



Biodiversity and Climate Change Adaptation in Tropical Islands

Edited by

Chandrakasan Sivaperuman

Ayyam Velmurugan

Awnindra Kumar Singh

Iyyappan Jaisankar



BIODIVERSITY AND CLIMATE CHANGE ADAPTATION IN TROPICAL ISLANDS

Page left intentionally blank

BIODIVERSITY AND CLIMATE CHANGE ADAPTATION IN TROPICAL ISLANDS

Edited by

CHANDRAKASAN SIVAPERUMAN

*Zoological Survey of India, Andaman & Nicobar Regional Centre,
Government of India, Ministry of Environment & Forests, Port Blair, India*

AYYAM VELMURUGAN

ICAR-Central Island Agricultural Research Institute, Port Blair, India

AWNINDRA KUMAR SINGH

ICAR-Central Island Agricultural Research Institute, Port Blair, India

IYYAPPAN JAISANKAR

ICAR-Central Island Agricultural Research Institute, Port Blair, India



ACADEMIC PRESS

An imprint of Elsevier

Academic Press is an imprint of Elsevier
125 London Wall, London EC2Y 5AS, United Kingdom
525 B Street, Suite 1800, San Diego, CA 92101-4495, United States
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom

Copyright © 2018 Elsevier Inc. All rights reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the Library of Congress

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

ISBN: 978-0-12-813064-3

For information on all Academic Press publications visit our website at
<https://www.elsevier.com/books-and-journals>



Working together
to grow libraries in
developing countries

www.elsevier.com • www.bookaid.org

Publisher: Andre Gerhard Wolf

Acquisition Editor: Anna Valutkevich

Editorial Project Manager: Pat Gonzalez

Production Project Manager: Sreejith Viswanathan

Designer: Christian Billbow

Typeset by Thomson Digital

Contents

List of Contributors xi

Preface xiii

I

PREAMBLE

1. The Nature and Characters of Tropical Islands

AYYAM VELMURUGAN

- 1 The Background 3
- 2 Tropical Islands – An Introduction 4
- 3 Physical Features of Tropical Islands 10
- 4 Island Ecosystem and Biodiversity 23
- 5 Climate Change and Tropical Islands 26
- 6 Conclusions 28
- References 28

2. Tropical Islands: Ecosystem and Endemism

CHANDRAKASAN SIVAPERUMAN,
IYYAPPAN JAISANKAR, AYYAM VELMURUGAN,
TADIMALLA VENKATA RAMALINGASWARA
SUBRAHMANYA SHARMA

- 1 Introduction 31
- 2 Endemism 32
- 3 Distribution of Endemic Species 36
- 4 Endemism: A Case Example of Andaman
and Nicobar Islands 38
- 5 Threat to Endemism and Endemic Species 49
- 6 Conservation 50
- 7 Conclusions 50
- References 51

II

BIODIVERSITY OF TROPICAL ISLANDS

3. Diversity of Ethno-Medicinal Plants of Tropical Islands – With Special Reference to Andaman and Nicobar Islands

MAYUR Y. KAMBLE, SANTOSH S. MANE,
CHIDAMBARAM MURUGAN, IYYAPPAN JAISANKAR

- 1 Introduction 55
- 2 Scope and Extent of Ethno-Medicinal
Plant Use 56
- 3 Ethno-Medicinal Plants of Andaman and Nicobar
Islands, India 61
- 4 Climate Change and Habitat Degradation 61
- 5 Conservation 101
- 6 Conclusions 102
- References 102

4. Biodiversity of Polynesian Islands: Distribution and Threat From Climate Change

GUILLÉN CARLOS, AYYAM VELMURUGAN, B.A. JERARD,
R. KARTHICK, IYYAPPAN JAISANKAR

- 1 Introduction 105
- 2 Physical Setting 106
- 3 Biodiversity of Polynesian Islands 108
- 4 Climate Change and Vulnerability 113
- 5 Biodiversity Loss 115
- 6 Threats to Biodiversity 116
- 7 Biodiversity Conservation 119
- 8 Conclusions 121
- References 122

5. Structure and Species Diversity of Mangrove Ecosystem

JOJU P. ALAPPATT

- 1 Introduction 127
- 2 Structure and Composition of Mangrove Communities 128
- 3 Habitat Adaptations 130
- 4 Global Pattern 133
- 5 Mangroves of Andaman and Nicobar Islands – A Case Study 136
- 6 Conclusion 142
- References 143

6. Coconut Biodiversity – Nature's Gift to the Tropical Islands

B.A. JERARD, V. DAMODARAN, IYYAPPAN JAISANKAR,
AYYAM VELMURUGAN, T.P. SWARNAM

- 1 Introduction 145
- 2 Botanical Description 146
- 3 Land Suitability and Establishment of Coconut 147
- 4 Area and Production 148
- 5 Distribution and Spread of Coconut 150
- 6 Coconut Biodiversity 151
- 7 Use of Biodiversity in Coconut Improvement 166
- 8 Climate Change and Its Impact on Coconut 168
- 9 Breeding for Drought Tolerance in Coconut 171
- 10 Biodiversity and Economic Benefit in Coconut 173
- 11 Conservation of Coconut Biodiversity 175
- 12 Conclusion – Gift of Nature's Journey Into the Future 179
- References 181

7 Habitat Ecology and Diversity of Rocky Shore Fauna

KUNAL SATYAM, GANESH THIRUCHITRAMBALAM

- 1 Introduction 187
- 2 Description of the Rocky Shore Habitat 188
- 3 Species Diversity 194
- 4 Food Chain and Food Web 197
- 5 Rocky Shore Faunal Assessment – A Case Example of Andaman Islands 198

- 6 Rocky Shore Habitat and Species – An Analysis 207
- 7 Effect of Anthropogenic Activity 208
- 8 Conclusion 212
- References 213

8. Marine Ecosystems of Andaman and Nicobar Islands – Species Abundance and Distribution

NAMBALI VALSALAN VINITHKUMAR,
THADIKAMALA SATHISH, APURBA KUMAR
DAS, CHANDRAKASAN SIVAPERUMAN,
CHELLADURAI RAGHUNATHAN,
GOPAL DHARANI, RAMALINGAM KIRUBAGARAN,
NAMBALI VALSALAN SUJATHKUMAR

- 1 Introduction 217
- 2 Andaman and Nicobar Island Geography 218
- 3 Coastal Ecosystems and Offshore Marine Ecosystems 219
- 4 Marine Faunal Resources of Andaman and Nicobar Islands 236
- 5 Fish Biodiversity and Their Distribution in the Ecosystems 246
- 6 Marine Protected Areas 248
- 7 Conclusion 250
- References 250

9. Invasive Species in Freshwater Ecosystems – Threats to Ecosystem Services

R. KIRUBA-SANKAR, J. PRAVEEN RAJ, K. SARAVANAN,
K. LOHITH KUMAR, J. RAYMOND JANI ANGEL,
AYYAM VELMURUGAN, S. DAM ROY

- 1 Introduction 257
- 2 Impact of Invasive Species on Native Ecosystem 258
- 3 Economic Significance of Non-Native Fishes 261
- 4 Climate Change and Non-Native Fishes 262
- 5 Some Case Examples From Tropical Islands 264
- 6 Impact of Invasions 277
- 7 Conservation 281
- 8 Conclusions 285
- References 286

10. Avian Diversity of Bay Island and Its Assessment Tools

CHANDRAKASAN SIVAPERUMAN

- 1 Introduction 297
- 2 Avifaunal Studies in Andaman and Nicobar Islands 299
- 3 Avifaunal Diversity in Andaman and Nicobar Islands 300
- 4 Endemic Avifauna 301
- 5 Avian Diversity Assessment Tools – A Case Example of North Andaman 303
- 6 Conservation and Suggestions of Avifaunal of the Andaman and Nicobar Islands 313
- 7 Conclusion 314
- References 315

11. Marine Fishery Resources and Species Diversity of Tropical Waters

PUNNAKULAM T. RAJAN

- 1 Introduction 323
- 2 Status of Global Marine Fishery 324
- 3 India and the IO Region 328
- 4 Tropical Islands of IO 335
- 5 Taxonomy of IO Marine Fish Diversity 340
- 6 Conservation and Management 350
- References 351

12. Rice Genetic Resources in Tropical Islands

P.K. SINGH, K. VENKATESAN, T.P. SWARNAM

- 1 Introduction 355
- 2 Rice – Area, Production and Productivity in the Tropical World 356
- 3 Importance of Rice in Human Diet 358
- 4 Nomenclature of *Oryza* Species Complex 358
- 5 Origin of Cultivated Rice 361
- 6 Domestication of Rice 362
- 7 Dispersal of Cultivated Rices 365
- 8 Diversity in Rice Cultivation 365
- 9 Collection, Conservation and Utilisation of Rice Germplasm 367

- 10 Rice Diversity and Cultivation in Andaman and Nicobar Islands 375
- 11 Conservation of Rice Genetic Diversity 380
- 12 Future Prospects 381
- 13 Conclusions 382
- References 382

III

CLIMATE CHANGE AND ITS IMPACTS ON TROPICAL ISLAND

13. Climate Change Projections and Addressing Intrinsic Uncertainties

RAMASAMY GOWTHAM,
AMMAPET PALANISAMY RAMARAJ,
VELLINGIRI GEETHALAKSHMI

- 1 Introduction 387
- 2 Climate Change 388
- 3 Future Climate Projections 389
- 4 Uncertainties in Projections 391
- 5 Nature and Origin of Uncertainty 392
- 6 Major Approaches in the Assessment of Uncertainty 393
- 7 Assessment for Agricultural Decisions 394
- 8 Treatment of Uncertainty for Adaptation Decisions: Case Study of Rice Over Thanjavur, India 395
- 9 Conclusion 400
- References 401

14. Climate Resilient and Livelihood Security – Perspectives for Mauritius Island

B. LALLJEE, AYYAM VELMURUGAN, AWININDRA K. SINGH

- 1 Introduction 403
- 2 Settlement and Economic History 405
- 3 Livelihood 406
- 4 Mauritius Island – Physical Features 407
- 5 Biodiversity of Mauritius 409
- 6 Climate Change and its Impact 416
- 7 Climate Resilient by Adaptive Management 424
- 8 Conclusions 430
- References 430

15. Livestock and People – The Intimate Relation Under Threat

T. SUJATHA, A. KANNAN, S. JEYAKUMAR,
A. KUNDU, AYYAM VELMURUGAN, J. SUNDER,
T.P. SWARNAM, A.K. DE

- 1 Introduction 433
- 2 Livestock-based Farming Systems 434
- 3 Climate Change and Livestock Sector 436
- 4 Effect of Climate Change on Animal Production System 437
- 5 Adaptation to Climate Change 442
- 6 Climate Change and Livestock Sector – A Case Example of Andaman and Nicobar Islands 444
- 7 Conclusion 455
- References 455

16. Shifting Equilibrium of Pest and Diseases in Agriculture

M. MOHAN, B. KARIYANNA

- 1 Introduction 459
- 2 Changing Pest Outbreaks in Relation to Changing Climate 460
- 3 Effect of Climate Change 462
- 4 Climate Change on Plant Disease Occurrence 471
- 5 Climate Change on Weeds 476
- 6 Climate Change on Nematode 477
- 7 Conclusions 478
- References 478

17. Uncertainties in Measuring Climate Change Impact on Marine Biodiversity

P.M. MOHAN, AYYAM VELMURUGAN

- 1 Introduction 487
- 2 Climate Change and its Effect on the Marine Environment 488
- 3 Biodiversity and Climate Change 492
- 4 Sampling Methods 498
- 5 Management of Uncertainty 498
- 6 Conclusion 500
- References 500

18. Biodiversity and Climate Change Impacts on the Lakshadweep Islands

AYYAM VELMURUGAN, V.M. ABDUL GAFOOR,
IYYAPPAN JAISANKAR, T.P. SWARNAM, JOHN MATHAI

- 1 Introduction 503
- 2 Lakshadweep Islands 504
- 3 Biodiversity of the Lakshadweep Islands 507
- 4 Climate Change and Biodiversity 513
- 5 Challenges to Biodiversity Conservation 518
- 6 Lakshadweep Biodiversity and Strategy Action Plan 519
- 7 Conclusions 520
- References 520

IV

ADAPTIVE MANAGEMENT

19. Biodiversity Conservation: Issues and Strategies for the Tropical Islands

IYYAPPAN JAISANKAR, AYYAM VELMURUGAN,
CHANDRAKASAN SIVAPERUMAN

- 1 Introduction 525
- 2 Biodiversity Types 527
- 3 Need for Biodiversity Conservation 528
- 4 Status of Biodiversity Distribution 530
- 5 Importance of Tropical Region Biodiversity 532
- 6 Threats to the Biodiversity 534
- 7 Biodiversity Conservation Objectives and Strategies 541
- 8 Biodiversity Conservation 543
- 9 Climate Change and Biodiversity Conservation 549
- 10 Conclusion 549
- References 550

20. Diversification of Island Agriculture – A Viable Strategy for Adaptation to Climate Change

T.P. SWARNAM, AYYAM VELMURUGAN, N. RAVISANKAR,
AWNINDRA K. SINGH, S.K. ZAMIR AHMED

- 1 Introduction 553
- 2 Status of Agriculture 554

3	Climate Change	557
4	Adaptation	560
5	Agricultural Diversification	561
6	Farm Diversification	564
7	Diversification Through Alternative Farming in Tropical Islands	569
8	Conclusion	574
	References	574

21. Land Shaping Methods for Climate Change Adaptation in Coastal and Island Region

AYYAM VELMURUGAN, S.K. AMBAST, T.P. SWARNAM,
D. BURMAN, SUBHASIS MANDAL, T. SUBRAMANI

1	Introduction	577
2	Shrinking Land and Water Resources	578
3	Production System Constraint	582
4	Technological Options	582
5	Effect of Land Shaping	591
6	Conclusions	595
	References	595

22. Harnessing Genetic Resources in Field Crops for Developing Resilience to Climate Change

AWNINDRA K. SINGH, R.M. SINGH, AYYAM VELMURUGAN,
R. RAHUL KUMAR, UTPAL BISWAS

1	Introduction	597
2	World Food Production	598
3	Interdependence of Crop Diversity and Climate Change	602
4	Climate Change Impact on Food Grain Production	603
5	Utilisation of Genetic Diversity for Adaptation	605
6	Breeding and Modern Biotech Tools	610
7	Use of Physiological Parameters for Higher Selection Efficiency	614
8	Use of Biodiversity Through System Approach	615
9	Conservation of Biodiversity in Field Crops	618

10	Conclusion	619
	References	619

23. Coping with Climatic Uncertainties Through Improved Production Technologies in Tropical Island Conditions

SHRAWAN SINGH, D.R. SINGH, AYYAM VELMURUGAN,
IYYAPPAN JAISANKAR, T.P. SWARNAM

1	Introduction	623
2	Crop Weather Relations	624
3	Importance of Horticultural Crops in Tropical Islands	625
4	A Comparative Study of Tropical Islands—Cuba, Samoa, Sri Lanka and Andaman and Nicobar islands	628
5	Management of Uncertainties Due to Abiotic Stresses	634
6	Management Options for Climatic Uncertainties	636
7	Urban Agriculture	648
8	Management of Climatic Uncertainty by System Approach	651
9	Plant Protection Under Uncertain Situations	657
10	Land Shaping/Modification Techniques	659
	References	662

24. Bioshield: An Answer to Climate Change Impact and Natural Calamities?

IYYAPPAN JAISANKAR, AYYAM VELMURUGAN,
T.P. SWARNAM

1	Introduction	667
2	Importance of Coastal and Island Ecosystem	668
3	Climate Change and Natural Calamities	669
4	Impacts	672
5	Adaptation Options	673
6	Bioshield	674
7	Effect of Bioshield—A Case Example of Little Andaman, India	681
8	Limitations of Bioshield	690
9	The Way Forward	693
10	Conclusions	694
	References	695

V

POLICY DECISIONS AND BIODIVERSITY CONSERVATIONS IN THE TROPICAL ISLANDS

25. Coastal Area Management: Biodiversity and Ecological Sustainability in Sri Lanka Perspective

ABHAYA BALASURIYA

- 1 Introduction 701
- 2 Coastal Zones 702
- 3 Coastal Area Ecosystems – A Case Example
of Sri Lanka 703
- 4 Significance of Coastal Habitats 712
- 5 Threats to Coastal Ecosystem 714
- 6 Coastal Area Conservation 718
- 7 Coastal Habitat Management in Sri Lanka 719
- 8 Sustainability 720
- 9 Restoration 721
- 10 Strategic Planning 722
- 11 Conclusion 722
- References 723

26. Conservation of Coral Reef Environment: Perspectives for Tropical Islands

P.M. MOHAN, RADHA KARUNA KUMARI

- 1 Introduction 725
- 2 Coral Reef and its Environment 726
- 3 Species Distribution and Diversity 729
- 4 Economic Aspects of Coral Reef 733
- 5 Threat to the Coral Ecosystem 738
- 6 Conservation of Coral Reef Environment 740

- 7 Conclusions 742
- References 743

27. Marine Biodiversity – Strategies for Conservation, Management and Ecological Restoration

CHERUVATHOOR LINOY LIBINI, K.A. ALBERT IDU,
C.C. MANJUMOL, VASANT KRIPA,
KOLLIYIL SUNIL MOHAMED

- 1 Introduction 745
- 2 Climate Change and Other Stresses 746
- 3 Management Strategy 757
- 4 Ecological Restoration 760
- 5 Conclusions 760
- References 761

28. Agro-Meteorological Advisory Services for Informed Decision Making in India

NABANSU CHATTOPADHYAY, SWATI CHANDRAS

- 1 Introduction 763
- 2 Agromet Advisories and Adaptation 764
- 3 Reaching Out to the Stakeholders – A Case
Example of India 765
- 4 Organisational Set-Up for Dissemination
of Information 766
- 5 National Meteorological Services 767
- 6 Network of Observatory 768
- 7 Use of Different Weather Forecasts in Indian
Agriculture 769
- 8 Management of Extreme Events 780
- 9 The Way Forward 782
- 10 Conclusions 783
- References 783

- Index 785

Contributors

- V.M. Abdul Gafoor** Krishi Vigyan Kendra, ICARI-CIARI, Kavaratti, India
- Joju P. Alappatt** Andaman and Nicobar Administration, Port Blair, India
- K.A. Albert Idu** Blacklip Pearl Oyster Laboratory of CMFRI, Fisheries Training Centre, Marine Hill, Port Blair, India
- S.K. Ambast** ICAR-Indian Institute of Water Management, Bhubaneswar, India
- J. Raymond Jani Angel** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- Abhaya Balasuriya** Rajarata University of Sri Lanka, Mihintale, Sri Lanka
- Utpal Biswas** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- D. Burman** ICAR-Central Soil Salinity Research Institute, Regional Research Station, Canning Town, Parganas, India
- Guillén Carlos** Instituto Nacional de Salud Agrícola Integral (INSAI), Mérida, Venezuela
- Swati Chandras** India Meteorological Department, Shivajinagar, India
- N. Chattopadhyay** India Meteorological Department, Shivajinagar, India
- V. Damodaran** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- Apurba Kumar Das** Andaman and Nicobar Centre for Ocean Science and Technology, National Institute of Ocean Technology, Port Blair, India
- A.K. De** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- G. Dharani** National Institute of Ocean Technology, Ministry of Earth Science, Government of India, Chennai, India
- V. Geethalakshmi** TNAU, Madurai, India
- R. Gowtham** Agro Climate Research Centre, TNAU, Coimbatore, India
- I. Jaisankar** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- B.A. Jerard** Coconut specialist, Indian Technical and Economic cooperation, Ministry of Agriculture, Government of Fiji, Suva, Fiji
- S. Jeyakumar** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- Mayur Y. Kamble** National Orchidarium and Experimental Garden, Yercaud, Salem, India
- A. Kannan** Baylor College of Medicine, Houston, TX, United States
- B. Kariyanna** ICAR-National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka, India
- R. Karthick** SDS Biotech K.K, Tokyo, Japan
- R. Karuna Kumari** Pondicherry University, Port Blair, India
- C.R. Kirubakaran** National Institute of Ocean Technology, Ministry of Earth Science, Government of India, Chennai, India
- R. Kiruba-Sankar** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- V. Kripa** Central Marine Fisheries Research Institute, Kochi, India
- A. Kundu** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- B. Lalljee** Faculty of Agriculture, Agriculture University of Mauritius, Reduit, Mauritius
- C. Linoy Libini** Blacklip Pearl Oyster Laboratory of CMFRI, Fisheries Training Centre, Marine Hill, Port Blair; Kerala University of Fisheries & Ocean Studies, Kochi, India
- K. Lohith Kumar** ICAR-Central Island Agricultural Research Institute, Port Blair, India

- Subhasis Mandal** ICAR-Central Soil Salinity Research Institute, Regional Research Station, Canning Town, Parganas, India
- Santosh S. Mane** Collaborative Research Centre for Veterinary Ayurveda, GADVASU, Ludhiana, India
- C.C. Manjumol** Blacklip Pearl Oyster Laboratory of CMFRI, Fisheries Training Centre, Marine Hill, Port Blair, India
- John Mathai** Government of Kerala, Thiruvananthapuram, India
- K.S. Mohamed** Central Marine Fisheries Research Institute, Kochi, India
- M. Mohan** ICAR-National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka, India
- P.M. Mohan** Pondicherry University, Port Blair, India
- C. Murugan** Botanical Survey of India, Southern Regional Centre, Coimbatore, India
- J. Praveen Raj** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- P.T. Rajan** Zoological Survey of India-ANRC, Port Blair Andaman and Nicobar Islands, India
- Chelladurai Raghunathan** Zoological Survey of India, Andaman and Nicobar Regional Centre, Ministry of Environment and Forests and Climate Change, Port Blair, India
- R. Rahul Kumar** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- A.P. Ramaraj** TNAU, Madurai, India
- N. Ravisankar** ICAR-Indian Institute of Farming Systems Research, Modipuram, India
- S. Dam Roy** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- K. Saravanan** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- T. Sathish** Andaman and Nicobar Centre for Ocean Science and Technology, National Institute of Ocean Technology, Port Blair, India
- Kunal Satyam** Pondicherry University, Port Blair, India
- T.V.R.S. Sharma** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- Awnindra K. Singh** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- D.R. Singh** ICAR-National Research Centre for Orchids, Pakyong, Sikkim, India
- P.K. Singh** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- R.M. Singh** Banaras Hindu University, Varanasi, India
- Shrawan Singh** ICAR-Indian Agricultural Research Institute, New Delhi, India
- C. Sivaperuman** Zoological Survey of India, Andaman and Nicobar Regional Centre, Ministry of Environment and Forests and Climate Change, Port Blair, India
- T. Subramani** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- T. Sujatha** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- N.V. Sujathkumar** Fisheries College and Research Institute, Tamil Nadu Fisheries University, Thoothukudi, India
- J. Sunder** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- T.P. Swarnam** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- Ganesh Thiruchitrambalam** Pondicherry University, Port Blair, India
- A. Velmurugan** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- K. Venkatesan** ICAR-Central Island Agricultural Research Institute, Port Blair, India
- N.V. Vinithkumar** Andaman and Nicobar Centre for Ocean Science and Technology, National Institute of Ocean Technology, Port Blair, India
- S.K. Zamir Ahmed** ICAR-Central Island Agricultural Research Institute, Port Blair, India

Preface

Biodiversity, global climate change and food insecurity are the three major challenges before the humanity, with climate change appearing to escalate faster than the others. The issue is more pertinent to small islands than the larger countries located in different continents. In this context, tropical islands comprising small island developing states and small islands of continental countries located in four different tropical regions namely, Indian Ocean, Pacific Ocean, Atlantic and Caribbean are very unique in terms of their biodiversity, resource endowments, climate and socio-economic profile. The unique biodiversity of these islands and the limited resources, which sustain human population on these islands are under increasing threat from climate change and anthropogenic activities. The natural resources are over exploited in many of the tropical islands in spite of their fragile ecosystem to meet growing rural poverty and strive for economic growth. All these factors together with climate change are responsible for the extinction or threatened status of a number of species in these islands.

Observational data and model output predicting climate change with reference to tropical islands indicated that these islands are facing increasing threat from sea level rise besides increase in sea surface temperature, tropical cyclone and long dry spell which can alter ecosystems and habitability of island regions. However, the vulnerability of islands varies with their physical attributes and their adaptive capacity. Therefore it is imperative to force for regional and international cooperation to conserve the biodiversity of these islands and implement suitable and adequate adaptation measures. At the same time the impacts of changes in climate and climate variability on biodiversity and agricultural production system of tropical islands will be greater than other parts of the world due to their intrinsic nature. This will also seriously affect the livelihood security of the native population. On the other hand, most of the tropical island farmers practise rainfed farming and averting this challenge requires that farmers adapt by making changes in farming and land management decisions that reduce the negative consequences associated with change.

Although these islands are among the least responsible of all nations for climate change, they are likely to suffer strongly from its adverse effects and could in some cases even become uninhabitable. The issue of climate change and biodiversity loss in the tropical islands needs to be considered within the context of multiple stressors, which are factors other than climate change. This is what makes them such a special case requiring the help and attention of the international community. Therefore, the sustainable development path for these islands should essentially balance the economic development and natural resource conservation by suitable green technologies, innovation in service sector, shifting to climate resilient production system besides appropriate adaptation measures.

In this publication on 'Biodiversity and Climate Change Adaptation in Tropical Islands' attempt has been made to extract all the afore mentioned key information and ideas from

different sources and discuss the current state of knowledge on tropical islands, biodiversity and climate change in five different sections namely, Preamble, Biodiversity of Tropical Islands, Climate Change and Its Impacts on Tropical Island, Adaptive Management and Policy Decisions and Biodiversity Conservations in the Tropical Islands. We have largely derived the core content of this book from the ideas and research outputs of the editors and from various reputed scientists who have contributed immensely on various aspects of biodiversity and climate change. All this information and expertise of researchers with suitable illustrations are compiled in this book. Undoubtedly this book covers a huge range of biodiversity documentation, conservation measures, strategies which are useful to several stakeholders that can be applied to various sectors, from forests to agriculture. The editors are grateful to the authors for preparing excellent contributions and strongly supported our efforts to put up comprehensive information in this book. We also place on record our sincere gratitude to Ms. Gonzalez Pat and the entire publication team of Elsevier who ably guided and supported us to complete this task.

*A. Velmurugan
C. Sivaperuman
Awnindra K. Singh
I. Jaisankar*



SECTION I

PREAMBLE

- 1 *The nature and characters of tropical islands* 3
- 2 *Tropical islands: ecosystem and endemism* 31

Marine Biodiversity – Strategies for Conservation, Management and Ecological Restoration

Cheruvathoor Linoy Libini^{*,†}, K.A. Albert Idu^{*},
C.C. Manjumol^{*}, Vasant Kripa^{**}, Kolliyil Sunil Mohamed^{**}

^{*}Blacklip Pearl Oyster Laboratory of CMFRI, Fisheries Training Centre, Marine Hill, Port Blair, India; ^{**}Central Marine Fisheries Research Institute, Kochi, India;

[†]Kerala University of Fisheries & Ocean Studies, Kochi, India

1 INTRODUCTION

Biodiversity has become a buzzword after Rio de Janeiro Earth summit in 1992. The biological diversity is considered as one of the central themes of ecology, and knowledge on biodiversity became an integral part for the assessment and conservation of any type of biota. According to Convention on Biological Diversity (CBD), biodiversity is defined as 'the variability among all living organisms from all sources, including, *inter alia*, terrestrial, marine and other aquatic ecosystems and ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'. As many countries including India are party to the CBD, each nation has the solemn and sincere responsibility to record the species of flora and fauna occurring in their respective countries geographical realm. It helps to assess the biodiversity properly and evolve suitable management strategies for conserving the biodiversity which is often described as the Living Heritage of Man. Biodiversity maintains a healthy biosphere and provides direct and indirect value to humans. There are direct and indirect economic, aesthetic and scientific reasons for preserving biodiversity and it describes mainly three types, ecological diversity, species diversity and genetic diversity.

Among the components of biodiversity basically, marine realm consists of many important biodiversity-rich ecological units such as coastal wetlands, estuaries, coral reefs, mangroves, lagoons, sea grasses and seaweeds ecosystems. Diversity of the flora and fauna of these habitats has an inevitable and collective role in the existence, maintenance and wellbeing of the

larger coastal and marine zones. Why we human beings are bothered much on biodiversity especially marine biodiversity? As like as terrestrial ecosystems, Man is also highly depend on marine ecosystem and its flora and fauna for the day-to-day needs in his life. In addition, human activities have been inflicting heavy damage to the structure and functioning of the marine biodiversity, of course humans are the major force responsible for the degradation of all ecosystems. Reduction of a single species can affect the energy flow in the respective food web and later it reflects on the entire ecosystem. Thus the gradual decline of a species end to its extinction and resulted in reduction of biodiversity which might have a serious and long-term effects on the biosphere. Similarly, to cater the increasing need for seafood in the world, catch of fish species are inevitable and also pass thorough different phases such as commercial exploitation, overexploitation and finally extinction of species. The loss of biodiversity in marine realm influenced by a quite lot of issues namely, habitat loss, habitat fragmentation, edge effect, pollution, bio-magnification, eutrophication, introduction of cultivable species and invasive species through ballast water. Other anthropogenic stressors such as anchoring of boats in coral reef areas, sewage water pollution from the urban areas, tourism pressure in the pristine beaches, harvest of ornamental shells for sale, destructive fishing using explosives are also equally important in devastation of the biodiversity in the most diverse marine environments.

The main factors which influence or threaten the biodiversity are evolved by the activities of single species, *Homo sapiens*, that is, man. The unconditional usages of the all the resources by humans have lead into the degradation of the renewable and non-renewable resources in the earth. In recent times it is apparent that all regions of the planet earth in some ways are being adversely affected by the global warming trend. Therefore, it is imperative to sustainably use of all these resources for conservation of biodiversity in any type of ecosystems. In this context, conservations of biodiversity can be achieved initially by implementation of various programme include declaration of protected areas like wildlife sanctuaries, national parks and zoo or botanical gardens. Subsequently advanced form of preservation of unique biodiversity such as seed banks and gene banks should be employed. The conservation strategies also included the effective execution of resources management techniques including habitat enhancement and stock restoration programme.

2 CLIMATE CHANGE AND OTHER STRESSES

Climate change is one of many human-induced stressors on marine ecosystems and biodiversity. Other stressors include destruction and fragmentation of habitat, pollution, overexploitation and invasive species. [Halpern et al. \(2007\)](#) has demonstrated the staggering extent of multiple stressors on oceans with 40% of the world's Oceans already heavily impacted by human activities, and no area of the global oceans left unaffected by human influence Fishing impacts marine ecosystems through overfishing, destruction of habitat and by catch ([Worm et al., 2006](#)). Combined, these stressors affect the resilience of ecosystems, thereby increasing their vulnerability to climate change.

There is often a threshold beyond which an altered ecosystem cannot recover from many kinds of disturbances. To overcome these stress protected areas are created, but protection works best as a conservation tool if the area remains protected for the foreseeable future.

But under climate change, species for which a particular protected area was established may no longer survive there. This means climate change impacts are uncertain therefore, monitoring provides important information on which to base future management decisions.

2.1 Conservation and Management Protocols

The protocols for the conservation and management of biodiversity in marine environment are illustrated in the form of flow chart (Fig. 27.1). Based on the strategies followed for the biodiversity conservation and resource management are described basically in three main sections namely:

- Protective measures,
- Stock management programmes and
- Future challenges

2.1.1 Protective Measures

The basic measures for the conservation and protection of biodiversity can be achieved by the proper implementation of laws of the land/sea and proclamation of protected areas.

2.1.2 Wildlife Protection Acts

It is a legal instrument which provides for the protection of wild animals, birds and plants, as well as for matters connected there with or ancillary or incidental there to. Such legal measures are in place in several countries. At the international level more emphasis is placed in recent decades on preserving endangered wild life, both flora and fauna which resulted in the formation of international wild life laws and treaties. Many of the species protected under the international wildlife laws have international significance and some have medical

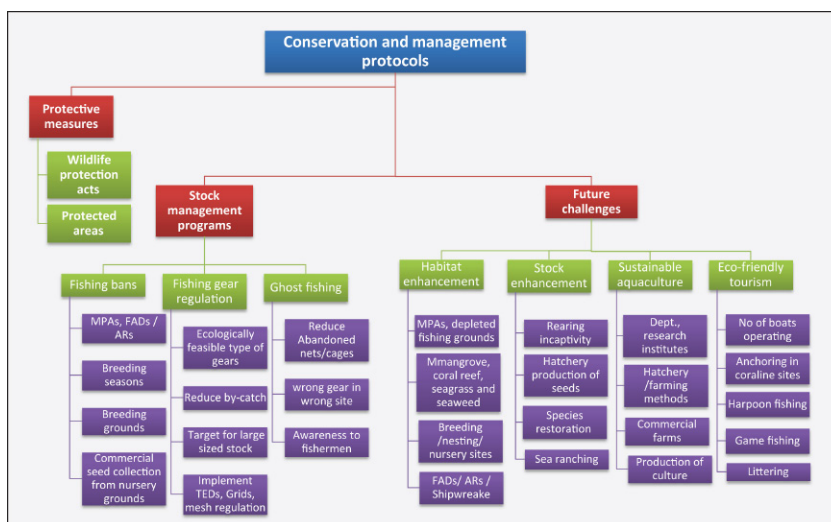


FIGURE 27.1 Protocols for the conservation and management of biodiversity in marine environment.

importance. The environmental crime programme of INTERPOL is active in policing compliance with these acts and treaties as they have an international impact on the environment and health. Some of the treaties and laws protecting wild life of global significance are:

WILDLIFE PROTECTION ACTS AND TREATIES

- Migratory Bird Treaty with Canada, Signed by Great Britain 1916
- Antarctic Treaty 1959
- CITES 1973
- Environmental Protection Treaty with the Russian Federation 1973
- Polar Bear Treaty 1974
- African Elephant Conservation Act 1989
- Antarctic Treaty System
- Convention on Biological Diversity
- Convention on International Trade in Endangered Species of Wild Fauna and Flora
- Ramsar Convention

OCEAN AND MARINE LIFE PROTECTION ACTS AND TREATIES

- Convention on Fishing and Conservation of Living Resources of the High Seas
- Marine Mammal Protection Act
- Marine Protection, Research, and Sanctuaries Act of 1972
- United Nations Convention on the Law of the Sea

In India, a number of wildlife acts have been made from time to time by central and state governments for wildlife protection. Indian Board of Wildlife (IBWL) is the main advisory body of Government of India on Convention on International Trade in Endangered Species (CITES), which made recommendations for unified legislation for wildlife conservation in India. Among the various acts, the Wildlife Protection Act 1972 (WPA, 1972), widely adapted one and undergoes improvements and strengthening by consecutive amendments during various periods. The IBWL is functioning and addressing the various issues of wildlife like promotion of conservation, control of poaching, advice on setting up protected areas, policy making on export of live animals and trophies and creating awareness to the people.

To support the policy making for biodiversity conservation, periodic status surveys are done to update the distributional status of species which are present in an area and the species considered to be protected under purview of WPA 1972. These status surveys will give the complete picture about the species diversity, abundance, behaviour and their ecological significance in the existing ecosystem. In India, a number of organisations and departments are working in this direction in national as well as state level to do the detail surveys and their dedicated observations and records are documented. It helps the ecosystem managers make appropriate decisions on various conservation measures and protection strategies to be followed for the betterment of affect species or groups.

2.1.3 Marine Protected Areas

According to IUCN, a marine protected area (MPA) is defined as 'an area of intertidal or sub-tidal terrain, together with its overlying waters and associated flora, fauna historical and cultural features which have been reserved by legislation or other effective means to protect part or whole the enclosed environment'. The main purposes of establishment and management of

protected areas are to protect a species in its natural habitat (in situ conservation) to support scientific research, preservation of species and genetic diversity, education, and maintenance of cultural and traditional attributes. Based on the management and conservation priorities, the MPAs are categorised further to ensure a complete preservation of biodiversity into marine biosphere reserves, marine national parks, marine sanctuaries etc.

2.2 Stock Management Programmes for Sustainable Utilisation of Resources

Various human activities, including fishing, have an impact on marine organisms. There are concerns about the impact of these activities on the resilience of ecosystems, that is, on an ecosystem's capacity to continue to support and maintain a balanced, integrated and adaptive biological community, which has a species composition, diversity and functional organisation comparable to that of similar natural habitats in the region. In implementing a plan to conserve ecosystem structures and processes, fishing practices that involve excessive use of resources, or use of fishing gear in a manner or at a location that causes destruction of habitat, or the use of fishing methods that are themselves destructive, need to be stopped in the interest both of conserving the ecosystem and of ensuring optimal productivity in its use. Other issues arise when considering the resilience of ecosystems. They are the extent of the problems of lost or abandoned fishing gear, which can continue to catch fish when no longer under the control of the fisher. Also, improving the selectivity of fishing gear and methods that presently harvest unwanted catch becomes an issue. The following management programme should be performed for the better utilisation of the available resources for sustainable marine fish stock management. They are fishing ban, fishing gear regulation, minimise the incidents of ghost fishing, etc.

2.2.1 Fishing Bans

The exploitation pressure on the targeted species can be reduced by the implementing fishing regulations through fishing ban in the MPAs such as national parks and sanctuaries. Similarly, the other conservation areas with fish aggregative devices (FADs)/artificial reefs (ARs) also avoided for the commercial exploitation. Fishing regulations should be imposed in the breeding and nursery grounds of commercially important finfishes and shellfishes. Most of the organisms in the marine environment are exhibiting seasonality in maturation and breeding. The catches during breeding seasons lead to the depletion of the breeding stocks and adversely affect their recruitment patterns in those waters.

In recent years, the aquaculture practices of commercially important species of finfishes and shellfishes were also increased due to the heavy demand on animal protein to cater the need of growing human population. This was created to the developments of the appropriate and economically feasible hatchery techniques for these organisms to supply of seeds for farming. However, the seeds produced from hatchery operations are imperative but not sufficient to meet the demands from the various farming sectors. Furthermore, the availability of brooders along with the unpredictable issues such as growth, survival and immunological resistance to diseases are also induces the affinity of farmers towards the natural seeds. The studies were showed that the commercial seed collection of a particular species from the nursery grounds such as mangroves, estuaries and backwaters lead into the destruction of seeds of hundreds of other species.

2.2.2 Fishing Gear Regulation

Fishing gear regulation also has importance in the stock management and towards the conservation of stock under depletion as similar as a ban on fishing activities during the breeding seasons. There is no specialised gear meant for exploitation of any single species. The catches by any widely used fishing gears include many other species of less commercial value (by-catch) along with major commercial stock exploited. Some time, this by-catch also causes the incidental mortality of the organisms having high significance in conservation point of view. Such by-catch incidents could not be avoided but manageable in some extent. This is possible by adopting mesh regulations, time of operation, specified size grids and turtle excluding devices (TEDs). Apart from the gear type, the materials, which are used for making these gears, are equally important in their ecological viability and commercially feasible.

2.2.3 Ghost Fishing

The reasons for the occurrence of ghost nets in the sea are mainly divided into two. (a) incidental loss of fishing gears due to unfavourable weather conditions, collisions of gears with other objects during hauling, damage of set nets by gears used by other vessels, lack of precise navigation devices, damage of identifying marks of fishing gears by cargo ships and (b) intended loss due to the lack of possibilities to access the stretched gear and high costs for repairing and reusing.

Recently, a project on collecting ghost nets in the Baltic Sea was came out with shocking report that 1500 set nets are lost annually in Polish economic zone and 150 in Lithuanian economic zone (Milewska, 2013). It has been assessed by that the amount of nets deposited in the Baltic Sea varies from 270 to 810 tonnes in Polish economic zone and from 67 to 100 tonnes in Lithuanian water. These nets continue to catch fish that will never reach our plates. Additionally, due to the baffling catch of endangered or threatened species such as birds, turtles, shark, dolphins and other sea mammals, the ghost nets could negatively influence the ecological balance of the marine environment. Unfortunately, such information from our waters is missing. We have to address this issue in near future and it may be a disgusting piece of information for our stakeholders and the ecosystem managers in our country. The negative impacts of ghost fishing in the marine ecosystem cannot be achieved by avoiding our fishermen, who are the real contributors to reduce or nullify these adverse effects. The mitigation measures include creating awareness and effective disposal of damaged fishing gears as well as weather prediction reports to make their voyage in safe and to prevent the accidents in high seas. This can be accomplished by coordinating the various government departments and research institutions to make collective efforts against ghost fishing incidents.

2.3 Future Challenges in Conservation Measures

2.3.1 Habitat Enhancement Programme

In conservation of any species in the ecosystem is highly linked with their habitat support the living activities of the particular species. Based on the zone of functioning and the group of animals are benefited, these structures are divided into two categories namely ARs, which is meant for demersal fishes and FADs aim for column and pelagic fishes. The ARs/FADs influence the various functions in the life cycle of fishes. They support ecological succession

and form ecological niches. It acts as a habitat for feeding ground, diurnal changes in fish behaviour, refuge from predators, nursery ground for larvae and juveniles and also playing key role in conservation of fish stock from over exploitation. The hook and line are found to be an ideal gear for fishing in the AR areas (Vivekanandan et al., 2006).

Based on the use or purpose, ARs are classified into 5 types as follows:

- Environmental purposes such as biodiversity or ecosystem management, restoration, water quality management etc.;
- Living marine resources: attraction, enhancement, production and protection;
- Promotion of tourism and leisure activities like angling, scuba diving, surfing, boating etc.;
- Scientific research and education and multi-purpose structures.

The general guidelines for placement and establish of ARs/FADs structures in the sea has to be done based on following criteria. They should placed near to fishing village to reduce fuel cost for fishing trips but a site of strong tidal current should be avoided. It should not find place in commercial fishing area (trawling), in shipping routes and the areas near to river mouth. Hard bottom areas are highly preferred for installation to prevent subsidence and the depth of reef must be appropriate for targeted species.

In the recent observations made on the economic performance of ARs deployed in Tamil Nadu coast, south India was shown that a low operational expenditure and high net income for the hook and line units as well as gillnetting units from AR site than those of non-AR sites (Kasim et al., 2013). Three types of modules were tried at 11 sites along the coast (Fig. 27.2) and 70 each forms a cluster, occupying 1000 m² area, with about 500 m³ volume and offering about 3000 m² surface area for attachment.



FIGURE 27.2 Artificial reef modules used for marine fisheries management in Tamil Nadu coast. *Source: Photo courtesy CMFRI.*

2.3.2 Stock Enhancement Programme

Stocking is only viable option where the habitat is acceptable, the fishery recruitment is limited and fishing pressure can be managed. It may be preferable to consider an improved management as the first step in improving fishery production. For a stocking programme to be successful, a sound management is required. Proposal for stocking marine areas should examine why the stock needs enhancement, establish stocking objectives, empower local communities to manage stocking programme or fishery and provide for extension services to educate and train local stakeholders. Based on the availability of resources, status of the resource and fishery, market and expertise, fishery managers should choose appropriate local resident species and then develop stocking into a management plan that includes evaluation and monitoring. The most important hurdle in stock enhancement is not how to produce millions of larvae through hatchery breeding technique for release. Rather than this the involvement and establishment of co-management strategies between government departments or institutions and local communities in stock enhancement process by conducting assessment, evaluation, protecting native stock and habitat management.

Stock enhancement programme of marine species has been reported from the various countries are listed in Table 27.1. Asia-Pacific reported the most number of marine species stocked, with the majority was reported from Korea. Among the various groups, the enhancement activities were reported more of molluscan species followed by fishes of salmonids, seabass, seabreams, perches, mullets and crustaceans (Bartley et al., 2004). In India, The stock enhancement and sea ranching programme are at its primary level or such reports were not yet documented well. Based on available information, we have summarised that such activities were occurring in the various regions of Indian waters (Table 27.2).

A long-term sustainability of enhancement programme is critically difficult in the country like India due to the identification of responsible institutions for financial support to provide funds for hatchery, management and monitoring aspects. However, in developed countries, this issue is administratively tackled by taxes levied on commercial and recreational fishers (Kent and Drawbridge, 1999).

2.3.3 A Case Example – Andaman and Nicobar Pearl Oyster Resource Enhancement Programme (ANPOREP)

The Indo-Australian Archipelago is considered as an important region for the distribution of pearl oysters in the world. Andaman and Nicobar Islands recognised as one of the important region in this archipelago, bestowed with a good numbers of islands, islets, creeks and enclosed bays. With these geographical peculiarities, the marine ecosystem of these islands has been considered as potential grounds for mariculture particularly pearl culture. The lustrous black pearls produced in the blacklip pearl oyster *Pinctada margaritifera* have produce the one of most valuable pearls on earth with prices ranging from a minimum of 100 US\$ to 10,000 US\$ per pearl of exceptional and rare quality. The global trade of black pearls is 125 million dollars (Southgate, 2007) and India does not contribute to this. In the Pacific Ocean, the black lipped pearl oysters support many island nations economy. Through the production of black pearls from *P. margaritifera*, the island country of Tahiti became the global leader controlling 28.8% of the world market. Most countries with natural stock of *P. margaritifera* had developed extensive mariculture programme in the second half of last century to rebuild the natural stock and develop black pearl farms. In the cultured pearl industry, implantable

TABLE 27.1 Summary of Marine Species and the Countries Which has Carried Out Stock Enhancement Programmes (Based on Reports of FAO)

Country	Species stocked for enhancement
Argentina	<i>Oncorhynchus mykiss</i> , <i>Salmo salar</i>
Australia	<i>Oncorhynchus tshawytscha</i>
Belize	<i>Strombus gigas</i>
Brazil	<i>O. mykiss</i>
Brunei	<i>Lates calcarifer</i> , <i>Penaeus monodon</i>
Chile	<i>Oncorhynchus gorboscha</i> , <i>O. keta</i> , <i>O. kisutch</i> , <i>O. masou</i> , <i>O. mykiss</i> , <i>O. tshawytscha</i>
China	<i>Penaeus (orientalis) chinensis</i>
Taiwan	<i>Haliotis diversicolor aguailis</i> , <i>Lateolabrax japonicus</i> , <i>L. calcarifer</i> , <i>Pagrus major</i> , <i>Penaeus japonicus</i> , <i>Mugil cephalus</i>
Colombia	<i>Mugil incillis</i> , <i>Mugil spp.</i>
Cyprus	<i>Dicentrarchus labrax</i> , <i>O. mykiss</i> , <i>O. kisutch</i> , <i>Puntazo puntazo</i> , <i>Sparus auratus</i>
Egypt	<i>Penaeus spp.</i> , <i>S. auratus</i> , <i>M. cephalus</i> , <i>Liza ramada</i>
Estonia	<i>Coregonus lavaretus</i>
Fiji	<i>Tridacna spp.</i>
Finland	<i>Coregonus spp.</i> , <i>C. lavaretus</i> , <i>O. mykiss</i> , <i>Salmo trutta</i> , <i>S. salar</i>
France	<i>Coregonus spp.</i> , <i>O. mykiss</i> , <i>O. kisutch</i> , <i>S. trutta</i> , <i>Acipenser spp.</i>
French Polynesia	<i>L. calcarifer</i>
Grenada	<i>Crassostrea rhizophorae</i> , <i>Crassostrea virginica</i>
Iceland	<i>S. salar</i>
Iran	<i>Acipenser spp.</i> , <i>O. mykiss</i>
Japan	<i>Patinopecten yessoensis</i> , <i>P. major</i> , <i>Acanthopagrus schlegeli</i> , <i>Ebynnis japonica</i> , <i>Paralichthys olivaceus</i> , <i>Seriola quinqueradiata</i> , <i>S. aureovittata</i> , <i>S. dumerili</i> , <i>P. japonicus</i> , <i>Crassostrea gigas</i>
Korea	<i>A. schlegeli</i> , <i>Chrysophrys major</i> , <i>Fugu rubripes</i> , <i>Haliotis notohaliotis</i> , <i>Hemicentrotus pulcherrimus</i> , <i>M. cephalus</i> , <i>O. keta</i> , <i>O. masou</i> , <i>O. mykiss</i> , <i>Oplegnathus fasciatus</i> , <i>P. major</i> , <i>P. olivaceus</i> , <i>P. japonicus</i> , <i>Penaeus monodon</i> , <i>Penaeus orientalis kishimouye</i> , <i>Pinctada fucata martensii</i> , <i>Plecoglossus</i> , <i>Portunus trituberculatus</i> , <i>Sebastes schlegeli</i> , <i>Strongylocentrotus lividus</i> , <i>Sulculus diversicolor aquatilis</i>
Lithuania	<i>S. salar</i> , <i>C. lavaretus</i>
Madagascar	<i>O. mykiss</i>
Malaysia	<i>L. calcarifer</i> , <i>Penaeus merguensis</i>
Mauritius	<i>P. monodon</i> , <i>Rabdosargus sarba</i> , <i>Scylla serrata</i>
Mexico	<i>Crassostrea spp.</i> , <i>Haliotis fulgens</i> , <i>O. mykiss</i>
Micronesia	<i>Tridacna derasa</i>
Morocco	<i>O. mykiss</i> , <i>S. trutta</i>

(Continued)

TABLE 27.1 Summary of Marine Species and the Countries Which has Carried Out Stock Enhancement Programmes (Based on Reports of FAO) (cont.)

Country	Species stocked for enhancement
Mozambique	<i>Perna Perna</i>
New Caledonia	<i>T. niloticus</i>
New Zealand	<i>O. tshawytscha</i>
Norway	<i>S. salar</i>
Panama	<i>Penaeus stylirostris</i> , <i>P. vannamei</i>
Peru	<i>O. mykiss</i> , <i>Basilichthys bonaariensis</i> , <i>Agropecten purpuratus</i>
Poland	<i>S. trutta</i> , <i>S. salar</i> , <i>C. lavaretus</i>
Portugal	<i>Penaeus japonicus</i> , <i>S. auratus</i>
Sao Tome	<i>S. gigas</i>
Seychelles	<i>P. monodon</i>
Singapore	<i>Epinephalus fuscoguttatus</i> , <i>L. calcarifer</i> , <i>P. merguiensis</i>
Solomon Islands	<i>T. derasa</i> , <i>T. squamosa</i> , <i>T. maxima</i> , <i>T. gigas</i>
South Africa	<i>O. mykiss</i>
Sweden	<i>S. salar</i>
USA	<i>Sciaenops ocellatus</i> , <i>O. gorbuscha</i> , <i>O. keta</i> , <i>O. mykiss</i> , <i>O. tshawytscha</i> , <i>O. nerka</i> , <i>O. kisutch</i> , <i>S. trutta</i> , <i>S. salar</i> , <i>Morone saxatilis</i>
USSR/Russia	<i>Pecten</i> spp., <i>Coregonus</i> spp., <i>Acipenser</i> spp.
Tonga	<i>Tridacna crocea</i> , <i>T. squamosa</i> , <i>T. maxima</i> , <i>T. niloticus</i> , <i>T. marmoratus</i>
Tunisia	<i>D. labrax</i>
Turks and Caicos Islands	<i>Mithrax spinosissimus</i> , <i>S. gigas</i>
United Arab Emirates	<i>Acanthopagrus latus</i> , <i>R. sarba</i> , <i>Siganus canaliculatus</i>
Venezuela	<i>O. mykiss</i>

size adult (mother) oysters are sourced either from natural populations or from farm grown hatchery spats or naturally collected spats. In India, particularly in Andaman and Nicobar Islands, the black lip pearl oyster, *P. margaritifera* farming is yet to be commercialised due to limited pearl oyster resources in the natural beds. These pearl oysters have been used mainly by shell craft industries as mother of pearl artefacts and not for producing pearls. Almost all nations having black lip pearl oysters have used these oysters for producing pearls and enhancing their economies.

The naturally sparse pearl oyster population may not be able to produce enough larvae and seed to make dense oyster populations. Very high predation rates of the small oysters also hinder natural stock survival. Hence hatchery-produced seed can be used for increasing the natural population. The process of releasing hatchery-produced seed into the wild population is called sea ranching or stock enhancement. Understanding the need to utilise the natural resources of the islands for the benefit of the Islanders, the Central Marine Fisheries Research Institute

TABLE 27.2 Stock Enhancement and Sea Ranching Programme of Marine Species Reported From Indian Waters

Species	Area/region	Department/institute involved
<i>Penaeus semisulcatus</i>	Palk Bay	CMFRI
<i>P. fucata</i>	Pearl paar, off Tuticorin and Gulf of Mannar	CMFRI
<i>Meretrix casta</i> , <i>Anadara granosa</i> , <i>Paphia malabarica</i> ,	Ashatamudi lake, Kerala	CMFRI
<i>Holothuria scabra</i>	Tuticorin	CMFRI
<i>Babylonia spirata</i> , <i>Xancus pyrum</i> , <i>Chicoreus virgineus</i> , <i>Hemifusus</i> <i>pugilinus</i> , <i>Rapana rapiformis</i>	Gulf of Mannar	Department of Zoolgy, Kamaraj College, Tuticorin
<i>Rachycentron canadum</i>	Vizhinjam	Rajiv Gandhi Centre for Aquaculture
<i>P. fucata</i>	Gulf of Kachchh	Junagadh Agricultural University
<i>Portunus pelagicus</i>	Tamilnadu coast	Annamalai University
<i>L. calcarifer</i>	Madras coast	Central Institute of Brackishwater Aquaculture
<i>P. margaritifera</i>	Andaman waters	CMFRI
<i>Penaeus monodon</i>	Astamudi lake, Kerala	Department of Fisheries, Kerala

CMFRI, Central Marine Fisheries Research Institute.

(CMFRI) Kochi has developed the technology of seed production (Mohamed et al., 2010) in the project hatchery at Port Blair with financial assistance of Ministry of Earth Sciences (MoES).

People's participation is essential in the development of any restoration programme. Children, youth, environment clubs, caretakers of marine parks, personal from marine protection authorities and other villagers who reside near the sea ranching site can get involved in ANPOREP. The programme was initiated at Burmanallah, South Andaman district by volunteership of school children of GSS Rangachang, under Department of Education. A group of 15 high school student are selected as volunteers and they have been described the various aspects of the ANPOREP, importance and its ecological role in laboratory as well as in the restoration site.

The hatchery-produced seed of pearl oysters (2–4 cm length) are attached on to small live rocks (10–20 cm length/dia) collected from intertidal zone where ranching is proposed to be done. This can be achieved by placing the seed oysters over the rocks and leaving them undisturbed in the tank. The oysters would produce the byssus threads and attach on the rocks within 6–12 h. Then these rocks with oysters are placed inside a metal mesh protected concrete platform of 0.50 × 0.50 × 0.15 m harboured in natural beds (Fig. 27.3). Care should be taken to firmly place the cages at the selected location such that it is not disturbed. The location where the seed will be released should be marked with the help of small floats and also this should be geo-referred using a Global Positioning System (GPS). This is mainly for evaluating the impact after the stock enhancement programme.



FIGURE 27.3 ANPOREP activities for stock enhancement of blacklip pearl oyster in Andaman waters.

Though, the outcome of stock enhancement programme was not as hoped as initially. It is important to notice that different size groups of pearl oyster were responded differently. The mortality was comparatively very high in the smaller sized ones because of they are easily predated than the larger ones. One of the major causes of mortality after release is predation (Spencer, 1992) and preventive methods for improving survival should be examined. Survival rates after release vary according to a set of factors include time and size at release, habitat, carrying capacity and species composition of prey and predators. The involvement of the volunteers was equally important for the successful maintenance of protected platforms to reduce the mortality and entry of predatory organisms into the enclosures. The less social commitments of the villagers and vandalism in the ANPOREP areas also negatively affected the grace of the programme. However, the programme is inevitable and will focus on the issues and demerits noticed and improve in the consecutive trails of stock enhancement.

Similarly, *Turbo marmoratus* (Turban shell) and *Trochus niloticus* (top shell) are two important species of gastropods endemic to these islands are exploited due to commercially valuable shells in shell craft industry from which thousands of islanders make their livelihood. Shell-fishing was controlled by the Andaman and Nicobar Islands fisheries regulations (1938) and recently these animals have been classified as endangered, threatened and protected (ETP) and brought under the purview of the Indian Wildlife Protection Act (1972). To restock and rebuild depleted of these gastropod populations it is necessary to initiate sea ranching programme after developing appropriate seed production techniques. Other gastropods like *Lambis* spp., *Cassia* spp., *Fasciolaria* spp. also deserve stock enhancement programme. The stock enhancement programme for the other groups of marine animals

such as giant clams, mussels, Lobsters, holothurians, groupers, sea breams and ornamental fishes etc., are also to be advised to have in the coming decades. However, the recent survey done by Zoological Survey of India indicates the stock recovery of *T. niloticus* and a higher abundance in natural habitat, which necessitate the reopening of its fisheries in a controlled manner.

All the stock enhancement programmes comprise potential benefits along with some risks or challenges too (Waples and Drake, 2004). The benefits include:

- It helps to reduce short-term extinction risk of targeted species and in maintain population well before issues for decline.
- It ensure a hasten recovery of wild stock before overexploitation pressure and helps to establish a reserve population for use.
- It initiates the reseeding process in the vacant or deceased habitat.
- It provide scientific information about conservation of natural populations by satisfy legal mandates.
- It increases the harvest opportunity, ecosystem restoration, and public education/ awareness.

The risks or challenges have involved in stock enhancement are loss of genetic diversity, loss of fitness in comparatively with wild population, competition and predation while stocking of hatchery raised seeds, chances of disease transfer cultured animals to wild population, doubt on habitat utilisation of cultured stock as like as natural population, influence of non-genetic productivity effects in growth as well as fecundity, and unexpected issues in brood-stock management in captivity. However, these constraints can be minimised or overcome completely by following effective management strategies.

3 MANAGEMENT STRATEGY

The current management strategy typically considered each activity or threat is in isolation; coordinated management of cumulative impacts is rare. In this context, it is essential to understand the ecosystem at local, regional and global level. In simple terms an ecosystem is a dynamic complex of plants, animals, microbes and physical environmental features that interact with one another. Humans are an integral part of ecosystems, marine and terrestrial. The 'interconnectedness' within and among ecosystems is provided both by the physical environment and by biological interactions. Therefore, ecosystem based approach should be followed for holistic management and sustainability.

Ecosystem based management of the marine biodiversity is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors (Yazdi and Shakouri, 2011). Specifically, ecosystem-based management:

- Emphasises the protection of ecosystem structure, functioning and key processes.
- It is place-based in focusing on a specific ecosystem and the range of activities affecting it.

- Acknowledges interconnectedness among systems, such as between air, land and sea; and integrates ecological, social, economic, and institutional perspectives, recognising their strong interdependences.
- Explicitly accounts for the interconnectedness within systems, recognising the importance of interactions between many target species or key services and other non-target species.

Some of the very specific current activities concerning coastal areas for management are,

3.1 Ecologically Sustainable Aquaculture

The global experiences and assessments of various bodies on climatic change, depletion of wild catch rate and increase demand for fish protein, concluded that aquaculture practices should be boosted up to overcome these issues. The expansion of aquaculture industry and increases the production of seafood and helps the management agencies to be more precautionary and reduce exploitation rates on depleting wild fish stocks. Farming practices also became a major world enterprise which provides food and employment for future generations. This will reduce the exploitation pressure from the wild and help to retain the biodiversity in nature (New, 1997). In India, CMFRI was successful in the development of hatchery technologies and started mariculture activities of several food fishes in open sea cages as well as earthen ponds (Fig. 27.4).



FIGURE 27.4 Hatchery and farming technology of fishes developed by CMFRI. Source: Photo Courtesy CMFRI.

3.2 Eco-Friendly Tourism

Tourism and recreational activities in the marine realm is increasing day by day and the islands are considered as holiday destination worldwide. Because of this tourist pressure in the unique ecosystem will negatively influence the biodiversity conservation. The activities include visiting to various biodiversity-rich sites namely beaches, coral reefs, mangrove swamps and seagrass meadows for swimming, snorkeling, scuba diving etc. To facilitate this, there is an increase in number of boats are operating in these areas and also support the other adventurous trips meant for game fishing or recreational fishing. Such tourist trips causes littering of plastic bags, pet bottles and wraps of foods items etc. to these pristine environs was carried by them. In addition, the damages made to fringing corals and reefs are enormous due to coral walking and boat anchoring.

3.3 Climate Change

It is apparent that all regions of the planet earth in some ways are being adversely affected by the global warming trend. Most of the corrective measures pertain mainly to the industrialised world, such as developing alternate sources of energy rather than depending heavily on fossil fuels, or manufacturing more petrol efficient automobiles, to name a couple of actions. In tropical biomes the big issue is preserving ecosystems that absorb atmospheric carbon dioxide. This measure would encourage the cessation of rampant clearing of tropical forests for conversion to agricultural production. Also in this regard, adopting programmes to revitalise reforestation in formerly cleared but unproductive lands would be a stellar activity. As nations within the tropical biomes become progressively industrialised, there too, energy sources and means of transportation will become significant issues. Yazdi and Shakouri (2011) suggest three ways to manage the issues viz.

3.3.1 Preventing Change

It is the optimum way to reduce the impacts of climate change on protected areas is to dramatically reduce the heat-trapping gases that are being emitted by the burning of fossil fuels (coal, oil and natural gas). If these emissions are not cut deeply and quickly, there will be little chance of saving many protected areas. The power sector is responsible for 37% of those emissions globally and has many opportunities to switch from coal to clean power.

3.3.2 Managing for Change

It is observed that many climate change impacts are exacerbated by other pressures. For example, even climate-related phenomena such as coral bleaching and dieback are increased by pollution and mechanical damage. WWF is publishing a guide to adaptation strategies, 'Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems', the first comprehensive account of how protected areas might be managed in a rapidly changing climate.

3.3.3 Planning for Change

In several instances, it is seen that protected area agencies need advice and political support for planning protected area networks to withstand or adapt to change as much as possible.

This needs to be a collaborative, global exercise. WWF proposes that the World Commission on Protected Areas would be one obvious body to coordinate such an effort, perhaps as a task force under its theme on management effectiveness.

4 ECOLOGICAL RESTORATION

Ecosystem Restoration is the 'process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed'. The ultimate goal of restoration is to create a self-supporting ecosystem that is resilient to perturbation without further assistance. Restored ecosystem should have the following attributes: (1) similar diversity and community structure in comparison with reference sites; (2) presence of indigenous species; (3) presence of functional groups necessary for long-term stability; (4) capacity of the physical environment to sustain reproducing populations; (5) normal functioning; (6) integration with the landscape; (7) elimination of potential threats; (8) resilience to natural disturbances; and (9) self sustainability (SER, 2004).

Many of the world's ecosystems including many of marine systems have undergone significant degradation with negative impacts on biological diversity and peoples' livelihoods. In the case of the oceans, the anthropogenic signature is strongest in the coastal zone (Vitousek et al., 1997). In the tropics, the major coastal ecosystems are coral reefs, seagrass beds and mangrove forests. Perhaps one of the most important human disturbances on coral reefs is over fishing (Hodgson, 1999).

Restoration, using principles from ecology and techniques from engineering, is feasible for all three major coastal ecosystems in the tropics, namely, coral reefs, seagrass beds and mangrove forests. The level of difficulty, however, varies with the different types of ecosystems. When viewed in these terms, mangrove forests are probably the easiest habitats to restore, followed by seagrass beds, and then coral reefs. An example of success in restoration on a relatively large-scale is the work of Guzman (1991) on reefs on the Pacific coast of Costa Rica which have been devastated by a combination of natural and human disturbances. A total of 110 live fragments of colonies from nearby reefs were transferred to the affected sites and attached with wire to 30 cm long steel stakes. After 3 year, there was 79%–83% survivorship, and a 41%–115% increase in new colonies due to fragmentation. Mangrove forests are probably the easiest habitat to restore. Mangrove silviculture has been practised in some Asian countries since the 19th century (Kaly and Jones, 1998). This gained momentum in the South and Southeast Asian nations and small islands located in the Indian Ocean after the December 2004 tsunami. Because mangrove ecosystem acts as a natural bioshield in protecting the coastal areas against the sea surges and reduce the impact of tsunami waves.

5 CONCLUSIONS

Available evidences and data on marine life and climate change and marine life, though, with shortcoming, highlight the negative consequences of climate change and the projection is not healthy for the marine ecosystem to function. Therefore, strategies for conservation and management of the natural resources should be organised for implemented, based on

the appropriate mitigation and legislation with the orientation of technological and institutional bodies involved in it. Such approaches will ensure the attainment and continued satisfaction of human needs for present and future generations. Successful programmes have demonstrated ecological feasibility as well as compatibility with aims to conserve marine biodiversity for humankind. Since stock enhancement programmes highly depend on hatchery-produced seed for restoration activities, hatchery technology and culture techniques must be developed in harmony with wild environment. Habitat enhancement, stock enhancement and sea ranching programmes not only help in conservation of species but will also enhance the fisheries production, support the food security of the nation. Effective measures in fisheries management such as Fishing bans, gear regulation, preventing ghost fishing can be to reduce the catch and discards of valuable resources will enhance the nature biodiversity. The constructive steps in ecologically sustainable aquaculture and eco-friendly tourism are also a pressing need of the hour. It must be emphasised that the awareness, active participation and collective efforts of students, youth, researchers, wildlife actives and fishers is an essential for all the conservation activities to a grand success.

Acknowledgement

We sincerely thank the organisers of the interactive workshop on 'people, forest and wildlife conservation' for the kind invitation, support and brought out the manuscript in the present form. We are indebted to Director, Central Marine Fisheries Research Institute, Kochi for facilities. Authors are grateful to the Ministry of Earth Sciences, New Delhi for funding a project on blacklip pearl oyster farming for Andaman and Nicobar Islands and Department of Fisheries, Andaman Administration for functioning as nodal agency.

References

- Bartley, D.M., Born, A., Immink, A., 2004. Stock enhancement and sea ranching in developing countries. In: Leber, K.M., Kitada, S., Blankenship, H.L., Svasand, T. (Eds.), Chapter 4. Stock Enhancement and Sea Ranching – Developments, Pitfalls and Opportunities. Blackwell Science Ltd, Oxford, pp. 48–57.
- Guzman, H.M., 1991. Restoration of coral reefs in Pacific Costa Rica. *Conserv. Biol.* 5, 189–195.
- Halpern, B.S., Selkoe, K.S., Micheli, F., Kappel, C.V., 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. *Conserv. Biol.* 21 (5), 1301–1315.
- Hodgson, G.A., 1999. Global assessment of human effects on coral reefs. *Mar. Pollut. Bull.* 38, 345–355.
- Kaly, U.L., Jones, G.P., 1998. Mangrove restoration: a potential tool for coastal management in tropical developing countries. *Ambio* 27, 656–661.
- Kasim, H.M., Rao, G.S., Rajagopan, M., Vivekanandan, E., Mohanraj, G., Kandasami, D., Muthiah, P., Jagadis, I., Gopakumar, G., Mohan, S., 2013. Economic performance of artificial reefs deployed along Tamilnadu coast, South India. *Indian J. Fish* 60, 1–8.
- Kent, D.B., Drawbridge, M.A., 1999. Developing a marine ranching programme: a multidisciplinary approach. In: *Marine Ranching: Global Perspective With Emphasis on the Japanese Experience*, FAO, Rome, FAO Fishery Circular 943, pp. 66–78.
- Milewska, E., 2013. Collecting Ghost Nets in the Blatic Sea. BSRAC Project Report, Blatic Sea Regional Advisory Council 2020, Poland.
- Mohamed, K.S., Kripa, V., Linoy Libini, C., Shanmugam, K., Prakash Rao, K., Velayudhan, T.S., 2010. Hatchery production of blacklip pearl oyster spat in the Andaman and Nicobar Islands – A success story. *Fishing Chimes* 30 (2), 40–41.
- New, M.B., 1997. Aquaculture and the Capture Fisheries – Balancing the Scales. *World Aquaculture*, June, 11–30.
- SER (Society for Ecological Restoration International Science & Policy Working Group, 2004. The SER International Primer on Ecological Restoration. Society for Ecological Restoration International, Tucson, Arizona. Available from: <http://www.ser.org>.

- Southgate, P.C., 2007. Overview of the cultured marine pearl industry. Bondad-Reantaso, M.G., Mc Gladdery, S.E., Berthe, F.C.J. (Eds.), *Pearl Oyster Health Management: A Manual*, vol. 503, FAO Fisheries Technical Paper, Rome, pp. 7–17.
- Spencer, B.E., 1992. Predators and methods of control in molluscan shellfish cultivation in north European waters. DePauw, N., Joyce, J. (Eds.), *Aquaculture and Environment 1991*, vol. 16, European Aquaculture Society Special Publication, pp. 309–337.
- Vitousek, P.M., Mooney, H.A., Lubchenco, J., Melillo, J.M., 1997. Human domination of earth's ecosystems. *Science* 277, 494–499.
- Vivekanandan, E., Vekatesan, S., Mohanraj, G., 2006. Service provided by artificial reef off Chennai: a case study. *Indian J. Fish* 53, 67–75.
- Waples, R.S., Drake, J., 2004. Risk or benefit considerations for marine stock enhancement: a Pacific Salmon perspective. In: Leber, K.M., Kitada, S., Blankenship, H.L., Svasand, T. (Eds.), *Chapter 22: Stock Enhancement and Sea Ranching – Developments, Pitfalls and Opportunities*. Blackwell Science Ltd, Oxford, pp. 260–306.
- Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson, R., 2006. Impacts of biodiversity loss on ocean ecosystem services. *Science* 314, 787–790.
- Yazdi, S.K., Shakouri, B., 2011. The climate change and marine biodiversity. *International Conference on Biology, Environment and Chemistry, IPCBEE*, vol. 1, IACSIT Press, Singapore, pp. 257–267.

Biodiversity and Climate Change Adaptation in Tropical Islands

Edited by

Chandrakasan Sivaperuman

Zoological Survey of India, Andaman & Nicobar Regional Centre, Haddo, Port Blair, A & N Islands, India

Ayyam Velmurugan, Awnindra Kumar Singh and Iyyappan Jaisankar

ICAR-Central Island Agricultural Research Institute, Port Blair, India

Biodiversity and Climate Change Adaptation in Tropical Islands provides comprehensive information on climate change, biodiversity, possible impacts, adaptation measures and policy challenges to help users rehabilitate and preserve the natural resources of tropical islands. Although biodiversity and climate change of tropical islands has previously received less attention, it is ironically one of the most vulnerable regions in this regard. The core content of the work derives largely from the ideas and research output from various reputed scientists and experts who have recorded climate change impacts on aquatic and coastal life in tropical regions.

Contributors have direct working experience with the tribes in some of the tropical islands; their expertise and information is compiled and presented in the work, including coverage related to climate change. This book highlights the ever-growing need to develop and apply strategies that optimize the use of natural resources, both on land and in water and judicious use of biodiversity.

Biodiversity and Climate Change Adaptation in Tropical Islands is a critical resource on tropical island biodiversity for researchers, academicians, practitioners and policy makers in a variety of related disciplines.

Key Features

- Covers a wide range of biodiversity documentation, conservation measures and strategies that can be applied to various sectors, from forests to agriculture
- Brings together expertise from researchers in the area who have direct experience in the regions described
- Contains a wealth of field research related to biodiversity conservation and its applications from a variety of tropical islands



ACADEMIC PRESS

An imprint of Elsevier

elsevier.com/books-and-journals

ISBN 978-0-12-813064-3



9 780128 130643