珠江及沿岸环境研究

ENVIRONMENTAL RESEARCH IN PEARL RIVER AND COASTAL AREAS

黄创俭 朱嘉濠 陈清潮 马小玲 编

广东高等教育出版社

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内容简介

本书收集了珠江及沿岸环境研究论文十八篇和五篇论文摘要。阐述了珠江及其河口的生态学、富营养化及赤潮、环境污染和环境管理等方面,可为珠江环境和资源研究的科技人员、管理干部以及高等院校有关专业的师生提供必要的参考。

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珠江及沿岸环境研究研讨会与会人士合影

Participants of the Symposium on the Environmental Research in Pearl River and Coastal Areas

研讨会在进行

Symposium in piogress

目　录

CONTENTS

Ⅳ. 环境管理 ENVIRONMENTAL MANAGEMENT

PREFACE

The Pearl River estuary is created by the inflow of freshwater from the largest river system in the South China Sea. The Pearl River has a watershed of 230,000 km^2. The river water is extremely turbid covering an area of greater than 8,000 km^2 during periods of peak discharge. Enriched by the large amount of river-borne nutrients, the Pearl River estuary supports large populations of marine organisms and contribute significantly to the fisheries in southern China, Hong Kong and Macau. In recent years, rapid economic development in the Guangdong province has led to over-exploitation of bioresources in the estuary and excessive release of wastes into the estuarine and coastal environment. Recognizing the importance of these problems, a symposium on the Environmental Research in Pearl River and Coastal Areas was held at the Chinese University of Hong Kong (CUHK), 5-6 May 1994. The goal of the symposium was to provide a forum for the environmental scientists in Guangdong and Hong Kong to exchange information and ideas, identify new areas of studies and explore possibilities for collaborative research.

The symposium was hosted by the Centre for Environmental Studies and the New Asia College of CUHK. The Organizing Committee, headed by Dr. Y. Leung, Director of the Centre, composes of Dr. K. H. Chu, Dr. L. S. Ho and Dr. C. K. Wong.

Twenty-three papers were presented in the two-day symposium. Twelve papers were presented by invited scholars from the South China Sea Institute of Oceanology, Chinese Academy of Sciences, the South China Environmental Sciences Institute, National Environmental Protection Agency, the South China Sea Fisheries Resesearch Institute, Chinese Academy of Fisheries Science, and the Environmental Protection Agency of the Guangdong province. The remaining eleven papers were presented by participants in Hong Kong, including those from the Chinese University of Hong Kong, University of Hong Kong, Hong Kong University of Science and Technology, City Polytechnic of Hong Kong, Baptist College, the Open Learning Institute, and World Wide Fund for Nature, Hong Kong. The names and addresses of the speakers are given in the appendix to this book. In addition to those who presented papers, the symposium was attended by more than thirty environmental scientists from tertiary institutes, the Environmental Protection Department, and environmental consultant firms in Hong Kong.

This book contains most of the papers that were presented at the symposium. The abstracts of other papers presented in the symposium are listed in the appendix. The papers encompass a wide range of subject matters on environment research in the Pearl River area and could be arranged in many different ways. We choose to put papers on the ecology of the Pearl River area in the first section to emphasize the importance of basic ecological studies. The first paper examines the relationship between primary productivity and environmental variables in the mouth of Pearl River. The second paper concerns the complex relationship between primary production, secondary production and environmental factors. The next two papers present data on the diversity and ecology of zooplankton in the estuary. The fifth paper reports on the distribution and ecology of ichthyoplankton in the estuary. The last paper of the section outlines the environmental research at the Mai Po Marshes Nature Reserve in Hong Kong.

The section on ecology is followed by a second section which consists of four papers on eutrophication and red tides. In the Pearl River estuary, as in many other areas of the world, red tides have become more frequent and are posing a real threat to human health. The first paper examines the relation between eutrophication and phytoplankton dynamics. The second paper discusses the mechanisms underlying red tide formation. An attempt on the mathematical modeling of red tides is presented in the third paper. These research efforts aim to the prediction, thus to provide early warning of red tide occurrences. The last paper in the section reports on the analysis of paralytic shellfish toxin in bivalves of the Pearl River estuary.

The third section deals with a variety of environmental pollution problems in the Pearl River estuary and adjacent coastal areas. The first paper presents data on dissolved oxygen, chemical oxygen demand, nutrients, petroleum hydrocarbons, heavy metals and other pollutants in the estuary. This is followed by a paper on the heavy metal levels in different marine organisms in the area. The third paper reports on the presence of the pathogen *Yersinia enterocolitica* in surplus activated sludge in Hong Kong. In the last paper of the section, the approach of using benthic diatom deformities for monitoring coastal pollution was examined.

The last section in this volume addresses several important issues in environmental management in the Pearl River Delta. In the first paper, the mathematical modeling techniques for the tidal river networks in the Pearl River Delta were presented. In the second paper, strategies for environmental protection of the area were suggested, based on its geographical and socio-economic characteristics. The third paper discusses the cooperation between Guangdong and Hong Kong in the environmental protection in the delta area. The last paper considers the conceptual and practical issues in environmental management, using South China as a case study.

While the papers in the book consider a wide variety of topics, we like to point out that in most cases more research is needed for definite answers or solutions to emerge. We hope. that these papers will help to foster productive new research with a view to strive for a harmonious socio-economic and environmental equilibrium in the Pearl River area giving benefits to all.

Both the Centre for Environmental Studies and the New Asia College of the Chinese University of Hong Kong contribute staff time and financial support to ensure success of the symposium. With funds from the Ming Yu Foundation, Prof. P. C. Leung, Head of New Asia College, initiated the New Asia Academic Seminar Series, of which the present symposium is the eighth one of the series. Prof. Leung and Dr. Y. Leung, Director of the Centre for Environmental Studies allocated funds not only to organize the symposium but also to publish these proceedings. The editors also like to express sincere appreciation of the efforts of the following: Ms. O. L. Leung of the Centre for Environmental Studies for her executive support in organizing the symposium, Dr. Peter Man and Mrs. Faith Ho of the New Asia College for their help during the symposium, and Mr. L. S. Leong for his clerical and technical assistance in the symposium and in preparing these proceedings.

C. K. Wong
K. H. Chu
Q. C. Chen
X. L. Ma

January 1995

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生态学

ECOLOGY

珠江及沿岸环境研究，1994.

珠江虎门附近水域基础生物量与环境关系初步研究*

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摘　要

本文根据1988—1993年多次调查的资料，着重研究珠江虎门附近水域基础生物量的分布变化和饵料生物结构、演替，并讨论某些环境因子对其影响。初步分析结果表明，该水域受珠江冲淡水以及沿岸工农业污水的影响，水质环境污染物质日益增多，限制了初级生产和饵料生物的繁殖生长，使虎门水域的基础生物结构明显发生变化。文中较深入地分析了基础生物量，包括初级生产、次级生产以及主要饵料生物的季节分布与演替，限制基础生物量变化的主、次因子，提出有关的模式，为加强珠江流域的环境整治和资源开发利用提供理论依据。

一、前　　言

珠江虎门内河段是东江、北江和西江部分河流汇合进入南海的冲口，同时又是水上运输通道和各种来往船只停泊的主锚地；两岸有广州、东莞、番禺、南海等市区，城乡人口密集，工农业发展迅猛，其生活污水和废物排放愈来愈多，河流受污染日益加重，对生态与环境造成不利影响。为保护环境，减少污染，避免损失，发展资源，迫切需要尽快摸清珠江河流背景和水质、生态状况，提出切实可行的对策和措施。过去对珠江河口的环境与生态已有不少研究[1,2,4,5,7,8,11]，但内河段的生态结构与生物资源尚未进行深入的研究报道，本文根据近几年来的调查资料，着重探讨该河段的基础生物量与环境关系，为加强珠江河流整治和环境保护，深入研究河流生态系统结构与资源动态提供理论基础，这无论在理论上或实际应用上都具有重要意义。

二、材料与方法

分别在1988年7、10月，1990年8、11月和1993年6月对珠江虎门内河段进行过5个航次的采样调查，除7月侧重于沙角附近外，其它航次为整个虎门内河区，测站见图1。叶绿素采用荧光法(Turner 10型荧光计)测定[10]，浮游动、植物分别使用浅水Ⅰ、Ⅲ型浮游生物网由底至表垂直拖网采集，样本用福尔马林固定，在实验室借用生物显微镜进行鉴定和计数。环境资

*国家自然科学基金(No. 39170173)和中科院南海海洋所所长择优基金资助项目。尹健强、袁文彬、陈雪梅、蔡创华、阎位兵等曾参加部分海上工作，同时还得到温伟英研究员和何悦强研究员的支持帮助，谨此表示谢意。

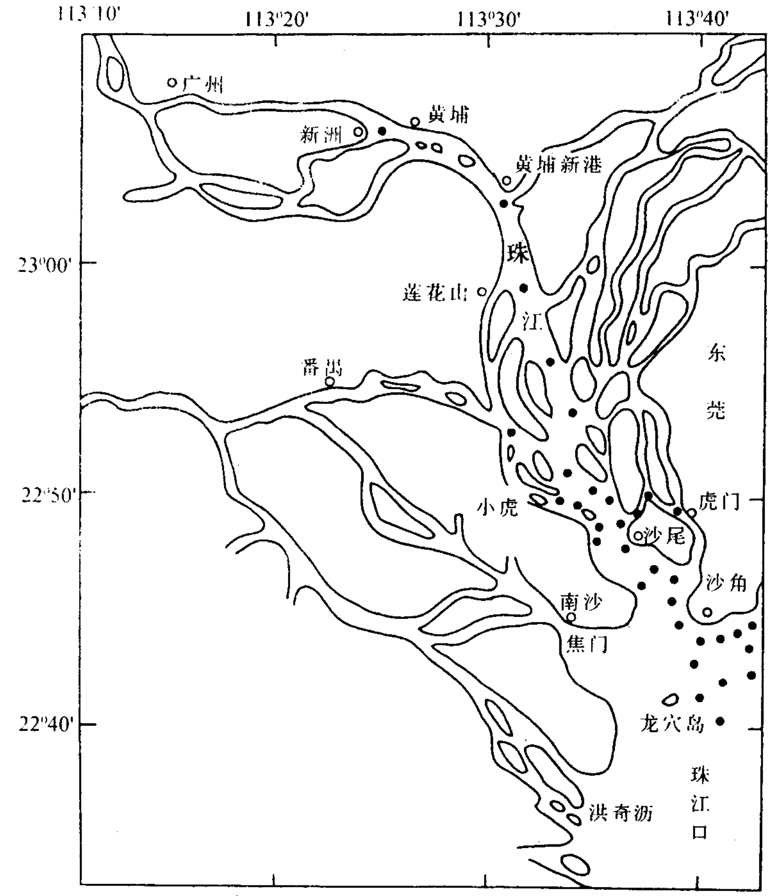

图1　采样站位示意图

料取自其它专业同步分析的数据。

三、结果与讨论

1. 水域生态环境

珠江水通过虎门口汇入伶仃洋每年达650亿m^3，枯水期和丰水期经流量差别很大，水环境特征也处于复杂多变过程。丰水期降雨量明显大于枯水期，内河冲淡水流经虎门口增多，因而浊度增大，盐度、透明度降低，其它环境参数与枯水期也有所不同（表1），而且受潮汐影响，涨潮或退潮时各种因子都有一定差别。

表 1　该水域某些环境参数比较

项　目	丰水期		枯水期	
	退　潮	涨　潮	退　潮	涨　潮
t(C)	31.1	31.2	22.8	22.3
PH	7.53	7.38	7.61	7.62
浊度(度)	141	94	69	75
DO(mg/l)	7.05	8.77	7.41	8.52
COD(mg/l)	2.89	2.65	1.65	1.60
PO_4-P(μmol/l)	0.37	0.32	0.13	0.17
NO_3-N(μmol/l)	0.99	1.36	6.45	5.78
NO_2-N(μmol/l)	0.06	0.06	0.38	0.43
NH_4-N(μmol/l)	0.002	0.005	0.009	0.007
透明度(m)	0.3		0.5	0.8

有关理化因子和基础生物量的区域分布由表 2 可见，内河段盐度分布明显由里向外递增，与潮汐(外海水入侵)有关；PO_4-P 含量则相反，NO_3-N 在莲花山附近水域测值最高，而另二种无机氮的高值出现在新洲水域。整个研究水域的营养成份与沿岸海湾明显不同[3,6]，主要污染物质，如油类、重金属和硫化物等已有超过水质标准迹象①，有害物质的日趋污染，将对生态环境造成不利影响，突出的表现是基础生物量减少，饵料生物结构发生变化，进一步证实了 Knox(1986)提出的观点和有关的研究结果[5,8,9]。

表 2　珠江河段基础生物量及环境参数的变化(枯水期)

项目 \ 河段名	新洲	黄埔新港	莲花山	小虎	沙角	龙穴岛
水温(C)	27.8	27.8	27.8	27.0	26.2	26.2
盐度	0.1	0.1	2.2	11.6	14.6	17.6
PO_4-P(μmol/l)	0.30	0.16	0.10	0.17	0.09	0.06
NO_3-N(μmol/l)	3.26	2.23	7.88	5.19	4.97	4.23
NO_2-N(μmol/l)	2.23	0.46	0.52	1.20	1.13	1.11
NH_4-N(μmol/l)	5.11	0.45	0.58	0.85	0.83	0.85
叶绿素 a(mg/m^3)	11.07	4.29	3.39	3.38	5.18	5.18
类胡萝卜素(mg/m^3)	4.27	1.62	1.09	1.23	2.20	1.18
浮游植物数量($\times 10^6 cells/m^3$)			51.1	42.6	23.5	16.1
浮游动物个体数($Ind./m^3$)			876	128	1612	1085

① 中国科学院南海海洋研究所，1991，东莞虎门电厂水域环境影响评价报告。

2. 生物量变化

丰水期(8 月)该水域叶绿素 a 含量较大,测值范围在 2.4—11.7mg/m^3 之间,平均为 4.82mg/m^3,初级生产力平均为 118mgC/m^2.d。在东莞虎门镇内河区出现叶绿素 a 高值,含量大于 5mg/m^3,在沙角西北部(即虎门口)一带含量较低,小于 3mg/m^3。脱镁叶绿素含量在 0.82—2.13mg/m^3 之间变化,平均为 1.30mg/m^3,大约相当于叶绿素 a 的 27%。浮游植物数量平均为 2.2×10^{7}cells/m^3(表 3),最高达 8.6×10^{7}cells/m^3,较高值主要分布在东莞虎门镇内河区,较低值在虎门口一带(4×10^{5}cells/m^3 左右),与叶绿素 a 的分布趋势相一致。浮游动物生物量很低,平均为 13.4mg/m^3,平面分布很不均匀,在虎门镇内河区最高可超过 50mg/m^3,但在调查区中部(沙尾以北)最低,只有 3mg/m^3;个体数量也很少,平均仅 13Ind./m^3(表 4)。

表 3 浮游植物种类与数量

项　　目	丰　水　期		枯　水　期	
	变化范围	平均值	变化范围	平均值
种　数	41		73	
多样性指数	0.02—0.26	0.10	2.80—3.86	3.31
均匀度	0.01—0.06	0.03	0.58—0.84	0.71
数量(×10^{5}cells/m^3)	4.4—863.5	221.7	260—615	462

表 4 浮游动物种类与数量

项	丰　水　期		枯　水　期	
	变化范围	平均值	变化范围	平均值
种　数	21		25	
多样性指数	1.30—2.73	2.30	1.00—2.54	1.88
均匀度	0.65—1.00	0.90	0.42—1.00	0.69
个体数(Ind/m^3)	5—32	13	4—1273	326
生物量(mg/m^3)	3—58	13.4	3—543	137

枯水期(11 月)的叶绿素 a 含量比丰水期的低,在 0.95—4.94mg/m^3 之间变化,平均为 2.57mg/m^3,平面分布与丰水期有所不同,内河测站(虎门镇附近)含量较低。脱镁叶绿素含量平均为 1.20mg/m^3,相当于叶绿素 a 含量的 46%左右。根据叶绿素 a 含量估算,水域透明度较大,初级生产力与丰水期相近,平均为 124mgC/m^2.d。浮游植物数量平均为 4.6×10^{7}cells/m^3,平面分布与叶绿素 a 相似,在珠江河段的变化是由内向外递减(见表 2)。浮游动物生物量明显高于丰水期,多数测站高于 100mg/m^3,最高可达 543mg/m^3,平均为 137mg/m^3,相当于丰水期的 10 倍,其河流分布是由里向外递增;浮游动物个体数量变化幅度较大,在 4—1273Ind./m^3 之间,平均为 326Ind./m^3。

由上可知,虎门附近水域基础生物量随季节而变化(表 5),这不但与生物本身生理特性有关,而且与水域的营养条件和某些环境要素密切相关。为探索它们之间的定量关系,应用多元

逐步回归分析法，获得枯水期珠江河段（新洲—龙穴岛）叶绿素 a 含量（Chl—a，mg/m^3，代表初级生产）与环境关系（1）及沙角附近叶绿素 a 与生态因素之间（2）的相关模式如下：

$$Chl-a=6.03-12.94PO_4-0.33NO_3+1.95NH_4 \quad (1)$$

$$(n=6, r=0.995)$$

$$Chl-a=29.39-3.43NO_3+0.029Pi-0.0076Zi \quad (2)$$

$$(n=16, r=0.829)$$

式中 Pi、Zi 分别代表浮游植物（$\times 10^5 cells/m^3$，下同）和浮游动物（$Ind./m^3$，下同）数量。而浮游动物个体数量（代表次级生产 Zi，$Ind./m^3$）与环境因子（3）或初级生产（4）之间的关系可用下式表示：

$$Zi=-1572.43-245.17DO+1042.16NO_2+716.53NO_3-4707.37PO_4+1.73Pi \quad (3)$$

$$(n=16, r=0.905)$$

$$Zi=1305.85-53.08Chl-a \quad (4)$$

$$(n=11, r=0.744)$$

表 5 虎门附近水域基础生物量的季节变化

时间	叶绿素 a (mg/m^3)	脱镁叶绿素 (mg/m^3)	初级生产力 ($mgC/m^2 \cdot d$)	浮游植物数量 ($\times 10^5 cells/m^3$)	浮游动物个体数 ($Ind./m^3$)
93.6	0.80	0.40	18	6.2	27
88.7	3.40	0.89		13.1	7
90.8	4.82	1.30	118	221.7	13
90.10	4.26	0.60	606	88.2	735
90.11	2.57	1.20	124	462.0	326
88.2	1.21			3.8	
平均	2.84	0.88	217	132.5	222

以上分析结果表明，珠江河段初级生产和次级生产都不同程度受水质环境所控制，关系比较密切的因子有 N、P 和 DO 等，初级生产对次级生产的影响受无机环境的调节，反映出河流基础生物量的变化与环境和生物要素都有关。该河段水体中营养物质已过于丰富，造成对初级生产起负作用。与沿岸海湾或某些河口区的分析结果有所不同[3,6,9]。与深圳湾分析的结果具有相似之处。

3. 浮游生物种群结构

根据采获标本，经初步分析，该水域丰水期生物种类较少，8 月份共有浮游植物 41 种，以颗粒直链藻（*Melosira granulata*）占绝对优势，占浮游植物总数的 99%，最少的 6 月份也占 50%以上（表 6），其数量分布以虎门镇内河区较高。由于优势种突出，种类分布不均匀，多样性指数和均匀度值都特别低，分别为 0.10 和 0.03，反映出水质受污染，浮游植物种群结构发生变化。浮游动物在丰水期采获的数量很少，种类组成也较单调，8 月份只有 21 种，以仔鱼七丝

鲚(*Coilia grayi*)的数量最多,约占浮游动物总数量的31%(表7),其次是中华异水蚤(占15%以上),由多样性指数分析结果看来,浮游动物的种群结构变化仍不大。

表6 虎门附近水域浮游植物的主要种类

时 间	种 类	数量 ($\times10^5$cells/m^3)	占总数的百分比(%)
93.6	颗粒直链藻 *Melosita granalata* 钝角脆杆藻 *Fragilaria capucina*	3.2 2.1	51.4 34.2
88.7 (沙角附近)	颗粒直链藻 *Melosita granalata* 奇异菱形藻 *Nitzschia paradoxa*	12.5 0.4	95.6 3.1
90.8	颗粒直链藻 *M. granulata*	219.0	99.1
88.10	骨条藻 *Skeletonema costatum* 琼氏圆筛藻 *Coscinodiscus jonesianus*	60.2 16.4	68.3 18.6
90.11	骨条藻 *SK. constatum* 条纹小环藻 *Cyclotella striata* 长菱形藻 *Nitz. longissima*	135.6 99.7 32.1	29.3 21.6 6.9

表7 虎门附近水域浮游动物主要种类

时 间	种 类	个体数 (Ind./m^3)	占总数的百分比(%)
93.6	短尾类幼体 Brachyura larva 桡足类 Copepoda 长尾类幼体 Macrura larva	12 6 5.5	44.4 22.2 20.4
88.7 (沙角附近)	中华异水蚤 *Acartiella sinensis* 球状许水蚤 *Schmackeria forbesi*	2.7 2	38.6 28.6
90.8	七丝鲚 *Coilia grayi* 中华异水蚤 *A. sinensis*	4 2	30.8 15.4
88.10	刺尾纺锤水蚤 *Acatia spinicauda* 中华异水蚤 *A. sinensis* 球型侧腕水母 *Pleurobrachia globosa*	239 145 91	32.5 19.7 12.3
91.11	刺尾纺锤水蚤 *Acartia spinicauda* 中华异水蚤 *A. sinensis* 真刺唇角水蚤 *Labidocera euchaeta*	105 83 72	27.9 22.1 19.1

枯水期浮游生物种类相对较多,11月份浮游植物采获73种,以骨条藻(*Skeletonema costatum*)和条纹小环藻(*Cyclotella striata*)为主,分别占总数量的21.6%和29.3%,10月份骨条藻的数量则占68.3%。相比之下,优势种没有丰水期那么突出,种类分布较为均匀,多样性指数和均匀度值属正常范围,分别为3.31和0.71。浮游动物的种类也比丰水期较多,11月份有25种,主要优势种是刺尾纺锤水蚤(*Acartia spinicauda*)、中华异水蚤(*Acartiella sinensis*)等(表7),占浮游动物总数量的20%以上,种类多样性和均匀度值略低于丰水期,平均分别为1.88和0.69。

浮游生物种群结构发生变化,基础生物量较低,反映出水质背景和生态条件较差,这与珠