RESEARCH AND DEMONSTRATION
OF
PURIFYING EUTROPHICATION WATER BY FISHERIES TECHNOLOGY IN LIHU LAKE

蠡湖净水渔业研究与示范

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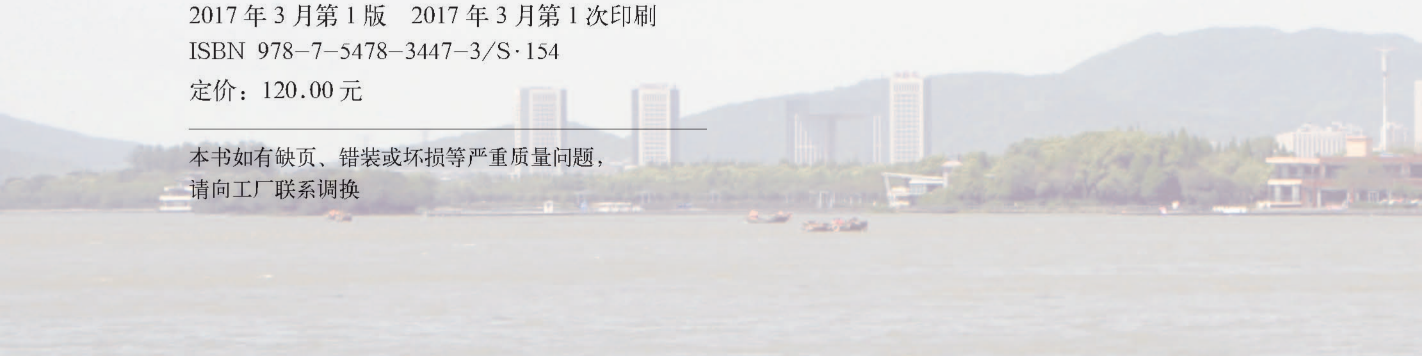

内容提要

本书系一部关于运用净水渔业理念实施浅水湖泊生态修复方面的专著。采用内源性生物操纵手段调控湖水中的氮、磷，以减缓富营养化，防止出现蓝藻暴发产生的危害。

在总结前人研究基础上，针对太湖内湾蠡湖的氮、磷含量居高不下和蓝藻过多的情况，以多项技术集成组装的净水渔业技术，对水环境整治后的蠡湖开展了以渔净水的研究与示范，使原来的劣Ⅴ类水质上升为Ⅲ类水质，将重富营养湖泊修复为中营养湖泊，达到了预期的效果和目的。在实践示范中，通过同步监测水质与水生生物的动态变化、多种方法综合评价水质，证实了鲢、鳙的净水作用。

全书共分6章，从蠡湖及其环境治理、净水渔业技术实施前的蠡湖渔业生态环境、净水渔业技术试验的技术路线和方法、净水渔业技术试验及其效果、净水渔业技术对蠡湖水质的影响、净水渔业技术对蠡湖水生生物群落的优化调控等方面进行纪实性阐述。

本书内容丰富，理论与实践相结合，可供水环境、渔业、生命科学等相关领域的研究人员、大专院校师生和管理人员参考，也可为其他浅水湖泊在生态修复实践中提供思路和参考借鉴。

Synopsis

This book is a monograph on the use of water-purification fishery concept to carry out ecological remediation in shallow lakes. In order to slow down the eutrophication and prevent blue-green algae bloom, endogenous bio-manipulation was used to regulate and control nitrogen and phosphorus in lake water.

On the basis of former research and aiming at the high concentrations of nitrogen, phosphorus, blue-green algae in Lihulake, an inner bay of Taihu Lake, the research and demonstration of water-purification fishery technology which integrated many technologies and used fishery to purify eutrophication water were carried out in Lihu Lake whose water environment had been treated previously. The water quality of Lihu Lake increased from worse than level Ⅴ to level Ⅲ and from heavy eutrophic state to mesotrophic state after carrying out water-purification fishery technology, and the anticipative effects and aims had been reached. The water purification effect had been verified in the practice and demonstration by the way of monitoring water quality, dynamic changes of aquatic organism and using many methods to assess the water quality.

The book is classified into six chapters. The documentary elaboration is carried out as following: Lihu Lake and its environmental treatment, fishery eco-environment of Lihu Lake before carrying out water-purification fishery technology, technical route and method of test, test and effect of water-purification fishery technology, water-purification fishery technology decreasing the nitrogen, phosphorus and trophic level, optimization and regulation of water-purification fishery technology on ecosystem.

The book is rich in content and is reviewed with theory and practice combined. The book can be used by research personnel, teachers and students in colleges and universities and management personnel with the interesting areas of water environment, fishery, life sciences and other related areas, and it also provides ideas for other shallow lakes in the practice of ecological restoration.

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前言

一个机遇，使我们有了实践净水渔业理念和净水渔业技术的机会。

在实施了污染控制和生态重建技术后水中氮、磷仍居高不下的无锡蠡湖，我们用净水渔业理念进行生物修复，其方法是运用净水渔业技术。

净水渔业理念，即依据一定数量的滤食性鱼类（鲢、鳙）和底栖动物（螺、贝等）对水体中浮游生物有控制效应，可抑制蓝藻的生长，并让水中的氮、磷通过营养级的转化，最终以渔产量的形式得到固定，当捕捞出水体时就移出了氮和磷。

净水渔业技术与一般湖泊水库的放养鲢、鳙不同，它要求放大规格鱼种(2 龄)、回捕高规格成鱼(4 龄以上)，要求禁捕时间长（确保鲢、鳙生长安全）和水域中有一定的鲢、鳙群体。鲢、鳙对藻类水华的控制作用虽已众所周知，但成效不显著，尤其在太湖、巢湖等大型湖泊，关键就在鲢、鳙的放、管和捕。

本书详述了净水渔业研究与示范的过程、取得的第一手监测数据、对照和参考其他科研工作者的研究成果进行分析研究，提出的思考和问题，供大家参考。为此，对蠡湖水生态修复的前期试验作了较为详细的阐述，试图提供众多治理方法中运用生物学或生态学方法治理湖泊富营养化的理论研究与实践相结合的示范典例；验证放养滤食性鱼类对湖泊水生态有减缓富营养化进程、净化水质的作用，通过长达数年的原位试验研究表明，鲢、鳙确有净水作用，但与环境条件、运作方法密切相关。本书可为其他浅水湖泊的生态修复实践提供思路。

在净水渔业研究与示范中，特别感谢：

无锡市水产技术推广站张宪中研究员及其团队，在放流、管理与回捕净水的鲢、鳙中所作的贡献。

中国水产科学研究院淡水渔业研究中心的环境保护研究室和水生生物资源研究室的科研人员，对实施净水渔业技术前后的蠡湖环境生态变迁、蠡湖鱼类资源变动提供了数以千计的实测数据；胡庚东研究员等在蠡湖敞水区的水生植物调研和杨健研究员及其团队的以移养背角无齿蚌测评湖泊的重金属污染动态变化等为本研究提供了基础依据。

著作者

2016 年 10 月

Introduction

It is a good opportunity that we have the honor to carry out "water-purification fishery" concept and water-purification fishery technology.

Aiming at the high concentrations of nitrogen and phosphorus in Lihu Lake even after the pollution control measures and ecological reconstruction technologies having been carried out, we used "water-purification fishery" concept whose method was water-purification fishery technologies to carry out bioremediation.

"Water-purification fishery" concept is a concept that using a type of special and appropriate fishery practice to purify eutrophication water. And its general principle is as follow: nitrogen and phosphorus in eutrophication water can be absorbed by phytoplankton, and phytoplankton can be eaten by zooplankton, and phytoplankton and zooplankton can be eaten by filter-feeding fish (silver carp and bighead carp) and zoobenthos (snail and shellfish). Therefore, the nitrogen and phosphorus will be taken out of the eutrophication water by the way of catching fish. That is to say, the nitrogen and phosphorus could be removed and phytoplankton, including blue-green algae, could be controlled by the above food chain.

Water-purification fishery technology is different from the general practice of releasing silver carp and bighead carp into lake. Water-purification fishery technology requires releasing large-size fingerling (2 years old fingerling) and catching large-size adult fish (more than 4 years old), therefore the no catching time is very long, and what is more, a certain quantity of silver carp and bighead carp have to be left after catching. It has been well known that silver carp and bighead carp could control water bloom, however, the efficiency was not so good especially in Taihu Lake and Chaohu Lake, the crucial reasons are release, manage and catch of silver carp and bighead carp.

The research and demonstration of water-purification fishery technology and firsthand monitoring data of the research are described in this book. For the good reference purpose, we have compared with and referenced the research results of other scientists, and analyzed, researched and presented some thoughts and questions in this book. Therefore, in order to provide a model demonstration example with the combination of theoretical research and practice that using biological or ecological methods to treat lake eutrophication, the earlier stage test of eco-remediation of Lihu Lake has been described particularly. The effect of releasing filter-feeding fish on slowing down lake eutrophication and purifying water has been verified. The in situ test lasting for many years has showed that silver carp and bighead carp have the eutrophic water remediation function, however, this eutrophic water remediation function is closely related to environmental condition and operation method. This book can provide ideas for other shallow lakes in the practice of ecological restoration.

In the process of water-purification fishery research and demonstration, the authors acknowledge support from professor Zhang Xianzhong and his team from Wuxi Aquaculture Technology Extending Station for releasing, managing and catching silver carp and bighead carp that used to eutrophic water remediation. Acknowledge support from scientists from Fishery Environmental Protection Department and Large Water Hydrobiology Resources Department of Freshwater Fisheries Research Center for providing thousands of measured data about the ecological environment changes and fish stocks dynamics of Lihu Lake before and after the carrying out of water-purification fishery technology. Acknowledge support from professor Hu Gengdong for aquatic plants investigation in open water area of Lihu Lake, support from professor Yang Jian and his research team for monitoring and evaluating heavy metal pollution dynamics by the way of transplanting “standardized” Anodonta woodiana, their works have provided foundation and basis for the research.

Xu Pao et al.

October 2016

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Content

第 1 章

蠡湖及其环境治理

本章主要简述实施净水渔业技术前的蠡湖环境及其综合治理概况。

1.1　蠡湖地理概况

蠡湖又名五里湖。蠡湖是太湖北部湖湾梅梁湖伸入无锡市的内湖，位于东经 119° 13′ 12″ 至 17′ 11″，北纬 31° 29′ 54″ 至 32′ 50″，地处无锡市西南郊，属浅水型湖泊（图 1–1）。湖泊大体呈葫芦状，东西长约 6.0km，南北宽 0.3 ～ 1.8km，湖区水较浅、水域开阔，来往船只较多。蠡湖历来以宝界桥为界，分称为东蠡湖和西蠡湖。从 20 世纪 60 年代起，因忽视对环境资源的保护，在蠡湖大面积围湖造田、筑塘养鱼、围网养殖，沿湖渔业无序开发，湖岸被侵占吞食，污水直接入湖，生态环境遭到破坏，蠡湖水面从早期的 $9.5km^2$ 缩小为 $6.4km^2$。2002 年，平均水深 1.6m，容积约为 $10.24\times10^6m^3$。西部通过犊山防洪枢纽的节制闸与梅梁湖连通，北面有骂蠡港河道与无锡城区连接，东面由曹王泾河道与京杭大运河连通，南面的长广溪河道与太湖

图 1–1　蠡湖地理位置

Fig. 1–1　Geographical position of Lihu Lake

另一湖湾贡湖连通，沿湖还有多条支河与周边城镇和农村相连接，形成一个既相对独立又相互联系的水系。由于蠡湖深处腹地，相对封闭，水体流动缓慢，换水周期长约 400d，因此自净能力较差。

1.1.1　水环境特征与变迁

1951 年的蠡湖基本保持着原有的自然湖泊形态，以天然湖岸为主，沿岸带有较大面积的浅滩，生长着茂密的芦苇、菱、水鳖、苦草、范草、穗花狐尾藻等大型水生植物；20 世纪 60 年代以后，湖滩地被大面积围垦（图 1–2），沿岸又建筑人工堤坝，使得蠡湖基本上失去了适合大型水生植物生长的浅水滩地，更兼 60 年代后期开始放养草食性鱼类，导致处在高水位等不利条件下的深水区的沉水植物消失。20 世纪 50 ~ 60 年代的蠡湖水草茂盛、水质清新；到 70 年代后，水草逐渐减少，周边筑塘造鱼池约 300hm^2（图 1–3），鱼池肥水及污泥未经处理直接排入蠡湖，水质开始变差；80 年代起，蠡湖成为一个小型养殖湖泊，

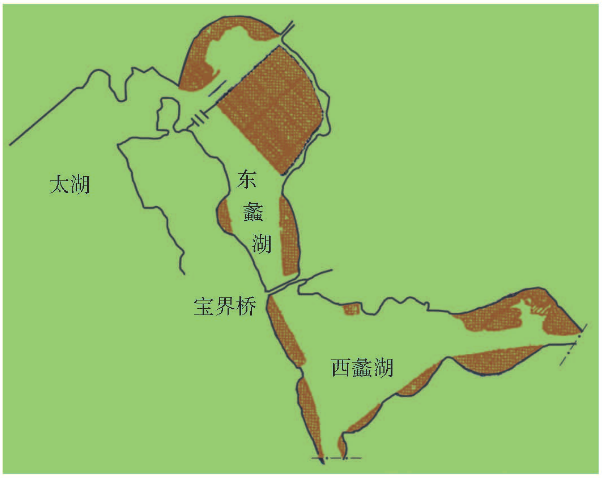

图 1–2　蠡湖的围垦示意图

Fig. 1–2　Sketch map of Lihu Lake reclamation

图 1–3　蠡湖围垦后建成的鱼池

Fig. 1–3　Ponds along Lihu Lake after reclamation

湖区由两个渔场分别以宝界桥为界进行网围养殖生产，东蠡湖为 167hm^2，西蠡湖为 130hm^2。两个渔场均采取春季放流鱼种，并投饵施肥，冬季大捕捞的生产方式，放养物种主要是鲢、鳙，其他鱼类少量。据《2001 年无锡市水产统计年报》统计，渔业产量为 7.75×10^5kg，起捕规格鲢平均为 1.5kg/ 尾、鳙为 1.25 ~ 1.5kg/ 尾。自 2002 年蠡湖实施综合整治起，停止了放养渔业。

1.1.2 水文

蠡湖地区多年平均降雨量为 1 112.3mm，平均水位为 3.06m，历史最高水位为 4.88m，最低水位为 1.92m，正常蓄水位为 3.30m 左右，平均水深 1.60m，相应库容约为 1 500 万 m^3。湖区平均水温为 17℃左右，年最高水温出现在 7 ~ 8 月份，达 38℃左右；年最低水温出现在 12 月下旬至翌年 2 月上旬，最低水温 0℃。

历来蠡湖西端与太湖（梅梁湖湖区）直通，与太湖间存在频繁的由风涌水引起的水流交换，水位基本与太湖保持一致，而且蠡湖西部与梅梁湖的水质也基本相近。围垦使得蠡湖与太湖之间的通道变小，加之 20 世纪 90 年代初在通道上修建了水闸，将蠡湖与太湖隔离开来。蠡湖成为一个独立的湖体后，与太湖间的水流交换受到了严格控制，但水位仍与太湖接近一致。

此后，蠡湖湖水的主要补给来源为周边的生活污水、工业废水、鱼塘尾水，以及通过长广溪、曹王泾、骂蠡港河道流入蠡湖的污水。其中骂蠡港、曹王泾等数条小河与梁溪河相通，而梁溪河又直通无锡城区污染严重的京杭大运河，因此加剧了对蠡湖的污染。

1.1.3 水质

20 世纪 50 年代初蠡湖的水质调查表明，当时的水质处于中营养状态，完全符合饮用水源标准[1]；60 年代初期，据中科院南京地理研究所调查，蠡湖仍保持着良好的水质[2]；70 年代水生植物消失，水质趋于富营养化；80 年代污染的加剧加速了富营养化的发展，水体中的高锰酸盐指数、总磷和总氮浓度呈上升趋势[3]（图 1–4）；到 90 年代初已达到重富营养化水平[4]。

据无锡市环境监测中心站的监测数据表明，2001 年蠡湖大部分水质指标接近或超过《地表水环境质量标准》（GB 3838—2002）中的Ⅴ类水标准，其中的高锰酸盐指数、5 日生化需氧量、总磷、总氮和叶绿素 a 年平均值相当于全太湖的 1.39 倍、2.63 倍、1.93 倍、2.44 倍和 2.61 倍，湖水处于重富营养状态[4]。经过 2002 ~ 2005 年水污染综合治理后，水环境总体上逐步得到较大改善[5]（表 1–1），但总磷为Ⅳ类、总氮仍为劣Ⅴ类。