The Abdus Salam International Centre for Theoretical Physics

2066-5

Workshop and Conference on Biogeochemical Impacts of Climate and Land-Use Changes on Marine Ecosystems

2 - 10 November 2009

Great Rivers and Changing Oceans

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U.S.A

Great Rivers and Changing Oceans

Moyo Ogundipe, Mami Wata, 1999 Acrylic on canvas

Acknowledgments

- NASA SIMBIOS and Ocean Biology Program
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- Maren Voss, Joachim Dippner IOW
- Patricia Yager UGa

What’s in a name?

Iteru - Great River
Indus - River (so Indians are river people?)
Ganges - Stream
Mississippi - Big River
Yangtze - Big or Long River
Euphrates - Sweet Water
(and Mesopotamia - Land between Rivers)
Amazon - from stories of women warriors, original name Maranon after a local fruit)

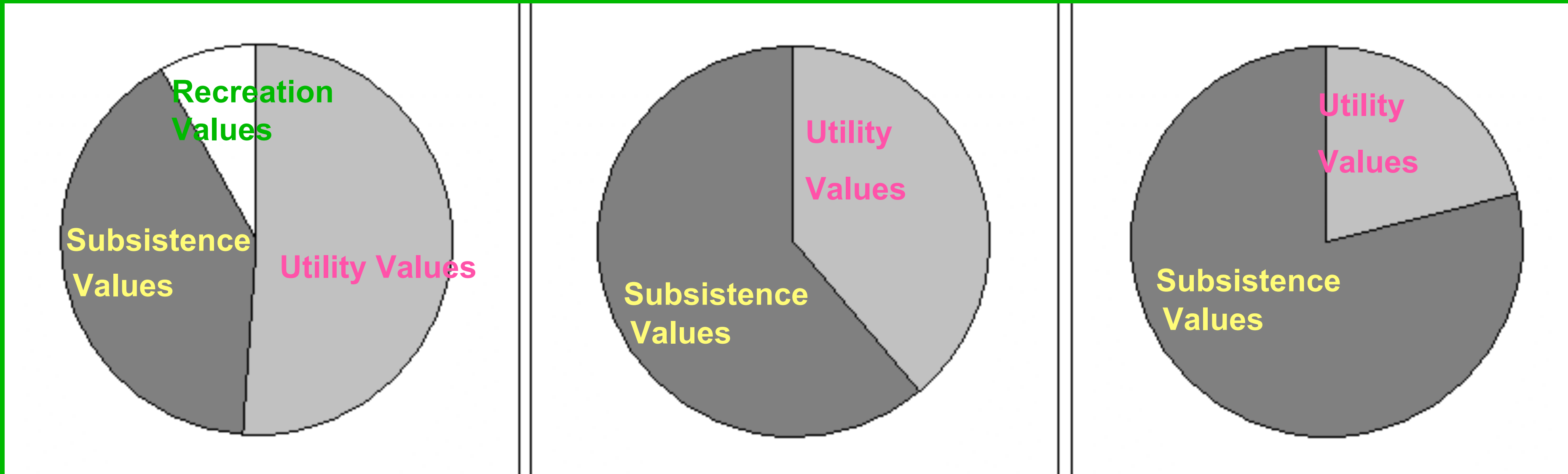
Nile - a greek corruption of nwy meaning water
Original name itwr

Hapi
“The running one”
Predynastic 5500-3100 BC
Son of Horus
Male and female
God of fertility (basket of food)

Ganga symbolizes purity and fertility. Hindu belief holds that bathing in the river on specific occasions absolves you of your sins and helps you attain salvation

Ganga riding on Makara - a vehicle that was half alligator half fish
Beginning of Earth Systems?

Societal Perception of Water Use



Youngest Gen — **18-39**

Middle Generation — **40-59**

Elders — **60<**

Subsistence Uses: drinking, animal and plant habitat, transportation to hunting and fishing, spiritual connection –

“We have always been a salmon people, The salmon come up the river because we are their people and we are grateful for them.

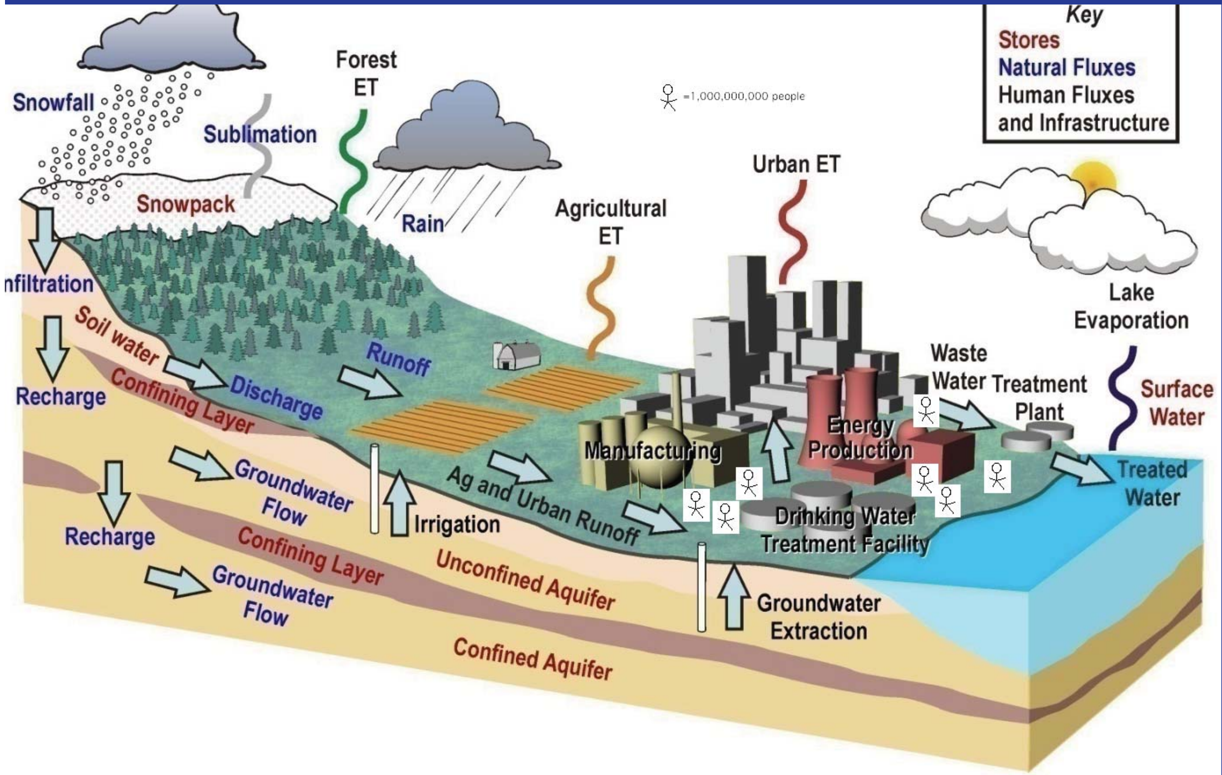
They feed us and we take care of the river.”

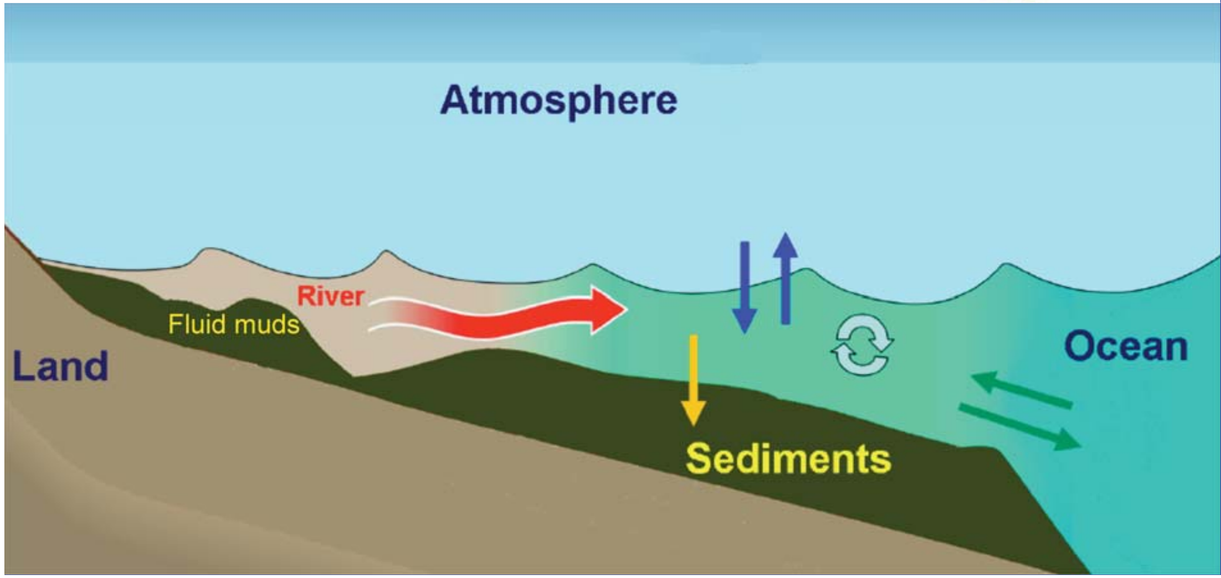
Utility Uses: Transportation, electricity, washing clothes, bathing

Recreational Uses: Swimming, boating, enjoyment/contemplation

Alessa et al. Global Environmental Change 2007

Water Systems Science & Engineering

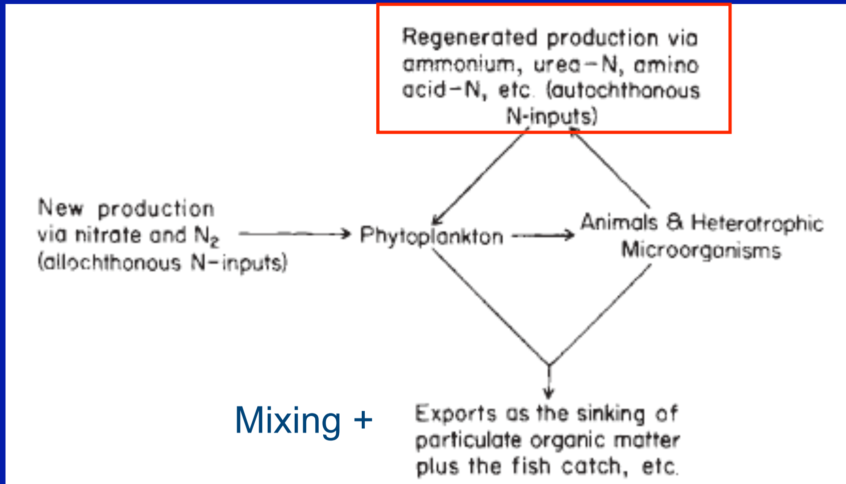




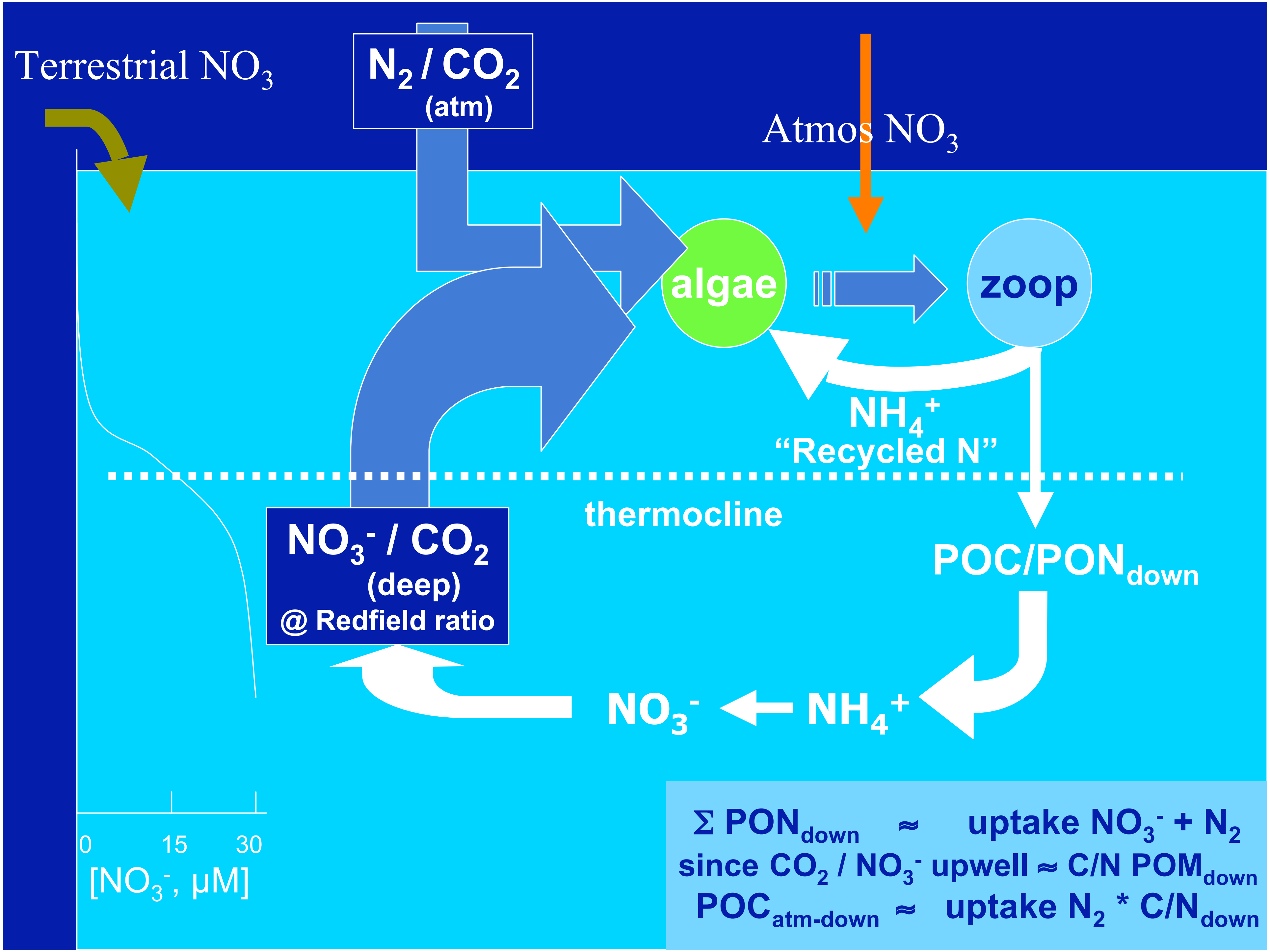
Studying river plumes requires an integrative approach to earth system science - they connect land and water use, and biogeochemical cycling on land, atmosphere, oceans and require knowledge of physical, chemical, biological, and geological oceanography

Need understanding of weathering processes on land and climatic influence of precipitation, feed back loops, economics of land use, sociology of agriculture

New production, *f* ratios, and recycling revisited



- The plume as a closed system
- Definition of *f* ratio = New production/Total production = rate of nitrate incorporation/rate of nitrate + NH_4 + urea + and other organic N
- Recycling r = (1- *f*)/ *f* = number of times a nutrient element is recycled before sinking



Terrestrial NO3
N2 / CO2
(atm)
Atmos NO3
algae
zoop
NH4+
"Recycled N"
thermocline
NO3- / CO2
(deep)
@ Redfield ratio
POC/PONdown
NO3- ← NH4+
0 15 30
[NO3-, µM]
Σ PONdown ≈ uptake NO3- + N2
since CO2 / NO3- upwell ≈ C/N POMdown
POCatm-down ≈ uptake N2 * C/Ndown

Photoproduction of labile N

UV radiation

Humic or fulvic acids
Proteins
Large organic moieties

NH_4^+
DPA
NO_2^-

phytoplankton

bacteria

NH4 regeneration was 6X greater than NH4 uptake (D Bronk, personal communication)

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 106, NO. C8, PAGES 16,807–16,813, AUGUST 15, 2001

Photomineralization of fluorescent dissolved organic matter in the Orinoco River plume: Estimation of ammonium release

Julio M. Morell and Jorge E. Corredor

Morell and Corredor calculated that the time based ammonia release rate in the Orinoco River plume was about 264 μmol m^{-2} d^{-1} This is about 50% the total N demand calculated by Muller-Karger 1989 and needs to be balanced against microbial uptake.

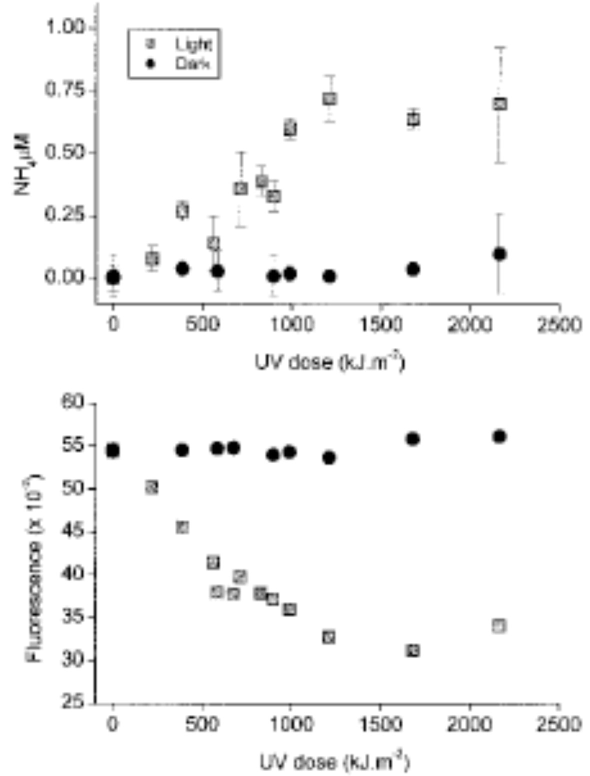
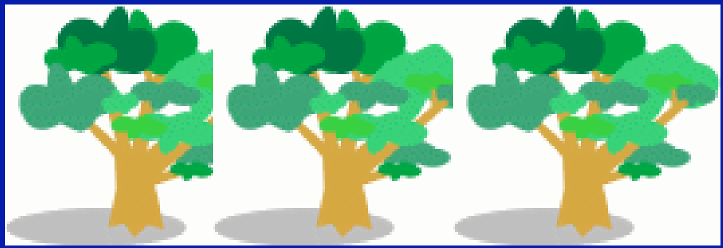


Figure 6. Results of the photoexposure experiment. NH_4 production and concurrent DOM fl reduction in surface water collected from the Gulf of Paria.



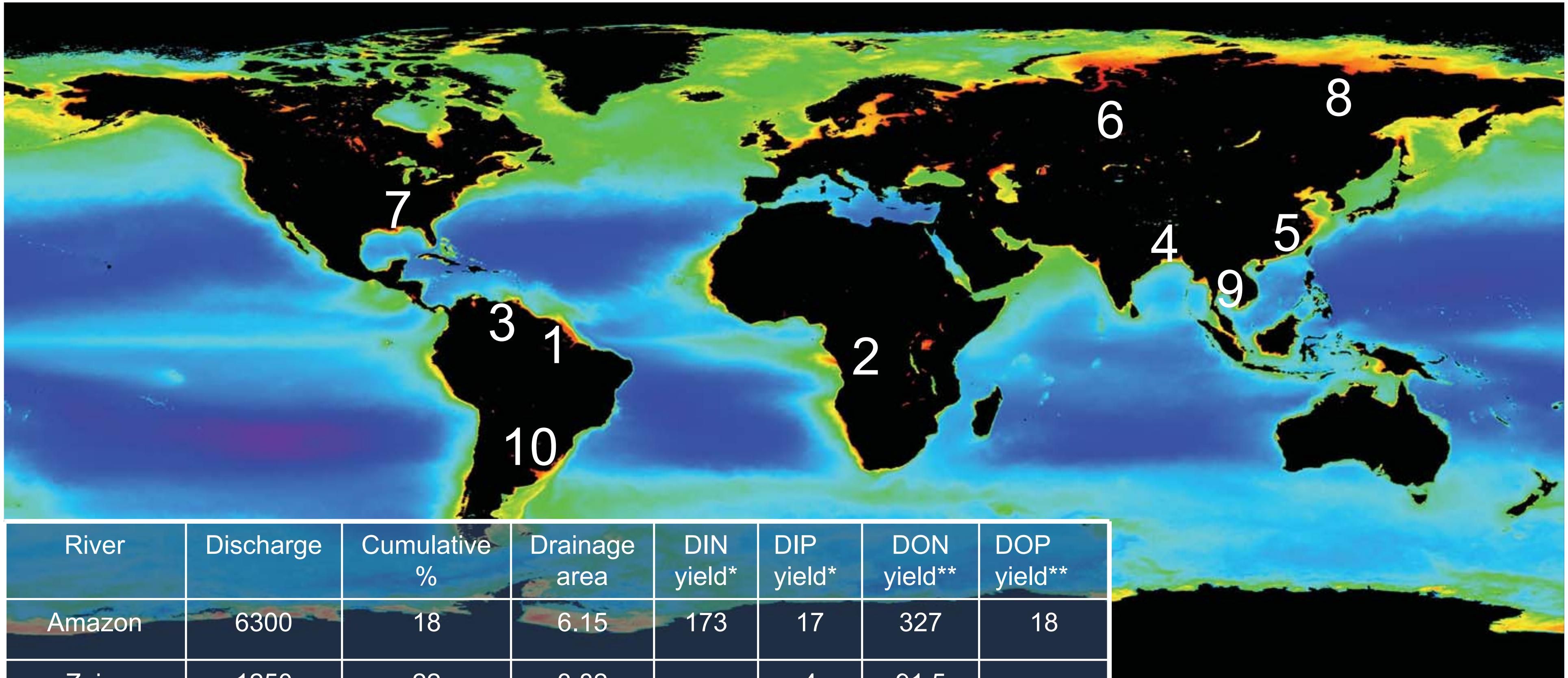
Pre Industrial Modern Post modern

All kinds of nuances

- Photoproduction of labile N from DON
- Autotrophic uptake of DON
- Nitrification to produce nitrate
- UREA

Importance of the bathymetric kopplung

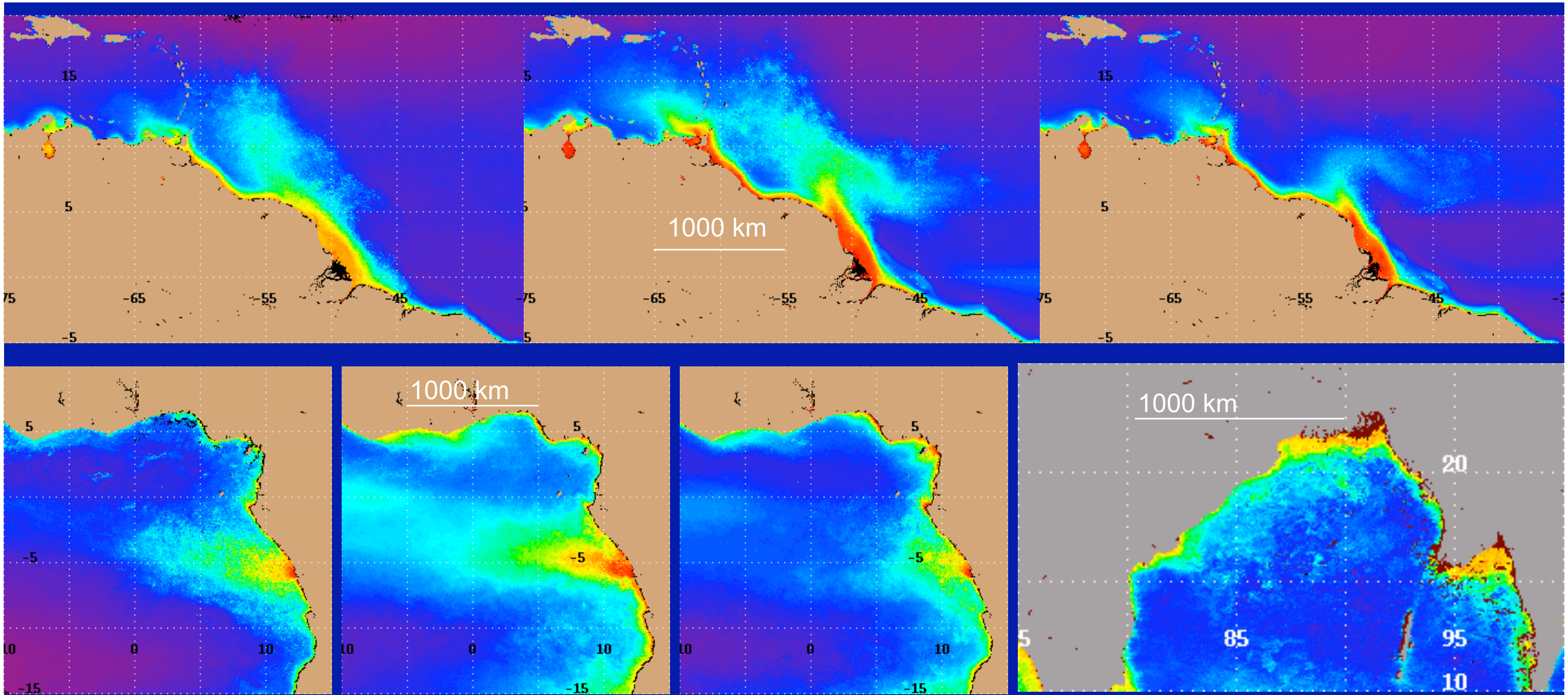
- Role of mobile muds - time/space buffers?
- Denitrification
- Fe/P interaction in anoxic sediments - source of SRP and labile Fe?

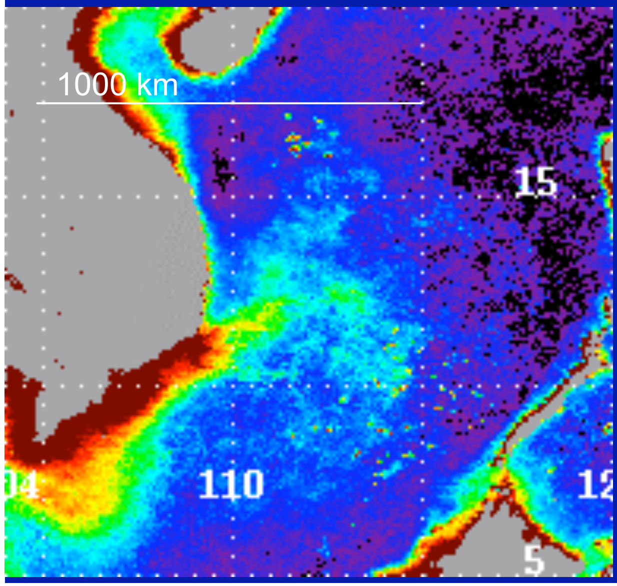


River	Discharge	Cumulative %	Drainage area	DIN yield*	DIP yield*	DON yield**	DOP yield**
Amazon	6300	18	6.15	173	17	327	18
Zaire	1250	22	3.82		4	91.5	
Orinoco	1200	25	0.99		4	313	17
Ganges-Brahmaputra	970	28	1.48		25	164	
Yangtze	900	31	1.94	326	16		
Yenisey	630	33	2.58		1		
Mississippi	530	34	3.27	256	7	54	3
Lena	510	36	2.49	21	2	58	3
Mekong	470	37	0.79				
Parana	470	38	2.83	44	2	61	
All others	21168	100					

* From Dumont et al 2005
** From NEWS Model (Harrison et al 2005)

Yields in Kg N or P/km^2/yr





Big plumes (twice the size of Texas/ size of the Gulf of Mexico) often extending more than 1000 of km offshore and often lasting many months

What sustains these plumes?

What are the biogeochemical consequences?

THE WALL STREET JOURNAL.

FRIDAY, SEPTEMBER 28, 2007 - VOL. CCL NO. 75 ★★★★ $1.50

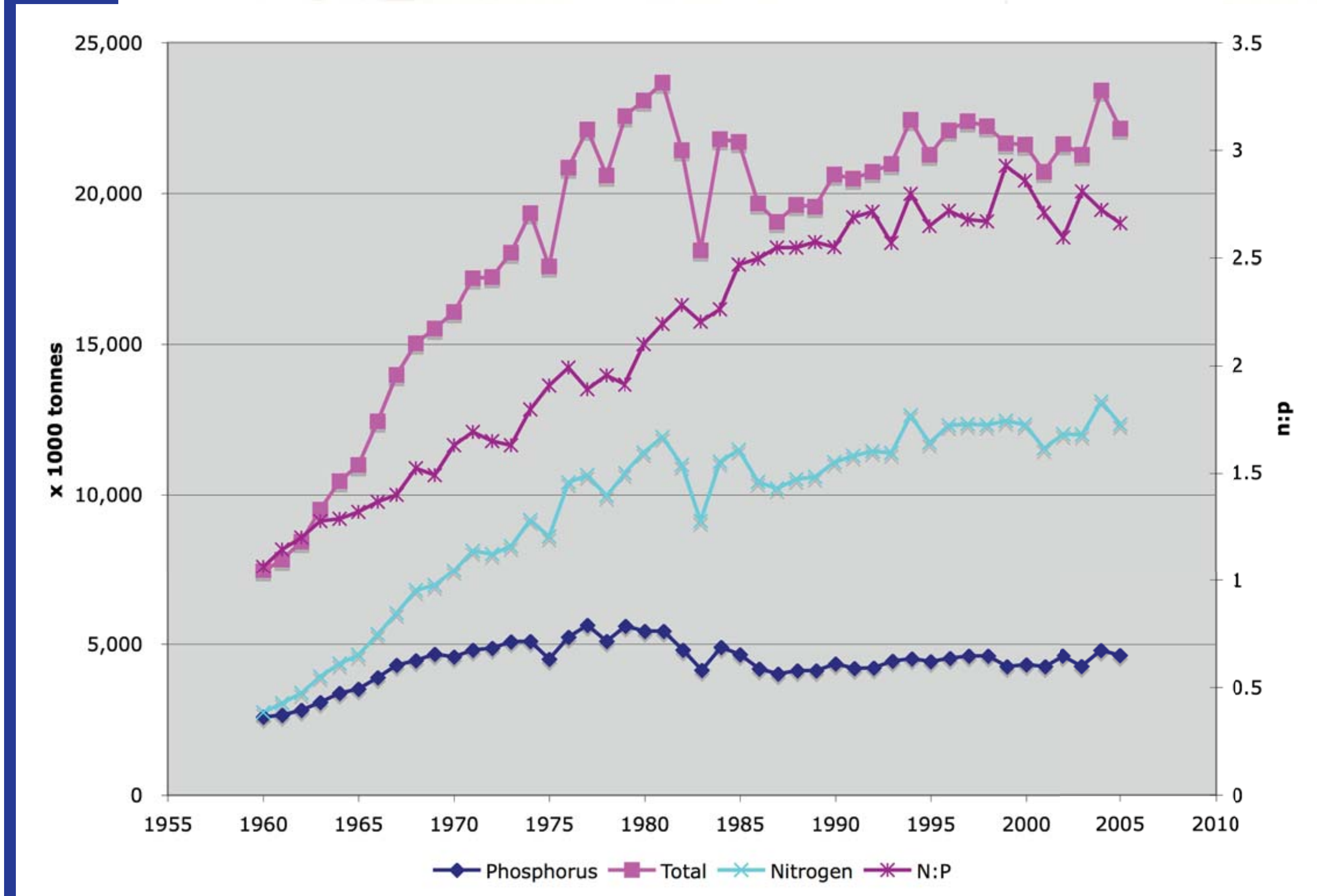
4.79 0.3% NASDAQ 2709.59 ▲0.4% NIKKEI 16832.22 ▲2.4% DJ STOXX 50 3822.40 ▲0.7% 10-YR TREAS ▲13/32, yield 4.571% OIL $82.88 ▲$2.58 GOLD $732.70 ▲$4.10 EURO $1.4147 YEN 115.65

Historic Surge In Grain Prices Roils Markets

By Scott Kilman

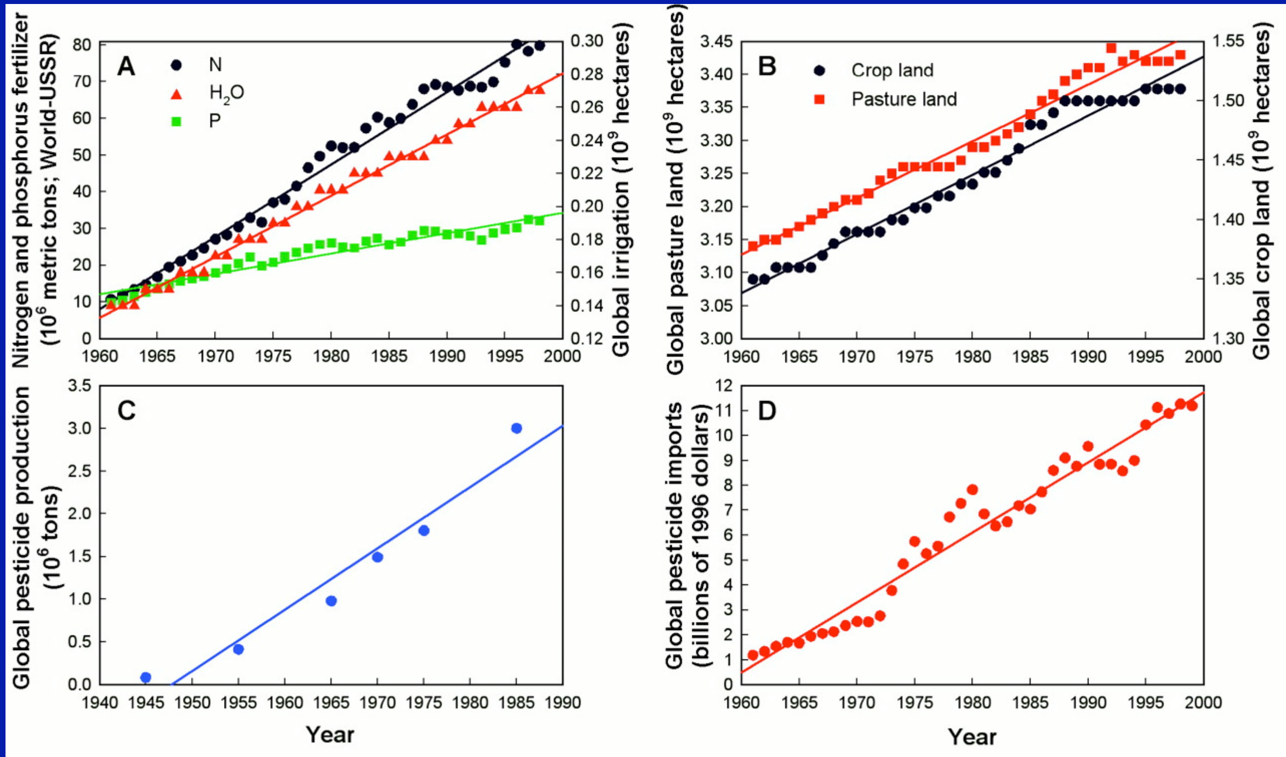
Rising prices and surging demand for the crops that supply half of the world's calories are producing the biggest changes in global food markets in 30 years, altering the economic landscape for everyone from consumers and farmers to corporate giants and the world's poor.

"The days of cheap grain are gone," says Dan Basse, president of AgResource Co., a Chicago commodity fore-



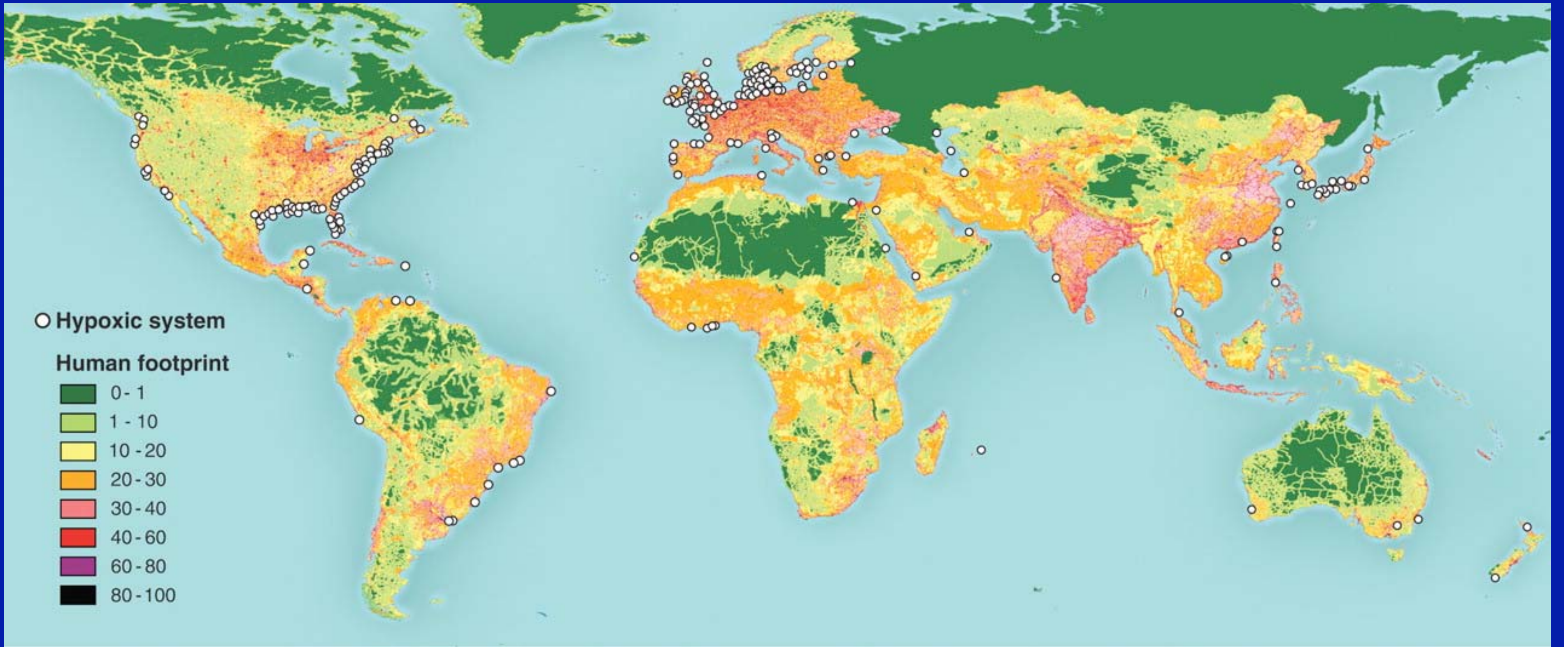
Increased global demand for animal protein, ethanol, speculation

Trends in annual rates of application of nitrogenous fertilizer (N) expressed as mass of N, and of phosphate fertilizer (P) expressed as mass of P2O5, for all nations of the world except the former USSR (18, 19), and trends in global total area of irrigated crop land (H2O) (18). (B) Trends in global total area of land in pasture or crops (18). (C) Trend in global pesticide production rates, measured as millions of metric tons per year (30). (D) Trend in expenditures on pesticide imports (18) summed across all nations of the world, transformed to constant 1996 U.S. dollars. All trends are as dependent on global population and GDP as on time (Table 1).



D. Tilman et al., Science 292, 281 -284 (2001)

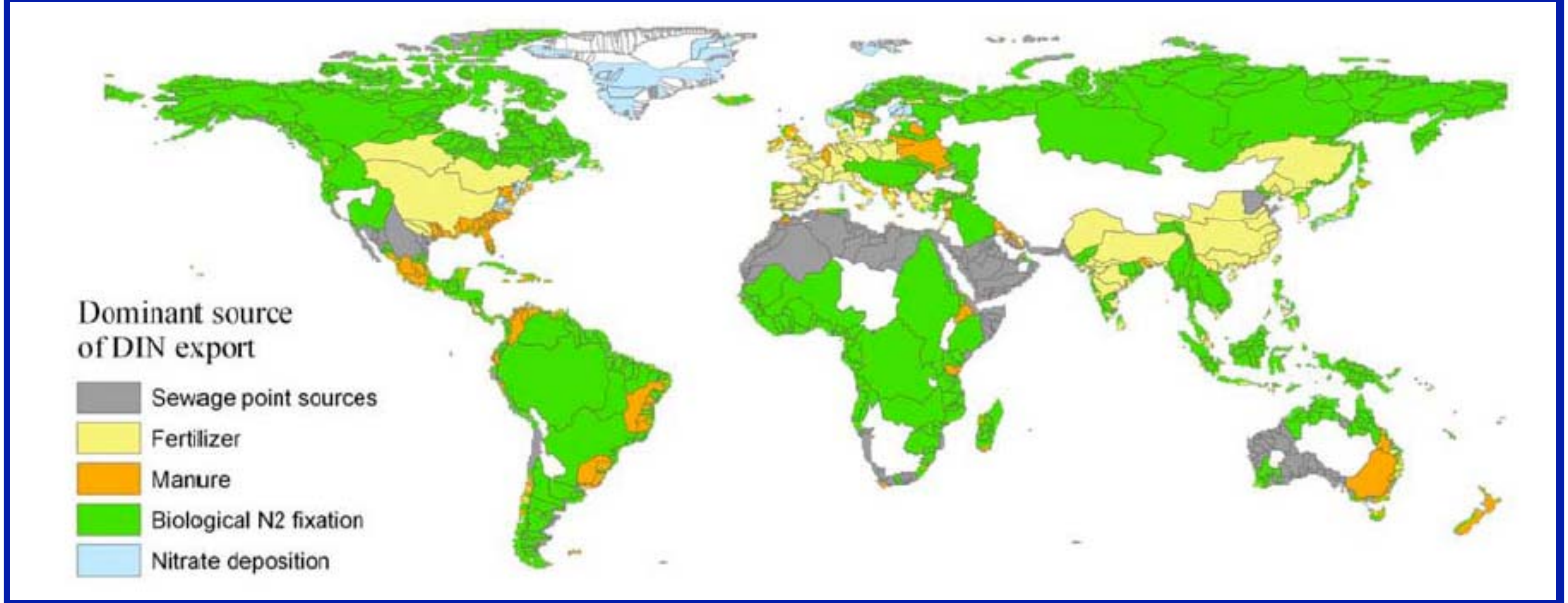
Global distribution of 400-plus systems that have scientifically reported accounts of being eutrophication-associated dead zones



R. J. Diaz et al., Science 321, 926 -929 (2008)

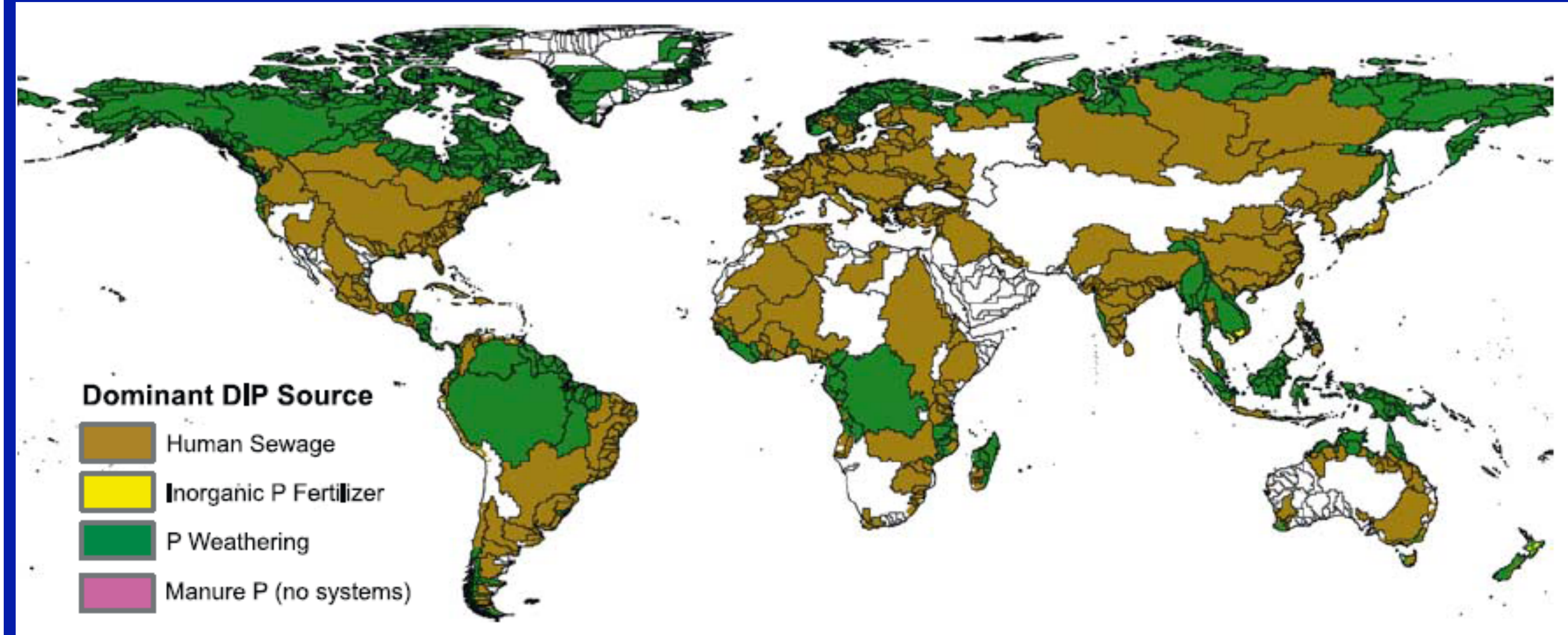
Published by AAAS

NEWS-DIN-predicted dominant sources of DIN export



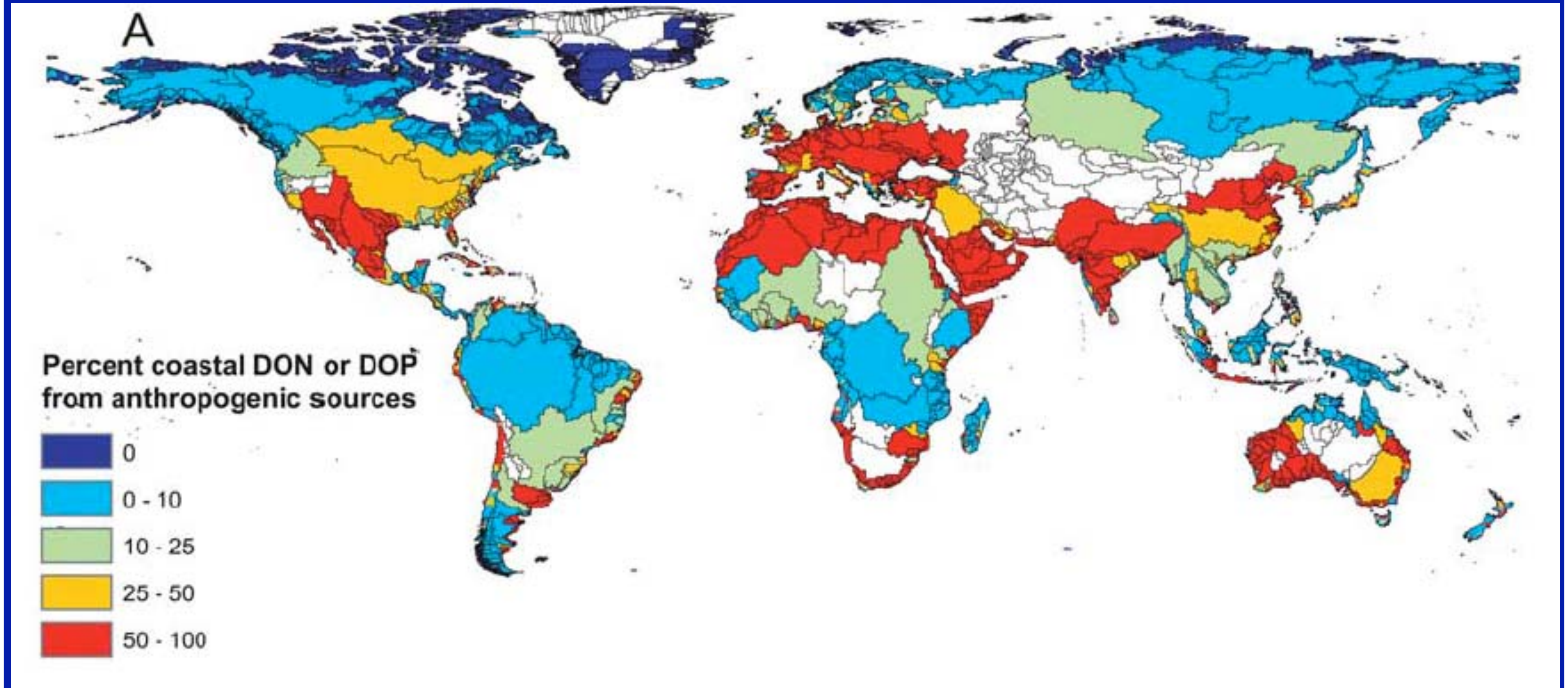
Dumont et al 2005 GBC

Dominant sources of DIP



Harrison et al 2005 GBC

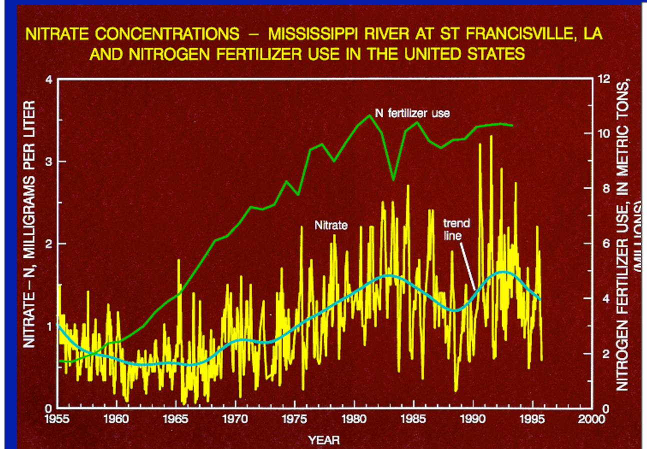
DON/DOP – Percent from Anthropogenic Sources

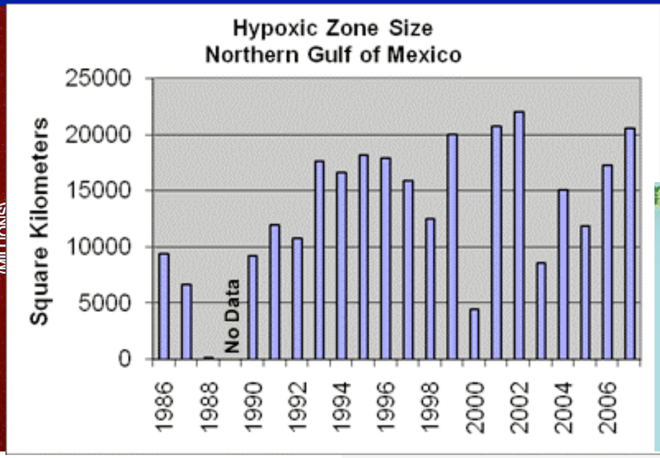


Harrison et al 2005 GBC

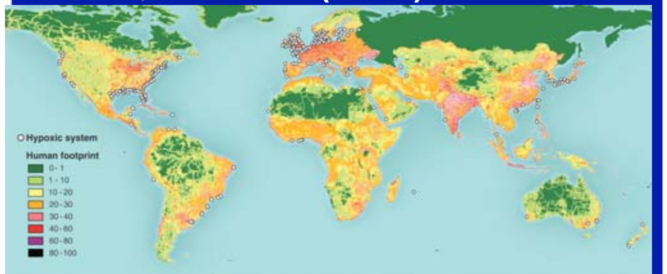
Future changes

- Anthropogenic loading (where does urea from fertilizers fit in the new production paradigm?)
- Climate related changes to the hydrological cycle





R. J. Diaz et al., Science 321, 926 -929 (2008)



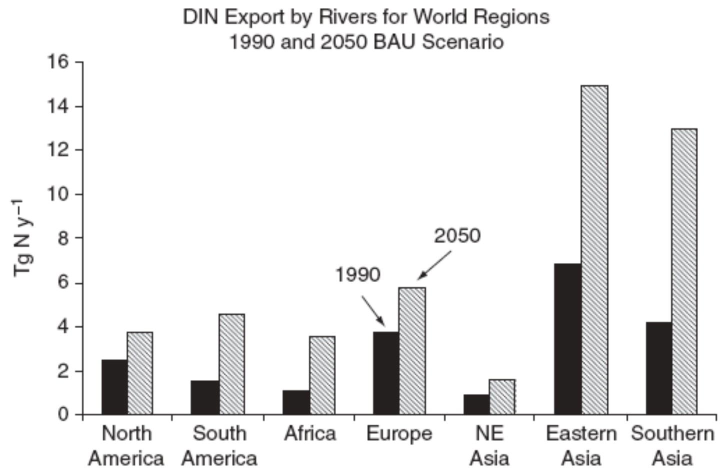
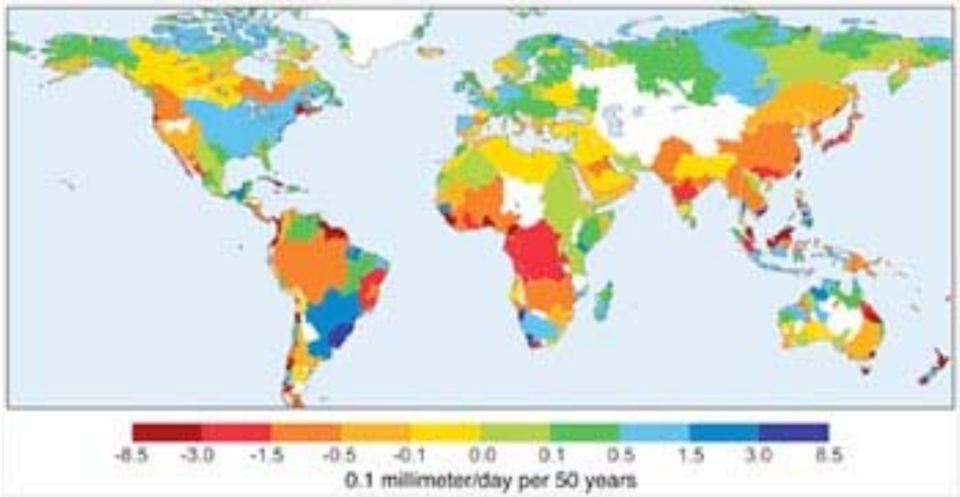


Figure 9.8 Predicted increases in DIN export to coastal systems between the years 1990 and 2050 under a business-as-usual (BAU) scenario. Modified from Kroeze and Seitzinger (1998).



Dai et al 2009 Journal of Climate

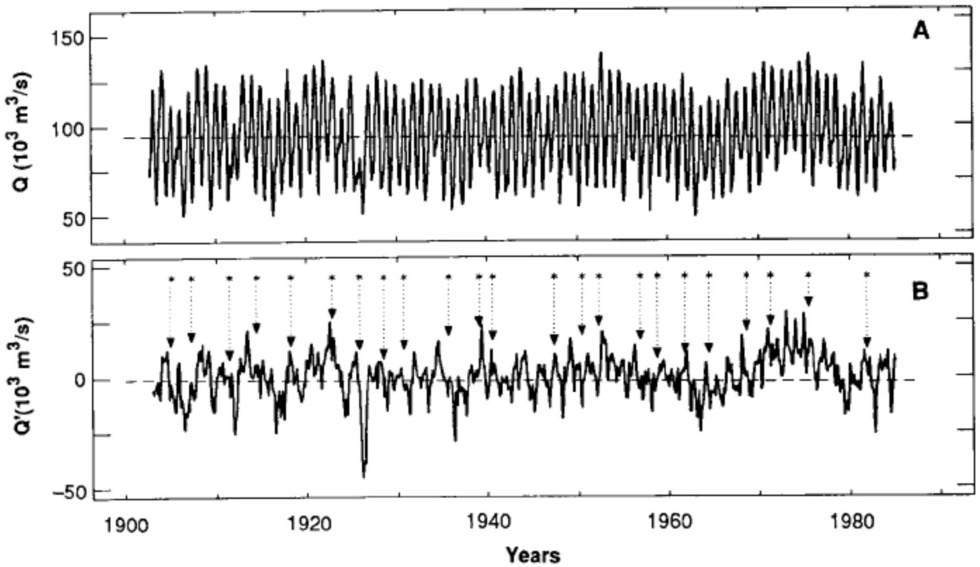


Fig. 2. Discharge of the Amazon River at Manacapurú; (**A**) discharge time series, 1903 to 1985; (**B**) deseasonalized Q′ hydrograph, 1903 to 1985. Arrows indicate occurrence of ENSO events.

Amazon River Discharge and Climate Variability: 1903-1985
Richey, Jeffrey E; Nobre, Carlos; Deser, Clara
Science; Oct 6, 1989; 246, 4926; Research Library
pg. 101

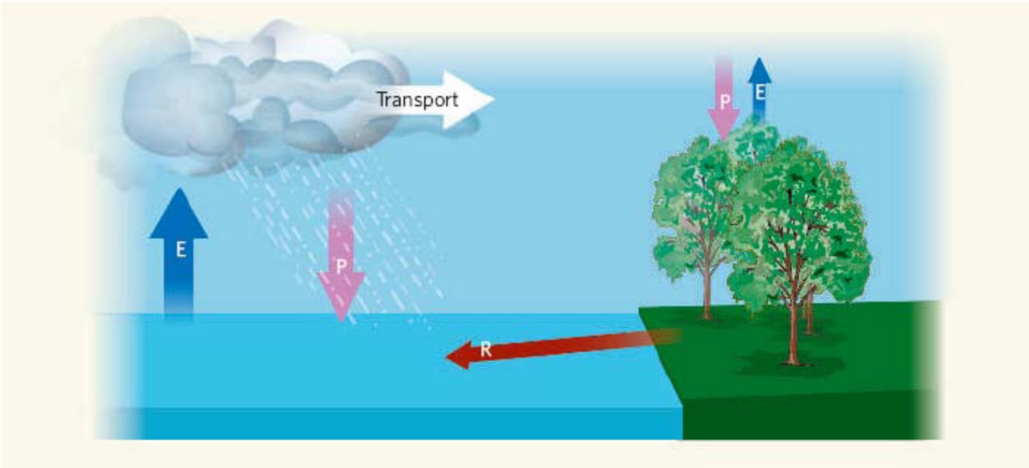


Figure 1 | Plants, CO_2 and the global water cycle. The balance between precipitation (P) and evaporation (E) over land determines the surface runoff (R), which returns water from the continents to the oceans. Plant photosynthesis plays an integral role in the global water cycle, by mediating the transfer of water from the land surface to the atmosphere. Elevated CO_2 can lead to closure of leaf stomata, which reduces leaf water loss and thereby decreases overall continental evaporation. Gedney *et al.*[2] show that this process, initiated by increased atmospheric CO_2, can account for the increases in surface runoff observed over the past century.

TABLE 1

Nutrients concentrations in some major unpolluted rivers ($\mu g\ l^{-1}$)

	$P\text{-}PO_4$	TDP	$N\text{-}NO_2$	$N\text{-}NH_4$	N_K	DON	$N\text{-}NO_3$	TDN	DOC	TOC
Tropical rivers										
Sumatra-Borneo	7						175			
Niger	13		1.4	14			100			
Zaire	24	60	3	7			90			8800
Orinoco	6.2						90			
Zambezi	10									
Purari	1.5			40			40			
Mekong							240			
Solimoes	15	25	1	(40)		150	50	(240)	2000	
Negro	6	8	1	(25)		300	25	(350)	6300	8360
Amazon	12	(20)	1	(35)		200	40	275	(5000)	(10000)
Desert rivers										
Orange	9.1							41		

From Meybeck 1982

River	P	N	N:P
Amazon	20	275	13.75
Orinoco	6.2	90	14.5
Congo	24	90	3.75

Devol (1991) found that Amazon alone is responsible for 30% of the global riverine supply of SRP

Amazon Nutrients

DeMaster and Pope 1996

Subramaniam et al 2008 PNAS

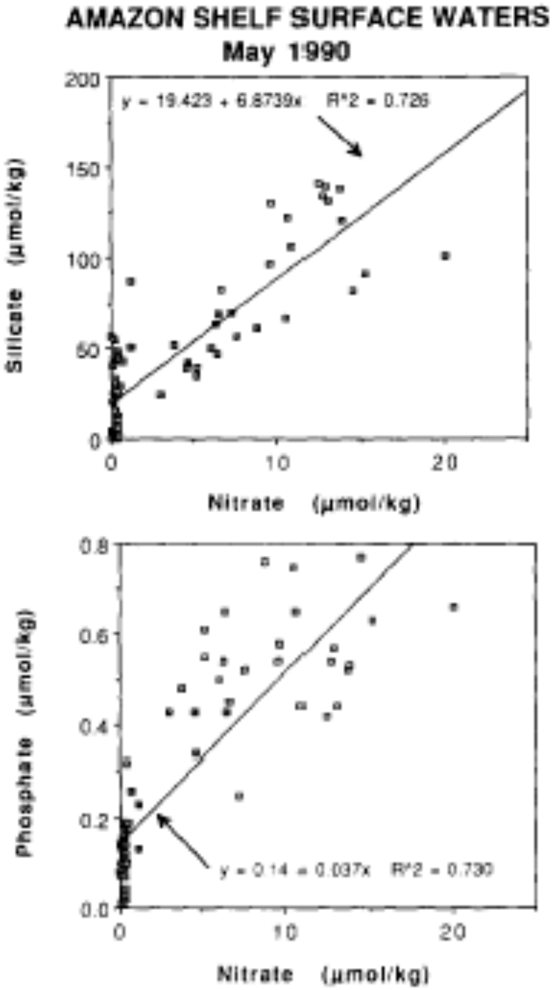
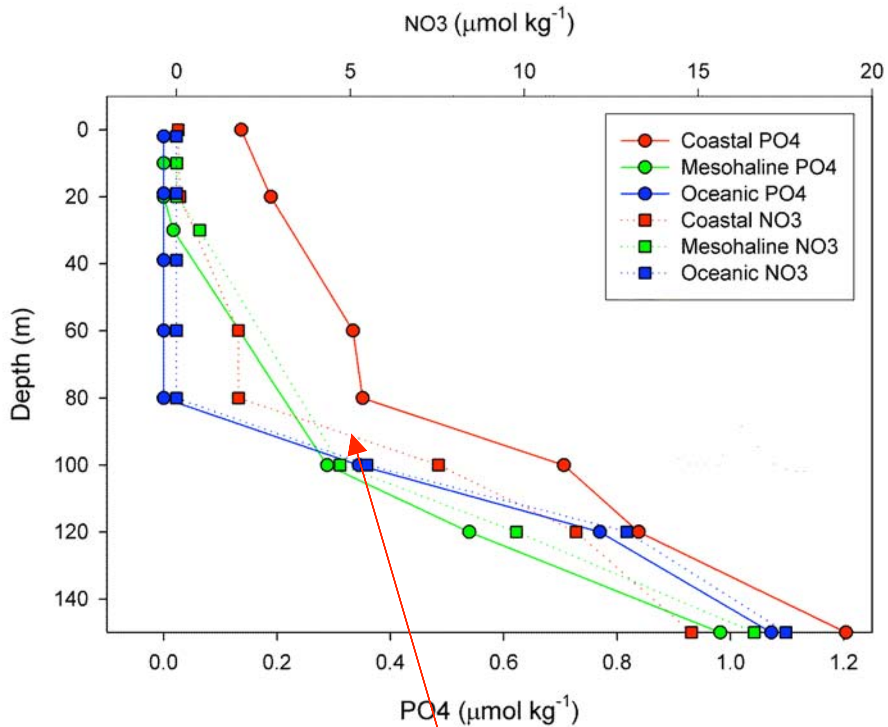


Fig. 7. Phosphate and silicate concentrations in Amazon shelf surface waters plotted as a function of nitrate concentration for AMASSEDS Cruise III (May 1990; high river discharge). In all four of the cruises the phosphate and the silicate intercepts (i.e. zero nitrate concentration) were positive and significantly different from zero indicating that the algae on the shelf are primarily limited by nitrate and not phosphate or silicate.



Buoyancy effect

Source of P/ Si

DeMaster and Aller 2001

Table 17.2 Biogeochemical Cycling of Si, P, and N on the Amazon Shelf

	External Nutrient Supply* ($x10^8$ mol d^{-1})	% of Ext. Nutrient Supply to Shelf from Rivers	Gross Production ($x10^8$ mol d^{-1})	% of Gross Production from Recycling	% of Ext. Nutrient Supply that is Exported Offshore**
Si	32	66%	27	0%	91.97%
P	0.7-0.8	28%	1.7	56%	100%
N	10-12	20-50%	27	60%	50%

* External nutrient supply is defined as the supply of dissolved nutrient that is biologically available for shelf plankton. The sources of these nutrients are from the river and upwelled offshore waters, nitrogen fixation regenerated terrestrial organic matter, and absorbed material. The flux of P from desorption is considered part of this external supply, whereas the recycling of estuarine biogenic material (via microbial degradation or dissolution) is not.

** This export includes only the dissolved species and biogenic material that re or can be (following degradation/dissolution) available to marine biota. Less than 4% of the dissolved bioavailable N supplied to the shelf is buried as marine organic matter. However, nearly all of marine PON reaching the seabed is converted to molecular nitrogen, which cannot be utilized by most oceanic plankton. Consequently, only 50% of bioavailble, dissolved, externally supplied N to the shelf is exported in a form that is useable by marine biota.

Tricho can use DOP but P limitation may still occur

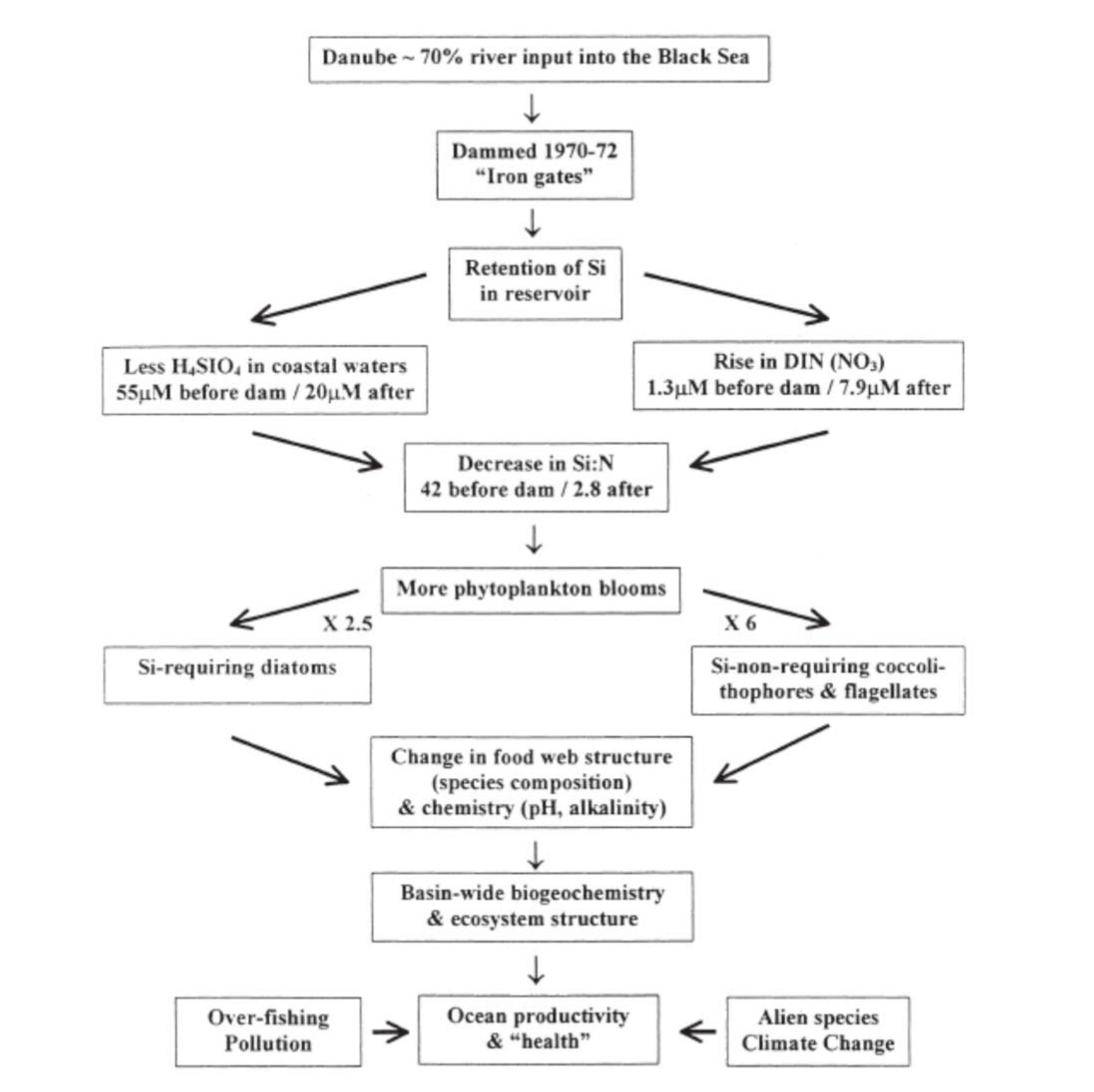
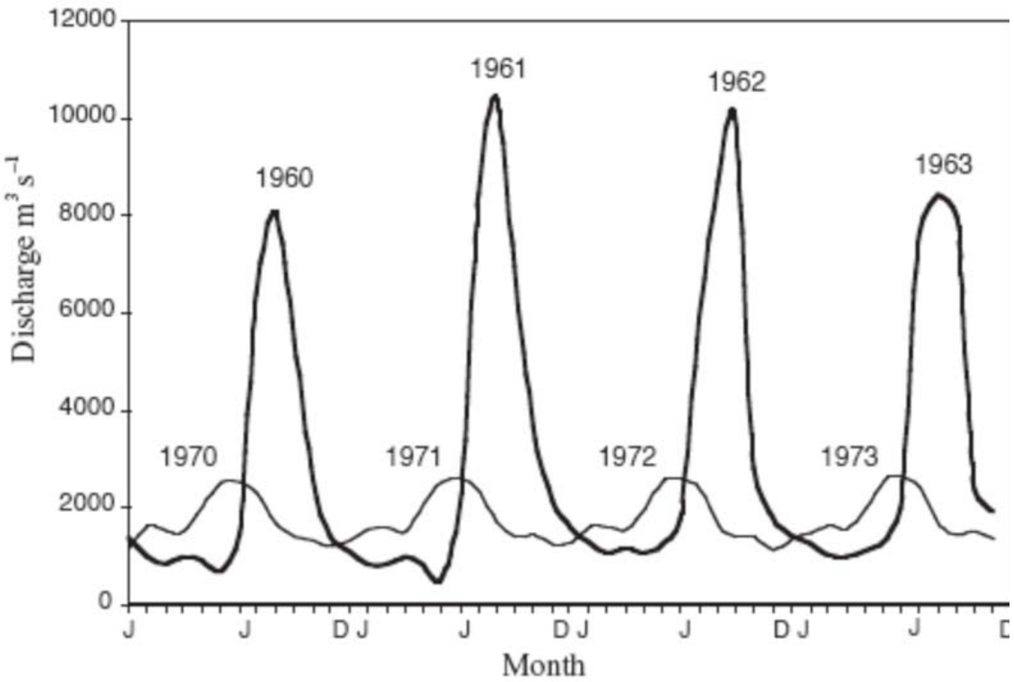
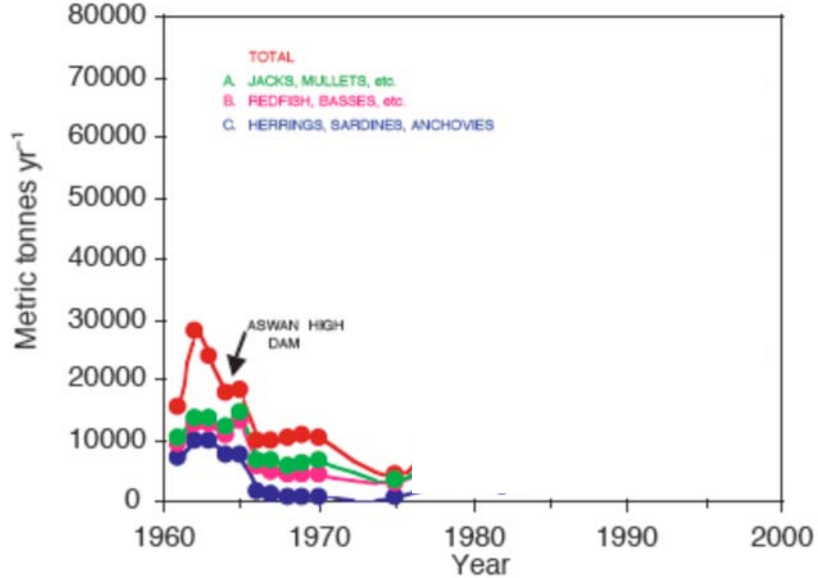

Danube ~ 70% river input into the Black Sea
Dammed 1970-72 "Iron gates"
Retention of Si in reservoir
Less H_4SIO_4 in coastal waters 55μM before dam / 20μM after
Rise in DIN (NO_3) 1.3μM before dam / 7.9μM after
Decrease in Si:N 42 before dam / 2.8 after
More phytoplankton blooms
X 2.5
X 6
Si-requiring diatoms
Si-non-requiring coccoli-thophores & flagellates
Change in food web structure (species composition) & chemistry (pH, alkalinity)
Basin-wide biogeochemistry & ecosystem structure
Over-fishing Pollution
Ocean productivity & "health"
Alien species Climate Change

Figure 1. Discharge of the Nile at Aswan before and after closure of the High Dam in 1965 (Data from 14).



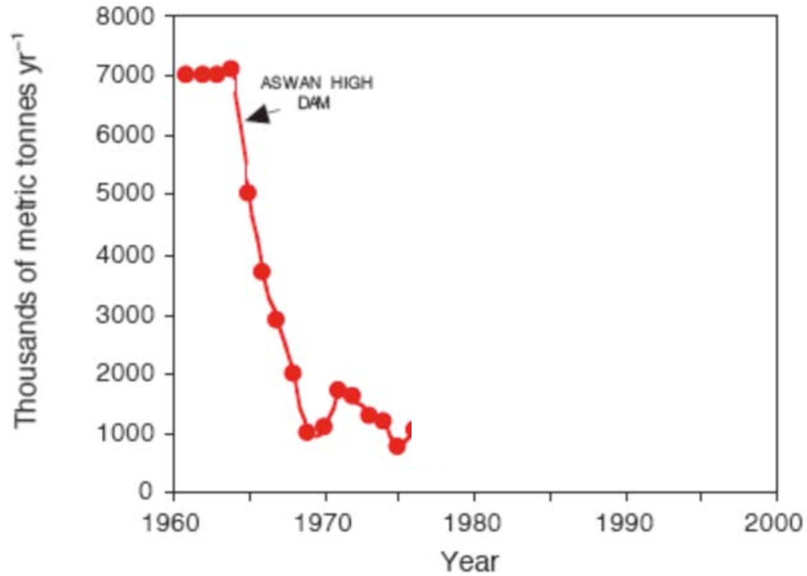
Egypt-Mediterranean fisheries landings

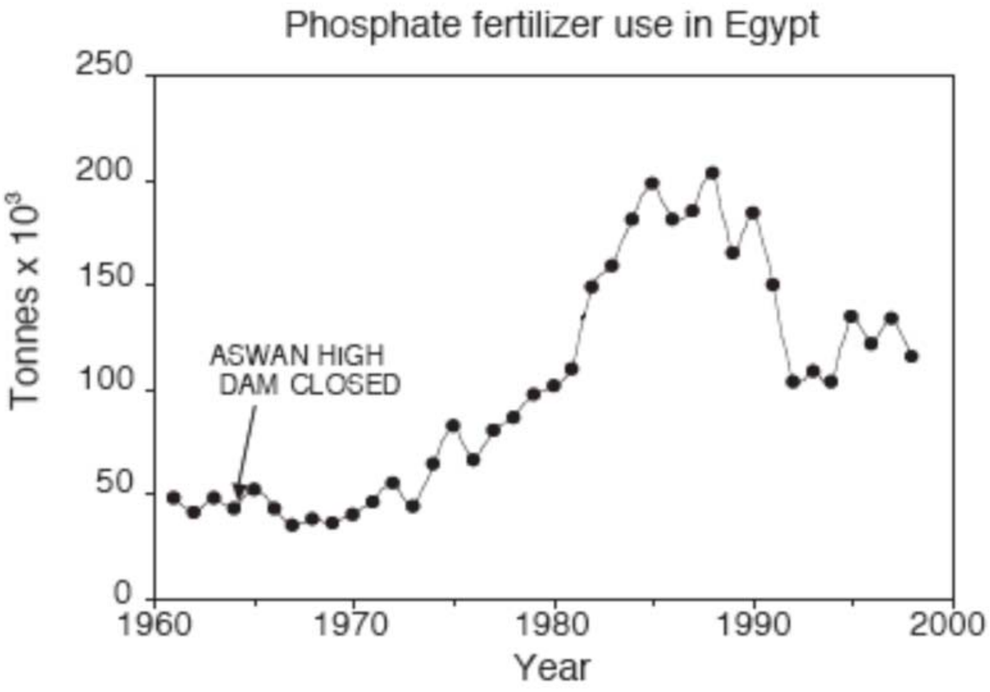


Changes in fisheries landings
Decrease after dam due to reduced productivity of the delta

Increase due to fertilizers
OR
Increase due to better catch per effort, more powerful ships, efficient gear

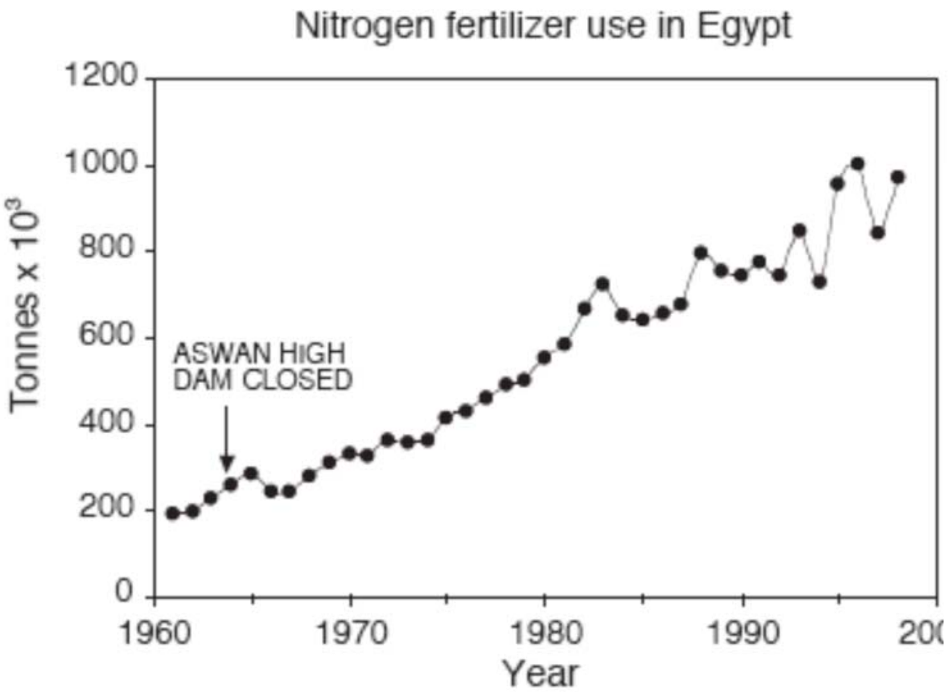
Shrimp landings

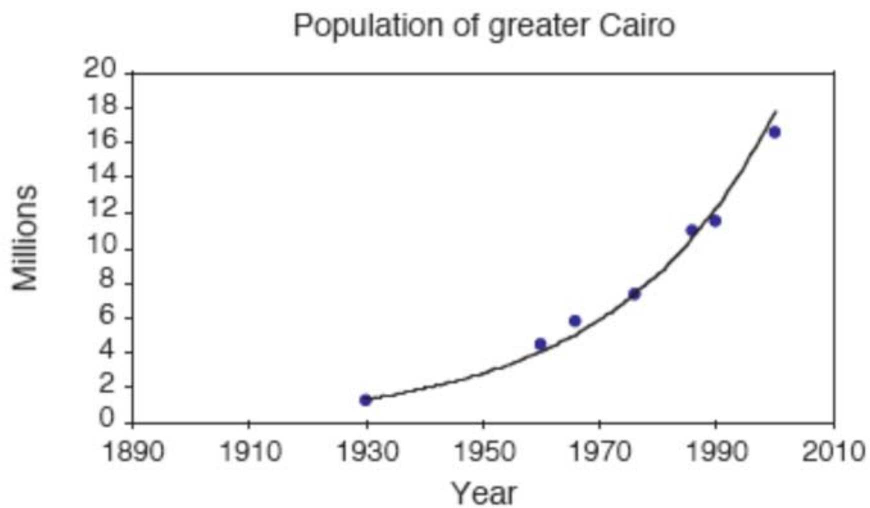




		10^3 tonnes yr^{-1} P	N
The Nile			
Pre-Aswan High Dam			
Dissolved		3.2	6.7
On sediments		4–8	?
	Total	7–11	6.7
Post-High Dam			
Dissolved	0.03	0.2	
On sediment		0	0
	Total	0.03	0.2
Human Waste			
Total Generated in Cairo and Alexandria			
1965		4.4	21
1985		8.9	55
1995		12.6	87
Potential N and P in wastewater discharge, Cairo and Alexandria[1]			
1965		1.1	5
1985		3.6	22
1995		9.5	65
Potential N and P in wastewater discharge, Total urban population[2]			
1965		2.4	12
1985		6.7	41
1995		15.8	108

[1]Assuming that the population connected to the sewers was 25% in 1965, 40% in 1985, and 75% in 1995 (52). The 1965 estimate is very uncertain.
[2]Extrapolated from Cairo and Alexandria assuming that the accounted for 45% of the total urban population in 1965, 54% in 1985, and 65%





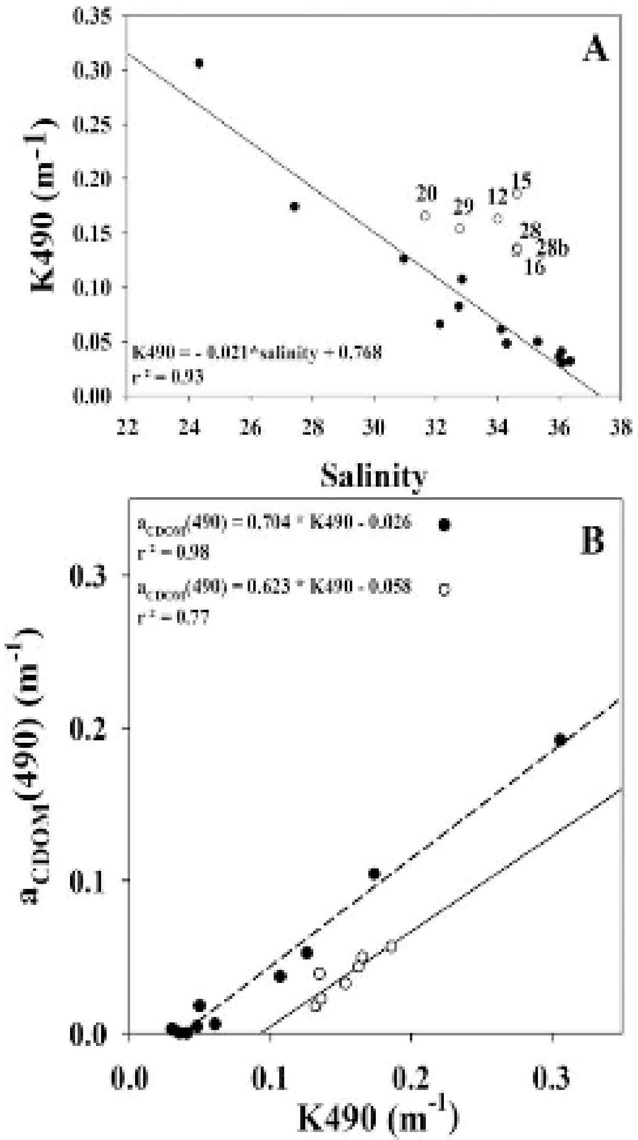


Figure 5. (a) K490 to salinity dependence and (b) $a_{CDOM}(490)$ to K490 dependence in the WTNA during May 2003. Solid circles represent the Amazon River plume (Transect A) and offshore waters (Region A and Region B without intense diatoms bloom). Open circles represent stations with intense diatoms bloom (Region B). Numbers refer to stations. Lines represent linear regressions with parameters reported in figure and statistics in Table 1.

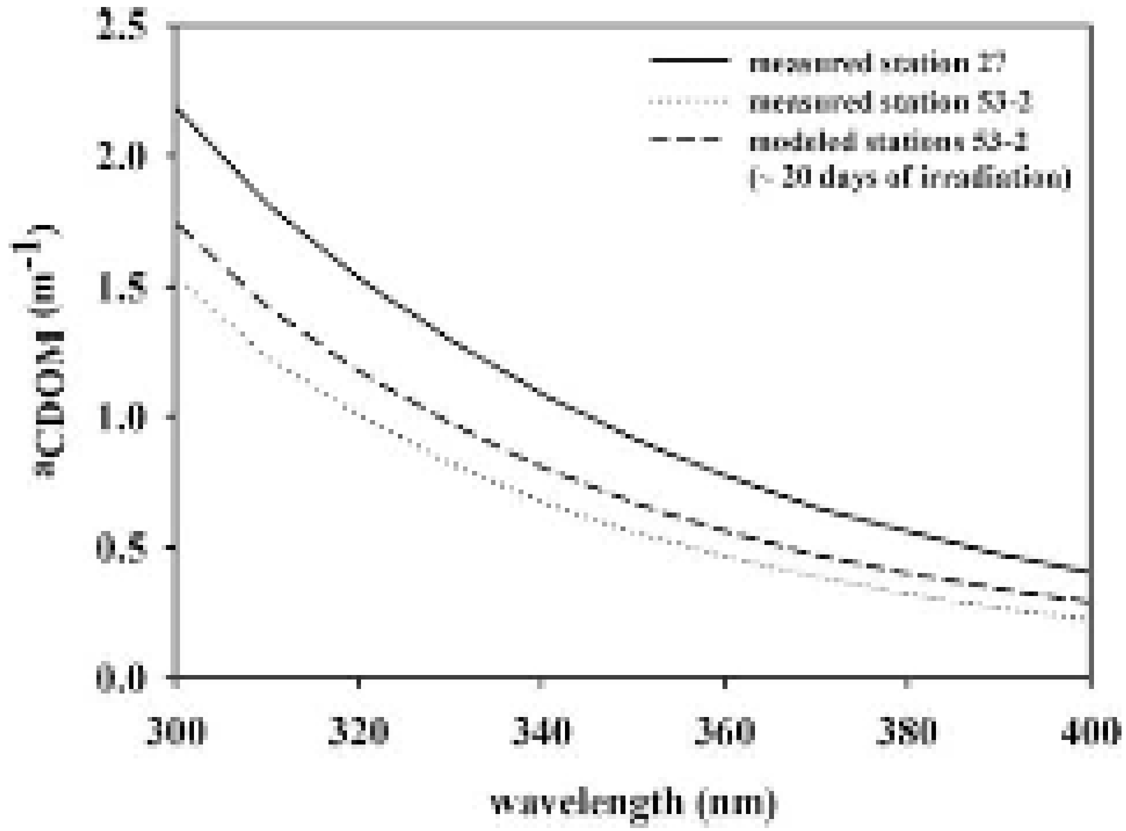
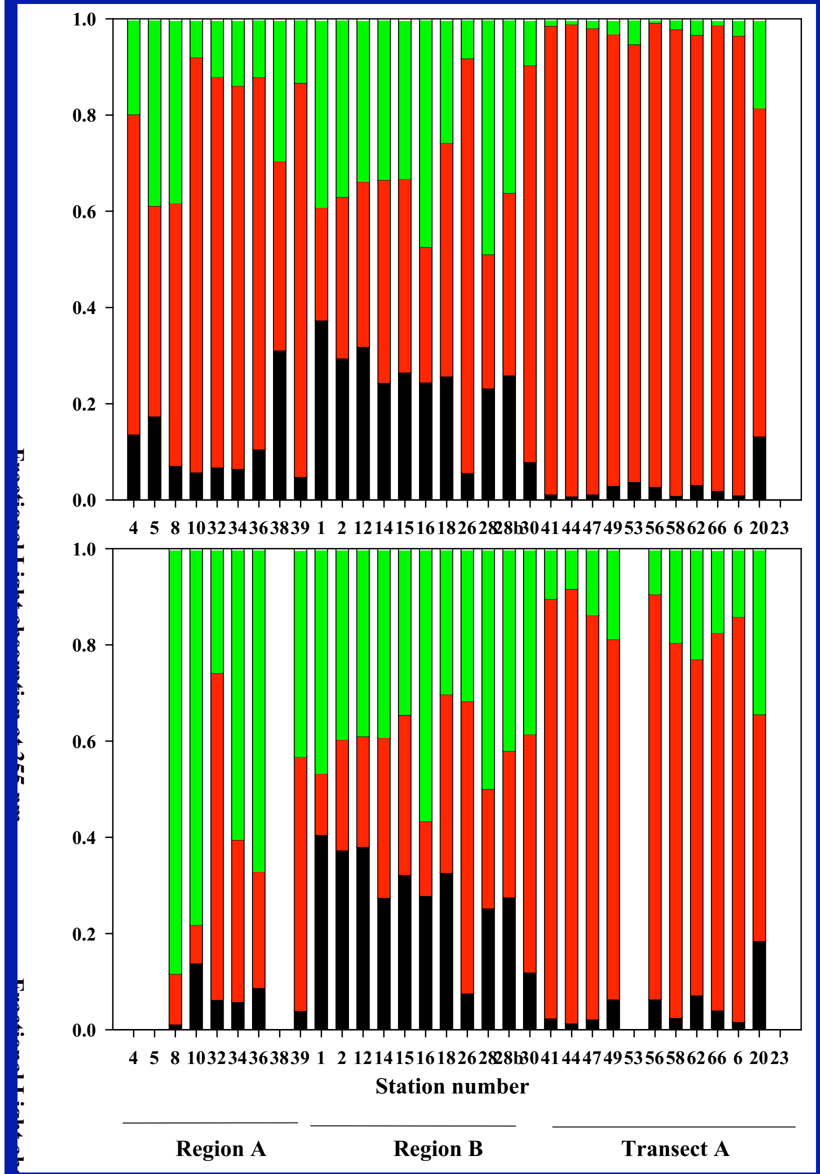


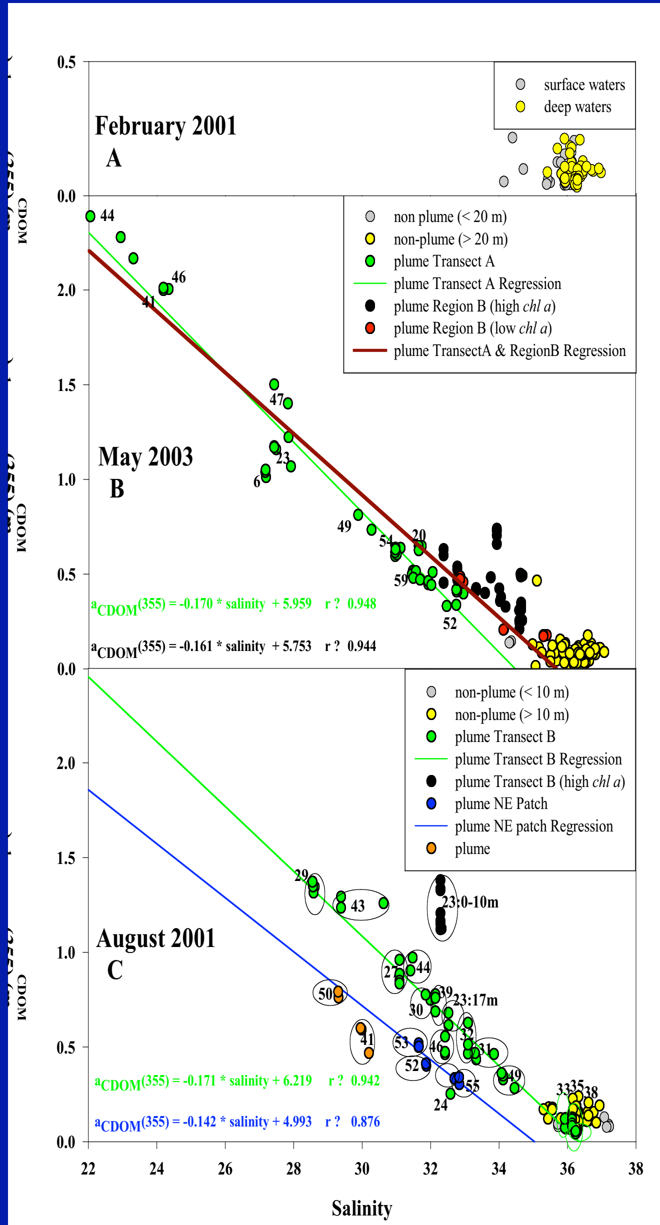
Figure 10. Measured (stations 27 and 53-2) and modeled (after 20 days of light exposure) a_{CDOM} during August 2001 in the WTNA.

Del Vecchio, R. and A. Subramaniam (2004) Influence of the Amazon River on the surface optical properties of the Western Tropical North Atlantic Ocean. Journal of Geophysical Research. 109, C11001, doi:10.1029/2004JC002503

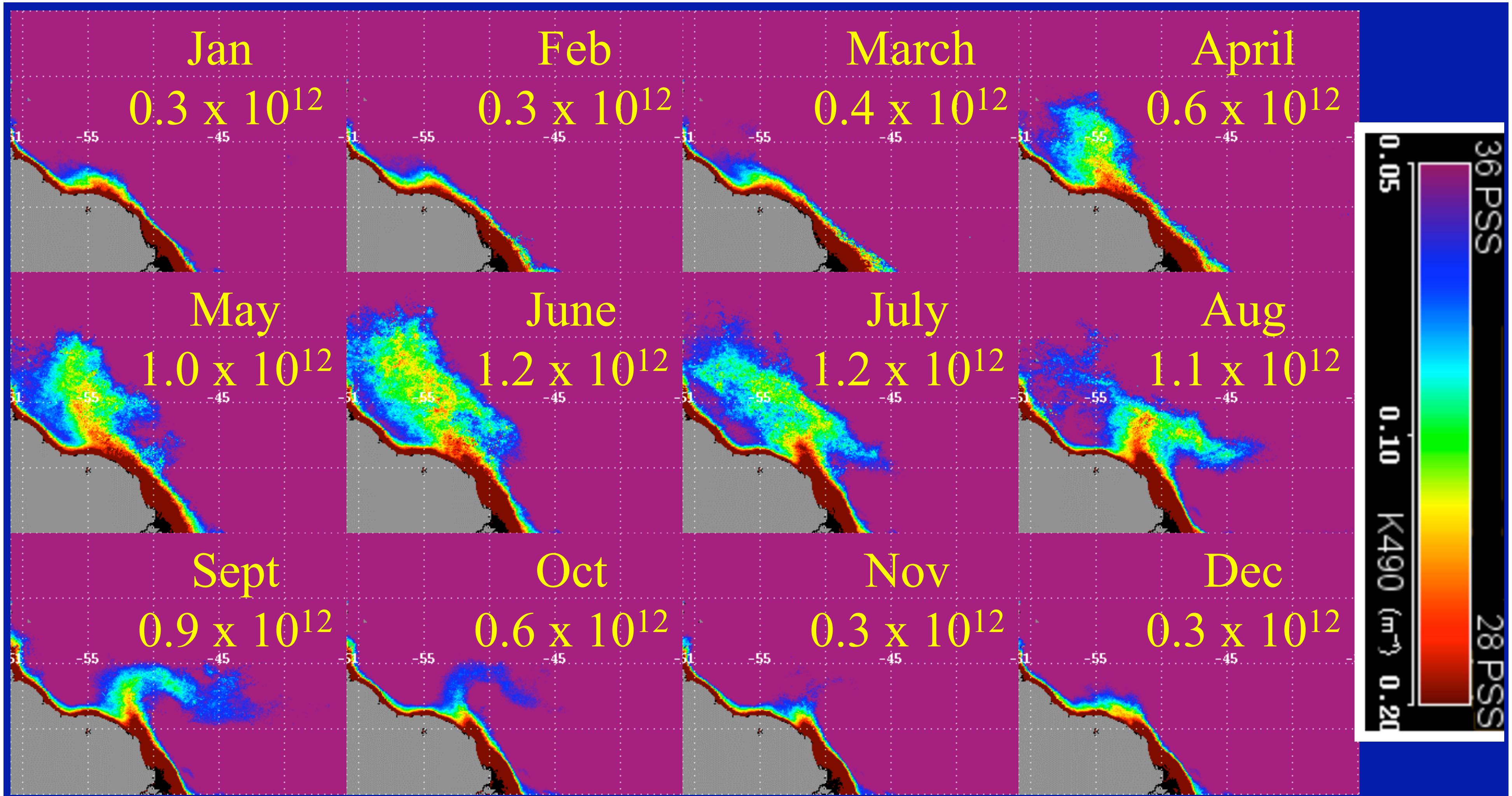


offshore out-of-plume   offshore in-plume closer to shore in-plume

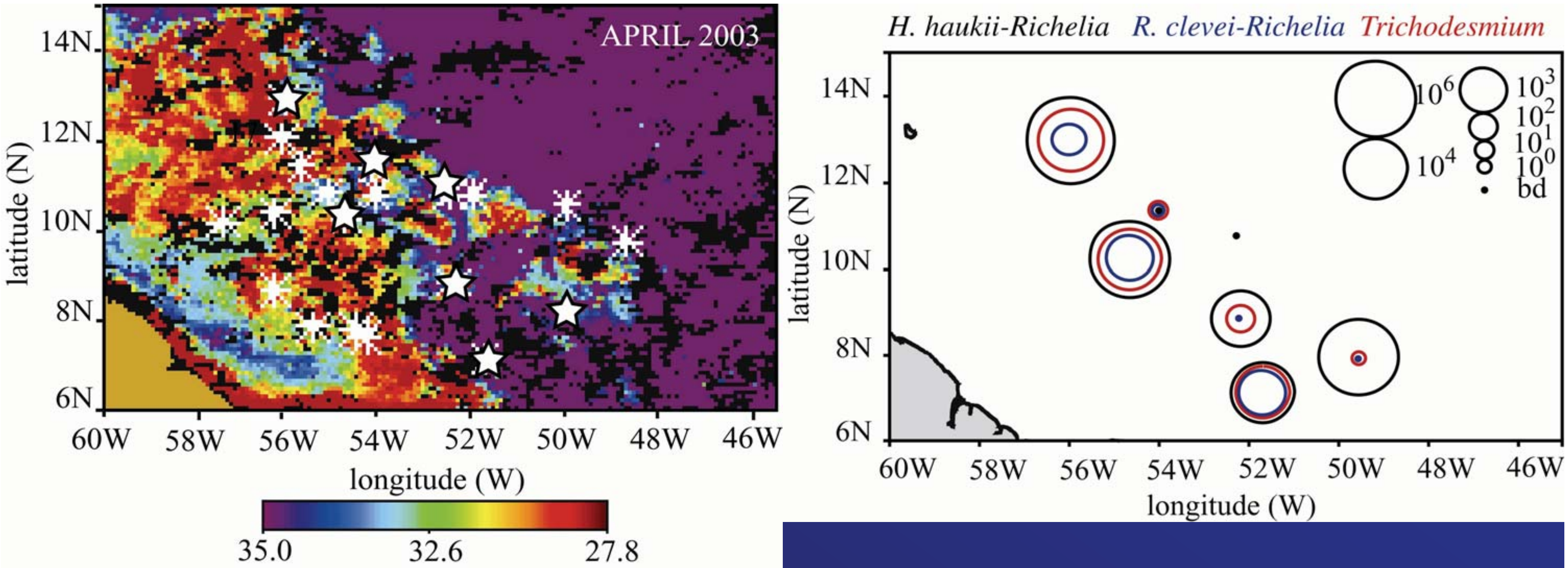
CDOM absorption coefficient at 355 nm [a_{CDOM}(355)] (m^{-1}) to salinity dependence for waters from the WTNA. Numbers refer to stations.



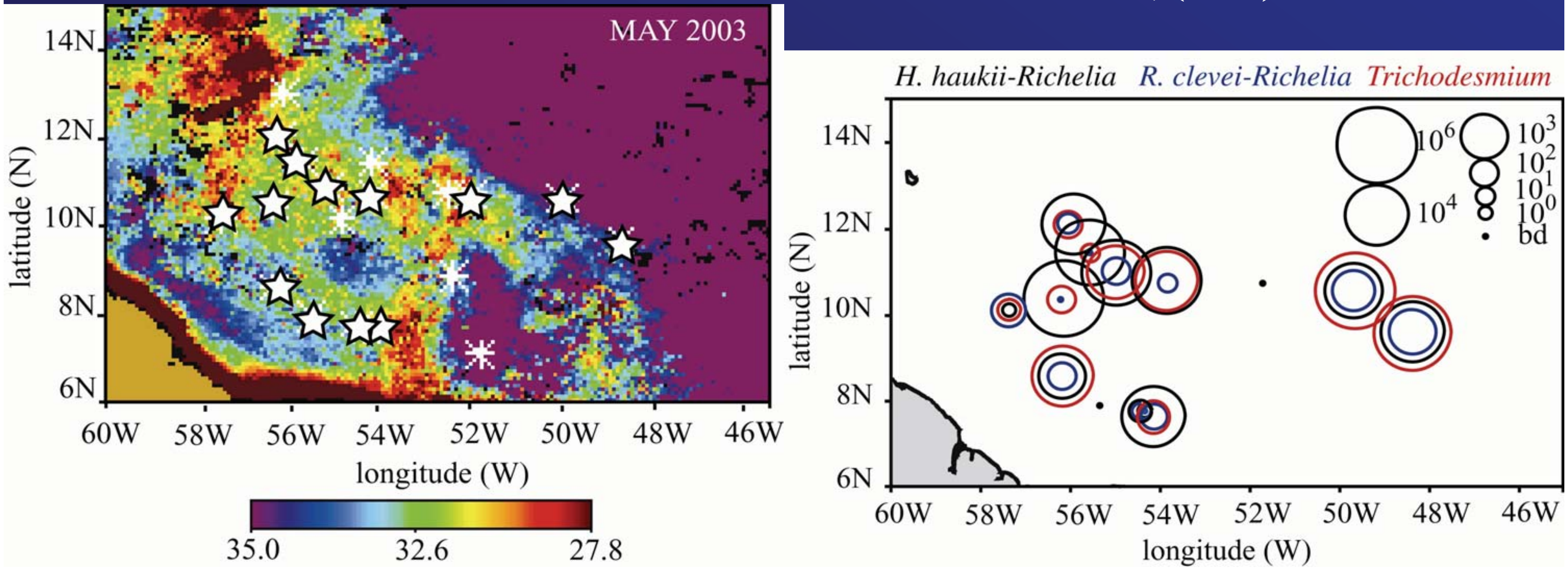
Del Vecchio, R. and A. Subramaniam (2004) Influence of the Amazon River on the surface optical properties of the Western Tropical North Atlantic Ocean. Journal of Geophysical Research. 109, C11001, doi:10.1029/2004JC002503

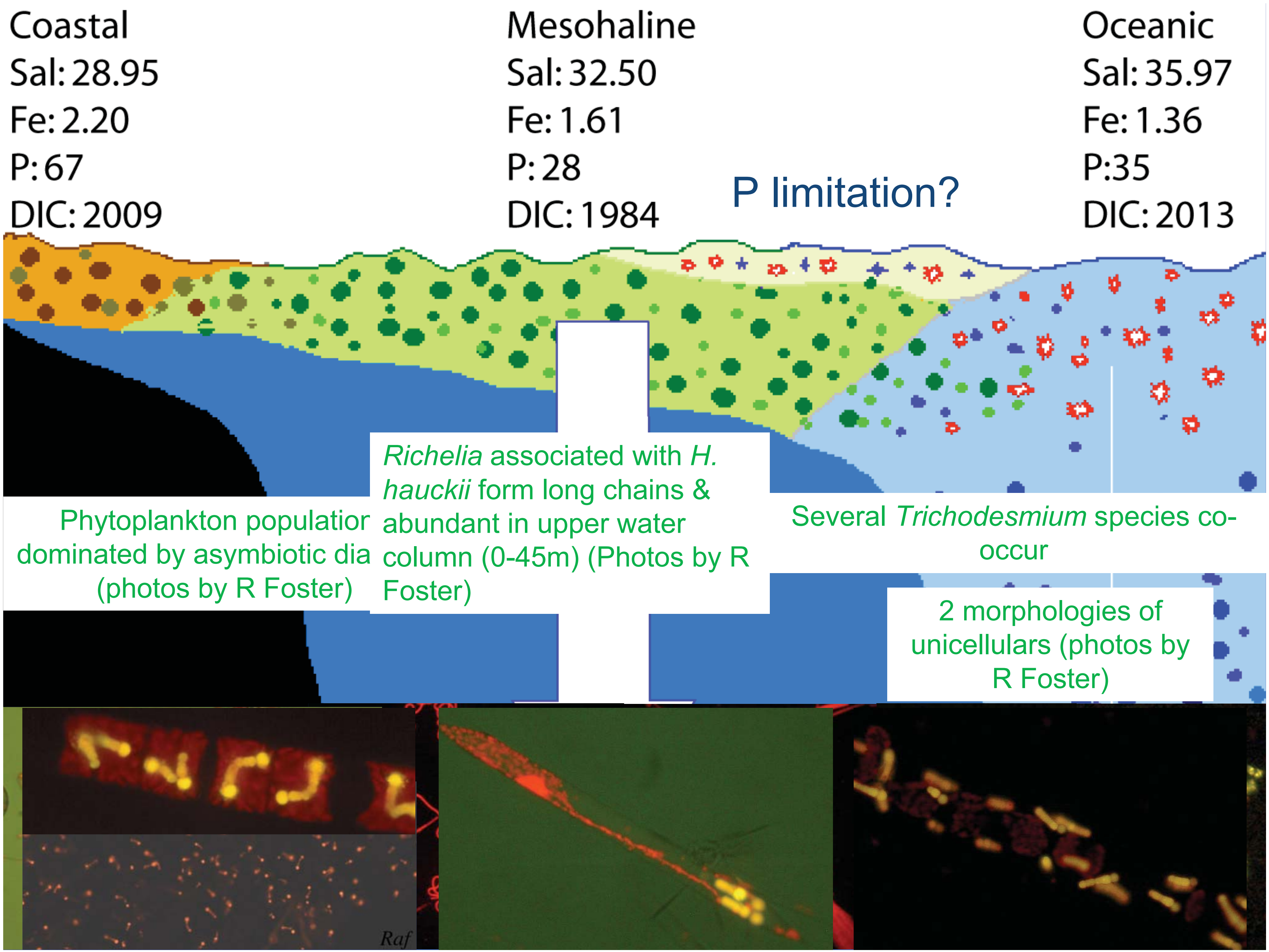


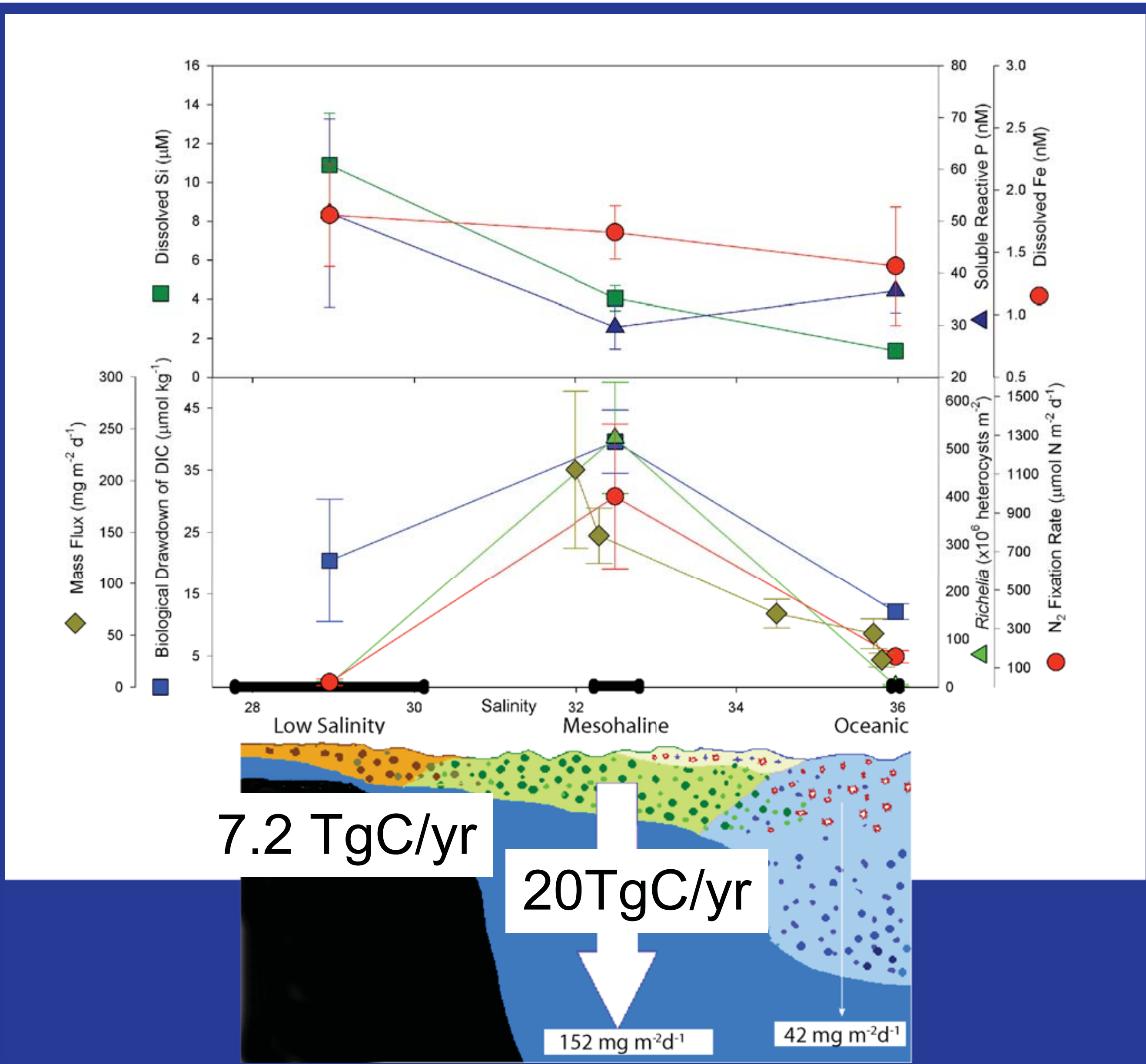
f $_{river}$ for the Amazon calculated using the technique of Muller-Karger et al 1989 was 0.03 for the plume implying that N had to be recycled 39 times to meet the measured primary production demand.



Foster et al., (2007) *L & O.*

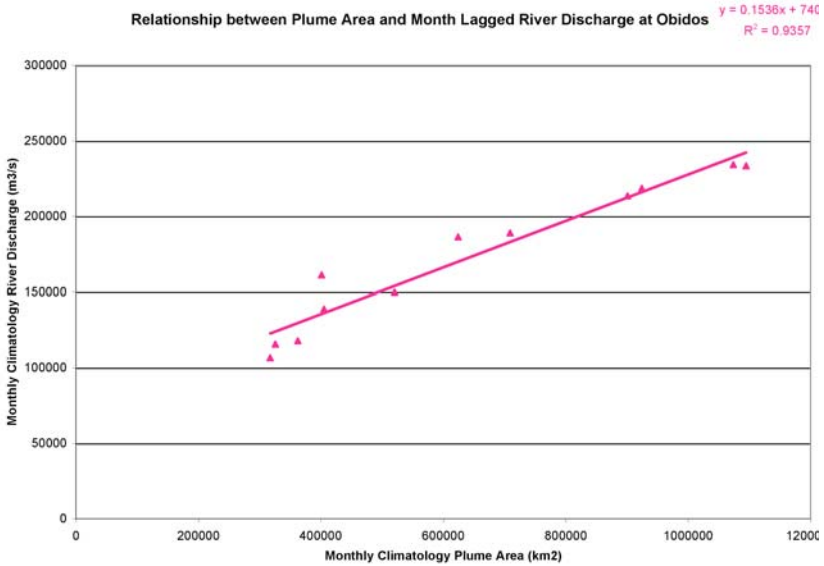


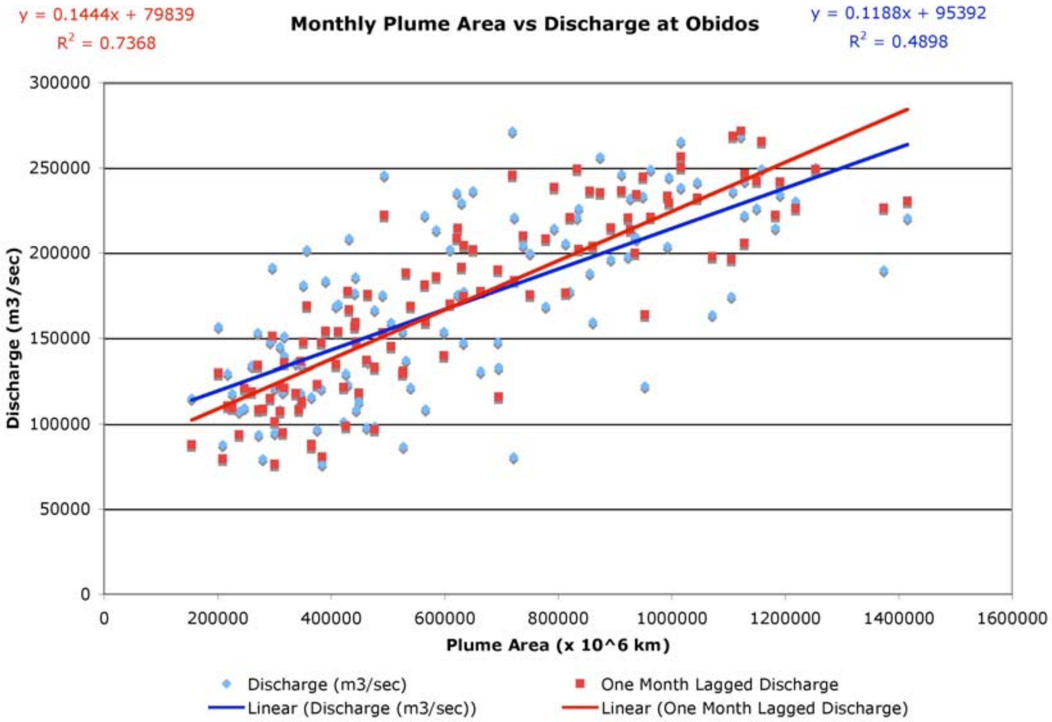

Coastal
Sal: 28.95
Fe: 2.20
P: 67
DIC: 2009
Mesohaline
Sal: 32.50
Fe: 1.61
P: 28
DIC: 1984
P limitation?
Oceanic
Sal: 35.97
Fe: 1.36
P:35
DIC: 2013
Phytoplankton populatior dominated by asymbiotic dia (photos by R Foster)
Richelia associated with H. hauckii form long chains & abundant in upper water column (0-45m) (Photos by R Foster)
Several Trichodesmium species co-occur
2 morphologies of unicellulars (photos by R Foster)

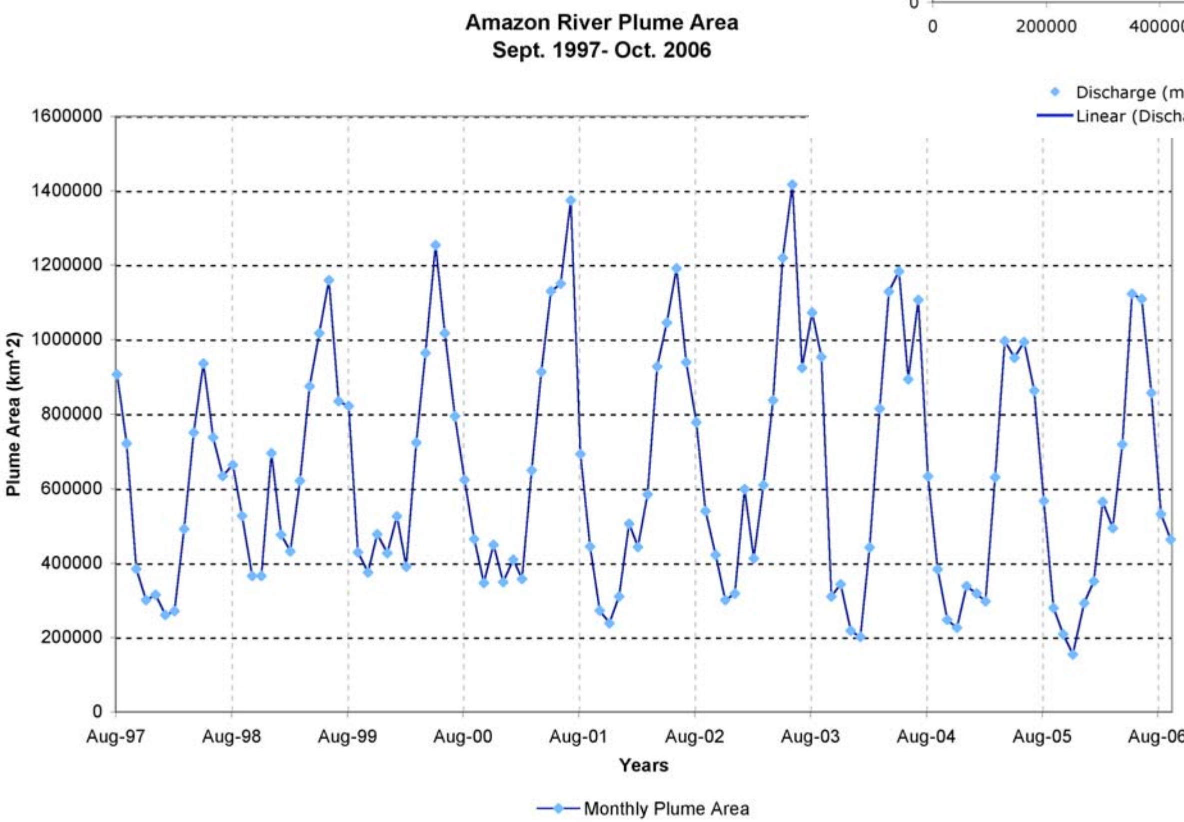


Tropical North Atlantic goes from net source of 30 Tg C/yr to neutral or even a sink for C

Subramaniam, A., PL. Yager, EJ. Carpenter, C. Mahaffey, K. Björkman, S. Cooley, AB. Kustka, JP. Montoya, SA. Sañudo-Wilhelmy, R. Shipe, & DG. Capone. (2008) Amazon River enhances diazotrophy and carbon sequestration in the tropical North Atlantic Ocean. (Proceedings of the National Academy of Sciences)







Amazon River Discharge and Climate Variability: 1903 to 1985

Jeffrey E. Richey, Carlos Nobre, Clara Deser

Reconstruction of an 83-year record (1903 to 1985) of the discharge of the Amazon River shows that there has been no statistically significant change in discharge over the period of record and that the predominant interannual variability occurs on the 2- to 3-year time scale. Oscillations of river discharge predate significant human influences in the Amazon basin and reflect both extrabasinal and local factors. Cross-spectrum

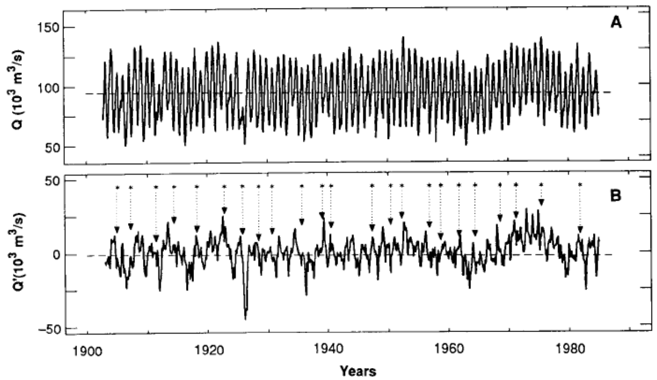
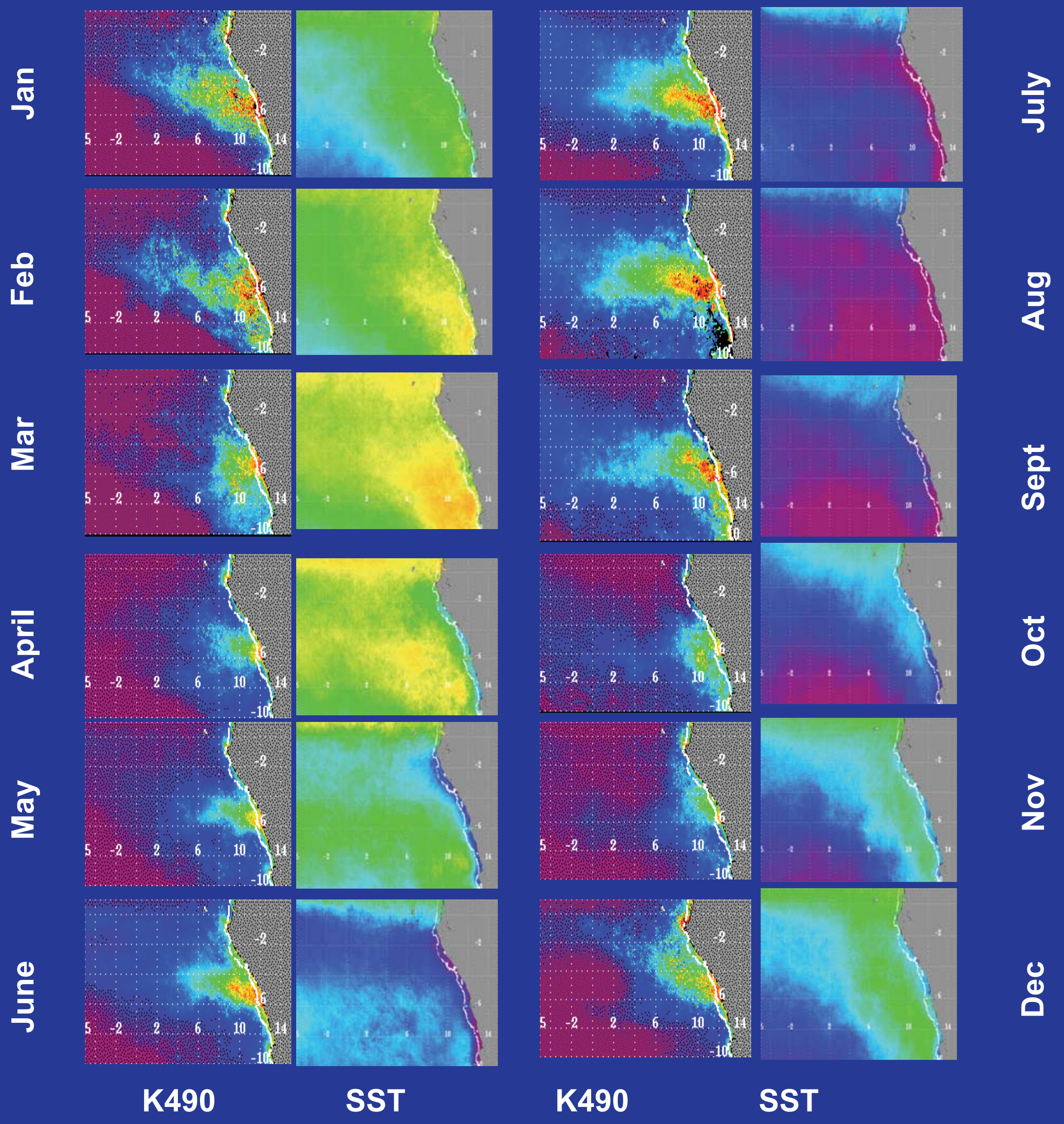
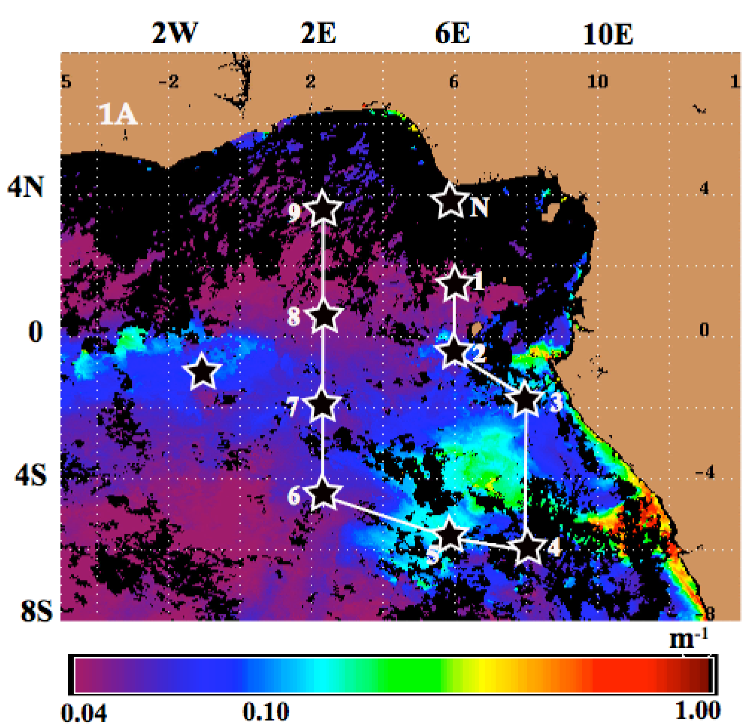


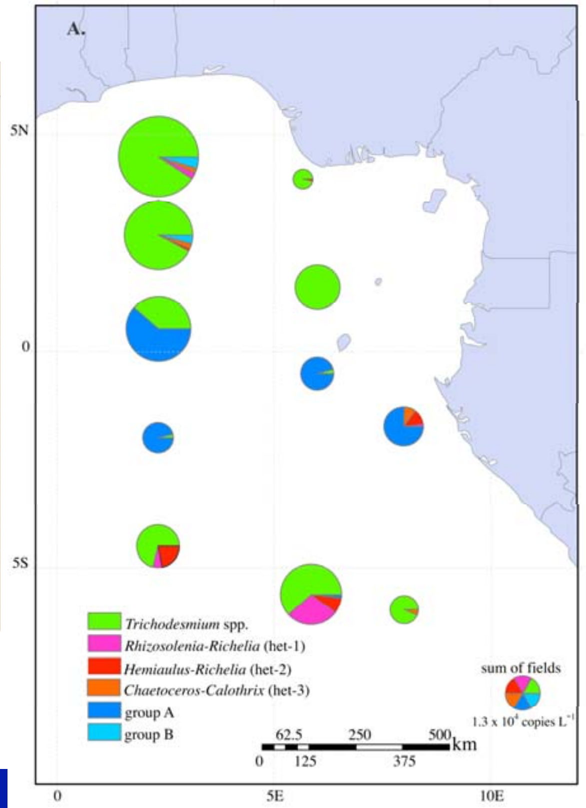
Fig. 2. Discharge of the Amazon River at Manacapurú; (**A**) discharge time series, 1903 to 1985; (**B**) deseasonalized Q′ hydrograph, 1903 to 1985. Arrows indicate occurrence of ENSO events.

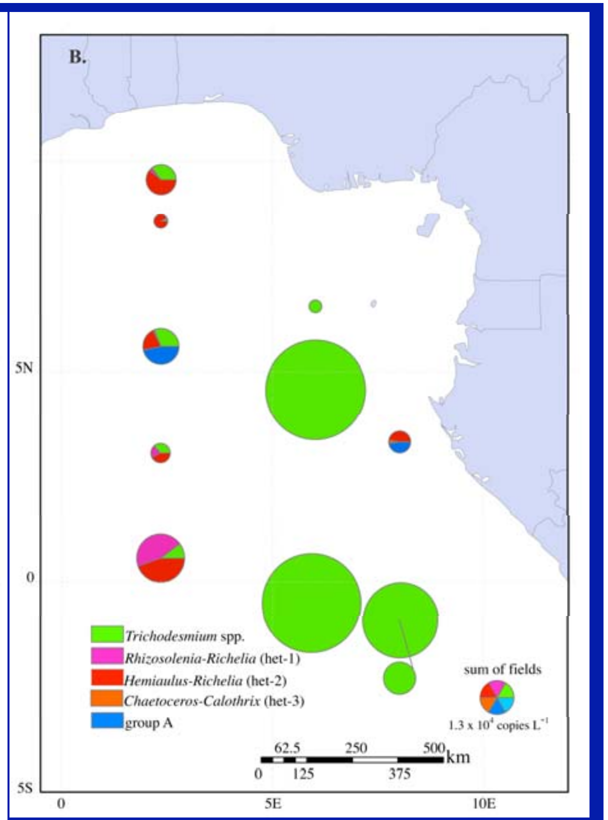
Congo

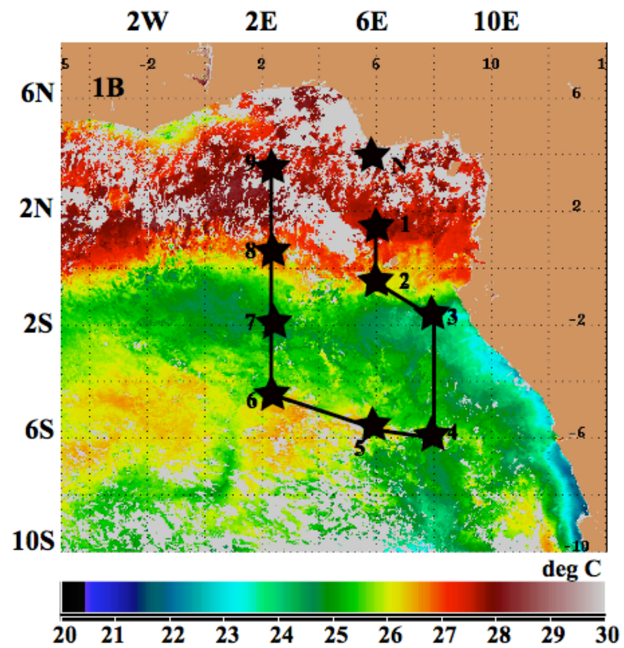


Colebank, Y., Reison, D., Subramaniam, A. Using Argo Profilers And Ocean Color Satellite Data To Trace The Congo River. 2008 Ocean Sciences Meeting, Orlando, FL.









Foster, R.A., A. Subramaniam, Z.P. Zehr. (2009). Distribution and activity of diazotrophy in the Eastern Equatorial Atlantic. Environmental Microbiology

doi:10.1111/j.1462-2920.2008.01796.x

Congo River 2006

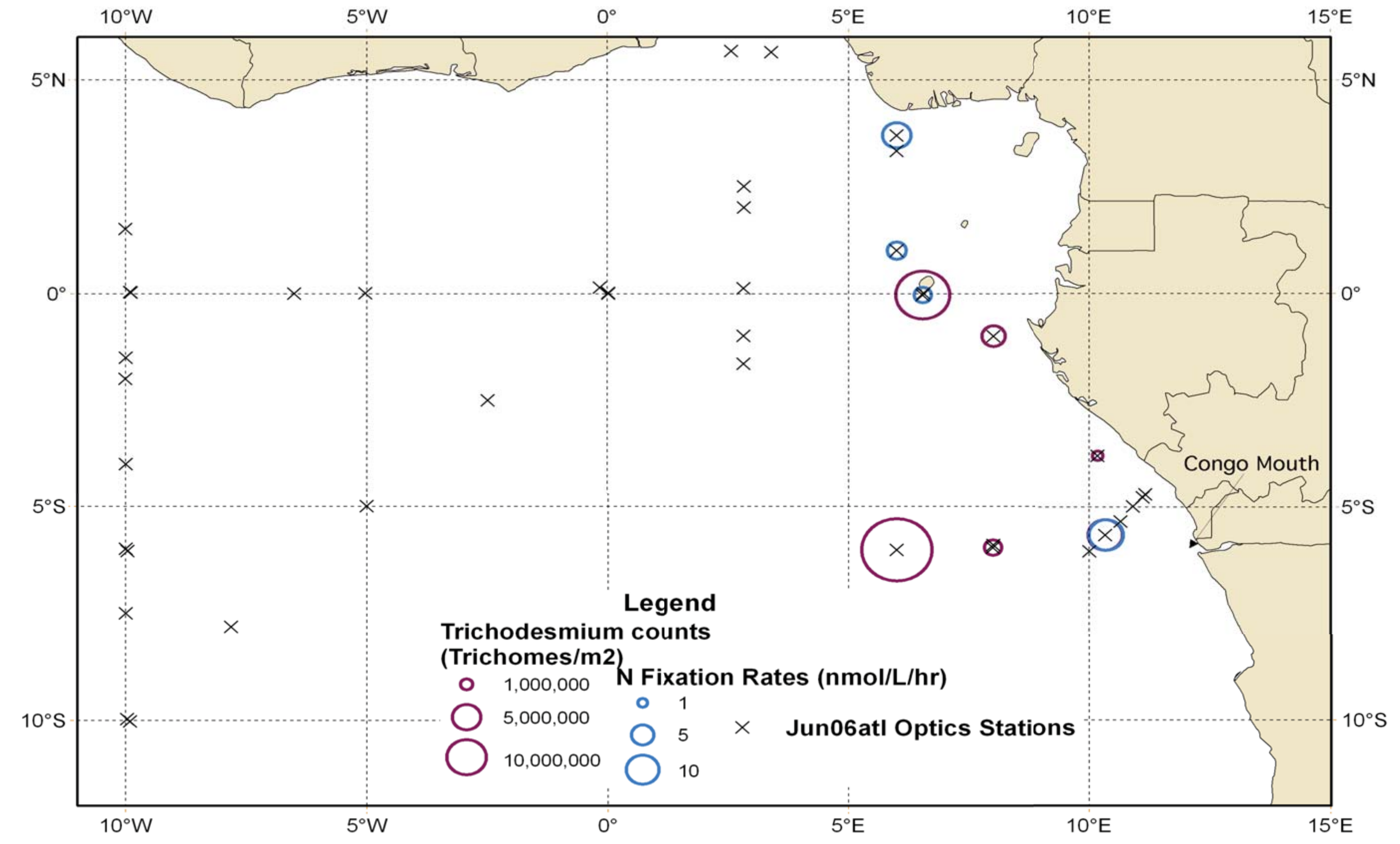
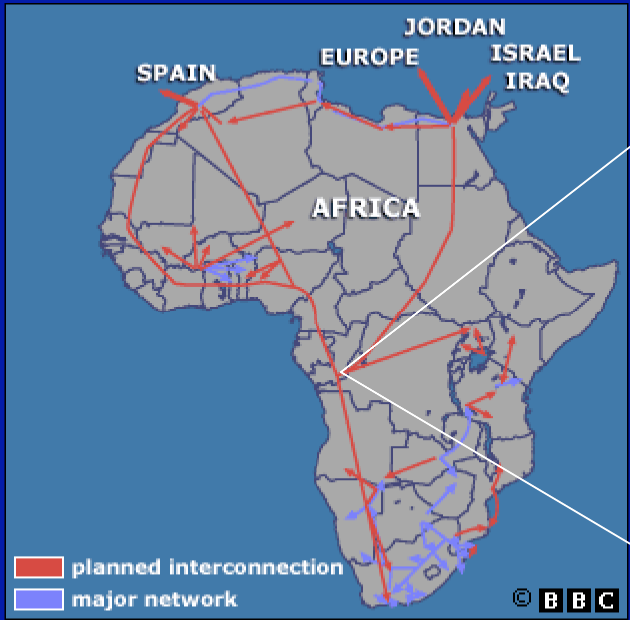
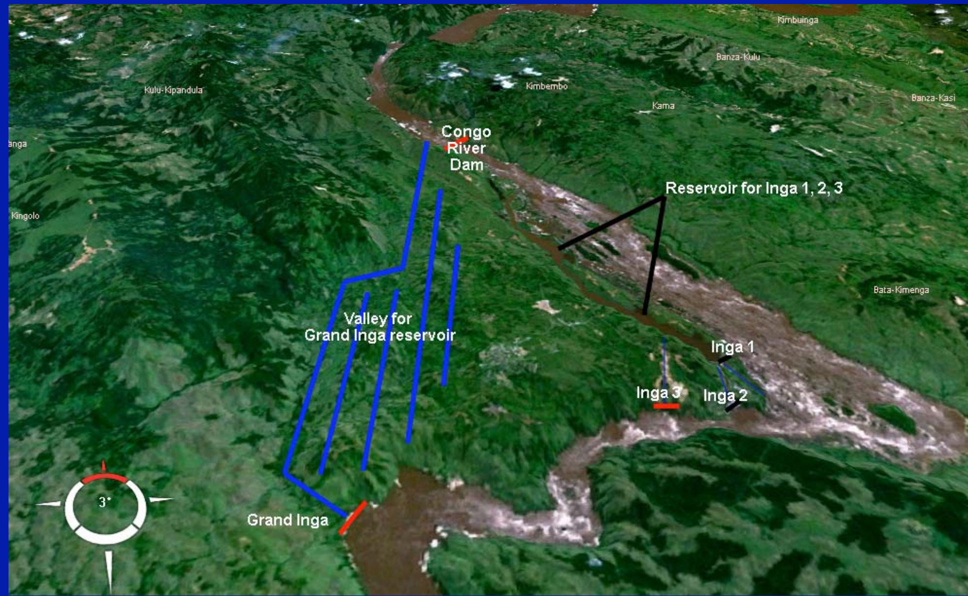


Figure 2 Map of stations occupied in June 2006. Some preliminary data was collected on nitrogen fixation rates and *Trichodesmium* abundance.

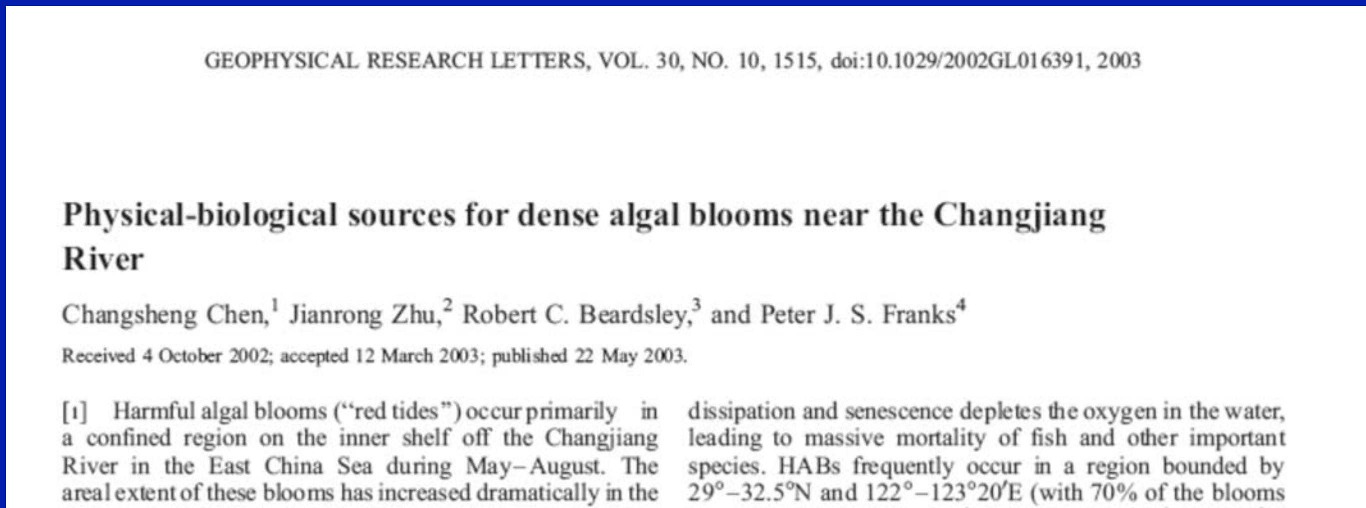
The Grand Inga Project





-Twice the hydroelectric power generation as the Three Gorges Dam

-Green power? Methane, mercury emissions, loss of carbon sink



GEOPHYSICAL RESEARCH LETTERS, VOL. 30, NO. 10, 1515, doi:10.1029/2002GL016391, 2003

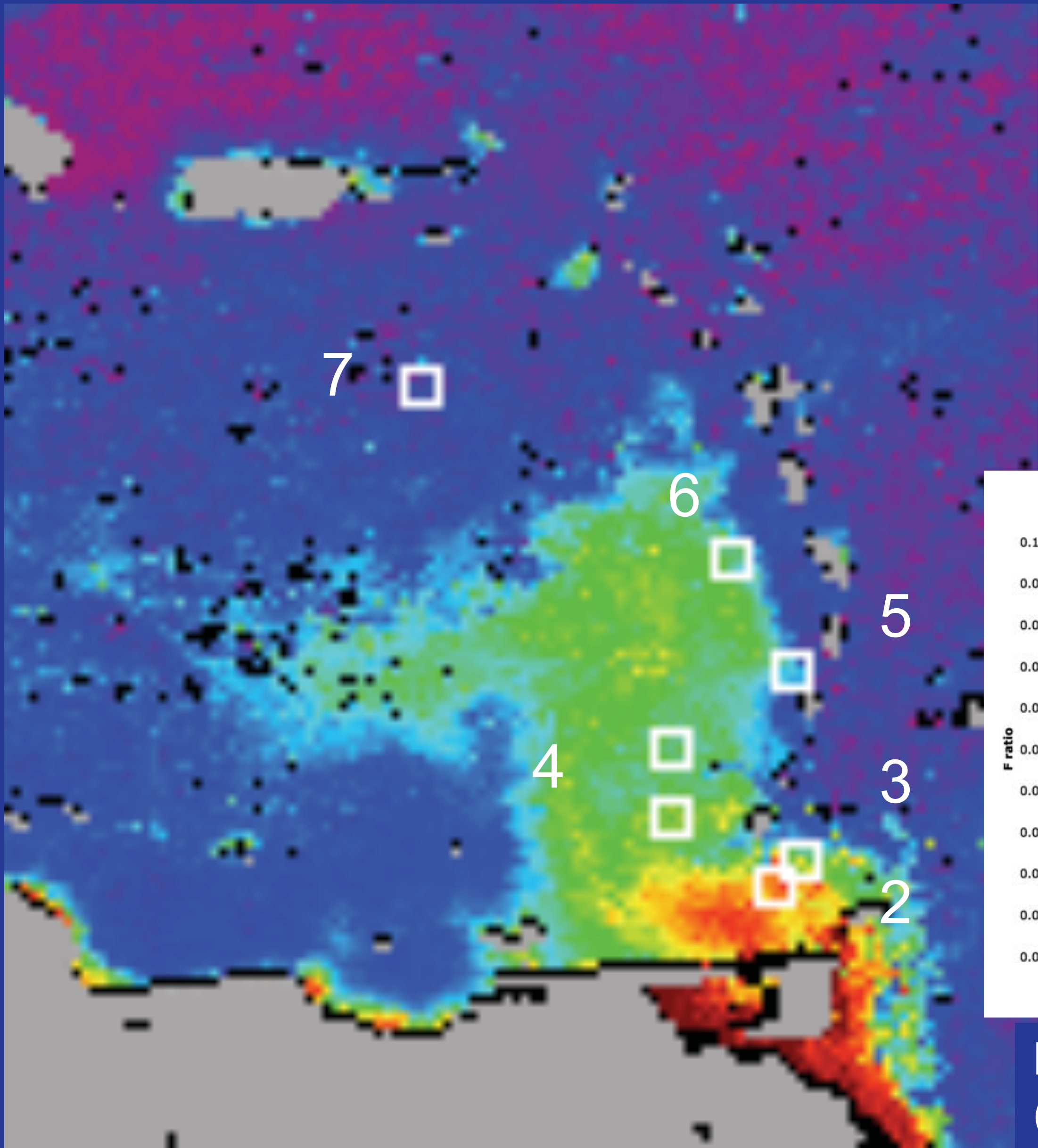
Physical-biological sources for dense algal blooms near the Changjiang River

Changsheng Chen,[1] Jianrong Zhu,[2] Robert C. Beardsley,[3] and Peter J. S. Franks[4]

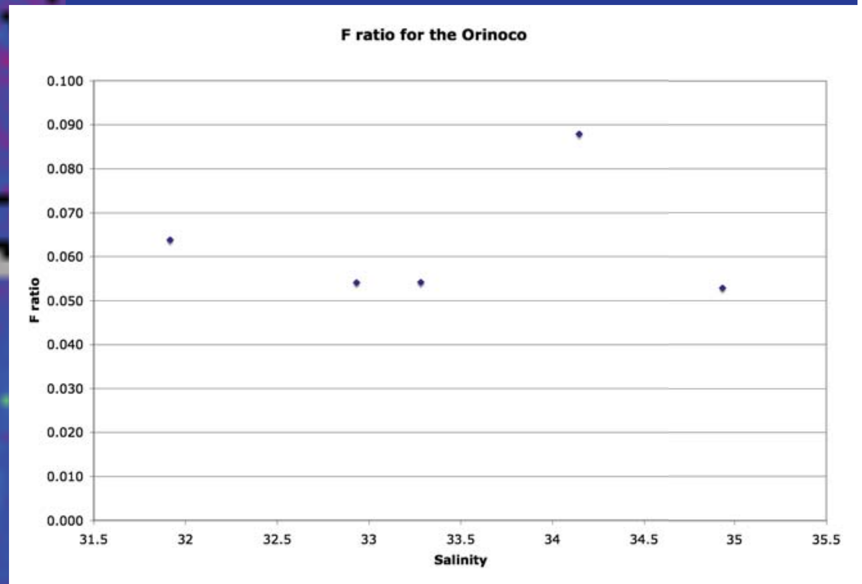
Received 4 October 2002; accepted 12 March 2003; published 22 May 2003.

[1] Harmful algal blooms ("red tides") occur primarily in a confined region on the inner shelf off the Changjiang River in the East China Sea during May–August. The areal extent of these blooms has increased dramatically in the dissipation and senescence depletes the oxygen in the water, leading to massive mortality of fish and other important species. HABs frequently occur in a region bounded by 29°–32.5°N and 122°–123°20′E (with 70% of the blooms

f_{river} for the Orinoco

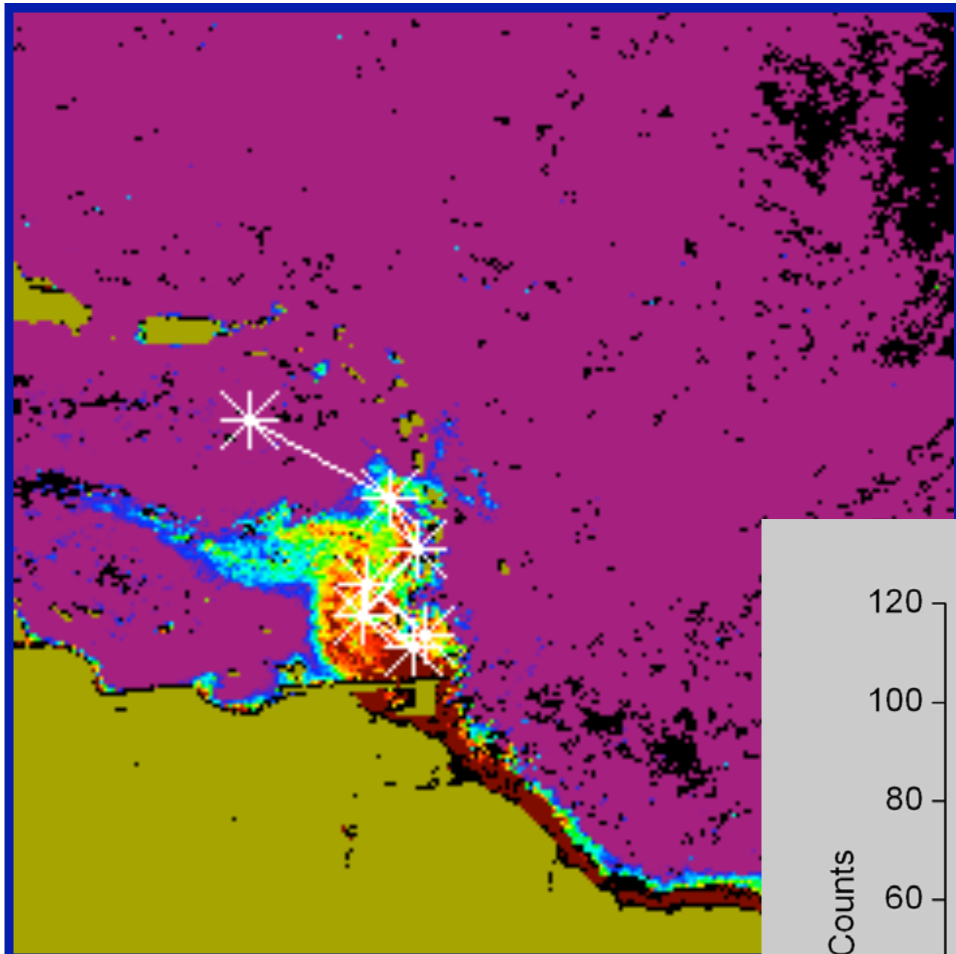


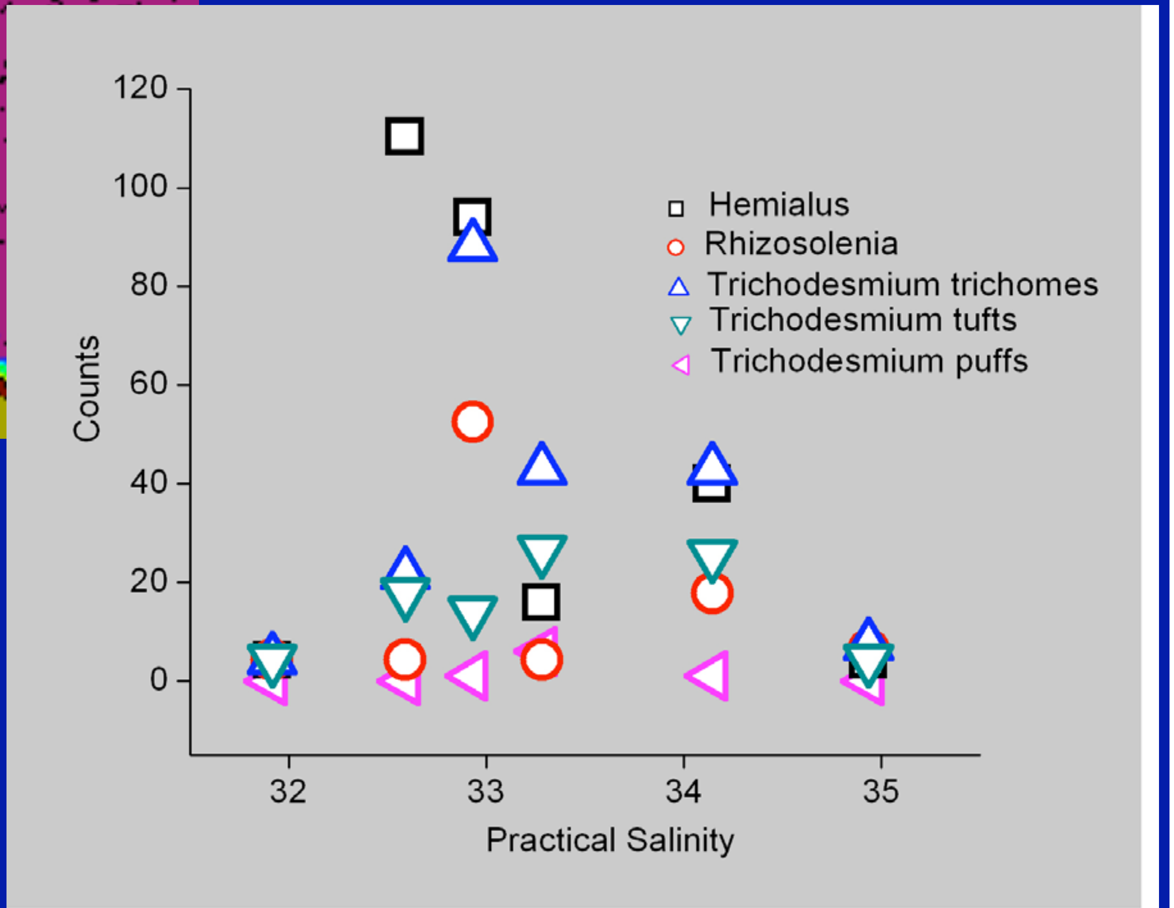
Muller-Karger et al 1989 estimated f_{river} of 0.02 to 0.12, i.e. recycling 7-65 times. The measured values are much less confirming other sources of N



N recycled between 10 and 18 times (D. Bronk, Personal communication)

Orinoco River





Cruise data from September 2006
from Corredor, Morrel, Cabrera

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 106, NO. C8, PAGES 16,807–16,813, AUGUST 15, 2001

Photomineralization of fluorescent dissolved organic matter in the Orinoco River plume: Estimation of ammonium release

Julio M. Morell and Jorge E. Corredor

Morell and Corredor calculated that the time based ammonia release rate in the Orinoco River plume was about 264 μmol m^{-2} d^{-1} This is about 50% the total N demand calculated by Muller-Karger 1989 and needs to be balanced against microbial uptake.

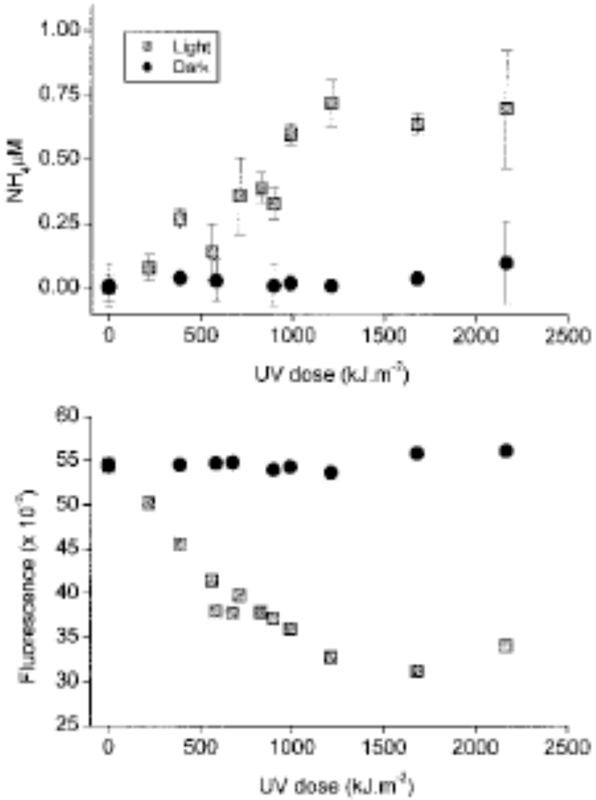


Figure 6. Results of the photoexposure experiment. NH_4 production and concurrent DOM fl reduction in surface water collected from the Gulf of Paria.

Sort of same old story in the Bay of Bengal

A sink for atmospheric carbon dioxide in the northeast Indian Ocean

M. Dileep Kumar, S. W. A. Naqvi, M. D. George, and D. A. Jayakumar

National Institute of Oceanography, Dona Paula, Goa, India

Abstract. Intensive observations in the northeast Indian Ocean (Bay of Bengal) during the pre-southwest and northeast monsoon seasons of 1991 reveal that freshwater discharge from rivers of the Indian subcontinent exerts the dominant control over total carbon dioxide (TCO_2) and pCO_2 distributions in surface waters. Low pCO_2 levels occur within the low-salinity zones, with a large area in the northwestern bay acting as a sink for atmospheric CO_2. Only a part of the observed pCO_2 variation can be accounted for by the effect of salinity, and biological production supported by external nutrient inputs in conjunction with strong thermohaline stratification may be more important in lowering surface water pCO_2 by >100 µatm relative to that in the atmosphere. The pCO_2 distribution is seasonally variable and appears to be controlled by the spreading of fresher waters by the prevailing surface circulation.

Indian Ocean Rivers - the great unknowns
Bay of Bengal
Ganges/Brahmaputra/Irrawady/Salween

Intense blooms of *Trichodesmium erythraeum* (Cyanophyta) in the open waters along east coast of India

*R. Jyothibabu, N. V. Madhu, Nuncio Murukesh, P. C. Haridas, K. K.C.Nair & P. Venugopal

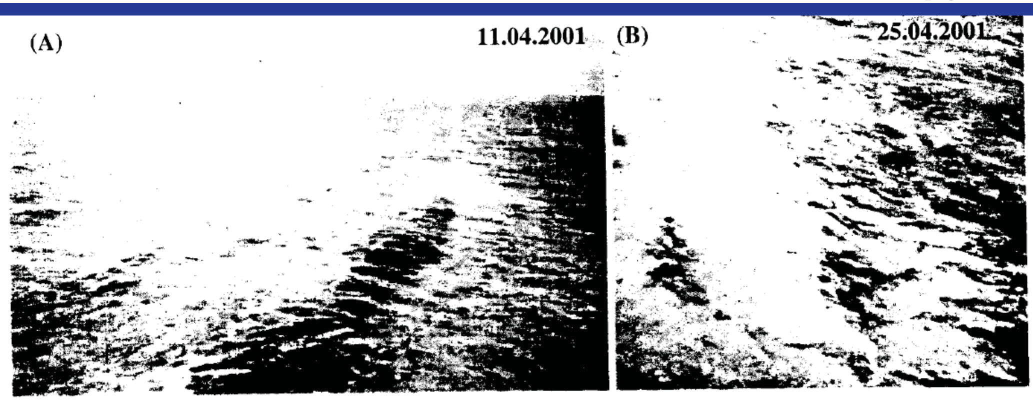


Fig. 2 — *Trichodesmium erythraeum* bloom observed (A) off Karaikkal, (B) off south of Calcutta

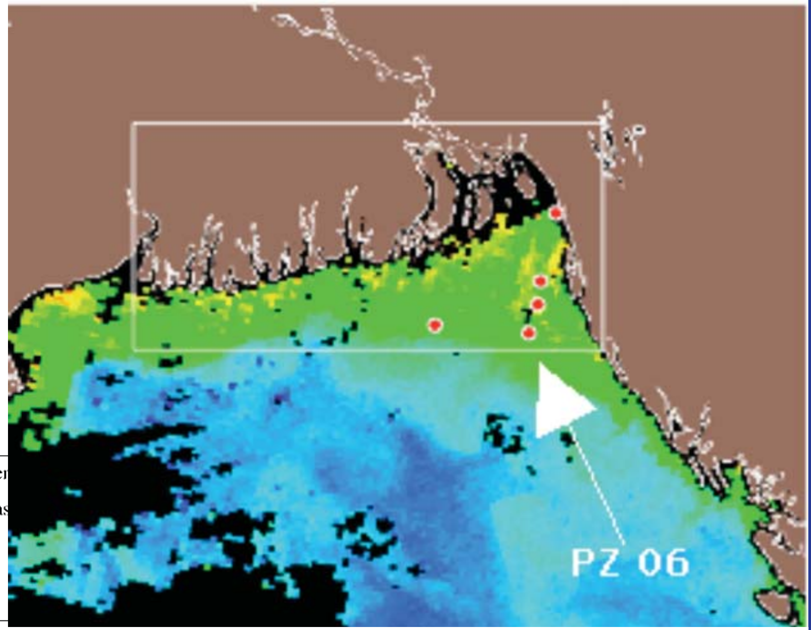


Table 1 — Details of the location, nutrients, primary production and mesozooplankton biomass of the bloom regions in the Bay of Ben

Bloom date	Lat (°N)	Long (°E)	Nutrients (μ mol.l^{-1})			Primary production (mgC m^{-2} d^{-1})	Zooplankton biomas (ml 100m^{-3})
			Nitrate	Phosphate	Silicate		
11 April 2001	10° 58'	81°50'	0.05	0.9	2.2	2160	22.8
25 April 2001	19°44'	89°04'	0.14	0.56	—	1740	17.7

Biogeochemistry of particulate organic matter from the Bay of Bengal as discernible from hydrolysable neutral carbohydrates and amino acids

Daniela Unger*, Venugopalan Ittekkot, Petra Schäfer, Jörg Tiemann

Zentrum für Marine Tropenökologie, Fahrenheitstraße 6, D-28359 Bremen, Germany

Table 1. *Range (in parenthesis) and mean values (±SD) of water parameters in the three regions.*

Parameters	KKD bay region	GG estuary region	Mangrove region
NO_2–N (μM)	(0.50 – 2.24) 1.33 ± 056	(0.68 – 1.72) 1.23 ± 0.39	(1.21 – 6.49) 3.41 ± 1.6
NO_3–N (μM)	(0.86 – 12.5) 6.03 ± 3.55	(13.9 – 21.4) 17.18 ± 2.64	(7.47 – 16.2) 11.15 ± 2.42
NH_4–N (μM)	(0.82 – 2.49) 1.51 ± 0.60	(0.33 – 2.25) 1.13 ± 0.54	(0.79 – 14.2) 4.83 ± 3.4
PO_4–P (μM)	(0.92 – 6.9) 2.54 ± 1.68	(1.76 – 4.53) 3.05 ± 1.09	(1.89 – 5.85) 3.17 ± 0.99
SiO_4–Si (μM)	(9.26 – 57.7) 33.93 ± 17.37	(42.5 – 142.0) 90.38 ± 35.39	(68.6 – 139.0) 102.35 ± 25.73
TN (μM)	(13.7 – 120.0) 59.95 ± 40.79	(15.8 – 42.6) 26.44 ± 8.65	(21.3 – 196.0) 43.02 ± 45.94
TP (μM)	(2.01 – 15.5) 7.46 ± 3.85	(3.69 – 16.2) 8.4 ± 3.99	(2.46 – 21.7) 10.52 ± 5.01
pH	(7.10 – 7.93) 7.55 ± 0.28	(7.2 – 7.8) 7.52 ± 0.22	(7.19 – 7.58) 7.42 ± 0.13
Salinity (PSU)	(11.9 – 31.4) 21.06 ± 6.76	(0.27 – 9.65) 3.87 ± 3.9	(0.27 – 9.48) 3.29 ± 3.88
DO (mg l^{-1})	(5.85 – 8.65) 7.03 ± 0.93	(5.49 – 6.38) 5.87 ± 0.33	(1.39 – 5.45) 2.88 ± 1.55
BOD (mg l^{-1})	(2.88 – 5.85) 4.88 ± 1.13	(1.52 – 2.8) 2.32 ± 0.5	(3.68 – 6.12) 4.79 ± 0.74
Chl *a* (μg l^{-1})	(0.68 – 25.9) 12.49 ± 9.55	(0.86 – 15.9) 5.23 ± 4.84	(2.36 – 16.2) 5.42 ± 4.74
Chl *b* (μg l^{-1})	(0.04 – 4.08) 1.1 ± 1.21	(ND – 2.41) 0.61 ± 0.85	(ND – 4.53) 1.48 ± 1.44
Chl *c* (μg l^{-1})	(0.15 – 7.17) 1.83 ± 2.03	(ND – 2.6) 0.87 ± 0.94	(0.05 – 12.9) 2.88 ± 3.14
Pp (μg l^{-1})	(0.44 – 21.1) 7.92 ± 7.22	(ND – 7.05) 2.2 ± 2.28	(0.88 – 6.25) 3.16 ± 1.72

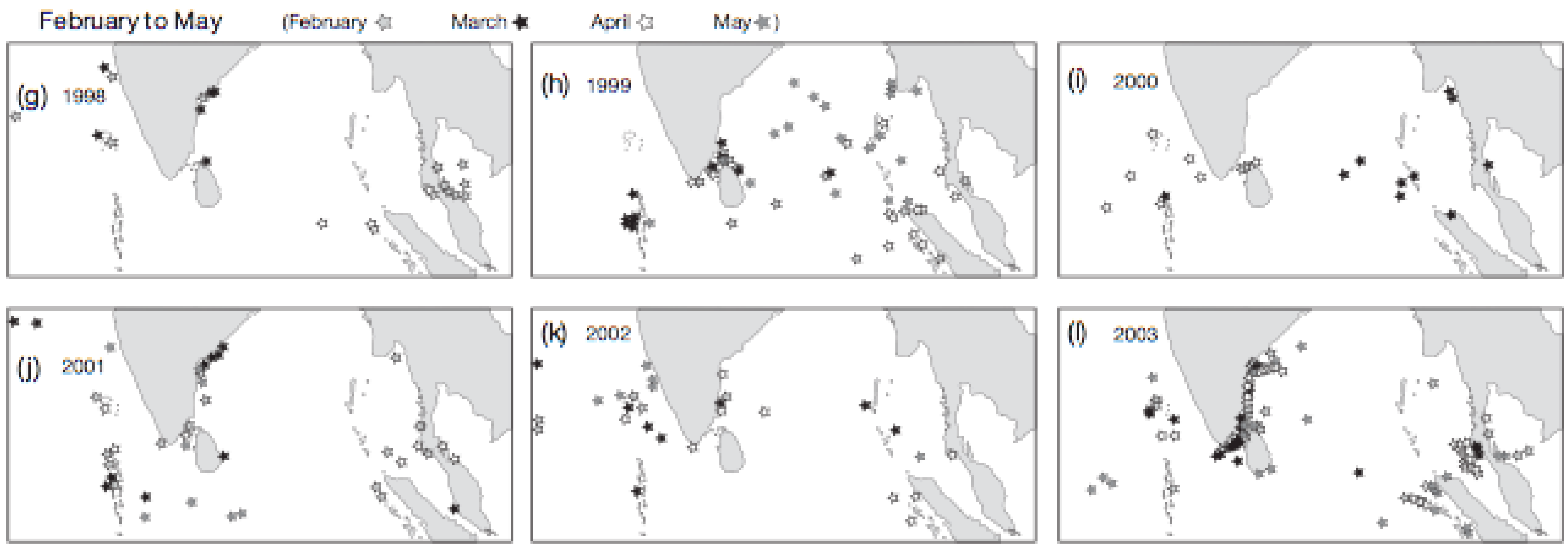
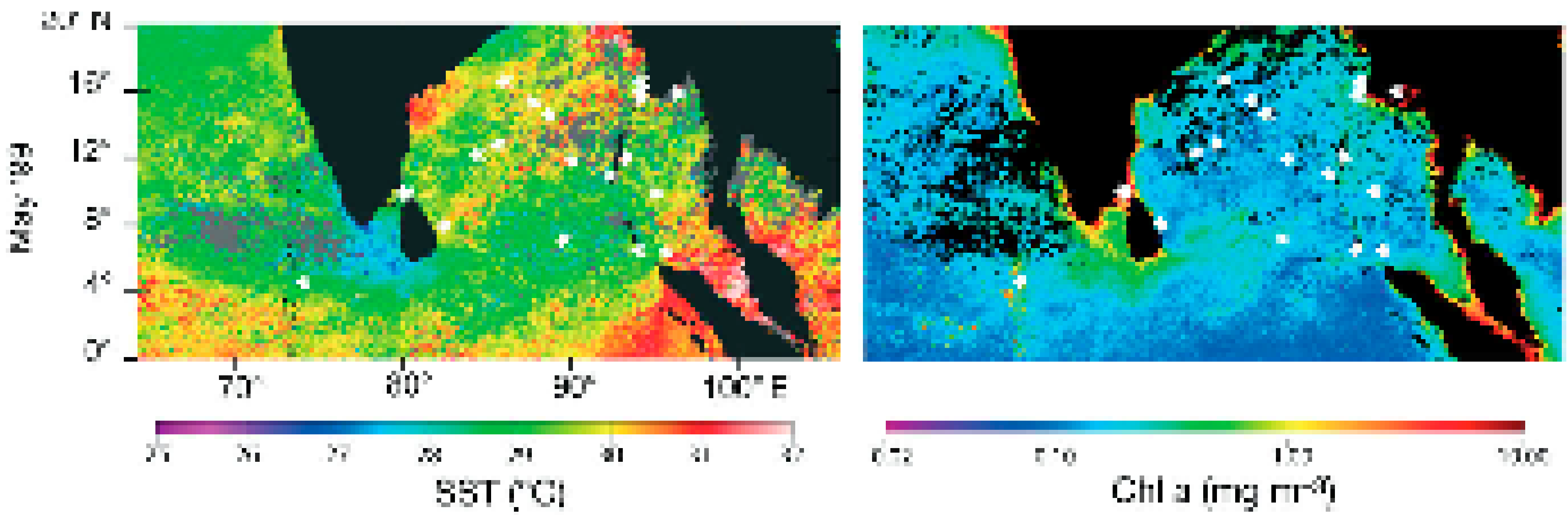


Fig. 3. Remotely sensed *Trichodesmium* occurrences superimposed on a map of the region for the period of 1997–2003. (a–f) November to January (circles); (g–l) February to May (stars)



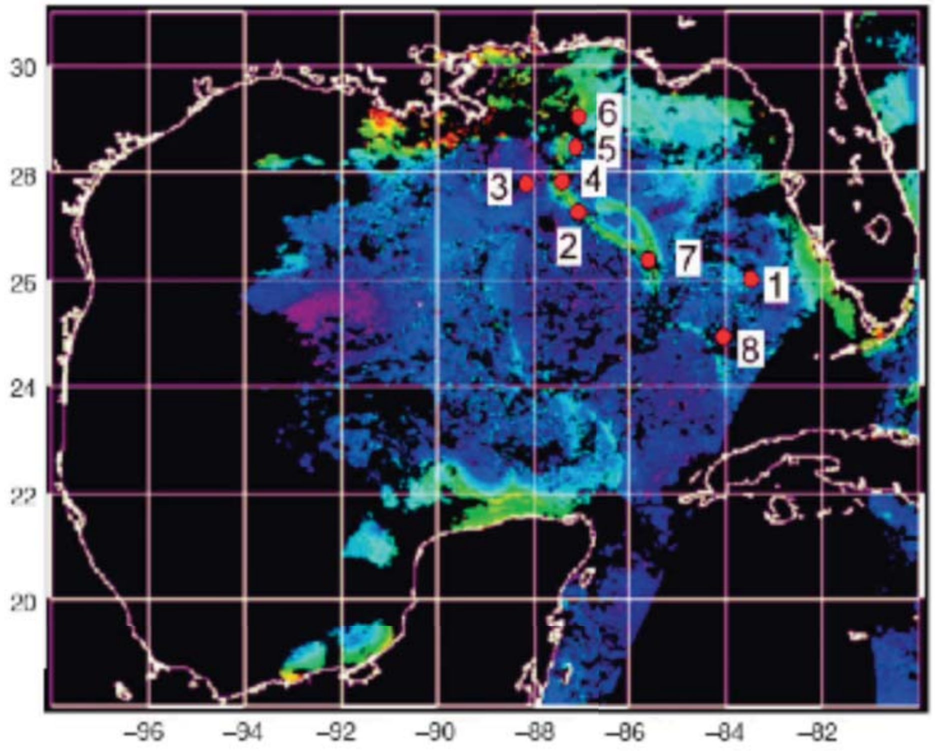
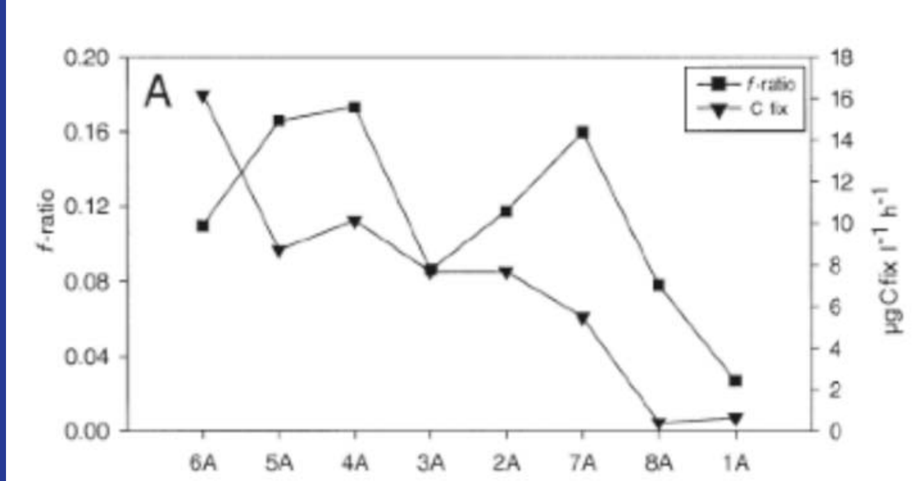
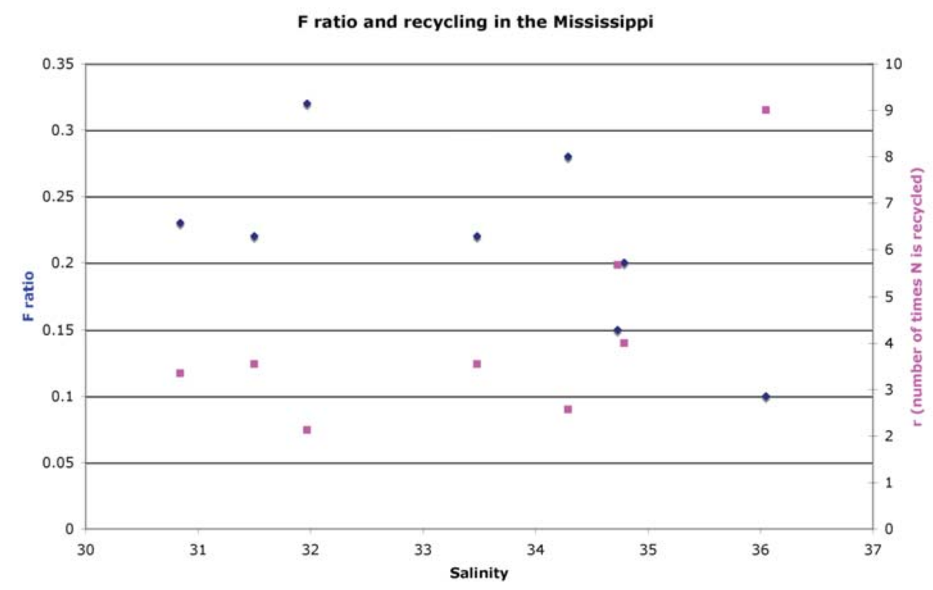


Fig. 1. Surface chl a concentrations in the NE Gulf of Mexico derived using the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS). Lighter colors indicated higher amounts of colored material in surface water. Concentrations near the Mississippi River Delta and in the river plume, as well as in other coastal areas, are subject to known effects by high concentrations of colored dissolved organic matter, suspended sediments, or bottom reflectance, which can artificially raise chl a estimates. Land and clouds are colored black. Station locations are indicated





Wawrik and Paul 2004 AME

Mekong River

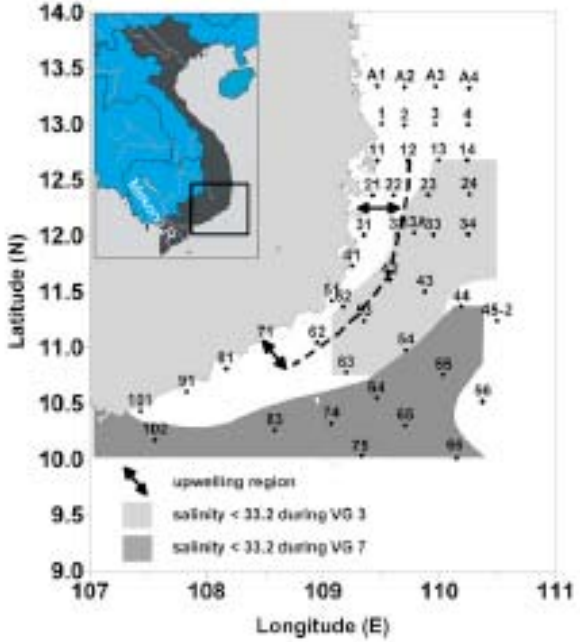
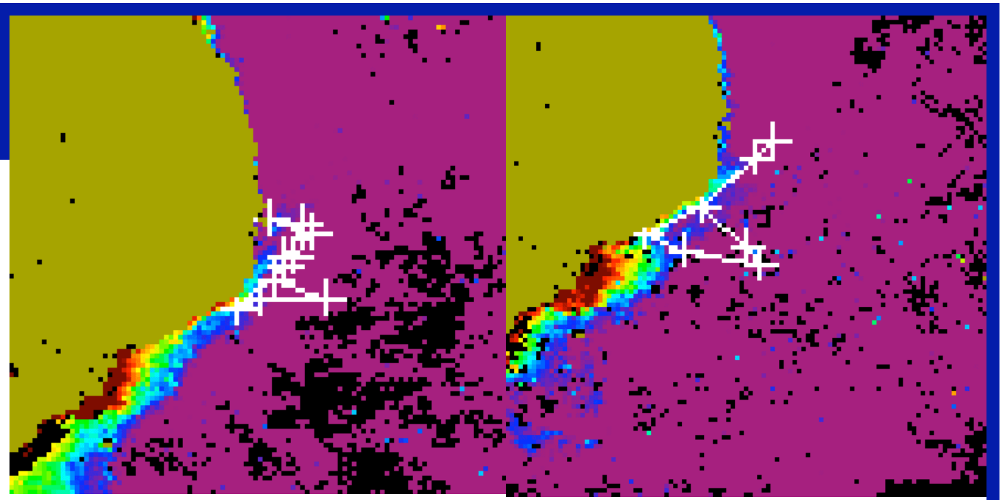


Figure 1. Map of the South China Sea off Vietnam with all CTD stations, the insert shows SE Asia. (N_2-fixation was measured at the 28 stations). Stations A1 to A4 and 1 to 4 were only visited during VG4, stations 62 to 65 only during VG7. The shaded area denotes Mekong river influence and the line the extension of the upwelling region from the coast.



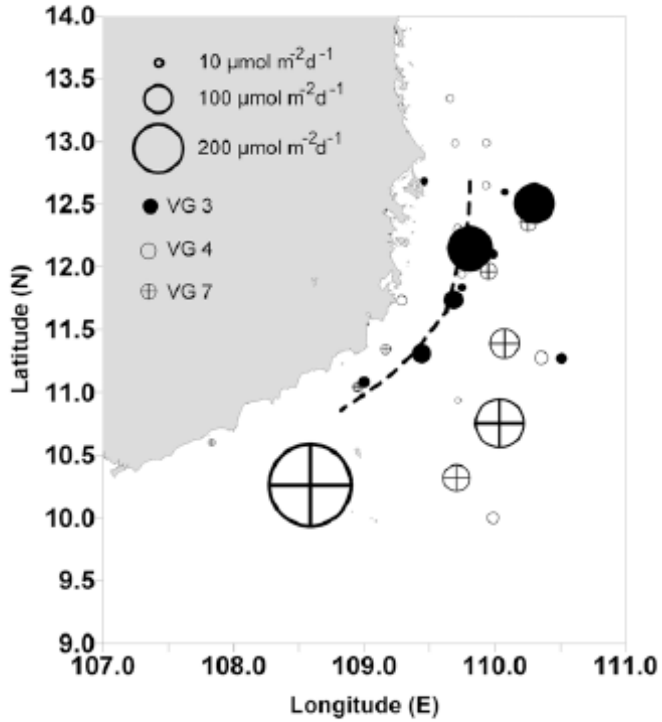


Figure 2. N_2-fixation rates, symbols are scaled linearly proportional to the measured values. The line visualises the offshore limitation of the upwelling area.

Voss M et al. (2006) Riverine influence on nitrogen fixation in the upwelling region off Vietnam, South China Sea. GRL 33



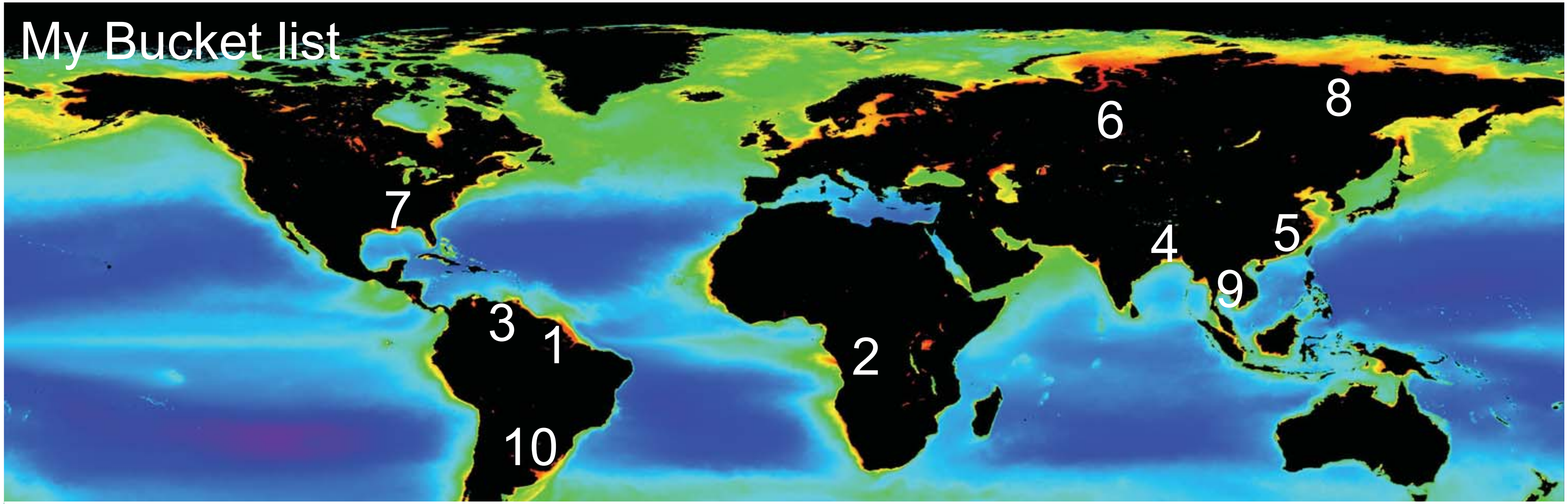



Sweet Jubilee

Mami Wata – a symbol of water systems science and engineering?

Who is Mami Wata?

- She is Mother Water, Mother of Fishes, goddess of oceans, rivers and pools, with sources in West and Central Africa and tributaries throughout the African Americas, from Bahia to Brooklyn. Usually shown as a half-woman, half-fish, she slips with ease between incompatible elements: water and air, tradition and modernity, this life and the next.



River	Discharge	Cumulative %	Drainage area	DIN yield*	DIP yield*	DON yield**	DOP yield**
Amazon	6300	18	6.15	173	17	327	18
Zaire	1250	22	3.82		4	91.5	
Orinoco	1200	25	0.99		4	313	17
Ganges-Brahmaputra	970	28	1.48		25	164	
Chiang Jiang	900	31	1.94	326	16		
Yenisey	630	33	2.58		1		
Mississippi	530	34	3.27	256	7	54	3
Lena	510	36	2.49	21	2	58	3
Mekong	470	37	0.79				
Parana	470	38	2.83	44	2	61	
All others	21168	100