The Role of Physical Processes in Mangrove Environments

Manual for the Preservation and Utilization of Mangrove Ecosystems

Cover illustration: (Front) Feedback system in mangrove environments; (Back, top) Effect of mangrove vegetation on coastal protection; (Back, bottom) Collection of mud crabs at a mangrove tidal flat.

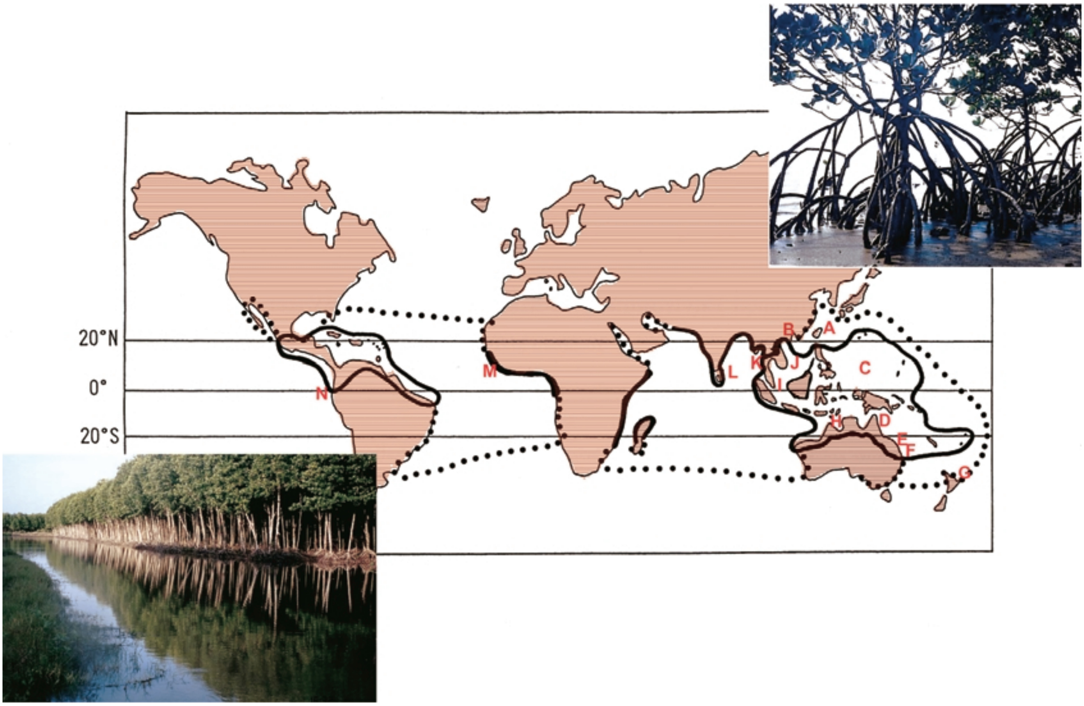

Plate 1. General world distribution of mangrove trees. Solid and dotted lines show the areas vegetated by mangroves more than 5 species and less than 4 species, respectively (after Chapman, 1984). In the figure, the areas which are described in the text are shown as the signs A to N.

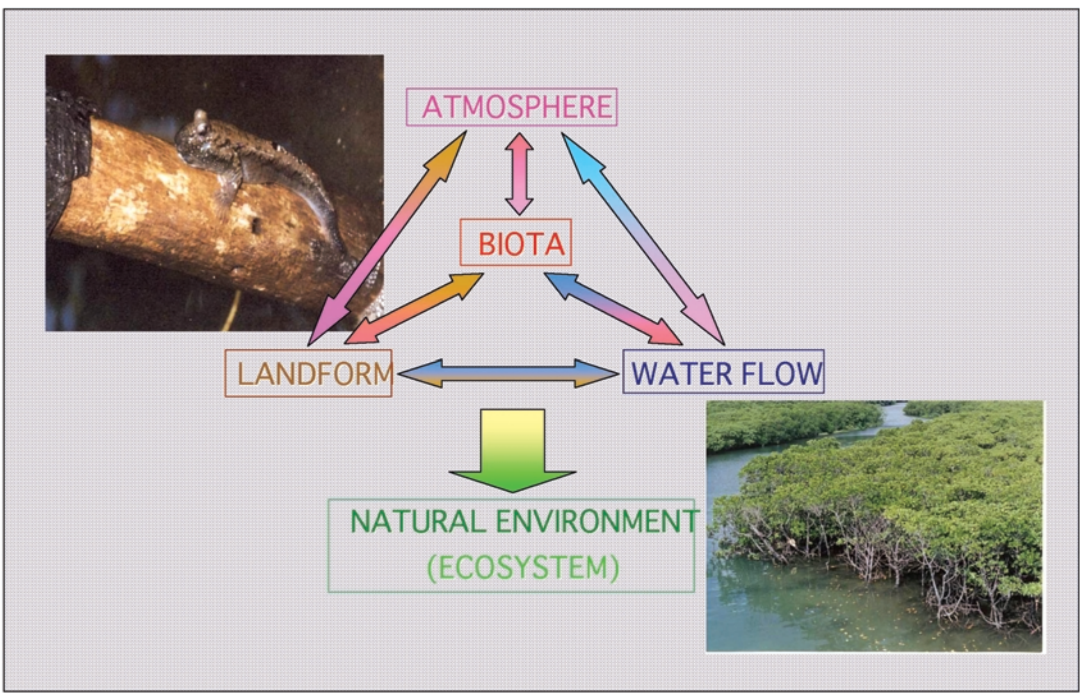

Plate 2. Feedback system in mangrove.

Plate 3. Various near-bottom vegetation in mangrove swamps.

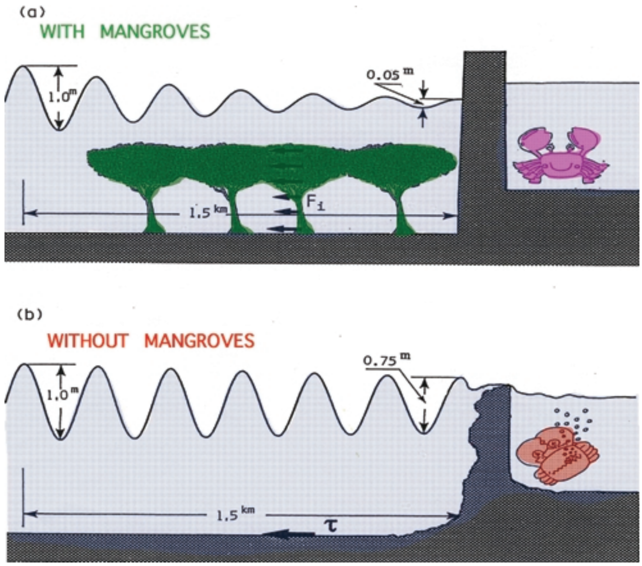

Plate 4. Differences in the effect of wave reduction (a) with and (b) without mangroves (after Mazda *et al*., 1997 [3.2]).

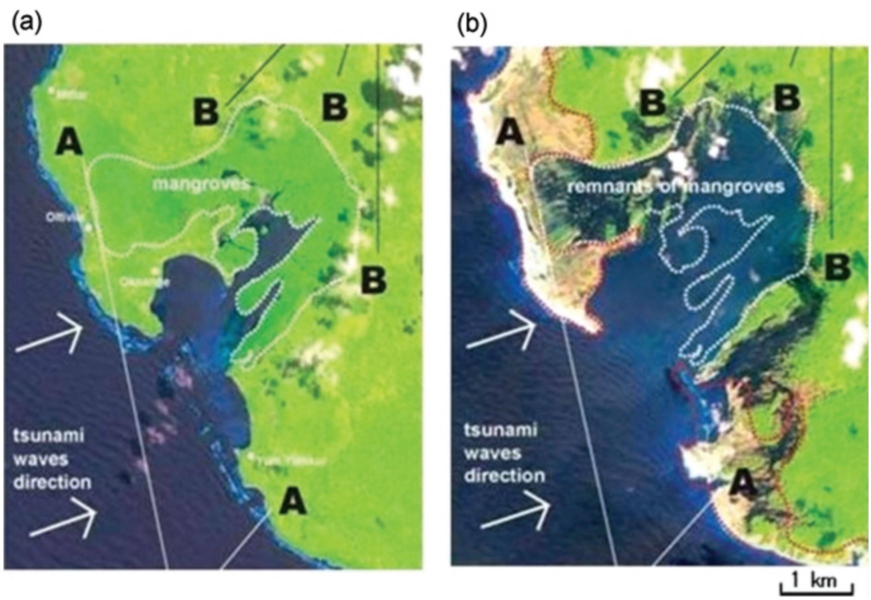

Plate 5. Satellite images of a west coast of Kitchall Island, Nicobars, Indian Ocean (K in Plate 1; Mazda *et al*., 2007 [3.4]): (a) Before the Sumatra tsunami occurred on 26 December 2004; (b) After the tsunami. The tsunami invaded along the white arrows as shown in the figures. The bay area is bordered by a white dotted line. Before the attack by the tsunami, the bay area had been covered with mangrove canopies. After the attack, however, no mangroves could be seen in the bay on the satellite image. This means that the tsunami scoured the bottom soil in the bay and uprooted or snapped off all of the mangrove trees. After the attack of the tsunami, the assessment of satellite images suggests that vegetation and villages in the area marked "B" behind the mangroves were not badly impacted by the tsunami disaster, while villages and agricultural areas marked "A" without mangroves were destroyed or saverely damaged by the tsunami. A comparison of the two satellite images from Katchall Island suggests that the tsunami was huge, given that all of the mangroves in the bay seemed to have been destroyed. Notwithstanding that, land areas behind the mangroves were protected perhaps by the sacrifice of them.

Plate 6. Corals covered by mud discharged from a mangrove swamp (Missionary Bay in northern Queenslans, Australia; E in Plate 1).

Plate 7. Investigation in mangrove areas.

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Yoshihiro Mazda, Eric Wolanski, and Peter V. Ridd

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Part II
Case studies of mangrove physics

FOREWORD

A Vital Information Tool for Managers and Decision-makers Working to Safeguard Our Mangrove Ecosystems

Being a scientific society with a vested interest in the protection and restoration of mangroves and other coastal environments, it is with great pride that The International Society for Mangrove Ecosystems (ISME) provides the foreword to this important new work. In recognising the economic and ecological importance of mangrove forests and ecosystems, we have a responsibility to provide the means to sustainably manage and protect this vital coastal resource for future generations.

Edited by three outstanding mangrove experts—Prof. Y. Mazda, Dr. E. Wolanski and Dr. P.V. Ridd—this book targets members of the scientific community who are interested in the preservation and sustainable utilisation of mangrove forests. The book has set itself five principal objectives:

1) To instruct mangrove researchers and engineers in developing countries on the physical processes taking place in the mangrove environment;
2) To encourage students to undertake studies of physical processes in mangrove areas;
3) To make coastal physical researchers recognise the peculiarity of mangrove physics;
4) To show the physical mechanisms that have been solved and need to be solved; and
5) To save research time by providing ready access to scientific articles and papers that appear in diverse media in different countries.

As reliable information is fundamental to the long-term health of mangrove ecosystems, ISME believes that this book will provide and contribute to the strengthening of scientific understanding, as well as the development and exchange of essential data and information required for the conservation, restoration and management of mangrove forests. The information developed and provided in the book constitutes a vital new resource for effective decision-making and policy formulation in the sustainable management of all mangrove ecosystems.

The first part of the book provides an outline of the physical processes within mangrove systems through sections on: the state of mangrove studies from a physical viewpoint; physical factors that shape mangrove environments; hydrodynamics and physics supporting the mangrove environment; feedback processes that maintain the mangrove environment; research technology and the modeling of mangrove systems; and current and future studies on the preservation and utilisation of mangroves. The second part compiles global case studies on mangrove physics in various areas, including: relationships between tidal flow, mangrove vegetation and landforms; the action of sea waves on mangrove swamps; groundwater flow; physical mechanisms affecting water properties; sediment dynamics; the role of the atmosphere; material exchanges between mangrove areas and the open sea; and the interrelation between physical, chemical and biological processes in the mangrove environment.

It is our belief that this publication will provide a vital information tool for managers and decision-makers, as well as an invaluable resource for scientists and researchers working to safeguard our mangrove ecosystems.

Nairobi, 15 December 2006

Salif Diop
President,
The International Society for Mangrove Ecosystems (ISME)

FOREWORD

An Up-to Date Systematic Study on the Physical Processes in Mangroves

Living in tropical areas, every year the coastal communities in many Asian countries have to suffer from various natural calamities such as storms, typhoons or tsunamis. Other threats to coastal zones have emerged in recent years, including global warming and sea level rise. Coastal dwellers in some countries have for a long time known that protected natural mangrove forests or planted mangrove belts can help mitigate the consequences.

Due to the pressures of population overgrowth and economic development, however, mangrove forests have been severely destroyed or converted to other economic uses. It is obvious that mangroves the world over are in great danger.

Strong typhoons and tsunamis have recently caused very serious damage to human beings and their properties in South Asian and South East Asian. However, where natural mangroves are well conserved or there are wide belts of planted mangroves, the damage was substantially reduced.

There have been numerous studies on the socio-economic aspects as well as management of mangrove ecosystems. Nevertheless, there have not been many which focus on the physical processes and mechanisms in mangroves. In the years ending the 20th century and beginning the 21st century, a number of scientists such as Y. Mazda, E. Wolanski, B. Kjerfve, P.V. Ridd, etc. have published part of their works on these fields in scientific journals. These articles have actively contributed to the database of mangrove related research papers, and also helped to raise awareness and understanding of the role of mangroves in the protection of the coastal life and environment. Some articles on the relation between the tidal flow and mangrove vegetation, action of sea waves intruding mangrove swamps and sediment dynamics in the Vietnam coastal areas with mangroves of Professor Mazda, Dr. Wolanski and their associates have been translated into Vietnamese. Through scientific analysis of empirical data, these articles have been very successful in proving the importance of mangrove forests to local authorities.

In addition to those articles, I have found in the draft of this book useful and up-to-date systematic on the hydro-dynamics and physical processes in mangroves. I believe that researchers, local authorities in mangrove areas, forestry engineers, lecturers and especially students in developing countries with mangrove forests will be grateful to receive this book as a manual for the preservation and sustainable use of the mangrove ecosystem which focus on physical processes.

I hope that the publication of The Role of Physical Processes in Mangrove Environments will stimulate a wide range of studies on Mangrove Ecosystems and will result in many publications. I am pleased to recommend this book to the readers.

Hanoi, 11 December 2006

Phan Nguyen Hong
Director,
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FOREWORD

Physics Helps Elucidate the Mechanisms of Mangrove Environments

Mangroves construct unique ecosystems along the coasts and estuary areas of tropical and sub-tropical regions in the world. Mangrove ecosystems consist of a limited number of tree species and some animals, and they are regulated by a number of environmental factors.

In Japan, several scientists have studied mangroves from the standpoint of taxonomy and vegetation ecology from the 1950s to the 1970s. . Then from about 1978 Professor Jiro Sugi developed research of mangrove ecosystem with new and challenging in cooperation with Thai mangrove scientists. In 1978, he organized four mangrove research projects. The first focused on vegetation ecology and physiology; the second on fishery and marine biology; the third on meteorology and soil science; the fourth on marine science and physics.

The third and fourth projects were very innovative and important as new research fields of mangrove ecosystems. They helped measurably elucidate the mechanisms controlling mangrove environments and ecosystems.

Dr. Y. Mazda, the lead author of this book, has investigated the tidal and sea wave behavior in mangrove areas for 25 years, as the leader of the fourth group within our mangrove research projects. He has gathered important knowledge of how physics control mangrove ecosystems. This methodology and knowledge that he developed establish useful methods for the conservation of mangrove forests and sustainable utilization of the mangroves.

As a botanist, I have also researched and surveyed mangrove forests in South East Asia in practice and I found that this knowledge of mangrove oceanography contribute significantly to the advancement of research of mangrove ecosystems.

This book is a fruitful result of Mazda's research and surveys, including the results of two other authors, Dr. E. Wolanski and Dr. P.V. Ridd, who are prominent mangrove physicists for a long time for mangrove forests worldwide.

I hope that this book is used as a set text, particularly for young mangrove scientists and students.

Tokyo, 20 December 2006

Takehisa Nakamura
Former President,
Japan Society for Mangroves

PREFACE

Mangrove forests are important to people living near tropical and sub-tropical coasts as wood and food resources and for coastal protection. They are also important from the global view point of the earth's natural environment. Mangrove environments are formed through strong feedback relations between biota, landform, water flow and the atmosphere. Though the earlier studies of mangroves focused on the trees, later studies revealed that water flows play a very important role in mangrove ecosystems, differentiating from freshwater wetlands and terrestrial ecosystems. Mangrove areas are periodically inundated by brackish water, with salinity ranging from that of seawater to that of freshwater, usually twice a day by astronomical tides. The hydrodynamics caused by the tide and sea waves are the dominant physical factors affecting the mangrove ecosystems. Unfortunately, the importance of hydrodynamics and physical processes has often been underestimated or even ignored by resources managers, sometimes the local people living next to mangrove areas, and commonly by many scientists, even though there a number of scientific publications about hydrodynamics and physical processes in mangroves have appeared in the last quarter of a century. This problem has arisen because scientists often do not communicate with the public, and because physical and biological oceanographers and foresters have commonly found it difficult to integrate their studies. In mangrove forests, biota, for example, mangrove trees have prudently watched water stream which inundates with tidal period, and survived from generation to generation. In order to ensure the conservation and ecologically sustainable utilization of mangrove environment the above physical actions and their roles in the environment must be understood. After the old saying that "when in Rome ...",

"When in mangrove forests, watch the stream as mangroves have done."

To make these possible, this book focuses on

1) to introduce the importance of physical processes to foresters, coastal managers, researchers and engineers who are dealing with mangrove environments;
2) to illustrate the physical mechanisms that have been understood and those for which further research is necessary;
3) to help coastal physical researchers and geographers recognize the peculiarity of the physical mechanisms in mangrove areas, in comparison with other coastal areas;
4) to encourage students to study physical processes in mangrove areas;
5) to save students' research time by collecting articles that are at present widely scattered.

This book comprises two parts. In Part I, the outline of mangrove physics particularly connected to mangrove environment is described, centering on the following aims,

1) to summarize the present state of mangrove physics, citing the articles reprinted in Part II, which are presented as case studies;
2) to show the roles of physical processes in the natural environment in mangrove areas; and
3) to distinguish the physical processes in mangroves which have been solved and those which need further studies.

Unfortunately, articles cited in this book are limited to those written in English, because of the above purposes. We can find many articles written in other languages, which include original and valuable information. We hope they will be informed worldwide with English from the above viewpoint.

In Part II, the published papers by the three authors of this book are collected into several groups based on generic subjects.

The authors hope that this book will be used as a manual for preserving and utilizing the mangrove environment, and be helpful to scientists, foresters, geographers, engineers, government agencies and students not only in the field of physics but also in the fields of forestry, fisheries, ecology, biology, chemistry, dendrology, geology, and also sociology and eco-tourism, etc., all of which dealing with the mangrove environment.

Yoshihiro Mazda

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We wish to extend our sincere gratitude to Keidanren Nature Conservation Fund (KNCF), The International Society for Mangrove Ecosystems, Tohoku Ryokka Kankyohozen Co. Ltd., Mikuniya Corporation and the OG Graduates' Association, Tokai University, for the sponsorship and support to the publishing this book.

Thanks also to Action for Mangrove Reforestation (ACTMANG) and the members of ACTMANG not only for supporting to publish this book but also helping us to study the mangrove environment in various areas worldwide.

In Part II of this book we re-use articles that were originally published in the following journals;

Australian Journal of Marine and Freshwater Research
Estuarine, Coastal and Shelf Science
Hydrobiologia
Journal of Coastal Research
Mangroves and Salt Marshes
Mangrove Science
Wetlands Ecology and Management

We thank the publishers and editors of these journals for the kind permission to re-use their articles. Details of each re-used article are specified individually in Part II of this book. We also thank the co-authors of these re-used articles for agreement to re-use them in this book.

We thank Mr. Faizal Parish of Global Environment Centre (Malaysia), Mr. Finn Danielsen of Nordic Agency for Development and Ecology (Denmark) and anonymous scientific staff of Singapore University for providing satellite images of Katchall Island in Indian Ocean (Plate 5), and Earth Remote Sensing Data Analysis Center (Japan) and Mr. Kazuyo Hirose of Nikko Exploration & Development Co., Ltd. for providing a satellite image of Can Gio area in southern Vietnam (the upper right of Plate 1; METI and NASA retain the ownership of the ASTER data).

Special thanks are owed to Prof. Salif Diop, Prof. Phan Nguyen Hong and Emeritus Prof. Takehisa Nakamura for providing the forewords to this book, and Dr. Sigeyuki Baba, who is the executive secretary of the International Society of Mangrove Ecosystems, for his kind support to distribute this book worldwide.

We would like to extend our thanks to TERRAPUB for the goodwill of the publication of this book, particularly, to Ms. Yumi Terashima, who is a publishing editor of TERRAPUB, for her assistance to improve this book.

Finally, for the support and patience of our three families we are truly thankful.

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