TREATISE ON ESTUARINE AND COASTAL SCIENCE

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EDITORS-IN-CHIEF

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VOLUME 1
CLASSIFICATION OF ESTUARINE AND NEARSHORE COASTAL ECOSYSTEMS

VOLUME EDITORS

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University of Washington, USA

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AMSTERDAM BOSTON HEIDELBERG LONDON NEW YORK OXFORD
PARIS SAN DIEGO SAN FRANCISCO SINGAPORE SYDNEY TOKYO
Academic Press is an imprint of Elsevier

ACADEMIC PRESS

Academic Press is an imprint of Elsevier
32 Jamestown Road, London NW1 7BY, UK
225 Wyman Street, Waltham, MA 02451, USA
525 B Street, Suite 1900, San Diego, CA 92101-4495, USA

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

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

ISBN: 978-0-12-374711-2

For information on all Elsevier publications
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Printed and bound in Italy

12 13 14 15 10 9 8 7 6 5 4 3 2 1

Editorial: Hannah Rutland, Gemma Mattingley
Production: Laura Jackson

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Eric Wolanski, FTSE, FIE Aust, is a coastal oceanographer and ecohydrologist. His research interests include the oceanography and sediment dynamics of coral reefs, mangroves, and muddy estuaries. They also include the interaction between physical and biological processes determining the ecosystem health in tropical riverine, estuarine, and waters. Wolanski leads the UNESCO-ROSTE estuarine ecohydrology modeling efforts to quantify the impact from farming, dams, irrigation, and urbanization on the ecological services that estuaries provide to humanity. The ecohydrology models that have resulted have been applied to assess the human impact on coral cover in the Great Barrier Reef, Darwin Harbour, coastal waters of Micronesia, and Tanzania savannah ecosystems. Wolanski has more than 330 scientific papers and seven books. He is a fellow of the Australian Academy of Technological Sciences and Engineering, the Institution of Engineers Australia, and l'Académie Royale des Sciences d'Outre-Mer. He was awarded an Australian Centenary medal for services in estuarine and coastal oceanography, a Doctorate *Honoris Causa* from the Catholic University of Louvain, and a Queensland Information Technology and Telecommunication award for excellence. Wolanski is the chief editor of *Estuarine, Coastal and Shelf Science*, *Wetlands Ecology and Management*, and the *Treatise of Estuarine and Coastal Science*. He is a member of the editorial board of *Journal of Coastal Research*, *Journal of Marine Systems*, *Continental Shelf Research*, and *Ecohydrology and Hydrobiology*. He is a member of the Scientific and Policy Committee of the International Geosphere-Biosphere Programme (IGBP)'s LOICZ (Land Ocean Interactions in the Coastal Zone) and of EMECS (Japan-based International Center for Environmental Management of Enclosed Coastal Seas).

Donald McLusky was for many years a senior lecturer in marine biology at the University of Stirling, Scotland, UK. He also served as the Head of Department and Vice-Dean of the Faculty of Science. He holds a BSc degree in zoology from the University of Aberdeen and a PhD degree on estuarine ecophysiology from the University of Stirling. While at Stirling his research interests were centered on the biology of the Forth estuary, with many studies of the intertidal fauna including the annelids, molluscs, and crustaceans. For over 25 years, he was responsible for the monitoring of the effects on the intertidal environment of a large petrochemical complex at Grangemouth on the Forth. He also studied the impact of two marine oil terminals on the surrounding marine environment. He supervised the PhD programs of many young estuarine and marine scientists both at Stirling and in Sri Lanka, Bahrain, and Portugal.

Away from Stirling University, he was a visiting fellow at the University of Copenhagen's marine laboratory at Helsingør on several occasions, as well as a visiting professor at the University of Paris and Rivers State University, Nigeria. He was the honorary secretary of the Estuarine and Coastal Sciences Association (ECSA) and remains their trustee. He was a member of the Council of the Scottish Marine Biological Association and a member of the Scientific Advisory Committee of Scottish Natural Heritage.

He is the author of over 60 scientific papers on marine, estuarine, and freshwater biology. He is the author of the well-established textbook *The Estuarine Ecosystem*, which is now in its third edition, as well as *Ecology of*

Estuaries, and the editor of several volumes including *The Freshwaters of Scotland, North Sea – Estuarine Interactions*, and *The Environment of the Estuary and Firth of Forth*. He was the editor of the journal *Estuarine and Coastal Shelf Science* for ten years, from 2000.

VOLUME EDITORS: BIOGRAPHIES

Dan Baird is a Senior Professor in the Department of Botany and Zoology at the Stellenbosch University, South Africa. Prior to his appointment at Stellenbosch University in 2008 he was Chair of the Department of Zoology, Nelson Mandela Metropolitan University (formerly the University of Port Elizabeth) since 1981. He obtained the PhD degree from the University of Stellenbosch in fisheries science, and has published more than 100 papers in refereed journals, a number of chapters in books, and was co-editor of a volume on the *Estuaries of South Africa* (Cambridge University Press). Professor Baird conducted research and published widely with fellow academics, amongst others, from the University of Maryland, MD, the East Carolina University, NC, University of North Carolina, NC, the Alfred Wegener Institute for Polar and Marine Research, Germany. Professor Baird specializes in the fields of ecosystem theory, analysis and modelling, marine and coastal zone ecology, and management, water quality of, and nutrient dynamics in, shallow water ecosystems.

Luís Chícharo is Professor of Ecology at the University of Algarve, Portugal. He is the Director of the International Centre for Coastal Ecohydrology, under the auspices of UNESCO. He coordinates the LOICZ node in Europe for Middle East and North Africa regions and is Chairman of the Steering Committee of the UNESCO Ecohydrology Program, as well as the European Working Group on Estuaries and Coastal Ecohydrology. He is the coordinator of the International Erasmus Mundus Master Course in Ecohydrology. He coordinated several international projects and published more than 50 papers in international journals and several book chapters. He is member of the scientific editorial board of the Journals *Estuarine Coastal and Shelf Science, Ecohydrology and Hydrobiology* and of *ISRN Ecology*. His interests are the development of land-ocean integrated ecohydrologic solutions, harmonized with the human dimensions, for the sustainable management of estuaries and coastal areas.

Robert Costanza is Professor of Sustainability, Institute for Sustainable Solutions at Portland State University. Before moving to PSU in 2010, he was the Gund Professor of Ecological Economics and founding director of the Gund Institute for Ecological Economics at the University of Vermont. Before Vermont, he was on the faculty at Maryland and LSU, and visiting scientist at the Beijer Institute in Sweden, and the Illinois Natural History Survey. Dr. Costanza is also currently a Distinguished Research Fellow at Ecological Economics Research New Zealand (EERNZ), Massey University, Palmerston North, New Zealand, a Senior Fellow at the National Council on Science and the Environment, Washington, DC, and a Senior Fellow at the Stockholm Resilience Center, Stockholm, Sweden.

Dr. Costanza received BA and MA degrees in Architecture and a PhD in Environmental Engineering Sciences (Systems Ecology with Economics minor) all from the University of Florida.

Dr. Costanza's transdisciplinary research integrates the study of humans and the rest of nature to address research, policy, and management issues at multiple time and space scales, from small watersheds to the global system. Dr. Costanza is co-founder and past-president of the International Society for Ecological Economics, and was chief editor of the society's journal, *Ecological Economics* from its inception in 1989 until 2002. He is founding co-editor (with Karin Limburg and Ida Kubiszewski) of *Reviews in Ecological Economics*. He currently serves on the editorial board of ten other international academic journals. He is also founding editor-in-chief of *Solutions* a new hybrid academic/popular journal.

His awards include a Kellogg National Fellowship, the Society for Conservation Biology Distinguished Achievement Award, a Pew Scholarship in Conservation and the Environment, the Kenneth Boulding Memorial Award for Outstanding Contributions in Ecological Economics, and honorary doctorates from Stockholm University and the Ecole Normale Supérieure de Lyon.

Dr. Costanza is the author or co-author of over 500 scientific papers and 22 books. His work has been cited in more than 7,000 scientific articles and he has been named as one of ISI's Highly Cited Researchers since 2004. More than 200 interviews and reports on his work have appeared in various popular media.

Mike Elliott is the Director of the Institute of Estuarine and Coastal Studies and Professor of estuarine and coastal sciences at the University of Hull and a marine biologist with a wide experience of marine and estuarine biology and its environment, management, and policy. His teaching, research, and advisory and consultancy work have included studies of most ecological components as well as policy, governance, and management. In many instances, he has concentrated on the interactions between these aspects, usually in relation to human activities and on the way in which environmental change influences organisms and vice versa. He has taken a particular interest in the way in which water bodies are defined and analyzed for policy and management. Mike has produced more than 140 peer-reviewed scientific publications and has co-authored or edited 11 books and conference proceedings on estuarine and marine issues. This includes co-authoring *The Estuarine Ecosystem: Ecology, Threats and Management* (with DS McLusky, OUP, 2004) and *Ecology of Marine Sediments: Science to Management* (with JS Gray, OUP, 2009). He has been/is a chair and/or member of many advisory panels for teaching and research both in the UK and elsewhere and is a member of the editorial boards of several international scientific journals as well as the Editor-in-Chief of *Estuarine, Coastal and Shelf Science*. He was previously employed by the Forth River Purification Board (now the Scottish Environmental Protection Agency), Tidal Waters Section as the Senior Marine Biologist. Professor Elliott has recently been appointed to the UK governmental Marine Conservation Zone Science Advisory Panel.

Burghard W. Flemming began his academic education at the University of Kiel (Germany) where he graduated in 1972 (MSc equivalent), majoring in marine geology and sedimentology. While in Kiel, he qualified as a scientific diver, his master's thesis having essentially been an underwater project on wave abrasion and deposition in the western Baltic Sea. Early in 1973, a foreign student exchange scholarship took him to the University of Cape Town (South Africa) where he engaged in a PhD project on depositional processes in Saldanha Bay and Langebaan Lagoon located along the west coast of South Africa. He was awarded his PhD degree in 1977. In 1975 he became a member of the newly created National Research Institute for Oceanology (CSIR) where he assisted in building up a marine geoscience division, which he took over as Divisional Head in 1980. During this time his research focused on regional current-generated bedforms and sediment dispersal along the southeast African continental margin driven by the Agulhas Current. In October 1984, he followed in the footsteps of Hans-Erich Reineck as Head of the Senckenberg Marine Research Station in Wilhelmshaven (Germany), being mainly engaged in the investigation of tidal depositional processes. At the same time he gave undergraduate courses in sedimentology at the University of Bremen, being honoured for his teaching engagement with an extramural professorship in 1998. Burg Flemming retired in 2009 at the age of 65, having published over 150 papers in scientific journals and books.

Jim Hansom is Reader in Geographical and Earth Sciences at the University of Glasgow, Scotland and Professor of Geography at the University of Canterbury, Christchurch, New Zealand. He graduated with MA (Hons) from Aberdeen University, before continuing at Aberdeen with his PhD on spatial variations in sub-Antarctic coastal geomorphology. He has held lecturing positions at the National University of Ireland (University College Dublin) (1977-1979), University of Sheffield, England (1979-1990), University of Canterbury (1991) and, since 1991, at the University of Glasgow. His research and consultancy interests lie in the geomorphology and coastal zone management of mid and high latitude coasts, particularly in the light of recent variations in the drivers of coastal change. He is the author of over 150 research publications and reports as well as three books: Hansom, J.D. 1988. Coasts Cambridge University Press; Hansom, J.D. and Gordon, J.E. 1998. Antarctic Environments and Resources: a Geographical Perspective. Addison, Wesley, Longman; May, V.J, and Hansom J.D. 2003. Coastal Geomorphology of Great Britain, Geological Conservation Review Series. 28. UK Joint Nature Conservation Committee.

Carlo Heip is former Director of the Royal Netherlands Institute of Sea Research NIOZ and former director of the Centre of Estuarine and Marine Ecology of the Netherlands Institute of Ecology. He is also emeritus professor at the Universities of Gent (Belgium) and Groningen (The Netherlands), teaching biological oceanography and estuarine ecology. His research at the University of Gent, where he founded the Marine Biology Section, centered on the ecology of (meio)benthos. In 1992 he created the department of Ecosystem Studies at the NIOO in Yerseke that focuses on processes at the interface between biogeochemistry and benthic biology. He has over 360 publications including 138 papers in peer-reviewed journals (Hirsch index 40, over 5000 citations) and edited six books. He was PI in many national and EU-sponsored projects, a member of the editorial board of 12 scientific journals and a member of several peer review committees and scientific advisory boards. As President of the European Marine Research Stations MARS network (1995-2004), he has been heavily involved in creating a marine biodiversity research programme in Europe. He was co-ordinator of the EU Network of Excellence MARBEF (Marine Biodiversity and Ecosystem Functioning) and active in the Scientific Steering Committee of SCOPE, the DIVERSITAS programme and the Census of Marine Life. He is now president of the European Institute for the Study of Marine Biodiversity and Ecosystem Functioning MarBEF+, member of the Executive Committee of the ESF Marine Board and the chair of WG5 Marine Biodiversity of GEO BON.

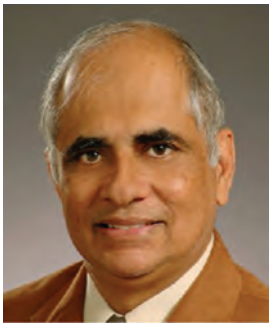
Michael J. Kennish is a research professor and faculty member in the Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, New Jersey. He is also the research director of the Jacques Cousteau National Estuarine Research Reserve in Tuckerton, New Jersey. Dr. Kennish has conducted biological and geological research on estuarine, coastal ocean, and deep-sea environments for more than 30 years, and has taught marine science classes at Rutgers for many years. Much of his research has involved the development and application of innovative methods to determine the condition and overall ecosystem health of aquatic systems. He is internationally known for his work on human impacts in estuarine and marine environments. In the US, Dr. Kennish has served on many environmental panels and workgroups assessing anthropogenic problems in coastal marine environments, while also collaborating extensively with state and federal government agencies to remediate degraded habitats. Most notably, he has been heavily engaged in integrative ecosystem assessment, particularly investigations of impairment and remediation of impacted estuarine systems. These include studies of the natural and anthropogenic stressors that affect environmental change, and the dynamics of environmental forcing factors that generate imbalances in biotic community structure and ecosystem function. His research is multidisciplinary in scope, addressing a wide range of internationally significant problems such as the effects of watershed development on coastal bays and nearshore ocean waters, wastewater discharges, habitat loss and alteration of aquatic systems, nutrient enrichment and eutrophication, hypoxia and anoxia, organic pollution, chemical

contaminants, climate change, sea-level rise, overfishing, invasive species, watercraft effects, dredging and dredged material disposal, freshwater diversions, calefaction of estuarine waters, and entrainment and impingement of electric generating stations. He has also examined the effects of construction and operation of industrial facilities, maintenance of shorelines and waterways, and human use of coastal space and aquatic systems. Much of his basic research has entailed investigations of benthic communities and habitats, as well as seafloor mapping and habitat characterization. In addition, he has studied the biology and geology of mid-ocean ridges and hydrothermal vent systems as a member of the Center for Deep-Sea Ecology and Biotechnology at Rutgers. As the co-chair of the Coastal Climate Change Group in Rutgers' Climate and Environmental Change Initiative, he is involved in the study of long-term climate change impacts on the New Jersey coast. In 2009, he was appointed by Governor Corzine to serve on the New Jersey Coastal and Ocean Protection Council. He was awarded the 2009 NOAA and NERRA national award for outstanding contributions to the National Estuarine Research Reserve System. In 2010, he was awarded the Graham Macmillan National Award of the American Littoral Society for outstanding contributions to marine science and conservation in the United States. While maintaining a wide range of research interests in marine ecology and marine geology, Dr. Kennish has been most actively involved in leading research teams investigating estuarine and coastal marine environments. He has published 12 scholarly books and more than 160 research articles in science journals and books. In addition, he has edited six compendium journal volumes on various topics in marine science.

Hartwig H. Kremer is Chief Executive Officer of Land-Ocean Interactions in the Coastal Zone (LOICZ), an Earth system research project of the International Geosphere-Biosphere Program, IGBP, and the International Human Dimensions Programme on Global Environmental Change, IHDP, based at the Helmholtz-Zentrum Geesthacht, Centre for Materials and Coastal Research, Germany. His background covers biological and physical oceanography, fisheries, and trace metal analysis. He received his master's degree (1988) and PhD (1994) in marine zoology, physical oceanography and fisheries at the University of Kiel. He holds a second degree as a senior public advisor for fisheries economy received from the Ministry for Food, Agriculture, Fisheries and Forestry. He was the manager responsible for a training program for Integrated Coastal Zone Management and Food Security tailored to public institutions worldwide. Scientifically he focuses on the interplay of coasts and river-catchments, changing social-ecological systems with complex interaction between nature and society. He has promoted a new research in LOICZ looking into institutional dimensions, governance and the science policy interface on various scales. He co-authored and published the new Science and Implementation Strategy of LOICZ, today the only global research cluster mandated to analyze Earth system change in coasts taking a holistic and interdisciplinary natural and social science perspective.

Remi Laane is a senior scientist with DELTARES, which is an independent Dutch knowledge institute for applied research in the field of water, subsurface and infrastructure. Professor of marine biogeochemistry at the University of Amsterdam and author of more than 300 scientific papers and reports, and six popular books on various aspects of the North Sea.

Joseph Luczkovich graduated with a BS degree in Biology in 1978 at Lehigh University in Bethlehem, Pennsylvania. He began graduate study at Rutgers University in New Brunswick, New Jersey, where he studied Ichthyology under Professor Kenneth Able and Fish Behavior with Bori Olla. During that period, Joseph worked as a fishery technician in the Behavior Department at the Sandy Hook Laboratory of the National Marine Fisheries Service, part of the US National Oceanic and Atmospheric Administration. His thesis concerned the commensal relationship of juvenile red hake *Urophycis chuss* and sea scallops, *Placopecten magellanicus*, and the behavior and ecology of that relationship. After completing his MS in Ecology at Rutgers in 1982, he moved to the Florida State University, in Tallahassee, to pursue a doctoral degree. He worked with Dr. Robert J. Livingston on juvenile fishes living in seagrasses, which is an important nursery habitat for many species of economically important species of fishes. He was focused on selective use of resources by these fishes, and eventually focused on pinfish, *Lagodon rhomboides*, completing the degree in 1987. After finishing his doctoral degree, Dr. Luczkovich moved to a post-doctoral fellowship at the Harbor Branch Oceanographic Institute, in Ft. Pierce, Florida with R. Grant Gilmore on mangrove fishes, specifically the common snook, *Centropomus undecimalis*, which are selective feeders on mangrove fishes like mosquitofish, *Gambusia holbrooki*. Working on this species, and comparing the snook's ram-feeding behavior to the biting feeding mode used by pinfish, led to the eventual publication of the book *Ecomorphology of Fishes* (2005). It was at Harbor Branch that he was introduced to work Dr. Gilmore was doing with passive acoustics and the Sciaenidae (drums and croakers). He left Florida in 1988 to teach at Humboldt State University, Department of Fisheries, in Arcata, California. There he gained valuable insights on the trophic ecology and fisheries of the coastal systems of the Pacific Ocean. He returned to the East Coast to work on seagrass experimental ecosystems in North Carolina as a research associate at NC State University in 1989-1990. In 1990, Dr. Luczkovich became a Visiting Assistant Professor of Biology and an Assistant Scientist at the Institute for Coastal and Marine Resources (ICMR) at East Carolina University (ECU). He initially researched the biology of the pinfish, with special interest in how these fishes are able to use algae and seagrasses in their diets (commensal, cellulose-producing bacteria in the intestinal tract of the fish allow them to gain energy). He was promoted to Visiting Associate Professor in Biology and Associate Scientist with ICMR in 1997, his current position. At ECU he has worked on two lines of research: 1) passive acoustics and sound production in fishes, and 2) food web models of fishes and fisheries.



Ashish Mehta obtained his bachelor's degree in chemical engineering from the University of California at Berkeley (1966), and his doctoral degree in Civil Engineering (1973) from the University of Florida in Gainesville, where he is professor emeritus in the Department of Civil and Coastal Engineering. His areas of teaching and research include the application of physical principles and engineering to coasts, estuaries and lakes, especially in Florida. He has investigated the hydraulics of finegrained sediment transport in which the behaviour of cohesive flocs in turbulent flows requires an understanding of the basics of physical chemistry. He has also examined the hydraulics and sediment transport at numerous tidal inlets in Florida.

Jack J. Middelburg (1963) studied biogeology at the University of Groningen, geochemistry at Utrecht University, and obtained his PhD from Utrecht University in 1990. After that he worked at the Centre for Estuarine and Marine Ecology of the Netherlands Institute of Ecology in Yerseke before returning to Utrecht University in 2009. His research is at the interface of biogeochemistry and ecology and covers the whole aquatic continuum from lakes and rivers, via estuaries, to the coastal and open ocean, including the sediments. He combines field observations, field and laboratory experiments and numerical models to further biogeochemical process knowledge. Besides holding the geochemistry chair at Utrecht University, he has adjunct positions at the Centre for Estuarine and Marine Ecology in Yerseke and Gent University, Belgium.

Professor Stephen Monismith's research in environmental and geophysical fluid dynamics involves the application of fluid mechanics principles to the analysis of flow processes operating in rivers, lakes, estuaries, and the oceans. Making use of laboratory experimentation, numerical modeling, and field measurements, his current research includes studies of estuarine hydrodynamics and mixing processes, flows over coral reefs, wind wave–turbulent flow interactions in the upper ocean, turbulence in density-stratified fluids, and physical–biological interactions in phytoplankton and benthic systems. Because his interest in estuarine processes is intertwined with an interest in California's water policy issues, he has been involved with efforts at developing management strategies for improving the health of San Francisco Bay through regulation of freshwater flow into the Bay. Professor Monismith is currently Director of the Environmental Fluid Mechanics Laboratory at Stanford University. He is a 1989 recipient of the USA's Presidential Young Investigator award. Prior to coming to Stanford, he spent 3 years in Perth (Australia) as a research fellow at the University of Western Australia.

Catharina J. M. Philippart (1960) studied biology at Wageningen University (The Netherlands) and obtained her PhD on *Eutrophication as a possible cause of decline in the seagrass Zostera noltii of the Dutch Wadden Sea* in 1994. Between 1990 and 1994, she combined her seagrass studies with research on the effects of marine eutrophication on phytoplankton and macroalgae at the Institute for Forestry and Nature Research on the island of Texel. Since 1994, she has been working as an estuarine ecologist at the Royal Netherlands Institute for Sea Research. Here, she studies the trophic interactions between marine primary producing microalgae (phytoplankton and microphytobenthos) and primary consumers (with a focus on marine bivalves) of shallow temperate coastal waters such as the Wadden Sea. This research is performed by means of various techniques such as automated monitoring networks, field surveys, remote sensing (airborne and satellite) techniques, and laboratory experiments under controlled environmental conditions. She presently coordinates several large multidisciplinary national and European research programs on primary production, climate change, and marine monitoring networks.

James L. Pinckney is an associate professor in the Department of Biological Sciences at the University of South Carolina. He received his Bachelor of Science degree in Biology (1983) and Master of Science degree in Marine Biology (1987) from the College of Charleston in Charleston, SC. In 1992, he received his Doctor of Philosophy degree in Ecology from the University of South Carolina in Columbia, SC. From 1992 to 1998 he was a Research Assistant Professor at the University of North Carolina at Chapel Hill, Institute of Marine Sciences in Morehead City, NC. Dr. Pinckney accepted a faculty position in the Department of Oceanography at Texas A&M University in College Station in 1998. Both he and his wife, Tammi Richardson, accepted faculty positions in the Department of Biological Sciences at the University of South Carolina in 2005 and have a primary appointment in the Marine Science Program.

Estuarine and coastal studies form the core of research activities performed by Dr. Pinckney. General areas of interest include marine ecology, microbial ecology, microalgal ecophysiology, phytoplankton-nutrient interactions, harmful algal blooms, and ecosystem eutrophication in estuarine and coastal habitats. Specific interests are centered around the ecophysiological factors and processes that influence carbon partitioning, allocation (growth), and interspecific competition in multispecies assemblages. Most of Dr. Pinckney's work over the past 25 years has emphasized investigations of the ecophysiology of benthic and phytoplanktonic communities and their contribution to ecosystem function. Analytical approaches involve manipulative field and laboratory experiments for examining the ecological physiology and responses of microalgal communities.

Graham Shimmield graduated from the University of Durham in Geology, and received a PhD in Marine Geochemistry from the University of Edinburgh in 1985, where he remained until 1996 as part of the academic staff. He then became the combined director of Scottish Association of Marine Science (SAMS) and the NERC-funded Institute, within the Dunstaffnage Marine Laboratory (DML) for 12 years.

Graham's particular interest is in marine geochemistry, which includes the fundamental studies of geochemical processes operating in oceans through identifying indicators of ocean and climate change, and examining human impacts and contamination in coastal and deep seas. He has had significant involvement in marine biotechnology as the Managing Director of the European Centre for Marine Biotechnology, and Chairman of the Board of GlycoMar Ltd, a small biotech start-up.

Graham has served on many European national and international committees, including the UK Natural Environment Research Council (NERC) Science Strategy Board. He has been president and vice-president of the European Federation of Marine Science and Technology Societies (EFMS). He was also Chairman of the European Census of Marine Life Program.

In 2000, Graham was awarded the title of Honorary Professor at the University of St Andrews. He is a Fellow of the Royal Society of Edinburgh, and the Society of Biology. He has published over 65 scientific peer-reviewed articles. He joined Bigelow Laboratory for Ocean Sciences in March 2008. In November 2011 Graham was named by MaineBiz as one of ten "Nexters" helping to shape the future of Maine's economy.

Charles ("Si") Simenstad is a Research Professor in the University of Washington's School of Aquatic and Fishery Science, where he coordinates the Wetland Ecosystem Team. He holds a BS and MS from the University of Washington. Prof. Simenstad is an estuarine and coastal marine ecologist who has studied estuarine and coastal marine ecosystems throughout Puget Sound, the Washington coast, and Alaska for over 30 years. He is an American Association for the Advancement of Science Fellow, associate editor of three scientific journals and recipient of the 2009 NOAA-AFS Nancy Foster Award for Habitat Conservation.

His research has focused on food webs of estuaries and coastal ecosystems, and particularly their support of juvenile Pacific salmon and other nekton, and the associated ecological processes that are responsible for enhancing nekton production and life history diversity. Recent research has integrated basic ecosystem interactions with applied aspects of restoration, creation and enhancement of estuarine and coastal wetland ecosystems, and ecological approaches to evaluating the success of coastal wetland restoration at ecosystem and landscape scales, including the role of coastal restoration in benefitting ecosystems functions, goods and services. Prof. Simenstad's current research includes studies of juvenile salmon rearing in, and restoration of, estuarine/coastal ecosystems in estuaries of the Pacific Northwest – Columbia River, San Francisco Bay – Delta, Russian River – Alaska, Fox River, Kachemak Bay – Alaska, USA; developing and testing an estuarine ecosystem classification system for the Columbia River estuary; initiating a new, interdisciplinary study of restoration process at Liberty Island in the Sacramento River delta; and serving as Chair of the Nearshore Science Team (NST) of the Puget Sound Nearshore Ecosystem Research Program (PSNERP) that is providing scientific guidance in developing a feasibility plan for large-scale restoration of estuarine and nearshore ecosystems of Puget Sound.

Reginald James Uncles obtained a BSc Hons. (First Class) in Physics from Imperial College, University of London, in 1969 and stayed there to complete a PhD in Theoretical and Computational Plasma Physics in 1972. He is an Associate of the Royal College of Science and a Fellow of the Institute of Physics. Currently, he is President of the Estuarine and Coastal Sciences Association (ECSA). He has led research teams at the Plymouth Marine Laboratory and served on its Senior Management Team. His current work is devoted to research and research applications. His personal research activities include theoretical and experimental work on physical processes in estuaries and shallow coastal waters, with applications to biology, chemistry and ecology. Special areas of interest include the mechanisms

responsible for fine sediment accumulation and saltwater intrusion in the upper reaches of estuaries. He has worked overseas for extended periods of time in Australia, Africa, Argentina, Germany, Malaysia and the USA on problems concerned with estuaries, publishing more than 125 peer reviewed research articles in international journals and books.

Marjan van den Belt is the Director of Ecological Economics Research New Zealand at Massey University. She is an Ecological Economist and an Associate Professor. She is a Science Leader of Sustainable Pathways 2, an urban program aiming to design a toolbox for spatial planning. She is also involved in Manaaki Taho Moana (MTM), focusing on coastal ecosystem services, responsible for a Mediated Modeling component in this program. A third program on Integrated Freshwater Solutions is anticipated; all three programs are geared toward collaborative and adaptive management. Prior to her arrival in Palmerston North in early 2009, Marjan was an independent consultant with Mediated Modeling Partners, LLC in Vermont, USA, which she founded. She authored the book *Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building*, published by Island Press in 2004. Between 2003 and 2008, she taught an Adjunct Professor at the University of Vermont. She also co-developed a co-housing/eco-village in Vermont during this period.

She is currently a strategy advisor for a European hedge fund specializing in sustainability investing – Roodhals Capital.

Native of the Netherlands, Marjan has a Master's in Business Economics from Erasmus University in Rotterdam (1991). In 2000, she received a PhD in Marine Estuarine and Environmental Sciences and a Certificate in Ecological Economics from the University of Maryland, USA. She co-founded the consultancy firm Ecological Economics Research & Applications Inc. in Maryland, USA.

Marjan's prior experience includes a period of 5 years in Stockholm, Sweden, where she was employed as an Environmental Economist in the Research Department of Sweden's largest energy generator and distributor, Vattenfall, AB. Her first consulting firm was Waste Reduction in Stockholm, Sweden, and she consulted with industry on waste and energy audits and the development of environmental management systems.

James G. Wilson is an Associate Professor in Zoology and Environmental Science at Trinity College, University of Dublin (TCD).

Prof. Wilson graduated from the University of Glasgow in 1976 with a PhD in Zoology (Marine Biology) before moving to TCD. There, he devised two synoptic indices of estuarine quality, the BQI and the PLI, which have now been applied in the Republic of Ireland, France and the USA as well as the Black Sea.

Prof. Wilson main research interests center on the fitness (in the Darwinian sense) of organisms and this is a key concept to understanding natural systems and anthropogenic impacts. From this arises his work in bioenergetics, bioindicators and indices, and in the network analysis of ecosystems.

Prof. Wilson has written or edited six books and over 100 peer-reviewed papers covering the whole range of his research interests. These have been supported by national and international funding and have included collaborations with colleagues throughout the European Union as well as Russia, Ukraine, Georgia, USA, and Australia.

In addition to his duties in the university, including five years as Head of Department, Prof. Wilson has been an active member of, and held executive posts in, many outside organizations, such as the Irish Marine Sciences Association, the Institute of Ecology and Environmental Management, the Environmental Sciences Association of Ireland, the Life Sciences Committee of the Royal Irish Academy, and the Estuarine and Coastal Sciences Association.

He is a qualified cricket umpire, and still plays for the TCD Taverners side (for fixtures please contact).

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He received the Prize of Japan-France Oceanographic Society in 1986 and the Prize of Good Book in Ehime Prefecture in 1989. He was a SAP member of IGBP/START/SARCS from 1993 to 1997 and SSC member of IGBP/LOICZ from 1993 to 1998.

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Professor Maciej Zalewski is a Director of the International Institute of the Polish Academy of Sciences – European Regional Centre for Ecohydrology under the auspices of UNESCO and a Chairman of the Department of Applied Ecology University of Lodz. He is the Chief Editor of the international scientific journal Ecohydrology and Hydrobiology and a leading scientist of the UNESCO International Hydrological Programme – Ecohydrology. His scientific research includes use of ecosystem processes as management tool for sustainable development, economic growth and conservation of biodiversity, use of ecosystem processes in river and lake basins for reduction of eutrophication, elimination of toxic algal blooms, reduction of sedimentation rate and bioenergy production, and restoration of water and ecosystem resources in urbanized spaces for economic development, human health and quality of life improvement. He is also a Coordinator of international projects in 6FP, 7FP, and Life+ Programmes.

From the mid-1980s he has been a Coordinator of the International Scientific Programmes and Working Groups in UNESCO, FAO, and UNEP. Recently, he represents Poland in European Commission – European Strategy Forum on Research Infrastructures (ESFRI) and Joint Programming Initiative.

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PREFACE

Why a Treatise?

For the inhabitants of many of the world's major cities and towns, estuaries and coasts provide their nearest glimpse of a natural ecosystem which, despite the attempts of man to pollute it or reclaim it, has remained a fascinating insight into a natural world where energy is transformed from sunlight into plant material, and then through the steps of a food chain is converted into a rich food supply for birds and fish. In spite of natural and man-made problems, life in estuaries can be very abundant because estuarine vegetation and muds are a rich food supply, which can support a large number of animals with a large total weight and a high annual production. Indeed, estuaries have been claimed to be among the most productive natural habitats in the world. Estuaries and coastal waters and their shores provide a wealth of food and ecosystems which support fish, birds, and other wildlife and contribute significantly to the quality of life for humanity.

When we talk about the problems and productivity of the sea, for most people this means the estuaries, coasts, and shores that they can see and explore. When students study marine science in all its aspects, they usually study their local estuaries and coasts and rarely set sail for the deep open ocean. When socio-economists study estuaries and coastal waters, they focus on valuing in economic terms the direct (i.e., with direct monetary values) and indirect values of the ecosystem services that these waters provide to humanity; such valuation is essential for planning the future of estuaries and coastal waters in a crowded, full world anthroposphere. Thus, while estuaries and coasts make up only a small fraction of the total area of the world's seas, they are not only responsible for much of the fish production that we consume but, just as important, are also essential for the quality of life of the 50% of the human population on Earth that lives near the coast. The link between the watersheds and the estuaries and coastal seas, the direct human impact on estuaries and coasts, and the resilience of these waters to human impact determines the severity of environmental problems that mankind faces in connection with the sea. In turn, science can offer solutions for improving estuarine and coastal management practices at the local scale and at the watershed scale in order to improve the resilience of the system and mitigate or even reverse, partially at least, environmental degradation. In the context of climate change, some estuaries and coastal seas may be measurably impacted by small changes to sea level, temperature, and pH, but other estuaries and coasts have the potential to adapt to climate change and to provide our culture and economy a level of future protection. For all these reasons, it is vital that scientists use all the information available to them for the management of our estuaries and coasts. All this information was gathered together for this Treatise. All the editors involved in the production of this Treatise believe that complete information about the science of our estuaries and coasts is vital for the future of this planet.

Ecosystem-based science and management has been identified by many communities, most recently in the US Commission on Ocean Policy, as the approach needed for sustainable natural resource management. Our coasts, estuaries, and inland waters are the poster children for why we need this approach. The *Treatise on Estuarine and Coastal Science* provides the most up-to-date reference for system-based coastal and estuarine science and management. It avoids classical, habitat-oriented science, or just biophysical science, to focus on the linked physical–biological–chemistry–ecosystem–human–ecological economics processes. It does that to specifically address the big issues facing the world on how to best use multidisciplinary science to ensure the sustainability of both humanity and the environment. The aim of the publication is to provide a comprehensive scientific resource on estuarine and coastal science, which will be updated biennially to keep up with the newest developments in the field.

Coastal seas, wetlands, estuaries, deltas, and contributing rivers are at the heart of society's cultural, economic, and social development. On a global scale, they provide more than an estimated half of worldwide ecosystem goods and services. As such, the wider coastal zones are a key life support system to humanity. As a consequence, since millennia humans have altered the coastal zone in service of trade, settlement, resource extraction, and recreation.

The *Treatise on Estuarine and Coastal Science*, in an incomparable effort of multidisciplinary synthesis and assessment, elaborates on key features of coasts. It describes and classifies the processes of ecosystem functioning and the fluxes of water and materials, and it also features the human footprint affecting estuarine and coastal characteristics. This outstanding collective effort is bridging across traditionally divided scientific disciplines and worldviews of coastal researchers to reflect coastal functioning and effects of global change on a multiplicity of temporal and spatial scales. The notion of coastal zones as social–ecological systems is promoted.

The Treatise therefore represents a substantial contribution and community effort to the global Earth system sciences namely, the Land–Ocean Interactions in the Coastal Zone (LOICZ) core project of the International Geosphere–Biosphere Program and the International Human Dimensions Program on Global Environmental Change. LOICZ with its global network of researchers and institutions in the natural, social, and humanity sciences is working to support sustainability and adaptation to global change in the coastal zone. Its operations are feeding into the next decade of Earth system research on global sustainability that looks at the feedbacks of human interaction with nature and response options. The Treatise as a living and dynamic source of knowledge is particularly important in this context, providing insight into the latest concepts and findings of coastal change and human dimensions research.

What is in the Treatise?

The *Treatise on Estuarine and Coastal Science* is a 12-volume series which aims to provide a comprehensive scientific resource for all professionals and students in the area of estuarine and coastal science, with up-to-date chapters covering a full range of topics.

The *Treatise on Estuarine and Coastal Science* examines our estuaries and coasts, and its interactions and feedbacks with humanity, from the inland watershed to the ocean shelf. Under the leadership of two chief editors, a physical oceanographer and a marine biologist, and 23 volume editors, each of whom is a recognized worldwide expert in their subject area, the Treatise is a 12-volume series detailing:

1. Classification of Estuarine and Nearshore Coastal Ecosystems (edited by C Simenstad and T Yanagi);
2. Water and Fine-Sediment Circulation (edited by RJ Uncles and SG Monismith);
3. Estuarine and Coastal Geology and Geomorphology (edited by BW Flemming and JD Hansom);
4. Geochemistry of Estuaries and Coasts (edited by G Shimmield);
5. Biogeochemistry (edited by RWPM Laane and JJ Middelburg);
6. Trophic Relationships of Coastal and Estuarine Ecosystems (edited by JG Wilson and JJ Luczkovich);
7. Functioning of Ecosystems at the Land-Ocean Interface (edited by CHR Heip, JJ Middelburg and CJM Philippart);
8. Human-Induced Problems (Uses and Abuses) (edited by MJ Kennish and M Elliott);
9. Estuarine and Coastal Ecosystem Modeling (edited by D Baird and AJ Mehta);
10. Ecohydrology and Restoration (edited by L Chícharo and M Zalewski);
11. Management of Estuaries and Coasts (edited by HH Kremer and JL Pinckney); and
12. Ecological Economics of Estuaries and Coasts (edited by M van den Belt and R Costanza)

Each volume has approximately 10–15 chapters, with each chapter written by an acknowledged expert in that topic. Each chapter provides an up-to-date review of its subject area and is well illustrated with full color available throughout. With the Treatise being available online, supplementary data and information has been added, which has allowed authors to include not only data sets, but also animations, web links, PowerPoint presentations, and any additional multimedia in order to enhance the articles. In addition, the editors of each volume have provided an overview of their subject, summarizing the state of knowledge and the future directions of inquiry.

The *Treatise on Estuarine and Coastal Science* is available electronically through ScienceDirect. The online publication allows increased functionality and includes internal and external links that will enable efficient cross-referencing between related subjects and for referencing to related published material.

The *Treatise on Estuarine and Coastal Science* is unprecedented in its coverage and provides an invaluable resource for researchers, students, engineers, and professionals managing rivers, estuaries, and coastal seas.

In accord with its intent to provide a comprehensive, state-of-the-art description of estuarine and coastal science, the level of discussion is appropriate for researchers and practitioners at the cutting edge. Nevertheless, topics are discussed in sufficient detail that the *Treatise on Estuarine and Coastal Science* will be useful for advanced undergraduates and graduate students and researchers requiring an introductory discussion of a subject.

Geographical limits

In preparing the *Treatise on Estuarine and Coastal Science*, the editors had to agree on where to set the geographical limits.

For estuaries, it was agreed to set the inland limit at the tidal limit (the 'head of tide'). This therefore includes 'tidal freshwaters' following the Dione, as quoted by Fairbridge, definition of an estuary, namely that:

> an estuary is an inlet of the sea reaching into a river valley as far as the upper limit of tidal rise, usually being divisible into three sectors: (1) a marine or lower estuary, in free connection with the open sea; (2) a middle estuary subject to strong salt and freshwater mixing; and (3) an upper or fluvial estuary, characterized by freshwater but subject to strong tidal action. The limits between these sectors are variable and subject to constant changes in the river discharges.

Other definitions have used the upstream limit of salt penetration, whereas this definition has the upstream limit of tidal penetration. In an unmodified estuary, the limit of tidal penetration will always be further inland than the limit of salt penetration.

The outer limits at mouths of estuaries as they merge into coasts may be more difficult to determine and agree. There may or may not be convenient geographical discontinuities in the coastline and, there may be sub-tidal physical features denoting the marine, tidal conditions, such as linear sandbanks in wide-mouth estuaries, but these may not be present elsewhere. In general, the presence of full-strength seawater is a reliable indicator of the outer limit of an estuary. The topic of estuarine definitions is covered in much more detail in Volume 1 (Classification of Estuarine and Nearshore Coastal Ecosystems (edited by C Simenstad and T Yanagi)).

The Treatise has also included 'closed or intermittently open' estuaries (common in Australia and South Africa, for instance), man-made estuaries (e.g., residential canals and lagoons), lagoons, and marine lakes, and fringing wetlands – salt marshes/mangroves. Where appropriate, using the holistic approach, the watersheds have been included through their influence on the riverine inflow, and the groundwater inflow/outflow as well, and, where appropriate, the factors controlling the variability of this inflow quality and quantity.

For coasts, the editors agreed to include both the intertidal and the sub-tidal on all marine coasts. On the open coast, the offshore limit of one nautical mile was suggested. This follows the UN Law of the Sea and other international definitions: "*out to one nautical mile from landward baseline – except along mouths of estuaries and heads of bays where it cuts across open water.*" This definition permits inclusion of large bays and estuaries, such as Chesapeake Bay and others.

All the volumes were asked to include brackish and semi-enclosed seas, such as the Baltic Sea, and semi-enclosed seas, such as the Seto Inland Sea, but were not expected to include fully enclosed brackish seas, such as the Caspian Sea.

Future editions

We are planning future editions of the Treatise, and will take the opportunity then to fill any gaps which are identified in the present edition. We invite readers to help us identify any additions for future editions.

Acknowledgments

In preparing this Treatise, we have had the help of many colleagues and we wish to thank all the volume editors and authors for their willingness to undertake this major task.

We wish to thank especially Hannah Rutland, Charlotte (Charlie) Kent, and Gemma Mattingley, successive Development Editors at Elsevier Oxford and Laura Jackson and Sue Jakeman, the production team, who have borne the burden of e-mailing authors and editors and sending out reminders when needed, and of preparing

the final publication. We also thank Laura Kelleher, the Publishing Editor at Elsevier US, who was responsible for developing the original idea and for appointing the editors. We should also acknowledge that, prior to Laura, the original idea came from Frank Cynar, and after Laura's promotion we thank John Fedor for seeing the Treatise though to its final production.

Eric Wolanski and Donald McLusky