

# Characterization of carbon and nitrogen uptake by marine biota in the Indian Ocean

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## CERTIFICATE

I feel great pleasure in certifying the thesis entitled “**Characterization of carbon and nitrogen uptake by marine biota in the Indian Ocean**” by Arvind Singh under my guidance. He has completed the following requirements as per Ph.D. regulations of the University

- (a) Course work as per the university rules.
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I am satisfied with the analysis of data, interpretation of results and conclusions drawn.

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## DECLARATION

*I Mr. Arvind Singh, S/o Mr. Bhisham Singh Bhadoriya, resident of Room No. - 203, Thaltej Hostel, PRL residences, Navrangpura, Ahmedabad - 380009, hereby declare that the research work incorporated in the present thesis entitled “**Characterization of carbon and nitrogen uptake by marine biota in the Indian Ocean**” is my own work and is original. This work (in part or in full) has not been submitted to any University for the award of a Degree or a Diploma. I have properly acknowledged the material collected from secondary sources wherever required. I solely own the responsibility for the originality of the entire content.*

Date:

Arvind Singh  
(Author)

Dedicated To

my family

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## Abstract

Primary productivity is mostly limited by the unavailability of reactive nitrogen in the sunlit surface layer of tropical oceans. The supply of such new nitrogen to the surface ocean is through upwelling,  $N_2$  fixation by diazotrophs, riverine flux and atmospheric deposition. The relative and absolute importance of these processes in the Indian Ocean is studied here.

$N_2$  fixation is estimated directly for the first time using the  $^{15}N_2$  tracer technique in the Arabian Sea during the spring inter-monsoon 2009. Estimates are double the values reported earlier and can account for a substantial fraction of the nitrogen gained by the Arabian Sea. Carbon uptake rates are also estimated using the  $^{13}C$  tracer technique. Further, contribution of atmospheric deposition and riverine fluxes to new productivity in the two biogeochemically different basins of the northern Indian Ocean, the Arabian Sea and the Bay of Bengal, is presented. An upper bound of the contribution of atmospheric deposition to new productivity in the northern Indian Ocean is  $\sim 2.5\%$ . On an average  $1.73 \text{ Tg N y}^{-1}$  is deposited into the northern Indian Ocean through dry and wet deposition of aerosols. On the other hand, most of the dissolved inorganic nitrogen ( $\sim 81\%$  in the case of the Arabian Sea and  $96\%$  in the case of the Bay of Bengal) through riverine flux is not transported to the ocean and is consumed on the course of the rivers or in the estuaries. Coastal Bay of Bengal and Arabian Sea receive  $\sim 0.38 \text{ Tg N y}^{-1}$  and  $\sim 0.06 \text{ Tg N y}^{-1}$ , respectively, through rivers. A large variation in the contribution of DIN through river fluxes to new productivity is found in both these basins. Our estimate of nitrogen fluxes through  $N_2$  fixation, aerosols and rivers is a step towards significantly reducing the uncertainty in the global nitrogen budget.

Application of stable isotopes is extended further by simulating nitrogen loss process in the Arabian Sea. An equation describing isotopic fractionation in open systems, wherefrom material is not only removed with isotopic fractionation, but fresh material of a different isotopic composition is added from an external source, is derived. This model is further applied to understand other oceanographic processes as well. With the help of a new data set, spatiotemporal variation in the



oxygen isotopic composition and salinity ( $\delta^{18}\text{O}$ -S) relation of the northern Indian Ocean is studied. While the results are consistent with positive P-E (excess of precipitation over evaporation) over the Bay of Bengal and negative P-E over the eastern Arabian Sea, a significant spatiotemporal variability in the slope (also intercept) of the relation is observed in the Bay; the temporal variability is difficult to discern in the Arabian Sea. Both the slope and intercept appear to be sensitive to rainfall; the slope (intercept) is higher (lower) during years of stronger monsoon. The observed variability in the  $\delta^{18}\text{O}$ -S relation implies that caution needs to be exercised in paleosalinity estimations, especially from the Bay of Bengal, based on  $\delta^{18}\text{O}$  of marine organisms.

*Key words: Marine Carbon Cycle, Marine Nitrogen Cycle, Nitrogen fixation, The northern Indian Ocean, Rayleigh fractionation, Aerosol deposition, Riverine flux*

## Abbreviations

$\alpha$	fractionation factor between product and source
$\epsilon$	enrichment factor i.e. $(\alpha-1) \times 10^3$
$\delta^{18}\text{O}$	Oxygen isotope composition of water with VSMOW as standard
$\delta^{15}\text{N}$	Nitrogen isotope composition of PON with air as standard
‰	per mil (or parts per thousand)
Anammox	Anaerobic Ammonium Oxidation
DIC	Dissolved Inorganic Carbon
DIN	Dissolved Inorganic Nitrogen
DNRA	Dissimilatory Nitrate Reduction to Ammonium
EA	Elemental Analyzer
EP	Export productivity
FIM	Fall Inter monsoon
FORV	Fishery and Oceanographic Research Vessel
GC	Gas Chromatograph
GNIP	Global Network on Isotopes in Precipitation
HNLC	High-nutrient, low-chlorophyll
IAEA	International Atomic Energy Agency
IAPSO	International Association for the Physical Sciences of the Ocean standard seawater
IPCC	Intergovernmental Panel on Climate Change
IRMS	Isotope Ratio Mass Spectrometer
IRS-P4-OCM	Ocean Colour Monitor on Indian Remote Sensing Satellite IRS-P4
ISRO-GBP	Indian Space Research Organisation - Geosphere Biosphere Programme
ITCZ	Inter Tropical Convergence Zone
JGOFS	Joint Global Ocean Flux Study
JRF	Junior Research Fellow
MLD	Mixed Layer Depth

N <sub>r</sub>	Reactive Nitrogen
N/P	Nitrate to Phosphate ratio
N/Si	Nitrate to Silicate ratio
NARM	Narmada
NCAOR	National Centre for Antarctic and Ocean Research
ND	no data available
NIO	National Institute Of Oceanography
NOAA-AVHRR	National Oceanic and Atmospheric Administration-Advanced Very High Resolution Radiometer
NP	New Productivity
OMZ	Oxygen Minimum Zone
ORV	Oceanographic Research Vessel
PAR	Photosynthetically Active Radiation
POC	Particulate Organic Carbon
POGO	Partnership for Observation of the Global Oceans
PON	Particulate Organic Nitrogen
PP	Primary Productivity
ppmv	parts per million volume
PRL	Physical Research Laboratory
R	Ratio of heavier to lighter isotopes
S	Salinity
SAC	Space Applications Centre
SCOR	Scientific Committee on Oceanic Research
SIM	Spring Inter monsoon
SM	Summer monsoon
SOM	Soil Organic Matter
SST	Sea Surface Temperature
TAD	Total (wet + dry) atmospheric nitrogen deposition

TRMM	Tropical Rainfall Measuring Mission
UNESCO	United Nations Educational, Scientific and Cultural Organization
VSMOW	Vienna Standard Mean Oceanic Water
WM	Winter monsoon
WMO	World Meteorological Organization

# Contents

<b>Acknowledgements</b>	<b>i</b>
<b>Abstract</b>	<b>iv</b>
<b>Abbreviations</b>	<b>vi</b>
<b>List of Figures</b>	<b>xiii</b>
<b>List of Tables</b>	<b>xv</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Marine Nitrogen Cycle . . . . .	2
1.1.1 N <sub>2</sub> fixation . . . . .	2
1.1.2 Nitrification . . . . .	4
1.1.3 Assimilatory nitrate reduction . . . . .	4
1.1.4 Ammonification . . . . .	5
1.1.5 Denitrification . . . . .	5
1.1.6 Anammox . . . . .	5
1.1.7 DNRA . . . . .	6
1.1.8 Nitrate Reduction . . . . .	6
1.2 Ocean-atmosphere-land interaction . . . . .	6
1.2.1 Atmospheric Nitrogen Deposition . . . . .	6
1.2.2 Nitrogen fluxes through rivers . . . . .	7
1.3 Stable Isotopes and their applications . . . . .	8
1.3.1 Rayleigh equation . . . . .	10

## Contents

1.4	The northern Indian Ocean . . . . .	12
1.4.1	Previous studies on N <sub>2</sub> fixation . . . . .	13
1.4.2	Previous studies on Nitrogen inputs through Aerosols and rivers . . . . .	14
1.4.3	Previous studies on $\delta^{18}\text{O}$ -salinity relation . . . . .	15
1.5	Scope of the present work . . . . .	16
1.6	Outline of the thesis . . . . .	17
1.7	Major questions addressed in the present study . . . . .	18
<b>2</b>	<b>Materials and Methods</b>	<b>20</b>
2.1	Estimation of N <sub>2</sub> fixation rates and primary productivity in the ocean	20
2.1.1	Tracer preparation . . . . .	25
2.1.2	Tracer addition . . . . .	25
2.1.3	Incubation . . . . .	26
2.1.4	Filtration and preservation . . . . .	26
2.1.5	Mass spectrometric analysis . . . . .	27
2.1.6	Nutrient measurements . . . . .	33
2.1.7	Experimental precautions . . . . .	33
2.1.8	Uptake rate calculations . . . . .	34
2.1.9	Chlorophyll <i>a</i> measurements . . . . .	36
2.2	Methods to measure $\delta^{18}\text{O}$ of sea water samples . . . . .	36
2.2.1	The CO <sub>2</sub> equilibration method . . . . .	38
2.2.2	Salinity measurement . . . . .	45
2.3	Role of Aerosol deposition and riverine fluxes to new production .	45
2.3.1	Calculation of dry and wet deposition fluxes . . . . .	47
2.3.2	Calculation of new and primary production . . . . .	48
2.3.3	Calculation of riverine fluxes . . . . .	49
<b>3</b>	<b>N<sub>2</sub> fixation and Carbon uptake estimates in the sea water and sediments</b>	<b>52</b>
3.1	N <sub>2</sub> fixation and Carbon uptake rates in the Arabian Sea . . . . .	53
3.1.1	Earlier results on N <sub>2</sub> fixation and primary productivity . . .	55

3.1.2	Environmental conditions during spring 2009 . . . . .	57
3.1.3	Nutrients . . . . .	60
3.1.4	Chlorophyll <i>a</i> . . . . .	62
3.1.5	N <sub>2</sub> fixation and carbon uptake rates . . . . .	62
3.1.6	Nitrogen isotopic composition ( $\delta^{15}\text{N}$ ) of natural surface samples	68
3.1.7	Revising the nitrogen budget . . . . .	69
3.2	N <sub>2</sub> fixation and carbon uptake rates in the Janssand Flat . . . . .	70
3.2.1	N <sub>2</sub> fixation rates . . . . .	71
3.2.2	Carbon uptake rates . . . . .	73
3.2.3	Integrated rates . . . . .	75
3.3	Conclusion . . . . .	75
<b>4</b>	<b>Simulating nitrogen loss in the ocean and its application in other processes</b>	<b>77</b>
4.1	Deriving the equation . . . . .	78
4.2	Simulating denitrification in the Arabian Sea . . . . .	84
4.3	Soil organic matter decomposition . . . . .	86
4.4	$\delta^{18}\text{O}$ -salinity relation in the northern Indian Ocean . . . . .	88
4.4.1	Results . . . . .	90
4.4.2	Discussion . . . . .	94
4.5	Conclusions . . . . .	103
<b>5</b>	<b>An assessment of the contribution of atmospheric and riverine fluxes to new productivity in the northern Indian Ocean</b>	<b>105</b>
5.1	Contribution of atmospheric deposition to new productivity . . . .	105
5.1.1	Classification of Zones . . . . .	108
5.1.2	Seasonal variations in new productivity and atmospheric deposition flux . . . . .	109
5.1.3	Spatiotemporal variations in the productivity and the atmospheric deposition flux . . . . .	114
5.1.4	Contribution of atmospheric nitrogen deposition to new productivity in the northern Indian Ocean . . . . .	115

## Contents

5.1.5	Effect of rainfall variations (including El Nino) on the estimates of wet deposition flux and new productivity . . . . .	117
5.1.6	Relationship between new productivity and the flux of reactive nitrogen through atmospheric deposition . . . . .	118
5.1.7	Changes in the Redfield Ratio and biodiversity . . . . .	119
5.1.8	Synthesis of the available estimates . . . . .	120
5.1.9	Other nitrogen sources to the Arabian Sea . . . . .	121
5.1.10	Other nitrogen sources to the Bay of Bengal . . . . .	121
5.2	Contribution of riverine fluxes to new productivity . . . . .	122
5.2.1	Bay of Bengal . . . . .	125
5.2.2	Arabian Sea . . . . .	129
5.2.3	Riverine flux versus coastal upwelling . . . . .	131
5.2.4	Submarine ground water discharge . . . . .	132
5.2.5	Changes in the Redfield Ratio and biodiversity . . . . .	132
5.3	Conclusion . . . . .	133
<b>6</b>	<b>Summary and scope for future work</b>	<b>135</b>
6.1	Results from the N <sub>2</sub> fixation experiments . . . . .	135
6.2	Results from Simulation of nitrogen loss in the ocean . . . . .	136
6.3	Results from atmospheric and riverine fluxes . . . . .	137
6.4	Scope for future work . . . . .	139
	<b>References</b>	<b>141</b>
	<b>Publications</b>	<b>159</b>



# List of Figures

1.1	Nitrogen Cycle . . . . .	3
2.1	Sampling locations in the Arabian Sea during spring . . . . .	21
2.2	Blooms observed during the sampling period . . . . .	22
2.3	Sampling locations in the Janssand Flat . . . . .	23
2.4	CTD rosette sampler . . . . .	24
2.5	GC-IRMS at the University of Agricultural Sciences, Bengaluru . .	27
2.6	Elemental Analyzer interfaced with IRMS . . . . .	29
2.7	Calibration Plots . . . . .	32
2.8	Sampling locations of surface water samples collected for isotopic measurements and salinity . . . . .	37
2.9	WES System . . . . .	39
2.10	Gilson needle . . . . .	40
2.11	Inlet Part . . . . .	41
2.12	Locations of deposition flux measurements . . . . .	46
2.13	Locations of primary productivity measurements . . . . .	46
2.14	Locations of new productivity measurements . . . . .	50
3.1	Depth profiles of PAR at various stations . . . . .	58
3.2	Depth profiles of salinity and Temperature . . . . .	59
3.3	Depth profiles of Nutrients . . . . .	61
3.4	Depth profiles of N <sub>2</sub> fixation and primary productivity . . . . .	63
3.5	Integrated uptake rates . . . . .	66
3.6	Nitrogen fixation rates . . . . .	72

## List of Figures

3.7	Carbon uptake rates . . . . .	74
4.1	Example 1 . . . . .	81
4.2	Example 2 . . . . .	82
4.3	Example 3 . . . . .	83
4.4	Denitrification in the ocean . . . . .	85
4.5	Soil organic matter decomposition . . . . .	87
4.6	$\delta^{18}\text{O}$ -salinity relation in the northern Indian Ocean . . . . .	93
4.7	Simulating $\delta^{18}\text{O}$ -salinity relation in the northern Indian Ocean . . .	97
4.8	$\delta^{18}\text{O}$ -salinity relation at deeper depths . . . . .	100
4.9	Relationship between rainfall and slope and intercept of the $\delta^{18}\text{O}$ - salinity relation . . . . .	102
5.1	Deposition flux estimates . . . . .	112
5.2	New productivity estimates . . . . .	113
5.3	Relationship between atmospheric deposition and new productivity	119
5.4	DIN fluxes to the Bay of Bengal . . . . .	129
5.5	DIN fluxes to the Arabian Sea . . . . .	130

# List of Tables

2.1	Precision of isotopic measurements . . . . .	31
2.2	Reproducibility Table . . . . .	44
2.3	Comparing the results . . . . .	45
3.1	Environmental conditions during spring 2009 in the Arabian Sea . .	58
3.2	Nitrogen Budget . . . . .	69
3.3	Integrated N <sub>2</sub> fixation and carbon uptake rates . . . . .	75
4.1	$\delta^{18}\text{O}$ -salinity relation in the northern Indian Ocean . . . . .	91
4.2	Model results . . . . .	98
5.1	Nitrogen deposition flux . . . . .	110
5.2	Nitrogen deposition flux . . . . .	111
5.3	Riverine nitrogen fluxes in the course river . . . . .	126
5.4	Riverine nitrogen fluxes in the rivermouths/estuary . . . . .	127