Coastal Wetlands of the World

Geology, Ecology, Distribution and Applications

Salt marshes and mangrove forests, the intertidal wetlands of the world's coastlines, provide key ecological services to all areas of the globe, and are vital sinks and sources in carbon budgets. They are crucial indicators of both modern-day anthropogenic impacts on climate and ecosystems, and paleoecological changes during much of Earth's history.

This cutting-edge, richly illustrated book introduces the essential elements of coastal wetlands and their applications. It unites geological and oceanographic approaches in an accessible way, providing scientific names for key plant and animal species. The book opens by introducing coastal oceanography, the physical features of wetlands, their ecology and human impacts upon them, giving students from all fields the necessary background for wetlands studies. It then presents detailed case studies from all areas of the world, with extensive illustrations, presenting students with a broad, global-scale picture of wetlands geomorphology and biodiversity. The final chapters discuss some unique applications of coastal wetlands, including geological monitoring, uses in biotechnology and agriculture and various experimental mesocosms.

This is ideal as supplementary reading to support students on a wide range of Earth and Life science courses, from environmental science, ecology, and paleoecology to geomorphology and geography. Providing citations to a variety of more specialist articles, it will also be a valuable interdisciplinary reference for researchers.

David Scott is a Professor in the Earth Sciences Department of Dalhousie University, where he teaches micropaleontology and Quaternary geology. Other positions held include VP on the Cushman Foundation Board, membership of the Geological Society of America and Paleontological Society, and serving as associate editor for the Canadian Journal of Earth Sciences. He has written over 130 refereed papers, has edited three NATO volumes on coastal geomorphology and paleontological subjects, and is also the co-author of *Monitoring in Coastal Environments Using Foraminifera and Thecamoebian Indicators* (with Franco Medioli and Charles Schafer, CUP 2001). Professor Scott has conducted field work in most major marshes of North America, and several wetlands in South America and Europe, in addition to participating in Ocean Drilling Program studies in the Indian Ocean.

Jennifer Frail-Gauthier is a PhD Candidate in earth sciences and biology at Dalhousie University, and her research topic is small food webs in salt-marsh ecosystems, specifically foraminifera, which form an important part of this book. Her PhD focus is on experimental approaches to salt marshes for studies in ecology, biology, geology, restoration and other human impacts. Ms Frail-Gauthier is a science writing tutor and teaches third-year applied coastal ecology, which focusses on the various coastal ecosystems of the world, including

geology, ecology and anthropogenic impacts, and also teaches various biology courses. She has received several major scholarships and awards during her graduate studies, and also holds a Teaching Excellence Award and a University Medal from Dalhousie University.

Petra Mudie is an Adjunct of the Graduate Studies Faculty at Dalhousie University, Adjunct Professor of the Memorial University of Newfoundland, and a Scientist Emeritus with Geological Survey of Canada Atlantic. Her previous work includes heading up a halophyte research laboratory at the Scripps Institute of Oceanography, including surveys of coastal wetlands from Canada to Mexico, working on environmental marine geology for the Canadian Government until 2001, and subsequently leading an international programme, studying palynological records of the history of climate and sea-level change in the Black-Sea–Eastern-Mediterranean Corridor. She is the author of over 80 papers in science journals. Dr Mudie and Professor Scott have collaborated on salt-marsh and Arctic paleoenvironmental studies for nearly 40 years, co-supervising many graduate students.

'This is a major new contribution to the study of salt marshes and mangrove forests. Uniquely comprehensive, the book provides extraordinary coverage of coastal wetlands from the Arctic to the tropics with superb case study examples from Africa, Europe, Asia, and both Americas.

Importantly, this innovative volume covers not only the physical, ecological and human interventions controlling the development, loss and future of coastal wetlands but also provides the reader with modern approaches to geological monitoring, conservation of plant biodiversity, and experimental methods. The readability of the book, with supporting graphics and informative photographs, makes it accessible to readers at all levels.'

– **Professor Curtis J. Richardson**, *Director, Duke University Wetland Center*

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CAMBRIDGE
UNIVERSITY PRESS

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University Printing House, Cambridge CB2 8BS, United Kingdom

Published in the United States of America by Cambridge University Press, New York

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107056015

First published 2014

Printed in the United Kingdom by TJ International Ltd. Padstow Cornwall

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

Library of Congress Cataloguing in Publication data
Scott, D. B.
Coastal wetlands of the world : geology, ecology, distribution and applications / David B. Scott, Jennifer Frail-Gauthier, Petra J. Mudie.
pages cm
ISBN 978-1-107-05601-5 (hardback)
1. Wetland ecology. 2. Wetland conservation. 3. Coasts. 4. Coastal ecology.
I. Frail-Gauthier, Jennifer. II. Mudie, Petra J. III. Title.
QH541.5.M3S36 2014
577.68–dc23
2013035761

ISBN 978-1-107-05601-5 Hardback
ISBN 978-1-107-62825-0 Paperback

Additional resources for this publication at www.cambridge.org/coastalwetlands

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Preface

Coastal Wetlands of the World follows the book by Scott, Medioli and Schafer (2001) on *Monitoring in Coastal Environments*. We are motivated to write this new book based on concern about the status of mangroves and salt marshes all over the world, from pole to pole, and by the fact that few students have the chance to look at our changing shorelines from both a geological and an ecological perspective. Coastal wetlands are being destroyed and degraded at alarming rates, and only a fraction remains. These wetlands protect us from storm buffering and have extremely high primary production, making them important storehouses of carbon and energy, habitats that nurture juvenile stages of commercially important fishes and that filter our waste water – yet we continue to damage them faster than we can preserve them. In some areas, less than a third of natural wetlands remain along the coast, and very few are entirely unaffected by *direct* human impacts. Furthermore, all our coastal wetlands are changing in response to *indirect* human impacts: global warming, sea level rise and increasing numbers of severe coastal storms. These impacts are further magnified in the Arctic, where the pace of climate warming is four times faster than other places on Earth, and where disappearing sea ice is encouraging rapid expansion of oil and gas exploration, with the associated risks of long-lasting pollution damage. Arctic people say that 'The Earth is faster now' – and it appears that traditional methods of coastal living are no longer viable. It is likely that circumpolar regions are already irreversibly changed – and the spill-over impacts on global air and ocean systems is already being felt by people in crowded cities of warm temperate regions.

We take an interdisciplinary approach to *Coastal Wetlands of the World* – there literally is something for everyone between the covers of this book. It was initially written for undergraduate students, focussing on classical studies that are the baselines for evaluating recent changes, but it soon became clear that more detail was needed to guide readers towards the proliferation of new scientific literature. As a result, we have included innumerable up-to-date references that will also help graduate students, naturalists and coastal-resource managers obtain a fresh view of tidal wetlands research across a wide spectrum of disciplines. Geologists, ecologists, conservationists, environmentalists, archeologists, historians and social scientists can all learn something new and clearly understand the issues at hand, for any area of the world. The book's global focus and ample illustrations are also intended to draw the student beyond their familiarity with a limited neighbourhood marshland toward a much bigger picture of wetlands geomorphology and biodiversity on a global scale.

Why yet another book covering coastal wetlands and ecosystems? Our literature search of the most widely used texts showed a large imbalance in coverage of the world's continents, despite the shrinking size of our Internet-linked Global Village. We have attempted to fill in large gaps for under-reported regions of Mexico, South America, Africa, Eastern Europe

and China, and we provide the only systematic and focussed coverage of global tidal wetlands. Most other wetlands books are broken into vari-authored chapters and/or report on either marshes or mangroves, presenting a somewhat schizophrenic perspective to the reader, as though the world has sharp boundaries. In contrast, our readers are provided a seamless virtual tour from the northern tip of continental North America to the southern tip of New Zealand. From geology to biology to ecology to human impacts, we introduce wetlands from a generic stand point (Chapters 1–6). We then dive into information about coastal wetlands across all continents, giving specific historical case studies, and earmarking new research and paradigm shifts in traditional concepts about drivers of coastal climate changes. The last section of our book focusses on unique applications of coastal wetlands studies, including a chapter on paleoseismology, paleoclimate and forecasting (updated and much expanded in the range of proxies from *Monitoring in Coastal Environments*), and an outline of how coastal wetlands are used as experimental mesocosms to better understand and replace what is lost. We are the first to cover both traditional knowledge and cutting-edge subcellular and genetic knowledge of the potential for salt-tolerant plants to combat crises of soil salinization in agricultural crops. The development of new salt-tolerant crops is a major part of the new Green Revolution needed to feed the world's rapidly expanding human population – simultaneously representing major carbon credits and conserving our fast-dwindling global freshwater resources. Education is the first step in the coastal crisis facing everyone 'living on the edge' – the more that can be taught about tidal wetlands, the more our global population can see the dire need to save what remains and wisely restore what we have destroyed.

We are indebted to many people and organizations who have helped in the writing of this book, answered multiple questions about places less familiar to us and provided illustrative materials. Invaluable help with diagrams comes from Rob Gauthier, Alexandre Pelletier-Michaud, Gary Grant and Matthew Chedrawe, and we are indebted to Ken Wallace for photo-compilations and design. The extended family of Petra Mudie have provided photo-coverage from all continents where there are tidal wetlands (thanks to Anita and Hilton Whittle, Helen Pease and Peter Mudie) and we sincerely thank all those who graciously provided other beautiful photos of wetlands and animals, as acknowledged in the figure captions. Finally, we are most grateful to Laura Clark and others at Cambridge University Press, who provided encouragement, guidance, and answered no less than 100 questions to help get this book from our heads into a beautiful printed volume.

List of acronyms and abbreviations

Organizations

AGEDI	Abu Dhabi Global Environmental Data Initiative
ASEAN	Association of Southeast Asian Nations
CC	Creative Commons (free-to-use images from Wikipedia or Flickr)
CIMI	Canada-Iraq-marshlands Initiative
CITES	Convention on International Trade in Endangered Species
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CNES	Centre National d'Etudes Spatiales
CONABIO	Comisión Nacional para el Conocimiento y Uso de la Biodiversidad
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DFO	Department of Fisheries and Oceans (Canada)
FAO	Food and Agriculture Organization of the United Nations
GSCA	Geological Society of Canada Atlantic
IPCC	Intergovernmental Panel on Climate Change
IRD	l'Institut de recherche pour le développement
IRRI	International Rice Research Institute
MEA	Millennium Ecosystems Assessment
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NEIC	National Earthquake Information Center
NOAA	National Oceanic and Atmospheric Administration
RIS	Ramsar Information Sheet
SRTM	Shuttle Radar Topography Mission
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USFWS	United States Fish and Wildlife Service
USA	United States of America
USGS	United States Geological Survey
WCMC	World Conservation Monitoring Centre
WRI	World Resources Institute

Standard and other abbreviations or notations

‰	parts per million
$\delta^{13}C$	delta carbon-13 value in mille, which is the ratio between stable carbon isotopes (C-12 and C-13) relative to PeeDee Belmnite × 1000
ASL	above sea level
BCE	before the Common/Christian Era
BP	before present
cal yr BP	calendar years before present
BTEX	benzene, toluene, ethylbenzene and xylenes
CAT	storm/hurricane category
CE	Common/Christian Era
CHC	chlorinated hydrocarbons
DDT	dichlorodiphenyltrichloroethane
DNA	deoxyribonucleic acid
EHW	extreme high water (highest tide line)
GW	gigawatt
IP_{25}	ice proxy with 25 carbons
LIA	Little Ice Age
LGM	last glacial maximum
M_w	unit for earthquake magnitude
MHW	mean high water
MHHW	mean higher after first high water (see Box 2.1 for more details)
MIS	marine isotope stages
MLW	mean low water
MSL	mean sea level
MSX	*Haplosporidium nelsoni* shellfish disease
MW	megawatt
PAH	polycyclic aromatic hydrocarbon
PLF	pingo-like feature
psu	practical salinity unit
RSL	relative sea level
sp.	singular species; plural = spp.
VP	vice president