

# Contents

Preface — V

List of contributing authors — XV

Josefin C. Comiso

1 **Variability and trends of global sea ice cover and sea level: effects on physicochemical parameters — 1**

- 1.1 Introduction — 1
- 1.2 Variability and trends of global sea ice — 2
- 1.2.1 Arctic Region — 5
- 1.2.2 Antarctic Region — 8
- 1.3 Variability and trends in sea level — 12
- 1.3.1 Contributions from warming oceans — 13
- 1.3.2 Contributions from glaciers, ice sheets and others — 15
- 1.4 Effects on physicochemical parameters — 19
- 1.4.1 Large-scale changes in surface temperature — 19
- 1.4.2 Large-scale changes in plankton concentration and primary productivity — 20
- 1.4.3 Changes in other physicochemical parameters — 26
- 1.5 Discussion and conclusions — 29

Begoña Espiña, Marta Prado, Stephanie Vial, Verónica C. Martins, José Rivas, and Paulo P. Freitas

2 **New techniques in environment monitoring — 35**

- 2.1 Introduction — 35
- 2.2 *In situ* harmful algal bloom monitoring — 36
- 2.2.1 Optical remote sensing — 36
- 2.2.2 Automated monitoring — 38
- 2.2.3 HABs sampling based on absorption — 42
- 2.3 Liquid chromatography and mass spectrometry — 44
- 2.4 Biosensors for HABs monitoring — 46
- 2.4.1 Optical biosensors — 49
- 2.4.2 Electrochemical biosensors — 51
- 2.4.3 Mass biosensors — 51
- 2.4.4 Magnetic-based biosensors — 52
- 2.5 Advances in nanotechnology for HAB detection — 53
- 2.5.1 Nanoparticles — 54
- 2.5.2 Analytical nano-applications — 55
- 2.6 Molecular biology-based techniques for HABs detection — 64

2.6.1	Overview — 64
2.6.2	DNA/RNA targets — 65
2.6.3	Hybridization-based techniques — 70
2.6.4	Amplification-based techniques — 72
2.6.5	Aptamers for toxin detection — 75
2.7	Future perspectives — 76

**Mikko Nikinmaa and Katja Anttila**

<b>3</b>	<b>Responses of marine animals to ocean acidification — 99</b>
3.1	Introduction — 99
3.2	What causes ocean acidification — 99
3.2.1	Effect of atmospheric carbon dioxide loading — 100
3.2.2	Influence of primary production — 101
3.2.3	Carbon balance in coastal areas — 101
3.2.4	Interactions between temperature changes and ocean acidification — 102
3.3	Processes of animals that are expected to be affected — 102
3.3.1	pH regulation — 102
3.3.2	Calcification — 107
3.3.3	Development — 108
3.3.4	Oxygen transport and metabolism — 110
3.3.5	Behavior — 114
3.4	Conclusions — 115

**Shauna Murray, Uwe John, and Anke Kremp**

<b>4</b>	<b><i>Alexandrium</i> spp.: genetic and ecological factors influencing saxitoxin production and proliferation — 125</b>
4.1	Introduction — 125
4.2	<i>Alexandrium</i> taxonomy, phylogenetics and species evolution — 126
4.3	What are saxitoxins? — 129
4.3.1	Which species produce saxitoxins? — 130
4.3.2	The <i>sxt</i> genes in dinoflagellates — 131
4.4	Ecological factors influencing <i>Alexandrium</i> spp. proliferation and toxicity — 133
4.4.1	The role of ecophysiological adaptations in ecology and bloom formation of <i>Alexandrium</i> life cycles — 133
4.4.2	Mixotrophic nutrition — 133
4.4.3	Allelopathy — 134
4.5	Effects of environmental factors on <i>Alexandrium</i> proliferation and toxicity — 135
4.5.1	Nutrients — 135
4.5.2	Temperature — 135

4.5.3	CO <sub>2</sub> — 138
4.5.4	Salinity — 139
4.6	Adaptation to changing climate conditions — 141
 Susanna A. Wood, Jonathan Puddick, Hugo Borges, Daniel R. Dietrich, and David P. Hamilton	
5	<b>Potential effects of climate change on cyanobacterial toxin production — 155</b>
5.1	Introduction — 155
5.1.1	Microcystins and nodularins — 156
5.1.2	Cylindrospermopsins — 157
5.1.3	Saxitoxins — 157
5.1.4	Anatoxin-a and homo-anatoxin-a — 157
5.1.5	Anatoxin-a(S) — 158
5.1.6	Lipopolysaccharides (LPS) — 158
5.2	Effects of climate change on common toxin producing species — 159
5.2.1	Microcystis — 160
5.2.2	Cylindrospermopsis — 161
5.2.3	Dolichospermum — 161
5.2.4	Planktothrix — 162
5.2.5	Phormidium — 163
5.3	Effects of climate change on toxin regulation — 164
5.3.1	Microcystins — 164
5.3.2	Nodularins — 166
5.3.3	Cylindrospermopsins — 166
5.3.4	Saxitoxins — 167
5.3.5	Anatoxins — 167
5.4	Climate change and its effect on cyanobacteria and toxin production in Polar environments — 168
5.5	Conclusions — 170
 Gustaaf M. Hallegraeff	
6	<b>Harmful marine algal blooms and climate change: progress on a formidable predictive challenge — 181</b>
6.1	Introduction — 181
6.2	Algal bloom range extensions and climate change — 182
6.3	Range extensions further aided by ship ballast water transport — 184
6.4	The formidable challenge of predicting phytoplankton community responses — 187
6.5	We can learn from the fossil record, long-term plankton records and decadal scale climate events — 188
6.6	Mitigation of the likely impact on seafood safety — 188

**Elke S. Reichwaldt, Som Cit Sinang, and Anas Ghadouani**

<b>7</b>	<b>Global warming, climate patterns and toxic cyanobacteria — 195</b>
7.1	Introduction — 195
7.2	The effect of global warming on inland water bodies — 196
7.2.1	Direct effects of global warming on inland water bodies — 196
7.2.2	Indirect effects of global warming on inland water bodies — 197
7.3	The ecology of cyanobacteria and toxin production — 203
7.3.1	Environmental factors affecting cyanobacterial biomass — 203
7.3.2	Environmental factors affecting microcystin production — 204
7.3.3	Ecological factors affecting cyanobacterial blooms: competition — 206
7.4	Direct and indirect effects of global warming on cyanobacterial growth — 208
7.4.1	Temperature, stratification, and mixing — 215
7.4.2	Nutrients — 216
7.4.3	Salinity — 217
7.4.4	Turbidity and pH — 217
7.5	Direct and indirect effects of global warming on microcystin concentration — 217
7.6	Why should we care? — 219

**Aristidis Vlamis and Panagiota Katikou**

<b>8</b>	<b>Human Impact in Mediterranean coastal ecosystems and climate change: emerging toxins — 239</b>
8.1	Introduction — 239
8.2	Mediterranean coastal ecosystems — 240
8.2.1	Human impact — 242
8.2.2	Socio-economical implications of Climate Change — 244
8.2.3	Effect to ecosystem from extreme events of climate change — 245
8.2.4	Ecological response to Climate Change — 246
8.3	Emerging toxins in the Mediterranean Sea — 248
8.3.1	Identified emerging toxins and climate change effects — 249
8.4	Conclusion — 259

**Gurjeet S. Kohli, Hazel Farrell, and Shauna A. Murray**

<b>9</b>	<b><i>Gambierdiscus</i>, the cause of ciguatera fish poisoning: an increased human health threat influenced by climate change — 273</b>
9.1	The genus <i>Gambierdiscus</i> — 273
9.2	Morphology and phylogenetics — 274
9.3	Geographic distribution and abundance — 279
9.3.1	The Pacific and Indian Ocean Regions — 282
9.3.2	The Atlantic Ocean Region — 282
9.4	CTXs and MTXs — 283

9.5	Toxicity of different species of <i>Gambierdiscus</i> — 288
9.6	Detection of CTXs and MTXs in seafood — 289
9.7	Conclusion — 303

Dani J. Barrington, Xi Xiao, Liah X. Coggins, and Anas Ghadouani

**10 Control and management of Harmful Algal Blooms — 313**

10.1	Introduction — 313
10.2	Global water crisis — 313
10.3	Cyanobacteria and cyanotoxins — 314
10.4	Cyanobacterial prevention and mitigation — 315
10.5	Cyanobacterial management — 320
10.6	Case study: The management of cyanobacteria in waste stabilization ponds — 323
10.7	Treatment of cyanobacteria and cyanotoxins with hydrogen peroxide — 326
10.8	New techniques for the control and characterization of cyanobacterial blooms — 335
10.8.1	Allelopathic control of cyanobacteria — 335
10.8.2	Optimization of the FDA-PI method using flow cytometry to measure metabolic activity of cyanobacteria — 336
10.9	New perspectives and future directions — 338

Joaquín Espinosa, Sara Silva-Salvado, and Óscar García-Martín

**11 Global climate change profile and its possible effects on the reproductive cycle, sex expression and sex change of shellfish as marine toxins vectors — 359**

11.1	Introduction — 359
11.2	Shellfish as marine toxins vectors — 360
11.2.1	General considerations — 360
11.2.2	Global increase in HABs — 362
11.2.3	Global climate change — 365
11.3	Reproductive cycle, sex expression and sex change in shellfish — 378
11.3.1	Reproductive cycle, reproductive period and sex expression in bivalve mollusks — 378
11.3.2	What is sex? — 379
11.3.3	Sex determination: everything happens in the embryo — 380
11.3.4	Sex determination of the gonad and sex differentiation of primordial germ cells (PGCs): molecular basis and regulation — 381
11.3.5	Gonad somatic sex and germline sex in bivalve mollusks — 382
11.3.6	Sex, sex reversal, types of sexuality and sex change in bivalve mollusks — 384

- 11.3.7 What does sex change mean and how could this process be performed by bivalve mollusks? — 391
- 11.3.8 Temperature, photoperiod, reproductive cycle and sex change in bivalve mollusks — 393
- 11.3.9 Climate change, reproductive cycle, sex expression and sex change in bivalve mollusks — 398
- 11.4 Concluding remarks — 402

M. Carmen Louzao, Natalia Vilariño, and Luis M. Botana

- 12 Effects on world food production and security — 417
  - 12.1 Introduction — 417
  - 12.2 Foodborne and waterborne diseases — 417
  - 12.3 Zoonosis and other animal diseases — 418
  - 12.4 Product safety in fisheries — 419
  - 12.5 Aquaculture food production — 423
  - 12.6 Harmful algal blooms — 423
  - 12.6.1 Impact of temperature change on harmful algal blooms — 424
  - 12.6.2 Acidification of waters and effect on harmful algal blooms — 426
  - 12.6.3 Impact of sea-level rise and increased precipitation on harmful algal communities — 426
  - 12.6.4 Microalgal toxicity — 427
  - 12.7 Harmful algal blooms and aquatic food safety — 428
  - 12.7.1 Predictive modeling — 433
  - 12.8 Future perspectives — 434

Natalia Vilariño, M. Carmen Louzao, Marfa Fraga, and Luis M. Botana

- 13 From science to policy: dynamic adaptation of legal regulations on aquatic biotoxins — 441
  - 13.1 Introduction — 441
  - 13.2 Current worldwide regulations on marine phycotoxins — 441
  - 13.2.1 Maximum permitted levels — 441
  - 13.2.2 Official detection methods — 446
  - 13.3 Current worldwide regulations on cyanotoxins — 447
  - 13.4 New occurrences of toxic episodes challenge protection of consumer's safety — 455
  - 13.5 Limitations for the development and implementation of new regulations: from science to policy or from policy to science? — 457
    - 13.5.1 Technical limitations for recent/future toxin regulations — 457
    - 13.5.2 Toxicological limitations for new toxin regulations — 461
    - 13.5.3 Economic limitations — 465
  - 13.6 Modification of monitoring and surveillance programs — 466

- 13.7      **Integrative example: tetrodotoxin as a biomarker of climate change — 467**
- 13.8      **Concluding remarks — 470**

**Index — 483**