

# THE GREAT BARRIER REEF

Biology, Environment and Management

Pat Hutchings, Mike Kingsford and Ove Hoegh-Guldberg



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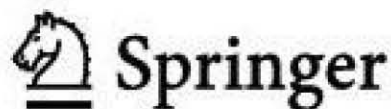
Biology, Environment and Management

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# Preface

*Hon Virginia Chadwick AO*

Formerly Chairman of the Great Barrier Reef Marine Park Authority.

In 1922 the Australian Coral Reef Society was established as the first association in the world specifically concerned with the study, research and conservation of coral reefs. Over decades the Society's work has contributed significantly to our understanding of the Great Barrier Reef.

Increased knowledge and understanding is critical if students are to feel encouraged and inspired to follow careers in research or management of coral reef ecosystems.

For those in government, or in organisations such as the Great Barrier Reef Marine Park Authority, the results of scientific research provide both a catalyst and a foundation for policy responses to identified threats and challenges.

Additionally, through conferences, lectures, and the media, the Society provides the broad Australian community with independent and expert information about the issues impacting on a great Australian icon.

This book, 'The Great Barrier Reef: Biology, Environment and Management', published by the

Commonwealth Scientific and Industrial Research Organisation (CSIRO), continues to explain, inform and educate. It will be valued by non experts, students and researchers.

Those who have contributed are recognised as Australian experts in their field and each chapter has been peer reviewed. The end of each chapter lists 'Additional reading' relevant to the chapter. More references are available at [http://www.australiancoralreefsociety.org/GBR\\_book.htm](http://www.australiancoralreefsociety.org/GBR_book.htm) [Verified 21 March 2008].

I commend the Australian Coral Reef Society for this initiative that provides such a wealth of information in an accessible form.

For those who care for the Great Barrier Reef this book provides confirmation of the continuing need for sound science and informed management if the reef, as we know it, is to survive current and future challenges.



# Acronyms

ABRS	Australian Biological Resources Study, Canberra, ACT
ACRS	Australian Coral Reef Society
AIMS	Australian Institute of Marine Science, Townsville, Qld
ARC	Australian Research Council
CRC	Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DDM	Day-to-day Management Program
DPI & FISH	Department of Primary Industries and Fisheries
ENCORE	Enrichment of Nutrients on Coral Reefs
EPICA	European Project for Ice Coring in Antarctica
GBR	Great Barrier Reef
GBRCA	Great Barrier Reef Catchment Area
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority, Townsville, Qld
GBRWHA	Great Barrier Reef World Heritage Area
IPCC	Intergovernmental Panel on Climate Change
JCU	James Cook University, Townsville, Queensland
MODIS	Moderate Resolution Image Spectroradiometer on the Terra and Aqua satellites, available at <a href="http://modis.gsfc.nasa.gov/">http://modis.gsfc.nasa.gov/</a> [Verified 21 March 2008].
MST	Marine Science and Technology
NGOs	Non Government Organisations
NIWA	National Institute of Water and Atmospheric Research, Wellington, New Zealand
NQAIF	North Queensland Algal Identification/Culturing Facility
NTM	Museum and Art Gallery of the Northern Territory, Darwin, NT, Australia
QDNR&M	Queensland Department of Natural Resources and Management
QDPI	Queensland Department of Primary Industries
QPWS	Queensland Parks and Wildlife Service
OSCAR-NOAA	A NOAA project mapping, using satellite altimetry, the water surface elevation of the ocean, from which the near-surface water currents are calculated.
RAP	Representative Areas Program
ROV	Remote Operated Vehicle
RWQPP	Reef Water Quality Protection Plan
SeaWiFS	Sea-viewing Wide Field-of-view Sensor (see <a href="http://oceancolor.gsfc.nasa.gov/">http://oceancolor.gsfc.nasa.gov/</a> SeaWiFS [Verified 21 March 2008].

# Author Biographies

## S. T. AHYONG

Shane Ah Yong is a Research Scientist at the National Institute of Water and Atmospheric Research (NIWA), in Wellington, New Zealand. He is an international authority on the stomatopod and decapod crustaceans. Research interests include crustacean phylogeny and systematics invasive species and biosecurity, and deep-water faunas.

## P. ALDERSLADE

Phil Alderslade has been researching the identification of octocorals since the early 1970's and for the last 25 years has been the Curator of Coelenterates at the Northern Territory Art Gallery and Museum (NTM). With Katharina Fabricius he has co-authored 'Soft Corals and Sea Fans'—the only comprehensive field guide to the shallow water octocorals of the Red Sea, Indo-Pacific and central west Pacific regions of the world.

## C. ALEXANDER

Christopher Alexander was appointed lecturer in Marine Biology at the University College of Townsville (later James Cook University (JCU)) in 1968 and retired in 2003. During that period, he taught a wide range of subjects, researched and supervised honours and graduate students in plankton, invertebrates (especially Crustacea) and Neurophysiology. He is currently Adjunct Associate Professor and regularly tutors in laboratory classes in plankton and crustaceans and gives guest lectures in these subjects and introductory neurophysiology. Degrees: Zoology (University of Wales), M.Sc. Plankton (University of Southampton), Ph.D. crustacean neurophysiology (University of Wales).

## T. J. ANDERSON

Tara Anderson is a Research Scientist (Benthic Ecologist), Geosciences Australia. Her research over 15 years has focused primarily on the relationships between

benthic habitats and biota, including biophysical sea floor mapping, in a broad range of coastal and offshore marine ecosystems in New Zealand, Australia, and along the west coast of the United States.

## P. BOCK

Philip Bock became fascinated by bryozoans while geological mapping in south-west Victoria, where the sediments are often packed with their skeletons. He took up study of the living bryozoans of southern Australia in order to gain an understanding of their environmental variation. After working at RMIT (Royal Melbourne Institute of Technology) University for over 30 years, he retired in 1997, and maintains an active interest, including keeping the Bryozoa Home Page website available at <http://www.bryozoa.net/> [Verified 21 March 2008].

## J. BRODIE

Jon Brodie is a research scientist with the Australian Centre for Tropical Freshwater Research at James Cook University. He has held positions as Director, Institute of Applied Science, University of the South Pacific, and Director, Water Quality and Coastal Development Group, GBRMPA (Great Barrier Reef Marine Park Authority). Jon has collaborated with a wide range of research colleagues from AIMS (Australian Institute of Marine Science), GBRMPA, CSIRO (Commonwealth Scientific and Industrial Research Organisation), QDNR&M (Queensland Department of Natural Resources and Management), QDPI (Queensland Department of Primary Industries), JCU (James Cook University) and the Reef CRC (Co-operative Research Centre) to establish the effects of changed terrestrial runoff on GBR (Great Barrier Reef) ecosystems.

## M. BYRNE

Maria Byrne's research on the biology of invertebrates involves echinoderms and molluscs. She received her



B.Sc. from Galway University, Ireland, and Ph.D. from University of Victoria, Canada. At the Smithsonian Institution she investigated Caribbean echinoderms and returned to Ireland working on sea urchin aquaculture and fisheries. Her research on life history evolution uses Australian echinoderms with divergent life histories to investigate the role of evolution of development in generating larval diversity and speciation in the sea. Maria is Director of One Tree Island Research Station, southern Great Barrier Reef. She has published over 130 refereed articles and book chapters.

#### J. H. CHOAT

Howard Choat is an Adjunct Professor of Marine Biology at James Cook University and has worked extensively on coral reef fishes over the Indian, Pacific, and Atlantic Oceans.

#### B. C. CONGDON

Brad Congdon is a Reader in Ecology at James Cook University, Cairns. He is a field ecologist with a special interest in seabird conservation and evolution and over 25 years experience working with seabirds both in Australia and overseas. His research group has recently demonstrated that seabirds are sensitive indicators of multiple, previously indistinguishable, climate change impacts at upper trophic levels and were the first to clearly establish rising sea-surface temperatures as a major conservation issue for seabirds of the GBR.

#### J. DAY

Jon Day is currently the Director, Outlook Report Taskforce, within GBRMPA. He has been closely associated with the Great Barrier Reef for 22 years, having worked initially in the park management and planning sections in GBRMPA. Jon was responsible for commencing and co-ordinating the Representative Areas Program, the major rezoning program undertaken for the Marine Park, between 1998–2003. This marine planning approach is widely considered as 'world's best practice', and has received eleven national and international awards, including the Banksia and Eureka Awards, and the UNESCO/MAB Environmental Prize (2005 Sultan Qaboos Prize for Environmental Preservation).

#### G. DIAZ-PULIDO

Guillermo Diaz-Pulido grew up in Colombia. He completed his B.Sc. (Hons) in Marine Biology in Colombia in 1995 and his Ph.D. in Marine Botany at James Cook University in 2002. He has done pioneering work on the ecology and diversity of reef algae from the Caribbean Sea and the Great Barrier Reef. His current research focuses on the dynamics of algae after coral disturbances, coral-algal interactions, and impacts of climate change on macroalgae. He is associated with the Universidad del Magdalena in Colombia and is currently a Research Fellow at the Centre for Marine Studies at the University of Queensland.

#### P. J. DOHERTY

Peter Doherty, currently Research Director of the Australian Institute of Marine Science (AIMS), gained his Ph.D. in 1980 by describing the population dynamics of damselfishes at One Tree Island. In 1989 he joined AIMS and led a research group in tropical fisheries ecology. In 1998, he joined the Co-operative Research Centre for the Great Barrier Reef World Heritage Area. One of his achievements was to facilitate the \$9 million research collaboration known as the 'GBR Seabed Biodiversity Project'. His fondest memories are more than 100 days spent at sea on the RV Lady Basten working the back deck from midnight to midday.

#### S. DOVE

Sophie Dove obtained an undergraduate degree in Mathematics and Philosophy from the University of Edinburgh, and a Ph.D. in Biological Sciences from the University of Sydney. She is presently a Senior Lecturer at the Centre for Marine Studies at the University of Queensland. Her research interests predominantly lie in the area of dinoflagellate-coral symbiosis, especially with regard to their photobiology, clonal nature, and their ability to deposit calcium carbonate. The goal of this research is to understand how these basic features of scleractinian corals respond to the environmental change inclusive of anomalous atmospheric CO<sub>2</sub> concentrations.

#### N. C. DUKE

Norm Duke is a Mangrove Ecologist of more than 30 years standing, specialising in mangrove floristics,



biogeography, genetics, climate change ecology, vegetation mapping, plant-animal relationships, pollution and habitat restoration. As Principal Research Fellow he currently leads an active research and teaching group on marine tidal wetlands at the University of Queensland Centre for Marine Studies. With his detailed knowledge and understanding of tidal wetland processes he regularly advises on effective management and mitigation of disturbed and damaged ecosystems. He has published more than 130 peer-reviewed articles and technical reports, including his recent authoritative popular book 'Australia's Mangroves'.

#### K. FABRICIUS

Katharina Fabricius is a coral reef ecologist at the Australian Institute of Marine Science. She has worked on coral reefs around the world since 1988. Her main research interest is to better understand the roles of environmental conditions and disturbances, including changing water quality, for the biodiversity of near-shore coral reefs. Katharina was awarded a Ph.D. in 1995 for her work on octocoral ecology, and presently holds the position of a Principal Research Scientist. She has published over 70 journal articles, book chapters, and a book on Indo-Pacific octocorals, jointly produced with Phil Alderslade.

#### L. GERSHWIN

Lisa-ann Gershwin, National Marine Stinger Advisor, is an international authority on medusae and ctenophores. Her research interests are primarily on taxonomy, systematics, biogeography, and biodiversity, with recent work on the prediction of the presence of marine stingers and prevention and treatment of their stings. She has worked on medusae and ctenophores around the world since 1992, with particular focus on Australian species since 1998. While working in Australia she has collected many thousands of specimens, with at least 151 species new to science, including 14 new genera and four new families.

#### D. P. GORDON

Dennis Gordon FLS has been studying bryozoans for 40 years. He is a past President of the International Bryozoology Association and a Principal Scientist at the

National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand.

#### H. HEATWOLE

Harold Heatwole is an ecologist and herpetologist, who in the past 47 years successively held academic posts at the University of Puerto Rico, University of New England, and North Carolina State University. His main research interests are sea snakes, island ecology, ants and tardigrades.

He is the author of over 300 scientific articles and 11 books. He also produces videos for educational purposes. He holds a D.Sc. and Ph.D's in Zoology and Botany. The last dealt with vegetation dynamics on the small cays of the Great Barrier Reef. He is a Fellow of the Explorer's Club.

#### K. HEIMANN

Kirsten Heimann is a phycologist in the School of Marine and Tropical Biology at James Cook University (JCU) and has 20 years experience in this research area. She established the North Queensland Algal Identification/Culturing Facility (NQAIF) within the School of Marine and Tropical Biology. The research facility has established tropical microalgal cultures from the Great Barrier Reef, thereby creating the first systematic microalgal record for the region. She is especially interested in algal bloom development, the impact of phosphate/nitrate eutrophication on, for example, dinoflagellate/diatom reproduction dynamics/levels of toxicity, determinants of invasiveness, and the use of microalgae as indicators of water quality.

#### O. HOEGH-GULDBERG

Ove Hoegh-Guldberg is Director of the Centre for Marine Studies at the University of Queensland. After completing his B.Sc. (Hons) Ove travelled to the United States to complete his Ph.D. After postdoctoral work and lectureship Ove returned to Sydney in 1992. In 2000 he moved to the University of Queensland where he leads a group focused on the physiological ecology of coral reefs, particularly regarding global warming and ocean acidification. He has produced over 120 peer reviewed scientific articles and runs the blog:



<http://www.climateshifts.com> [Verified 21 March 2008]. In 1999 he was awarded the Eureka prize for scientific research into coral bleaching and climate change. In May 2008, he became the 2008 Queensland Smart State Premier's Fellow.

#### J. N. A. HOOPER

John Hooper, Head of the Biodiversity & Geosciences Programs, Queensland Museum, is an international authority on sponges (Phylum Porifera) with specific research interests in taxonomy, systematics, biogeography, biodiversity and conservation biology, and collaborating with 'biodiscovery' agencies over the past two decades in the search for new therapeutic pharmaceutical compounds (and discovering thousands of new species along the way).

#### D. HOPEY

David Hopley is a coastal geomorphologist, holding the position of Professor Emeritus in the School of Earth and Environmental Sciences at James Cook University. He held a personal chair in marine science and has a 43 year association with the University. He worked on coral reef evolution, and changing sea levels, especially on the Great Barrier Reef. He has more than 150 scientific papers on this and related topics including two major books, 'The Geomorphology of the Great Barrier Reef: Quaternary Evolution of Coral Reefs' (Wiley Interscience, 1982) and, with Scott Smithers and Kevin Parnell, 'The Geomorphology of the Great Barrier Reef: Development, Diversity and Change' (Cambridge University Press, 2007).

#### T. P. HUGHES

Terry Hughes has written over 90 research articles on coral reef science, including 21 in the journals *Science* and *Nature*. He has received numerous prizes and awards, and was elected to the Australian Academy of Sciences in 2002, for his contribution to reef science. His publications focus mostly on the dynamics of coral reefs, and issues relating to managing fisheries, pollution and climate change. Terry is Director of the Australian Research Council's Centre of Excellence for Coral Reef Studies, where he leads a \$50 million research program. He provides frequent advice to gov-

ernments and NGOs on marine science, coral reef management and policy.

#### P. A. HUTCHINGS

Pat Hutchings is a Senior Principal Research Scientist at the Australian Museum and has spent her research career working on the systematics and ecology of polychaetes. In addition, she has been studying the process of bioerosion not only on the GBR but also in French Polynesia, collaborating with French researchers. As well as publishing extensively she has been actively involved in the Australian Coral Reef Society (ACRS) for many years and commenting on management and zoning plans for Australian coral reefs.

#### R. KELLEY

Russell Kelley is a science communication consultant specialising in invisible or time dependent processes through animation and multimedia techniques. His printed work includes a series of popular publications visualising the biological and physical connections between the Great Barrier Reef and its catchments.

#### M. J. KINGSFORD

Michael Kingsford is currently Head of the School of Marine and Tropical Biology at James Cook University. The School is a recognised world leader in tropical marine studies. He is also co-ordinator of the Area of Research Strength, Marine Science at James Cook University (JCU), member of the International Advisory Committee of the Great Barrier Reef Research Foundation, Immediate Past President of the Australian Coral Reef Society, and the former Director of One Tree Island Research Station in the southern Great Barrier Reef. He has published extensively on the ecology of reef fishes, jellyfishes, and biological oceanography. His projects have encompassed a range of latitudes and include a well respected book on temperate marine environments. A major focus of his research has been on connectivity of reef fish populations and how the findings can assist managers of marine parks. In addition to research and leadership, he teaches undergraduate and postgraduate students and supervises many postgraduate students.



## P. KOTT

Patricia Mather (née Kott) AO, FMLS was, before retirement, a senior curator in the Queensland Museum. She has published on the history and roles of museums, taxonomy, conservation, and the Great Barrier Reef and is an internationally recognised authority on the taxonomy of the Ascidiacea. Her appointments include: membership of the MST Grants Committee, ABRS (Australian Biological Resources Study) Consultative Committee, Australian Research Council (ARC) Biological Panel, and a nine-year term on the Consultative Committee of the Great Barrier Reef Marine Park Authority that she had helped to establish. She is a past president of the Great Barrier Reef Committee and senior editor of the 'Coral Reef Handbook'.

## A. W. D. LARKUM

Anthony Larkum has worked in many fields—from molecules to ecosystems. His early interests were in the way plants absorb nutrients. However, an interest in SCUBA diving stimulated an interest in algae and in how algae are adapted to light fields underwater. This led to a lifelong interest in the physiology and ecology of algae and seagrasses. He has edited two books on the biology of seagrasses. He was instrumental in setting up the University of Sydney's One Tree Island Research Station and has been fascinated with the various roles of algae in the coral reef ecosystem. He initiated the ENCORE (Enrichment of Nutrients on Coral Reefs) Project at One Tree Island that looked at the effect of raising the local levels of nitrogen and phosphorus on coral reef organisms. He is also currently working on the potential effects of global climate change.

## V. LUKOSCHEK

Vimoksalehi Lukoschek completed her Ph.D. in 2007 at James Cook University where she studied the evolutionary and conservation genetics of hydrophiine sea snakes, with a focus on species occurring in Australian waters. She obtained her B.Sc. in marine and terrestrial biology with an emphasis on marine conservation, and a First Class Honours investigating the foraging ecology of benthic, carnivorous coral reef fishes. She has also worked on a variety of projects in molecular biology and marine mammal ecology.

## H. MARSH

Helene Marsh is Professor of Environmental Science and Dean of Graduate Research Studies at James Cook University, Townsville. Her research interests include marine mammalian population ecology with an emphasis on life history, reproductive ecology, population dynamics, diet, distribution, abundance and movements of dugongs. She has also supervised several PhD students working on coastal cetaceans. Helene has produced some 200 scientific publications including one book, about 100 articles in refereed journals, chapters in books and encyclopaedia, conference proceedings and technical reports. She was awarded a Pew Charitable Trust Fellowship in Marine Conservation, the most prestigious international scientific award in marine conservation in 1998 and a Distinguished Service Award by the Society of Conservation Biology in 2007.

## D. MCKINNON

David McKinnon has over 25 years experience as a biological oceanographer, and has published extensively on copepod dynamics and systematics. David completed his undergraduate education at the University of Otago, New Zealand before moving to Melbourne, where he completed an M.Sc. His Ph.D., on environmental regulation of copepod production, was completed at the University of Queensland. As part of the Australian Institute of Marine Science Water Quality and Ecosystem Health team he leads research into the environmental impacts of tropical aquaculture, and on the biological oceanography of Australia's tropical seas.

## J. M. PANDOLFI

John Pandolfi is Professor in the Centre for Marine Studies and the Department of Earth Sciences at the University of Queensland. His research integrates palaeoecological, ecological, historical, and climate data to provide critical insights into how marine communities are assembled and structured in the face of environmental variability and human impacts over extended periods of time.

## C. R. PITCHER

Roland Pitcher, Principal Research Scientist, CSIRO Marine and Atmospheric Research, and Principal Investigator



of the Great Barrier Reef Seabed Biodiversity Project. His research over 25 years on seabed habitats and biota, including distribution and abundance mapping, effects of prawn trawling, recovery and dynamics, population modelling and assessments, provides an objective foundation to assist management in achieving sustainability of the seabed environment.

#### B. C. RUSSELL

Barry Russell is Principal Scientist (Marine Biodiversity) with the Northern Territory Department of Natural Resources, Environment and the Arts. He has over 30 years research experience on the systematics, ecology, and behaviour of tropical demersal fishes of the Indo-West Pacific. His current research interests include the taxonomy and phylogenetics of wrasses (Labridae), groupers (Serranidae), threadfin breams (Nemipteridae) and lizardfishes (Synodontidae).

#### C. SYMS

Craig Syms is a lecturer at the School of Marine and Tropical Biology at James Cook University. He has published a range of papers on the relationships between reef fishes and their habitats. His current research examines the role of different spatial and temporal scales of habitat variability in structuring communities. In addition to research, he has also advised extensively on marine resource management and evaluation of marine reserves in California. He teaches postgraduate sampling and experimental design and statistics, and supervises postgraduate students in a range of different marine projects.

#### C. C. WALLACE

Carden Wallace is the Principal Scientist of the Queensland Museum, based at the Museum of Tropical Queensland in Townsville. She has researched coral

biodiversity and evolution on reefs around the world and is author of the monograph *Staghorn Corals of the World*. Her current research focus is on taxonomy, biogeography, fossil history, evolution and post-bleaching recruitment of family Acroporidae. She is also reviewing the sea anemone fauna of Australia, with Dr Daphne Fautin and others.

#### R. C. WILLAN

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