TABLE OF CONTENTS

		Page
Abstract		i
Résumé		iii
Acknowledgements		vii
List of Abbreviations		xi
Chapter 1	**Introduction**	**1**
1.1	**Marine Phytoplankton**	**2**
1.2	**Iron Biogeochemistry in the Ocean**	4
1.2.1	Iron Hypothesis	5
1.2.2	Iron Sources to the Oceans	6
1.2.3	Iron Speciation and Chemistry	7
1.3	**Nitrogen Fixation**	**8**
1.3.1	Oceanic Nitrogen Cycle	9
1.3.2	Nitrogen Fixers	10
	1.3.2.1 Nitrogenase	11
	1.3.2.2 Environmental Controls	12
1.4	**Climate Change**	**14**
1.4.1	Dust Deposition	15
1.4.2	Ocean Acidification	19
1.4.3	Ocean Warming	25
1.5	**Thesis Objectives and Outline**	**29**
Chapter 2	**Material and Methods**	**33**
2.1	**Dissolved Inorganic Carbon System**	**34**
2.1.1	Total Alkalinity	34
2.1.2	pH	36
2.1.3	In situ pCO_2	36
2.2	**Phytoplankton Growth Parameters**	**37**
2.2.1	Fluorescence	37
2.2.2	Cell Abundance	38
2.2.3	Chl-a Concentrations	38
2.3	**Nutrients Analyses**	**39**
2.3.1	Dissolved Nitrate	39

Page

2.3.2 Dissolved Phosphate 40
2.3.3 Dissolved Silicate 40
2.4 Ferrozine Method 41
2.4.1 Theory 41
2.4.2 Reagents 43
2.4.3 Procedure 43
2.4.4 Linear Ranges of the Method 44
2.4.5 Salt and EDTA Effects 45
2.5 Biogenic Silica 47
2.6 Particulate Organic Carbon and Nitrogen 48
2.7 N_2 Fixation 48
2.7.1 Theory 48
2.7.2 Preparation of $^{15}N_2$-enriched Seawater 50
2.7.3 $^{13}C/^{15}N$ Enrichment in DIC ($\delta^{13}C$-DIC) / N_2 ($\delta^{15}N$-N_2) Pools 50
2.7.4 Calculation of N_2 and C Fixation Rates 51
2.8 Statistical Analyses 51

Chapter 3 Biological Responses of the Marine Diatom *Chaetoceros socialis* to Changing Environmental Conditions 53

3.1 Culture Experimental Design 54
3.1.1 The Strain Information 54
3.1.2 Medium Preparation 55
3.1.3 Desert Dust 56
3.1.4 Experimental Setup 58
3.1.5 Statistical Treatment of Data 60
3.2 Results 60
3.2.1 Carbonate Chemistry System 60
3.2.2 Effects of Dust Addition 61
3.2.3 Effects of Ocean Warming and Acidification 64
3.3 Discussion 67
3.3.1 Dust Deposition 67
3.3.2 Ocean Acidification 70
3.3.3 Ocean Warming 72
3.3.4 The Effects of Climate Change on Nutrients Cycles 75
3.4 Conclusions 77

Page

Supplementary Materials 78

Chapter 4 Nutrient Limitation on *Trichodesmium* IMS101 83

4.1 Culture Experimental Design 84
4.1.1 The Strain Information 84
4.1.2 Medium Preparation 86
4.1.3 Experimental Setup 87
4.1.4 Statistical Treatment of Data 89
4.2 Results 89
4.2.1 Fe Addition Bioassay Experiments 89
4.2.2 PO4 Addition Bioassay Experiments 92
4.2.3 Dust Addition Bioassay Experiments 95
4.3 Discussion 99
4.3.1 Fe Limitation 99
4.3.2 P Limitation 100
4.3.3 Dust Deposition 101
4.4 Conclusions 103

Chapter 5 CO_2 and Temperature Control on *Trichodesmium* IMS101 105

5.1 Culture Experimental Design 106
5.1.1 Stock Cultures 106
5.1.2 Experimental Cultures 108
5.1.3 Statistical Treatment of Data 110
5.2 Results 111
5.2.1 Growth Rates 111
5.2.2 POC and PN Production Rates 112
5.2.3 N_2 and C Fixation Rates 113
5.2.4 PO4 and Fe Uptake Rates 115
5. 3 Discussion 115
5.3.1 Effects of Ocean Acidification 115
5.3.2 Effects of Ocean Warming 117
5.4 Conclusions 119

Chapter 6 Marine N_2 fixation in the Temperate Northeast Atlantic: Role of Fe 121

Page

6.1 Material and Methods 122
6.1.1 Study Site 122
6.1.2 Seawater Sampling 123
6.1.3 On-board Incubation Experiments 124
6.2 Results 125
6.2.1 Biogeochemical Environmental Settings 125
6.2.2 Natural N_2 Fixation 128
6.2.3 UCYN Abundance 130
6.2.4 Fe Addition 130
6.3 Discussion 131
6.3.1 Fe Limitation in the Temperate Atlantic Ocean 131
6.3.2 Importance of UCYN in the Temperate Atlantic Ocean 133
6.4 Conclusions 135

Chapter 7 General Remarks & Conclusions 137
7.1 Future Ocean 138
7.2 Biological Responses to Future Ocean 140
7.2.1 Impacts of Dust Deposition 140
7.2.2 Impacts of Ocean Acidification 141
7.2.3 Impacts of Ocean Warming 142
7.3 Role of Iron 144
7.4 Perspectives 145

References 147

Appendices 167
Appendix 1: Curriculum Vitae 169
Appendix 2: 6th International SOLAS Summer School 2013 173
Appendix 3: IMBER Open Science Conference 2014 174
Appendix 4: SOLAS Open Science Conference 2015 175
Appendix 5: EGU General Assembly 2016 176
Appendix 6: Goldschmidt Conference 2017 177
Appendix 7: Open access research article published in *PLoS ONE* 178
Appendix 8: Manuscript submitted to *Progress in Oceanography* 179
Appendix 9: Statistical Tables 207