Contents

1 Introduction: Coral Bleaching - Patterns, Processes, Causes and Consequences 1
J.M. Lough and M.J.H. van Oppen

References 4

2 The Evolution of the Coral–Algal Symbiosis 7
G.D. Stanley Jr and B. van de Schootbrugge

2.1 Introduction. 7
2.2 Detecting Photosymbiosis in the Fossil Record. 8
2.3 Mesozoic Reefs and Coral Evolution. 9
2.4 The Suessiaceae: Late Triassic Dinoflagellate Symbionts? 13
2.5 Geological Perspectives on Current Coral Bleaching 16
References 17

3 Coral Bleaching in Space and Time. 21
J.K. Oliver, R. Berkelmans, and C.M. Eakin

3.1 Introduction. 21
3.1.1 Early Bleaching Records (Pre-1982) 22
3.1.2 Bleaching Records from 1982 Onwards. 23
3.2 Global Patterns of Coral Bleaching 25
3.2.1 Temporal Patterns 25
3.2.2 Spatial Patterns in Bleaching Reports 28
3.3 Great Barrier Reef 30
3.3.1 Time Series 30
3.3.2 Spatial Patterns 31
3.4 Relationships with El Niño–Southern Oscillation Events 33
3.5 Discussion. 34
References 37

4 Climate Variability and Change: Monitoring Data and Evidence for Increased Coral Bleaching Stress 41
C.M. Eakin, J.M. Lough, and S.F. Heron

4.1 Introduction. 41
4.2 Data for Understanding Thermal stress and Bleaching Patterns Worldwide. 42
4.2.1 Century-Length Global SST Reconstructions from Instrumental and Paleoclimatic Data. 43
4.2.2 Satellite Observations of SST and Thermal Stress. 43
4.3 Tropical SST Trends Since the Nineteenth Century 48
4.3.1 Tropical SST and Global Temperature Trends. 49
4.3.2 Regional Trends in Thermal Stress 52
4.3.3 Role of El Niño–Southern Oscillation and Other Large-Scale Patterns 55
4.4 Other Local Environmental Variables 60
4.5 Summary. 61
References 62

5 Detecting and Monitoring Coral Bleaching Events 69
M. Spalding

5.1 Introduction. 69
5.2 Broad-Scale Approaches 70
5.2.1 Remote Sensing of Bleaching Events. 70
5.2.2 Remote Sensing of Indicators of Bleaching Likelihood. 71
5.2.3 Summary of Remote Sensing Tools 73
5.3 Field-Based Observation. 73
5.3.1 Describing Bleaching 74
5.3.2 Assessing Mortality 75
5.3.3 Broader Patterns Across the Reef. 76
5.4 Colony Scales and Finer. 76
5.5 Temporal Contexts 78
5.6 Connecting Across Scales 79
References 80

6 Bleaching Resistance and the Role of Algal Endosymbionts 83
Madeleine J.H. van Oppen, Andrew C. Baker, Mary Alice Coffroth, and Bette L. Willis

6.1 Introduction. 83
6.2 Genetic Diversity of *Symbiodinium* 84
6.3 Biogeographic Patterns in *Symbiodinium* Diversity. 85

6.4 Physiological Differences among Genetically Distinct *Symbiodinium* Types 88
6.5 Shifts in Symbiont Communities as a Mechanism to Cope with Environmental Change? 92
6.6 Prediction of Changes in *Symbiodinium* Diversity and Distribution over the Next Century 95
6.7 Conclusions and Major Knowledge Gaps 96
References 96

7 Bleaching and Mortality Thresholds: How Much is Too Much? 103
R. Berkelmans

7.1 Introduction. 103
7.2 Methods 105
7.2.1 Statistical Modelling. 105
7.2.2 Bleaching Thresholds 106
7.2.3 Mortality Thresholds 107
7.3 Results. 107
7.3.1 Is Temperature Appropriate for Modelling Bleaching Thresholds? 107
7.3.2 Bleaching Thresholds 109
7.3.3 Mortality Thresholds 112
7.4 Discussion. 113
References 117

8 Consequences of Coral Bleaching for Sessile Reef Organisms 121
T.R. McClanahan, E. Weil, J. Cortés, A.H. Baird, and M. Ateweberhan

8.1 Introduction. 121
8.2 Affected Taxa 121
8.3 Immediate Responses 123
8.4 Delayed Effects. 128
8.4.1 Reproduction. 128
8.4.2 Size and Growth 129
8.4.3 Recruitment. 130
8.4.4 Disease 130
8.5 Population Dynamics and Community Structure. 131
8.6 Ecosystem Processes 132
8.7 Interactions with Management 133
8.8 Conclusions. 134
References 134

9 Coral Bleaching and Consequences for Motile Reef Organisms: Past, Present and Uncertain Future Effects 139
M.S. Pratchett, S.K. Wilson, N.A.J. Graham, P.L. Munday, G.P. Jones, and N.V.C. Polunin

9.1 Introduction 139
9.2 Short-Term Effects (up to 3 Years) 142
9.2.1 Coral Dependence and Ecological Versatility 142
9.2.2 Sub-Lethal Effects of Coral Depletion 144
9.3 Medium-Term Effects (3–10 Years) 145
9.3.1 Recovery Scenario 145
9.3.2 Reef Collapse 146
9.3.3 Phase-Shifts to Macroalgal-Dominated Systems 148
9.4 Long-Term Effects (>10 Years) 149
9.4.1 Direct Effects of Climate Change on Motile Reef Organisms 150
9.4.2 Impacts on Fisheries and Direct Economic Costs of Coral Bleaching 151
9.5 Conclusions 151
References 152

10 Future Scenarios: a Review of Modelling Efforts to Predict the Future of Coral Reefs in an Era of Climate Change 159
Simon D. Donner, Scott F. Heron, and William J. Skirving

10.1 Introduction 159
10.2 Modelling Future Climates 159
10.3 Predicting Coral Bleaching from Climate Models 161
10.4 The Great Barrier Reef: a Case Study 167
10.5 Future Improvements in Physical Modelling 169
10.6 Conclusions 170
References 171

11 Synthesis: Coral Bleaching - Patterns, Processes, Causes and Consequences 175
M.J.H. van Oppen and J.M. Lough

References 176

Index 177