SEASONAL VARIABILITY OF CARBON FLUX IN THE NORTH-EASTERN BAY OF BENGAL: SEASONAL CARBON ABSORPTION

Md Ariful Islam Milon

Roll No.: 0120/03

Registration No.: 851

Session: 2020-2021

A thesis submitted in the partial fulfillment of the requirements for the degree of Master of Science in Marine Bioresource Science

Department of Marine Bioresource Science

Faculty of Fisheries

Chattogram Veterinary and Animal Sciences University

Chattogram-4225, Bangladesh

AUGUST 2022

Authorization

I hereby declare that I am the sole author of the thesis. I also authorize the Chattogram Veterinary and Animal Sciences University (CVASU) to lend this thesis to other institutions or individuals for the purpose of scholarly research. I further authorize the CVASU to reproduce the thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

I, the undersigned, and author of this work, declare that the **electronic copy** of this thesis provided to the CVASU Library, is an accurate copy of the print thesis submitted, within the limits of the technology available.

Md Ariful Islam Milon

August 2022

SEASONAL VARIABILITY OF CARBON FLUX IN THE NORTH-EASTERN BAY OF BENGAL: SEASONAL CARBON ABSORPTION

MD ARIFUL ISLAM MILON

Roll No.: **0120/03**

Registration No.: **851**

Session: **2020-2021**

This is to certify that we have examined the above Master's thesis and have found that is complete and satisfactory in all respects and that all revisions required by the thesis examination committee have been made.

……...	
Sumi Akter	**Avijit Talukder**
Supervisor	**Co-supervisor**

……...

Dr. Md Sadequr Rahman Khan

Chairman of the Examination Committee

Department of Marine Bioresource Science

Faculty of Fisheries

Chattogram Veterinary and Animal Sciences University

Khulshi, Chattogram-4225, Bangladesh

AUGUST 2022

DEDICATED

TO

MY BELOVED PARENTS AND

FAMILY MEMBERS

ACKNOWLEDGMENT

First and foremost, all the praises are for the almighty **Allah,** who gave me the ability and strength to accomplish this internship program along with the report due time.

I would like to convey my earnest gratitude to my parents, **Md Abdul Quddus** and **Mst Mahera Khatun,** who brought me into the light of earth and nursed me with all the facilities to be succeeded in life. Also, thanks to my other family members for their selfless love, blessing care, dedicated effort, valuable prayer, and continuous support during the academic period.

I sincerely express my intense gratitude to the honorable Vice-Chancellor, **Professor Dr. A.S.M Lutful Ahasan**, and **Professor Dr. Mohammed Nurul Absar Khan,** Dean, Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, for arranging and offering me all administrative support to complete my master's thesis research work.

The author would like to express his deepest sense of gratitude, profound regrets, and indebtedness to his research supervisor **Ms. Sumi Akter**, Assistant Professor, Department of Marine Bioresource Science, Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, for her co-operation, constant inspiration and indomitable guidance throughout the period of research work.

The author finds it a great pleasure in expressing his heartfelt gratitude to his research co-supervisor **Avijit Talukder**, Associate Professor, Department of Marine Bioresource Science, Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, for his sympathy, sincere cooperation, inspiration, fantabulous and well-planned guidance and valuable suggestions for the competition of the research work.

The author thankful from the core of my heart to **Mohammad Dr. Sadequr Rahman Khan**, Associate Professor and Head, Department of Marine Bioresources Science, Chattogram Veterinary and Animal Sciences University for his fantabulous, well-planned guidance and support during in the research period.

The author is glad to take the opportunity to express his heartfelt gratitude to all his other respected teachers of the Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, for their valuable teaching and encouragement.

The author would like to convey profound gratitude to **Mehrab Souhardya** and **Mishu Acharjee** for their support and valuable suggestions for completing the research work.

I also acknowledge the Lab assistants, Technicians, and other supporting staff of the Oceanography lab, the Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University for their help and co-operation during lab work.

The Author

Md Ariful Islam Milon

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE NO.
	AUTHORIZATION	II
	ACKNOWLEDGMENT	V-VI
	LIST OF TABLES	X
	LIST OF FIGURES	XI-XIII
	LIST OF APPENDICES	XIV
	LIST OF ABBREVIATIONS	XV-XVI
	ABSTRACTS	XVII
1	INTRODUCTION	1-5
	1.1 Background	1-3
	1.2 Statement of the problems	3
	1.3 Significance of the study	4
	1.4 Objectives	5
2	REVIEW OF LITERATURE	6-10
3	MATERIALS AND METHODS	11-26
	3.1 Research boundary	11
	3.2 Sampling frequency	12
	3.3 Analysis of coastal and oceanic productivity	12
	3.3.1 Water sample collection for SETCOL	12
	3.3.2 SETCOL procedure	13
	3.3.3 Chlorophyll-a measurement	14-15
	3.3.4 Phytoplankton sinking rate measurement	16
	3.3.5 Phytoplankton sample collection and analysis	16-17
	3.3.6 Qualitative and quantitative estimations of phytoplankton	17-19
	3.3.7 Total carbon estimation in each cell and a specific depth	19-21

	3.3.8 Carbon flux determination	**21**
	3.4 Nutrients components analysis	**21-24**
	3.4.1 Nitrite-nitrogen (NO_2-N)	**21-22**
	3.4.2 Phosphate-Phosphorus (PO_4-P)	**22-23**
	3.4.3 Silicate-Silicon (SiO_3-Si)	**23**
	3.4.4 Nitrate-nitrogen (NO_3-N):	**23-24**
	3.5 Analysis of Physico-chemical water quality parameters:	**24-26**
	3.5.1 Onsite analysis of hydro-meteorological parameters	**24-25**
	3.5.2 Laboratory analysis of hydro-meteorological parameters	**25-26**
	4. Statistical data analysis	**26**
4	**RESULTS**	**27-56**
	4.1 Ocean and coastal productivity	**27**
	4.1.1 Chlorophyll-a (Chl-a)	**27-28**
	4.1.2 Phytoplankton sinking rate (PSR)	**28-29**
	4.1.3 Phytoplankton density (Pl. den)	**29-30**
	4.1.4 Total carbon (TC)	**30-31**
	4.1.5 Carbon Flux (CF)	**31-32**
	4.2 Nutrients components availability	**32-36**
	4.2.1 Nitrate nitrogen (NO_3-N)	**32-33**
	4.2.2 Nitrite-Nitrogen (NO_2-N)	**33-34**
	4.2.3 Phosphate-phosphorus (PO_4-P)	**34-35**
	4.2.4 Silicate-silicate (SiO_3-Si)	**36**
	4.3 Water physicochemical parameters	**37-45**
	4.3.1 Water temperature	**37**
	4.3.2 Water salinity	**38**
	4.3.3 Sodium chloride percentage (NaCl %)	**39**
	4.3.4 Water pH	**40**

	4.3.5 Dissolved Oxygen (DO)	**41**
	4.3.6 Total dissolved solids (TDS)	**42**
	4.3.7 Total suspended solids (TSS)	**43**
	4.3.8 Turbidity (Turb)	**44**
	4.3.9 Electric conductivity (EC)	**45**
	4.4 Principal components analysis (PCA)	**49-56**
	4.4.1 Season-wise Principle Component Analysis of Physico-chemical parameters	**51-52**
	4.4.2 Station-wise principle component analysis (PCA) of Physico-chemical parameters	**52-53**
	4.4.3 Transect-wise principle component analysis (PCA) of Physico-chemical parameters	**54-55**
	4.4.4 Depth-wise principle component analysis (PCA) of Physico-chemical parameters	**55-56**
5	**DISCUSSION**	**57-64**
	5.1 Ocean and coastal productivity	**57-59**
	5.2 Nutrient components	**59-60**
	5.3 Water physicochemical parameters	**60-63**
	5.4 Principal Component Analysis (PCA) discussion among season, station, transect, and depth	**63-64**
6	**CONCLUSION**	**65**
7	**RECOMMENDATION AND FUTURE PERSPECTIVES**	**66**
	REFERENCES	**67-76**
	APPENDICES	**77-78**

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
1	Comparison of water quality parameters in four seasons using two-way ANOVA	**46**
2	Comparison of water quality parameters in two station using two-way ANOVA	**46-47**
3	Comparison of water quality parameters in four transects using two-way ANOVA	**47**
4	Comparison of water quality parameters in three depths using two-way ANOVA	**48**
5	Maximum and minimum value range of physico-chemical parameters	**48-49**
6	Kaiser-Meyer-Olkin Measure and Bartlett's Test of Sphericity.	**50**
7	Component variation in Principal Component Analysis (PCA).	**50**

LIST OF FIGURE

FIGURE NO.	TITLE	PAGE NO.
1.	The geographical location of Sonarpara (Cox's Bazar) and Kutubdia station.	**12**
2.	The sequence of water sample collection for SETCOL bottle.	**13**
3.	SETCOL bottle and different layer of bottle.	**14**
4.	The sequence of Chlorophyll-a measurement.	**15**
5.	The sequence of phytoplankton sample filtration and collection.	**17**
6.	The Sequence of phytoplankton counting and identification.	**19**
7.	The sequence of microscope calibration for biovolume measurements.	**20**
8.	Chlorophyll-a fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate mean value.	**28**
9.	Phytoplankton sinking rate fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate median value and red line indicate the mean value.	**29**
10.	Phytoplankton density fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate median value and red line indicate the mean value.	**30**
11.	Total carbon content fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate mean value.	**31**
12.	Carbon flux fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate median value and red line indicate the mean value.	**32**
13.	Nitrate nitrogen fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate median value and red line indicate the mean value.	**33**
14.	Nitrite-Nitrogen (NO_2-N) fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate mean value.	**34**
15.	Phosphate-phosphorus a fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate median value and red line indicate the mean value.	**35**

16.	Silicate-silicate (SiO_3-Si) fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate mean value.	**36**
17.	Water temperature fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate mean value.	**37**
18.	Water salinity fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate median value and red line indicate the mean value.	**38**
19.	Sodium chloride (NaCl %) a fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate mean value.	**39**
20.	Water pH fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate median value and red line indicate the mean value.	**40**
21.	Dissolved Oxygen (DO) fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate mean value.	**41**
22.	Total dissolved solids fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate median value and red line indicate the mean value.	**42**
23.	Total suspended solids fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate mean value.	**43**
24.	Water turbidity fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate median value and red line indicate the mean value.	**44**
25.	Electric conductivity fluctuation in northeastern BoB, A) Seasonal variation, B) Station-wise variation, C) Transect-wise variation, D) Depth-wise variation and black line indicate mean value.	**45**
26.	Correlation among different parameters.	**49**
27.	Scree plot of Principal Component Analysis (PCA).	**50**
28.	PCA biplot describing the season-wise correlation **a)** PC1 and PC2, **b)** PC3 and PC4	**51-52**

29.	PCA biplot describing the station-wise correlation **a)** PC1 and PC2, **b)** PC3 and PC4	**53**
30.	PCA biplot describing the transect-wise correlation **a)** PC1 and PC2, **b)** PC3 and PC4	**54-55**
31.	PCA biplot describing the depth-wise correlation **a)** PC1 and PC2, **b)** PC3 and PC4	**56**

LIST OF APPENDICS

APPENDIX	TITLE	PAGE NO.
A.	A book used for cell biovolume measurement.	**77**
B.	Observed phytoplankton community during study period.	**78**

LIST OF ABBREVIATION

Abbreviations	Meaning
SETCOL	Settling Column
ppt	Parts Per Thousands
^{o}C	Degree Celsius
M	Mean
SD	Standard Deviation
min	Minutes
NaCl %	Sodium Chloride Percentage
pH	Negative Logarithm of H^{+} concentration
chl-a	Chlorophyll-a
ANOVA	Analysis of Variance
NTU	Nephelometric Turbidity Unit
m	Meter
mS/cm	Millisiemens Per Centimeter
g/l	Gram Per Liter
psu	Practical Salinity Unit
Cells/l	Cells per liter
ppm	Parts Per Million
m day^{-1}	Meter Per Day
et at.	And His Associates
%	Percentage
µg	Microgram
µg/l	Microgram Per Liter
v/v	Volume per volume
mg C m^{-2} day^{-1}	Milligram Carbon per meter square per day
Gt C yr^{-1}	Gigatons Carbon per year
km^2	Square Kilometer
L	Liters
$µm^3$	Micro cubic meter
ml	Milliliter
RPM	Revolutions per minute
mm	Millimeters
Pg C/Cell	Pico-gram Carbon per cell
mg/l	Milligram per liter
cm	Centimeter
nm	Nanometers
mg/m^{-3}	Milligram per cubic meters
NS	No significance difference
Sig.	Significance difference
POC	Particulate organic carbon

DOC	Dissolved organic carbon
>	Greater than
<	Less than
PC	Principle component
S1	Winter season
S2	Pre-monsoon season
S3	Monsoon season
S4	Post-monsoon season
St1	Cox’s Bazar
St2	Kutubdia
T1	Transect point-1 (Cox’s Bazar)
T2	Transect point-2 (Cox’s Bazar)
T3	Transect point-3 (Kutubdia)
T4	Transect point-4 (Kutubdia)
D1	0 meter/ surface water
D2	5 meter
D3	10 meter
MS	Master of Science
BoB	Bay of Bengal

ABSTRACT

Carbon dioxide emissions are the major contributor to global climate change. Increases of CO_2 in atmosphere rise surrounding environment temperature and ocean acidification. By photosynthetic activity phytoplankton are responsible to remove CO_2 from atmosphere. Globally 50% of carbon sinks into the ocean via process called biological pump. This research was conducted over four major seasons in the northeastern Bay of Bengal to measure the seasonal variation of carbon flux. An associated factor of carbon flux was the phytoplankton sinking rate determined by SETCOL method. The carbon flux showed that the monsoon season act as the major contributor to carbon flux (2.52 ± 2.33 mg C m^{-2} day^{-1}), followed by 2.03 ± 1.73 mg C m^{-2} day^{-1} in the winter season, whereas 1.65 ± 1.56 mg C m^{-2} day^{-1} and 1.56 ± 0.86 mg C m^{-2} day^{-1} found during pre-monsoon and post-monsoon season respectively. The data also demonstrated that the Kutubdia station exchanged more carbon than Cox's Bazar station. Carbon flux correlated with the turbidity, SiO_3-Si, PO_4-P, total suspended solids, plankton density, phytoplankton sinking rate, and carbon content. Carbon flux negatively correlated nutrients (NO_2-N, NO_3-N) and positively related with SiO_3-Si, PO_4-P. ANOVA test showed carbon flux significantly differs among depths [$F(1, 2) = 3.811$, $p<0.05$]. Carbon flux-related factor phytoplankton sinking rate significantly varied with depth change and ranged from 0.04 to 1.86 m day^{-1}. Major seasonal carbon sinking rate was observed in the winter season as 0.57 ± 0.52 m day^{-1}. Phytoplankton sinking rate was correlated with nutrients, salinity, total suspended solids, total dissolved solids, and conductivity. This research finding gives us an understanding of seasonal carbon flux variation contributed by phytoplankton and demonstrated daily carbon sequestration in the northeastern Bay of Bengal and correlated with various biogeochemical factors.

Keywords: Phytoplankton, sinking rate, seasonal variation, carbon flux