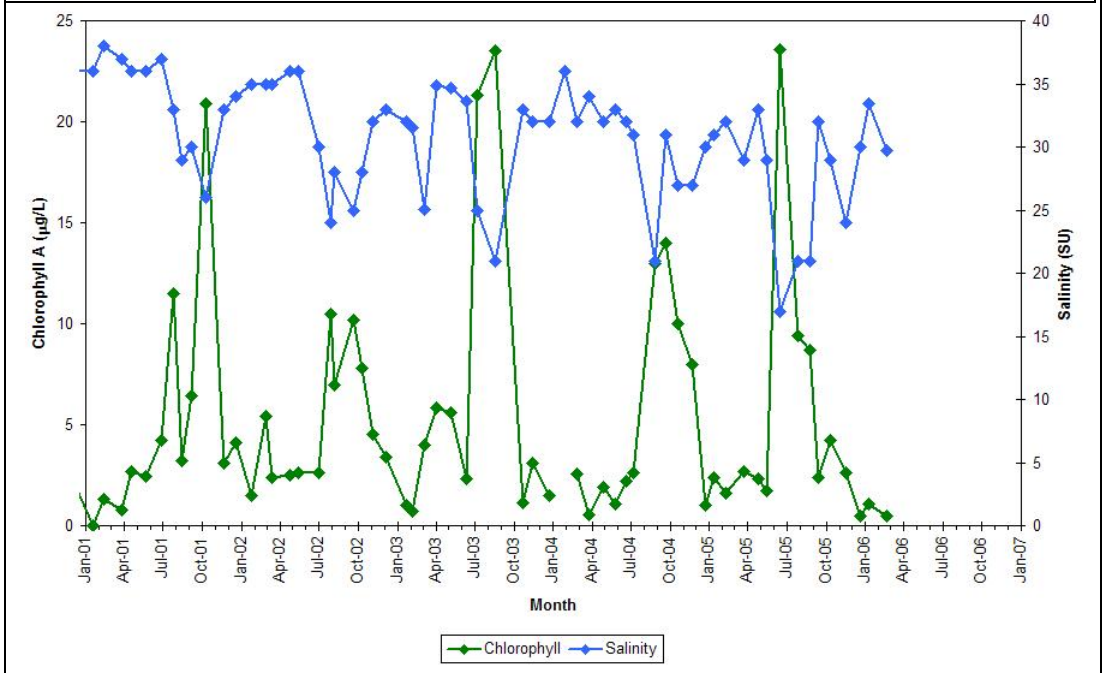
Charlotte Harbor



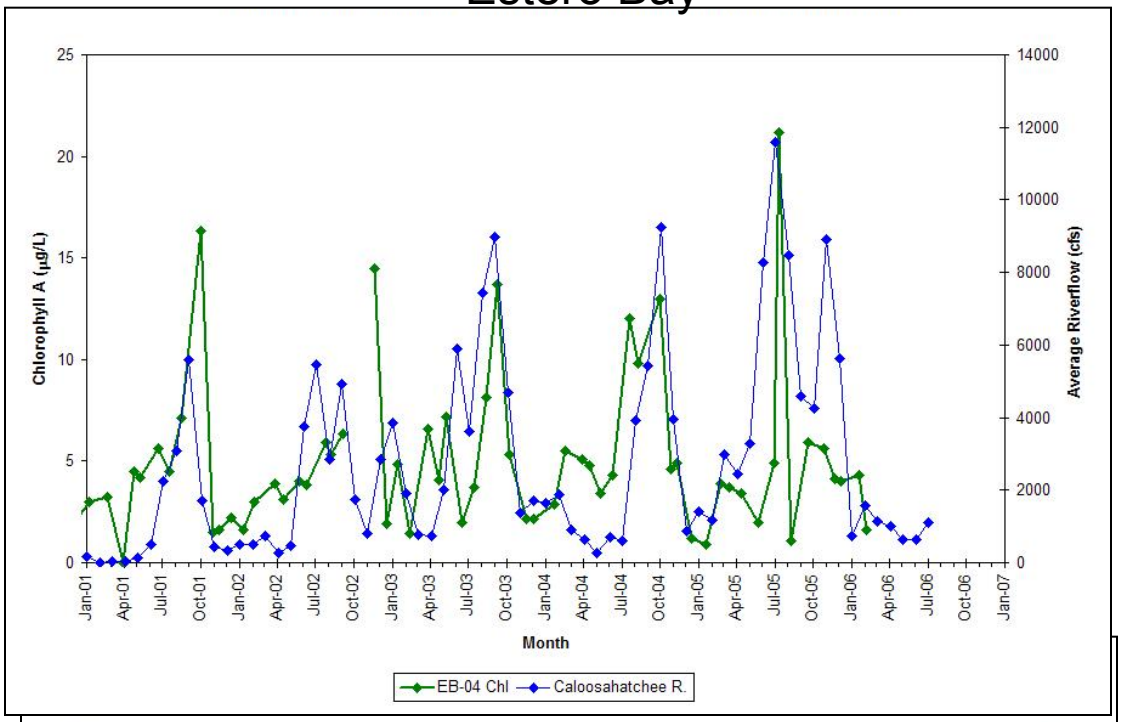


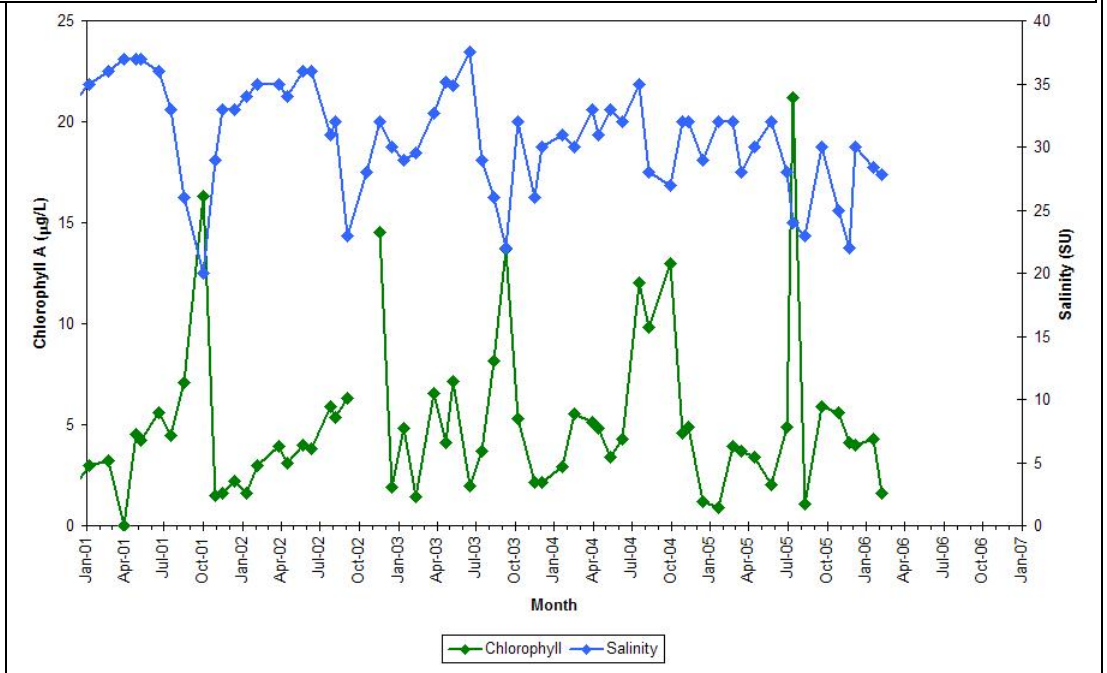
Pine Island Sound



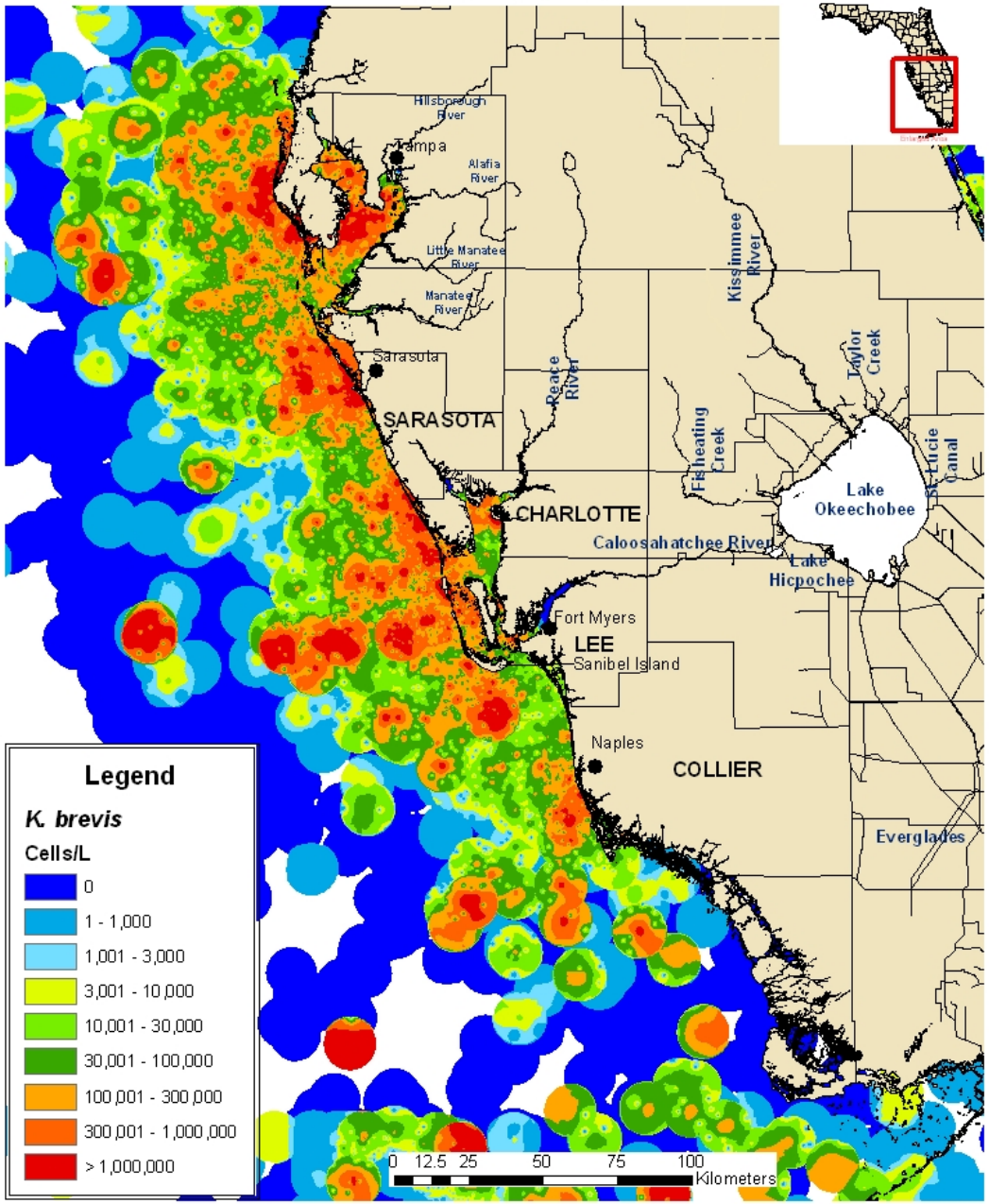


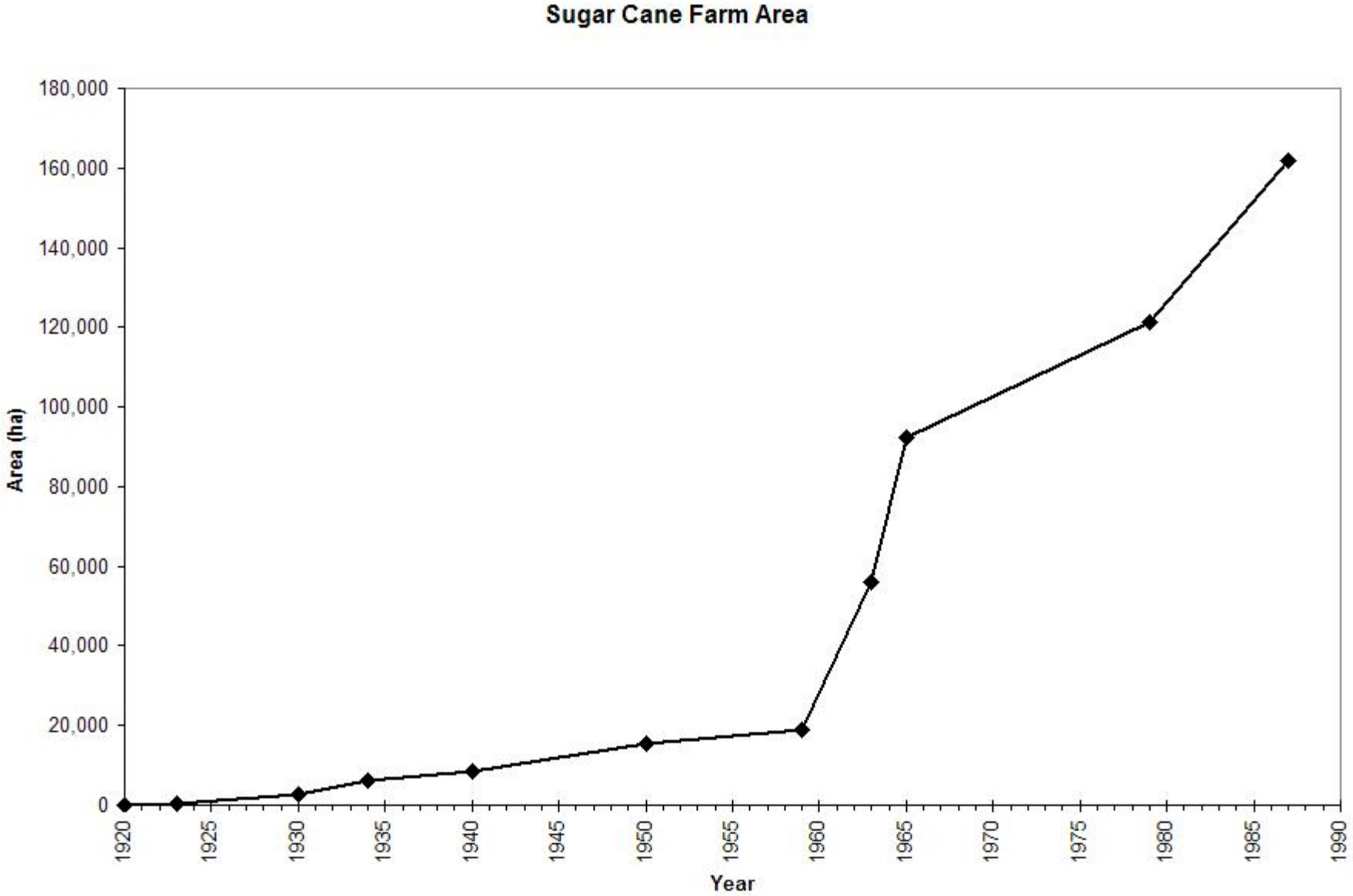
Estero Bay

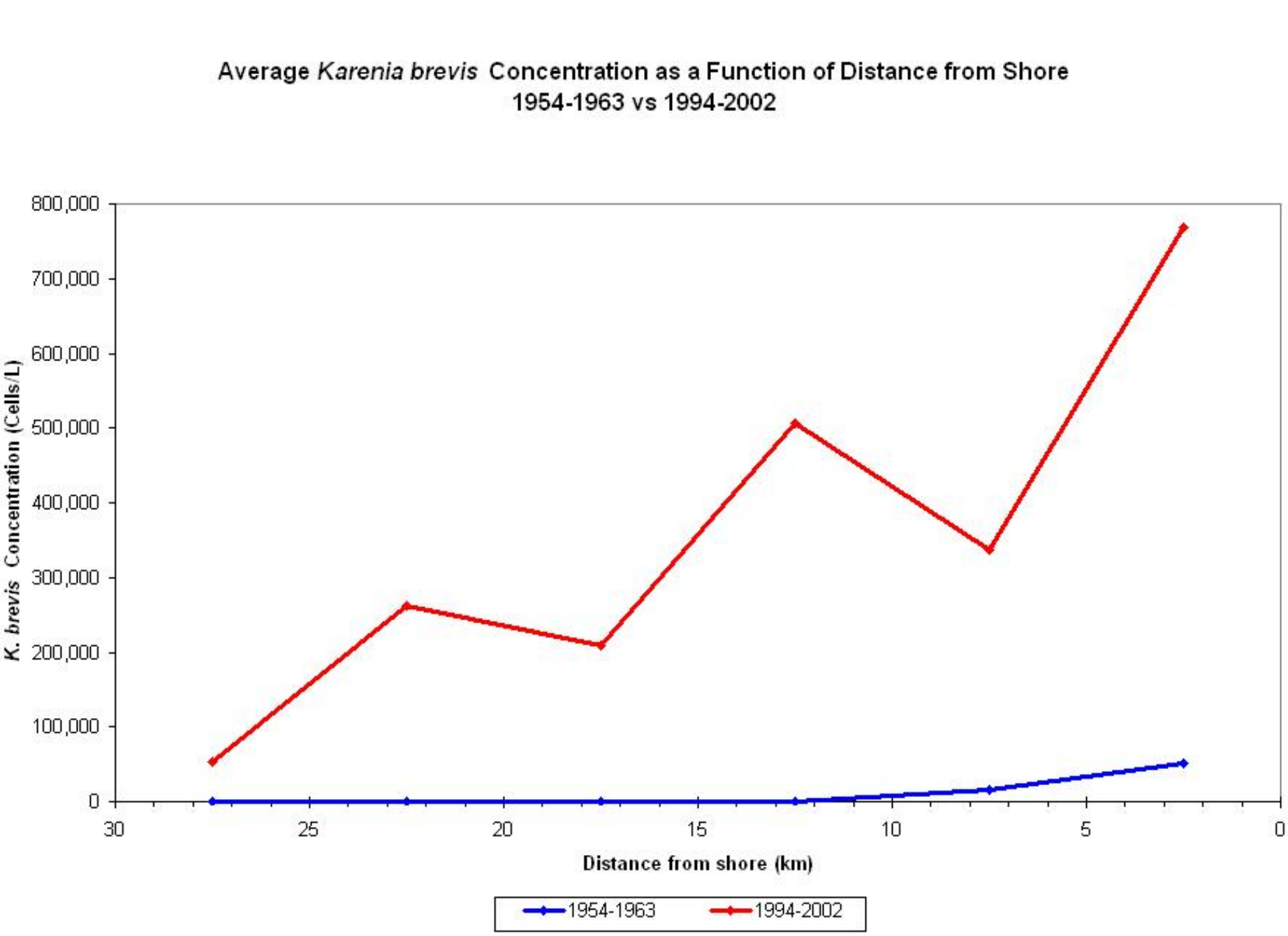

Chlorophyll A (µg/L)
Average Riverflow (cfs)
Month
EB-04 Chl
Caloosahatchee R.

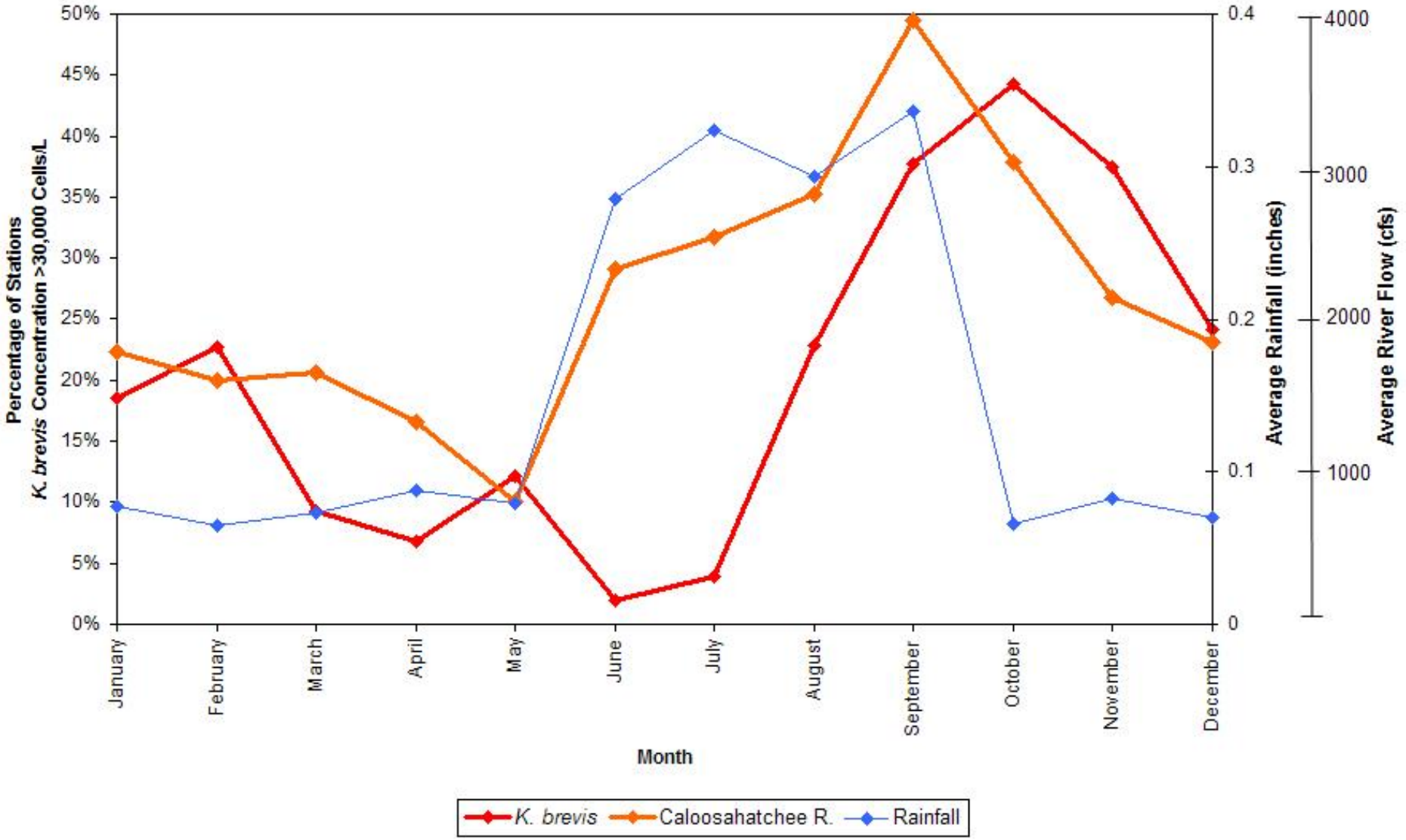

Chlorophyll A (µg/L)
Salinity (SU)
Month
Chlorophyll
Salinity

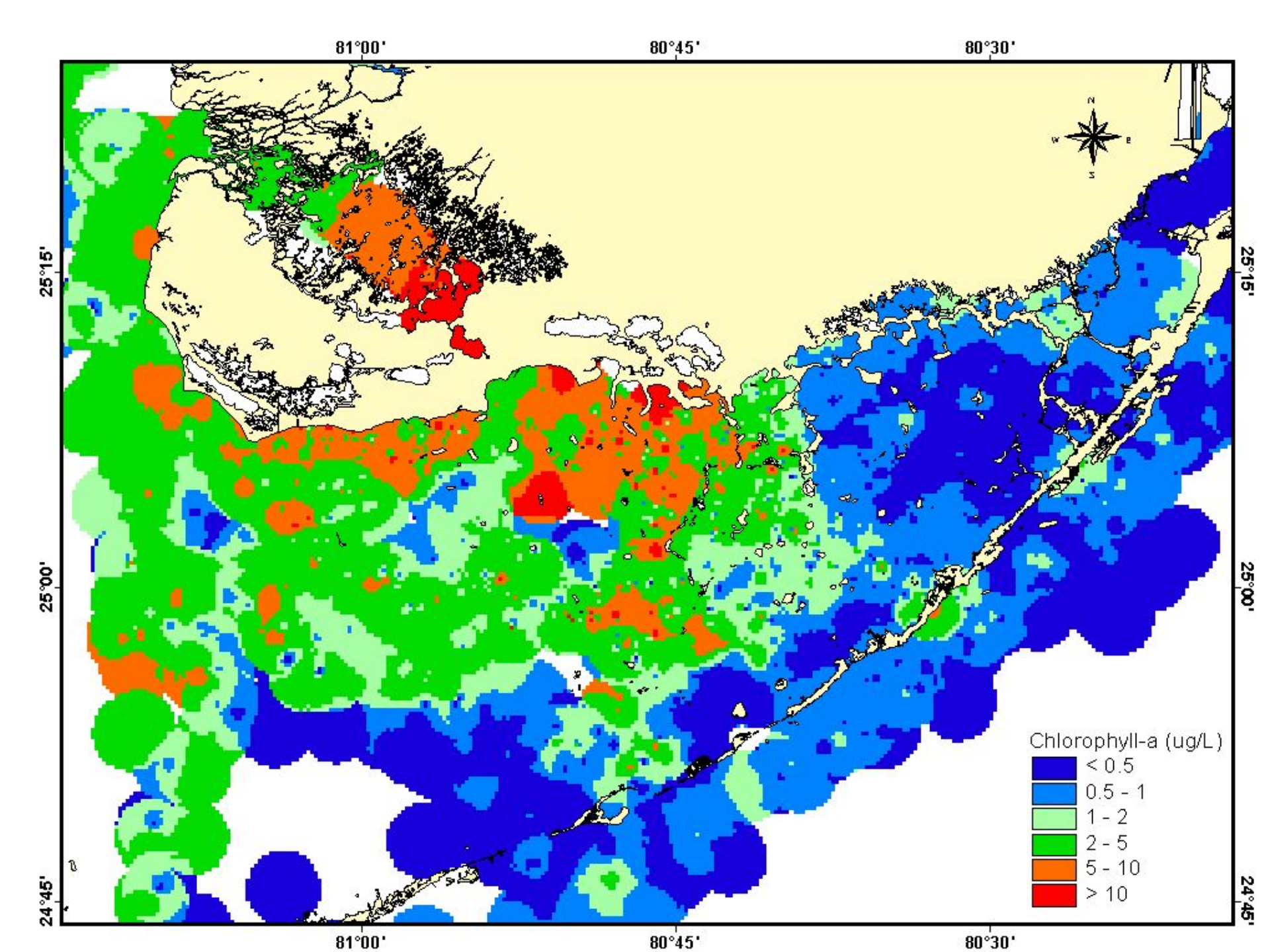
Karenia brevis Concentrations
1954 - 2002

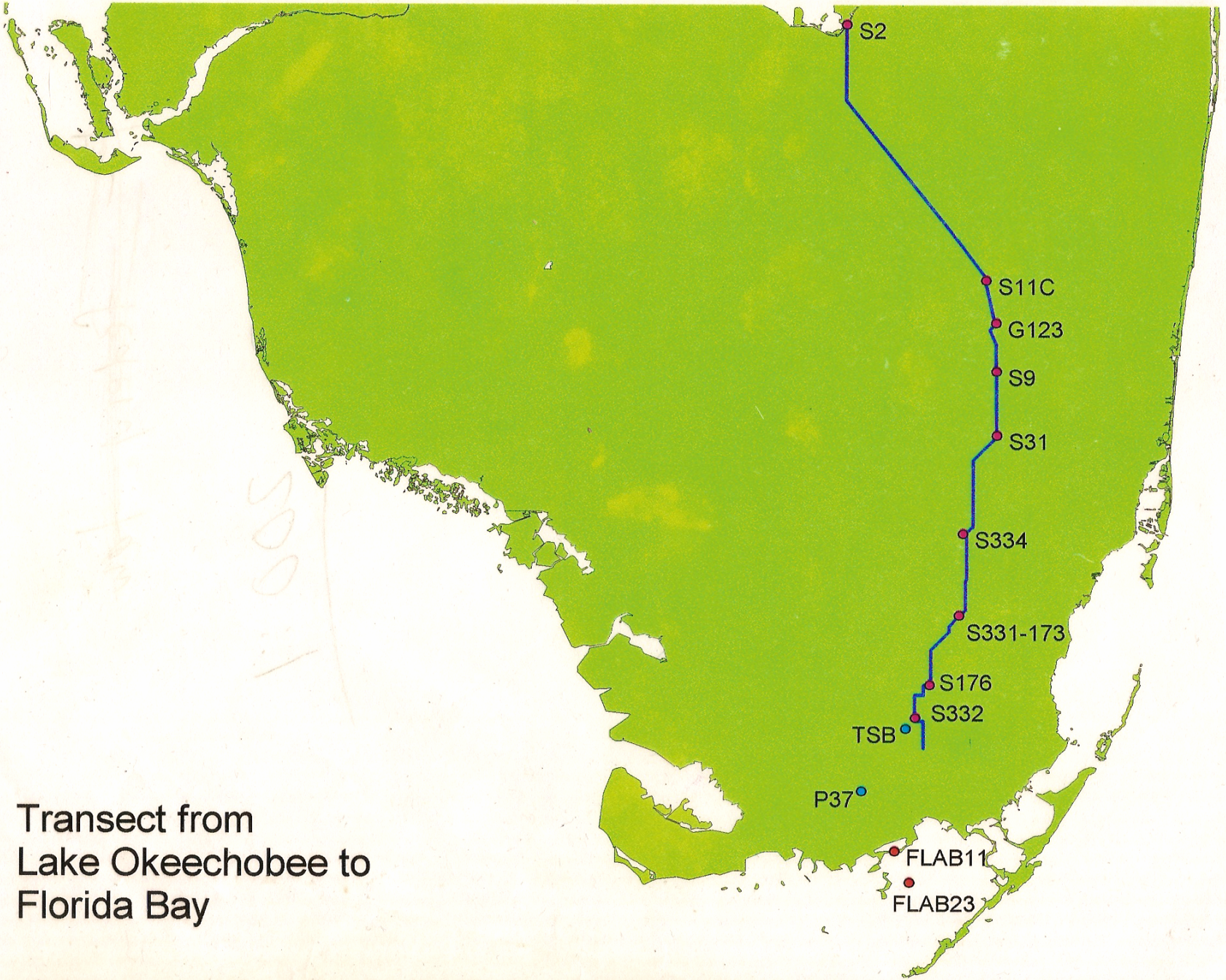



Sugar Cane Farm Area
Area (ha)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
Year


Average Karenia brevis Concentration as a Function of Distance from Shore
1954-1963 vs 1994-2002
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
K. brevis Concentration (Cells/L)
30
25
20
15
10
5
0
Distance from shore (km)
1954-1963
1994-2002

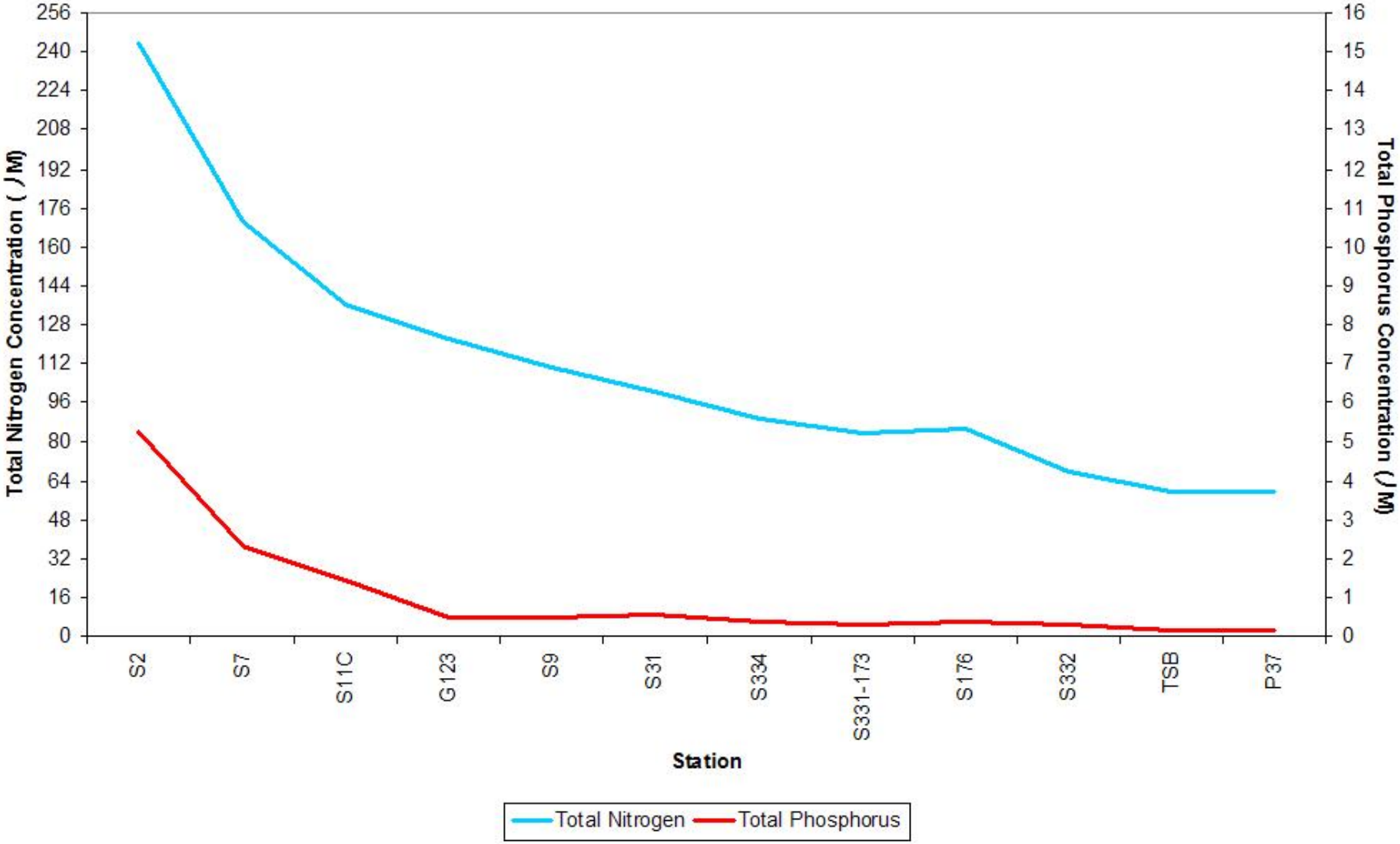

K. brevis Abundance, Caloosahatchee River Flow and Rainfall at Fort Myers
1994-2002
Percentage of Stations
K. brevis Concentration >30,000 Cells/L
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.4
0.3
0.2
0.1
0
Average Rainfall (inches)
4000
3000
2000
1000
Average River Flow (cfs)
January
February
March
April
May
June
July
August
September
October
November
December
Month
K. brevis
Caloosahatchee R.
Rainfall

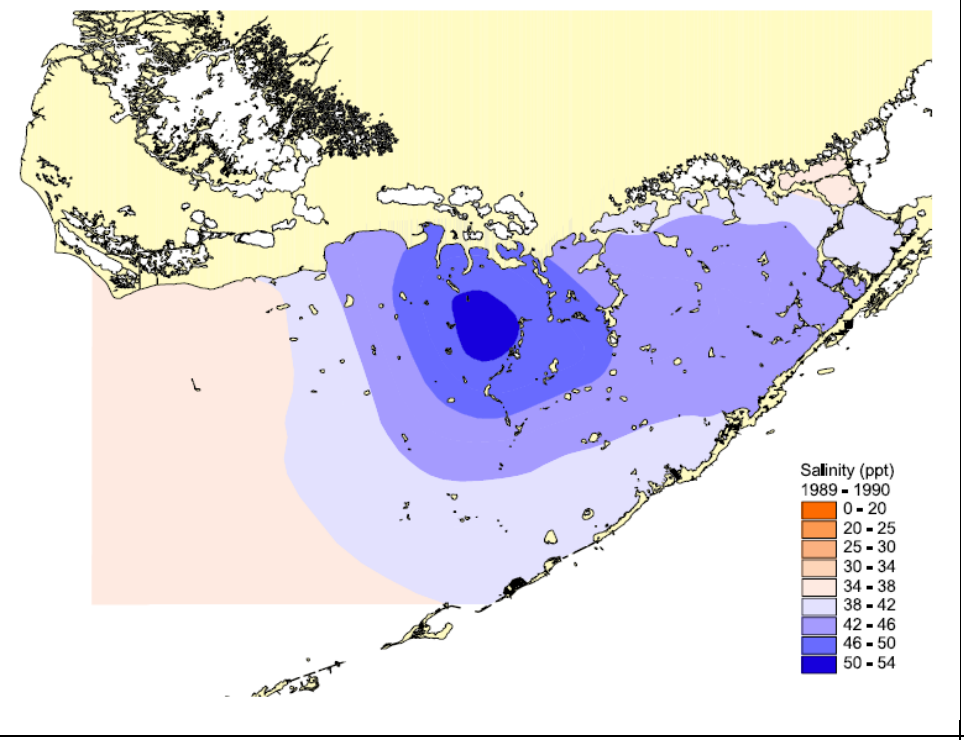

81°00'
80°45'
80°30'
25°15'
25°00'
24°45'
Chlorophyll-a (ug/L)
< 0.5
0.5 - 1
1 - 2
2 - 5
5 - 10
> 10

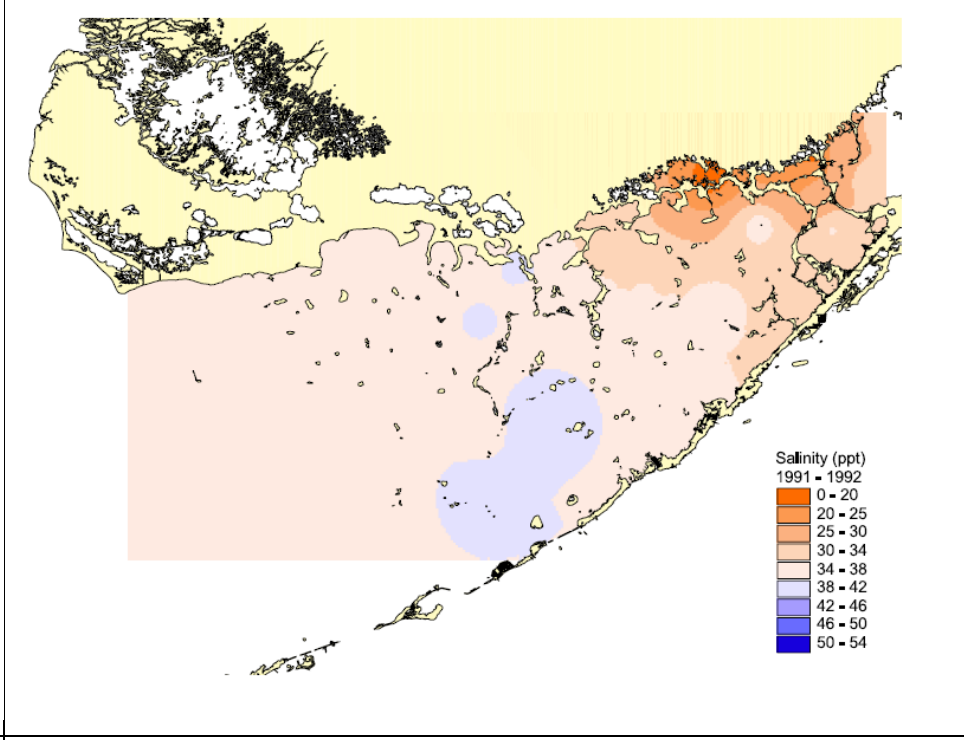


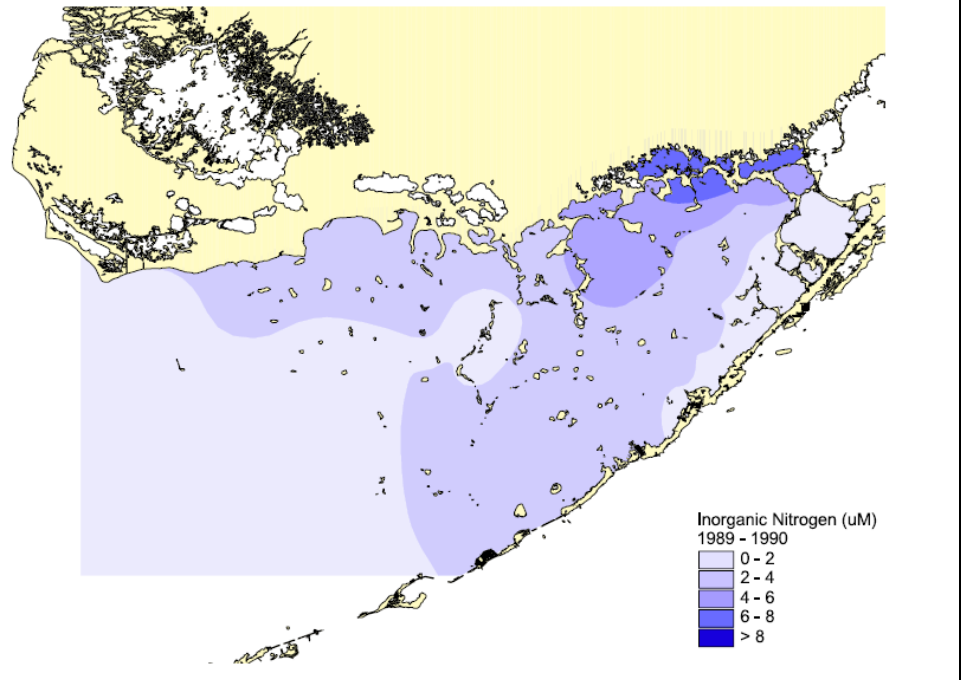
Transect from
Lake Okeechobee to
Florida Bay

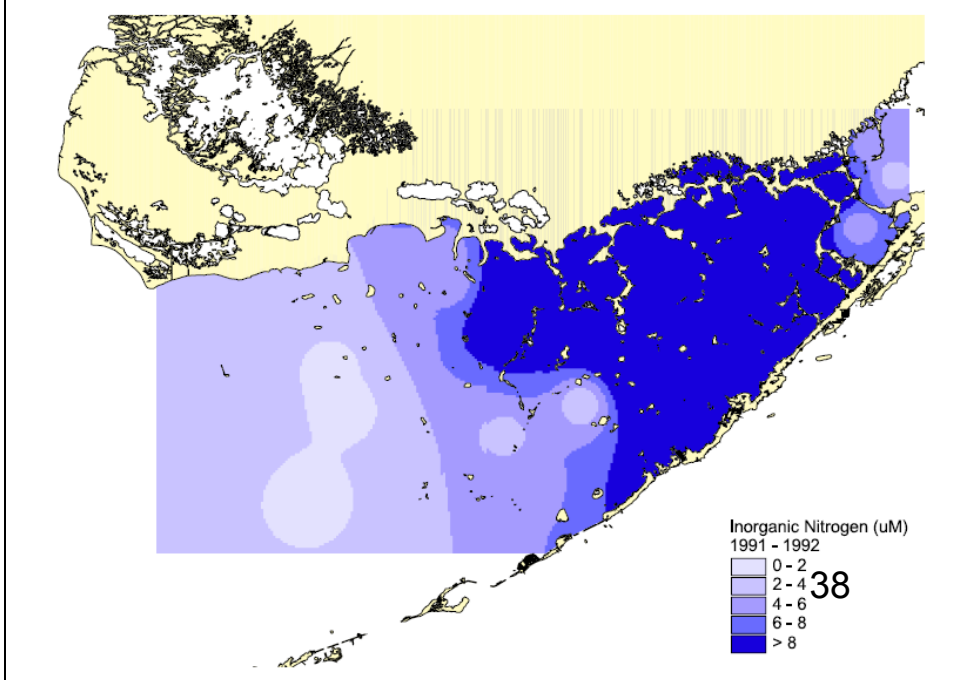
Average Estimated Nutrient Concentrations from Lake Okeechobee to Taylor Slough 1998

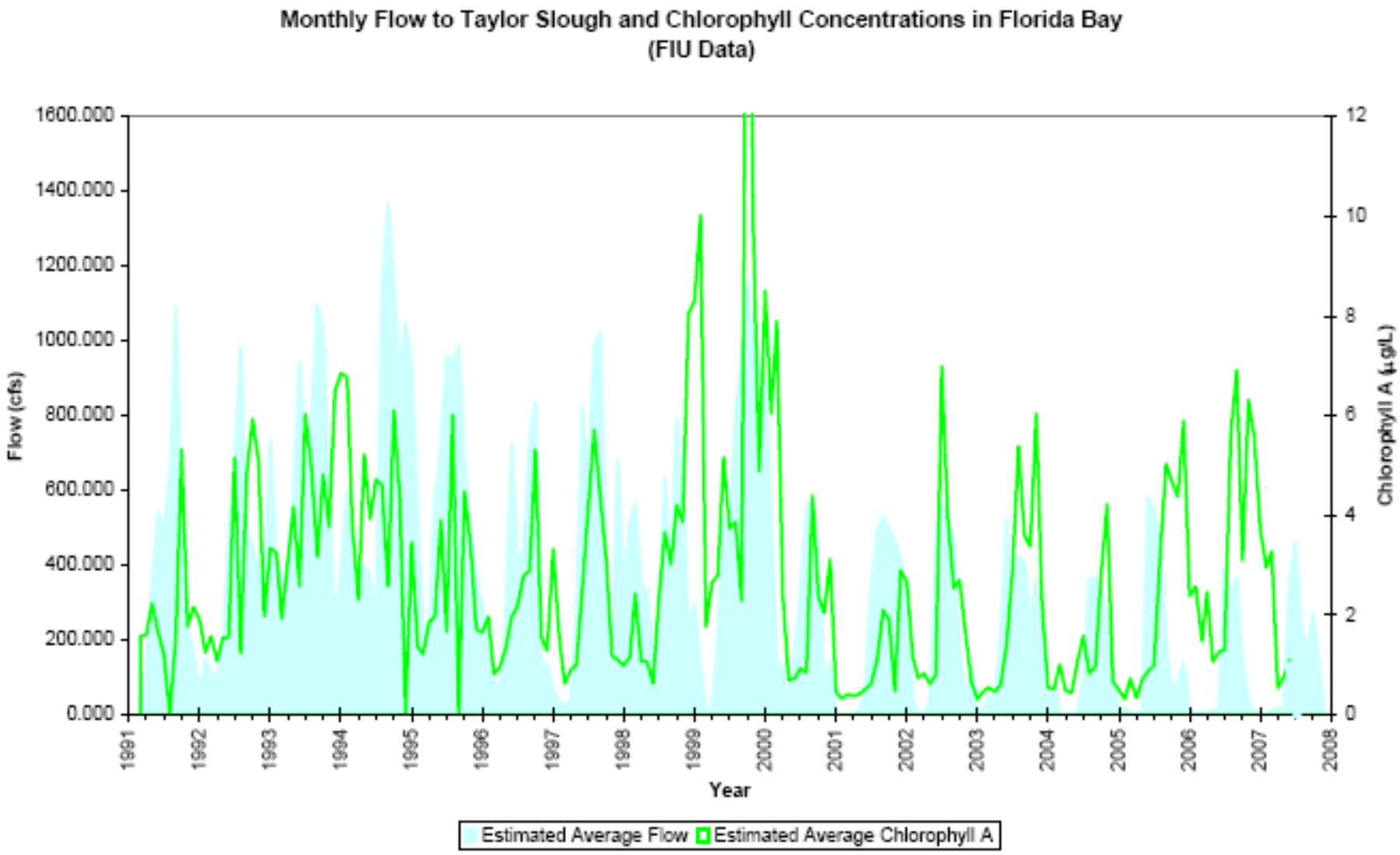


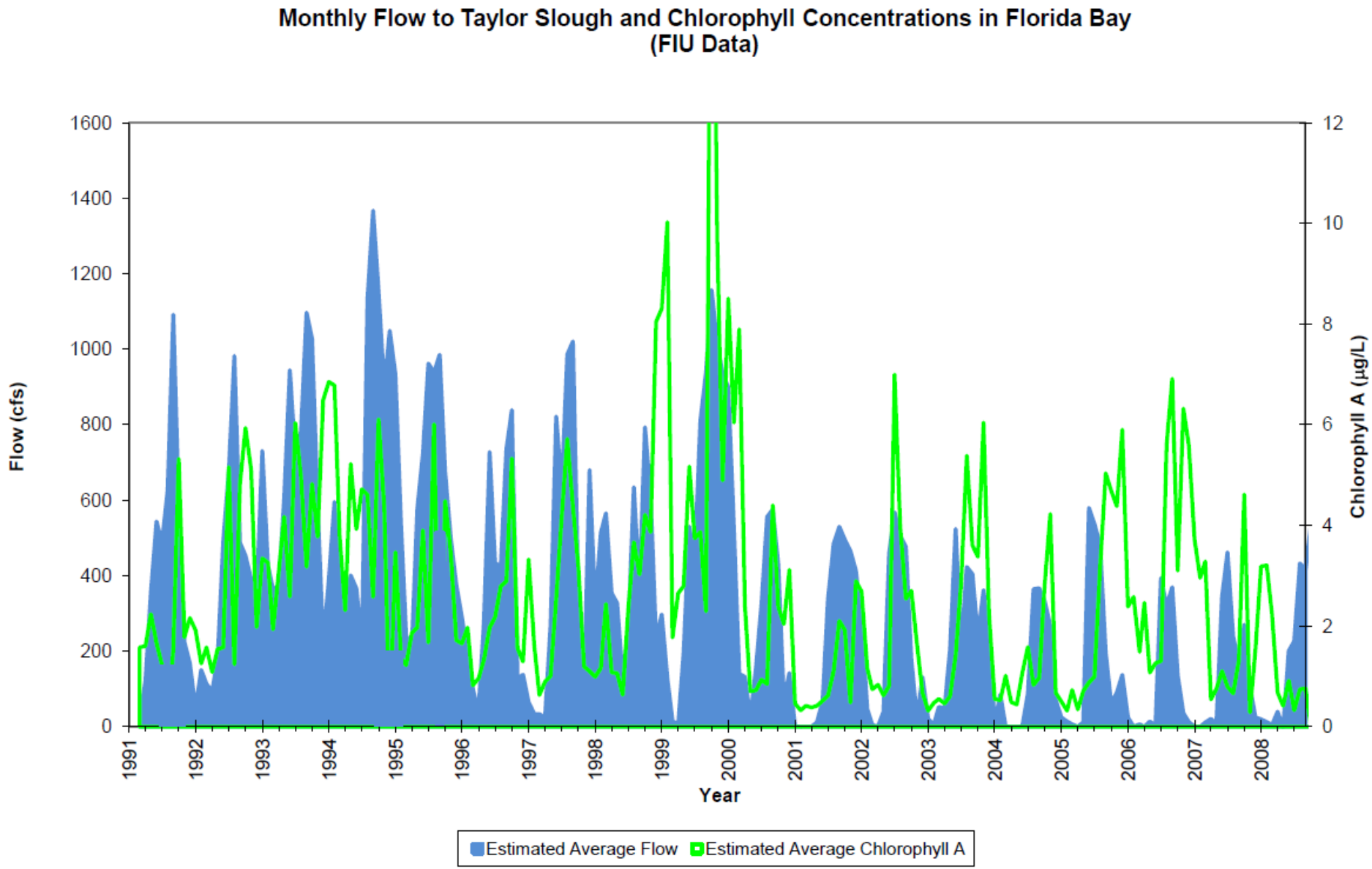

Salinity (ppt)
1989 - 1990
0 - 20
20 - 25
25 - 30
30 - 34
34 - 38
38 - 42
42 - 46
46 - 50
50 - 54

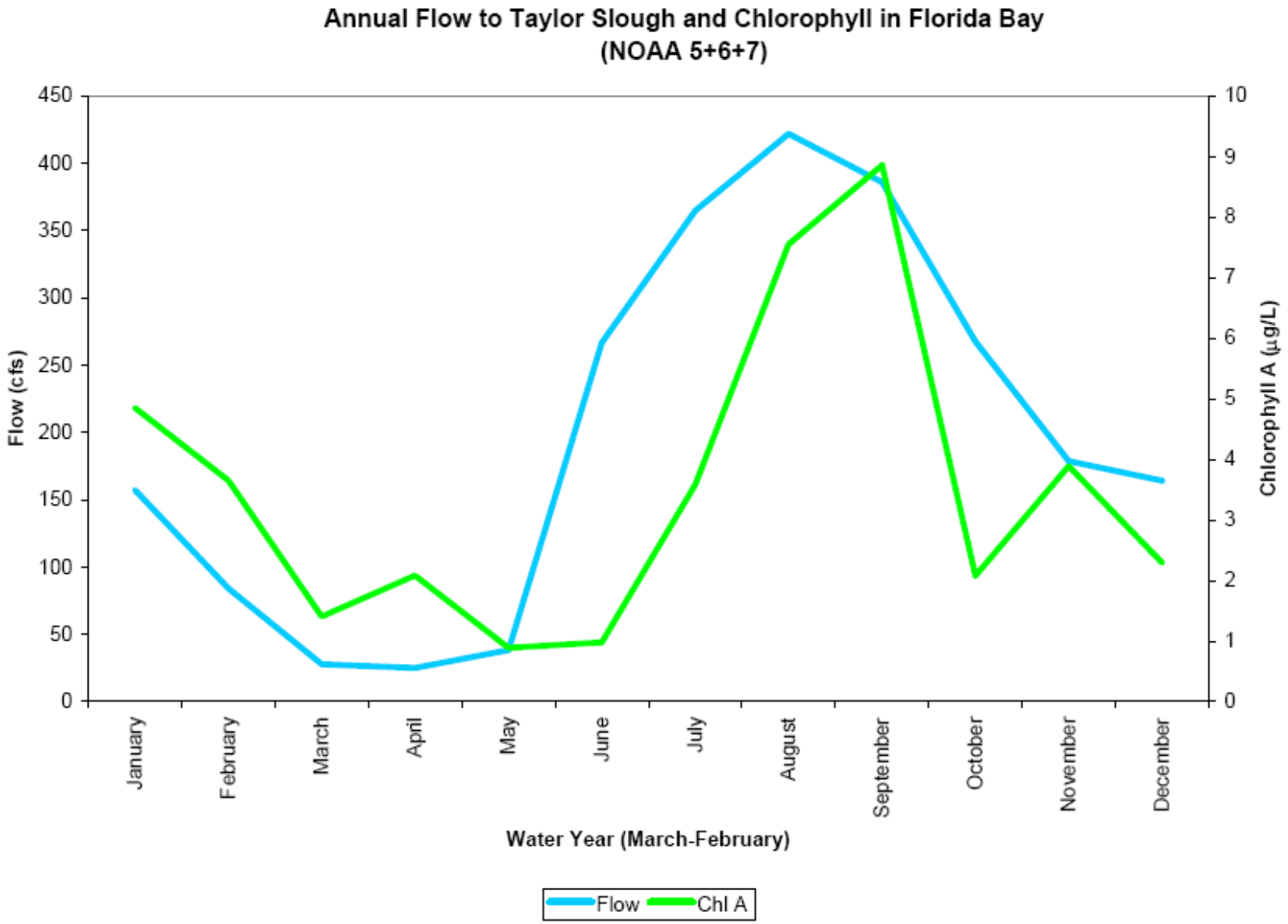

Salinity (ppt)
1991 - 1992
0 - 20
20 - 25
25 - 30
30 - 34
34 - 38
38 - 42
42 - 46
46 - 50
50 - 54

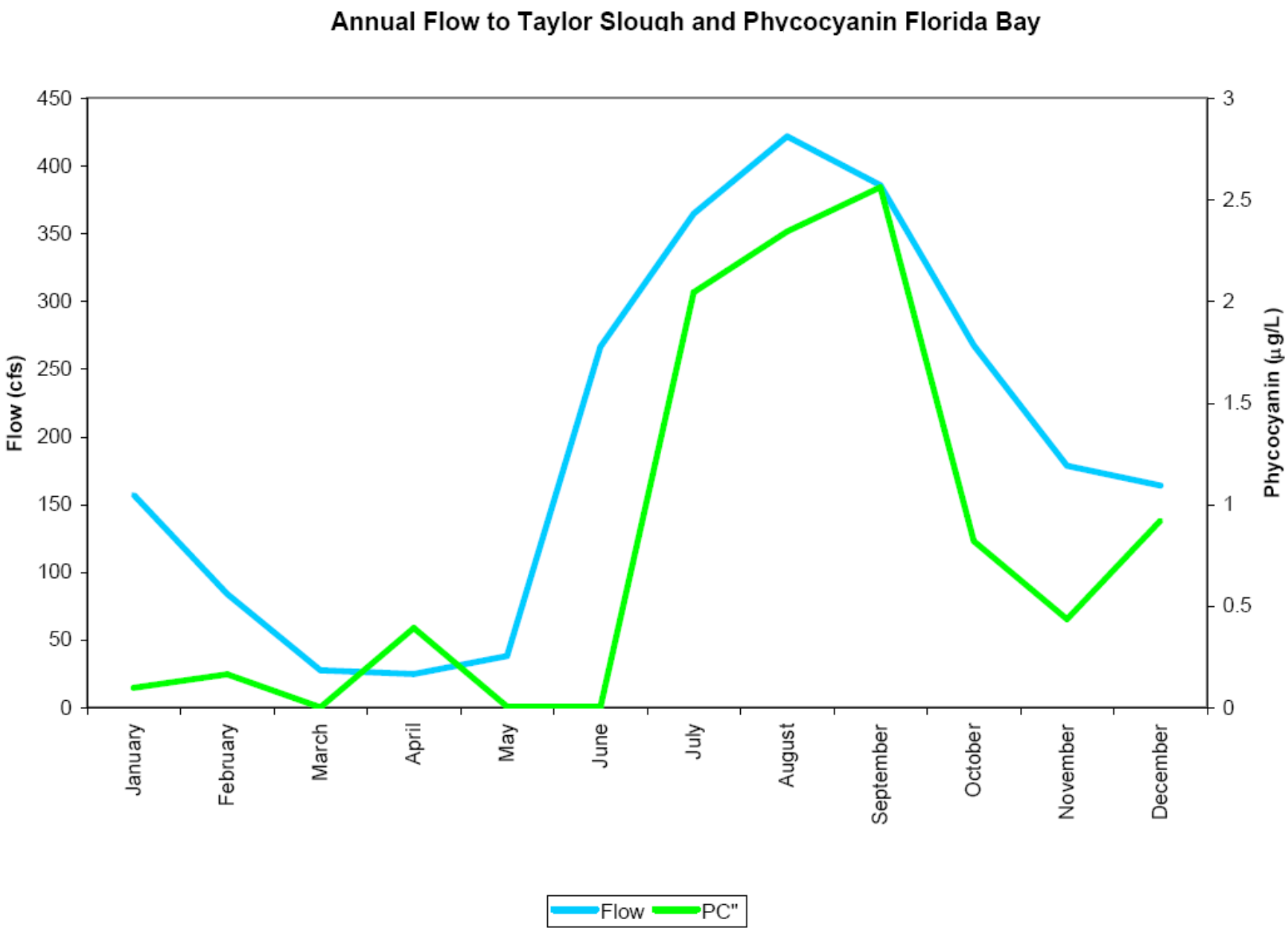

Inorganic Nitrogen (uM)
1989 - 1990
0 - 2
2 - 4
4 - 6
6 - 8
> 8

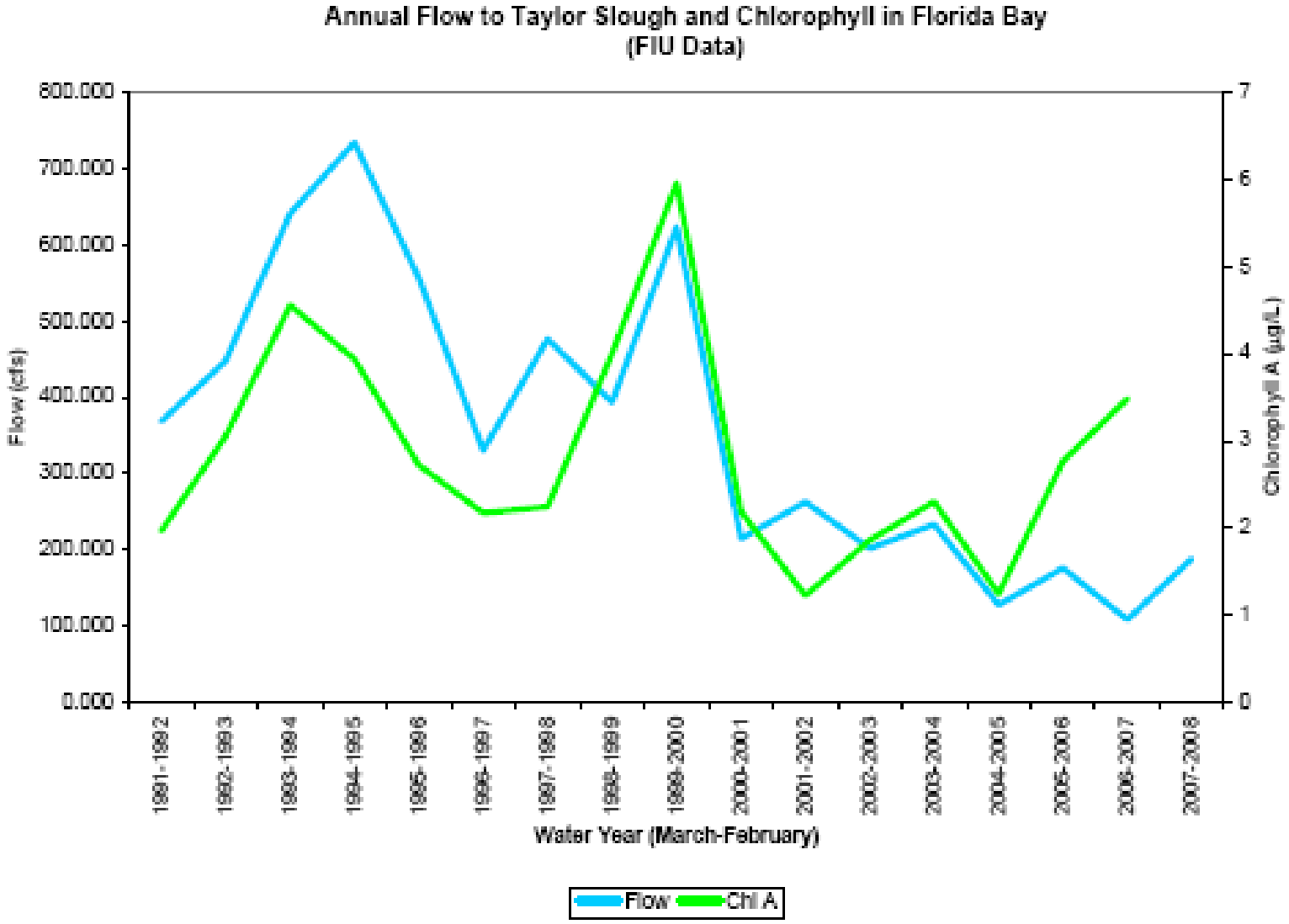

Inorganic Nitrogen (uM)
1991 - 1992
0 - 2
2 - 4
4 - 6
6 - 8
> 8

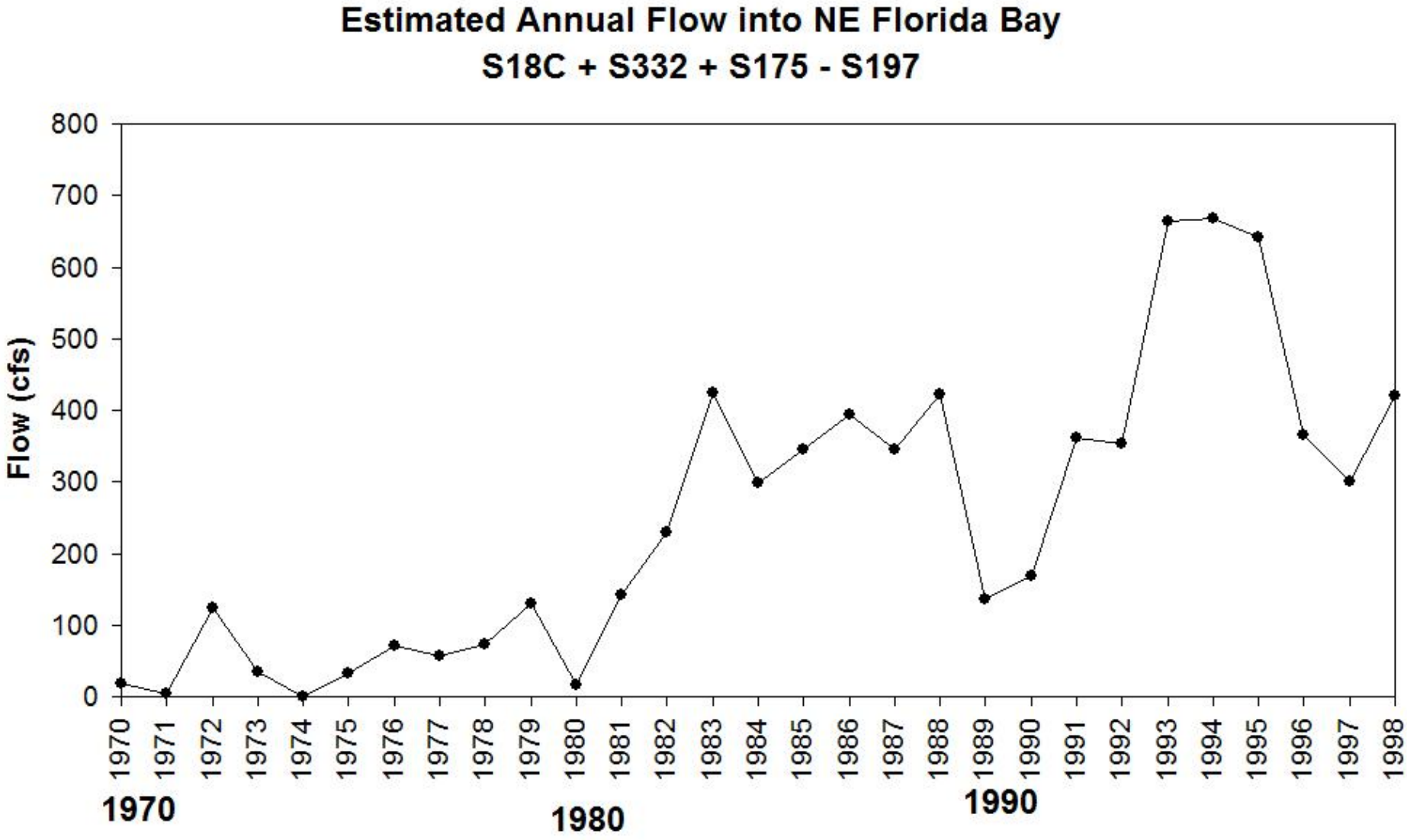

Monthly Flow to Taylor Slough and Chlorophyll Concentrations in Florida Bay
(FIU Data)
Flow (cfs)
1600.000
1400.000
1200.000
1000.000
800.000
600.000
400.000
200.000
0.000
Chlorophyll A (µg/L)
12
10
8
6
4
2
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year
Estimated Average Flow
Estimated Average Chlorophyll A


Monthly Flow to Taylor Slough and Chlorophyll Concentrations in Florida Bay
(FIU Data)
Flow (cfs)
Chlorophyll A (µg/L)
Year
1600
1400
1200
1000
800
600
400
200
0
12
10
8
6
4
2
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Estimated Average Flow
Estimated Average Chlorophyll A


Annual Flow to Taylor Slough and Chlorophyll in Florida Bay
(NOAA 5+6+7)
Flow (cfs)
Chlorophyll A (µg/L)
450
400
350
300
250
200
150
100
50
0
10
9
8
7
6
5
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
November
December
Water Year (March-February)
Flow
Chl A


Annual Flow to Taylor Slough and Phycocyanin Florida Bay
Flow (cfs)
Phycocyanin (µg/L)
450
400
350
300
250
200
150
100
50
0
3
2.5
2
1.5
1
0.5
0
January
February
March
April
May
June
July
August
September
October
November
December
Flow
PC"


Annual Flow to Taylor Slough and Chlorophyll in Florida Bay
(FIU Data)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0,000
Flow (cfs)
7
6
5
4
3
2
1
0
Chlorophyll A (µg/L)
1991-1992
1992-1993
1993-1994
1994-1995
1995-1996
1996-1997
1997-1998
1998-1999
1999-2000
2000-2001
2001-2002
2002-2003
2003-2004
2004-2005
2005-2006
2006-2007
2007-2008
Water Year (March-February)
Flow
Chl A


Estimated Annual Flow into NE Florida Bay
S18C + S332 + S175 - S197
Flow (cfs)
800
700
600
500
400
300
200
100
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1970
1980
1990

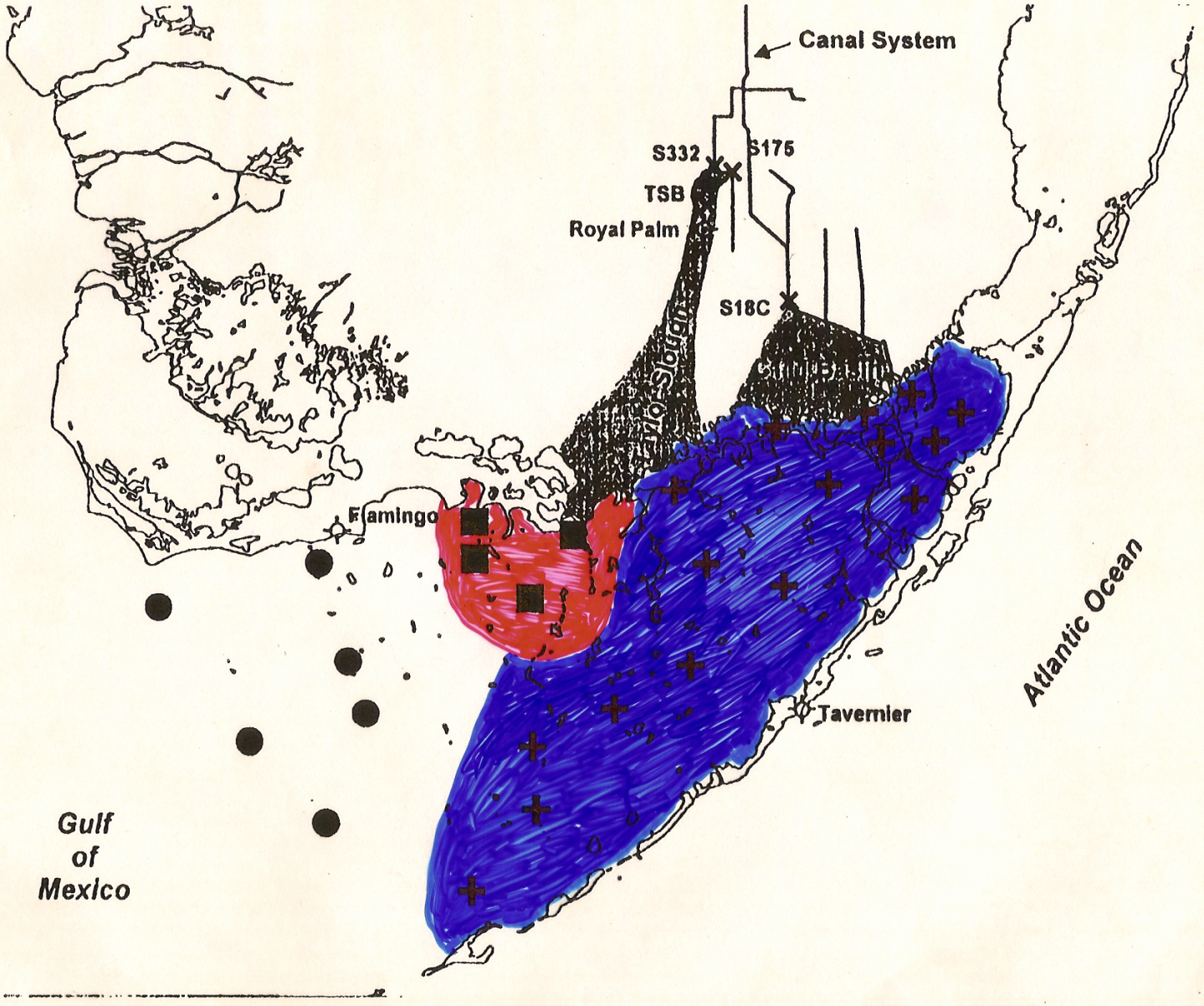
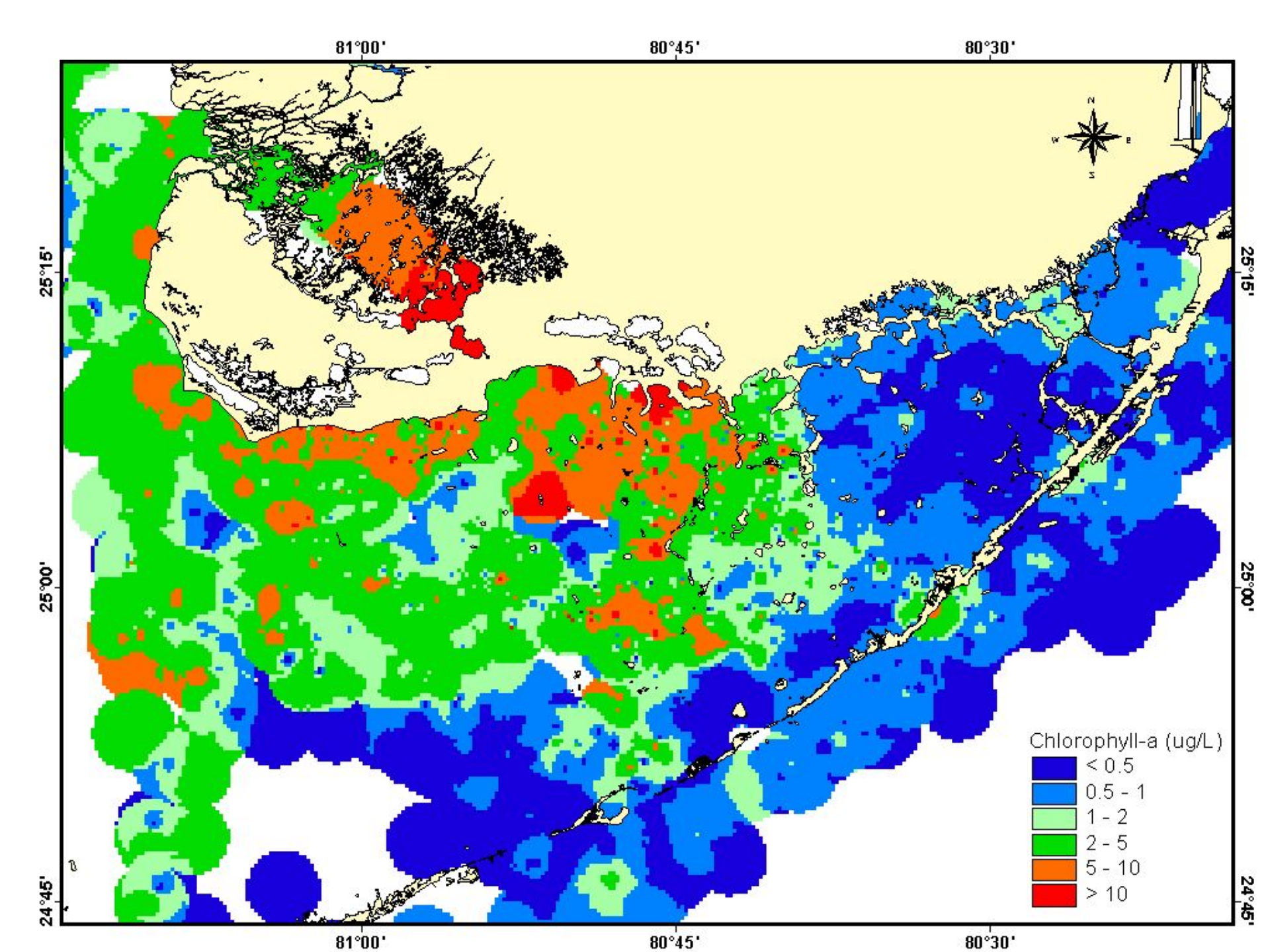


FIGURE 24.1 Map of Florida Bay station clusters (Boyer et al. 1997). Stations as labeled are: eastern Florida Bay (✚), central Florida Bay (■), and western Florida Bay (●). Gauging stations of the water distribution network (✖) include the Taylor Slough (S175 and S332), Taylor Slough bridge (TSB), and C111 coastal basin (S18C). Locations of precipitation gauges


81°00'
80°45'
80°30'
25°15'
25°00'
24°45'
Chlorophyll-a (ug/L)
< 0.5
0.5 - 1
1 - 2
2 - 5
5 - 10
> 10

"Ladies and gentleman, we have clean water in Florida. Don't let any environmentalist tell you otherwise. It is clean; it smells good; it looks good."

~ Barney Bishop

President of Associated Industries of Florida

Associated Industries of Florida
Association of Florida Community Development
CF Industries
Farm Credit of Northwest Florida
Farm Credit of Central Florida
Farm Credit of Florida
Florida Beverage Association
Florida Cattlemen's Association
Florida Chamber of Commerce
Florida Citrus Mutual
Florida Crystals Corp.
Florida Electric Cooperatives Association
Florida Electric Power Coordinating Group Inc.
Environmental Committee (FCG EC)
Florida Engineering Society
Florida Farm Bureau Federation
Florida Fertilizer & Agrichemical Association
Florida Forestry Association
Florida Fruit & Vegetable Association
Florida Gulf Coast Building & Construction Trades Council
Florida Home Builders Association
Florida Land Council
Florida League of Cities
Florida Nursery, Grower & Landscape Association
Florida Pest Management Association
Florida Pulp & Paper Association
Florida Rural Water Association
Florida Water Environment Association Utility Council
Florida Water Quality Coalition Inc.
Floridians for Industry, Jobs and Growth
Gulf Citrus Growers Association
PCS Phosphate, White Springs
Rayonier
South Walton Utility Co.
Sugar Cane Growers Cooperative
The Fertilizer Institute
United Food and Commercial Workers International Union
U.S. Sugar