

Research on Restoration Technology of Coastal Wetland Ecosystems
— A Case Study of Shenzhen Bay

滨海湿地生态系统 修复技术研究

——以深圳湾为例

咎启杰 谭凤仪 李喻春 编著

Editors Qi-Jie Zan Nora Fung-yee Tam Yu-chun Li



海洋出版社

滨海湿地生态系统修复技术研究

——以深圳湾为例

Research on Restoration Technology of Coastal Wetland Ecosystems ——A Case Study of Shenzhen Bay

答启杰 谭凤仪 李喻春 编著

Editors

Qi - Jie Zan Nora Fung - yee Tam Yu - chun Li

海洋出版社

2013 年 · 北京

内 容 简 介

本书以我国深圳湾滨海湿地生态系统为主要研究对象,探讨了深圳湾湿地生态系统退化进程中各个子系统的生态特征变化,结合生态理论和修复实践,阐述了深圳湾湿地生态系统生态修复的目标、任务、范围、技术指标及需要解决的关键技术等,重点从滨海河口湿地、围垦后的红树林湿地、基围鱼塘湿地、红树林虫害等子系统方面,系统地研究、集成、创新生态修复技术,并结合深圳福田凤塘河生态修复示范区建设工程、深圳湾湿地修复工程、华侨城湿地修复工程的实践,将技术成果示范应用。全书内容全面,数据翔实,理论和实践结合紧密,技术成果原创性较强,提出了滨海湿地生态系统修复的新思路、新方法和新技术,具有重要的理论指导意义和较强的实践应用价值。

本书可供海洋、林业、农业、环境、生物、生态工程等多个学科的大学生和科研机构研究人员参考,同时,也可供环境保护、湿地建设、林业管理等部门及地方政府作为保护和管理滨海湿地的科技指导用书。

图书在版编目(CIP)数据

滨海湿地生态系统修复技术研究:以深圳湾为例/咎启杰,谭凤仪,李喻春编著. —北京:海洋出版社,2013. 8

ISBN 978-7-5027-8640-3

I. ①滨… II. ①咎… ②谭… ③李… III. ①海滨-沼泽化地-生态环境-环境治理-研究-深圳市 IV. ①P942. 653. 78

中国版本图书馆 CIP 数据核字(2013)第 202520 号

责任编辑:杨传霞

责任印制:赵麟苏

海洋出版社 出版发行

<http://www.oceanpress.com.cn>

北京市海淀区大慧寺路 8 号 邮编:100081

北京画中画印刷有限公司印刷 新华书店发行所经销

2013 年 8 月第 1 版 2013 年 8 月第 1 次印刷

开本:787mm×1092mm 1/16 印张:36.25

字数:860 千字 定价:186.00 元

发行部:62132549 邮购部:68038093 总编室:62114335

海洋版图书印、装错误可随时退换

本专著为国家海洋公益性行业科研专项 资助项目之深圳子课题

《围垦后滨海湿地生态系统修复与工程示范》 (200905009-4)的重要成果

项目负责人:

咎启杰 谭凤仪 李喻春

项目完成人:

李凤兰	周 凯	廖文波	黄立南	王英永	单锦城	关利平
张肇坚	韦萍萍	许会敏	田婷婷	胡章立	雷安平	陈俊开
陈里娥	杨新林	杨 琼	刘莉娜	付贵平	黄建荣	李鸣光
卢 群	伍 娥	杨婷娟	言 丹	方谊翎	刘正武	李坚贞
杨 远	程华荣	李 瑜	黄 鹄	孙秀波	余世孝	陈保瑜
曾 琳	徐华林	田穗新	徐 萌	邢东耀	郑志文	咎 欣
周海旋	程丛星	陈鹭真	周海超	郭 彬	邹小勇	孙红斌
赵丽娜	王佐霖	樊蓓莉	张佳红	蓝汉良		

项目主持单位:

香港城市大学深圳研究院

项目参加单位:

广东内伶仃福田国家级自然保护区管理局
中山大学
深圳大学
深圳华侨城都市娱乐投资公司
深圳市东华园林绿化有限公司
深圳市绿九洲园林绿化有限公司
中咨城建设计有限公司
深圳市观鸟协会

《滨海湿地生态系统修复技术研究 ——以深圳湾为例》 编写委员会

编著小组成员:

咎启杰	谭凤仪	李喻春	胡章立	李凤兰
周凯	田婷婷	韦萍萍	许会敏	陈里娥

编著人员:

咎启杰	谭凤仪	李喻春	胡章立	李凤兰
周凯	田婷婷	韦萍萍	许会敏	陈里娥
王英永	雷安平	廖文波	付贵平	黄立南
刘莉娜	杨琼	钟音	卢群	陈清华
陈鹭真	韩诗畴	徐华林	彭辉银	李罡
王勇军	周海超	李睿	梁士楚	曾辉
肖海燕	黄建荣	余世孝	邓旭	陈保瑜
梁铭忠	谢强	张佳红	黄鹄	孙秀波
孙省利	张才学			

序

湿地生态系统是地球表面三大生态系统之一,位于陆地与水体之间,兼有水、陆两者的生态功能。滨海湿地是处于海陆交汇处的“边缘地区”,是湿地生态系统的重要类型之一。滨海湿地具有调节陆海物质交换、维持生物多样性、降解污染物、调节区域气候及提供重要物种迁徙路线的生境等重要生态服务功能。滨海湿地是海洋产业赖以发展的环境和资源,也是维系区域经济可持续发展的关键。如何保护湿地生态环境,是无论发达国家还是发展中国家都无法回避的问题。

近30年来,随着中国沿海新兴经济区的快速发展和人口密度的急剧增加,滨海湿地面积因围垦而减少,污染排放使得水质污染加剧,人为干扰活动使生态环境退化及生物多样性锐减,滨海湿地生态安全问题日益突出,因此,承载着重要生态服务功能的中国滨海湿地已经成为极为脆弱的生态系统,再加之随着全球气候变化加剧、海平面上升、风暴潮和海啸增加、暴风雨强度和频率的变化,以及水流状况和沉积物迁移随之出现的变化,中国滨海湿地将面临着更加严峻的考验。如果这些问题不能及时解决,将对新兴经济区的生态环境,乃至区域经济发展造成不可估量的损失。在此情况下,保护滨海湿地、恢复受损滨海湿地已成为日益迫切而重要的工作。

滨海湿地的地理环境复杂多样,影响因素众多,自然环境条件恶劣,对全球变化和人类活动非常敏感,这使得修复滨海湿地生态系统面临一系列的工程技术瓶颈。《全国湿地保护工程规划》(2004—2030年)指出,滨海湿地面临的主要问题是过度利用和浅海污染;建设重点之一要以生态工程为技术依托,对退化海岸湿地生态系统进行综合整治、恢复与重建。湿地退化机制、退化湿地恢复与重建及人工湿地构建研究是目前国际湿地科学研究前沿领域的热点问题之一。

深圳湾地处两个国际大都市深圳和香港之间,是一个半封闭的且与外海直接相连的、风浪相对较小的内湾湿地,兼具河口和海湾的性质。深圳湾是后海湾红树林(香港米埔红树林和福田红树林)的发源地,也是东半球鸟类南北迁徙的歇脚地和栖息地,地理位置和生态社会价值非常重要。由于近年来深港经济的持续快速发展,两地工业、农业和生活产生的污染物基本排入湾内,加上围垦养

殖、填海造地、城市建设占用湿地等不合理开发和利用海洋资源,深圳湾湿地生态功能下降,急需进行生态修复以恢复湿地生态系统的结构和功能,确保湿地生态系统持续、稳定、安全地运行。

本专著主要是国家海洋公益性行业科研专项资助项目“新兴经济区滨海湿地生态系统修复技术与工程示范”的深圳子项目“围垦后滨海湿地生态系统修复与工程示范”研究成果的集成,同时也融合了从2003年至2012年间深圳湾湿地生态系统研究的成果。全书内容丰富,涉及面广,涵盖了海洋学、生态学、地球与环境科学、植物学、动物学、昆虫学、工程学等多个学科,既有面上基础环境状况调查,又有专项问题的深入研究;既有理论研究,又有工程实践;既有宏观生态领域的探究,又开展了分子生物学鉴定等微观领域的研究;不失为湿地生态学及相关学科领域的一部值得学习、借鉴的好书。

该书立足于深圳湾湿地现状,以提升自然湿地单位面积生态承载力为主要修复目标,从水环境与水动力、植物修复、工程技术修复等方面因地制宜地研究开发适宜的修复技术,并建立了滨海湿地修复技术应用示范工程,研究成果可以促进深圳湾湿地生态系统良性循环发展,从而形成健康的、可持续的、近自然的滨海湿地生态系统。

本书编著者经过多年的研究努力,有计划、有步骤地把湿地生态系统修复研究工作引向深入,目的在于揭示人类对湿地生态系统运行机制和服务功能的认识,展示滨海湿地为人类带来的巨大效益,从而达到修复湿地、保护湿地、维护湿地持续发展的目的。此书还展示了滨海湿地修复的最新技术和成功的应用案例,为全世界滨海湿地修复提供了可借鉴的湿地修复研究的思路和湿地生态修复的技术方法,将推动世界滨海湿地的保护和发展。

此书对我国华南滨海湿地的保护和修复,特别是红树林湿地生态系统的恢复重建具有重要作用,对于其他城市在社会经济发展过程中如何保护好环境、做到经济和环境资源的可持续发展,实现城市与环境、人与自然和谐发展也是一个重要的借鉴。

欣闻此书付印在即,谨撰数语为序。

香港科技大学副校长



2013年3月1日

前 言

我国湿地面积约 $6\,594 \times 10^4 \text{ hm}^2$, 约占世界湿地面积的 10%, 位居亚洲第一位, 世界第四位(陈桂珠等, 2005)。其中, 滨海湿地分布于沿海 11 个省区和港、澳、台地区, 海域沿岸有 1 500 多条大中河流入海, 形成了浅海滩涂、河口湾、海岸湿地、红树林、珊瑚礁、海岛等生态系统, 它们是我国湿地生态系统中生物多样性最为丰富的地带, 是陆地生态系统和海洋生态系统交界的生态关键区, 也是国际候鸟重要的越冬地和停歇地, 是东亚地区通过中国沿海的三大水禽迁徙路线的必经之路, 因此, 修复和保护好我国滨海湿地具有区域性和全球性的重要作用。

深圳湾滨海湿地是我国滨海湿地的重要代表之一, 其代表性主要表现在保护国际候鸟的重要性、被围垦后受到国际国内社会的关注度、新兴经济发展与湿地保护的和谐持续性等方面。深圳湾滨海湿地地处深圳、香港两个国际大都市之间, 受过去 30 多年经济快速发展、城区快速扩张、海岸带快速被占用等影响, 湿地结构和功能发生了巨大变化, 但其作为国际候鸟栖息地和迁徙中转站的功能仍没有改变, 生态价值更显重要, 其受到国际环境保护组织的关注度日益增强, 因此, 深圳湾湿地保护和修复问题可以说是中国新兴经济区的滨海湿地修复与保护的一个典型代表, 它对中国经济发展到一定程度后, 如何将滨海湿地的适度利用和刚性保护协调起来, 提出了新课题, 以期探求出新思路和新方法。

近年来, 深圳湾滨海湿地仍然受到海岸侵蚀、污染加剧、泥沙沉积、过度利用、入侵植物等威胁, 但从中央到地方, 从政府到企业, 从专家学者到普通百姓, 积极主动参与保护滨海湿地的行动越来越多, 湿地保护受到党、政、民前所未有的重视, 党的“十八大”也明确提出了生态文明治国方略, 这些都为我们点亮了保护蓝色海洋、生态海洋的希望明灯。

关于深圳湾湿地保护方面的专著已有《深圳福田红树林湿地生态系统研究》(张宏达等, 1998) 和《深圳湾红树林生态系统及其持续发展》(王伯荪等, 2002) 两部, 每部专著都对前一个时期的深圳湾湿地生态系统的结构、组成、功能及其生物多样性的变化作了较为详尽的阐述, 对当时深圳湾湿地生态系统的恢

复和变化情况做了系统性的研究和论述,本书不再赘述。

本书作者主要是将国家海洋公益性行业科研专项资助项目“新兴经济区滨海湿地生态系统修复技术与工程示范”的深圳子项目“围垦后滨海湿地生态系统修复与工程示范(资助编号为200905009-4)”的研究成果进行系统的梳理,并将2003年至2012年的深圳湾湿地生态系统修复方面的最新研究成果进行归纳和总结,融为一体,形成本书。

本书完成之际,恰逢香港城市大学和广东内伶仃福田国家级自然保护区管理局合作共建的“福田—城大红树林研发中心(以下简称研发中心)”成立十周年,谨以此向研发中心成立十周年献礼。

本专著得到众多关心和支持研发中心的诸位教授、研究助理和研究生的支持,咎启杰、谭凤仪、李喻春、胡章立、周凯、陈里娥、雷安平、廖文波、王英永、付贵平、黄立南、邓旭、黄建荣诸位教授,李凤兰、田婷婷、韦萍萍、许会敏、刘莉娜、杨琼、钟英、周海超、陈鹭真、徐华林诸位博士、研究助理,以及卢群等硕士生、本科生参加了本书的编写工作。本书总策划、总构思、总统稿由咎启杰博士、谭凤仪教授、李喻春高级工程师完成,全书英文摘要部分由谭凤仪教授完成,全书的构思编排、资金筹集和出版工作的协调由李喻春处长(高级工程师)完成。具体各章节的作者分别是:前言,咎启杰、谭凤仪、李喻春;第1章,第1节、第2节之1、2、3、4、5,韦萍萍,第2节之5、6,韦萍萍和咎启杰;第2章,第1、3、4、5、7节,刘莉娜,第2节,曾辉、肖海燕,第6节,周凯、孙省利、张才学,第8节,余世孝、陈保瑜、咎启杰,第9节,周凯、咎启杰、刘莉娜;第3章,第1、2节,韦萍萍,第3节之1到4,黄鹄、孙秀波、韦萍萍,第2节之4,陈里娥、徐华林;第4章,第1节至第3节,付贵平、张佳红,第4节之一,刘莉娜,第4节之2、3、4、5,黄鹄、孙秀波、付贵平、张佳红;第5章,第1节至第4节,许会敏,第5节,卢群、雷安平、胡章立;第6章,第1节至第3节,钟音、谭凤仪、雷安平、李睿,第4节,胡章立、邓旭、雷安平;第7章,第1节至第5节,杨琼、谭凤仪、陈里娥,第6节,陈清华、杨琼;第8章,第1、2、3节和第5、6、7节,韩诗畴,第4节之1、2,咎启杰,第4节之3、4、5,李罡、彭辉银;第9章,第1节,许会敏,第2、3、4节,李凤兰;第10章,第1、2、3节,梁士楚、谢强、梁铭忠,第4节,陈鹭真、曾雪琴、谭凤仪、徐华林,第5、6节,陈鹭真、咎启杰、周海超,第7节,陈里娥、廖文波、许会敏、徐华林;第11章,第1节和第5节,田婷婷、王英永,第2节,黄立南、田婷婷,第3、4节,黄建荣;第12章,第1节、第2节之一,田婷婷,第2节之二,田婷婷、黄建荣、黄立南,第3节,王勇军、

咎启杰、徐华林,第4节,田婷婷、咎启杰。各章统稿人为:第1章和第3章,韦萍萍;第2章,刘莉娜、周凯;第2章,付贵平;第5章,许会敏;第6章,雷安平、胡章立、杨琼;第7章,杨琼、陈里娥;第8章,韩诗畴、咎启杰;第9章,李凤兰;第10章,咎启杰、李喻春;第11章,田婷婷;第12章,田婷婷、咎启杰。参考文献及书稿整理和审校由咎启杰、李喻春、许会敏、田婷婷完成。

本书难免有不足之处,所研究发明创新的修复技术仅在广东部分地区实践应用,且应用示范时间较短,在全国其他地方推广应用尚需完善和验证,所提出的滨海湿地修复的观点、见解和论点也非完全确切,有待进一步验证和探讨,恳请赐教!

编著者

2013年1月于广东深圳

Preface

The total area of wetlands in China is about 65.94 million hectares, accounting for about 10% of the wetland areas in the world, ranking first in Asia and fourth in the world. In China, coastal wetlands are distributed across 11 provinces and autonomous regions, including Hong Kong SAR, Macao SAR and Taiwan. More than 1 500 large and medium-sized rivers run into the sea forming shallow beaches, estuaries, coastal wetlands, mangroves, coral reefs, islands and other ecosystems. These are the most diverse areas in our wetland ecosystems. The coastal wetlands in China are the critical junctions between terrestrial and marine ecosystems, important grounds and stopovers for international migratory birds during winter migration and the only migratory route for three types of waterfowls in East Asia. It is therefore regionally and globally important to restore and protect coastal wetlands in China.

The coastal wetlands in Shenzhen Bay are an important representation of China's coastal wetlands, as evidenced by its importance in the protection of international migratory birds, the concerns from the international and local societies after reclamation, the sustainable harmony between the emerging economic development and the wetland protection. The coastal wetlands in Shenzhen Bay are located between two international metropolises, Shenzhen Special Economic Zone and Hong Kong SAR. Its structure and function have undergone tremendous change due to the impacts of rapid economic development in the past thirty years, fast expansion of urban areas and the speedy occupation of coastal zones, but its function as a transit station or habitat for international migratory birds remains un-changed. Its ecological value is even more important than ever and receives more and more attention from international organizations promoting environmental protection. The protection and restoration of coastal wetlands in Shenzhen Bay, therefore, can be seen as a typical representation in the restoration and protection of China's coastal wetlands, especially in emerging economic zones. It demonstrates how to achieve a right balance between reasonable utilization and strict protection of coastal wetlands in China while allowing for a certain degree of economic development. The book also suggests new ideas and innovative ways to maintain this balance for continued, sustainable development in China.

In recent years, the coastal wetlands in Shenzhen Bay have been subjected to the threats of coastal erosion, increasing pressure of pollution, problems with sedimentation, overexploitation, invasive plants, etc. Nevertheless, more and more conservation measures and actions are available at different levels, from central to local governments, business sectors, experts, academics and the public. All of these entities are actively participating in the protection of coastal wetlands. The government and the people have paid unprecedented attention to wetland protection. The ecologi-

cal civilization statecraft clearly put forward in the 18th Party Conference, which lit a beacon of hope for the protection of the Blue Ocean and marine ecology.

So far, only two major publications are available on the protection of Shenzhen Bay's coastal wetlands, namely "Research on Mangrove Wetland Ecosystems in Futian, Shenzhen" by Zhang et al. in 1998 and "Mangrove Ecosystem in Shenzhen Bay and its Sustainable Development" by Wang et al. in 2002. Each gives a detailed and systematic account of the structure, composition, function, biodiversity, their changes and some restoration of the wetland ecosystems in Shenzhen Bay before the rapid economic development. Therefore, this book will not delve heavily into this aspect.

The book mostly focuses on our research findings from and practical experiences conducted for the Shenzhen subproject entitled "Restoration and Engineering Demonstration of Coastal Wetland Ecosystem after Reclamation" (No. 200905009 - 4) under the non-profit social benefit project called "Technological Development and Engineering Demonstration of the Coastal wetland Ecological Restoration in Emerging Economic Region" funded by the State Oceanic Administration. The book summarizes and integrates the latest research results and development of the restoration work on wetland ecosystems in Shenzhen Bay from 2003 onwards.

The publication of this book coincides with the tenth anniversary of the Futian-CityU Mangrove Research and Development Centre (hereafter referred as the Centre), which was established under the collaboration of City University of Hong Kong and the Authority of the Guangdong Neilingding Futian National Nature Reserve. The editors and authors would like to dedicate the book to the tenth anniversary of the Centre. The book received assistance and advice from various professors, research staff and research students who continue to support the Centre, including Qi-jie Zan, Nora Fung-yee Tam, Yu-chun Li, Zhang-li Hu, Kai Zhou, Li-e Chen, An-ping Lei, Wen-bo Liao, Ying-yong Wang, Gui-ping Fu, Li-nan Huang, Xu Deng, Jian-rong Huang, Feng-lan Li, Ting-ting Tian, Ping-ping Wei, Hui-min Xu, Li-na Liu, Qiong Yang, Yin Zhong, Hai-chao Zhou, Lu-zhen Chen, Hua-lin Xu, Qun Lu, and etc. Several undergraduate students from Shenzhen University also contributed. The ideas and overall organization of the book originated from Dr. Qi-jie Zan, Prof. Nora Fung-yee Tam and Senior Engineer Yu-chun Li. Prof. Nora Fung-yee Tam wrote the parts of the book that are in English, including the abstracts. Yu-chun Li handled the organization, financial means and logistics related to publication of the book. The following authors are responsible for each individual chapter and section as detailed below. Preface: Qi-jie Zan, Nora Fung-yee Tam and Yu-chun Li; Chapter 1, Section 1, 2 (Subsections 1-5): Ping-ping Wei, Section 2 (Subsections 5 and 6): Ping-ping Wei and Qi-jie Zan; Chapter 2, Sections 1, 3-5 and 7: Li-na Liu Section 2: Hui Zeng and Hai-yan Xiao, Section 6: Kai Zhou, Sheng-li Sun and Cai-xue Zhang, Section 8: Shi-xiao Yu, Bao-yu Chen and Qi-jie Zan, Section 9: Kai Zhou, Qi-jie Zan and Li-na Liu; Chapter 3, Sections 1 and 2: Ping-ping Wei, Section 3 (Subsection 1-4): Gu Huang, Xiu-bo Sun and Ping-ping Wei, Section 3 (Subsection 5): Li-e Chen and Hua-lin Xu; Chapter 4, Sections 1-3: Gui-ping Fu and Jia-hong Zhang, Section 4 (Subsection 1): Li-na Liu,

Section 4 (Subsections 2-5): Gu Huang, Xiu-bo Sun, Gui-ping Fu and Jia-hong Zhang; Chapter 5, Sections 1-4: Hui-min Xu, Section 5: Qun Lu, An-ping Lei and Zhang-li Hu; Chapter 6, Sections 1-3: Yin Zhong, Nora Fung-yee Tam, An-ping Lei and Rui Li, Section 4: Zhang-li Hu, Xu Deng and An-ping Lei; Chapter 7, Sections 1-5: Qiong Yang, Nora Fung-yee Tam and Li-e Chen, Section 6: Qing-hua Chen and Qiong Yang; Chapter 8, Sections 1-3 and 5-7: Shi-chou Han, Section 4 (Subsections 1-2): Qi-jie Zan, Section 4 (Subsections 3-5): Gang Li and Hui-yin Peng; Chapter 9, Section 1: Hui-min Xu, Sections 2-4: Feng-lan Li; Chapter 10, Sections 1-3: Shi-chu Liang, Qiong Xie and Ming-zhong Liang, Section 4: Lu-zhen Chen, Xue-qin Zeng, Nora Fung-yee Tam and Hua-lin Xu, Sections 5 and 6: Lu-zhen Chen, Qi-jie Zan and Hai-chao Zhou, Section 7: Li-e Chen, Wen-bo Liao, Hui-min Xu and Hua-lin Xu; Chapter 11, Sections 1 and 5: Ting-ting Tian and Ying-yong Wang, Section 2: Li-na Huang and Ting-ting Tian, Sections 3 and 4: Jian-rong Huang; Chapter 12, Sections 1 and 2 (Subsection 1): Ting-ting Tian, Section 2 (Subsection 2): Ting-ting Tian, Jian-rong Huang and Li-na Huang, Section 2 (Subsection 3): Yong-jun Wang, Qi-jie Zan and Hua-lin Xu, Section 2 (Subsection 4): Ting-ting Tian and Qi-jie Zan. In brief, the coordinator(s) for each chapter is(are): Ping-ping Wei for Chapters 1 and 3, Li-na Liu and Kai Zhou for Chapter 2, Gui-ping Fu for Chapter 4, Hui-min Xu for Chapter 5, An-ping Lei, Zhang-li Hu and Qiong Yang for Chapter 6, Qiong Yang and Li-e Chen for Chapter 7, Shi-chou Han and Qi-jie Zan for Chapter 8, Feng-lan Li for Chapter 9, Qi-jie Zan and Yu-chun Li for Chapter 10, Ting-ting Tian for Chapter 11 and Ting-ting Tian and Qi-jie Zan for Chapter 12. The references, editing and proof read of the Book are done by Qi-jie Zan, Yu-chun Li, Hui-min Xu and Ting-ting Tian. Qi-jie Zan completed the references, editing and proofreading of the book.

The book likely contains some inevitable inadequacies. For instance, the innovative and newly developed restoration technologies have only been practiced in some areas in Guangdong Province, and the demonstration work has only been conducted over a relatively short time. The concepts, research ideas, insights and arguments put forward in the book are still subject to further verification and exploration. The technologies certainly require improvement, and they need to be applied and validated in other parts of our country prior to large-scale application and promotion. Please send us your opinions and advice.

Editors

January 2013

Shenzhen, Guangdong

Synopsis

The book covers the research work on the coastal wetland ecosystem in Shenzhen Bay in Guangdong Province, China. The book quantitatively describes and analyzes the processes, dynamic characteristics and changes of three wetland subsystems, *gei wei*, mangroves and mudflats in Shenzhen Bay, based on the remote sensing images of the different periods from 1979 to 2009. Changes of the ecological characteristics of each subsystem during the degradation process of the whole wetland ecosystem in Shenzhen Bay are discussed. The book identifies and describes the targets, goals, scopes, technical indicators and key technologies needed for the restoration of coastal wetlands, derived from ecological theories and field practices. The focus is to develop innovative and practical ecological restoration technologies based on systematic, integrated and novel research on different subsystems, including estuarine coastal wetlands, reclaimed mangrove wetlands, *gei wei* fishponds and insect infestations in mangrove swamps. The research results are applied to various demonstration projects, including the ecological restoration of Feng Tang River in Futian, the wetland restoration project of Shenzhen Bay and the wetland restoration project of Overseas Chinese Town in Shenzhen. The book is divided into twelve chapters and describes the research progress of the restoration of coastal wetland ecosystems, the status and the historical changes of Shenzhen Bay wetlands. It systematically integrates and concludes the ecological restoration technology of various subsystems, including coastal wetlands, *gei wei* ponds, coastal estuarine wetlands and mangrove wetlands, and it presents an overview of the technologies for the remediation of coastal wetlands, the constructed mangrove wetlands for sewage treatment and the prevention and control of major pests in mangrove swamps. The invasion of exotic plants in coastal wetlands and the relevant control theory, and prevention technology in general are discussed. Ecological research on one of the invasive mangrove plant species, *Sonneratia*, in Shenzhen Bay is also reported. Lastly, the ecological benefits of wetland restoration are assessed comprehensively based on routine ecological monitoring of the demonstration areas undergoing restoration. The book includes abundant scientific data and comprehensive research findings, closely combines the theory and practice together, and has originality in various technologies. The book puts forward new ideas, innovative methods and technologies related to the restoration of coastal wetland ecosystems, which have significant theoretical and practical application values.

The book provides good references to researchers, university professors and students who major in disciplines such as marine science, forestry, agriculture, environment, biology and ecological engineering. It also presents a scientific basis for the administrative departments on environmental protection, wetland construction and forestry, as well as local government officials, to bet-

ter protect and manage coastal wetlands.

Chapter 1 Introduction

Coastal wetlands between terrestrial and marine ecosystems have high levels of productivity and are abundant in resources, providing food and feed for aquatic life and other organisms. Thus, it is important for the livelihood and development of humans and other animals. Over the past decades, the coastal wetlands in China have been seriously degraded, or have disappeared entirely, at alarming rates due to the severity of disturbance from human activities. These activities include expansion in aquaculture and agriculture, land and coastal reclamation, enlargement of urban cities, infrastructural developments, over-exploitation of wetland resources, pollution, invasion of exotic or alien species, changes in global climate and rises in sea level, etc. Protection and restoration of coastal wetlands have received more and more attention from academics, the public, non-government organizations and government authorities in China in recent years. Researchers, based on literature reviews, results from ecological surveys, field and bench-scale experiments, practical experiences from case studies, etc., have summarized the principles relevant and suitable for China, established goals and developed the technologies required for the restoration of coastal wetlands, particularly in Shenzhen Bay in South China.

This chapter gives an overview of coastal wetlands, including definitions, types, functions, current situations and associated problems, with the main emphasis on the coastal wetlands in China. The concepts and need for the restoration of coastal wetlands in China are introduced. The targets, different principles involved and the possible technologies for the restoration of coastal wetlands, particularly mangroves, as well as the problems associated with restoration, are elaborated further. The chapter ends with a case study on the mangrove wetland restoration in Overseas Chinese Town (OCT), Shenzhen.

Chapter 2 Historical Changes of Wetland Landscape in Shenzhen Bay and Targets for Wetland Restoration

Shenzhen Bay covers an area of 75 km² and is an important component of the Pearl River Estuary. It is a semi-enclosed bay with frequent tidal flushing and fluctuating salinities. The large, open mudflat areas in this Bay contain fertile sediment, rich in fine particulates and nutrients, which are suitable for the colonization of mangroves and other types of coastal wetlands. Therefore, Shenzhen Bay is one of the most valuable coastal wetlands in South China. The chapter starts with a general introduction on the current situation of Shenzhen Bay, including its geographical location, geology and geomorphology, climate condition, sediment properties and hydrodynamics. The types of mangrove communities in Shenzhen Bay, including the algorithms and data from observations, are then analyzed by hyperspectral remote sensing technique. Based on spectral analysis and field reconnaissance, the Decision Tree Classifier and hyperspectral analysis are combined and

proved to be an effective method to extract the derived data of the mangrove communities. The derived data can effectively support the classification of different mangrove plant communities in Futian Reserve, Shenzhen.

A total of 76 families, 192 genera and 238 species of plants are recorded in the coastal wetlands in Shenzhen Bay, most are seed plants made up of 65 families, 181 genera and 223 species. In Shenzhen Futian Nature Reserve, there are 51 families, 127 genera and 140 species of plants, while the plant community in Mai Po Nature Reserve in Hong Kong (just opposite Futian) has 60 families, 122 genera and 138 species. The number of common species found in both Reserves is around 40. The chapter then gives a detailed account on the diversity and community structure of mangrove plants in Futian, including the three major communities, namely *Kandelia*, *Aegiceras*, *Avicennia* and their mixture. Futian Nature Reserve also has a diverse group of phytoplanktons. According to a routine survey in four monitoring stations in Futian from 2008—2011, the community structure of phytoplanktons showed significant seasonal variations, ranging from 44 – 54 genera and 90 – 147 species. Most species (65.6% – 82.1% of the total number of species) belonged to the Phylum Bacillariophyceae, followed by Chlorophyta and Cyanophyta species.

The monitoring results revealed that there was no major change in the bird community structure in Futian Nature Reserve, but the number of birds declined significantly from 2008—2011, from 145,564 birds in 2008 to only 75,565 in 2011 (about 48% drop in four years). The decrease in Black-faced Spoonbill, an endangered wading bird species, was even more serious, dropping from 336 individuals in 2008 to only 82 in 2011 (76% decrease in four years). The diversity, density and biomass of macrobenthic animals and their seasonal variations in Futian Nature Reserve are also described in the chapter. The field survey on the zooplankton community structure, carried out in Shenzhen Bay in different seasons, from February to November in 2008, recorded a total of 38 species and 13 pelagic larvae groups, including fish larva, in this area. Among these, many were Copepoda (22 species). The dominant species were *Acartia pacifica*, *Acartia spinicauda*, *Oithona brevicornis*, *Diphyes chamissonis*, *Malagazzia carolinae*, Cirripedite larvae and Copepodite. The most abundant organisms (43 species including pelagic larvae) were found in autumn, followed by summer (30 species), with the least number in winter (merely 23 species). The annual average density and biomass were 406.7 individuals m^{-3} and 764.0 mg m^{-3} , respectively, with the maximum values in summer and the minimum in winter and spring. The chapter further analyses the ecological problems faced by the Futian Nature Reserve in Shenzhen. These include the separation of gei wei fishponds from the mangroves forming an ecological barrier, water pollution, deterioration in the function of gei wei fishponds, frequent occurrence of pests, etc., before restoration to rehabilitate and enhance the ecological functions of the Futian Nature Reserve.

Shenzhen Special Economic Zone (SEZ) was established as a model city in 1979 and has become a modern, industrialized urban area during the past three decades. This rapid urbanization has had a significant effect on the landscape, and Shenzhen Bay is a typical example. The urbani-

zation process in SEZ could be divided into four stages: early urbanization, developed urbanization, accelerated urbanization and later urbanization phases. Based on the five periods of remote sensing data in Shenzhen Bay, including MSS in 1979, and TM in 1989, 1998, 2003, 2009, the dynamic characteristic of three main landscape types, including *gei wei*, mangrove and intertidal zone in Shenzhen Bay, were analyzed by a series of techniques, including landscape classification, landscape transfer and landscape index analysis, under the software platforms including ERDAS IMAGINR, ARCGIS and FRAGSTATS. The results showed: (1) During the past three decades, because of human activities, the built-up area increased from 508.95 to 2072.52 hm^2 . Accordingly, the largest patch area index increased from 2.94% to 17.55%, leading to changes in landscape patterns; (2) *Gei wei* suffered the greatest human disturbance, its proportion in 1989 was 7.72% (the highest) but gradually evolved into built-up areas or other landscape types with a regular patch shape, due to the acceleration of urbanization during the last two phases of urbanization; (3) The total mangrove area decreased constantly in the first two phases of urbanization, but began to increase after 1998. After 1998, mangrove disappeared outside the core area. Landscape index analysis showed that the mangrove landscape did not become fragmented but was in larger landscape patches with increased landscape connectivity and (4) The area of the intertidal zone showed relatively large fluctuations over the past three decades, with areas reduced from 634.5 hm^2 in 1979 to 377.28 hm^2 in 2009, and the fragmentation and landscape heterogeneity increased. The landscape transfer intensity of these three types of landscape, namely *gei wei*, mangrove and mudflat, in Shenzhen Bay over the past three decades, and the analyses of different scales of transfer intensity grid based on the Jenks natural classification method, are further discussed in this chapter. The chapter ends with a summary on the restoration practices in different provinces in China, detailed research and case studies on the wetland restoration projects in Futian Nature Reserve and the recommended restoration targets.

Chapter 3 Restoration Technology for *Gei Wei* Fishponds in Coastal Wetlands

Gei wei fishponds in mangroves, which originated in the Pearl River Delta in China, is one of the traditional aquaculture techniques in coastal wetlands. It is a mangrove land-based enclosure aquaculture system, one of the reclamation modes of coastal wetlands. *Gei wei* fishponds are also common in sheltered bays and estuarine areas in Asia. This chapter gives a general introduction of *gei wei* fishponds, including definition, history and development, functions and services and the factors affecting the performance of *gei wei*, such as water level, pollution, etc. The only typical and traditional mangrove land-based enclosure *gei wei* aquaculture system still in operation in China is the Mai Po *gei wei* system in Hong Kong. The studies in Mai Po revealed that this kind of artificial coastal wetland system is fragile and sensitive to human disturbance.

The Mai Po *gei wei* system is an essential component of the “Mai Po Marshes & Inner Deep Bay International Important Wetlands” under RAMSAR. This land-based enclosure system, together with the other six, biodiversity management zones, in Mai Po is managed by the World