

RIHN-China Study Series No.3

湖の現状と未来可能性

川端善一郎、孔海南、吳德意、福士由紀、窪田順平 編



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湖泊的现状与未来可能性

川端善一郎 孔海南 吴德意 福士由纪 窪田顺平 编

Our Lakes: From the Present towards a Future Perspective

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Yuki FUKUSHI, Jumpei KUBOTA



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目次

目 录

Contents

RIHN-China Study Series No.3 の刊行にあたって	窪田順平, 福士由紀	5
湖の現状と未来可能性	川端 善一郎	6
Our Lakes: From the Present towards a Future Perspective	Zen'ichiro KAWABATA	7

第一部 湖の暮らし
第一部 湖泊与生活
Part 1 Living with Lake

第1章		
生态人类学视野下白族渔民生计方式变迁与文化适应性 ——以双廊镇岛依旁白族渔村为例	张桔, 段会林, 福士由纪	13
Changes in Ways of Livelihood and Cultural Adaptation in the Bai Fishing Village Viewed from an Eco-anthropological Perspective ---Focusing on Daoyipang Village, a Bai Fishing Village in Shuanglang Town, Dali City, Yunnan Province	Ju ZHANG, Huilin DUAN, Yuki FUKUSHI	19
第2章		
水上生活にみる慣習的共生システムの形成と湖保全の持続可能性	楊平	27
Development of Conventional Symbiotic Systems and Sustainability of Lake Preservation as Observed with Life on the Water	Ping YANG	33
第3章		
日本の湖岸地域における環境変化と住民の健康問題 — 琵琶湖彦根マラリア (1920-1950) —	市川智生, 東城文柄	41
Environmental Changes in the Lakeside Regions of Japan and the Health Problems of the Residents - Lake Biwa Hikone Malaria (1920 to 1950) -	Tomo ICHIKAWA, Bumpei TOJO	47

第二部 湖の環境変化
第二部 湖泊的环境变化
Part 2 Environmental Change of Lake

第4章

太湖流域の人間活動が水環境に与える影響及び解決策

..... 郝愛民, 久場隆広, 井芹寧, 張振家, 李春杰 57

Impact of Human Activities on the Water Environment of Lake Taihu Watershed
and Solutions for Environmental Problems

..... Aimin HAO, Takahiro KUBA, Yasushi ISERI, Zhenjia ZHANG, Chunjie LI 65

第5章

湖の環境変化と感染症

..... 源利文, 川端善一郎 75

Environmental Change of Lake and Infectious Disease

..... Toshifumi MINAMOTO, Zen'ichiro KAWABATA 81

第三部 湖の環境保全
第三部 湖泊的环境保护
Part 3 Environmental Preservation of Lake

第6章

Countermeasures for the Non-Point Pollution Control in the Watershed of Lake Erhai, China

..... Xiao SHANG, Hainan KONG 91

第7章

水化硅酸钙与沸石强化人工湿地处理水中低浓度氮磷研究

..... 李春杰, 吴德意, 张振家, 孔海南 111

Removal of Nitrogen and Phosphorus with Low-Concentration
by Constructed Wetlands Integrated with Calcium Silicate Hydrate and Zeolite

..... Chunjie LI, Deyi WU, Zhenjia ZHANG, Hainan KONG 117

第8章

洱海服务功能调查与评价

..... 谢杰, 吴德意 125

Study and Evaluation of the Service Function of Lake Erhai

..... Jie XIE, Deyi WU 131

第9章	
水生植物改善湖滨带水质的现场实证性研究	谢强, 吴德意, 源利文, 山中裕树
.....	本庄三惠, 川端善一郎 139
An On-Site Empirical Study on the Role of Aquatic Plants in Improving Lakefront Water Quality	Qiang XIE, Deyi WU, Toshifumi MINAMOTO, Hiroki YAMANAKA
.....	Mie N. HONJO, and Zen'ichiro KAWABATA 145

第四部 湖の環境ガバナンス

第四部 湖泊的环境治理

Part 4 Environmental Governance of Lake

第10章	
太湖流域の水環境ガバナンス	
—対話と協働による長期有効管理メカニズムの模索—	
.....	大塚健司 155
Governance of Water Environment in Taihu Lake Basin	
—Pursuit of Effective Long-term Management Mechanism Based on Dialogue and Collaboration—	
.....	Kenji OTSUKA 163

第11章	
流域ガバナンスの学際研究	
—琵琶湖の農業濁水問題を事例に—	
.....	谷内茂雄 173
Interdisciplinary Study of Watershed Governance	
— Using the Agricultural Turbid Water Problem of Lake Biwa as Reference —	
.....	Shigeo YACHI 181

后记	
.....	孔海南 190
Epilogue	
.....	Hainan KONG 191

RIHN China Study Series No. 3 の刊行にあたって

改革開放以来、経済発展に伴って、中国は日々大きく変化している。総合地球環境学研究所・中国環境問題研究拠点では、2007年の設立以来、中国各地で展開されている地球研プロジェクトの研究成果に立脚して、こうした経済発展や開発にともなう地域の文化・社会・自然環境の変容の実態を解明し、地域の発展と文化・社会・環境保全の望ましい姿をさぐるべく、研究を行ってきた。

2007年度から2011年度の第1期研究期間においては、「中国の社会開発と環境保全」というテーマの下、水資源をめぐる環境政策とその地域社会・文化への影響¹、半乾燥地帯の環境変化と人々の生活・社会の変化に関する研究成果²を、中国環境問題研究拠点研究報告集（RIHN-China Study Series）として刊行した。2012年度から2016年度の第2期研究期間では、「グローバル化する中国環境問題と東アジア成熟社会シナリオの模索」を新たなテーマとして掲げ、中国を中心とした東アジア圏を視野に入れつつ、住民の生活基盤の保障とリージョナルな資源開発・環境保全を両立させる「東アジア成熟社会」のありようの考察を進めている。本書は第1期の2冊の研究報告集に続く、シリーズ3冊目、第2期としては最初の報告集である。

本書は、2013年1月13日に、上海交通大学環境科学與工程学院と共催した第6回中国環境問題研究拠点国際シンポジウム「湖の現状と未来可能性」の成果に基づくものである。本シンポジウムは、第2期テーマを踏まえ、中国のみならず日本を視野入れた国際比較の視点、自然科学のみならず人文社会科学からのアプローチを含めた分野横断的視角から企画され、地球研プロジェクト「病原生物と人間の相互作用環（2005-2011年度、代表：川端善一郎）の成果を核としつつ、広く日中の関連の研究者の参加を得て、中国の湖に関わる現状と今後の方向性を展望した。

湖は、人間にとって貴重な水資源や漁業資源などを供給する場であるだけでなく、文化を含む多様な生態系サービスを提供する。一方で水の流れが緩慢であるという特徴から、周辺の間人活動の影響を受けやすく、いったん汚染されると復元が困難となる。本書では、中国・日本における湖をめぐる諸問題、取り組みを多分野の視角から紹介した論考を収録している。本書が、中国や日本のみならず、世界の湖をめぐる、今後の人間と環境の望ましい姿をさぐる研究の一助となることを願っている。

なお、本書の刊行にあたり、駒野恭子氏に編集・レイアウト作業などを行っていただいた。ここに感謝の意を表したい。

総合地球環境学研究所・中国環境問題研究拠点
窪田順平
福士由紀

¹ 総合地球環境学研究所・中国環境問題研究拠点『エゼネ旗コミュニティ発展と自然保護プロジェクト』（総合地球環境学研究所・中国環境問題研究拠点、2010年）

² Yuki Konagaya, Sarengerile, and Kanako Kodama eds. *An Oral History of Mothers in the Ejene Oasis, Inner Mongolia* (Kyoto: Shokadoh Book Sellers, 2011).

湖の現状と未来可能性

川端善一郎¹

本書は2013年1月13日に上海交通大学で、上海交通大学環境科学与工程学院(中国・上海)、総合地球環境学研究所(地球研)(日本・京都)、および中国環境問題研究拠点(日本・京都)²の共催で行われたシンポジウム「湖の現状と未来可能性」で発表された講演に新たな論文を追加し、一冊の本にまとめたものである。湖は河川に並んで人間が生きてゆくために不可欠な淡水資源となってきたし、これからもその貴重さは変わらない。ところが、近年、世界中で湖の富栄養化や環境変化が急激に進み、湖の生態系サービスの劣化が急速に進行している。その理由は三つある。第一の理由は湖自身の環境特性による。湖は閉鎖度の高い水域生態系であるため、人間の湖内や湖岸の活動のみならず、集水域の活動にも強く影響されることによる。第二の理由は集水域における人間の土地利用形態の変化や経済活動がここ数十年きわめて活発に行われているためである。まさに湖は人間活動を映し出す鏡なのである。第三の理由は湖の多面的利用による利害の調整の困難さに起因する。

湖の持続的利用は湖の保全があってはじめて可能になる。ところが多くの湖でその環境保全が進んでいない。これからの環境保全のためには、いくつかの留意点がある。第一に、湖を閉じた系とする従来型の理解に留まらず、時間的空間的な広がりの中で、湖の特徴を理解する必要がある。湖と集水域と人間の相互関係を過去、そして現在の時間軸上で理解し、未来のあるべき相互関係に外挿することが必要である。第二に、多面的な視点とその関係の中で問題を把握する必要がある。湖の環境劣化の原因を従来の自然科学的理解に留まらず、その原因の原因となる人間の活動の理解が必要である。さらに、改善策の提案とその実行には、社会の諸制度や人間の意識の理解まで必要となる。まさに、総合研究が必要である。第三に、湖の利用者と研究や保全活動に関わる多様な人と組織の連携が必要である。湖の利用には様々な利害関係が伴うからである。今や研究機関の研究者だけの問題ではなく、市民の身近な問題でもあるからである。研究者が得意とする分析や一般化から得られた知見と、市民の生活の知恵や感覚、そして経済的な活動をする人々との調整が必要である。

湖の恩恵を再認識し、現在湖が直面している問題を分析し、湖と人間の望ましい関係を築くための具体的な提案と行動が、現代に生きる私たちにあらためて求められている。これは世界共通の問題でもある。日本と中国の未来に向けた湖研究が世界の湖沼のモデルになることを期待したい。本書では上記の環境保全の新しい留意点に関連した研究成果を取り入れ、これからの湖の保全対策を提案し実行していく場合に参考になることを期待して編集した。

1 総合地球環境学研究所。

2 大学共同利用機関法人人間文化研究機構の現代中国地域研究推進事業の一環として地球研に設置された研究組織。

Our Lakes: From the Present towards a Future Perspective

Zen'ichiro KAWABATA¹

This book is a compilation of edited papers presented at the symposium, "The Present Status and Futuarability of the Lakes" and several invited papers. The symposium was held on 13 June, 2013, at Shanghai Jiao Tong University organized by School of Environmental science and Engineering, Shanghai Jiao Tong University (Shanghai, China), Research Institute for Humanity and Nature (Kyoto, Japan), and The RIHN Initiative for Chinese Environmental Issues (RIHN-China) (Kyoto, Japan)².

Lakes are indispensable resources for human survival. However, global observations show that the ecological services of lakes are shrinking rapidly due to human-induced environmental degradations such as eutrophication and habitat degradation. Three main causes are attribute to responses of the lakes. Firstly, lakes are sensitive to human activities within the entire basin as well as in the lake and littoral area because they are highly closed systems. Secondly, an enhancement of human economical activities and changes in land use have occurred in basins over the past few decades and lakes act as mirrors reflecting human activities. The third cause is the difficulty in adjusting the requirements from diversified user-interests.

Sustainable usage of lakes can only be ensured by conservation of the lakes. Nevertheless we have taken a tremendous amount of time and effort to recover lakes, and unfortunately it is very difficult to present examples of success. A few important points need to be adhered to when considering lake conservation. Firstly, it is necessary to understand the lake's features as a spatially-temporally expanded system rather than only a closed system. The interactions between humans and lakes and their associated basins need to be understood on a past and present time axis in order to formulate a proposal for future lake management. Secondly, any problems need to be understood in terms of multidimensional relationships and within a particular context. Wide range of knowledge of all human activities is indispensable. In addition, to make suggestions and ultimately implement the improvement of a lake's environment, it is also necessary to understand the local human social system and associated concepts. It is therefore considered that the use of interdisciplinary studies is undoubtedly required. Thirdly, inter-institutional cooperation is required between lake users and those who have been, and will be, involved in environmental conservation at various levels of activities, mainly because of their different sort of interests that they have in the usage of the lakes. Nowadays the conservation of lakes is of interest not only to researchers, but also to citizens. Synthesizing and adjusting the knowledge obtained by analyses and theorizing by researchers, the perceptions and experiences of citizens, and the opinions of people who are engaged in economical activities, are also required.

Living in our present society we urgently require substantial suggestions and actions which lead to the establishment of a good relationship between lakes and humans. This will evolve through our analyses of the problems which we are now facing, and through the recognition of eco-services, and such a method should be disseminated to all global citizens. It is my wish that we construct an adequate model for lake conservation through cooperative research with Japanese and Chinese researchers. This book is a compilation of edited papers that show innovative

1 Research Institute for Humanity and Nature

2 The initiative was founded at the RIHN in 2007 by the National Institute for the Humanities to promote the studies focusing on China's environmental issues, based on the RIHN research projects which have been implemented within several areas in China (<http://www.chikyu.ac.jp/rihn-china/about-en.html>).

points of views and new findings, and aims to contribute to society and provide perspectives for those intending to implement such ideas.

第一部 湖の暮らし

第一部 湖泊与生活

Part 1 Living with Lake



生态人类学视野下白族渔民生计方式变迁与文化适应性

——以双廊镇岛依旁白族渔村为例

张桔¹，段会林²，福士由纪³

生态人类学自 20 世纪 50 年代创立以来，至今已经发展为一门独立的人类学分支学科。总的来说，生态人类学以研究人、环境与文化之间的相互关系为主要研究对象。它不仅限于研究人和自然环境的相互关系，还研究这种相互关系产生的影响和被影响的文化（观念）体系间及二者间的相互关系。在人和自然环境的相互关系中，人口结构、社会组织、技术、环境等是作为重要的结构因素包括在内的。同时获得食物的活动和维持人口的活动是有关人类生存的最基本的活动。特别是为获得食物的集团、活动、技术等被总称为“生业（计）方式”。因此在考虑人类生活时，就必须考察事物资源的分布、生计方式和繁殖方式等三个问题。在生态人类学中，生计方式是最基本的研究问题（庄锡昌，孙志民：1988）。而文化适应主要是指文化对环境的适应，是一种文化在面对生存环境的变化时，或出于提高对自然资源的利用效率的需要，通过实际运行以新陈代谢的方式淘汰、改造和新增某些文化要素，逐步进行文化要素和结构的重组和整合，形成一种更具生存能力和稳定延续能力的新型文化（罗康隆：2006）。

本文根据笔者在大理双廊镇岛依旁自然村的田野调查，从生态文化人类学的视角，分析白族社区的当代生态环境变化、渔民生计方式与文化适应性之间的互动关系，加深对人与环境、文化关系的理解。

1. 岛依旁概况及洱海渔业发展史

岛依旁位于大理市洱海流域的东北角，隶属于云南省大理市双廊镇大建旁行政村，全村紧邻洱海，海拔 1975 米，年平均气温 15℃，年降水量 1080 毫米。全村以渔业收入为主，无田无耕地。全村该村有农户 57 户，乡村人口共 193 人，其中男性 113 人，女性 81 人。其中劳动力 120 人，全村都是白族。^{*}岛依旁是一个具有三千多年历史的渔村，全村世代都是渔民，20 世纪 70 年代以前，全村渔民靠海为生，保持和发展了以捕鱼为主的传统生计方式。而今，由于受到七个月的封海限制，因此除了老一辈的渔民继续固守传统的渔业生计方式，年轻一代几乎完全转型，放弃了传统的渔业捕捞的生计方式，转而从事旅游业、小生意和外出打工。

大理古代先民濒海而居，这里的居民，除农业外，捕鱼是他们的主要经济生活之一。从 1939 年 3 月至 9 月，大理苍山地区发掘的马龙遗址和佛顶遗址中，均发现石网坠。网坠的出土说明，人们捕鱼已经用网，用网捕鱼是一种较发达的捕捞方式。再以此推论，洱海地区的捕鱼活动还应早于新石器时期，否则，没有长期的渔业实践，是不可能发明并运用渔网的。从洱海地区的发展历史和文献记载来看，洱海具有较丰富的水产资源，渔业的发展也较发达。唐代樊绰《蛮书》记载：“鲫鱼，蒙舍池鲫鱼大者重五斤。西洱河及昆池之南接滇池，冬月，

1 云南大学民族研究院，昆明医科大学健康研究所

2 云南开放大学

3 日本综合地球环境学研究所

* 该数据由大理市双廊镇大建旁行政村村委会提供

鱼鹰，丰雉，水扎鸟遗于野中水际。”李元阳《云南通志》记载：“大理府鱼之属十七，蒙化府鱼之属七。”因此，洱海地区的居民中，一直保留有专门的渔业人口，根据民国二十四年四月出版的《云南省农邨调查记载》：“在洱海从事渔业之渔民，据大理县政府调查，有渔户二百二十六户，计一千二百五十四丁口，除少数兼营农业外，均系专营渔业，此与滇池渔民不同之点。”这些渔民从古至今保留并沿用着传统的捕鱼工具和捕鱼方法，洱海渔民常用鱼具有“鱼网、鱼笼、鱼罩、鱼鹰和小木船，捕捞的方法有鱼堆、鱼窝、鱼洞、抢水沟”（杨聪：1986），这些捕鱼方式有的至今还在沿用，因此，大理洱海地区的渔业发展史，就是一部渔民千年的自然捕捞史。

2. 洱海生态环境与白族渔民生计方式变迁

生计模式是不同的个人、群体或社会全体成员在一定的社会条件制约和价值观指导下所形成的满足自身生活需要的全部活动形式与行为特征的体系。生计模式是文化的另一种表述，与文化具有同构性，它是一种活动与行为体系（马塞尔·莫斯：2003）。根据洱海生态环境发生的变化，可以分为三个不同的生态时期，渔民的生计方式在不同时期也随之面临重新选择，从中看出洱海生态环境保护中的文化特点。

2.1. 洱海生态环境相对平衡与白族渔民传统生计方式的延续

20世纪50年代初至70年代，洱海流域的水质较好。在这一阶段，鱼的种类非常丰富，数量繁多。“根据建国后的调查与统计，洱海的鱼类有十八个土著品种。自1952年至1970年，洱海鱼类仍以土著鱼类为主，其中又以弓鱼、鳙鱼为主”（杨聪：1986）。长年从事洱海生态研究的学者指出，从当时的鱼类生态位的分布开看，是比较合理的，可判断洱海的生态系统处于平衡状态。在湖边可以捕到浅水鱼，在湖的深处可以划船捕到深水鱼（杜宝汉：2006）。洱海水非常清澈甘甜可以直接饮用，水生植物在洱海里随处可见。

这一阶段，渔民继续沿用传统生计方式，代表了早期洱海渔业文化。渔民延续世代相传的捕鱼技术和方式。捕鱼设备仍沿用一些鱼兜、小渔网和传统木船。渔民以个人或者传统家庭为单位进行捕鱼，捕鱼的时间、地点不受限制，有的渔民搭建简易的临时捕鱼帐篷，带上生活所需，吃住在帐篷里；也有的当天凌晨一早出发捕鱼，捕完后当天就回家。

这一阶段良好的生态环境，鱼类资源较为丰富，对渔民的捕鱼技术和方法没有提出太高要求，渔民对鱼类资源的获取没有限制，基本上能够满足一户传统家庭的日常开销，生态资源与渔民捕鱼行为之间处于相对平衡状态。

2.2. 洱海生态环境变化与白族渔民生计方式的多元演变

20世纪70至90年代，这一阶段，传统生计方式因资源有限而受到冲击。体现为渔民与生态环境，以及渔民之间，渔民与当地农户之间对水产资源的无序竞争。

20世纪70年代以后，随着对水资源的过度开发和沿湖水污染状况的加重，洱海水质开始恶化。由于人工放置外来鱼种，使得洱海的鱼类增至30种，同时，洱海开始引进太湖银鱼，太湖银鱼有排它性和吞食其他鱼类的特征，且银鱼生长的环境，很少捕到其他鱼类。这一时期，由于太湖银鱼的引种成功，渔民看到了银鱼较高的经济价值，因此，很多渔民放弃了之前的传统小木船捕鱼，采用了机动渔船捕鱼，刺激了机动渔船的大规模发展，由于机动船的燃料是柴油，也成为洱海污染的主要来源。

20世纪80年代初，因生态环境和生存状况发生了变化，白族渔民传统的生计方式不断受到

挑战和冲击，开始向多元发展和演变。在政策和经济的双重刺激下，有的渔民也开始从事在湖边“围湖造田”发展初级农业，种上成片的庄稼，在洱海水域拉起渔网，人工放置鱼苗，进行网箱养鱼。而当地主要从事农业的村民也开始自由养殖和捕捞，渔民和农业村民之间开始出现对鱼类资源的无序竞争，洱海里的捕鱼人数不断增加，捕鱼的范围在不断扩大，捕鱼人口较密集。

由于渔民之间的竞争不断出现，出现了渔民“捕鱼难”的问题，渔民也开始发展与设计了许多新型的捕鱼技术和方法，例如：“网眼细密的渔网，机动渔船，炸药、毒药、电力触鱼”（杨聪：1986），这些捕鱼工具和方法，对鱼类的捕捞强度极大，导致幼鱼幼虾被大量捕捞上市，过渡捕捞和消耗，一方面使洱海生态系统面临重重危机，另一方面也促使渔民面临生存的挑战和竞争。

2.3. 洱海生态环境恶化与白族渔民生计方式的回归与转型

20世纪90年代开始，由于生态环境与生态政策的双重压力，极大限制了渔民对鱼类资源获取，因此，渔民生计方式开始进入全面转型阶段。

1996年与2003年，先后两次洱海蓝藻大爆发，工厂里排出的工业废水、农田里的农业废水和居民的生活污水没有有效处理，直接流入洱海，造成洱海水质严重恶化。同时，开始封海禁止捕鱼，封海期从每年的2月一直延续到9月。这一时期，随着当地生态环境政策的实施与政策推力的影响，渔民传统的生计方式开始面临回归与转型。所谓传统生计方式的回归，即渔民在五个月的开海捕鱼期，重新使用传统的捕鱼工具和捕鱼方法。生态政策的推力与压力，使渔民对鱼类资源的期待与获取极其有限。

而岛依旁的渔民相比其他地方的渔民有了更多的选择，由于当地旅游业的快速发展，导致很多渔民放弃外出打工，有的出卖土地，有的建起客栈，从事私人旅馆服务，每年，全村村民从当地著名的南诏风情岛的旅游收入中可获得一笔可观的分红。

因此，原来的渔民因为洱海环境保护的需要，而转变身份成为了一线环保工作者。大多数渔民封海期选择外出打工，由于渔民缺乏专业技能，因此，到了工地上，往往也只能选择低报酬的体力工。这一时期，因生态环境保护的需要，带来渔民生计方式的回归与转型。

3. 洱海生态环境与白族文化的适应性

生活在不同自然环境中的人类群体，在从事物质生产的过程中创造出适应其环境的不同的民族文化，并随着生态环境的变化和时代的发展不断进行文化调适。一般认为，生态环境决定生计方式，生计方式决定生活方式，由生态环境和生计方式所决定的生活方式一经形成，并固定为传统和习俗，便会反作用于生计方式并影响到生态环（罗柳宁：2004）。

应当强调指出的是，地理生态环境既然是各民族的生存空间，在长期的适应和改造过程中，人与自然之间已形成一种和谐的关系，这种关系通过传统文化表现出来。因而传统文化中具有保护生态环境、维持生态平衡和可持续发展的功能和作用，否则一个民族的生计方式不可能千年地长期延续下去。

3.1. 白族传统文化通过现代变迁的方式得以延续

白羊村遗址的发现，不仅有力的证明了早在距今约4000前，洱海区域已属原始农耕文化体系；而且，人们定居于此进行农耕，已经有较长的时间（赵槽：1992）。大量的文献和考古资料证明，洱海地区很早就处于定居农耕文化圈的中心位置，同时采集、狩猎、渔猎作为生

计的补充。因此诸多白族传统节日都围绕洱海原始农耕祭祀衍生而来，反映出白族本主崇拜中原始的水神观和白族敬水、畏水的宗教信仰。耍海会的时间与农事节令有密切的关系，每年农历八月后都是一年鱼类生长较快，鱼类资源较丰富的时期，渔民也开始进入一年中最繁忙的捕鱼时节。于是需要通过节庆仪式，来展现渔民顺利获取生态资源的期待。

由于洱海区域旅游业的发展，结合渔民的开海捕鱼与当地的传统的本主庙会，传统耍海会被赋予了新的意义与使命，成为以展示渔民传统生计为主要内容，吸引游客的一项新型节日，即“开海节”。开海节即代表着封海期的结束，渔民可以合理合法进入洱海捕鱼。在开海节，渔民的很多传统捕鱼方式被打造为旅游文化项目，向游客展示。具有千年历史的鱼鹰捕鱼，即成为当地旅游文化项目中的一个主要内容，由于较长的封海期，使得鱼鹰饲养成本较高，大部分渔民已经放弃饲养鱼鹰，只有少数渔民依靠鱼鹰在旅游表演中获得的收入维持饲养。同时，也看到了一部分传统文化在旅游业发展的框架下，找到了新的生长点，以另外文化形式保存下来，渔民传统生计在继承和发展中，经历了现代变迁，有了新的特征。

3.2. 洱海生态环境保护中的白族传统生态伦理观对人的生态行为的影响

白族传统文化中蕴含了丰富的自然万物的宗教观，本土生态认知体系，环境选择的生产方式、组织形式等与生态环境相关的内容。在洱海生态环境保护中发挥着不可估量的巨大作用。

洱海的白族村民，世代都保持着不污染环境和河水的良好习俗。据史料记载，明清时期，洱海地区的种松、封山护林、水资源分配与保护、治河等乡规民约大多以勒石的形式保存下来。从洱海地区刻石所记的乡规民约内容看是多方面的，涉及村民的日常生活，具有道德行为规范的特点。从生态资源及环境保护的内容看，明代的乡规民约大多针对水资源分配和利用。进入清代以后，水资源分配和利用仍然是当地百姓生活中的大事，但乡规民约中更多地直接表现出呼吁恢复和保护自然资源，并付诸行动的特点（吴晓亮：2012）。

在以传统自然捕捞为基础的生计方式中，渔民通常以家庭为单位形成小规模捕捞队，遵循鱼的生长周期和活动进行捕鱼活动和作息，充分依循鱼类的成长规律，有效避免了无节制的酷鱼滥捕。这时期人们对鱼类产品的消费小于鱼类自然生长的时期，无需人工管理，任其捕捞是无碍鱼类生长的。家庭之间按照土地的有无、多少来划分主要从事的生产活动与属性，从而决定了对自然资源获取的优先权，有效避免了捕鱼人口与鱼类数量的失衡。这些都体现了白族村民与洱海生态环境的适应性，使得当地村民与洱海生态环境的长期以来和谐共处。洱海生态环境近几十年发生的深刻变化，与世居于洱海周边的渔民的生产生活有着密切联系，渔民对于洱海生态环境保护的需要也极其迫切，生态环境保护的需要既是社会发展需要，也是渔民的生存需要。因此，从个人到社区都能够自觉遵守封海期的捕鱼限制，在封海期内转变渔民的身份与生计方式，使人们对洱海生态资源依赖的压力减小。

4. 结语

由于共同的生存地域，共同的民族主题，使用共同的生产工具和技术，在洱海区域形成了以白族为民族主体的白族渔文化区。白族渔文化区的功能在于在生态环境保护的框架下如何发挥对具有共同文化特质的人群进行可持续性的综合发展。从渔民的视角来对自身的生计方式和生活方式进行解读，可以使生态政策在执行过程中的有效性增加。

生态环境变迁引起生计方式的变迁和文化的调适，三者互动中实现人与自然的和谐发展。由于生态环境的变化，引起了文化内部的一些因素发生变迁，通过文化对生态环境的适

应与调适，产生了这个民族对于自然生态环境的适应性体系，包括了这个民族内部自觉产生的与生态环境保护相关的生活习惯、生计方式、禁忌习俗、宗教信仰和观念。体现了少数民族生存方式中的生态伦理智慧，客观上起到了保护环境的作用。这也是洱海地区环境保护背后强大的文化适应性的具体体现，也是不同于其他地区环保问题的不同之处。

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**Changes in Ways of Livelihood and Cultural Adaptation in the Bai Fishing Village
Viewed from an Eco-Anthropological Perspective**
**Focusing on Daoyipang Village, a Bai Fishing Village in Shuanglang Town, Dali City,
Yunnan Province**

Ju ZHANG ¹, Huilin DUAN ², Yuki FUKUSHI ³

Established in the 1950's as a subject of anthropology, eco-anthropology has now developed into an independent anthropological discipline. In general, eco-anthropology studies relationships between humans, the environment and culture. It investigates not only the relationship between humans and the natural environment, but also the effects of such relationships and the correlations between influenced cultural systems. The important structural factors such as population composition, social organization, technology and environment are covered by the relationship between humans and the natural environment, while activities to acquire food and maintain population are the most critical activities required for human existence. The groups, activities and techniques for food acquisition are collectively called "livelihood". Therefore, the three issues of resource distribution, way of livelihood and reproduction must be taken into account. The livelihood is the most essential point in eco-anthropological study (Xichang ZHUANG and Zhimin SUN, 1988). Cultural adaptation is referred to as the adaptation of culture to environment, which is shown in the elimination, modification and addition of some cultural elements, as well as the reorganization and integration of cultural elements, when a culture faces a change of living environment or when the utilization of natural resources needs to be improved. This adaptation process leads to a more sustainable new culture (Kanglong LUO, 2006).

Based on field work at a natural fishing village on Shuanglang town, Dali city, this paper explores and analyzes contemporary ecological changes in the Bai ethnic community and interaction between the way of livelihood of fishermen and cultural adaptation, as well as the improved understanding of relationships between humans, the environment and culture.

1. Overview of Daoyipang and History of Fishing Activities in Lake Erhai

Daoyipang is located on the northeastern corner of Lake Erhai, Dali, and it belongs to an administrative village called Dajianpang in Shuanglang town, Dali city, Yunnan province. The village, with an elevation of 1,975 m, annual average temperature of 15°C and annual rainfall of 1,080 mm, is adjacent to Lake Erhai. Fishing is the primary form of subsistence, and no farmland exists in the village. There are 57 rural households with a total of 193 residents consisting of 113 men and 81 women in the village, 120 of whom make up the labor force. All the people in the village are the Bai ethnic group.* Daoyipang is a fishing village with a history of more than 3,000

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years, and the Bai have fished there since the village was formed. The traditional way of living, with a focus on fishing, had continued and developed until the 1970's, and fishermen in the village made their living from the lake. However, the current younger generation of fishermen has almost completely abandoned the traditional fishing style, against the wishes of the older generation of the village, in favor of tourism, small business and outside work, because of a prohibition on fishing for seven months each year.

Ancient ancestors in Dali resided near the lake, and the fishing was one of their economic activities in addition to agriculture. Stone net-weights were found at the Malong ruins and the Foding ruins in Cangshan Mountain, Dali, between March and September of 1939. It is believed that the people in those days fished with nets, an advanced fishing method. It is further induced that the fishing in Lake Erhai would have started prior to Neolithic Age, as fishing nets could not have been invented and used without a long time for development and mastery of the techniques involved. It is seen from the history of and the literature about Lake Erhai that fishing in this region had been well developed due to rich aquatic resources in Lake Erhai. It is recorded in the book of *Manshu* written by Fan Chuo of the Tang Dynasty that: "Large crucian carp in the pool called Mengshechi weighed 5 kg. In the winter, fish, hawks and wild birds stay in the waters of the the water outlet of Erhai River and South Kunchi River and Dianchi River." It is recorded in the book of *Yunnan Tongzhi*, written by Li Yuanyang that: "There are 17 fish species in Dali and 7 fish species in Menghua," These descriptions indicate that there were always professional fishermen among the residents of Lake Erhai. It is written in the Record of Rural Investigation in Yunnan, published in April 1934, that: "The investigation by the Dali Government shows that there are 226 fishing households with a total of 1,254 people who are engaged in fishing in Lake Erhai, and most of them are doing so professionally. Their methods are different from fishermen in Dianchi River." These fishermen have been keeping and using traditional fishing tools and methods since the ancient times. The common fishing tools used by fishermen in Lake Erhai include "fishing nets, fishing cages, fishing covers, fishing hawks and wooden boats, and the fishing methods are fishing piles, fishing cotes, fishing holes and water channels" (Cong YANG, 1986). Some of these ways of fishing are still being used. Therefore, the fishing evolution in Lake Erhai, Dali, constitutes a natural fishing history over a thousand years.

2. Ecological Changes and the Way of Livelihood of the Bai Fishermen in Lake Erhai

The Bai way of livelihood consists of all the activities and actions of the different individuals, groups or social members that are formed under social constraints and values in order to meet individual living needs. It is another expression of the culture and is isomorphic to the culture. The way of living is a framework of activities and actions (Marcel MAUSS, 2003). Ecological changes in Lake Erhai can be divided into three ecological periods, at which fishermen are face a change in their way of livelihood, and from which cultural features of the activities of ecological environment protection of Lake Erhai are seen.

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* The data are provided by the village committee in the Dajianpang Administrative Village, Shuanglang, Dali.

2.1. Finding a Balance between Protecting the Ecology of Lake Erhai and Maintaining the Traditional Way of Living of Bai Fishermen

At the phase between the 1950's and 1970's, the water quality of Lake Erhai was good and there was abundant and diverse fish life. "It is seen from investigations and statistics made after establishment of P.R.C that there were primarily 18 indigenous fish species in Lake Erhai from 1952 to 1970, dominated by bow fish and swim-bladder fish." (Cong YANG, 1986). Ecologists studying Lake Erhai have stated out that, according to fish population density during that period, the ecological system in Lake Erhai could be said to be in balance. The fish in shallow water could be captured near the lake shore, and the deep-water dwelling fish could be captured by sculling a boat offshore (Baohan DU, 2006). The water of Lake Erhai was very clear and drinkable, and aquatic plants were abundant.

At this phase, the traditional way of living used by fishermen represents the early fishing culture in Lake Erhai. Fishermen used the same fishing techniques and methods for generations. Fishing tools were still fishing bags, fishing nets and traditional wooden boats. Fishing was performed by individuals or families. Fishing was not restricted to certain times and areas. Some fishermen erected a simple and temporary tent for fishing where they lived with basic daily necessities for extended periods, while others went fishing very early in the morning and came back home afterward each day.

The good ecological environment and rich fish resources at this phase required no improvement of fishing techniques and methods and no restriction on acquisition of fish resources. They could basically satisfy the daily expenditure of a traditional family. There was a relative balance between ecological resources and fishing activities.

2.2. Ecological Changes in Lake Erhai, and Diversification and Evolution of the Way of Living of Bai Fishermen

Limited resources at the period between the 1970's and 1990's had made an impact on the traditional way of living, which manifested as fierce conflicts involving the aquatic resources between the fishermen and the ecological environment, local farmers and even amongst fishermen themselves.

The water quality of Lake Erhai began to deteriorate due to excessive exploitation of the aquatic resources and increased water pollution since the 1970's. Foreign fish brought artificially into Lake Erhai increased the number of fish species to 30. The silverfish from Lake Taihu, characterized by exclusiveness and predation of other fish, were introduced into Lake Erhai. Other fish could be rarely captured in environments dominated by silverfish growth. Fishermen recognized the high economic value of silverfish introduced successfully at this phase. Thus many of them abandoned their previous methods of fishing with traditional wooden boats and used motor boats for fishing. This spurred a great increase in motor boats. Diesel oil used as fuel for motor boats became a primary source of pollution in Lake Erhai.

In early 1980's, the traditional way of living of Bai fishermen was continually challenged and impacted by changes of the ecological environment and living conditions, and began to evolve and diversify. With both policy and economic stimulation, some fishermen began

to develop preliminary agriculture such as land reclamation at the lake side, by growing crops, pulling up fishing nets along Lake Erhai, and stocking fish fry for fish farming. The local villagers engaged primarily in agriculture also took advantage of the more accessible fish culture and resources. The disordered competition for fish resources between fishermen and agricultural villagers resulted in increased numbers in fishermen, expanded fishing areas and a more concentrated fish population in Lake Erhai.

The competition between fishermen led to difficulties on fishing. Fishermen started to develop and design many new fishing techniques and methods such as “fine fishing nets, motor boats, explosives, toxicants and electric shock” (Cong YANG, 1986). The tremendous increase in fishing as well as the impact of these fishing tools and methods resulted in depletion of the fish and shrimp larvae, which in turn led to ecological crises in Erhai Lake, as well as social and other living challenges among competing fishermen.

2.3. Deterioration of the Ecological Environment in Lake Erhai and Transformation of the Lifestyle of Bai Fishermen

The acquisition of fish resources restricted greatly by the changed eco-environment, and the local government’s ecological policies since 1990’s, have led to a thorough transformation of the fishermen’s way of living.

Between 1996 and 2003, the water quality of Lake Erhai deteriorated severely from two periods of proliferation of blue-green algae, as well as industrial sewage from factories, agricultural sewage from farmland and residential sewage, all of which flowed directly into Lake Erhai without effective treatment. The lake began to be closed from February to September of every year as restrictions were placed on fishing activities. The fishermen’s traditional way of livelihood started to change due to the impact of local environmental protection policies in this phase. Fishermen then again turned to the use of traditional fishing tools and methods in the 5 months period when the lake was open for fishing, because they could only expect a small catch of fishing, which would not afford to such investment as motor boats and fine nets, due to government fishing restrictions.

The fishermen in Daoyipang had more choices than those in other places. Quick development of the local tourism industry made many fishermen give up their traditional way of living. Some of them sold their land and some built lodges to provide private hotel services. All villagers can get a substantial monetary bonus from tour income earned at Nanzhao Island, which is a well-known local tourist destination.

Therefore, the original fishermen became environment protectors due to the governmental regulations imposed on Lake Erhai. Most fishermen choose to work outside in the lake closing period. In most cases they can only do physical labor with a low remuneration at the workplace because of their lack of special skills. The fishermen’s way of living began to be transformed due to the implementation of environmental protection policies in this phase.

3. Adaptation of Ecological Environment in Lake Erhai and Bai Ethnic Culture

Human populations living in different natural environments create ethnic cultures

suitable to their environments during the process of material production, and cultural adaptation occurs constantly over times and according ecological changes. Generally it is believed that the ecological environment determines the way of living, which in turn determines lifestyle. In a similar manner, after being formed and fixed to a custom, the lifestyle which was determined by the ecological environment and way of living will then react to and influence those two factors (Liuning LUO, 2004).

It should be noted that whereas the geographical and ecological environment is a living space for various nationalities and cultures, harmonious relationships between humans and nature have formed during the long adaptations and modifications and seen in traditional cultures. Thus traditional culture plays the role of protecting the ecological environment and maintaining the ecological balance and sustainable development. Without such balance, the way of living of an ethnicity cannot last over a thousand years, as evidenced with the Bai.

3.1. Sustainability of Traditional Bai Culture through Modern Transformation

The discovery of the Baiyang Village ruins demonstrates that there was already a farming culture system in Lake Erhai approximately 4,000 years ago (Lu ZHAO, 1992). A great deal of literature and archaeological data prove that Lake Erhai had been the center of a settled farming culture very early, where gathering, hunting and fishing was complementary to the way of living. Thus, a number of traditional festivals of the Bai were derived from farming sacrifice in Lake Erhai to reflect the original sense of the Water God of the Bai people and Bai Ancestor worship and veneration of water. The time of Lake Ritual is closely related to farming seasons. There is always a period after August of every Chinese calendar year, during which fish grow fast and fish resources are rich. This is also the busiest fishing time of the year. The fishermen's hopes for a successful catch are shown through festival ceremony.

Because of the development of tourism in Lake Erhai and the combination of the lake opening ceremony for fishing with the local traditional temple fair, the conventional lake fair has been given a new significance and mission, giving rise to a new festival to exhibit the fishermen's traditional way of living and attract tourists called the Lake Opening Festival. The lake opening festival represents the end of the period that prohibits fishermen from entering Lake Erhai for fishing. During the lake opening festival, many traditional fishing methods are rebuilt as tour programs and shown to tourists. The 1,000-year old hawk-fishing method is one of the primary local tour programs. Most fishermen have given up feeding fishing hawks because the long lake closing period makes hawk feeding costs higher, and only a few fishermen can afford to keep hawks with their income made from the tourist hawk performance. It can also be seen that part of the traditional culture re-emerges within the framework of tourism development and is preserved in another form of culture. The modern transformation of the fishermen's way of living through inheritance and development has been given new features.

3.2. The Effect of Traditional Bai Eco-ethics on Human Ecological Behavior during Ecological Environment Protection in Lake Erhai

Bai culture contains numerous examples of reverence for nature and the environment.

They are presented in such ecology-related forms as their accumulated knowledge on ecology, production systems established through environmental selection process and the forms of groups in their society. This reverence plays an immeasurably important role in the protection of the environment of Lake Erhai.

Bai villagers in Lake Erhai have a good custom of preventing the environment and rivers from pollution. According to historical records, most rural conventions in Lake Erhai during the period of the Ming and Qing dynasties, such as pine planting, mountain closing, forest protection, water resource distribution and protection and river regulation, have been preserved in the form of inscriptions. The rural conventions in Lake Erhai that are recorded in the form of inscriptions are comprehensive and involve villagers' daily life. They are characterized by a moral conduct code. Most of the descriptions about ecological resources and environmental protection in rural conventions made in the Ming Dynasty are aimed at water resource distribution and utilization. The rural conventions since the Qing Dynasty are more characterized by the call for recovery and protection of natural resources and the corresponding implementation of measures pertaining to such, although water resource distribution and utilization is still a big event for local people (Xiaoliang WU, 2012).

In the process of living based on traditionally natural fishing, usually a fisherman's family functions as a small fishing team that performs fishing duties and takes rests according to fish growth periods and activities. The fish repopulation law is fully followed to effectively avoid unrestricted and abusive fishing practices. During such period, the human consumption of fish is less than natural fish growth, and is without artificial management, and the fishing activities do not prevent fish growth. The priority on natural resource acquisition is determined by production activities and attributes divided according to the land that a family has. Thus an imbalance between those engaged in fishing and the fish population is effectively avoided. Through this process it can be seen how the Bai villagers have adapted to the ecological environment in Lake Erhai in a way that allows local villagers to coexist harmoniously with the ecology of Lake Erhai for an extended time. Significant changes of the ecology of Lake Erhai in recent decades are closely related to production and daily living activities performed by fishermen who have resided around Lake Erhai for generations. The fishermen's need for protection of the ecological environment in Lake Erhai is extremely urgent. The need for protection of the ecological environment can also contribute to social development and the fishermen's way of living. In this way, individuals and communities can willingly comply with fishing restrictions and change their way of living during the lake closing period in order to reduce human dependence on ecological resources in Lake Erhai.

4. Conclusion

The Bai fishing culture area where the Bai culture is dominant has been formed in Lake Erhai because of a sharing of living domain, ethnic theme and production tools and techniques. The function of the Bai fishing culture area is to foster sustainable and comprehensive development of the people with homogenous culture characteristics within the framework of protection of the ecological environment. A deeper understanding of the fishermen's living and

lifestyles can improve the effectiveness of ecological policies during implementation.

Changes in the ecological environment resulted in changes in the way of livelihood and adaptation of culture. The harmonious development of humans and nature is achieved through interaction with such factors. Changes in the ecological environment caused changes in some cultural elements. An ethnic-adaptive framework addressing the natural ecology is created through adaptation of the culture to the ecological environment. Such architecture covers daily habits, ways of living, conventions and religious beliefs, and a conscious protection of the environment within the ethnic group. It presents the eco-ethic wisdom of a minority ethnicity's way of living and objectively plays the role of environment protection. This also presents a case of strong cultural adaptation to environmental protection measures in Lake Erhai, which differs from environmental protection issues in other regions.

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水上生活にみる慣習的共生システムの形成と湖保全の持続可能性

楊平¹

1. はじめに

世界各地の湖にはそれぞれに固有の文化があり、その固有の文化は、各湖に独自のものとして受け継がれていく。湖の将来に向けて、暮らしの場で行われる取組みは千差万別である。しかし、例えば日本や中国でも聞かれる「マザーレイク」という表現に込められているように、そこに存在する「望ましい湖を次世代へ受け継いでいく」という湖の未来への人々の思いは、共通するものとして読み取ることができる。

では、どのような仕組みが、湖の持続的保全を可能にするのだろうか。そして、そうした仕組みを支える軸となるものは何なのか。ここでは、湖に関わるこうした共通問題の解明の糸口を、湖と生きる「水上生活」を通して考えてみたい。

2. 湖の保全と暮らし

日本の琵琶湖や中国の太湖では、かつての利水・治水事業、防波堤の建設などの水環境の総合開発から、現在行われつつある湖環境の再生まで、様々な試行錯誤が繰り返されてきた。湖の環境保全や地域の活性化を図るために、行政や住民による様々な取組みが実施され、それぞれの成果が上げられてきた。現在に至るまでの湖環境の形成には、行政による政策の実施のみならず、その地域で暮らしてきた人々の生活や生業も密接に関わってきた。湖では、人々の生活や生業に応じた、その地域ならではの多様な「経験」が積み重ねられてきた。

近年、こうした地域独自の「経験」や「文化」を活かした湖の環境保全に関する議論が蓄積されてきた。日本の環境民俗学分野では、複合的な生活・生業の検討を通して、人と環境との関わりを広い視点で捉える研究が行われている。例えば、菅豊は、「水辺」の資源と生業活動の多様性を見直し、水辺という環境における人間の営みを論じてきた(菅：1990)。また人と湖や水環境との関わりを扱う研究成果も多い(鳥越：1993、嘉田：1984、出口：1994、王：2007)。一方、中国・太湖の環境問題に関する従来の研究では、政府によるガバナンスや近代的技術による問題の解決、文化景観としての水辺環境の整備などを中心に論じる研究が多く蓄積されてきた。

太湖や周辺水域の環境が変容しつつある現在、実際にその現場に暮らす人々は、湖とどのように関わっているのか。そこでの暮らしは、どのようなものであり、湖にどのような影響をもたらしているのだろうか。近年、こうした課題が、湖に関する環境研究として注目されつつある。行政や外部によって推進される、環境資源として湖を活かそうとする取組みは、従来の公益の論理に基づく要素が大きく反映されるものである。そのため、湖保全とそこに暮らす人々の生活・生業活動との間に齟齬を引き起こしうる。こうした問題を解決するためには、湖とそこで生きる人々の生活の営みを踏まえた上で、湖の保全政策を各地に浸透させていくことが重要になってくる。その意味において、日常生活における湖の環境利用の実態を明らかにすることは重要性をもつ。

ここでは、中国・太湖における水辺のコミュニティを事例として取り上げ、湖とそこで生きる人々の生活慣習に焦点を当て、その生活現場での「経験」から今後の湖保全に応用可能な論理を探ることを試みる。

3. 湖と共に暮らすとは

1 滋賀県立琵琶湖博物館

3.1 水上コミュニティ

中国・太湖では、古くから漁業を生業として湖と暮らしてきた人々がいる。「漁人相传九代、十代」と言われるように、湖と暮らす文化は代々受け継がれてきた。湖と暮らす人々は、通常は居住用の船で暮らし、漁業用の木造船で湖やその周辺の水域で漁業を行う（ここでは彼らを「水上生活者」と呼ぶ）。太湖における水上生活者は、古くから湖や河川の水辺に停泊し、共同で暮らす専業漁民である。

水上生活者たちは、蝦、草魚、鯉、蓮魚などの漁獲種類による漁師グループに分かれて漁業を行う。朝日が昇る前に沖合へ出かけて行き、それぞれの漁場で漁を行うことが一般的である。漁業活動は、主に男性が中心であり、漁具の修理などの作業は女性が補助的に行う。

水上生活者たちは、漁業以外に湖上を操船して移動することはない。通常、数隻の船がかたまつて湖辺に近い特定の場所に停泊することが多く、長年にわたって集団で暮らしてきた。このような水辺で形成された生活集団をここでは「水上コミュニティ」と呼ぶ。これらの水上コミュニティは、数戸から数百戸で構成され、漁獲する魚の種ごとに分けられる組織によってコミュニティ運営や管理が行われている。

水上コミュニティ周辺の水辺空間では、水上生活者たちは漁業の一方で、小魚や鴨などを飼ったり、葦を植えたり、水辺に近い陸地の片隅で野菜を栽培する生活を営んでいる。菱などの植物は小魚の餌になり、小魚は鴨の餌になり、さらに鴨は人の食料の一部となる。また、葦などを調理用燃料として保護し育てることも慣習になっているという。長年、湖と生きる水上生活者は、「限られた資源を無駄なく循環的に利用することが肝心」だと語る。

3.2 水上生活と災害

太湖の北部に位置する無錫市では、1990年代の台風や1991年の洪水災害により、その周辺の村落の半数以上が浸水し、4万戸の家屋が倒壊、36万人が離郷するなどの被害を受けた（無錫市政府：1992）。また、1991年につづき、1999年の夏にも洪水が発生し、この時、太湖における最高水位は1991年時より高い5.08mが観測された（呉、毛：2000）。こうした自然災害に伴い、太湖流域においても防災基準が定められ、湖に流入する河川の疎水工事などの対策が行われた（無錫市政府：1992）。また、湖辺の都市整備に伴い、湖水の水位調整や都市からの汚水の太湖への流入を防ぐための堰も建設された。湖北の湖岸に位置する水上コミュニティK²の周辺では、2003年に湖岸道路や橋の建設が実施された。自然災害は、陸地の住民だけでなく、湖辺で暮らす水上生活者にも脅威となる。一般には、湖の脅威と言えば洪水などの自然災害が思い浮かべられるが、実際の水上生活者にとって、湖の脅威とはどのようなものであろうか。

「湖がすべてだ」と語られる言葉からは、水上生活者たちの暮らしがうかがえる。漁業を生業として生計を立てる水上生活者たちは、「穏やかな湖でも、厳しい湖でも向き合わなければならない。湖がどのような状況でも、その湖と共に暮らさなければならない」という。また、水上生活者たちは「災害とは常に隣り合わせ」であり、「日常的に対処する習慣づけをしなくてはならない」と語る。では、水上生活者は災害に備え日常的にどのような取組みをしているのであろうか。水上コミュニティKの事例を通して見てみよう。

水上コミュニティKは、台風や洪水が頻繁に起きる湖辺水域の一つにある。自然災害の中では、水害より台風が敏感である。台風時には、漁に出ることはできない。人々は、強風にそなえ、居住用と漁業用の船を固定させる。ロープを利用して各戸の居住船を繋いで固定し、その上で、比較的風をよけやすい湖辺や小さな川へ仲間とともに移動し、避難する。その共同の避難場所は、漁に出やすいよう、湖に比較的近い河川が選ばれることが多く、漁業を軸として、災害に伴うリ

²本調査内容は、2010年から2011年にかけて本事例地における漁師たち（水上生活者）への聞き取り調査に基づくものである

スクを回避する方法が選択されるのである。

また、写真1に見られるように、コミュニティの両脇には、葦帯が植え付けられている。これは「先祖の代からのもの」であり、長年にわたって代々葦帯の保護管理が行われてきた。葦帯は水上生活者の共同資源でもある。水上生活者たちは、この葦帯を漁具の材料、居住船の屋根材や炊飯時の燃料としてだけではなく、防風や防災のためにも用いている。「災害の天敵は、普段の共同作業と管理だ」と彼らはよく口にする。このような事例は「災害」に対処するためのヒントを示している。



写真1

4. 湖水の恵みと日常的环境保全

水上生活者たちは、伝統的に生活や生業などに必要なすべての水を太湖や河川に頼ってきた。飲料水や漁業に用いる水は、湖や河川の沖合で取水し、樽のような容器に入れて居住船の中に備えておく。洗濯用の水やその他の生活用水は、停泊する船の横から取水して利用する。

湖辺に比べ、河川の水辺で暮らす水上生活者は、船の出し入れがしやすく、また船の停泊地で取水して水を利用することが多いため、定期的に川の泥をすくい上げ、水草を刈り取る習慣を古くから受け継いできた。湖へと流れる河川の水辺で形成された水上コミュニティD³では、現在も河川の泥や水草、アオコをとっていた。この作業は、春から夏にかけては、各自によって居住船の近くで行われ、また漁閑期には、漁師のそれぞれの組ごとに定期的に行われていた。

コミュニティDでは、2003年ごろに共同の井戸を掘って以後、主に井戸水が利用されるようになり、また各水上生活者は、生活組織ごとに、ポンプで湖辺の地下水を引き、利用するようにもなった。しかし、井戸水が利用されるようになって以後も、従来通り川の泥や水草を除去する活動が行われていたことが聞き取り調査で確認できた。水利用についてたずねると、これまでは漁業だけではなく生活用水などのすべてを湖水の恵みに頼ってきたという回答を得られた。

かつては、船の停泊場の真下の湖水は、生活用水として利用されてきただけでなく、蝦や魚類といった漁獲物を保存するための水としても使われていた。漁師である水上生活者たちは、そ

³ 本事例地に関する調査内容は、主に2010年から2011年にかけて本事例における漁師たちへの聞き調査に基づくものである

の日にとれた魚や蝦などを、漁場から戻ってすぐに湖水を用いて保存していた。例えば、白蝦類を清水が入った樽に素早く入れ替えることで、鮮度を保つといったといった保存方法が伝えられていた。

また、女性たちは「船の横で洗濯をしていると、小魚や蝦が泳ぐのが見え、田螺を数えられるほど水が澄んでいた」とよく口にする。特に夏になると、水草や泥を取った後の川で泳ぎながら、手で捕まえた蝦を持ち帰り、おかずにすることも多かったという。このような事例は、水上生活者たちの水に対する思いをよく表している。

水上生活者たちは、「湖水は人にも魚にも使える」、「湖水が人や魚や蝦を守ってくれる」、「水まわりは日常生活の場」、「汚さないことが大事」と語る。しかし、「湖水をきれいにするために、どのような活動を行っているのか」とたずねると、「川の泥、水草やアオコをとる」、「葦帯をつくる」といった回答はほとんど聞かれなかった。近年、太湖におけるアオコや水草の大量発生などが未解決の環境問題として注目を集めているが、現在、湖に関わる様々な保全活動に従事する水上生活者は少ない。だが、このことは、水上生活者の環境保全意識が低いということを意味するわけではない。先祖代々湖と暮らしてきた水上生活者からすると、湖や河川の環境を保全すること自体が、代々受け継がれてきた伝統的な日常的行為なのである。

5. 湖保全の源流

以上、水上コミュニティの水辺空間利用、災害に対する日常的な対応、水環境への認識と習慣的な環境保全について述べてきた。これらの事象からは、水上生活者にとって、湖や河川といった自然は、暮らしの中の常に身近なところにあり、日常生活に組み込まれているということが共通して見てとれる。保全に関しても、水上生活者は、自然そのものを保全するというより、現状の生活様式に対応した形で自然に対して常に手を入れてきたのである。

水上生活には二つの共生システムが存在する。一つは植物や生物といった自然の循環的利用の思想であり、もう一つは、自然が常に日常生活や生業と密接に関わり続ける生活様式の維持である。これらは、水上生活者たちが湖と共に生きてきた中で、蓄積してきた智恵でもある。

水上生活者にとっては、湖や河川は生活・生業の場であり、慣れ親しんだ存在である。彼らの生活行動のいくつかは、湖の環境保全につながるものであるが、彼ら自身がそのように自己評価することはないだろう。彼らにとっては、それは生活の一部なのである。水上コミュニティにおいては、生活に内在する自然利用の仕組みが、生活保証の手段として維持され続けてきた。自然利用の仕組みの継承と持続は、結果として湖という実生活の場を守ることに繋がってきたのである。先祖代々、湖と生きてきた、こうした水上生活世界に内在する多様な要素は、現在の湖の環境保全に新たな示唆を与えてくれる。

湖の環境保全を持続可能にしていく方策は、そこで生きる人々の暮らしに目を向けてこそ、その答えが見つかるのではないだろうか。

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付記

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Development of Conventional Symbiotic Systems and Sustainability of Lake Preservation as Observed with Life on the Water

Ping YANG¹

1. Introduction

There is a native culture in lakes communities all over the world, and it is inherited as unique to each lake. An infinite variety of activities in people's livelihood relate to the future of the lake. However, as suggested by the term, "Mother Lake," used in Japan and China, it is possible to identify a general sentiment in the hearts of the people "to hand over a lake to the next generation that they wish for."

By what mechanism, then, can the sustainable maintenance of a lake be made possible, and where can one find the pillar that supports such sustainable maintenance? In this study, we hope to investigate the details of these common issues related to lakes through an examination of "life on the water."

2. Preservation of lake and livelihood

In Lake Biwa, in Japan, and Lake Taihu, in China, various trial-and-error attempts at preserving the natural landscape have been made, ranging from the general development of the water environment, such as irrigation, flood control, and breakwater constructions of the past, to the lake environment regeneration that is about to start. In order to plan for the environmental preservation of lakes and for regional revitalization, various measures have been implemented by the government and residents, which have respectively produced results. Thus, up to the present time, not only the enforcement of government policies, but also the life and livelihood of the region's residents have closely influenced the development of the lake environments. In addition, in the lake, various regionally specific "experiences" that correspond to people's lives and livelihood have been accumulated.

In recent years, there have been an increased number of discussions about contributing to the preservation of the lake environment by leveraging such regional original "experience" and "culture." In the field of Japanese environmental folklore, multiple approaches focus on people's livelihood and occupation, and studies are undertaken that take a wide view of the relationship between people and the environment. For instance, Yutaka Suga reexamined the diversity of "waterfront" resources and occupational activities, and discussed human activities in a waterfront environment (SUGA:1990). There are also many research results on the relationship of people, lakes, and water environments (TORIGOE:1993, KADA:1984, DEGUCHI:1994, WANG:2007). On the other hand, in much of the past research related to the environmental problems of Lake Taihu in China, the discussion centered on problem resolution through central governance policies and modern techniques, maintenance of the waterfront environment as a cultural landscape, and so on.

¹ Lake Biwa Museum

However, these do not address the question of how the people who actually live at the scene are being involved with the lake while the environment of Lake Taihu and the surrounding waters is being transformed. Their livelihoods at the scene are considered as outstanding environmental problems related to the lake, including such issues as the mechanisms through which they impact the lake. The efforts promoted by the government and by outsiders to leverage the lake as an environmental resource widely reflect conventional public interest thinking. Consequently, it is possible that lake preservation conflicts with the livelihood and occupational activities of the people living there. Therefore, in order to solve these problems, it is becoming more and more important to consider both the lake and the daily activities of the people living there, and to make lake preservation policy pervasive in all the regions. Hence, it is necessary to clarify this after looking at the daily life of those who utilizes the environment related to the lake.

In the next section, the example of the waterfront community at Lake Taihu in China is presented with a focus on the lake and the daily routines of the people living there, and an attempt is made to find the logic applicable for future lake preservation efforts based on the “experience” gained from the daily activities at the site.

3. Living with the lake

3.1. Community on the water

In Lake Taihu in China, there have long been people who make their living through fishing in the lake. There is an old saying that says, “The fisherman inherits nine to ten generations.” It indicates that the culture of living with the lake has been inherited over generations. People who make a living from the lake usually use wooden boats—different from those used for residence—for fishing in the lake and its surrounding waters (here, we call them “residents on the water”). The residents on the water in Lake Taihu have been fishermen who earn their living exclusively through fishing activities and who have lived together anchored in the lake or the shores of rivers since long ago.

The residents on the water are divided into groups according to the variety of fish they catch, such as shrimps, grass carps, carps, and silver carps. Typically, they go out from the shore before sunrise and each do their fishing on their own fishing grounds. The fishing activities are done mainly by the men, whereas the servicing of the fishing tools is mainly done with the assistance of women.

The residents on the water do not move about on the water with their boats for purposes other than fishing. Usually, a number of boats are anchored together at a specific spot near the lakeshore, and it has long been common for them to live as a group. This group life that has developed on the waterfront is called a “community on the water.” These communities on the water are made up of anywhere from a few to a few hundred households, and the communities are operated and managed by the different organizations based on the types of fish they catch.

In between their fishing activities, the residents on the water make a living from the waterfront space around these types of communities on the water raising small fish and ducks, planting reeds, and growing vegetables in the small patches of land near the shore. Plants such as water chestnuts become feed for the small fish; the small fish become feed for the ducks; and the

ducks, finally, become a source of food for the people. In addition, it is said that it has become a custom to protect and raise the reeds for use as fuel for cooking rice. As mentioned by residents on the water living with the lake for many years, "it is important that the limited resources are used without waste and are recycled."

3.2. Living on the water and natural disasters

The city of Wuxi, located in the northern part of Lake Taihu, suffered damages from the typhoons in 1990s and the flood disaster of 1991. More than half of the surrounding villages were flooded, 40,000 houses were destroyed, and 360,000 people were forced out of their hometowns (Wuxi Municipal Government:1992). In addition, following the flood damages incurred in 1991, flooding occurred in the summer of 1999, during which the maximum water level of the lake was recorded at 5.08 m, which surpassed that of 1991 (WU:2000). In reaction to these natural disasters, disaster prevention standards were established for the Lake Taihu basin, and countermeasures were set up, such as drainage works for the rivers flowing into the lake (Wuxi Municipal Government:1992). Moreover, with the urban development around the lake, dams were constructed to control the water level of the lake and to prevent sewage from the city from flowing into the lake. In the area surrounding the community on the water "K"², located in the northern shore of the lake, lakeshore roads and bridges were constructed in 2003. Natural disaster weighs heavily on the residents on the water living near the lakeshore, as well as on the people living on the land. Typically, natural disasters such as flooding are thought of as the main threat stemming from the lake. What types of hardship could the residents on the water experience from the lake?

The saying "the Lake is everything" gives some insight into the lives of the residents on the water. The residents on the water who make their living through fishing say, "we have to deal with the lake whether it is calm or unforgiving, and no matter what condition the lake is in, we have to live with it." These residents also say, "we live next door to disaster," and "it is necessary to make ourselves accustomed to it on a daily basis." Given this, how do the residents on the water routinely cope? We shall investigate this by examining the efforts of the community on the water "K".

The community on the water K is located on a part of the lakeshore where typhoons and flooding occur frequently. Among the natural disasters, it is more sensitive to typhoons than to flooding. When living on the water, it is necessary to tie down the residential boats and the fishing boats during a typhoon, as well as the fishing and boat anchorage areas, depending on the winds. It is obvious that no one must go out fishing during a typhoon or when there are strong winds, but ropes must also be used to tie and lock each household's residential boats together. In addition, residents can seek shelter from other group members by moving to the shores or to small rivers where winds are relatively weaker. That common shelter area is sometimes selected in a river relatively near the lake so that they can easily go out to fish, which indicates their choices revolve around fishing and avoid risks accompanying a disaster.

In addition, as shown in picture 1, there are patches of reeds planted on both sides of the

² The details of this research are based on the hearing surveys of the fishermen (residents on the water) of the referenced location from 2010 to 2011.

community's site. When asked about this, they say, "It's been there since our ancestors," and they have been taking care of it from generation to generation. It is a shared asset of the residents on the water. The residents on the water use the reeds not only as materials for fishing tools, roofing on the residential boats, and fuel for cooking, but also as protection against winds and disasters. They frequently mention, "The natural defense against disasters is the everyday group work and maintenance activities." This example shows what preventive measures are taken against "disasters."



picture 1

4. Blessing from Lake and Daily Activities for Preservation

The residents on the water have traditionally depended on Lake Taihu and its surrounding rivers as the domestic water resources for their living and occupation. Water used for drinking and fishing is drawn offshore and stored in a container, such as a barrel, where it is kept in the residential boat. Water for laundry and other daily use is drawn from the side of the anchored boat.

Compared to those living on the shores of the lake, the residents on the water who live near river shores encounter less difficulties launching and docking their boats. Since they draw their water for daily usage from the anchorage area, they regularly scoop up the dirt from the river and take out the waterweeds, a custom that they have inherited from the past. In the community on the water "D"³, which is formed on the shore of the river flowing into the lake, residents take out the river dirt, waterweeds, and water-blooms even today. They individually perform this activity mainly between spring and summer near their residential boats, or regularly as respective fishing groups during the fishing off-season.

³) The details regarding the referenced location is based on the hearing surveys of the fishermen of the referenced location conducted mainly from 2010 to 2011.

In this community “D”, a common well was dug in 2003, and they were able to use the well as a main water source. In addition, residents on the water in each livelihood organization were able to use the underground water from the lakeshores using pumps. However, even after gaining access to the well water, it was confirmed through a hearing survey that they still took out the dirt and the waterweeds as they did before. When asked about the water usage, they say that up to then, they had relied on the lake water not only for fishing, but also for all of their domestic use.

Formerly, the lake water immediately under the anchored ship was not only used to fulfill domestic needs, but as storage for shrimps and fish they had caught. As fishermen, it is crucial for the residents on the water to immediately store the fish and shrimps caught on that day in the lake water upon returning from the fishing ground. In particular, they say that quickly transferring Japanese glass shrimps into a barrel of clean water helps to preserve their freshness.

Also, the women often remarked, “When we did the laundry, the water was so clear that we were able to see the small fish and shrimps swim on the side of the boat, and even count the pond snails.” Especially in the summer, they swam in the river after the waterweeds and dirt had been taken out, and often took home the shrimps they caught by hand for eating. These types of examples demonstrate the residents’ strong sentiment toward the water.

Residents on the water made statements such as, “the lake water can be used for people and fish;” “the lake water protects people, fish, and shrimps;” “the water is place of daily activities;” and “do not contaminate.” However, when asked, “What have you done to clean the lake water?” They made no particular mention of such activities as taking out the dirt, waterweeds, and water-blooms from the rivers, or developing the reed patches. In recent years, despite the fact that environmental problems such as large outbreaks of water-blooms and waterweeds in Lake Tai remain unsolved, few residents on the water currently engage in maintenance activities related to the lake. However, from the point of view of the residents on the water who have lived with the lake for generations, actually cleaning the lake and river environments may seem like a longer journey.

5. Source of lake preservation

I have explained how the community on the water uses the waterfront space, provided details on the daily activities aimed at disaster prevention, and detailed the perception and the activities for preserving the water environment in their daily lives. The common threads are that the lake and river come into close contact with people in daily living, and that nature is gradually incorporated into daily activities. In other words, the relationship between the residents on the water and nature is not one of maintaining nature itself; instead, it involves executing constant maintenance by responding to their living style at the site.

There exist two symbiotic systems in the life on the water. One centers on the recycled use of nature, which applies to plants and living things. The other is the maintenance of a daily lifestyle in which nature is closely and continuously involved in the lives and occupational activities of residents. This can be viewed as the result of the accumulation of knowledge by the residents on the water over many years of living with the lake.

For the residents on the water, the lake and rivers are the places of their daily lives and occupational activities; they have a thorough knowledge of them. However, they may fail to appreciate a fundamental aspect of the activities related to their livelihoods, that these activities help clean the lake. Although it is difficult to conclude the degree to which the lake should be cleaned, that task is a part of the daily lives of those who live with the lake. The mechanism of the usage of nature that forms part of their daily lives has been preserved as a method of securing livelihood. Furthermore, it can be said that the continuity of these mechanisms have gradually led to the protection of the lake, the actual site of living. The diverse elements that have made up life on the water for generations provide clues about current lake preservation approaches. With regard to the policy aimed at making lake environment preservation sustainable, the answer may be found in the very lives of the people living there.

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Appendix

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日本の湖岸地域における環境変化と住民の健康問題

—琵琶湖彦根マラリア（1920—1950）—

市川 智生¹・東城 文柄²

1. はじめに

本研究は、戦後直後に琵琶湖周辺で発生したマラリアの流行状況について、主に環境改変との関連から検討する。

戦後直後、彦根で蔓延したマラリアの要因のひとつが城の堀にあることは、比較的よく知られた事実である（滋賀県史編さん委員会：1981、田中：2009）。彦根城は、1600年代初頭に井伊家によって築造され、内堀、中堀、外堀と三重の水路によって囲まれている。この堀の水面がマラリアを媒介する蚊の生息地となり、彦根の住民が罹患する背景となったというものである。もし、城郭の堀がマラリアを蔓延させる要因となりうるならば、彦根以外にも、同様の地域は多数存在するはずである。ここでは、湖水や河川に囲まれた住環境において、環境改変にともない、地域住民の健康問題がどのように変化するのかに着目したい。

滋賀県の湖岸地域における環境と人の暮らしの関係性を分析するために利用したデータは、1)行政刊行物や新聞資料など、2)統計資料、3)地理情報である。

2. 日本における土着マラリア

一般的に、マラリアのイメージは、熱帯あるいは亜熱帯の感染症であろう。たとえば、歴史的文脈において日本に直接関係するところでは、戦前戦後の琉球・沖縄や植民地期の台湾を主な流行地として挙げるができる。両地域は気候的には亜熱帯に属しており、近代化の途上において、マラリア対策はもっとも重要な課題のひとつであった（飯島：2005）。

しかし、実際には日本列島各地でも、マラリアは広範囲に分布していた。同病は、病原となる原虫の種類によって4つに分類される。日本各地で広くみられたのは、シナハマダラカ（*Anopheles sinensis*）によって媒介される、比較的良性（致死率が低い）の三日熱マラリアだった。そのため、この疾病は瘧（おこり）と呼ばれ、風土病あるいは地方病として地域固有の問題と認識されてきた。

シナハマダラカは、流れがゆるく水質の良い水面（たとえば、水田や浅水面など）で繁殖する傾向にあるとされる。彦根市は、彦根城およびその周辺の城下町を三重に取り囲む堀を媒介蚊の孵化地として、マラリアによって濃厚に汚染されていたと指摘されてきた。しかし、統計データから判断する限り、マラリアの発生はより広域的で、マクロな環境条件に規定された現象であった可能性がある。

戦前の日本では、1910年前後および1926年に大規模な調査が実施されており、この結果からマラリアが日本列島のほぼ全域で発生していたことが確認できる（内務省衛生局：1919、同：1928）。1910年代には、府県統計書にマラリアの罹患データが計上されているが、滋賀県の場合は郡別の入院記録に基づいており、その全貌を把握することは困難であ

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る（滋賀県：1917）。1926年3月には滋賀県マラリア予防調査委員が設置され、本格的な調査も実施された。同年の滋賀県における地方病調査からは、琵琶湖周辺で広範囲にわたりマラリアが蔓延していることが確認できる（内務省衛生局：1928年）。

戦後は、富山、石川、福井、愛知、滋賀の五県において、1950年代初頭までマラリアの発生が継続していた。滋賀県湖岸は、他地域と比較して罹患数が多く、戦前からマラリア予防撲滅週間の実施など、一定の対策が行われていた。また1940年代末には、滋賀県にマラリアの発生が集中したため、戦後の医療・衛生改革の対象となった（Figure1）。

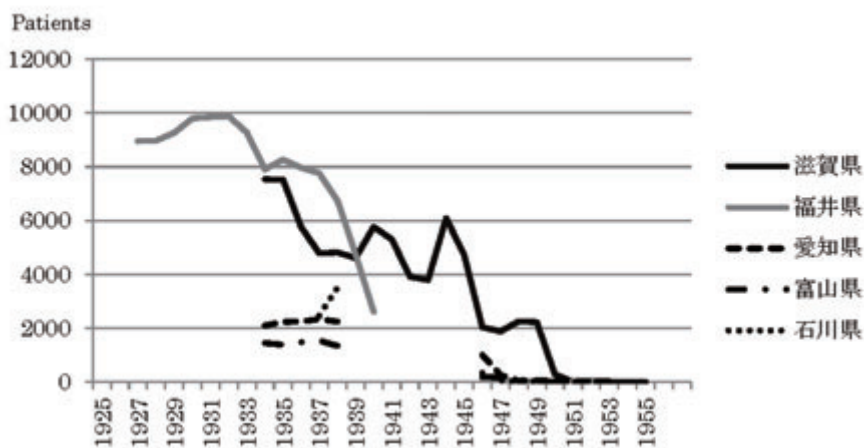


Figure 1 Number of malaria patients in 5 prefectures, 1925-1955

Source : Kobayashi (1955)

3. 彦根マラリア研究所による撲滅事業

このように、彦根のマラリアが問題化したのは戦後であった。1948年6月、彦根マラリア対策委員会が設立、翌年1月には滋賀県庁でマラリア撲滅対策会議が開催された。背景には、GHQによる保健衛生事業のなかに、彦根のマラリア対策が組み込まれ、日本側に勧告したことが考えられる。これを受け、彦根市は1949年6月に彦根マラリア研究所を設立、長崎医科大学を卒業し地元で開業していた市長の子息・小林弘（1916-1991）を所長兼衛生課長に据え、マラリア対策の研究・調査事業を展開した（小林：1952）。ここで決定的な役割を果たした人物のひとりが、当時同研究所・顧問の森下薫（1896-1978、大阪大学微生物病研究所・教授）であった。森下は、戦前に台北帝国大学医学部寄生虫学教室の教授をつとめ、台湾のマラリア対策を主導した人物である。従来、台湾におけるマラリア対策の方法論をめぐって、森下は環境改変による蚊のコントロールを主張していたことが明らかになっている（顧：2004）。しかし、台湾で実現した対策は、住民への原虫検査などに主眼をおいた、対人的なものであった。戦後彦根のマラリア対策に森下が深くかかわっていることは、対蚊対策を念頭において環境改変をすすめるか、原虫や蚊との接触を減らすために住民の生活行動を監視するのか、という対策の手法をめぐる議論が継続したことを示して

いる。

彦根マラリア研究所による撲滅プログラムは、①マラリア媒介蚊の分布調査、②DDT 噴霧、③衛生土木事業、④地域住民への教育宣伝の4つに大別することができる。まず、①の媒介蚊調査は、研究所の設置直後から、内堀、中堀、外堀の各域を対象として、シナハマダラ蚊の幼生の生態について確認作業が行われた。その結果、城の北側にある楽々園付近、護国神社近くの中堀、外堀の一部が濃厚生息地であることが判明した。この情報に基づき、彦根のマラリア対策は進められることになる（小林：1955）。

彦根マラリア研究所がもっとも力をいれたのが③の衛生土木事業である。これは、1949年から53年までの第一次五カ年計画および1954年から58年までの第二次五カ年計画によって、彦根城の堀および周辺湿地帯の埋め立てが策定された。なかでも、城の北側に位置する大湿地帯の埋め立てと外堀の改修工事は、マラリア対策のための重要課題として議論された。このうち、湿地帯は、第一次五カ年計画によってその大半が埋め立てられた。跡地には、当初は遊園地を建築する計画もあったが、その後計画が変更され、市民公園（現在の金亀公園）となっている。また、外堀の改修工事は、第一次および第二次五カ年計画を通して実施され、最終的にはコンクリートによる溝渠化が完了した。他にも②の DDT 噴霧および除虫菊乳剤散布による媒介蚊の幼生駆除や、④映画や撲滅週間などを通しての地域住民への啓蒙活動が行われた。これらの対策事業の結果、1954年には彦根のマラリア罹患者はゼロになり、56年1月に彦根マラリア研究所は閉鎖した（小林：1960、田中：2009）。

彦根マラリア研究所が展開した対策は、衛生土木事業による環境改変に力点が置かれたものであった。たしかに、蚊の分布を調査し、その水面を埋め立てるという方法は説得力を持つ。ただし、実際に埋め立てが完成したのは、彦根城北側の湿地帯のみで、それ以外の堀は、媒介蚊の生態が確認されたにもかかわらず、そのまま残されたことには注意が必要である。では、この埋め立て事業の成果により、実際にマラリアが消滅したといえるのだろうか。当時の各種報道のなかには、啓蒙書『マラリア読本』の出版や湿地の埋め立てが実施されるのと同時に、マラリア撲滅の成功が伝えられるといった、その成果がいささか誇張されたものもある（『滋賀新聞』1950年4月6日）。このように、彦根マラリア研究所のプログラムの効果として、同病の消滅を考えるには、無理がある。

4. マラリア罹患者発生の空間分布とその推移に対する環境改変の影響

ここまで見てきたように、日本の土着マラリアは特に滋賀県での罹患者数が他地域と比較して多く、しかも1940年代末に発生が集中したために、戦後の医療・衛生改革の対象となっていた。琵琶湖の東岸に位置する彦根市では、彦根城およびその周辺の城下町を取り囲む堀が媒介蚊の孵化地となり、県内でも特に濃厚なマラリア汚染地域になっていたといわれていた。一方、統計データは、マラリアの流行がより広域的で、マクロな地理的環境条件と結びついた現象であった可能性を示唆している。

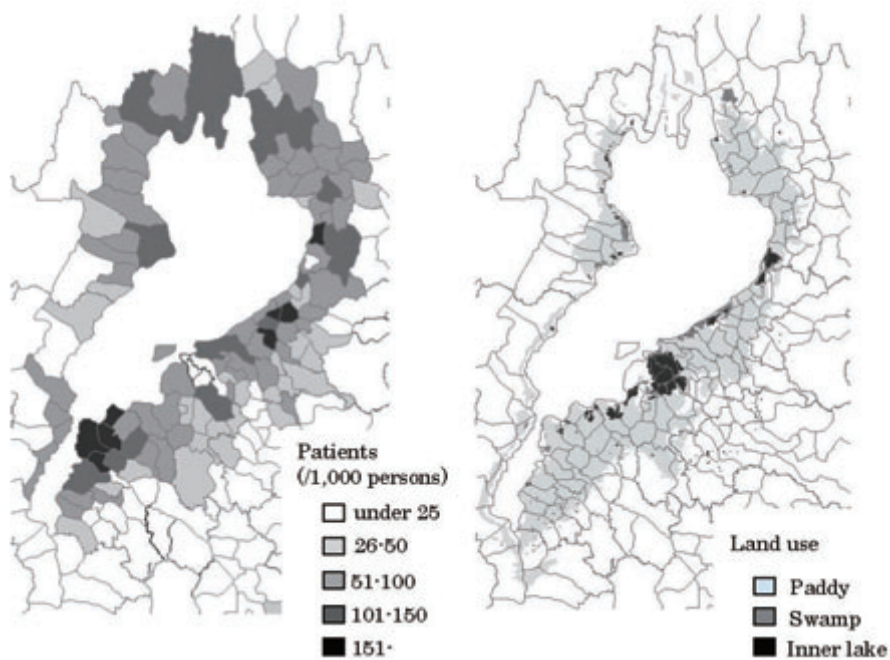


Figure 2 Distribution of malaria patients (village wise)
and land use (Lowland paddy, Swamp, Inner lake) of shiga prefecture in 1926

Source: Naimusho Eiseikyoku (1928)

Figure2 は作成された測量地図（縮尺 5 万分の 1）からデジタイジングした 1920 年時点の水田・浅水域（内湖）・泥田といった地理的環境と、統計資料（内務省衛生局：1928 年）から作成した村別の患者発生率の二つの空間分布を比較したものである。この図からは、1926 年時点の湖岸地域における村毎のマラリア罹患分布（対人口 1,000）は空間的に極めて不均一であり、① 一定数以上（千人対比で 50 人以上）の罹患分布域と水田域の分布、② 内湖等浅水域環境の分布と罹患発生ホットスポットの分布、の間の相関の高さが伺える。

Figure 3 は、湖岸の内湖の分布を、1926 年と 1947 年の二つの時期に関して比較した結果である。1926 年時点の内湖など浅水域環境は、1947 年に至るまでに彦根市（旧犬上郡）から蒲生郡の湖岸部を除いて、埋め立て等によってほぼ消失していることが確認できる。更に図 4 は、1926-53 年の間の湖岸地域におけるマラリア罹患患者の空間分布の推移である。滋賀県においてマラリアが最も猛威を振るっていた 1926 年の時点では、マラリア罹患患者数は県全体で 10,000 人を優に超え、その分布のホットスポットは彦根一帯よりも、湖岸北部（東岸では長浜市以北）と東岸南端（野洲市）にあった。それが 1947 年までに彦根市を中心とした分布（ただし総数は約 1/5 に減少）に収束し、1953 年には県全体でほぼ消滅するに至っている。

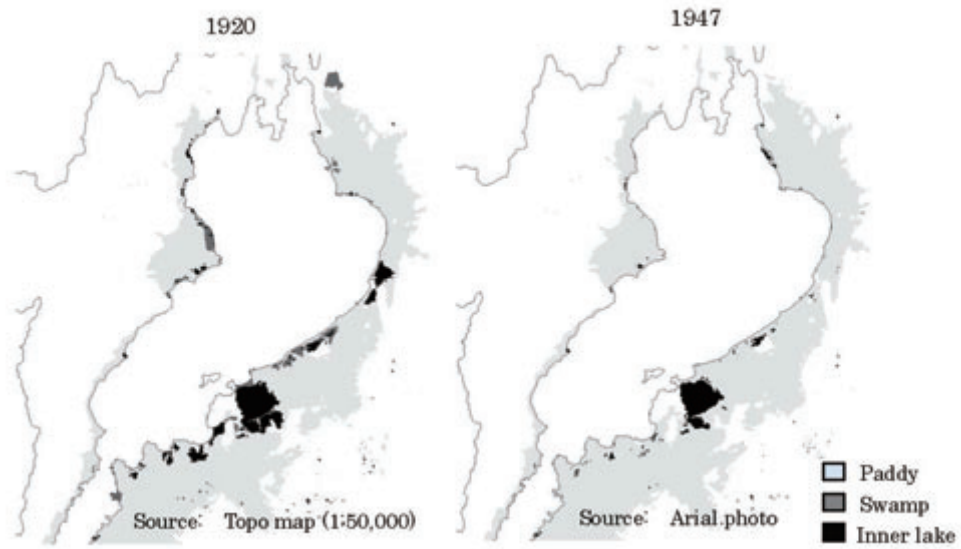


Figure 3 Distribution of shallow water area, 1920-1947

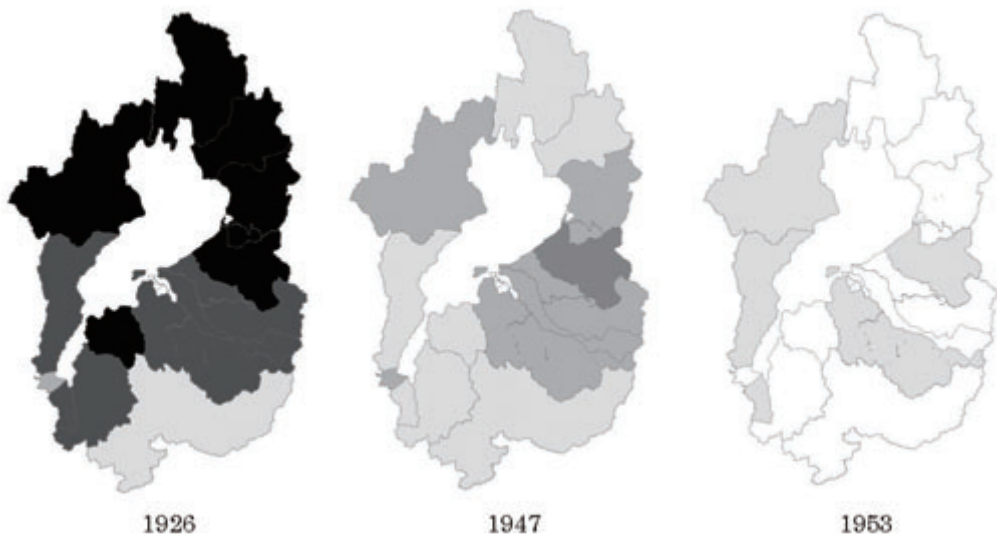


Figure 4 Number of malaria patients in shiga prefecture by district wise, 1926-1953

Source: Kobayashi (1955)

5. まとめと結論

統計情報の空間的な可視化によって、1920年代から50年代の期間について、湖岸地域において土着マラリア罹患者数の総数と分布は大きな変化を示していたことが明らかになった。この変化の背景には、内湖の埋め立て（農地化）による湖岸浅水域の大規模な縮小の進行によって、マラリア媒介蚊の繁殖域がマクロスケールで消失したからだということ

が明らかになった。

戦後の彦根市で社会問題とされたマラリアの発生は、実際には戦前から広域で濃厚に見られたマラリア流行の残滓と言える状況で、衛生土木事業などの彦根マラリア研究所の活動は、それ単体でマラリア撲滅という結果をもたらしたとは言い難いのではないか。彦根城の堀や湿地帯の埋め立ては、彦根市内に限定すれば、そのインパクトは無視できない。しかしその一方で、湖岸地域全体というスケールのなかではそれが果たした役割は極めて小さいものだったのではないかとわざわざを言わざるを得ない。

かつての湖岸地域には、内湖の広がりに見られるように、人々の居住・生活空間は浅水域に囲まれるようにして存在していた。これが時代とともに、大規模な湖岸の環境改変が進み、人々の居住・生活空間と水域は切り離されたものになっていった。戦後の彦根におけるマラリア撲滅活動に関する評価については、上記のような環境改変の結果として、湖岸地域全体で土着マラリアが終息に向かいつつあったことを理解した上で、研究所の活動が最後に強い一押しを加えたと解釈すべきであろう。

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Environmental Changes in the Lakeside Regions of Japan and the Health Problems of the Residents

– Lake Biwa Hikone Malaria (1920 to 1950) –

Tomo ICHIKAWA¹ and Bumpei TOJO²

1. Introduction

This research investigates the relationship of the outbreak of malaria in the regions around Lake Biwa just after the end of World War II mainly with the changes in the environment.

It is a well-known fact that the moats of castles were one of the factors for the outbreak of malaria in Hikone just after the end of World War II (The Shiga Prefecture History Editing Committee: 1981, TANAKA: 2009). The Hikone Castle was constructed by the Ii family in the early 1600's, and is surrounded by triple waterways - the inner moat, middle moat, and outer moat. The surface of the water in these moats became the habitat of the mosquitoes that transmitted malaria and was believed to be the background for the city residents to contract the disease. In this study, we are focusing on how the malaria outbreak related to the changes of a residential environment in the Shiga prefecture's lakeside regions. The data used to analyze are 1) government publications, newspaper materials, etc., 2) statistical information and 3) geographical information (topographic maps, aerial photos, satellite images).

2. Indigenous malaria in Japan

Generally, the image of malaria is that of infectious disease of the tropics or subtropics. For instance, for the areas that are directly related to Japan in the historic context, we can list the Ryukyu/Okinawa and Taiwan during the colony period as the major infected areas before and after the war. Both regions belong to the subtropics, and anti-malaria measure was one of the most important issues in the course of modernization (IIJIMA: 2005).

However, in reality, malaria was distributed widely across many parts of the Japanese islands. This infection can be divided into four groups according to the types of protozoans that cause the disease. In many parts of Japan, relatively benign (low fatality rate) tertian malaria was observed to be transmitted through Shinahamadaraka (*Anopheles sinensis*). Therefore, this disease was called "Okori" (ague), an endemic or local disease that came to be perceived as a region-specific problem.

Shinahamadaraka tends to breed in slowly flowing clear water surface (e.g., rice paddies or shallow pool of water). It was pointed out that in Hikone city, the triple moats which enclosed Hikone Castle and its surrounding castle town were the incubation place for the transmitting mosquitoes, and was contaminated heavily with malaria. However, judging only from the statistical data, the outbreak of malaria was more widespread and it is possible that it was a phenomenon that was influenced by macro environmental conditions.

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In prewar Japan, there was a large scale survey conducted around 1910 and in 1926, and the results confirmed that almost all the regions in the Japanese islands had outbreaks of malaria (Ministry of Home Affairs, Health and Medical Bureau: 1919, the same: 1928). In the 1910's, the malaria infection data are tabulated in the prefecture statistics document, but in the case of Shiga prefecture, they are based on hospital admission records grouped by counties and it is difficult to grasp the full picture (Shiga prefecture: 1917). The Shiga Prefecture Malaria Prevention Investigation Committee was established in March of 1926, and a full-scale investigation was conducted. It can be confirmed from the endemic disease investigation in Shiga prefecture in 1926, that malaria was widespread around the Lake Biwa regions (Ministry of Home Affairs, Health and Medical Bureau: 1928).

After the war, outbreaks of malaria continued up to the beginning of 1950's in five prefectures - Toyama, Ishikawa, Fukui, Aichi, and Shiga. Compared to other regions, the number of infections is high for the lakesides of Shiga prefecture, and a number of measures were taken from the prewar days such as the implementation of malaria prevention-and-eradication campaign week. Also in the end of 1940's, outbreaks of malaria were concentrated in Shiga prefecture and it became the focus of postwar medical and health reform (Figure 1).

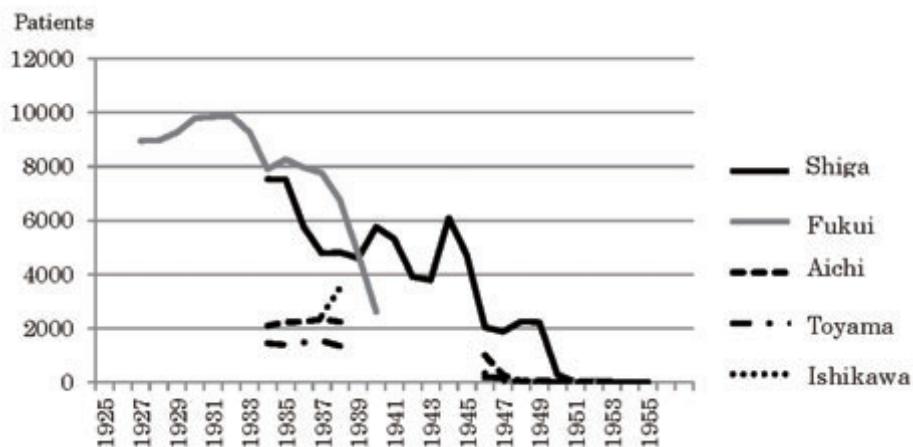


Figure 1 Number of malaria patients in 5 prefectures, 1925-1955

Source : Kobayashi (1955)

3. Eradication project by Hikone Malaria Research Center

As shown above, the Hikone malaria became a problem after the war. In June of 1948, the Hikone Anti-malaria Committee was established, and in January of the following year the Anti-malaria Eradication Meeting was held in Shiga prefecture office. It is surmised that in the background, the Hikone anti-malaria measure was included in the sanitation project by the GHQ (General Headquarters, the Supreme Commander for the Allied Powers) and was recommended to the Japanese side. Then, Hikone city established Hikone Malaria Research Center in June of 1949, placed Hiromu Kobayashi (1916 – 1991), a local practicing physician and the son of the mayor, who graduated from Nagasaki Medical School, as the head of the center and the manager of

sanitation of the city, and started the anti-malaria research and investigation project (Kobayashi: 1952). One of the people who played a decisive role at this time was the advisor to the research center, Kaoru Morishita (1896 – 1978, Professor of Osaka University, Microbial Disease Research Center). Morishita, who was a professor in the Department of Parasitology at Taipei Imperial University Medical School before the war, directed the anti-malaria policy for Taiwan. It has become clear, concerning the anti-malaria methodologies, that Morishita traditionally stressed the control of mosquitoes through environmental modification (KU: 2004). However, the measure taken in Taiwan focused on such activities as the protozoan screening of the residents, a people oriented one. The fact that Morishita was deeply involved in the postwar Hikone anti-malaria measure shows that there was a continued discussion concerning the countermeasure methodologies such as whether to implement the environmental modification with focus on anti-mosquito measures or to monitor the daily activities of the residents to reduce the contacts with the protozoan and mosquitoes.

The eradication program by the Hikone Malaria Research Center can be divided broadly into four categories: 1) the study of the distribution of the malaria transmitting mosquitoes, 2) DDT spraying, 3) sanitary construction projects and 4) educational publicity to the local residents. First, for the transmitting mosquitoes study (category 1), the verification was performed on the ecology of Shinahamadara mosquito larvae right after the establishment of the research center, for each of the inner, middle, and outer moat areas. As a result, the vicinity of Rakurakuen, the Japanese traditional garden with some ponds, located on the northern side of the castle, the parts of the middle and outer moats of Gokoku Shrine were found to be heavily infested habitats. The Hikone anti-malaria measure was carried out based on this information (KOBAYASHI: 1955).

Hikone Malaria Research Center focused most of its efforts on 3) sanitary construction project. The moats of Hikone Castle and the surrounding wetlands were decided to be reclaimed according to the First 5-year Plan, from 1949 to 1953, and the Second 5-year Plan, from 1954 to 1958. Above all, the reclamation of the wetlands located on the northern side of the castle and repair works for the moats were discussed as the important issues for the anti-malaria measure. Between these two, the wetlands were mostly reclaimed through the First 5-year Plan. At the time, there was a plan to construct an amusement park on the reclaimed site but was later changed and a public park (current Konki Park) was constructed. Also, the repair work for the moats was executed through the First and the Second 5-year Plan, and ultimately the canalization based on concrete was completed. In addition, the extermination of the transmitting mosquitoes and the larvae through 2) DDT and insecticide spraying, and 4) awareness program to the local residents through movies, eradication campaign week, and others were executed. As a result of these countermeasure projects, the number of infected individuals was reduced to zero in 1954, and the Hikone Malaria Research Center closed its doors in January of 1956 (KOBAYASHI: 1960, TANAKA: 2009).

The countermeasure implemented by Hikone Malaria Research Center put emphasis on the sanitary construction projects to modify the environment. Surely, the method of studying the mosquito distribution and reclaiming the watered areas sounds convincing. However, it is noteworthy that the actual area that was reclaimed was the wetland on the northern side of Hikone Castle only and the other moats were left as is even though the ecology of the transmitting

mosquitoes was confirmed. Then, can it be said that the reclamation project resulted in the actual extinction of malaria? Some of the various news media at the time reported a successful eradication of malaria simultaneously with the publication of the educational book *Malaria Guidebook* and the start of reclamation of the wetlands, indicating that there were some exaggerations of such results (Shiga Newspaper, April 6, 1950). Thus, it is unreasonable to think that the extinction of this disease was the only result of programs of Hikone Malaria Research Center.

4. The spatial distribution of the outbreak of malaria infection and the effect of the environmental modification on its trend

As shown thus far, the indigenous malaria in Japan infected more individuals especially in Shiga prefecture compared to other regions, and moreover, because the outbreak concentrated in 1940's, it became the focus of postwar health and medical reform. In Hikone city, located on the east coast of Lake Biwa, the moats that surrounded Hikone Castle and the castle town around it became a hatchery for the transmitting mosquitoes and they are said to be an especially heavily infested malaria region in the prefecture. On the other hand, the statistical data suggested that the malaria outbreak was more widespread and possibly was a phenomenon related to macro geographical conditions.

Figure 2 is a comparison of the two spatial distributions, the geographical environments such as rice paddies, shallow water regions (lakelets), muddy rice fields in the year 1920, digitized from topographic map (scale of 50,000:1) and the patient incidence rate by villages constructed from statistical data (Ministry of Home Affairs, Health and Medical Bureau: 1928). From this figure, it can be seen that the malaria infection distribution (per population of 1,000) in the year 1926 for the lakeside region is spatially quite heterogeneously, and there are high correlations between 1) the distribution of regions above a certain level of infected individuals (over 50 per 1000) and the distribution of rice paddy regions, and 2) the distribution of the shallow water regions such as the lakelets and the distribution of infection outbreak hotspots.

Figure 3 is the comparative result of the distribution of lakelets near the lakeside in the two periods, the year 1926 and 1947. It can be verified that the environment of the shallow water regions such as the lakelets in the year 1926 has mostly disappeared through reclamation by 1947, except for the lakeside part between Hikone city (formerly Inukami county) and Gamo county. Furthermore, the figure 4 shows the spatial distribution of the malaria infected individuals in the lakeside region during 1926 to 1953 period. In the year 1926 when malaria was most rampant in Shiga prefecture, the number of malaria infected individuals easily surpassed 10,000 people in the whole prefecture, and the hotspots of the distribution were more at the northern lakeside region (Nagahama city and north, in the east shore) and the southern tip of the east shore (Yasu city) than Hikone district. The distribution contracted to one that centered upon Hikone city (however, the total incidences were reduced to 1/5) by 1947, and the disease has become nearly extinct in the whole prefecture by 1953.

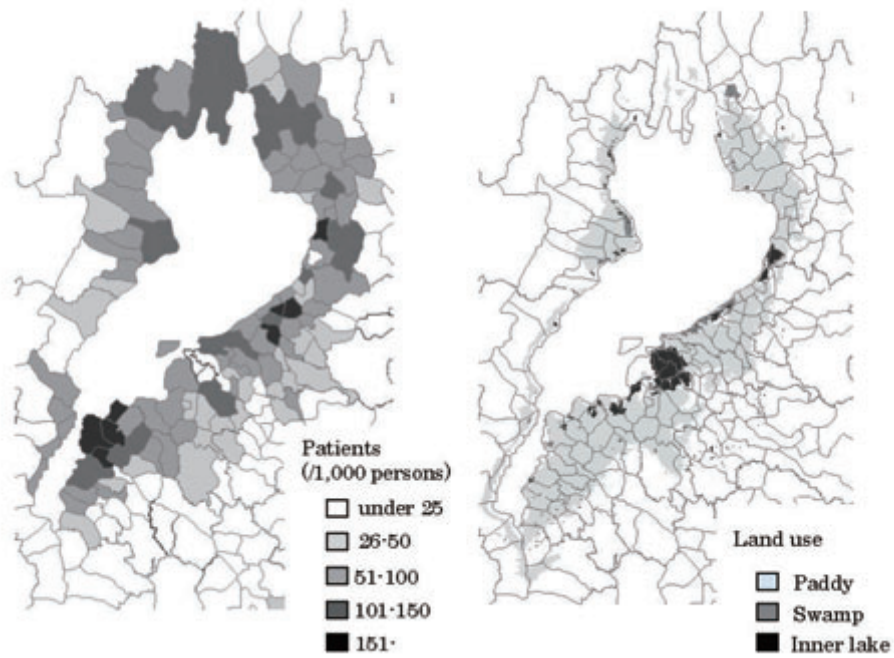


Figure 2 Distribution of malaria patient incident rate by villages and geographical environments (Rice paddies, Swamp, Lakelets) of shiga prefecture in 1926

Source: Ministry of Home Affairs, Health and Medical Bureau (1928)

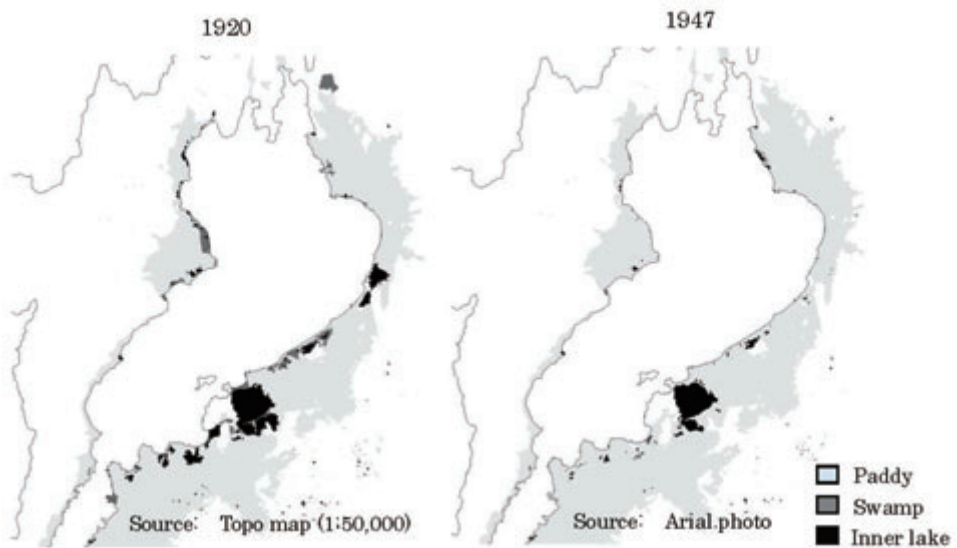


Figure 3 Distribution of shallow water area, 1920-1947

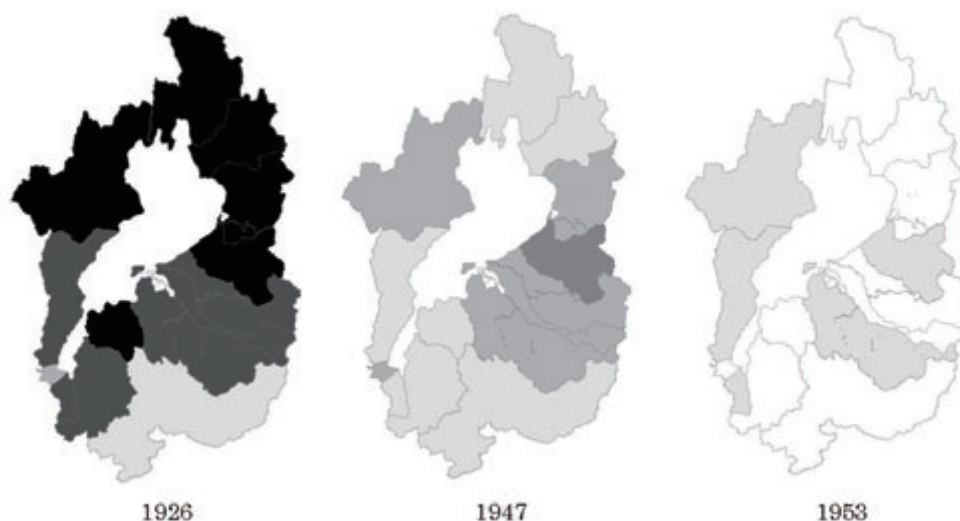


Figure 4 Malaria patient incident rate by districts in shiga prefecture, 1926-1953

Source: Kobayashi (1955)

5. Summary and conclusion

It has become clear, through the spatial transparency of the statistical information, that the total number and distribution of the indigenous malaria infected individuals showed a major change in the period between 1920's and 1950's. It has become clear that in the background of these change, the progressive large scale reduction of the lakeside shallow water regions through the reclamation of the lakelets (converted to rice paddies) caused the breeding grounds of the malaria transmitting mosquitoes to disappear in macro scale.

The postwar outbreak of malaria in Hikone city which was considered to be a social problem, was actually a condition that is remnants of the widespread and heavy outbreaks of malaria observed in prewar times, and such sanitary construction projects as the ones performed by Hikone Malaria Research Center cannot be said to have resulted in malaria eradication by themselves alone. The impact of the moats filling of Hikone Castle and the wetland reclamation cannot be ignored if only confined to within the city center. On the other hand, however, we have to say that the role they played on the scale of the whole lakeside regions might have been exceedingly small.

As seen by the widespread lakelets in the former lakeside regions, people's residences and living spaces were surrounded by the shallow water regions. As time passed by, a large scale environmental modification of the lakeside has been executed, and people's residences and living spaces have become separated from the water regions. Concerning the evaluation of the postwar malaria eradication activities in Hikone, keeping in mind that the indigenous malaria in the whole lakeside regions was in the course of being eradicated as a result of the above mentioned environmental modifications, it should be interpreted that the Research Center's activities gave the one last strong push.

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第二部 湖の環境変化

第二部 湖泊的环境变化

Part 2 Environmental Change of Lake



太湖流域の人間活動が水環境に与える影響及び解決策

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1. はじめに

近年、急速な経済発展とともに水質汚染による湖沼の富栄養化問題が深刻となっている。中国の太湖は、湖沼環境悪化を示す象徴ともなっており、毎年夏季にアオコが大量に発生し、本来の給水、漁業、水運、観光及び生態環境改善などの役割を果たすには大きな支障を与えている。本研究では、太湖流域における水環境保全策の立案及び持続的利用の向上を図るために、水環境変遷状況を把握すると共に、太湖の水質調査を行い、水環境に対する影響要因を検討した。また、それらの調査結果に基づき、「生態工学ダム」という新しいコンセプトの水質浄化システムを提案し、太湖流域において対応可能な水域環境及び利用状況の評価を行った。

2. 太湖流域の概要

2.1. 自然概況

太湖流域は、長江デルタの中心に位置し、東経 119° 08′ ~ 121° 55′、北緯 30° 05′ ~ 32° 08′ で、江蘇省、浙江省、安徽省及び上海市に跨り、流域面積は 36895 km² であり、江蘇省 52.6%、浙江省 32.8%、上海市 14.0%、安徽省 0.6% を占めている。本流域は季節風気候に属し、年平均気温 15~17℃、年間平均降水量 1177 mm、年間水面蒸発量 822 mm であり、冬季は乾燥寒冷、夏季は高温多湿、総降水量の約 60% が 5~9 月に集中する。流域の地形は西高東低で、平野部と山岳部に分けられ、西に位置する山岳部の標高は 300~700 m の範囲にあり、太湖への水の供給域を形成し、全流域の面積の 25% を占める。平野部は流域面積の 75% を占め、周辺部が高く中間部が低い盆地状を呈し、太湖はその平野の中心にある。東部の標高は 2~4 m の範囲にあり、中心部はほぼ 2 m 程度で太湖の水は蘇州から上海を経由して東シナ海に注ぐ。水系は河川、湖沼、ダムなどから構成され、総河道の長さ 12 万 km、密度 3.3 km·km⁻² である（崔：2009；Zheng：2009）。太湖は、湖面面積 2338 km²（琵琶湖の約 3.5 倍）、最大水深 2.6 m、平均水深 1.89 m、周囲長 436 km、平均貯水量 47.2 億 m³、年間の流入水量 52 億 m³ であり、流域内の水系調節と水生生態システムにおいて中心的役割を果たしている（Zheng：2009）。

2.2. 社会経済的状況及び水環境変遷特徴

太湖流域は地理的に重要な位置であり、貴重な自然環境及び歴史文化を有すると共に、経済発展に有利な条件が備わっており、中国国内でも工業化、都市化の水準が最も高い地区の一つである。20 世紀 50 年代まで太湖流域の水質は良好であったが、1980 年代以降、流域内の急速な経済発展及び都市化人口の集中に伴い、人間活動が水環境にさまざまな影

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響をもたらしている。水質の悪化による富栄養化問題も深刻化している。図 1、2 には太湖流域における近 30 年間の人口変動及び 2005 年の GDP を示した。1980 年から 2008 年まで流域内人口は 3,169 万人から 4,977 万人までの 1.6 倍に増加し、都市化率は 2005 年までに 70%に達した。2005 年における流域内の GDP は 21,221 億元で、国内 GDP の約 11.6%を占めており、1 人当たりの GDP は 4.7 万円で、国内平均の 3.4 倍に達した。そのうち、上海市の GDP 値が最も高く約 1 億元に上り、次は江蘇省であった。

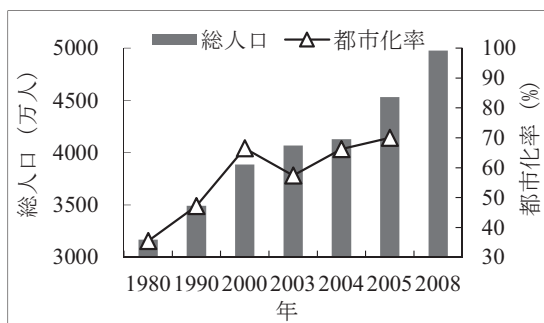


図 1 太湖流域の人口変動

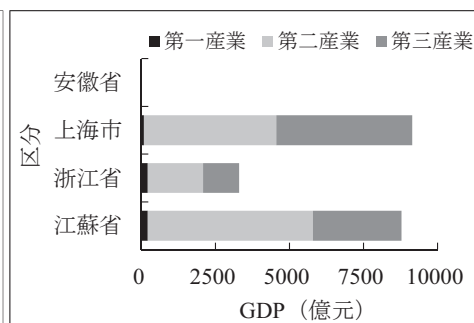


図 2 太湖流域の GDP (億元; 2005 年)

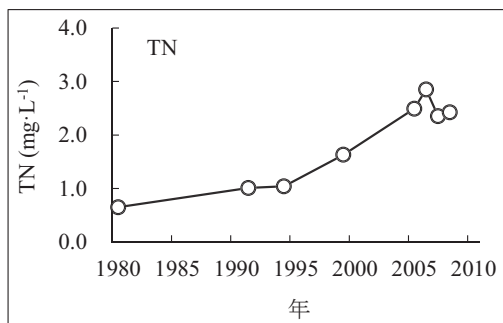


図 3 TN 濃度の年平均値の変化

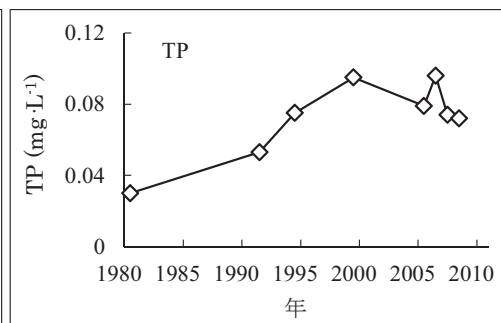


図 4 TP 濃度の年平均値の変化

太湖は本流域内において開放型の水体で周辺の水がすべて入り込むため、流域内の人間活動の水土資源への影響が太湖の水質に最終的に反映される(黄:2008)。図 3、4 には 1980 年から 2008 年まで太湖全体の全窒素(TN)濃度及び全リン(TP)濃度の年平均値の変化を示した。1980 年から 2008 年まで太湖全体の TN の年平均値は $0.65 \text{ mg} \cdot \text{L}^{-1}$ から $2.42 \text{ mg} \cdot \text{L}^{-1}$ までの約 4 倍, TP の年平均値は $0.03 \text{ mg} \cdot \text{L}^{-1}$ から $0.07 \text{ mg} \cdot \text{L}^{-1}$ までの 2 倍以上に増加した(秦:2007)。太湖の水質は、“「50 年代淘米洗菜」、「60 年代洗衣灌溉」、「70 年代水質変壊」、「80 年代魚蝦絶代」、「90 年代变成公害」”という歴史の実態が周知であり、既に深刻な水質の悪化が示されていた(黄:2008)。近年になって、汚染負荷量削減やアオコ回収などの対策が太湖で実施されているが、富栄養化は年々加速し、水環境の改善はみられていない(Zheng:2009; Gu:2011)。



図5 太湖の調査地（左：東太湖、中：梅梁湾、右：西部沿岸河川）

3. 太湖の水質調査

3.1. 調査水域・地点の設定

東太湖は、太湖の南東部に位置し、長さ 27.5 km、最大幅長 9.0 km、水域面積 131 km²、平均水深 1.2 m の水生植物の多い湖湾である（図 5 左）。梅梁湾は、太湖の北部に位置し、水域面積 124 km²、平均水深 1.5 m の浮遊藻類の多い湖湾である。太湖流域では夏季を中心に南東風が卓越するため、太湖の水面浮遊物は全体として北部の梅梁湾水域に吹き寄せられ、この水域ではアオコの集積が深刻である（図 5 中）。一方、西部沿岸は人口密度が低い、林地や農地が多いため、過剰施肥による流入河川の水質汚染が深刻であり、生態系が破壊されつつある（図 5 右）。

今回の調査は東太湖と梅梁湾及び西部沿岸を対象とし、調査地点を図 6 のように設定した。2011 年 7 月 26～30 日に東太湖では E1-E17 の 17 地点、梅梁湾では M1-M20 の 20 地点、西部沿岸では主要な流入河川の河口部において T1-T5 の 5 地点を調査した。

3.2. 調査方法・分析

水質調査は多項目水質計 (Hydrolab Logger DS5X) を使い、図 6 に示した各地点で水深方向に 10 cm 間隔で水温、pH、DO、クロロフィル a (Chl. a)、EC、濁度を測定した。同時に栄養塩分析用にハイロート型採水器 (250 mL) によって、各地点の表層水 (0.1 m) を採取した。採取した水試料の TN を紫外分光光度法及び TP を分光光度法（国家環境保護総局：2002）に準じて分析した。

4. 結果及び考察

図 7(a)-(f)、図 8(a)-(f) には東太湖及び梅梁湾における調査水域表層と底層の水質平面分布を示した。調査時期が夏季の 7 月であるため、全ての調査地点にお

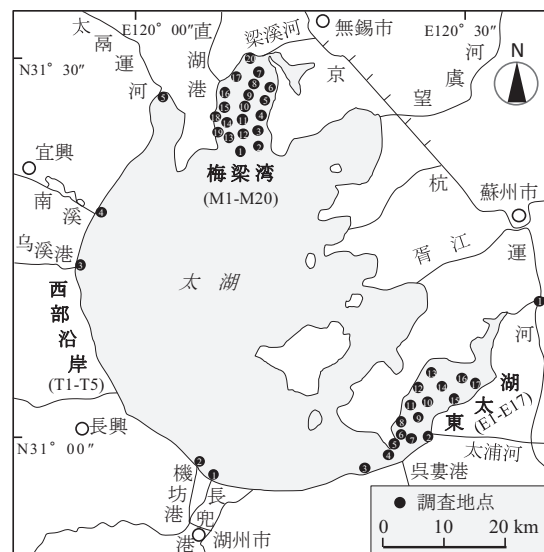


図 6 太湖の調査地点

いて水温(a)は30℃を超え、梅梁湾の沿岸付近の一部で34℃前後に達し、高水温値を示した地点ではアオコの発生も顕著であった。高水温条件は多数の植物プランクトンの増殖にとって不適であり、高温耐性を有するアオコの優占の一因であることが考えられる。

pH(b)は8.0~9.8の範囲で全体的にアルカリ性の水質であった。このようなpHの上昇に水中の溶解炭酸ガスの枯渇が伴うと、一般的な水生植物や植物プランクトンの増殖も制限される(渡辺:2002)。一方、*Microcystis*は溶解炭酸ガスに加え重炭酸イオンを利用できる(渡辺:2002)ため、アルカリ性の水環境条件はアオコの優占の一因となっていることが考えられる。

D0(c)は東太湖では5.8~10.8 mg·L⁻¹、梅梁湾では0.1~12.5 mg·L⁻¹であった。梅梁湾においてはD0が0.1 mg·L⁻¹であり、極度の貧酸素状態になっている地点もあった。水中の生物にとっては生存の厳しい状況となっている。

Chl. a(d)は東太湖では2.3~20.5 μg·L⁻¹であり、一部の地点の値が高かった。梅梁湾では4.4~9.6 μg·L⁻¹で地点間の差が小さかった。Chl. aは太湖の富栄養化を反映する重要な指標である(銭:2009)。アオコの集積地においては局所的にChl. aが高濃度となる傾向がみられたが、水域平均でみると、比較的アオコ集積の少ない東太湖では9.8 μg·L⁻¹であり、梅梁湾の5.8 μg·L⁻¹と比較して高くなった。これは梅梁湾では大量に発生したアオコがChl. aを左右しているのに対して、東太湖では水生植物や緑藻類も含めた多様な植物プランクトンの存在がChl. aに反映されているためであると考えられる。

EC(e)は全ての調査地点において高い値であって、地質的もしくは人為的な影響が考えられる。

濁度(f)は東太湖では28~60 NTU、梅梁湾では68~169 NTUで高い傾向にあった。梅梁湾において濁度が高く、東太湖の数十倍の値に達する地点もあった。現地観測で梅梁湾では流域からの濁水の流入や波浪による底泥の巻きあげ現象が確認された。

図9(g)-(h)には東太湖、梅梁湾及び西部沿岸における各調査地点表層水質のTN、TPの分析結果を示した。図中に示した数値のうち東太湖と梅梁湾の値はこれらの水域における最大値と最小値である。TN(g)及びTP(h)は、それぞれ0.93~23.52 mg·L⁻¹及び0.04~2.03 mg·L⁻¹であり、一般的に富栄養化を引き起こすTN濃度0.2 mg·L⁻¹及びTP濃度0.02 mg·L⁻¹の基準値(崔:2009)に比べ全体的にかなり高い値が示された。東太湖ではTN濃度が1.19~3.58 mg·L⁻¹と基準値(0.2 mg·L⁻¹)の6~18倍、TP濃度が0.04~0.15 mg·L⁻¹と基準値0.02 mg·L⁻¹の2~7.5倍であるのに対し、梅梁湾ではそれぞれ基準値の70倍、34倍、西部沿岸ではそれぞれ117倍、101倍で極めて高濃度であった。

東太湖は比較的水質が良好であり、従来 of 太湖の水域生態系が維持されている水域とみなされる。多様性のある生態系においては、特異な生物の異常増殖が生じにくいことから、生態的な作用により水質が改善され、アオコの異常増殖が抑制されている可能性がある。しかし、現状において大規模なカニ養殖による人工飼料の投入やカニの排泄物によってさらなる栄養塩負荷量の増大が予想されることから、将来的にアオコの大量発生が生じることが懸念される。

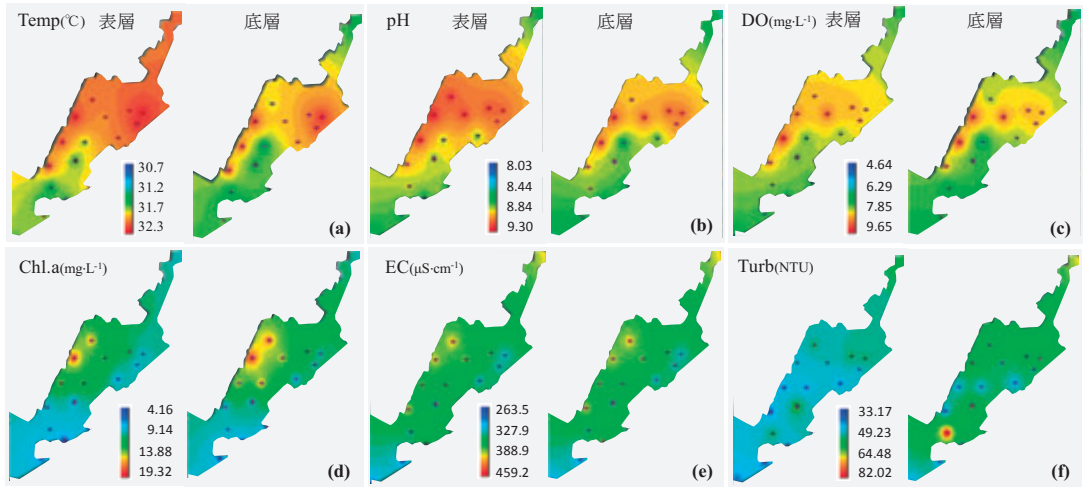


図 7(a)-(f) 東太湖における調査地点の表層・底層の水質平面分布

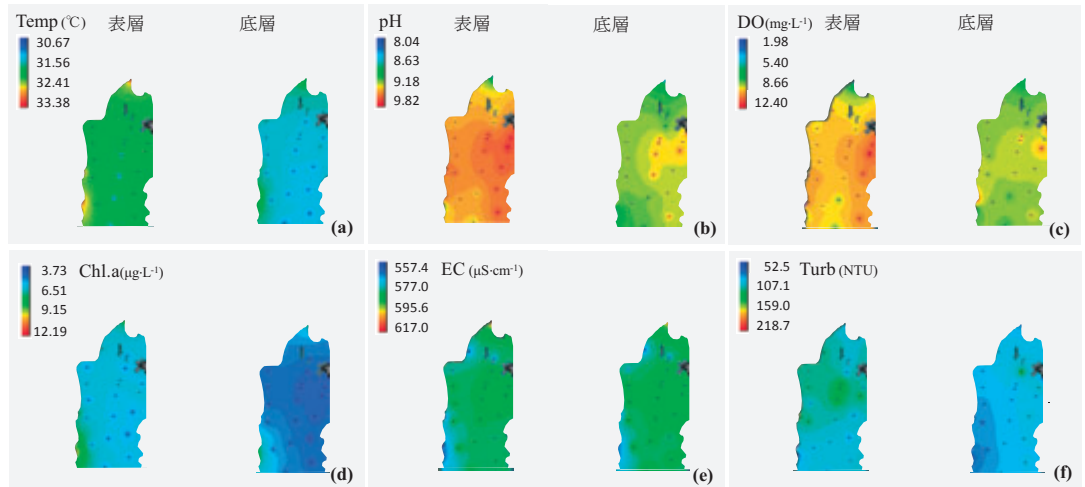


図 8(a)-(f) 梅梁湾における調査地点の表層・底層の水質平面分布

梅梁湾は2つの大きな河川流入口の梁溪河と直湖港を有し、その周辺の急速な経済発展や都市化の拡大に伴う流入汚濁負荷量の急増で水質が悪化している。汚濁物質中の高濃度の有機物や栄養塩などは水生植物に対し悪影響があり、負荷量が水生植物自体の浄化能力を上回ったことが水生植物群落の衰退の一因であると推察される。このように生態的な浄化能力が失われた状態に、湖水の流動に伴う太湖湖心域からのアオコの集積が加わり、DOが枯渇するほどの富栄養化状態に至っているものと考えられる。

西部沿岸は背後の山地が太湖の主涵養域となっている。西部沿岸流域の人口は少ないが、林地と農地が多く、過剰施肥の農地などの面源負荷源から河川を經由して流入する栄養塩負荷が指摘されている（崔：2009）。現地調査結果でも、TNとTPが最大値となった地点が示され、アオコが集積する地域でもあり、アオコの増殖を促進する栄養塩供給水域である

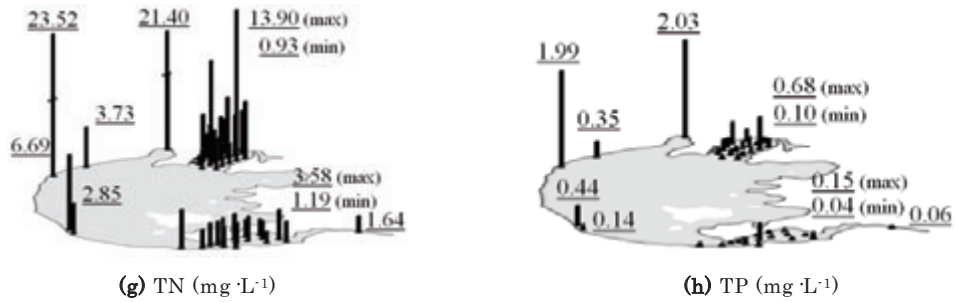


図9 調査地点 TN、TP の変化

ことが分かった。

5. 結論

太湖において東太湖、梅梁湾及び西部沿岸の3水域では異なった水質特性及び生物環境を有することが明らかとなった。水生生物の種構成及び分布は水質環境により支配され、アオコ発生水域では水質悪化により水生植物、植物プランクトンにとって不適な環境であることが示された。東太湖では比較的水質が良好であり、水生植物群落が多く、その水生植物群落がアオコの増殖を抑制し、生態的水質浄化に寄与していると考えられる。一方、梅梁湾と西部沿岸では水質汚濁が深刻であり、水生植物群落が衰退し、アオコの最終集積水域と農地からの栄養塩供給水域としてアオコの発生が顕著になっているものと考えられる。

太湖における水質汚染状況の改善及び良好な水生生態システムを回復させるためには、水環境汚染防止技術及び持続的な水環境管理対策が必要である。以下では、本研究の成果に基づき、水環境改善の解決策として富栄養化が進行した水域における人間生活、産業活動と水生生態系の関わり合いを考慮して、その中の物質動態に着目し、地域活性化機能、持続的水環境改善効果を有する「生態工学ダム」の水質浄化システムの構築を提案する。これは工学的、生態学的な方法を総合的に応用し、持続可能な水環境改善システムを回復させることを目標としている。

6. 「生態工学ダム」による水環境改善の解決策

「生態工学ダム」とは、水域生態系を造成する生物群を構造物として汚濁発生源からの水中の栄養塩や汚濁物質の流れをせき止めて、その一部を取り込み、人間生活に有用な物質に変換し循環利用することにより、水環境を改善するシステムである（図10）。

その作業手順及び特徴を以下に示す。

- ① 対象地域における人的関わりの特徴を踏まえ、生態工学ダムから得られるフラックスをその地域社会の産業などに活用できるような仕組みや汚濁排出者が積極的に生態工学ダムの管理を行う仕組みを組み込む。
- ② 在来の生物群、生態系、または既生物産業資源（養殖対象種等）を基本に、フラックスのせき止め、変換方法を検討する。富栄養化が進行した後の現状生態系の利用のみでは限界があると判断された場合、一時的な曝気施設等人工的な施設の併用を検討する。

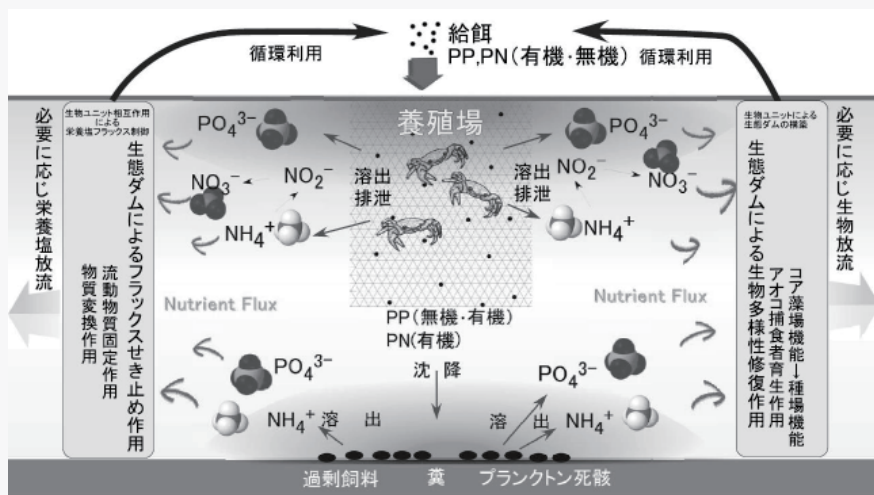


図 10 生態工学ダムによる水質浄化システム模式図

- ③ 生態系ダムの完成(安定)には十数年を要すると予想されるため、当初から最終イメージに到達するまでの生態系遷移を考慮することが重要である。また、途中過程では順応的管理が不可欠である。
- ④ 人工的な施設に必要なエネルギーは一時期には系外から供給することになるが、最終的に自然エネルギーを活用し、持続性のあるシステムとして調整する。
- ⑤ 水の流れ、在来水生生物の潜在種場(seed population)の分布などを把握し、複数の生態工学ダムを増設配置する。それらが生態コアダムとして、周辺の水環境の改善を促し、種場の供給源となり、生態コアダム間が有機的に連結しあった、巨大な生態工学ダムとして完成する。生態工学ダムの生物構造とその物質変換能力の関係及び連結可能な生態工学ダム間の距離は、対象水域で異なっているので、段階的实施のもと、水域環境のモニタリングを実施し、その結果をフィードバックしていくことが重要である。
- ⑥ 基本的に煩雑な管理を要しないシステムとして構築し、最終形としての生態工学ダムはその水域の自然生態系の中に同化することを目指す。

以上のシステムを実用化するため、2012年夏季より太湖流域の養殖場をフィールドに日中共同研究で現場検証試験を開始し、人工沈水生物帯を設置した。3カ月の後、コントロール実験区及び湖沼の水質に比べ、水体の透明度の改善機能を有したことが分かった。また、人工沈水生物帯による懸濁物の付着及び波浪の抑制による懸濁態の有機物・栄養塩の減少、植物プランクトン及び水生植物などの多様性の増加など固有の水生生物群集の回復効果を確認できた。さらに、生態工学ダム内部が安全な養殖ガニの脱皮場所として機能し、養殖の効率化につながっていることも明らかとなった。今後、引き続き、太湖の水環境保全のプロジェクトを遂行している期間中、「生態工学ダム」の現場試験を実行する予定である。

最後に「湖の現状と未来可能性」の創生として、筆者らは本紙を通じて、「湖沼問題、そして環境問題は人間が造り出したものであり、人間の智慧・能力により湖沼問題、環境問題も改善するべきである」という信念を述べたい次第である。

謝辞

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Impact of Human Activities on the Water Environment of Lake Taihu Watershed and Solutions for Environmental Problems

Aimin HAO ¹, Takahiro KUBA ², Yasushi ISERI ³ Zhenjia ZHANG ⁴, Chunjie LI ⁴

1. Introduction

In recent years, rapid economic development has caused water pollution, which has led to serious eutrophication problems of lakes and marshes. China's Lake Taihu has become a symbol of the deteriorating lake environment in the country. Every summer, huge mass of algal bloom appears in the lake and this has become a big obstacle for the lake to act as the resource for clean water supply, fishery, and tourism, as well as to allow water transportation and help improve the lake's ecosystem. In this study, in order to draw out a plan to protect the water environment of Lake Taihu watershed and improve its sustainability, we studied the transitions of the water environment, conducted water quality survey, and examined the effect factors of water environment. Furthermore, based on their results, we proposed a new type of water purifying system called "Eco-Engineering Dam," and conducted an evaluation on its effect on aquatic environment within Taihu Lake Basin and forecasted its application feasibility in future.

2. Brief overview of Lake Taihu watershed

2.1. Natural environment

Lake Taihu watershed is located at the center of Yangtze River delta at 119°08' to 121°55' east longitude, 30°05' to 32°08' north latitude. It stretches across Jiangsu Province, Zhejiang Province, Anhui Province and Shanghai City and takes up an area of 36,895 square kilometers, of which 52.6% belongs to Jiangsu Province, 32.8% to Zhejiang Province, 14.0% to Shanghai City and 0.6% to Anhui Province. The watershed has a monsoon climate with average annual temperatures of 15 to 17°C, annual rainfall of 1,177mm, and annual evaporation of 822mm. It is dry and cold in the winter, hot and humid in the summer, and 60% of its total annual rainfall is concentrated during May ~September. The watershed has a landscape that is high in the West and low in the East, and is separated between flat plains and mountainous regions. Altitudes of the mountainous region in the West are anywhere in the range of 300~700 meters, and these mountains form the water supply area for Lake Taihu and takes up 25% of the entire watershed area. Flat plains take up 75% of the watershed area, forming a basin where the rim is high and the central area is low in altitude. Lake Taihu is located at the center of the flat plains. Altitudes of the Eastern region are of 2 to 4 meters, and the central part is about 2 meters. The water of Lake Taihu flows from Suzhou to East China Sea via Shanghai. Water system consists of rivers, lakes and dams, and the total length of river channel is 120,000 km, density is 3.3 km·km⁻² and average

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storage capacity is 4.72 billion m³ (CUI: 2009; ZHENG: 2009). Area of the surface of Lake Taihu is 2,338 km² (about 3.5 times that of Lake Biwa), maximum water depth is 2.6 m, average water depth is 1.89 m, lake perimeter is 436 km, amount of influent quantity per year is 5.2 billion m³. Lake Taihu plays an important role in adjusting the water channel, and maintaining water and ecological system within the watershed (ZHENG: 2009)

2.2 Social and economic situation and characteristics of water environment transition

Lake Taihu watershed is at a geographically important location, and has some precious natural environment and historical culture. It also holds some characteristics, which are beneficial to the region's economic development, making it one of the regions in China where level of industrialization and urbanization is the highest. Until 1950s, quality of water in Lake Taihu watershed was fine. However, after 1980, along with the rapid economic development and concentration of population due to urbanization of the watershed area, human activities have posed various negative impacts on the quality of water. The lake's eutrophication caused by the declining quality of water is becoming serious.

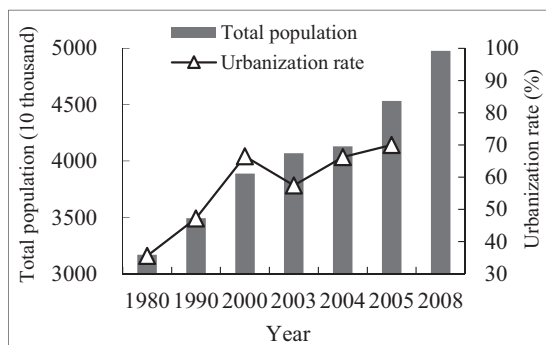


Figure 1 Population change in Lake Taihu watershed

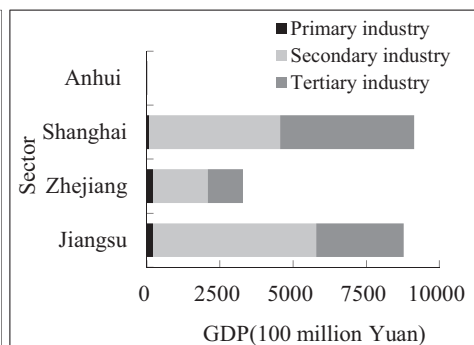


Figure 2 GDP in Lake Taihu watershed (100 million yuan; 2005)

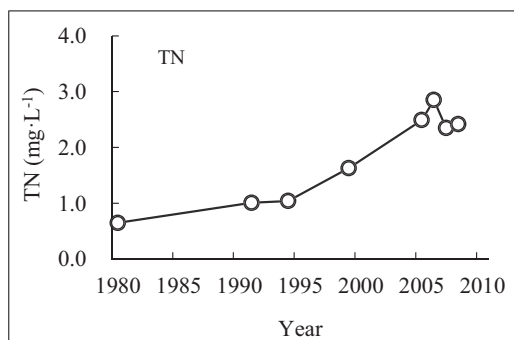


Figure 3 Annual average of TN concentration

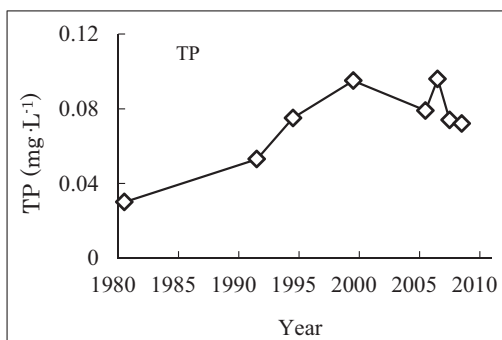


Figure 4 Annual average of TP concentration

Figure 1 and Figure 2 show the demographic changes in the Lake Taihu watershed during the past 30 years and 2005 GDP, respectively. From 1980 to 2008, population in the watershed increased 1.6 times from 31,690,000 to 49,770,000, and urbanization rate reached to 70% by 2005. GDP within the watershed reached to 21,221 yuan, accounting for 11.6% of the entire country's GDP. GDP per single person reached to 47,000 yuan, which is 3.4 times the country's average. Among different locations, Shanghai City's GDP was the highest at approximately 1 trillion yuan, followed by Jiangsu Province.

Because Lake Taihu is an open lake where waters from the surrounding area all flow in, impact of human activities on the water and land resources eventually effects the water quality of Lake Taihu as well (HUANG: 2008) Figure 3 and Figure 4 show the changes in annual average concentration of total phosphorous (TP) and annual average concentration of total nitrogen (TN) in Lake Taihu from 1980 to 2008. Between 1980 and 2008, annual average concentration level of TN in Lake Taihu rose approximately four times from $0.65 \text{ mg}\cdot\text{L}^{-1}$ to $2.42 \text{ mg}\cdot\text{L}^{-1}$, and annual average concentration of TP more than doubled from $0.03 \text{ mg}\cdot\text{L}^{-1}$ to $0.07 \text{ mg}\cdot\text{L}^{-1}$ (QIN: 2007) Water quality of Lake Taihu is known to have gone through historical changes described as follows: "In the 50s the water can be used to wash rice and vegetables"; "In the 60s the water can be used to wash clothing"; "In the 70s the water quality began to change"; "In the 80s fishes started to disappear"; "In the 90s the water was polluted." The water quality of Lake Taihu, therefore, was already known to have deteriorated to a serious level (HUANG: 2008). Although recently, measures to lower contamination load and clean up algal blooms are being conducted, eutrophication has continued to worsen every year, and we have not yet seen any improvement in water quality (ZHENG: 2009; GU: 2011).

3. Water quality survey on Lake Taihu

3.1. Selection of water and land area for the survey

East Taihu Lake is at the southeast of Lake Taihu. Its length is 27.5 km, maximum width is 9.0 km, the entire water area is 131 km^2 , and average depth is 1.2 m. It is a bay with many aquatic plants. (Figure 5, left) Meiliang Bay is in the north part of Lake Taihu. Its water surface area is 124 km^2 and average depth is 1.5 m. It is also a bay with algae bloom. At Lake Taihu, southeastern winds are common especially in the summer. Because of this, materials that float on the surface of Lake Taihu all flow toward Meiliang Bay, triggering serious problem of accumulated algal bloom in the water. (Figure 5, center) On the other hand, population is less concentrated on the west coast of the lake. However, because there are many forests and farmland in the area, water contamination of feeder rivers due to overfertilization has become serious, and the ecological system is starting to be destroyed.

The survey was conducted at East Taihu Lake, Meiliang Bay and the west coast of Lake Taihu at various spots indicated in Figure 6. During July 26 ~ 30, 2011, the survey was conducted at 17 spots from E1-E17 at East Lake Taihu; 20 spots from M1-M20 at Meiliang Bay and 5 spots from T1-T5 at the mouth of some major feeder rivers in the west coast.



Figure 5. Survey site at Lake Taihu
(Left: East Taihu Lake; Middle: Meiliang Bay; Right: West coast River)

3.2. Method of survey and analysis

Survey on water quality was done by using a multi-parameter water quality meter (Hydrolab Logger DS5X). At each spots shown in Figure 6, the water temperature, pH, DO, Chlorophyll a (Chl.a), EC, and turbidity were measured at 10 cm intervals toward the direction of water depth. Meanwhile, surface water (0.1m) was collected at each spot using Heyroth water sampler (250 mL) for analysis of nutrient salts. The collected water samples were analyzed for TN using ultraviolet spectrophotometry and TP using spectrophotometry (State Environmental Protection Administration 2002).

4. Results and discussion

Figure 7 (a)-(f) and Figure8 (a)-(f) show the planar distribution of water quality for surface water and bottom water of East Taihu Lake and Meiliang Bay survey sites. Since the survey was conducted in July, the water temperature (a) at every survey site marked above 30°C. At one spot near the coast of Meiliang Bay, the temperature reached to around 34°C, and algal blooms were evident in spots that marked high temperature readings. Because high water temperature is a condition unsuited for the growth of many phytoplankton, this may be a reason for the high-temperature-tolerant algae to dominate the waters.

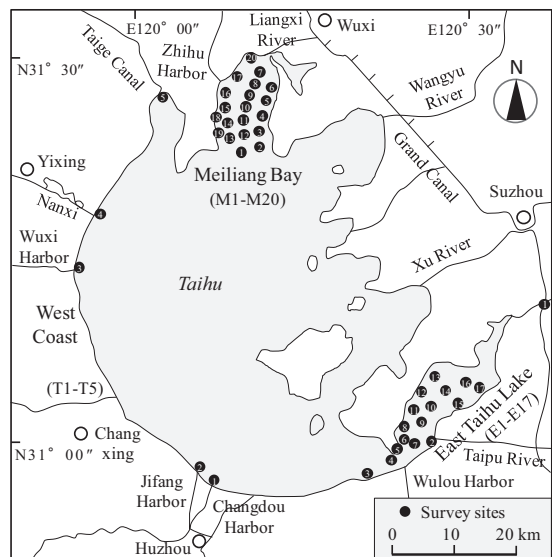


Figure 6 Survey sites at Lake Taihu

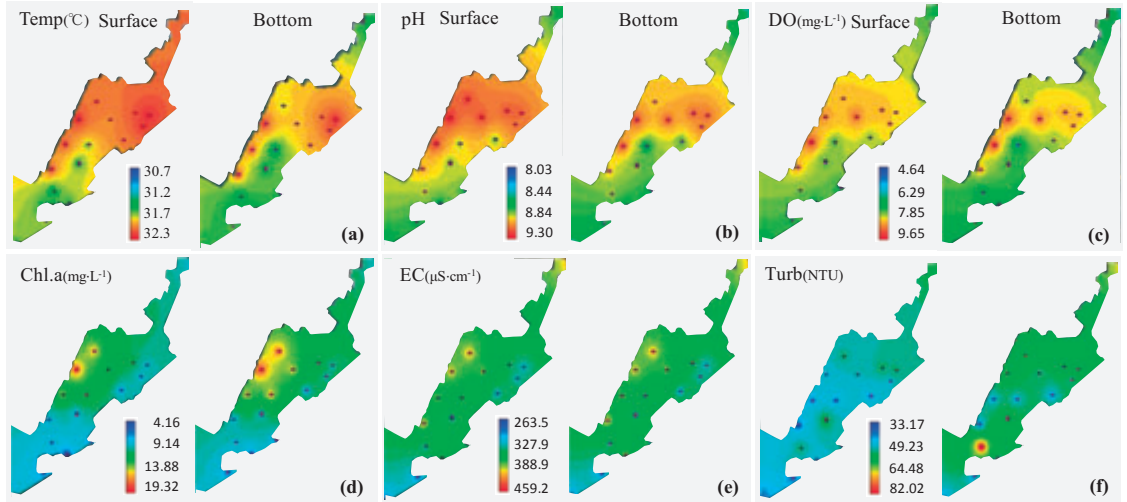


Figure 7 (a)-(f) Planar distribution of water quality for surface water and bottom water at East Taihu Lake survey sites.

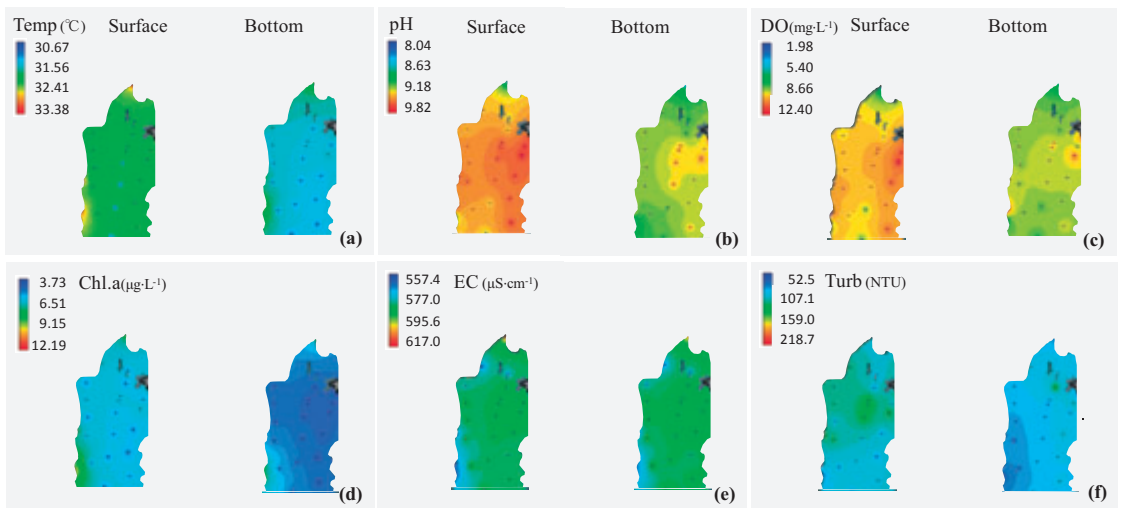


Figure 8 (a)-(f) Planar distribution of water quality for surface water and bottom water at Meiliang Bay survey sites.

Levels of pH(b) were in the range of 8.0~9.8 and the water were generally alkaline. When soluble carbon dioxide gas in the water runs out while the pH level is rising, growth of general aquatic plants and phytoplankton becomes limited (WATANABE : 2002). Since *Microcystis* can utilize bicarbonate ion in addition to soluble carbon dioxide gas (WATANABE : 2002), it is likely that alkaline water environment becomes a cause for *Microcystis* to dominate over aquatic plants and phytoplankton.

Levels of DO(c) for East Taihu Lake were 5.8~10.8 mg·L⁻¹, and 0.1~12.5 mg·L⁻¹ for Meiliang Bay. At Meiliang Bay, level of DO was 0.1 mg·L⁻¹, and some spots were in serious

dysoxic condition. Considering this, the water environment has become a place that is difficult for any living matter in the water to survive.

Levels of Chl.a(d) at East Taihu Lake were 2.3 to 20.5 $\mu\text{g}\cdot\text{L}^{-1}$, and there were some spots that showed high readings. At Meiliang Bay, the levels were 4.4 to 9.6 $\mu\text{g}\cdot\text{L}^{-1}$, and the readings were generally the same between different spots. Chl.a is an important parameter because it reflects the eutrophication of Lake Taihu (QIAN:2009). Although local concentration of Chl.a tended to become high at places with high concentration of algae, considering the average concentration of the entire watershed, the concentration levels came out relatively high at 9.8 $\mu\text{g}\cdot\text{L}^{-1}$ for East Taihu Lake, where there were less concentration of algae, and 5.8 $\mu\text{g}\cdot\text{L}^{-1}$ for Meiliang Bay. This is because at Meiliang Bay, algal bloom is what influences the concentration of Chl.a, whereas at East Taihu Lake, it is the aquatic plants and a wide variety of phytoplankton, including green algae that influence the concentration of Chl.a.

EC(e) values were high at all survey sites, which is likely to be due to geographic or man-induced causes. Turbidity at East Taihu Lake were 28 to 60 NTU, whereas at Meiliang Bay, the levels tended to be high at 68 to 169 NTU. Turbidity tended to be high at Meiliang Bay, where in some spots, the levels were as high as several tens of times the level at East Taihu Lake. During site observation at Meiliang Bay, we were able to confirm inflow of turbid water from the watershed and a phenomenon where the mud at the bottom of the lake is disturbed by wind waves.

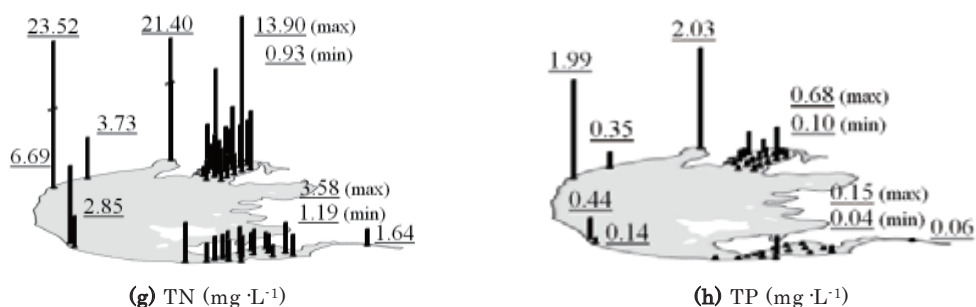


Figure 9 Distribution of TN and TP at survey sites.

Figure 9(g)-(h) shows the results of analysis on TN and TP of surface water taken at each survey site at East Taihu Lake, Meiliang Bay and Lake Taihu's west coast. Of the numerical values indicated in the figure, those for East Taihu Lake and Meiliang Bay are the maximum and minimum values observed within the watershed. Values for TN(g) and TP(h) were 0.93 to 23.52 $\text{mg}\cdot\text{L}^{-1}$, and 0.04 to 2.03 $\text{mg}\cdot\text{L}^{-1}$ respectively. These values were considerably high in general compared to the baselines of 0.2 $\text{mg}\cdot\text{L}^{-1}$ for TN concentration and 0.02 $\text{mg}\cdot\text{L}^{-1}$ for TP concentration, which are the levels that cause eutrophication in general, (CUI: 2009). At East Taihu Lake, TN values were 1.19 to 3.58 $\text{mg}\cdot\text{L}^{-1}$, which is 6~18 times the baseline (0.2 $\text{mg}\cdot\text{L}^{-1}$) and TP values were 0.04 to 0.15 $\text{mg}\cdot\text{L}^{-1}$, which is 2 to 7.5 times the baseline (0.02 $\text{mg}\cdot\text{L}^{-1}$). In contrast, however, at Meiliang Bay and the west coast, concentration of TN and TP were

considerably high at 70 times the baseline for TN and 34 times the baseline for TP at Meiliang Bay and 117 the baseline for TN and 101 times the baseline for TP at the west coast.

Since water quality of East Taihu Lake is relatively healthy, it is considered that the water area maintains the lentic ecosystem of Lake Taihu that has lasted for many years. In a diversified ecosystem, it is difficult for any particular living organism to overgrow, and because of this it is likely that such ecological effects have helped improve the water quality, preventing overgrowth of algae. However, due to the artificial feedstuff for crab farming poured into the lake and fecal matter that comes from the crabs, we can expect to see rising load of nutrient salt, which has raised concern for algal bloom.

Meiliang Bay has two large inflow entrances: Liangxi River and Zhihu Harbor, and the quality of water have been declining due to rapid economic development and urbanization of the surrounding area, which has fast raised the load of sludge that flows into the bay. Since high level of organic matter and nutrient salt pose negative effects on aquatic plants, we can say that one reason *aquiherbosa* has started to vanish is because such burden posed on the plants overwhelmed the plants' own cleaning capacity. From this we can say that adding to the situation where ecological self-purification capacity in the lake has been lost, accumulation of algae caused by the water flow of the lake has pushed the level of eutrophication at Lake Taihu to the level where DO was depleted. At the west coast of Lake Taihu, the rear mountains are the lake's main recharge area. Although population in the west coast is small, there are many forests and farmlands, which has raised concerns over the load of nutrient salt that flow into the lake from over-fertilized farmlands through the rivers (CUI: 2009). Results of local survey has marked the highest levels of TN and TP, which indicates that it is also a water area where algae often accumulates and abundant supply of nutrient salt that enhances growth of algae flow in.

5. Conclusion

It has become clear that at Lake Taihu, the three water areas; East Taihu Lake, Meiliang Bay and the west coast have different water features and biological environment. We have found that species composition and distribution of aquatic plants depends on the aquatic environment. And in water areas where algal bloom is evident, it has become clear that declining water quality has created an environment inappropriate for phytoplankton to live.

Water quality of East Taihu Lake is relatively healthy and there are many hydrophyte communities, which prevent growth of algae and contribute to the ecological water purification system. On the other hand, at Meiliang Bay and the west coast, water pollution has become a serious problem, resulting in the disappearance of hydrophyte communities. Algal bloom in these water areas have become evident since they are the final accumulation point for algae and where nutrient salt flow in from the surrounding farmlands.

In order to improve water pollution and restore healthy aquatic ecology at Lake Taihu, technology that can prevent polluting the water environment and sustainable water environment control measures are needed. Based on the results of this study, as a solution to improve water environment, we will consider the lives of human beings living around the waters where eutrophication has progressed, and the interaction between local industries and lentic ecosystem in

order to pay attention to the movements of various materials and suggest establishing "Eco-Engineering Dam," a water purification system that can contribute to community revitalization and offers sustained effects on improving the water environment.

6. Solution for improving water environment using "Eco-Engineering Dam "

"Eco-Engineering Dam" is a system that improves water environment through recycling of polluting materials in the water. (Figure 10) It works by using the biological communities that form the freshwater ecosystem to build a structure that dams polluting materials such as nutrient salt, while allowing a part of the materials to flow into the water so that they will eventually transform themselves into materials useful in human living environment.

- 1) Considering the characteristics of human relationship in regions suitable for the dam, we will include a system that allows local industries to utilize the material flux that emerge from Eco-Engineering Dam, and also a system where those responsible for discharging polluting materials will be encouraged to manage the Eco-Engineering Dam.
- 2). Method of damming and transition the water using material flux will be examined, while taking into account the community of native organisms, ecology, and existing aquaculture resource (aquatic animal or plant subject to aquaculture).
- 3). Since it is expected to take more than ten years for the Eco-Engineering Dam to be completed and operation Recycle is stabilized, it is important to consider how to control ecological succession so that the final ecological state will be the same as the image drawn up at the beginning. Flexible management is also indispensable during mid-course.
- 4). Energy necessary to operate the man-made facility will be supplied from outside the system at one point, however, adjustments will be made eventually to establish a sustainable system that operates with natural energy.

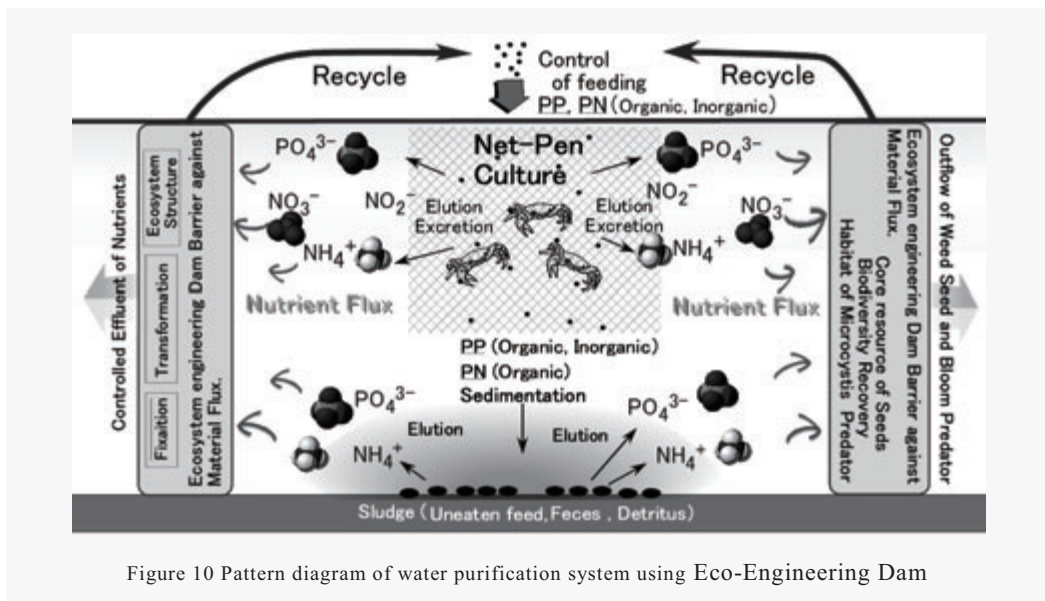


Figure 10 Pattern diagram of water purification system using Eco-Engineering Dam

- 5). By understanding the water flow, distribution of seed population of native aquatic organisms, we will build several numbers of the Eco-Engineering Dam. As the core Eco-Engineering Dam, each of these dams will help improve the surrounding water environment, work as the supplier of seeds, and finally realize a huge Eco-Engineering Dam system, where the core dams will be organically linked to one another. Relationship between the dam's biological structure and the conversion capacity of the organisms, as well as the feasible distance for linking the dams are different depending on the water area. Therefore, it is important to conduct a step-by-step monitoring of aquatic environment and provide feedback on the results.
- 6). Our target is to build a damming system that basically does not require cumbersome management procedure, and to see these Eco-Engineering Dams reach the final stage of blending in and becoming a part of the natural ecosystem.

In order to put the Eco-Engineering Dam system to practical use, on-site investigation for the dam was launched in summer of 2012. It was a part of the Japan-China joint research, whose research field was the aquaculture in Lake Taihu watershed. After three months from installing man-made submerged biotic formation, we found that the transparency of the water in the system had improved more than the water in the controlled test area or in the lake. Furthermore, we were able to observe suspended solids becoming attached to man-made submerged biotic formation, and decrease of organic matter and nutrient salt in suspended matter due to controlled wind waves. We also confirmed recovery of the water area's native aquatic community, for example, increase in diversity of phytoplankton and aquatic plants. The Eco-Engineering Dam also contributed to efficient crab farming by offering safe place for the cultured crabs to shed shells. In the future, we are planning to continue conducting field tests for "Eco-Engineering Dam" as long as the Lake Taihu water environment protection project continues.

Lastly, for the construction of "present state and future possibilities of lakes," authors of this paper would like to convey through this publication our belief on the issue as follows: "All problems of lakes and the environment are man-made, therefore, they should be and can be solved by human wisdom and ability."

Acknowledgment

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湖の環境改変と感染症

源 利文¹、川端善一郎²

1. どのような湖を未来に残すのか

我々は未来の湖にどのような姿を期待するのであろうか。現在一般的に我々が湖に求めるのは、飲料水や農工業用水の水源、水産資源、美しい自然や景観といった、いわゆる生態系サービスとしてまとめられることが中心であろう。湖から得られるサービスを維持するため、あるいは一旦失われてしまったサービスを回復させるため、水質汚濁の防止、資源管理、景観保全などの取り組みが行われており、それぞれに一定の成果をあげている。しかし、湖の未来可能性を考えるのであれば、我々人類の利益であるサービスの保全ではなく、湖の健全性そのものを直接のターゲットとするべきである。つまり、様々な生き物が健康に生息する湖を持続可能な状態に維持するといった目標をたてるのが本筋ではないだろうか。ここでは、野生生物の感染症を題材に、湖における環境改変が生息する生物の健康を脅かす例について紹介し、環境保全に野生動物の感染症予防を含む生態系の健全性確保の視点を取り入れることを提案したい。

健全な生態系は感染症を抑制すると考えられている。例えば、生物多様性が低下すると感染症の伝播が増大すると報告されている (KEESING et. al.: 2010)。このように、人間活動による環境改変は野生生物の感染症を発生・拡大させると考えられているが、それを実証的に示した研究例は少ない。そこで、我々は湖における環境改変と感染症の関係を実証的に解き明かすため、淡水域におけるコイヘルペスウイルス病と人間の間の相互作用環に関する研究を行った。

2. コイヘルペスウイルス病とは

コイヘルペスウイルス病は1990年代後半にヨーロッパで初めて報告された比較的新しい感染症である。その名前の通り、病原体であるコイヘルペスウイルスに感染することで発症する。感染するのは主にマゴイとニシキゴイ（生物学的には同種とされる）である。感染魚の死亡率は80%以上とされ、その感染力の強さとあわせて、一旦アウトブレイクが発生するとその被害は甚大なものとなる。当初、コイの密集する養殖場のみで発生する病気であると考えられてきたが、2003年以降に日本で発生した全国規模のアウトブレイクでは、自然の河川や湖沼でもコイの大量死がみられた。また、2007年にはカナダでも自然湖沼におけるアウトブレイクが発生した (GARVER et. al.: 2008)。2003年から2004年にかけて琵琶湖で起きたアウトブレイクは、世界でも最大規模のものと考えられており、この時だけで10万匹以上のコイが死んだと考えられている (MATSUI et. al.: 2008)。このときには大型のコイばかりが死んだとも報告され、大量死による生態系全体への影響も大きいと見込まれる。このように、本病は養殖産業のみならず自然生態系への脅威でもある。

3. 湖岸の環境改変とコイヘルペスウイルス病

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人類が生存する上で自然環境の改変は避けられない。湖においても、治水、利水、農地の拡大などのために湖岸を中心とした湖の改変が継続的に行われてきた。本稿では、このような環境改変が病原微生物（ここではコイヘルペスウイルス）やその宿主の生態に影響を与え、結果として感染症が発生・拡大したと見られるケースを紹介する。

3.1. 水温環境の変化による宿主のストレス増加

コイは変温動物なので、水温の変化は生理的な変化に直結する。また、コイヘルペスウイルス病の発病は水温がおよそ 15～25℃のときに限られることが知られている。そこで我々は水温に着目し、湖岸の形状改変が湖内の水温分布に影響を与えるとの仮説を立てた。その検証のため、琵琶湖の南湖において隣接する、なだらかな傾斜を持った自然湖岸と垂直に切り立った人工湖岸における水温の時空間分布を調査したところ、なだらかな傾斜を持った湖岸における水温分布は垂直湖岸よりも多様な水温を維持できることが判明した。水温は気温と同様に昼に高く夜に低い日内変動をするが、なだらかな湖岸では水温が多様なまま日内変動をし、逆に垂直湖岸では空間的には全体が一様な水温を保ちながら時間的な変動をすることも明らかになった（YAMANAKA et. al. : 2010）。できるだけ体温を一定に保ちたい魚の側からすれば、水温変動から逃れる余地のない垂直湖岸は、多様な水温の存在する自然湖岸に比べて、より強い水温ストレスにさらされる厳しい環境であると考えられる。

とはいえ、日内の平均的な水温変動幅は±3℃程度である。この程度の水温変動が魚にストレスを与えるのであろうかという疑問が残る。そこで次に、水温変化に対する魚のストレスの測定を行った。魚のストレス測定にはいくつかの方法があるが、我々は魚体から水中に放出されるコルチゾールを測定することによるストレス評価を行った。この手法は、魚を捕獲する必要がないため、測定自体がストレスになるおそれがなく、同一個体について、繰り返し測定を可能とし、水温変動によるストレスを測定するのに都合がよい。水槽に飼育したコイを用いて実験を行った結果、日内の±3℃の変動はコイにストレスを与えることが明らかになった（TAKAHARA et. al. : 2011）。さらに、水温変動を与えられたコイは与えられないコイと比べてコイヘルペスウイルスへの耐性が弱まる、すなわち同じ量のウイルスに曝露された際の死亡率が高まることも明らかになった。

これらの結果をまとめると、湖岸の垂直化は、水温環境の変化を通じてコイにストレスを与え、結果として感染症にかかりやすい状況を作り出すということになる。ここでは湖岸の垂直化による水温ストレスだけを取り扱ったが、一般的にストレスの増加が発病に影響することはよく知られている。現代の湖沼に生息する野生生物には、水温ストレスだけでなく、水質の悪化、レジャーボート等の騒音、都市域における夜間の光など、人間活動に由来する様々なストレスが加わっており、これらの面からも水域の保全を検討する必要がある。

3.2. 産卵適地の減少とコイの密集

コイの産卵と聞いてどのようなところでどのように行われるかをイメージできる人は多くはないだろう。コイは春先に浅瀬の抽水植物帯に集まり、一匹のメス個体を複数のオス個体が追いかける形で集団産卵を行う。我々は、この産卵場所がコイヘルペスウイルス病の新規感染の場であることを示した（UCHII et. al. : 2011）。産卵のためにコイが浅瀬に集まってくるとき、水中のコイヘルペスウイルス量が局地的に増加することや、感染履歴を示す抗体価が繁殖に参加する体長およそ 35cm を境に急増することなどが明らかになったのである。ウイルス側

から考えれば、繁殖行動によってストレスが高まった個体が密集する産卵場所は、感染拡大の絶好の機会といえる。

一方、琵琶湖におけるコイの繁殖適地は年々減少している。滋賀県によれば 1953 年から 1992 年の約 40 年間にびわ湖岸のヨシ群落はおよそ半減した。感染の場が減るのだから感染症が起きなくなるのではないかとするとそうではない。ヨシ群落の減少は、限られた繁殖適地へのコイの密集を招き、結果的にコイヘルペスウイルス症のまん延に寄与したと考えられる。ここでも湖岸の環境変化がコイヘルペスウイルス病の拡大に影響を与えたのである。また、人為的なコイの放流によるコイ密度の増加もコイの密集を招くと考えられ、やはり感染症拡大の一因となりうる。

4. コイヘルペスウイルス病の与えた影響

コイヘルペスウイルス病の発生による影響は多岐にわたる。第一に、コイやニシキゴイ養殖への壊滅的な打撃が挙げられる。例えば、茨城県の霞ヶ浦は国内最大のコイ養殖地であったが、2003 年から 2004 年にかけてのアウトブレイク発生後、約 60 あった養殖業者は全て廃業に追い込まれた (1)。インドネシアでの本病発生による経済損失が 2500 万米ドルにのぼるとの試算もあり、経済損失だけでも計り知れない規模である。

本病はコイの遺伝的多様性にも大きな影響を与えた。日本のコイには日本固有の従来型コイと、人為的に導入された移入型のコイがある。特に琵琶湖には従来型のコイが多く生息しており、地元でもノゴイなどと呼ばれ、移入型のそれとは区別されてきた。在来型と移入型との間の交雑も確認されており、在来型の減少が危惧されていたところに、コイヘルペスウイルス病が発生した。このとき、移入型より在来型のコイの方が多く死んだとの報告もあり、本病の発生により在来型のコイ集団がさらに減少し、移入型との交雑がより進んだことも確認された (UCHII *et. al.* : 2013)。人為的なコイの導入が感染症と相まってコイの遺伝的多様性を減少させてしまったわけである。

さらに、生態系エンジニア種とも呼ばれるコイの大量死によって、生態系全体への大きな影響も当然考えられるが、これの全貌把握にはさまざまな困難があり、現時点では推計することができていない。どのような影響が起きたのか、これから起きるのか、注意深く見守る必要がある。

5. 湖の健全性が感染症を抑制するのか

我々は国内だけでなく、中国の湖でもコイヘルペスウイルスの調査を行った。中国でも養殖場でのアウトブレイクが報告されていたからである。雲南省の洱海という湖で、一年間にわたって調査を行った結果、ここにもコイヘルペスウイルスが存在していた。しかし、ここではコイヘルペスウイルス病のアウトブレイクは起きていない。このような現象は実は日本でも見られている。我々の調査では日本の一級河川の 90%以上がコイヘルペスウイルスに汚染されているが、アウトブレイクが発生したのは約半数の河川に過ぎない (MINAMOTO *et. al.* : 2012)。つまり、ウイルスの存在とアウトブレイクの発生は必ずしもリンクしないのである。それでは何がアウトブレイクの発生を決定するのだろうか。現時点では科学的な結論には達していないが、水域の健全性が鍵を握るのではないだろうか。多様な水温の提供によるストレスの減少、自然な水辺が広く存在することによる産卵時の感染リスク低下、特定の種に偏らない多種の共存する環境など、環境と生物の多様性を保つことが、水域の健全性を保つことにつながるのである。

う。もちろん、日本でも中国でも環境保全の取り組みは行われている。琵琶湖では 2000 年に琵琶湖総合保全整備計画が策定され、そこでは「琵琶湖を健全な姿で未来に引き継ぐ」ことがうたわれている。一方洱海でも、1980 年代以降の開発や外来種導入により水質の悪化や多様性の減少が見られたが、国を挙げての水質改善のための取り組みがなされ、一度は人口護岸で埋め尽くされた湖岸も、今は自然湖岸に近い姿に戻されている。このような取り組みにより、洱海の水質は改善しており、環境や生物の多様性を含む湖の健全性も回復に向かっていると考えられる。日本においても中国においても、湖を健全に保つ試みがスタートしていることには希望がもてる。

6. おわりに

ここまで見てきたように、人間活動による環境変化がコイヘルペスウイルス病の拡大に寄与したことは疑いない。ここで明らかにされた問題はただ単に魚の感染症だけの問題ではない。病原体が野生動物集団と養殖動物（家畜や家禽を含む）の間を往き来しながら拡散する姿は、様々な感染症でおこることである。例えば 2009 年以降大流行した H1N1 型のインフルエンザや、2013 年春に人への感染が発覚した H7N9 型のトリインフルエンザなどでも、野生動物と家畜や家禽の関わり方が感染症の発生に寄与したと考えられる。環境のあり方によってはそれがさらに拡大するおそれがあると言われれば、それに対処する必要があることは万人の理解するところであろう。つまり、健全な環境を残すことは、間接的には人間の利益にもつながるのである。

どのような湖を未来に残すのか、そのためにどのような取り組みをしなければならないのか、わかりやすい直接的な利益から少し離れて見直すときではないだろうか。

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注記

(1) 現在では霞ヶ浦でのコイ養殖が再開されている。

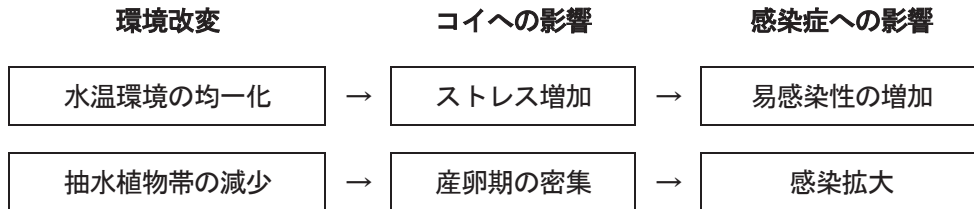


図 1 環境変化が引き起こす感染症の拡大の例。コイヘルペスウイルス病の場合、人間活動による環境変化がコイの生理や生態に影響を与え、感染症の拡大に寄与すると考えられる。

Environmental Change of Lake and Infectious Disease

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1. What kind of lakes should be left for the future?

What image do we expect for the future lakes? Currently, the typical expectations we have for lakes are perhaps mainly those that can be summarized as ecological services such as the source for drinking and industrial water, fishery resources, beautiful nature and scenery, etc. In order to maintain such services we can obtain from the lakes, or to recover those that were lost temporarily, various efforts have been made such as prevention of water pollution, resource management, landscape preservation, etc., and each effort has produced a given amount of results. However, if we are thinking of the futurability of the lakes, we should directly target the health of the lakes itself rather than the preservation of the services that benefit us. In other words, we should set the goal to preserve a sustainable environment for the lakes where various organisms live in good condition. In this report, the subject of the infectious disease of the wildlife is taken up, and the examples of how the change to the lake environment is threatening the health of the organisms inhabiting there will be introduced, and we hope to propose the adoption of a perspective for securing the health of the ecosystem that includes the prevention of infectious diseases of the wild animals in the environmental conservation.

A healthy ecosystem is believed to suppress infectious diseases. For instance, it is reported that infectious diseases spread more when diversity of organisms is reduced (KEESING et.al.: 2010). In this manner, it is thought that the environmental change by human activities can cause outbreaks of and spread of the infectious diseases in the wildlife, but there are few research case studies that succeeded in showing corroborative evidence for it. Therefore, in order to demonstratively clarify the relationship between the environmental change of the lake and the infectious diseases, we have investigated the interactions between the koi herpesvirus disease and humans in freshwater environments.

2. What is koi herpesvirus disease?

Koi herpesvirus disease is a relatively new infectious disease that was first reported in the late 1990's in Europe. As the name indicates, the disease develops through an infection by the pathogen koi herpesvirus (recently designated as *Cyprinid herpesvirus 3*). Mainly common carp and its ornamental subspecies, koi are infected. The mortality of the infected fish is over 80%, and along with its high infectivity, an enormous damage can be done once an outbreak occurs. Initially, the disease was thought to occur only in the fisheries where carp / koi are densely clustered, but in the nation-wide outbreaks that occurred in Japan since 2003, mass mortality of carp in the natural rivers and lakes was observed. Also, outbreaks were reported in the natural lakes in Canada in 2007 (GARVER et.al.: 2008). The outbreak that occurred in Lake Biwa from 2003 to 2004 is thought to be of the largest scale in the world, and over 100,000 carp individuals are estimated to have died (MATSUI et al.: 2008). It was reported that only the larger carp have died, and estimated that the impact of the mass mortality on the entire ecosystem is enormous. As shown, the threat of this disease is not limited to fish farming industry but

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also to the natural ecosystem.

3. Environmental change in lakeshore and the koi herpesvirus disease

It is unavoidable that the natural environment is changed through human activities. In the lakes, changes to the lakeshores were continuously made for such as flood control, irrigation, expansion of farmland, etc. In this report, case studies will be introduced where these types of environmental changes affect the pathogenic microbes (in this case, koi herpesvirus) and the ecology of their host, and as a result, outbreak and spreading of infectious disease occur.

3.1. The change in water temperature environment by lakeshore alteration

The carp is an ectotherm, and the change in the water temperature directly affects its physiology. Also, it is known that the koi herpesvirus disease occurs only in the water temperature range from 15 to 25°C. Therefore, we focused on the water temperature environments and hypothesized that the change of the shape of the shoreline of the lake contributes to the temperature distribution of the lake water. In order to test this hypothesis, upon investigating the spatial and temporal distribution of the water temperature at the natural gently-sloping shore and the steep man-made shore in the southern part of Lake Biwa, it is found that the water temperature distribution at the gently-sloping shore is able to maintain a more diversified water temperature compared to that of the steep shore. The water temperature has daily fluctuation, rising in daytime and falling in nighttime. However, it has become clear that at the gently-sloping shore the water temperature remains diversified in the daily fluctuation and, conversely, at the steep shore, the spatially uniform water temperature fluctuates temporally (YAMANAKA et.al.:2010). For the fish which wants to maintain a constant body temperature as much as possible, the steep slope where the fish cannot escape from the change in the water temperature can be thought of as a severe environment where it is exposed to stronger water temperature stress compared to the natural lakeshore with a diversified water temperature.

Even so, the range of daily fluctuation in the water temperature is about $\pm 3^{\circ}\text{C}$. The doubt remains whether that this level of water temperature fluctuation actually gives stress to the fish. Therefore, the stress to the fish by the change in water temperature was measured. There are several methods to measure the stress on fish, and here we adopted the evaluation of the stress by measuring the cortisol, an well-accepted indicator of the stress level, discharged from the fish into the water. This method is convenient for measuring the stress caused by the water temperature change because it does not require capturing the fish and there is no danger of applying stress to the subject animals, and a repeated measurement can be made for the same animal. As a result of performing the experiment using carp in a fish tank, it was found that the daily fluctuation of $\pm 3^{\circ}\text{C}$ does give stress to carp (TAKAHARA et.al.: 2011). Furthermore, it is found that the resistance to the koi herpesvirus is reduced in the carp for which the water temperature was changed, compared to the carp without the temperature change, that is, the mortality rate rises on exposure to the same dose of the virus (TAKAHARA et.al.:personal communication).

Taken together, these results indicate that the steep slope change to the lakeshores puts stress on the wild carp through the change in water temperature environment, and as a result, creates a condition which makes the fish more susceptible to infection. Only the steep slope change to the

lakeshores is focused here, but typically it is well known that an increase in stress affects the susceptibility to a disease. Other than the water temperature stress, the wildlife inhabiting the modern freshwater environments are subject to various stresses originating from human activities such as degradation of water quality, noise from leisure boats, nighttime lights in the urban areas, etc., and it is necessary to consider the preservation of water environments from these perspectives also.

3.2. Overcrowding of carp at the spawning sites

Probably most of readers cannot imagine where and how the spawning of carp happens. In early spring, carp gather in the emergent vegetation region of the shallows, and multiple male carp chase after a single female in a group spawning. We have shown that this spawning site is a hotspot for a new infection of koi herpesvirus disease (UCHII et.al.: 2011). It was found that when the carp gather in the shallows for spawning, the koi herpesvirus density in the water increases locally, and the antibody titer, an indicator of infection history, increases markedly for those carp participating in spawning with body size of about 35 cm and larger. From the virus perspective, the spawning site where the fish are crowded together in a highly stressed condition due to the spawning activity can be a perfect opportunity for spreading the infection.

On the other hand, suitable sites for carp spawning in Lake Biwa is diminishing each year. According to Shiga prefecture, the reed colonies have been reduced to almost half in the 40 years from 1953 to 1992 (http://www.pref.shiga.lg.jp/ouen/katsuyou/biwako_hozen/yoshi/index.html [in Japanese]). One might think that since the number of sites for infection is reduced the infection may not occur, but that is not the case. It is thought that the reduction of the reed colonies led to overcrowding of carp in a limited number of suitable sites for spawning, and consequently contributed to the spread of the koi herpesvirus disease. In this case also, the change in the lakeshore environment had accelerated the spread of koi herpesvirus disease. Also, increased density of carp due to artificial stocking of the lake with carp is thought to lead to crowding of carp and can also become a factor in spreading of the infection.

4. The impact of koi herpesvirus disease

The impact of the outbreak of koi herpesvirus is wide-ranging. First, the impact on the carp and koi fishery is devastating. For instance, Kasumigaura Lake in Ibaraki prefecture was the largest domestic carp fishery, but around 60 fish farms that existed there closed down their businesses after the outbreak of the disease from 2003 to 2004 (1) . In Indonesia, the economical loss from this disease is estimated to reach 25 million US dollars, an exorbitant loss just from the economical viewpoint.

This disease also affected the genetic diversity of carp. In Japan, there is an endemic common carp, and an artificially introduced foreign carp. Especially in Lake Biwa, there is many endemic carp and is differentiated from the other introduced foreign type. Crossbreeding between the endemic type and the foreign type is also confirmed, and there was a concern that the endemic carp is being diminished in the largest outbreak in Lake Biwa. It was reported at the time that there were higher mortality of the endemic type than the foreign type, resulting in further diminishing of endemic carp type, and increase in crossbreeding with the foreign type was also confirmed (UCHII et.al.: 2013). The artificial introduction of carp coupled with the infectious disease, has thus caused the decrease in the

genetic diversity of carp.

Furthermore, due to the mass mortality of the carp, also called the ecosystem engineering species, there could be a large impact to the overall ecosystem, but due to various difficulties in grasping the total picture, it is yet to be estimated at this point in time. It is necessary to monitor carefully, to find out what impact there was and there will be.

5. Does healthy lakes suppress infectious diseases?

We have conducted investigation of koi herpesvirus not only in Japan but also in the lakes in China because outbreaks in the fisheries were reported also in China. As a result of yearlong investigation in Lake Erhai in Yunnan province, koi herpesvirus was found to exist there. However, there is no outbreak of koi herpesvirus disease. A similar phenomenon is also observed in Japan. According to our investigation, more than 90% of the class-A rivers, which are assigned by government to be of importance for conservation of national land or for national economy, are contaminated with koi herpesvirus, but outbreaks have occurred in only about half of them (MINAMOTO et.al.: 2012). In other words, the existence of the virus and the outbreak of the disease are not necessarily related. What, then, determines the outbreak of the disease? No scientific conclusion is reached to date, but perhaps the health of the water system may hold the key. Preserving the diversity of the environment as well as the biodiversity leads to preserving the health of the water systems such as reducing stress through availability of diversified water temperature, decreasing the risk of infection during spawning when natural shores are widely available, creating an environment where no particular species is segregated but various species coexist, etc. Of course, environmental conservation activities are in progress in Japan as well as in China. For Lake Biwa, the Lake Biwa Comprehensive Preservation Initiatives is drawn up in 2000, and a declaration to “hand over healthy Lake Biwa to the future” is made in it. In Lake Erhai, although water quality degradation and diminishing of biodiversity was observed also since the development of the 1980’s and introduction of foreign species, the nation took efforts to improve the water quality and the lake shores that were once packed with artificial shore protections are now returned to the condition close to the natural shores. Through such activities as these, the Lake Erhai water quality has improved, and the health of the lake which includes the diversity of environment and organisms is believed to be on its way to recovery. The fact that initiatives for preserving the health of lakes are in progress in Japan and in China holds promise for the future of lakes.

6. Conclusion

As shown thus far, it is undeniable that the environmental change caused by human activities contributed to the spread of koi herpesvirus disease. What is revealed here is not only the problem of a fish disease. The image of pathogens, coming and going between the wild and farmed animals and then spreading, can be seen in various infectious diseases. For instance, in the cases of the H1N1 influenza pandemic of 2009 and the H7N9 avian influenza which was discovered to infect humans in the spring of 2013, the interaction between wild animals and domestic animals and poultry is thought to have contributed to the outbreaks of the diseases. When it is told that there is a danger that the disease could spread even more depending on the condition of the environment, everyone understands that it is necessary to take countermeasures for it. Namely, preserving a healthy environment indirectly leads to

the benefit of people.

What kind of lakes should be handed over to the future? What efforts should be made for it? Perhaps, it is time for us to take a step back from the obvious direct benefits and think it over.

Acknowledgement

This report is a compilation of a part of the results from Research Institute for Humanity and Nature “Effects of Environmental Change on the Interactions between Pathogens and Humans” (Project Leader: Zen’ichiro Kawabata). I thank the people related to the project and the staffs at Research Institute for Humanity and Nature.

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Notes

(1) Currently, the fishery in Kasumigaura is in operation.

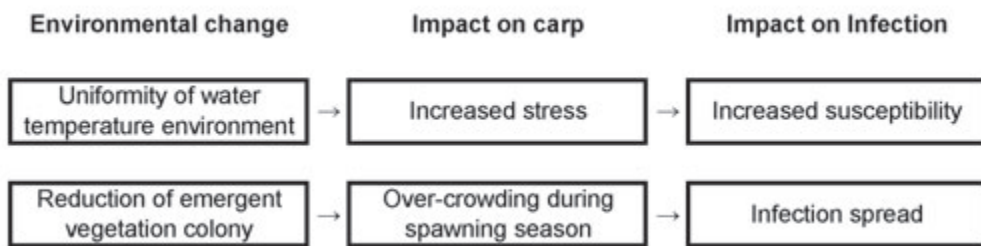


Figure 1 Examples of the spread of infectious disease caused by environmental change. In the case of koi herpesvirus, the environmental change due to human activities which impacted the biology and ecology of carp, is thought to contribute to the spread of the infection.

第三部 湖の環境保全

第三部 湖泊的环境保护

Part 3 Environmental Preservation of Lake



Countermeasures for the non-point pollution control in the watershed of Lake Erhai, China

Xiao SHANG¹, Hainan KONG²

1. Pollution problems in the Lake Erhai watershed

1.1. Rapid water quality degradation

In history, the Lake Erhai had clear water and was known as “Plateau Pearl” in honor. However, with the rapid population increase and economic development, from the 1970s on, water quality of the Lake Erhai degraded progressively and the fast degradation occurred after 1990s. The changes of water quality in the Lake Erhai shown in Figure 1 demonstrate this phenomenon. Almost all water body of the Lake Erhai belonged to Class II before 1996 according to National Environmental Quality Standards for Surface Water of China, while the Class III and even Class IV of water appeared in large area afterwards. The degradation trend of water quality in the Lake Erhai was obvious.

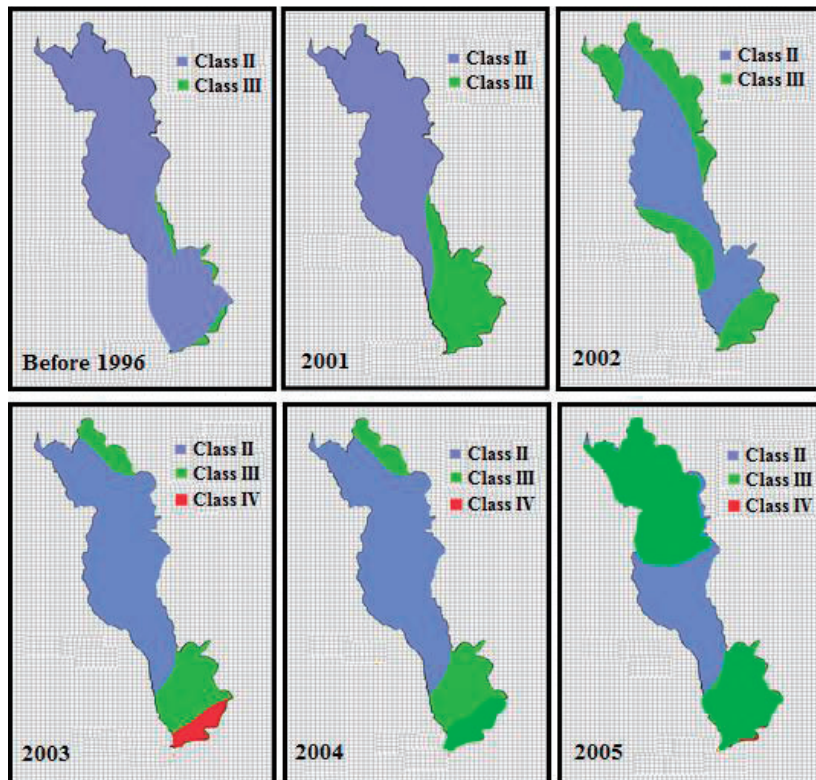


Figure 1 Water quality changes in the Lake Erhai

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1.2. Geographic features for causing lake eutrophication

The Lake Erhai is a typical deep and inland plateau lake. The maximum depth of the lake is 21.3m and average depth is 10.6m (Date of the “Three Lakes” in China: Lake Taihu is 1.89m, Lake Chaohu is 3.06m, Lake Dianchi is 5.03m). Partly because the lake is deep, the enclosed lake has poor water flow and exchanges capacity. The average hydraulic retention time is about 1004 days (Date of the “Three Lakes” in China: Lake Taihu is 309 days, Lake Chaohu is 168 days, Lake Dianchi is 916 days).

In addition, there are 23 main river inlets but only one natural river outlet for the Lake Erhai. Over the years, the annual inflow volume from watershed was $8.92 \times 10^8 \text{ m}^3$, but the annual outflow volume from the lake was $8.16 \times 10^8 \text{ m}^3$. The outflow capacity was relative limited. Besides, in 1977, a hydropower station, called Xierhe station, had been constructed in the downstream of the lake. Storing water in rainy season by this station further reduced the outflow capacity of the lake.

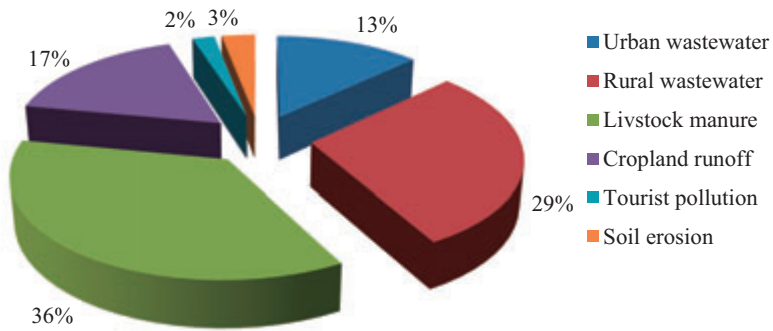
Moreover, the climate characteristics in the Lake Erhai region supply the good growth condition for aquatic phytoplankton with the big solar radiation intensity of $139.4 \sim 149.5 \text{ kCal/cm}^2$, the long sunshine duration of $2250 \sim 2480 \text{ hours/year}$, and the high average temperature of 16.2°C . Once the nutrient load is sufficient in the lake, the aquatic phytoplankton would be induced to multiply rapidly to cause eutrophication problem in the lake.

In conclusion, the unfavorable natural geographic conditions, in some extent, make some ecological safety problems such as eutrophication easily incurred in the Lake Erhai.

1.3. Serious agricultural non-point sources pollution

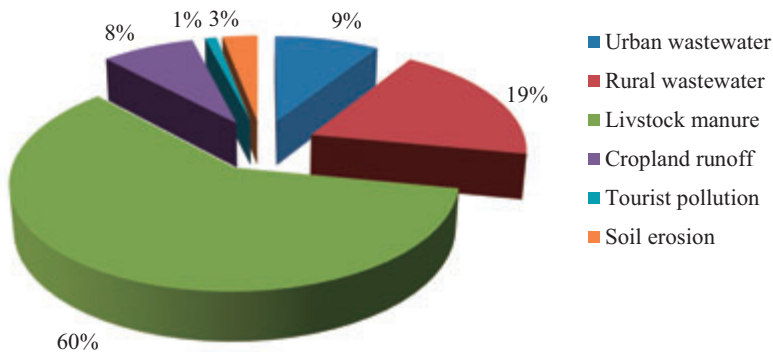
The existing research has demonstrated the added value of agricultural industry has strong correlation with the discharge amount of TN and TP in the Lake Erhai watershed. The increase of agricultural production is the biggest driving force of nutrients pollution, and moreover the grow trend of agricultural production has little potential to change within a short period of time (YANG: 2011). According to the current statistics data in Figure 2, the pollution sources of livestock manure and cropland runoff together contribute approximately 53% of nitrogen pollution and 68% of phosphorus pollution becoming the most important pollution sources in the Lake Erhai watershed. Rural wastewater is the subsequent important source, which contributes 29% of nitrogen pollution and 19% of phosphorus pollution. At the same time, other pollution sources including tourist pollution, urban wastewater and soil erosion make less contribution to TN and TP pollution.

TN pollution sources



(a) TN

TP pollution sources



(b) TP

Figure 2 Composition of TN and TP pollution sources in the Lake Erhai watershed

Due to the cheap labor cost, favorable climate condition and rich water and soil resources, the export-oriented agricultural economy has high comparative advantage in the Lake Erhai watershed. Taking garlic planting for an example, the garlic that grows in the watershed normally has more allicin content than other similar products, and moreover this garlic could appear in the market earlier than other similar products in China for at least 2 months. Thus, the sales market and prices of local garlic is very profitable for farmers. Another example is dairy breeding. The abundant natural resources in the watershed supply a nice breeding environment for dairy, especially for Holstein cows, Simmental cows and milk buffalo. Eryuan County locating in the upstream of the watershed is the biggest processing base of dairy products in the southwest of

China.

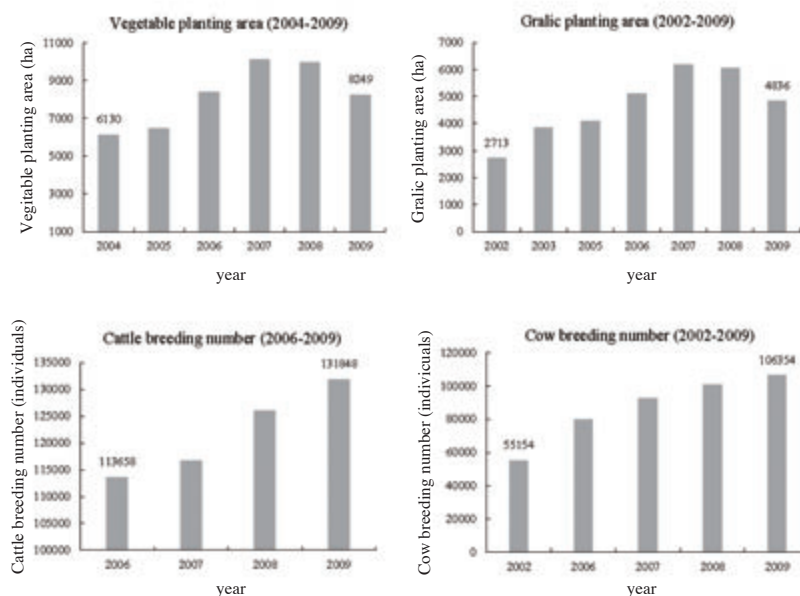


Figure 3 Annual changes of agricultural production scale in the Lake Erhai watershed

Relying on comparative advantages, in recent years, the breeding industry and vegetable planting industry have experienced a rapid development and gradually become the main income sources of local residents. Seeing the changes of agricultural production scale in the watershed in Figure 3, both the vegetable planting areas and the amount of cattle breeding experienced a significant increase in last ten years. At present, the watershed is the largest beef breeding base, the second largest pig breeding base and the important vegetable planting base within the prefecture.

However, from the perspective of nutrients pollution, on the one hand, vegetable requires more chemical fertilizer than grain crops for growth and farmers often apply fertilizer improperly in order to get high yield. For example, based on the results of field study (ZHAO: 2009), the nutrient balance ratios of garlic planting, which is the most popular vegetable crop, reach 230.82% for nitrogen and 589.23% for phosphorus. Simultaneously, with the expanding of vegetable planting area and the decreasing of grain crops planting area, farmers have to apply more fertilizer to grain crops to maintain total yield. To some extent, it also causes more fertilizer application. Overall, Figure 4 shows the significant increase in chemical fertilizer application in the watershed, and the amount of application reached 29725 t in 2009.

On the other hand, the livestock manure is another important source of nutrients pollution. The existing comparison study shows that the discharge pollution coefficients of cattle breeding are considerably higher than other livestock's, especially for dairy breeding which approximately produces manure of 19.4t per cattle in one year (ZHANG: 2006). Seeing the data in Figure 4, the amount of produced livestock manure in the watershed experienced a significant

increase in last ten years. However, this big amount of livestock manure has broken the balance between planting and breeding. The cropland areas are not enough to digest the excess of livestock manure so as to make more and more manure been dumped on the roadside. Due to the high content of crude protein amide in cattle manure and the local climate characteristic of high temperature and intensive rainfall, the manure nutrients became more easily to release.

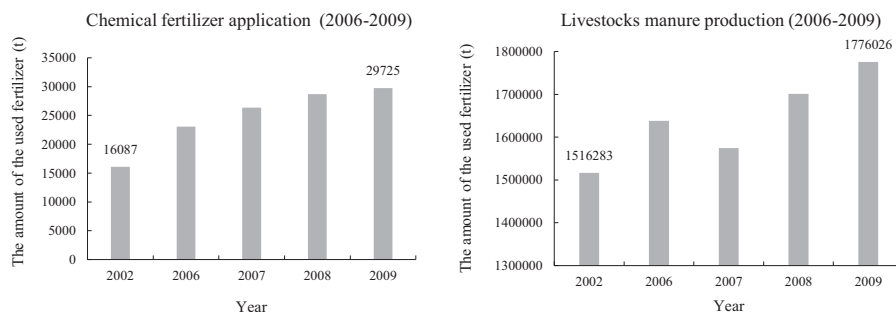


Figure 4 Annual changes of chemical fertilizer and livestock manure in the Lake Erhai watershed

Moreover, in the Lake Erhai watershed, like other places in China, farmers adopt Chinese family-contract responsibility system that makes agricultural pollution sources in the watershed to have properties of dispersibility, randomness and uncertainty. Therefore, it further increases the difficulty of controlling agricultural pollution in the Lake Erhai watershed. Currently, agricultural pollution sources, especially for the intensive livestock breeding and vegetable planting, in the watershed, cause a big pollution threat to water quality of the lake.

1.4. Distribution of pollution sources

With economic progress and population increase, the depth and breadth of land development in the Lake Erhai watershed constantly increase. On the one hand, Land use pattern in some extent determine the distribution of pollution sources; on the other hand, the unreasonable land use would enhance pollution risk. Based on the remote sensing survey of Environmental Monitoring Stations of Dali Prefecture, land use changes with the rising of elevation in the Lake Erhai watershed have been showed in Table 1 (LI:2011). The most of urban land, traffic land, cropland, and water area distribute on the place with elevation of lower than 2200 m, while the most of garden, grassland, scrubland, and forest land distribute on the land with elevation of higher than 2500 m. Thus, the main pollution sources concerning urban and agriculture concentrate on flat lands which are lower than 2200 m. Seen from the Digital Elevation Model map of the Lake Erhai watershed in Figure 5, the light color areas are likely concentrate more pollution sources. Currently, the industrial pollution sources mainly locate at Xiaguan city and Fengyi town in the south, Yinqiao town in the west and Shangguan town in the north. Tourism pollution sources mainly concentrates at Dali old town in the west and Cibihu town in the north. Agricultural pollution sources scatter over the whole watershed.

Land use	Lower than 2200m		2200~2500m		2500~2800m		Higher than 2800m	
	km ²	%	km ²	%	km ²	%	km ²	%
Urban land	144.31	92.70	8.17	5.25	3.03	1.94	0.16	0.10
Traffic Land	6.03	96.90	0.19	3.10	0.00	0.00	0.00	0.00
Cropland	355.83	79.66	54.08	12.11	31.30	7.01	5.46	1.22
Garden	0.92	6.82	1.26	9.31	0.13	0.98	11.23	82.90
Grassland	124.14	28.42	128.38	29.39	42.07	9.63	142.22	32.56
Scrubland	121.31	26.37	191.68	41.66	79.69	17.32	67.40	14.65
Bare land	2.03	53.43	1.46	38.49	0.31	8.08	0.00	0.00
Water area	275.17	99.80	0.21	0.08	0.17	0.06	0.18	0.06
Forest land	21.78	2.71	171.96	21.40	217.34	27.05	392.43	48.84
Total	1051.52	40.41	557.39	21.42	374.03	14.37	619.07	23.79

Note: “%” represents the area percentage of the same land use category.

Table 1 Land use changes with the rising of elevation in the Lake Erhai watershed

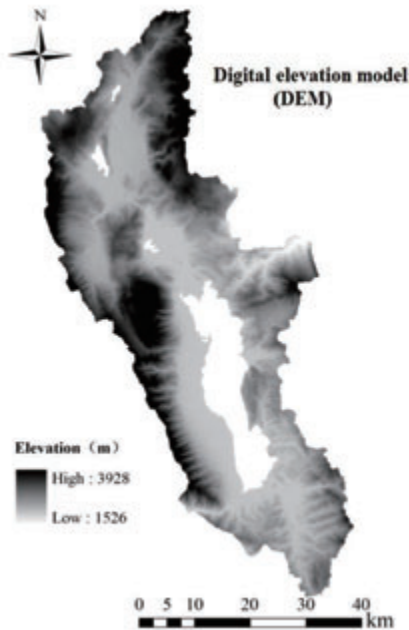


Figure 5 Digital elevation model map of the Lake Erhai watershed

Agricultural practices make up the most of nutrients pollution sources in the Lake Erhai watershed. Based on the pollution discharge coefficients and agricultural production data of 2009 year (SHANG: 2012), the amount of agricultural pollution produced from every town have been calculated and presented in Figure 6. The northern watershed gathers a large proportion of agricultural TN and TP pollution and the western watershed takes a second place. In contrast, the

eastern watershed has less agricultural pollution contribution. Overall, the notable towns were Sanying, Cibihu, Yousuo, Xizhou, Shangguan, Dali, Fengyi etc. Among them, the biggest agricultural pollution come from Yousuo town with contributing 584 t/a of TN pollution and 80t/a of TP pollution. In total, agricultural pollution sources in the Lake Erhai watershed produced 4485t/a of TN pollution and 688 t/a of TP in 2009.

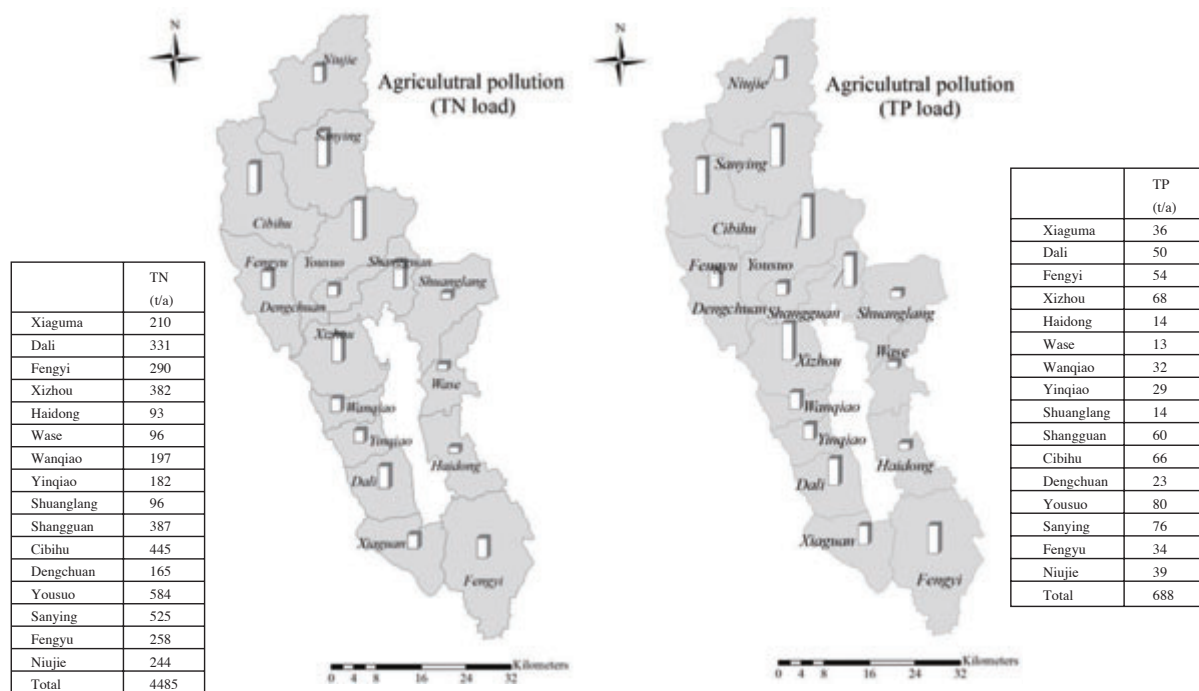


Figure 6 Spatial distribution of agricultural pollution in the Lake Erhai watershed

2. Effective measures and improvement of water quality

2.1. Effective measures and efforts

2.1.1. Policies and regulations

(1) “Management regulations of the Lake Erhai”

In 1984, prefecture government enacted “Interim management measures of the Lake Erhai” to started levying water charge and fishery resources charge, closing lake for prohibiting fishing in certain period of a year, and establishing special management organization that is the Lake Erhai Administration Bureau.

In 1988, people's congress of Dali prefecture adopted “Management regulation of the Lake Erhai” to replace “Interim management measures of the Lake Erhai”. From then on, the water environmental policy of the Lake Erhai entered a legal track which played an important role on water protection of the Lake Erhai. This rule regulated the development and usage of water resources, the management of lakeside zone, prevention of industrial and domestic pollution, and ecological protection and so on.

However, until then the overall thought of water policy is still focusing on the

development of the Lake Erhai and has not reflected environmental protection idea. The shortages of this regulation were: (a) not prohibiting cage culture in the lake; (b) having not enough attentions to ecological protection; (c) and moreover the regulations on functions of the Lake Erhai Administration Bureau have poor maneuverability.

In 1998, people's congress of Dali prefecture adopted the revised version of "Management regulation of the Lake Erhai" with making water environmental protection policy of the Lake Erhai into legal norms. Nevertheless, this regulation focused on regional problems and had not embodied systematic and comprehensive treatment idea.

By 2004, the revised regulations implemented well the principle of making protection and restoration a priority, and management of the Lake Erhai Administration Bureau was transferred to Dali City so that the status and functions of this bureau have been enhanced.

As experts acknowledged, the driving force to water quality degradation is the low water level and large amount of influent pollutants. The significant role of "Management regulation of the Lake Erhai" is making a regulation on water level adjustment. The lowest and highest water levels were set as 1972.61 m and 1974.31 m, respectively.

The regulation enacted in 1998 made the water management of the Lake Erhai involved not only the water environment in the lake but also the whole watershed which area could produce runoff to feed into the lake. Thereafter, the regulations insist this correct theory. Overall, "Management regulations of the Lake Erhai" is the most important regulation in water management and protection of the Lake Erhai.

(2) "Three Returns, Three Restorations"

From 1999 on, Dali prefecture started carrying out the policy of "Three Returns, Three Restorations" that is returning cropland to forestry, returning pond to lake and returning house to wetland. In 2001, the government invested more than 13 million RMB to implement this policy and until 2002 the areas of returning the pond to lake, returning cropland to forestry and returning house to wetland were 296.3 ha, 484.9 ha and 41.1 ha, respectively. Simultaneously, afforestation has been carried out by 333.3 ha.

"Three Returns, Three Restorations" and water level adjustment policy supplement each other. In order to raise the water level of the Lake Erhai, it must rely on effective implementation of "Three Returns, Three Restorations". In turn, the effective implementation of "Three Returns, Three Restorations" also should depend on the legal support of water level adjustment policy.

(3) "Two Cancels, Two Prohibitions"

From the end of 1996, Dali prefecture implemented the policy of "Two Cancels" that canceling fishing power boat and cage culture in the lake. By 1997, 11187 net cages and 2579 fishing power boat had been forbidden. The pollution from water aquaculture and power boat had been effectively prevented.

In November 1997, the production, sale and usage of phosphorus-based detergent were prohibited in the Lake Erhai watershed. Besides, in September 2006, the production, sale and usage of foam plastic tableware and the plastic that is not easy to degrade were also prohibited. This policy played an important role in preventing phosphorus pollution and "white pollution".

Nevertheless, implementation of water management policy in the Lake Erhai watershed

still exist the problem of capital shortage. According to the “Lake Erhai watershed protection planning (2003-2020)”, before 2020 there are 34 projects needing 3 billion RMB investment. Taking the period of Chinese 11th five year plan for an example, in 2006 and 2007, the actual investment of Dali prefecture was 102.7 million RMB which only occupied 7.01% of total planned investment. Like many other places in China, the environmental investment is insufficient in this watershed. In addition, the Eryuan County locating in the upstream watershed was ever a strong economic county, but after setting limits on developing heavily-polluting industries for environmental protection reasons, this county also lost many chances of economic development. At present, ecological compensation system have not been constructed well so that the problem of how to balance the relationship between economy and environment should be further considered in local water management policy.

2.1.2. Engineering and management measures

Chinese 9th five year period (1995-2000): Based on the long-term pollution management experience, the six projects have been identified as key programs of water pollution management in the Lake Erhai watershed (see Fig. 7). In the this period of 1995-2000, some important measures are listed as follow: (1) governing pollution from 23 important industrial point sources; (2) carrying out demonstration project of sediment dredging in the Lake Erhai; (3) improving comprehensive water environment for Miju River and Eighteen Streams; (4) constructing Eryuan wastewater treatment plant, Eryuan solid waste landfill, and biogas digester over the watershed; (5) carrying out ecological protection, afforestation, and landscape treatment projects; (6) improving the ability of water environmental monitoring;(7) promoting digitalization and informatization construction of the Lake Erhai; and (8) policy making of water management regulation and watershed development plan. Facts proved that these measures not only played important role on maintaining water environment of the Lake Erhai but also provided significant demonstration effect for projects to be implemented later.

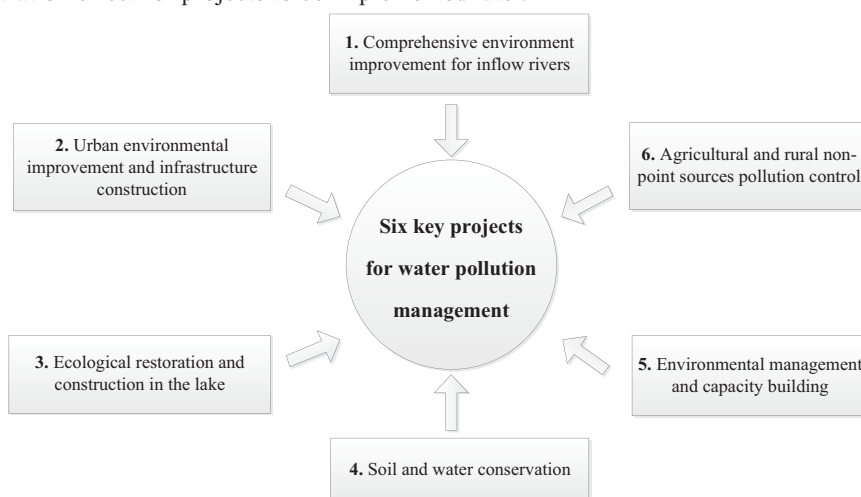


Figure 7 Six key projects for water pollution management in the Lake Erhai watershed

Chinese 10th five year period (2001-2005): On the basis of carrying out six key projects, the emphasis of pollution control projects had been put on point pollution sources, non-point pollution sources and inner sources pollution. The detail information of the implemented measures in this period has been listed in Table 2 (PENG: 2005).

Central treatment facilities: In theory, domestic wastewater is not directly discharged into the Lake Erhai. However, in fact part of the sewage did not access into sewage pipe but discharged into the river channel without treatment. Therefore, the construction of wastewater treatment plants and pipeline network became the important projects to be implemented.

Non-point sources pollution management: In this period, the pollution from planting and breeding are very outstanding. If these non-point sources pollution was not be controlled well, a large number of nutrients pollution would be released into the rivers and lake. However, the effective measures for controlling the non-point sources pollution were scarce. Some traditional measures had been implemented in this period such as biogas digester construction, soil and water prevention, and afforestation.

Inner sources pollution: Sediment dredging came to be valued in this period and was considered as an effective measure to control inner sources pollution in the lake. The measure could reduce inner sources pollution, increase capacity of the lake, and balance the growth of hydrophyte. From Nov. 2000 to Aug. 2001, a sediment dredging project with dredging volume of 3.029 million m³ and dredging area of 0.23 km² was carried out at the river outlet of Denglong River and Shacun Bay in Xizhou town, respectively.

Water resources adjustment and control: Water from the Yangbiji River into the Lake Erhai, water supply and demand contradiction was relieved, water resources quantity of the lake was ensured, and the ability of water purification was enhanced.

Science and technology demonstration engineering: Researches was made in the terms of sediment recycling, deposit sediment properties, and non-point sources pollution control measures. Besides, digitization of the Lake Erhai was done to finish drawing the 1/5000 underwater map and 1/500 land topographic map. Overall, the field surveying and mapping work was basically finished for digitization of the Lake Erhai.

Environmental management: This measure mainly focused on environmental monitoring capacity improvement involving management mechanism construction of protection zones in the Cangshan Mountains range and Lake Erhai watershed to make environmental quality evaluation more timeliness and accuracy.

Chinese 11th five year period (2006-2010):The major point of water pollution management in this period was to take the industrial economy structure adjustment as the basic measures, to mainly solve pollution problems in the terms of urban pollution, rural pollution and river comprehensive environment, and to firmly implement the six key projects. Moreover, the project investment, scale and breadth were all larger than before. In this period, the cumulative realized investment reached 1.711 billion RMB. The planned project had 29 items, and the whole project completion rate reached 96.6%. The entire wastewater treatment instrument normal operation ration reached 97.87%. The detail information of the implemented measures in this period has been described in Table 3.

Some environmental effects of the implemented projects are described as followed: (1) Construction project of Junmachang solid waste landfill made the produced waste from Eryuan County and three counties of Dali City which had approximately 220 thousand people to be effectively treated; (2) Pipeline network construction in the eastern Dali City (Phase II) and the area along the Boluo River let the domestic wastewater from these area to be effectively intensively treated; (3) The widely implemented soil testing and formulated fertilization reduced chemical fertilizer usage amount and release amount getting both social and environmental benefit; (4) The widely construction of methane tank and sanitary dry toilet saved a large amount of energy, improved sanitary environment of villages, and moreover controlled fecal pollution in the Lake Erhai watershed; (5) Public welfare forest construction and water and soil erosion treatment reduced the amount of soil and water erosion. on the whole, through the effectively implementation of various water pollution projects in this period, the non-point sources pollution, point sources pollution and the purification capacity of wetland had been improved. The environmental awareness of local residents was also gradually raised.

Overall, it can be realized that the implemented projects in Chinese 9th five year period (1995-2000) mainly played the demonstration effect for water pollution control in the Lake Erhai watershed, the effective projects begun to take shape in Chinese 10th five year period (2001-2005), and the scale effect of water pollution management projects began to reflect in Chinese 11th five year period (2006-2010). With the accumulation of experience, raise of environmental awareness and increase of engineering efficiency, the water environmental quality of the Lake Erhai is getting change for better.

Table 2 Projects of water pollution management implemented in the Lake Erhai watershed in the period of 2001-2005

Project category	Construction years	Project name
Treatment of point source pollution	1999~2003	Wastewater treatment plant of Dali City, pipeline network construction of Xiaguan town
	2002~2004	Pipeline network construction from Xiaguan town to Dali old town
	2002~2005	Underground arterial drainage channel construction in the south shore of Xier River
	2001~2004	Wastewater treatment plant of Eryuan County and pipeline network construction
	2000~2005	Comprehensive treatment of influent rivers (Miju River, Luoshi River, Boluo River)
	2001~2002	Dafengbasolid waste landfill of Dali City
	2002~2005	Solid waste landfill of Eryuan County
Treatment of non-point source pollution	2001~2005	Waste treatment and biogas digester construction
	1999~2000	Soil and water prevention
	2001~2005	Ecological agricultural construction in Qiliqiao town
	1999~2005	Afforestation and returning cropland to forest land
Ecological restoration (inner source pollution)	2001~2005	Comprehensive treatment and ecological protection of Lake Xihu, Lake Cibihu and Lake Haixihai
	1999~2005	Sediment dredging (Phase I), and ecological restoration of lakeside zone in the western lake
	2000~2005	Biodiversity protection
Water resources adjustment and control	2001~2005	Diverting Water from the Yangbiji Jiang River into the Lake Erhai
	2002~2005	Automated management and optimal scheduling
Science and technology demonstration	2001~2005	Treatment technology development in the terms of sediment, river channel and non-point sources pollution.
	1999~2002	Digitization of the Lake Erhai
Environmental management	2000~2005	Management mechanism construction of protection zones in the Cangshan Mountains range and Lake Erhai watershed
	2000~2005	Environmental monitoring capacity construction of the Lake Erhai

Table 3 Projects of water pollution management implemented in the Lake Erhai watershed in the period of 2006-2010

Project category	Project contents	Project scale
	Junmachang solid waste landfill engineering	40t/d
	Pipeline network construction and transformation of Xiaguan town	Transformation: 14.8 km Construction: 58.9 km
	Pipeline network construction of the eastern Dali City (Phase II)	80254.1 km
	Pollutant intercepting dam construction along the Lake Erhai	12.7 km
	Waste transfer station and transporting system construction	11 waste transfer stations and 603 dump pits
	Pipeline network construction of the eastern Dali City (Phase III)	38.59 km
	Pipeline network construction of the Fengyu areas along Luoshi River	25.67 km sewage networks and 18.17 km storm drainage networks
Urban environmental improvement and infrastructure construction	Waste water treatment project in Xizhou town	2000 m ³ /day wastewater treatment plant
	Pipeline network construction in Dali old town	22861 km sewage networks and 20469 km storm drainage networks
	Pipeline network construction in Dali tourism resort district	13694 km sewage networks and 14063 km storm drainage networks
	Wastewater treatment plant of Eryuan construction, and pipeline network construction (Phase II)	4000 m ³ /day wastewater treatment plant
	Wastewater treatment plant of Dengchuan construction, and pipeline network construction	4000 m ³ /day wastewater treatment plant
	Rural wastewater collection and treatment systems	200 wastewater treatment system
	Medical waste treatment plant construction	5 t/d
	Solid waste landfill of Eryuan County construction	25 t/d for short term and 60 t/d for long term

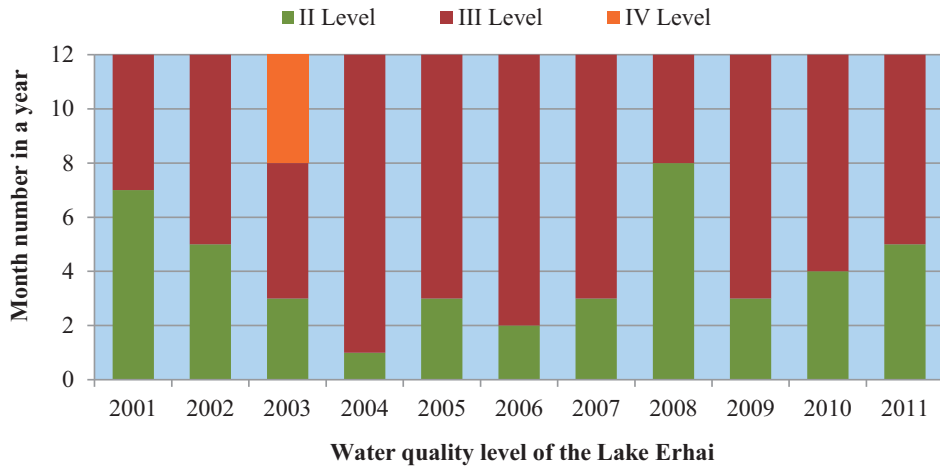


Figure 8 Water quality changes of the Lake Erhai. The water quality level is decided by the National Environmental Quality Standards of China for Surface Water (GB 3838-2002).

2.2. Water quality improvement of the Lake Erhai

The Lake Erhai watershed was experiencing a rapid economic development, but the water quality of the Lake Erhai has not been further worse. It indicates that the constant effort of water pollution management in the Lake Erhai watershed is effective. Although harmful algal bloom in the Lake Erhai in 1996 and 2003 gave the deep attacks on local people who need to live by water resources of the Lake Erhai, the water quality of the Lake Erhai was changing for better after 2004. The monitoring data of water quality showed that (see Figure 8) basically from 2004 the number of month having water quality of II level gradually increased. In particular for 2008, there was 8 months reached the water quality of II level.

Furthermore, seen from water quality index changes in Figure 9-11, after 2004 the average concentrations of both COD and TP in the Lake Erhai showed an obvious decrease trend. Although the average concentration of TN presented a relapse in 2009 and 2010, the overall trend was moving in a good direction. Thanks to the efforts of local government in controlling pollution in the Lake Erhai watershed and improving the local environment, the implemented water pollution management measures are effective and water quality of the lake has not been persistently deteriorated but improved. In Fig. 12, there are two photos taken on June 6, 2010 by Chinese newspaper of People's Daily. They show the wetland park by the Lake Erhai and a local people jumps into the Erhai Lake to swim. As the "mother lake" by local people, the Lake Erhai is so beautiful as if it recovers to the former beauty.

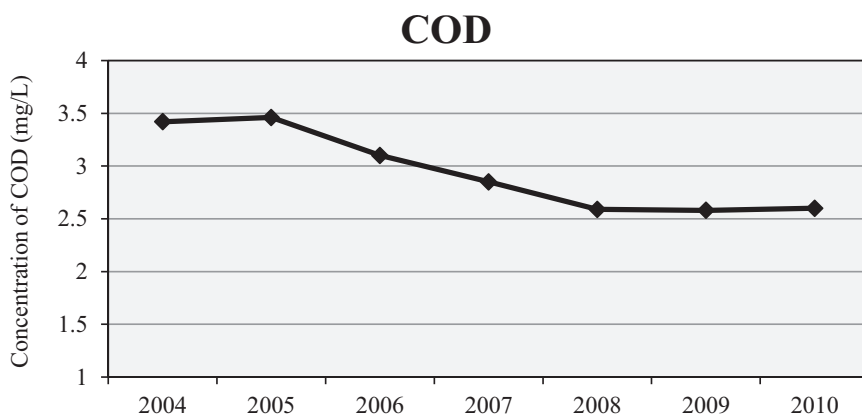


Figure 9 Monitoring data of COD in the Lake Erhai in the period of 2004-2010

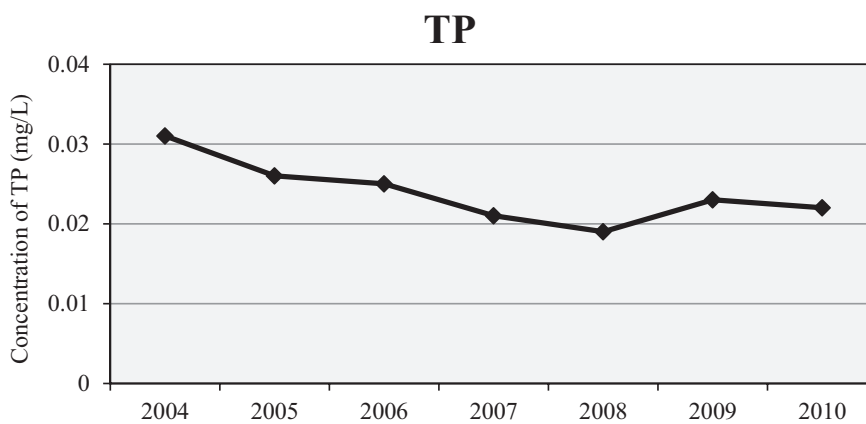


Figure 10 Monitoring data of TP in the Lake Erhai in the period of 2004-2010

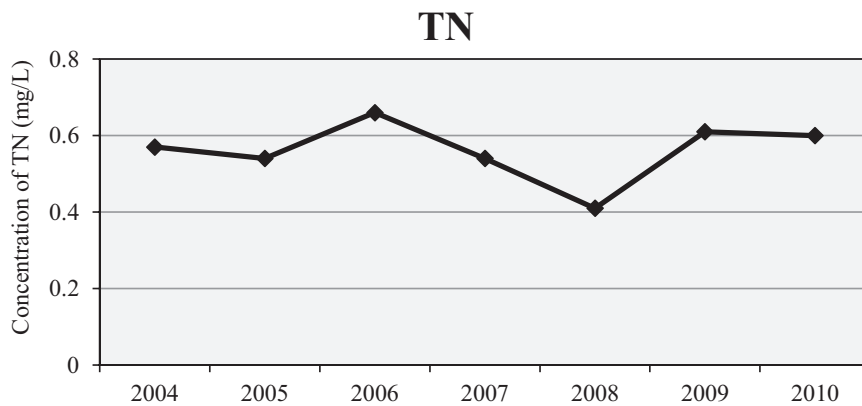


Figure 11 Monitoring data of TN in the Lake Erhai in the period of 2004-2010



Figure 12 Photos of the Lake Erhai taken by Chinese newspaper of People's Daily in 2010

Due to the significant contribution of water pollution management measures in the Lake Erhai watershed, the effective measures have been summarized as “Lake Erhai experience” to be used for reference to other rivers and lakes. In 2010, the water pollution management framework of the Lake Erhai which is based on six key projects was rewarded with the first prize of the scientific and technical award by Ministry of Environmental Protection of the People's Republic of China.

3. Experiences of water pollution management in the Lake Erhai watershed

The incidents of algal bloom happened in 1996 and 2003 are difficult to erase from local people's memory. Since 2003, the Dali government has spent more than 2 billion yuan (US\$299 million) to improve water quality of the Lake Erhai. Although this large environmental investment is so hard for this underdeveloped area, they got this achievement done on schedule. At present, the water environmental quality of the Lake Erhai is changing for better. What is more important, the later environmental protection work could be benefit from “Lake Erhai experience”. Thus, it should be realized that water pollution management experience of the Lake Erhai is derived from heavy cost in environment and economy. Therefore, it is very precious. Without a doubt, the “Lake Erhai experience” can offer water pollution management reference for other rivers and lakes in China and other countries over the world. Sharing the “Lake Erhai experience” is a significant thing to do.

(1) Clear purpose and management strategy

“One clear objective”: The objective of water environmental protection of the Lake Erhai is to make water quality reach II level of Chinese surface water quality standard.

“Two integrations”: The integration of pollution sources control and ecological

restoration; the integration of engineering measures and management measures.

“Three transformations”: The transformation from in-lake water quality improvement to watershed pollution management; the transformation from special problem treatment to comprehensive treatment; the transformation from special department governance to collaborative management by departments at all levels.

“Four focuses”: Four focuses of water pollution management are urban wastewater treatment, ecological restoration of lakeside, environmental improvement of influent rivers and agricultural non-point sources pollution treatment.

“Five innovations”: Innovations on mainly five aspects of awareness, mechanism, system, legal system and technology.

“Six key projects”: Six key projects for water pollution management in the Lake Erhai watershed includes: 1. Comprehensive environment improvement for influent rivers; 2. Urban environmental improvement and infrastructure construction; 3. Ecological restoration and construction in the lake; 4. Soil and water conservation; 5. Environmental management and capacity building; 6. Agricultural and rural non-point sources pollution control.

(2) Long effective management mechanism

Because the water pollution management of the Lake Erhai watershed was always on both Dali City and Eryuan County account, the problem of overlapping management was in serious trouble. In 2004, Jiangwei town and Shuanglang town which were belonged to Eryuan County were incorporated into Dali City, and moreover Lake Erhai Administration Bureau was transferred into the governance system of Dali City. Therefore, from then on all the Lake Erhai was only governed by Dali City.

The responsibility for water pollution management was delegated down to managers of each-level department. The pollution management area and internal rivers of every town were cleared divided. Special person was employed to be in the charge of every river reach.

These two points have been incorporated into the new “National Water Pollution Prevention Law, China” which was enacted in Feb. 2008. This is one contribution of “Lake Erhai experience” to Chinese water environmental protection.

(3) Much attentions on legal system building

For a long time, the Lake Erhai stores flood with bad water quality in summer and autumn seasons but discharge clean water to generate electricity in winter and spring seasons. The low water level accelerated the deterioration of water quality. On the basis of the repeating scientific verifications, in 2004, according to legal procedures “Management regulations of the Lake Erhai” had been revised. The lowest water level of the Lake Erhai was raised from 1971m to 1972.61 m to ensure ecological use of water. In the Chinese 10th five year period (2001-2005), besides for the “Two Cancels”, local government legally carried out the “Three Returns, Three Restorations”. Simultaneously, sand excavation on the mountain along the lake was regulated.

From 2004 on, closing lake and prohibiting fishing for the time of half a year in the Lake Erhai was implemented. In addition, Dali government also enacted the implementing measures in the terms of solid waste management and bottomland management. All above regulations and policies supplies legal ground for water pollution management in the Lake Erhai watershed.

(4) Relying on technology extension and application

The monitoring network of water quality in the Lake Erhai and agricultural non-point pollution sources in the watershed was scientifically established. On the aspect of the influent rivers, the monitoring frequency of water quality was once a month. Underwater topographic map of the Lake Erhai with 1/5000 scale and land topographic map with 1/500 scale were surveyed and mapped. The digitization of the Lake Erhai was primarily finished and the information management system was also primarily constructed. The Research Center of The Lake Erhai was established specifically for research and development of water pollution control technology and management in the Lake Erhai watershed.

In Chinese 11th Five year period (2006-2010), due to the strives of local government, the biggest scientific research project of environmental protection after new China founded, namely Major Science and Technology Program for Water Pollution Control and Treatment, set the Lake Erhai as pre-eutrophication lake to make pollution prevention research. This national research project attracted a lot of good researchers and a large amount of research fund to support technology development of water pollution measures in the Lake Erhai watershed. Particularly, technologies for diffuse sources pollution control experienced considerable progress in the watershed. So far, not only domestic technology development, but also technology introduction from other countries has contributed to water pollution management in the watershed such as Johkaso technology introduced from Japan and ecological dry toilet technology introduced from Europe.

(5) Innovative investment and financing system

Treatment and management of water pollution needs a large of money. Only in the Chinese 11th five year period (2006-2010), the total investment of water pollution management was approximately 1.5 billion RMB. Therefore, local government was always seeking the effective investment and financing system to raise fund from various channels (YANG: 2009). Firstly, incorporate water resource rates of the Lake Erhai into the local water rate. There is 1 RMB per cubic water used for water management of the Lake Erhai. Secondly, seek the help from bank. In the first season of 2009, Finance Bureau of Dali Prefecture won the money of 0.46 billion RMB from the World Bank to specially use for pollutant intercepting dam construction along the Lake Erhai, and in May of the same year, won the credit loans of 70 million RMB from Prefecture Bank for six key projects construction. Thirdly, rely on the social power. For example, Denglong River wastewater treatment plant (5000 m³/day) took lead in adopting BOT (Build, Operate and Transfer) model to attract investment of 3.5 million RMB from Zhongqing Technology Limited

Company. Besides, try actively to get the support from state and national capitals. So far, the objective of investment and financing goes well. It is vital to ensure the efficiency of water pollution management of the Lake Erhai.

(6) Public participation

Water environmental protection is a regional and systemic project which needs lead by government and participation of the whole social members. Dali prefecture attaches importance to enhance the consciousness of environmental protection from children. The protection of the Lake Erhai appears in textbooks for middle and primary school. Meanwhile, environmental protection concepts have been promoted through various approaches such as newspaper, broadcast, wall newspaper and television. Propaganda of environmental protection can be seen everywhere in the Lake Erhai watershed (Figure 13). The awareness of “Lake Erhai Clear, Dali Prosperous” and “Protecting Lake Erhai like protecting our eyes” is so deeply into local residents’ mind. The achievement of local water pollution management is closely linked with the support of public participation.



Figure 13 Propaganda of environmental protection can be seen everywhere in the Lake Erhai watershed

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水化硅酸钙与沸石强化人工湿地处理水中低浓度氮磷研究

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本研究针对入湖河流、城市尾水和景观水体等低浓度、大流量水质特点, 通过在人工湿地的传统基质砾石中添加沸石、水化硅酸钙等对氮磷具有富集作用的吸附材料, 构建基质强化型混合基质人工湿地系统, 加强其对氮磷营养盐的去除能力。

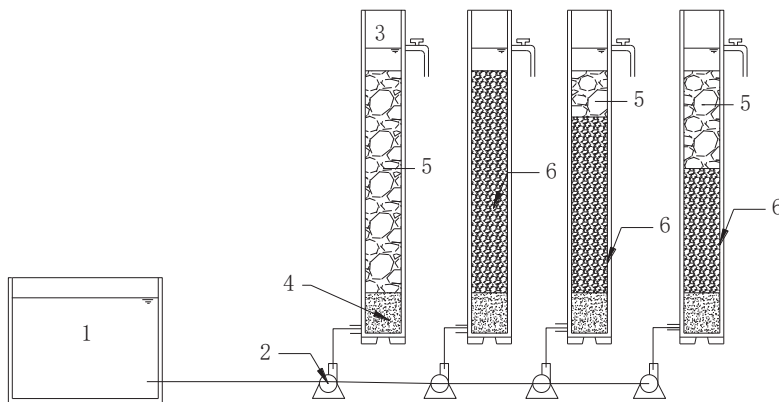
水化硅酸钙(CSH)是以生石灰、石英粉为原料, 经 150℃-210℃ 水热合成的无机材料, 具有极高的磷去除能力。其作用基于晶析原理, 促进水中的磷酸根离子与钙离子相结合, 以羟基磷酸钙的形式析出, 并附着在晶种表面, 从而达到去除目的。

沸石是吸附性能良好的天然硅铝酸盐, 其内部的孔道和空穴中的具有大量可交换的阳离子, 决定了沸石在不影响其骨架结构的条件下具有较强的阳离子交换能力。沸石的结构组成和吸附交换特性决定了沸石的良好吸附效果。

1. 水化硅酸钙与沸石滤柱试验

1.1. 材料和方法

试验装置如图 1 所示, 过滤柱由内径为 9cm 的 PVC 管制成, 柱体总高 80cm, 底部放置了 10cm 厚度, 直径为 1-2mm 的砾石作为承托层, 承托层上为过滤介质, 厚度为 55cm, 有效水深为 70cm, 试验采用个 4 组过滤装置, 编号柱 1、柱 2、柱 3、柱 4, 柱 1 全部填充水化硅酸钙, 柱 2 全部填充沸石, 柱 3 水化硅酸钙和沸石填充比例为 1:3, 柱 4 水化硅酸钙填充比例为 1:1。经测算, 4 组过滤装置的孔隙率在 64.72—69.55%。



1 原水箱, 2 单口蠕动泵, 3 过滤柱, 4 砾石承托层, 5 水化硅酸钙 6 沸石

图 1 四组滤柱装置图

设置四种不同的滤速, 分别为 0.7m/s, 0.175m/s, 0.058m/s, 0.029m/s 时, 滤柱对模拟污

1 上海交通大学环境科学与工程学院

水的净化效果。装置为连续运行，每个水力停留时间连续测定 7 天。每天取得的出水经过抽滤后，用钼酸铵分光光度法，纳氏试剂比色法测定磷酸盐浓度和氨氮浓度两项指标。

1.2. 试验结果

1.2.1. 除磷效果

如图 2 所示,在相同的滤速条件下,单一水化硅酸钙滤柱对磷酸盐的去除占有绝对优势,在滤速为 4.2m/d,1.392m/d,0.696m/d 时,四个滤柱的平均去除效果为:1 号滤柱>4 号滤柱>3 号滤柱>2 号滤柱。滤速为 16.8m/d 时,四者去除效果相差不大。由此可见水化硅酸钙对磷酸盐的去除起到主导作用。在滤速由 16.8m/d 变为 0.696m/d 时,单一水化硅酸钙滤柱的平均去除效果逐渐升高,由 84.68%升至 96.81%;单一沸石滤柱的平均去除效果下降,由 83.79%变为 75.13%。对于混合滤柱来讲,随着滤速的降低,对磷酸盐的去除效果越好,其中水化硅酸钙与沸石 1:1 混合的滤柱,平均去除率可达 96.39%,略好于 1:3 混合的滤柱的 95.39%平均去除率。

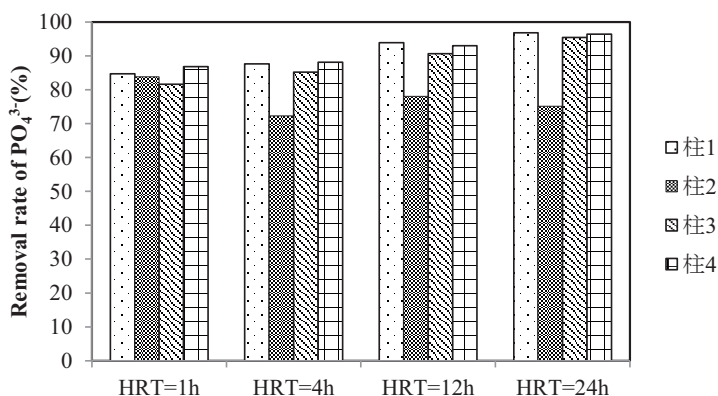


图 2 不同滤速下磷酸盐去除效果

1.2.1. 除氨氮效果

如图 3 所示,当滤速为 16.8m/d, 4.2m/d, 1.392m/d 时,在同一种滤速条件下的四种滤柱的平均去除效果为:2 号滤柱>3 号滤柱>4 号滤柱>1 号滤柱。当滤速为 0.696m/d 时,四者去除效果相差不大,3 号滤柱最低,为 76.29%,2 号滤柱最高,为 77.44%。由此可见,天然沸石在滤柱的动态吸附中起到主导作用。在不同的滤速条件下,2 号,3 号,4 号滤柱的平均去除率变化基本一致。2 号单一的沸石滤柱随着滤速的降低,平均去除率增大,由最初的 62.06%升高到 85.11%,随着滤速的进一步升高,平均去除率有所降低,但是维持在 77%左右,变化不明显。3 号 4 号混合滤柱的变化规律与 2 号相似,在最初滤速为 16.8m/d 降为 4.2m/d 时,平均去除率变化较大,由 3 号滤柱由 57.36%升为 82.56%,4 号滤柱由 55.84%升为 77.19%,随后随着滤速继续降低,变化较小。由此可以看出,氨氮的吸附主要取决于沸石,并且在滤速为 4.2m/d 时,可以达到最佳去除效果。

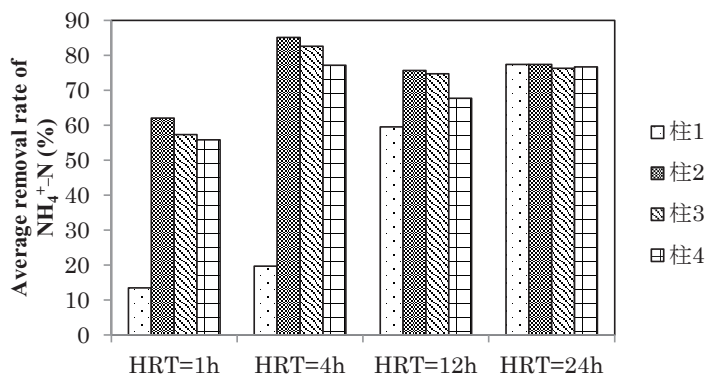


图3 不同滤速条件下平均氨氮去除率

2. 水化硅酸钙和沸石混合基质强化潜流湿地效果

本研究通过构建天然沸石和水化硅酸钙为基质材料的新型人工潜流湿地装置，并以砾石基质为对照，考察了潜流湿地系统对景观水的净化效果，以期了解该装置处理低污染景观水的运行效果。

2.1. 材料和方法

采用自行设计的水平流潜流人工湿地装置2台，由8mmPVC材质构建，每台尺寸为1.3m×0.5m×0.70m(L×W×H)，见图4。

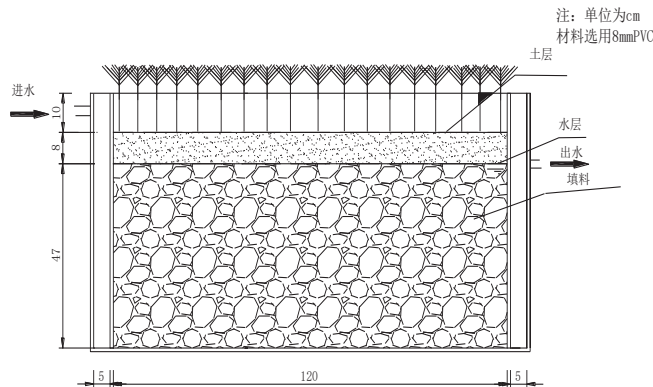


图4 水平潜流人工湿地模拟装置

沿垂直方向，基质层厚度为0.55m（有效水深为0.47m），上覆土层为0.10m，芦苇栽入土层中，其根系则直达装置底部。沿水流方向，依次为进水槽，湿地装置和出水槽，在进水槽与湿地装置之间和出水槽与湿地装置之间均以穿孔板相隔，以保证布水和走水的均匀。进水槽、湿地装置和出水槽分别为0.05m、1.20m和0.05m。其中一台装置选用天然沸石和水化硅酸钙混合基质（重量比为280kg/24kg）作为填料，记作HW3；另一台装置选用普通砾石（重量537kg）作为单一填料，记作HW4。

天然沸石材料：粒径3~5cm。该天然沸石为丝光沸石，但也含有石英和长石成分，氨氮

吸附法测定的阳离子交换容量达 1.77mmol/g (相当于最大氨氮吸附量 24.78mg/g)。

水化硅酸钙材料：粒径 3~5cm，主要成分为硬硅钙石 (xonotlite)。其对水中的磷具有良好的去除效果，去除能力达到 137 mg/g。

芦苇植物：其根系发达，移栽时尽量保护新芽及根的完整性。试验前洗净泥土，分割成单株，移栽于模拟人工湿地中，种植间距为 15cm*15cm，每个装置种植数量为 21 株。

试验装置设置于上海交通大学植物园景观水体旁的玻璃房内。装置于 2011 年 6 月 15 日至 2012 年 6 月运行。水力负荷采用 0.3m³/m²·d。

2.2. 试验结果

2.2.1. TP 去除效果

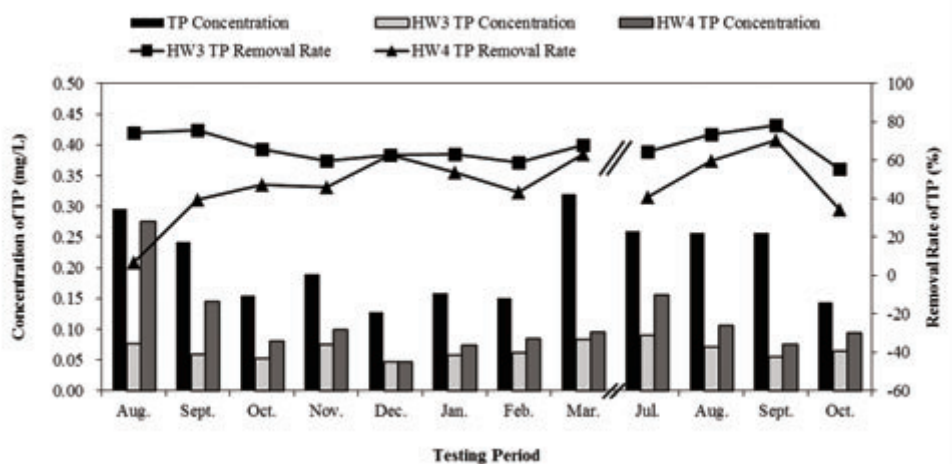


图 5 混合基质潜流湿地对 TP 的去除效果

由图 5 可知，HW3 对 TP 的去除率为 22.0~78.1% (平均 60.8%)，HW4 相对去除效果较差，但其出水 TP 浓度基本也可维持在 0.2mg/L 以下。HW3 中的水化硅酸钙基质所产生的 Ca²⁺ 离子，以及天然沸石基质所产生的 Ca²⁺、Al³⁺、Fe³⁺ 等多种离子很容易能吸附或晶析水体中的水溶性磷，从而达到去除可溶磷酸盐的目的。而 HW4 基本只能通过植物吸收和对 SS 的拦截作用来去除污染物，因此其对磷的去除效果也较差。

2.2.2. 总氮去除效果

水平潜流人工湿地装置对 TN 的去除效果如图 6 所示，在进水 TN 浓度为 0.54~1.91mg/L 时，2 台装置 HW3 和 HW4 对 TN 的去除率分别为 27.6%~93.2% (平均 50.5%)，8.4%~86.3% (平均 41.2%)，虽然去除率波动较大，但是复合基质人工湿地装置对 TN 的平均去除率仍优于砾石基质人工湿地。

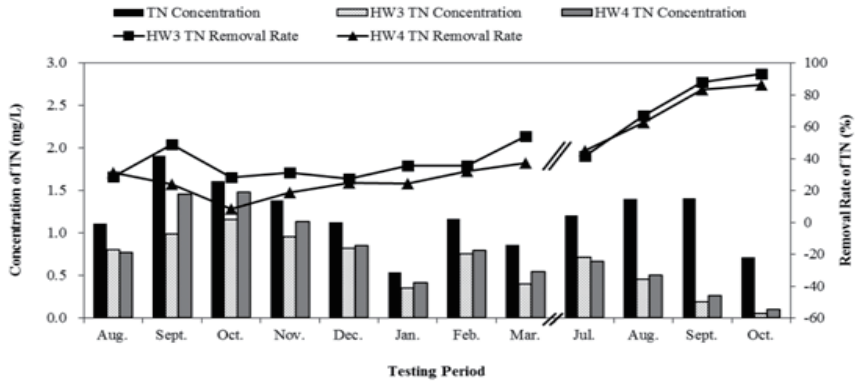


图 6 水平潜流人工湿地对 TN 的去除效果

3. 总结

沸石和水化硅酸钙基质分别对氨氮和磷酸盐具有良好的去除能力，水化硅酸钙与沸石作为混合基质强化潜流人工湿地也具有明显的作用，效果明显好于传统的以砾石为基质的人工湿地。混合基质潜流湿地可以针对不同水力负荷，选择不同的运行模式。

4. 致谢

本研究得到国家水体污染治理重大专项的支持。

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Removal of Nitrogen and Phosphorus with Low-Concentration by Constructed Wetlands Integrated with Calcium Silicate Hydrate and Zeolite

Chunjie LI¹, Deyi WU¹, Zhenjia ZHANG¹, Hainan KONG¹

This study discusses how to construct a wetland system with mixed and enhanced substrates and improve its ability to remove nitrogen and phosphorus nutrients. Based on the characteristics of low concentration and high flow of rivers flowing into lakes, tailwater out of cities and landscape water, zeolite, calcium silicate hydrate (CSH) which can collect nitrogen and phosphorus are added in the gravel, the commonly used substrate of constructed wetland.

CSH is an inorganic material synthesized by 150°C-210°C hydrothermal process. With calcium oxide and quartz powder as raw materials, CSH has a strong capability of removing phosphorus. Such removal is based on crystallization theory, according to which the phosphate anions combine with calcium ions to produce hydroxyapatite, and the hydroxyapatite attaches to the seed crystal.

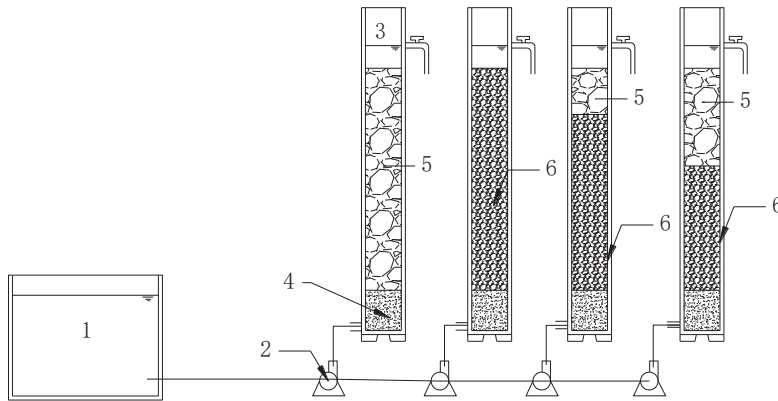
Zeolite is natural aluminosilicate with good adsorbability. Its inner ducts and cavities have a great many exchangeable cations, which ensures its strong exchangeability of cations with no influence on its frame and structures. Such structures and exchangeability of zeolite determine its good adsorbing effect.

1. Experiment of CSH and Zeolite Filter Columns

1.1. Materials and Methods

The test apparatuses are shown in Diagram 1. The filter columns are made of PVC pipes, each with an inner diameter of 9 cm and overall height of 80 cm. Ten-centimeter-thick gravel was put at the bottom of filter columns as supporting layers, with the diameter of pieces of gravel being 1-2 mm. The filtering media, whose thickness is 55 cm, was placed on the supporting layer. The available depth of water was set to be 70 cm. There are 4 sets of filter units, numbered Column 1, Column 2, Column 3 and Column 4. Column 1 was filled with CSH only, Column 2 with zeolite only, Column 3 with a CSH/zeolite ratio of 1:3, and Column 4 with a CSH/zeolite ratio of 1:1. After measured, porosity of the four filter units ranged from 64.72 to 69.55%.

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1. original water tank; 2. peristaltic pump with single inlet; 3. filter column;
4. supporting layer of gravel; 5. CSH; 6. zeolite

Diagram 1. Four sets of filter columns

The objective of the experiment was to test the capability of the filter columns to purify the sample sewage at filtering speeds of 0.7 m/s, 0.175 m/s, 0.058 m/s, and 0.029 m/s, respectively. The apparatuses operated continuously and measurements were taken for 7 consecutive days at each hydraulic point. The filtered water was taken every day and measured for concentration of phosphate and ammonia nitrogen with ammonium molybdate spectrophotometry and Nessler's reagent colorimetry.

1.2. Results

1.2.1. Effects of Phosphorus Removal

As shown in Diagram 2, at the same filtering speed, the filter column containing only CSH can remove the most phosphate. And at speeds of 4.2 m/d, 1.392 m/d, and 0.696 m/d, the removal efficiency on average of the filter columns was: Column 1 > Column 4 > Column 3 > Column 2. When the filtering speed was 16.8m/d, the four columns produced similar effects. From this we know that CSH is more active in removing phosphate. When the filtering speed changed from 16.8 m/d to 0.696 m/d, the average removal rate produced by the filter column containing only CSH improved to 96.81% from 84.68%, while the average removal rate by the filter column containing only zeolite fell to 75.13% from 83.79%. As for the filter columns with mixed substrate, smaller filtering speeds, produced better phosphate removal effects. Among them the filter column with a CSH/zeolite ratio of 1:1 removed 96.39% phosphate on average, higher than that of the 95.39% removed by the filter column with a CSH/zeolite ratio of 1:3.

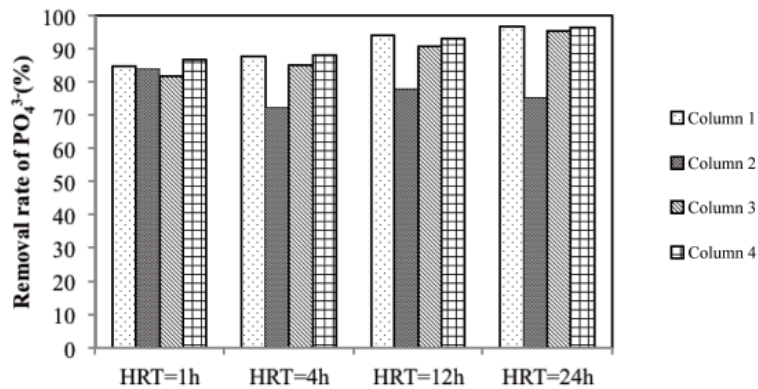


Diagram 2. Effects of phosphate removal at different speeds

1.2.2. Effects of Ammonia Nitrogen Removal

As shown in Diagram 3, when the filtering speeds were 16.8 m/d, 4.2 m/d, and 1.392 m/d, the average removal efficiency of the filter columns was: Column 2 > Column 3 > Column 4 > Column 1. When the filtering speed was 0.696 m/d, the effects produced by the four columns were similar, with the lowest rate of 76.29% produced by Column 3, and the highest rate of 77.44% by Column 2. It shows that natural zeolite plays a leading role in dynamic adsorption. At different filtering speeds, Column 2, Column 3 and Column 4 had a similar removal rate. As for the Column 2 with only zeolite, a smaller filtering speed resulted in a better average removal rate, increasing from 62.06% to 85.11%. But when the speed of filtering increased, the average removal rate declined to about 77%, without much variation found. The pattern of variation of Column 3 and Column 4 with mixed substrate was similar to that of Column 2. When the original filtering speed fell from 16.8 m/d to 4.2 m/d, the average removal rate will undergo obvious changes. As for Column 3, the rate increased to 82.56% from 57.36%. For Column 4, the rate increased to 77.19% from 55.84%. Later, when the filtering speed continued to fall, changes were less obvious. From the above it can be seen that adsorption of ammonia nitrogen greatly depends on zeolite, and the best effects will be realized when the speed reaches 4.2 m/d.

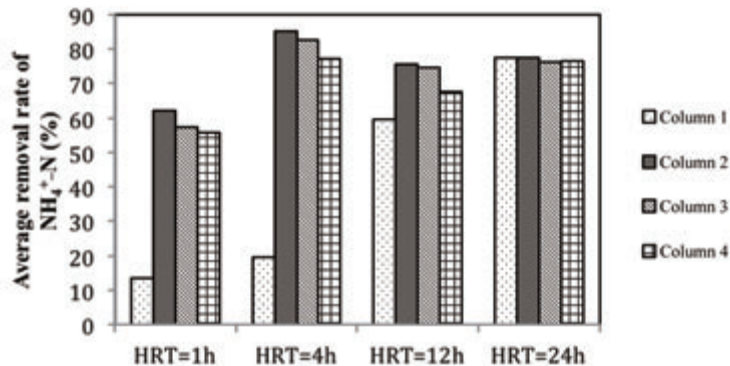


Diagram 3. Average removal rate of ammonia nitrogen at different filtering speeds

2. Effects of CSH and Zeolite as Mixed Substrate on Subsurface Flow Constructed Wetland

This study investigates the purifying effects of a subsurface wetland system on landscape water by setting up a new subsurface flow constructed wetland device with natural zeolite and CSH as its substrate. Comparing the device with one having gravel as substrate will allow us to observe how the device treats less polluted landscape water.

2.1. Materials and Methods

Two horizontal subsurface flow constructed wetland devices are designed and constructed. The devices were built with 8 mm PVC, each with dimensions of 1.3m×0.5m×0.70m (L×W×H), as shown in Diagram 4.

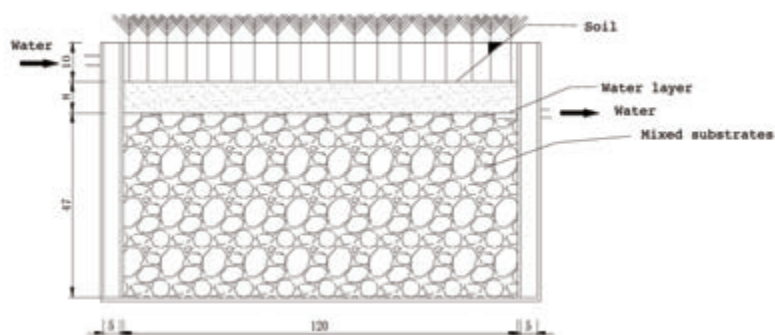


Diagram 4. Analog devices of horizontal subsurface flow constructed wetland

Vertical thickness of the substrate was 0.55 m (the depth of available water was 0.47 m) and the overlying soil was 0.10 m in thickness. The roots of reeds planted in the soil could reach the bottom of the device. The inflow trough, constructed wetland device and outflow trough were placed along the direction of flow. Perforated plates were placed between the above three devices to ensure the water flow was well-distributed. The lengths of the inflow trough, constructed wetland device and outflow trough were 0.05 m, 1.20 m and 0.05 m respectively. Among them, one device with natural zeolite and CSH (the weight ratio is 280 kg : 24 kg) as mixed substrates was marked HW3; another one with only common gravel (with a weight of 537 kg) as substrate was marked HW4.

Natural zeolite: the diameters of the zeolite particles ranged from 3 cm to 5 cm. This natural zeolite is mordenite with some quartz and feldspar. The cation exchange capacity measured by the method of ammonia nitrogen adsorption can reach 1.77 mmol/g (which is equal to the largest adsorbing capacity of ammonia nitrogen 24.78mg/g).

CSH: The diameter of particles ranged from 3 cm to 5 cm. The main ingredient of CSH is xonotlite, which can efficiently remove phosphorus from water; with a removal capacities that can reach 137mg/g.

Reeds: the reeds had well grown roots; when transplanted, their buds and roots must be kept complete. The mud adhered to the roots was cleaned off before the experiment; after the reeds were divided into small groups consisting of several stalks complete with buds and roots, they were transplanted in the constructed wetland. The space between groups was 15 cm*15 cm, with 21 groups in each device.

This experimental device was placed inside the glass house beside landscape water in the botanic garden of SJTU. The experiment lasted from June 15, 2011 to June 2012. The hydraulic load was 0.3 m³/m²d.

2.2. Results

2.2.1. Effects of Total Phosphorus (TP) Removal

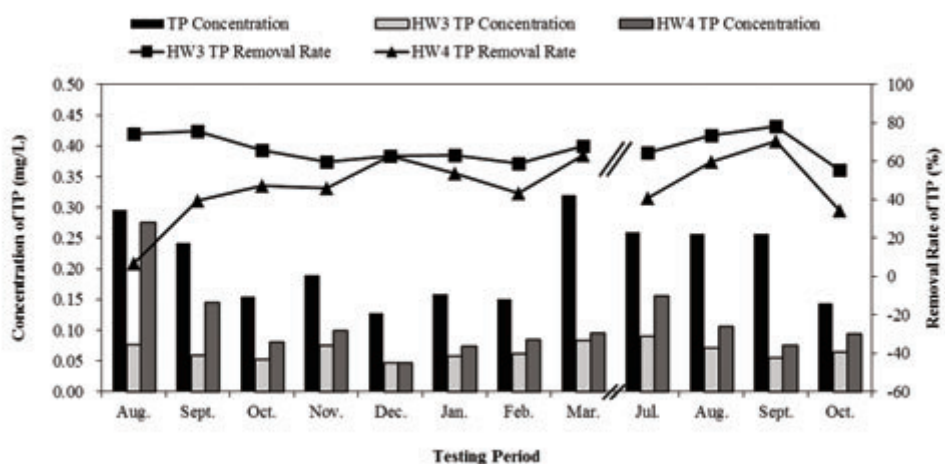


Diagram 5. Effects of TP removal produced by the subsurface wetland with mixed substrate

As shown in Diagram 5, the removal rate of TP in HW3 varied from 22.0% to 78.1% (with an average of 60.8%), while HW4 produced lower removal effects. But in HW4, TP concentration of outflow remained below 0.2 mg/L. The Ca²⁺ ion produced by the CSH substrate in HW3, and Ca²⁺, Al³⁺, and Fe³⁺ produced by the substrate of natural zeolite could easily adsorb or crystallize the water-soluble phosphorus in the water so as to remove water-soluble phosphate. While the TP removal of HW4 only depends on the adsorb of plants, being with less effect of gravel.

2.2.2. Effects of Total Nitrogen (TN) Removal

The effects of TN removal in the two horizontal subsurface flow constructed wetland devices are shown in Diagram 6. When the concentration of inflow TN was 0.54 mg/L to 1.91 mg/L, the removal rates in HW3 and HW4 reached 27.6% to 93.2% (with an average of 50.5%) and 8.4% to 86.3% (with an average of 41.2%), respectively. Although the removal rate varied widely, the device with mixed substrates performed better than the one with only gravel as substrate.

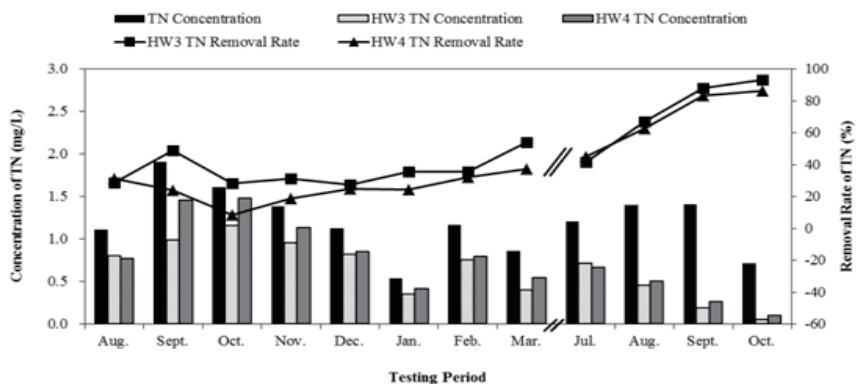


Diagram 6. Effects of TN removal by horizontal subsurface flow in constructed wetland

3. Conclusion

Zeolite and CSH have strong capabilities of removing ammonia nitrogen and phosphate respectively, and so do the substrates mixed with CSH and zeolite applied in the subsurface flow constructed wetlands. They showed to be more efficient than the constructed wetland with gravel as substrate. Different operation modes can be chosen since the mixed substrate can bear different hydraulic loads.

4. Acknowledgement

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洱海服务功能调查与评价

谢杰¹, 吴德意¹

1. 前言

洱海既是大理市主要饮用水源地, 又是苍山洱海国家级自然保护区和风景名胜区的核心地带, 具有调节气候、保护生物多样性、为流域内经济发展提供水源保障等多种功能, 是整个流域社会经济可持续发展的基础。

但是, 由于以前人们只片面强调和重视洱海生态系统服务所提供的具有市场价值或直接使用价值的资源性产品功能, 忽略了自然生态系统所具有的其它生态效用, 致使洱海生态系统发生了严重退化。80 年代开始, 人们对洱海进行了一系列的不合理开发, 导致洱海生态逐步变化; 水资源供需矛盾; 滩涂和湿地大面积丧失, 近岸湖滨区严重污染; 生物多样性逐渐减少。水质已由 20 世纪 90 年代的 II 到 III 类发展到现在的 III 类水临界状态。本文的目的是通过调查及评估洱海的生态服务功能状况, 为保护洱海生态环境, 促进洱海服务功能的可持续利用提供参考。

2. 调查内容

为了对洱海的生态系统服务功能有一个直观的了解, 并可以与经济、社会信息一起, 为环保政策制定、实施提供依据, 以谋求社会经济的持续发展和促进生态系统可持续管理。本文对一下服务功能做了详细调查: (1) 饮用水源地服务功能; (2) 水产品供给服务功能; (3) 鱼类栖息地服务功能; (4) 旅游与休闲娱乐服务功能; (5) 湖滨带水质净化服务功能; (6) 洱海水发电量及产值; (7) 灌溉。

2.1. 饮用水源地服务功能

大理市水资源丰富, 正常情况下大理市水资源可满足城市发展建设的需要。大理市现有 5 个自来水厂供水, 供水能力为 7.50 万 m³/d, 洱海是大理市的主要供水水源, 雨季和丰水年以苍山溪水和泉水(白鹤溪、桃溪、梅溪、鸡舌箐、中庄箐和宝林箐)为补充水源。

范弢等对大理市水资源环境现状做了详细研究(范弢: 2007), 2004 年大理市城区(古城、下关、凤仪和海东 4 城区)总供水量约为 20.90 万 m³/d (0.763 亿 m³/a), 其中生活用水占 55%, 工农业生产用水约占 32%, 服务业用水占 10%, 城市环境用水占 3%。长期以来大理市地下水开采量较低, 但随着城市用水量的逐年递增, 地下水的开采也呈递增趋势。2004 年开采地下水量为 0.807 万 m³/d (0.02946 亿 m³/a)。正常情况下大理市水资源可满足城市发展建设的需要, 见表 1。

2001 年洱海水质为 II 类, 2004—2007 年几年间, 洱海全湖的水质从 2003 年的局部下降到《地表水环境质量标准》(GB3838—2002)的 IV 类标准, 恢复到总体水平达到和保持 III 类。文红星等(文红星: 2011)对 2008—2010 年对海东、团山、才村三个监测断面的总藻细胞密度做了研究, 结果表明, 2008 年 7 月—2010 年 12 月, 团山、才村、海东三个监测断面总藻细胞密度大小在 0.21~28.8×10⁶ 个/L 之间, 其大小变化趋势同上述水质变化表现一致, 均为团山高于海东, 才村最低。在监测年份中, 三个断面细胞密度总体呈逐年降低的变化趋势, 其中最高值出现于 2008 年的 12 月月, 最低值出现于 2009 年的 4 月。

海东、金梭岛、团山是洱海污染较重的地区, 以上区域在洱海资料记录中曾经大面积爆发过蓝藻水华, 藻类相对数量和生物量与湖区有机污染物程度基本一致, 海东、才村、团山藻类相对集中。所以, 可以看

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出，近三年来，洱海的供水水质是逐渐好转的。

项目	2010年	2015年	2020年
总需水量	2.5656	2.8	3.26
城市供水需水量	0.6725	0.8898	1.3934
农村供水需水量	0.1426	0.1597	0.1161
牲畜需水量	0.0199	0.0199	0.0199
农业灌溉需水量	0.8864	0.8864	0.8864
水产养殖需水量	0.8442	0.8442	0.8442
可利用水资源量	11.34	11.34	11.34
水利工程可控水量	2.293	2.293	2.293
洱海多年可利用水量	7.264	7.264	7.264
地下水资源量	2.769	2.769	2.769
洱海蒸发量	-0.486	-0.486	-0.486
引洱入宾	-0.5	-0.5	-0.5

资料来源：《大理市市政公用设施给排水工程专项规划》2005

表1 大理市多年平均水资源与总需求量分析表

2.2. 水产品供给服务功能

洱海渔业资源丰富，主要有鱼、虾、贝三大类。

(一) 鱼类资源

鱼类资源历史上以洱海特有的土著种为主，有经济价值较高的黄壳鱼（土著鲤鱼的统称），弓鱼（大理裂腹鱼），油鱼（油四须鲃），鳊鱼（洱海四须鲃），鲫鱼等。因为外来渔种的引入，导致洱海土著鱼类有下降的趋势。杜宝汉等论述了50~90年代洱海鱼类的动态变化(杜宝汉:2001)，指出，80年代，鲫鱼种群数量猛增，1980年鲫鱼产量占洱海总总鱼获的70%以上，在洱海渔业中占首位，90年代后，太湖银鱼和杂鱼产量增加。

费骥慧(费骥慧:2011)等对1990~2008年洱海的年鱼产量情况做了详细调查(图1)。



图1 1990~2008年洱海的鱼产量

图 1 反映了 1990~2008 年洱海的年鱼产量情况。从图 1 中可以看出, 20 世纪 90 年代, 洱海的年鱼产量波动较大, 且总体呈下降趋势, 到 1999 年降至历年来最低值, 年鱼产量仅 1899.8 t, 这在一定程度上反映出了当前渔业管理方面的一些缺失。据研究记载, 在 20 世纪 80 年代中后期至 90 年代中叶, 洱海渔船数量猛增, 1995 年一度达到 5 488 只 (为 1985 年的 10 倍, 平均每百亩水面拥有 1.5 只); 90 年代太湖新银鱼引种成功后, 由于其较高的经济价值, 极大地刺激了渔民的捕捞力度, 加之银鱼网具网眼细密, 大量幼鱼被捕捞上市。鱼类群体的再生产力遭到破坏, 可能是导致 20 世纪 90 年代渔产量持续低下, 并在 90 年代末骤减的主要原因。21 世纪以来, 洱海加大了渔业管理的力度, 鱼类天然捕捞量持续上升, 平均年鱼产量达 4 907.95t, 且 2005 年以后的年鱼产量均在 5000 t 以上。据调查, 在洱海东岸的挖色镇海印村一带, 分布有大量的岸滩拉网, 其一网渔获量可达 500 kg, 渔获物主要为缀虎鱼(约占 38.7%)、太湖新银鱼(约占 6.7%)、鲮鱼(约占 6%)和虾(约占 54.6%)。

(二) 虾类资源

洱海仅有一种体长 2-3 厘米的米虾 (又叫小红虾)。后由大理州食品公司在 1962 年从昆明滇池引入日本沼虾, 先在大理州鱼类站内塘试养, 因 1966 年发大水, 而流入洱海。最高产量达 2759 吨 (1992 年), 以后年产量在 2000 吨左右。

(三) 贝类资源

有云南高原湖泊特有的螺蛳, 螺蛳资源存量据中国科学院南京地理与湖泊研究所张立测算 (1982 年) 为 14994 吨, 生物量甚为可观, 最高产量高达 2700 吨 (1961 年), 70 年代后期产量下降, 1984-2002 年, 鲜螺头年平均产量为 351 吨。

尽管近年来洱海水产品产量较大, 但是水产品的产品质量却明显下降, 主要有几方面的原因: (1) 口感鲜美的本地优质鱼种的灭绝; (2) 污染物的大量排放导致的水环境污染和水体富营养化问题造成水产品种污染物浓度上升, 产品质量下降。

2.3. 鱼类栖息地服务功能

洱海鱼类资源状况总体格局堪忧。由于人类社会经济活动 (过度捕捞、外来引种) 和湖泊富营养化进程对水生态系统影响, 以及洱海水生态环境的破坏, 造成洱海土著鱼类濒危或消失, 外来鱼种种类数量持续增加。

(一) 土著鱼类

20 世纪 50 年代, 洱海鱼类保持着以大理裂腹鱼、大理鲤、洱海鲤、洱海四须、油四须鲃等土著鱼类为优势种的结构特点(戴自福: 1990)。现在土著渔种已由 20 世纪 50 年代的 17 种递减为现在的 8 种。

洱海土著鱼类从其生活区的分布、摄食方式及产卵习性等方面的生物学特性上的差异, 有利于其种群并存, 组合面貌合理。但从 70 年代开始, 土著鱼类多半已处于濒危状态。

(二) 引进鱼种

洱海引进鱼种起始于 1962 年, 随着青、草、鲢、鳙四大家鱼的引入, 同时带入多种小杂鱼。1983 年起移植太湖银鱼, 成为洱海最重要的经济鱼类。1991 年代太湖新银鱼引种成功, 土著鱼类逐渐灭绝, 投放的青、草、鲢、鳙、团头鲂等经济鱼类产量下降, 小型地质鱼类比例上升, 鱼类多样性出现严重危机。现外来鱼种共计 17 种, 隶属 6 科 16 属, 使洱海的鱼类从原有 17 种增加到 34 种。

何彦敏(何彦敏:2010) 等对洱海鱼类资源现状进行了调查研究, 图 2 是对洱海三次鱼类资源调查比较分析。

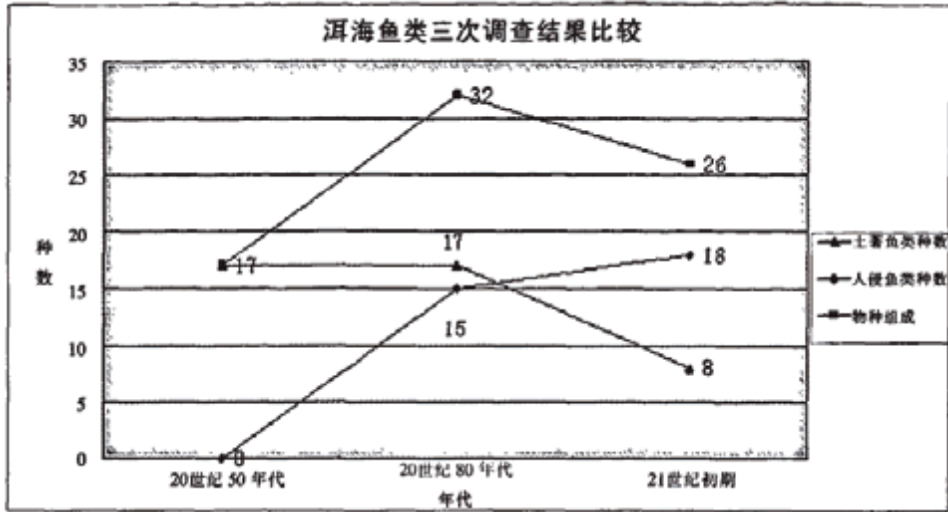


图2 洱海三次鱼类资源调查结果比较分析

从图2可以看出：洱海鱼类区系从20世纪50年代至今发生了很大变化，区系组成由原来的17种土著种变为80年代土著种和入侵种混杂有32种，至今降低为26种。其中土著种由原来的17种递减为现在的8种，而外来入侵种则由原来的0种递增至现在的18种。

(三) 洱海土著种的保护建议

洱海土著种因其肉质细嫩、味道鲜美长期以来备受当地居民的青睐。但随着盲目地引进外来种、不合理的捕捞、拦河坝的修建和滩地过渡利用，使得当地土著种资源锐减，严重影响了土著种资源的可持续利用。结合史料记载和当地实际情况，要保护好现有的洱海土著种资源，建议从以下三个方面着手：第一、改善鱼类区系组成，调整四大家鱼及团头鲂、土著鲤的放养比例，保护珍稀品种；第二、加强管理，确保土著种的正常产卵活动和满足幼鱼成长，明确规定禁渔期和禁渔区，取缔机动拖网、岸滩拉网、迷魂阵等有害网具，严格渔政管理，做好主要经济鱼类的繁殖保护工作；第三、加强洱海周边地区居民和工厂的污水排放管理工作，杜绝污水排入洱海；加强洱海水的合理排放管理工作，保持正常水位。

2.4. 旅游与休闲娱乐服务功能

洱海地区是云南省旅游业起步最早的地区之一，风光秀丽，历史文化厚重，是大理政治、经济、文化的摇篮。洱海西面有苍山横列如屏，东面有玉案山环绕衬托，生态环境极为优美，素有“银苍玉洱”、“高原明珠”之称。现在，洱海旅游已成为大理市经济发展，财政收入的重要部分。洱海自然风光，概括起来有“四洲、五湖、九曲和八景”。风景名胜主要有天生桥、洱海公园、海岛景区、罗荃寺景区、小普陀和南诏风情岛。

洱海流域有着丰富的旅游资源和极高的旅游知名度。改革开放30年来，尤其是21世纪以来，洱海流域的旅游业有了长足的进步。图3分别是大理市接待旅游者人数和旅游社会总收入。

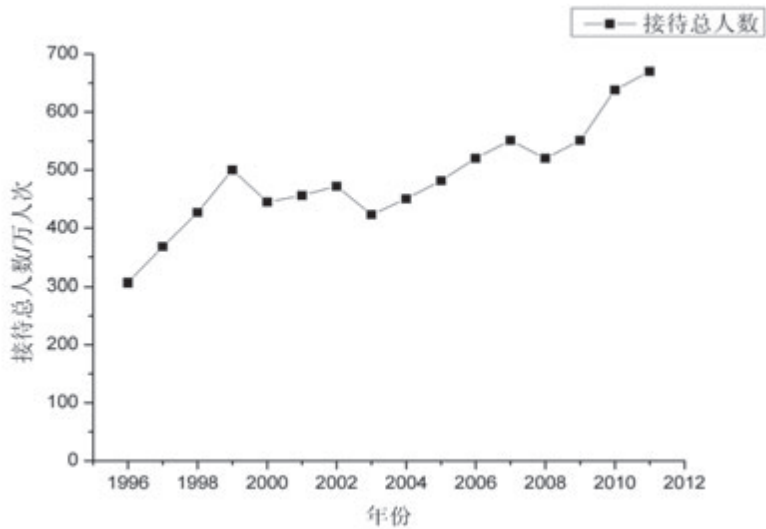


图3 大理市接待旅游者人数

可以看出,大理市旅游人数和收入呈上升趋势,在2002-2003年期间,略有下降,这可能是由于2003年洱海蓝藻爆发,导致游客减少。

由于国家对洱海环境保护的重视,社区生态环境得到改善。如向阳村建立了污水处理厂,使向阳村入湖河道水质明显改善。面山绿化、景区绿化、环湖公路绿化、沼气池建设等都取得了较大进步。但由于人们盲目追求经济利益和受传统的不合理的生活习惯的影响,再加上政府管理部门的不重视,使旅游社区环境保护面临着巨大压力,并有进一步“恶化”的倾向。

2.5. 湖滨带水质净化服务功能

洱海湖滨带范围主要以公路廊道为边界标志物。根据实地踏勘确定,湖滨带区域面积为63km²。

洱海湖滨带可以划分为4个区,每个区又可分为若干湖滨带类型。北部河口三角洲区主要有河口型、滩地型(包括湿地)、农田型和堤防型;西部及东南部低地平原区主要有农田型、河口型、鱼塘型、滩地型、堤防型、村落型和码头型;南部城市建成区和旅游休闲区主要有码头型、湖滨公园型、湖边休闲地型、滩地型和农田型;东部低山丘林区主要有陡岸型、旅游景点型、堤防型和农田型。

目前洱海湖滨带水位下降,水资源供需矛盾加剧,非点源污染严重,侵占滩地修建水田、围建鱼塘、填筑宅基地和填海建码头等蚕食湖滨带现象严重,洱海湖滨带自然群落的生态结构已经破坏殆尽,湖滨带的功能也随之减弱甚至丧失。

洱海湖滨带的功能主要表现为湖滨水陆交错带内生物或非生物因素的相互作用,对交错带内能量流动和物质循环的调节等。厉恩华(厉恩华:2011)等2009年5至12月对洱海湖滨带植被进行了3次调查,共鉴定出维管植物47科108属145种,其中乔灌木15种、湿生草本植物75种、挺水植物15种、浮叶和漂浮植物各7种、沉水植物26种;有红柳(*Salix cavaleriei*)、菰(*Zizaniatatifolia*)、菱(*Trapanatans*)和黄丝草(*Potamogetonmaackianus*)等15个植物群落,水生植物覆盖面积占洱海面积的8%,各点位平均物种数和生物量分别为9个和12.5 kg(FW)/m²,沉水植物 *Margalef* 物种丰富度指数为1.8706。结合资料分析表明:经10余年的治理和修复,洱海植物多样性有所提高,北部植物多样性降低的局面得到改善,但存在着湖滨带狭窄、挺水植物群落类型单调、植被覆盖面积变小、固有区系成分有待恢复等问题。应加强缓冲区建设,

以增强湖滨带功能，提高水体透明度，增加洱海植被覆盖面积。

3. 结论

在相关文献综述的基础上，探讨了洱海在饮用水源地；水产品供给；鱼类栖息地；旅游与休闲娱乐；湖滨带水质净化等方面的生态服务价值。

对各项指标进行分析后得出结论认为，洱海具有很高的生态服务功能价值，维护洱海的水质良好对大理市的经济，社会，生态都有很高的价值。但近年来，洱海水质不断受到威胁，整体生态服务功能逐年下降，而其污染主要是来自于洱海北部的农田污染-氮污染，因此，对洱海北部农田开展治理研究具有很深远的意义。

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Study and Evaluation of the Service Function of Lake Erhai

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1. Preface

Lake Erhai is not only the main source of drinking water for Dali City, but also the heart of Cangshan and Erhai National Nature Reserve and Scenic Spot, with the functions of regulating climate, protecting biological diversity, ensuring water supply for the economic development within its basin, making it the key element for sustainable social and economic development within the basin.

However, in the past focus was placed on only the ecosystem service function of Lake Erhai, given that it could provide resource products of market value and direct use value. At the same time, the other ecological functions of the natural ecosystems of Lake Erhai were ignored, and as a result, serious degradation occurred to its ecosystem. A series of ecologically unsound development projects started in the 1980s have impacted the lake environment. This led to changes in Lake Erhai ecology, a loss of large areas of beach and wetland, serious pollution of off-shore areas, and a decrease in biological diversity. Its water quality was downgraded from class II-III in the 1990s to its current class III water critical state. The purpose of this paper is to provide reference for protecting the ecological environment of Lake Erhai and promoting the sustainable use of the service function of Lake Erhai through the study and evaluation of the status of its ecological service function.

2. Study Content

With the purpose of forming a clear understanding of the ecosystem service function of Lake Erhai and providing a basis for the development and implementation of environmental policies together with economic and social data, and to pursue the sustainable development of the social economy and promote the sustainable management of the ecological system, this paper presents a detailed study of the following service functions. These include (1) drinking water source; (2) aquatic product supply; (3) fish habitat; (4) tourism and recreation; (5) water purification by lakefront.

2.1. Service function of drinking water source

Dali City is rich in water resources, and normally it can meet the needs of urban development and construction. At present, there are 5 waterworks in Dali City, with a water supply capacity of 75,000 m³/d; Lake Erhai is the main source of the water supply of the city; Cangshan Stream and other springs (Crane Creek, Peach Stream, Meixi, Jisheqing, Zhongzhuangqing, and Baolinqing) act as supplementary water sources in the rainy season and wet years.

Tao FAN et.al. have carried out detailed research on the present situation of the water resource environment of Dali City (Tao FAN: 2007). In 2004, the total water supply of Dali City (the 4 city subdivisions of Gucheng, Xiaguan, Fengyi and Haidong) was 209,000 m³/d (76,300,000 m³/a), of which domestic water accounted for 55%, water for industrial and agricultural production 32%, water for the service industry 10%, and water for urban areas 3%. For a long time, the groundwater of Dali City remained relatively free of exploitation, but with the

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gradual increase of urban water consumption, the use of the groundwater supply now shows a trend of increasing. The amount of groundwater accessed in 2004 was 8,070 m³/d (2,946,000 m³/a). Until recently, the water resources in Dali City have been sufficient to meet the needs of urban development and construction, as shown in Table 1.

Item	In 2010	In 2015	In 2020
Total water demand	2.5656	2.8	3.26
Urban water supply demand	0.6725	0.8898	1.3934
Rural water supply demand	0.1426	0.1597	0.1161
Livestock water demand	0.0199	0.0199	0.0199
Agricultural irrigation water demand	0.8864	0.8864	0.8864
Aquaculture water demand	0.8442	0.8442	0.8442
Available water resources	11.34	11.34	11.34
Controllable water through water conservancy projects	2.293	2.293	2.293
Usable water of Lake Erhai by year	7.264	7.264	7.264
Groundwater	2.769	2.769	2.769
Evaporation of Lake Erhai	-0.486	-0.486	-0.486
Drainage of Lake Erhai into lakeside	-0.5	-0.5	-0.5

Data source: "Special Plan of Water Supply and Drainage Engineering for the Municipal Utilities of Dali City", 2005

Table 1. Analysis of water resources and projected total demand of water in Dali City(100million m³/a)

The water quality of Lake Erhai in 2001 was class II; in 2003 the water quality of the lake partly fell to the standard of class IV according to the "Environmental Quality Standard for Surface Water" (GB3838—2002) but its overall level was restored to and kept at class III during the period between 2004 and 2007. Hongxing WEN et.al. (Hongxing WEN: 2011) researched the total density of algal cells at the three monitoring points of Tuanshan, Caicun, and Haidong in 2008 and 2010. Their result showed that the total density of algal cells at these three monitoring points was range from 0.21×10⁶/L to 28.8×10⁶/L between July, 2008 and December, 2010. In addition, the variation trend of density was the same as that of the water quality mentioned above, and in both cases, the water quality was higher in Tuanshan than in Haidong, with the lowest being in Caicun. During the monitoring period, the general density of cells at the three monitoring sections decreased year by year, among which the maximum value appeared in December, 2008, and the minimum in April, 2009.

Haidong, Jinsuo Island and Tuanshan were places with heavier pollution in the Erhai Area, and cyanobacterial bloom once happened in large areas of these locations according to the data record of Lake Erhai. The relative quantity of algae and biomass are basically in line with the pollution level of organic pollutants within the lake region, and algae are relatively concentrated at Haidong, Caicun and Tuanshan. So we can see that the quality of the water supply of Lake Erhai has gradually become better in recent three years.

2.2. Service function of aquatic product supply

Lake Erhai is rich in fishery resources, mainly consisting of three categories, fish, shrimp, and shellfish.

(1) Fishery resources

Historically, the fishery resources here have mainly consisted of the native species uniquely owned by Lake Erhai, including the yellow shell fish (a common name for native carp) with high economic value, Racoma (*Schizothorax taliensis*), Oilfish (*Poropuntius exiguous*), *P. sinensis* Bleeker (*Barbodes daliensis*), and crucian carp. And the introduction of exotic fish species has led to the decrease of native fish species of Lake Erhai. Baohan DU et.al. discussed the dynamic change of the fish species in Lake Erhai during the 1950s and 1990s (DU: 2001), stating that the population of crucian carp rose suddenly in the 1980s, with the production of crucian carp accounting for over 70% of the total annual catch of Lake Erhai in 1980, making it the primary species of fishery of Lake Erhai, while the harvesting of Taihu whitebait and rough fish began to increase after the 1990s.

Jihui FEI et.al. (Jihui FEI: 2011) conducted a detailed study of the annual harvesting of fish of Lake Erhai from 1990 to 2008 (Figure 1).

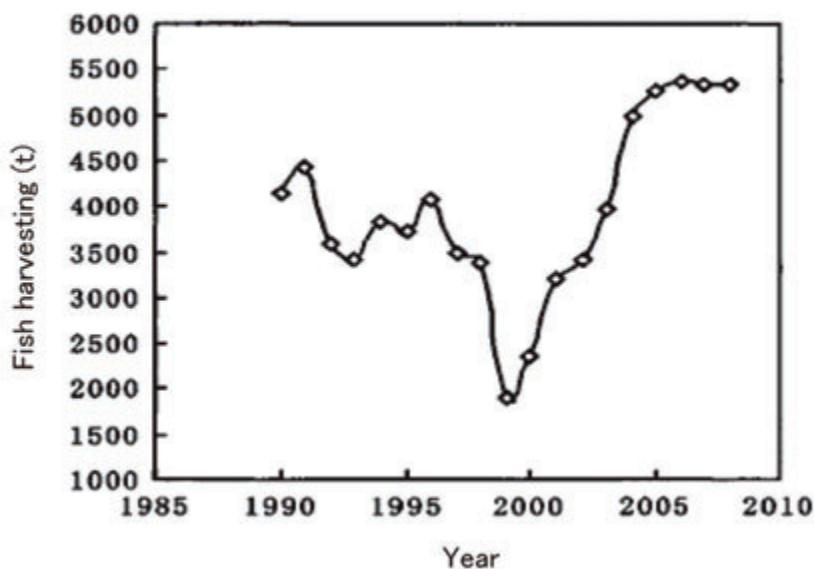


Figure 1 Fish harvesting of Lake Erhai from 1990 to 2008

Figure 1 shows the fish harvesting status of Lake Erhai from 1990 to 2008. We can see from Figure 1 that the annual fish harvesting of Lake Erhai in the 1990s showed great fluctuations and a downward trend as a whole, decreasing to its minimum value in 1999 with a harvest of only 1899.8 tons, which to some extent may reflect negligence in the present fishery management. According to research records, the number of fishing boats in Lake Erhai increased sharply from the mid-and-late 1980s to the mid-1990s, even reaching 5,488 in 1995 (ten times that of 1985, with an average of 1.5 boats per hundred mu water area); in the 1990s the successful introduction of new Taihu whitebait with its high economic value greatly stimulated the fishing effort, but due to the type of finely-woven fishing nets used, a significant number of underdeveloped fish were also caught. The falling reproductivity of fish populations may be the main reason why fish harvesting continued to fall in the 1990s and dropped sharply at the end of the 1990s. Lake Erhai has improved its fishery management since the start of 2000, leading to a rise in natural fish catches; average annual fish harvesting reached 4,907.95 tons; and annual fish harvesting after 2005 reached more than 5,000 tons. According to the study, large areas of beach dragnet are distributed along Haiyin Village of the town of Wase in the east of Lake Erhai, producing 500 kg of fish in a single

catch, mainly consisting of goby (accounting for about 38.7%), new Taihu whitebait (about 6.7%), minnows (about 6%) and shrimp (about 54.6%).

(2) Shrimp resources

Originally, there was only caridina (red shrimp) in Lake Erhai, whose body is only 2-3 centimeters long. In 1962 Dali Prefecture Foods Company introduced *macrobrachium nipponensis* from Kunming Dianchi Lake, which were first raised in a fish pond of Dali Prefecture for research. The shrimp was then flowed to Lake Erhai due to the flood in 1966. The largest harvest of shrimp in Lake Erhai was 2,759 tons (in 1992), and annual production has reached about 2,000 tons since then.

(3) Shellfish resources

There are spiral shells in plateau lakes, which was also a specialty in Yunnan province. According to measurements and calculations by Zhang Li of the Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, the stock of spiral shell resources was 14,994 tons in 1982, and the biomass was quite considerable. The maximum harvesting reached 2,700 tons in 1961, and gradually decreased in the late 1970s; average annual harvesting of fresh spiral shell was 351 tons between 1984 and 2002.

Although in recent years, the output of fishery products in Lake Erhai has been relatively large, their quality has decreased considerably. The main reasons are as follows, (1) the extinction of local fish species with good-tasting; (2) massive discharges of pollutants leading to water pollution and eutrophication, which results in rising concentrations of pollutants in fishery products and a subsequent fall in fishery product quality.

2.3. Service function of fish habitat

The overall situation of fishery resources in Lake Erhai is concerning. The social and economic activities of humans (overfishing, introduction of exotic species) and the process of eutrophication have negative impacts on the water ecosystem. Destroying the ecological water environment of Lake Erhai has resulted in endangerment or extinct of the native fish in Lake Erhai, while at the same time the species and quantity of exotic fish continue to increase.

(1) Native fish

In 1950s, the predominant biological makeup of Erhai fish were still such native species as *Schizothorax taliensis*, *Cyprinus daliensis*, *Cyprinus barbatus*, *Barbodes daliensis*, *Poropuntius exiguous* (Zifu DAI: 1990). The species of native fish have since decreased from 17 in the 1950s to its current 8.

The diversity in biological characteristics (such as the distribution of the living area, feeding habits, spawning habits, etc.) of the native fish of Lake Erhai is in favor of the coexistence and reasonable combination of these species. But since the 1970s, most of the native fish have become endangered.

(2) Exotic fish species

Starting in 1962, four major Chinese carps were introduced into Lake Erhai, including black carp, grass carp, silver carp, and bighead carp; meanwhile, many rough fish were also introduced with them. And Taihu whitebait, transplanted there in 1983, has become the most important commercial fish of Erhai. In 1991, a new Taihu whitebait was successfully introduced; native fish gradually became extinct; the harvesting of commercial fish (such as the grass carp, black carp, silver carp, bighead carp, *megalobrama amblycephala*, etc.) reduced; and the proportion of small geological fish rose, leading to a serious crisis in fish diversity. At present, there are 17 kinds of exotic fish, which belong to 6 families, and 16 genera, making the number of fish species of Erhai Lake increase from the original 17 to 34.

Yanmin HE, et.al. (Yanmin HE: 2010) carried out research on the current situation of the fishery resources of Lake Erhai. Figure 2 shows a comparative analysis of the three-time study of Erhai fishery resources.

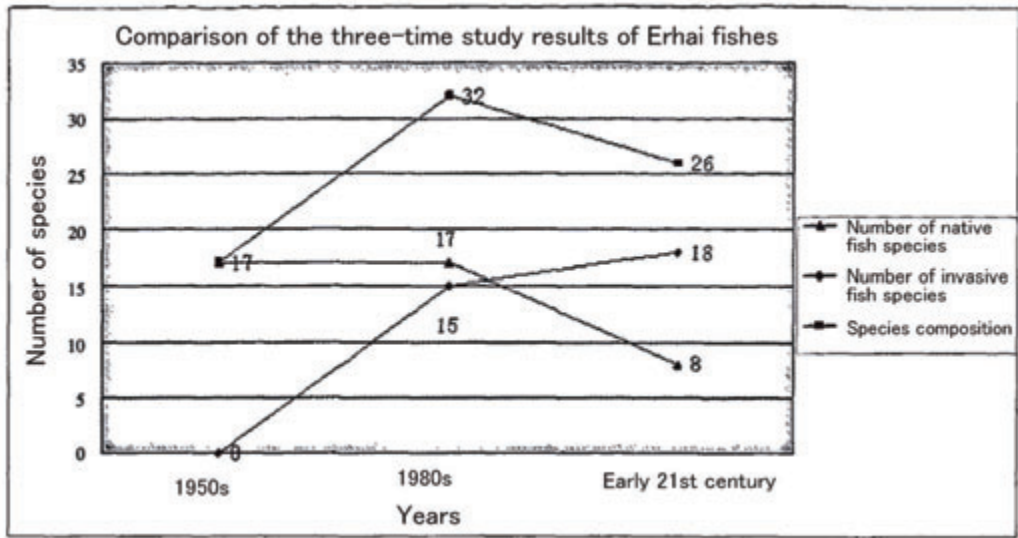


Figure 2 Comparative analysis of the three-time studies on Erhai fishery resources

According to Figure 2 the fish fauna of Erhai has changed greatly since the 1950s, and the composition of fauna has changed from the original 17 native species to 32 native and invasive species in the 1980s, and is currently 26. The number of native species has decreased progressively from the original 17 to the current 8, while the number of invasive species has increased gradually from none to the present 18.

(3) Advices for protecting the native species of Lake Erhai

The native fish of Lake Erhai have been much favored by the local residents because of their tender meat and delicious taste. But with the blind introduction of exotic species, unreasonable fishing practices, dam construction and the overuse of beaches, the native species have reduced sharply, which has greatly influenced the sustainable use of local species. An analysis of historical records and the current situation indicate a need for the following measures to protect the resources of current native species of Lake Erhai: 1) improve the composition of fish fauna, adjust the stocking ratio of the four major Chinese carps, *Megalobrama amblycephala* and native carp, and protect the rare species; 2) strengthen the system of management to ensure the normal spawning activities of the native species and meet the requirements for juvenile fish growth, clearly define the seasons and areas in which fishing is prohibited, ban harmful net fishing practices (such as motorized trawling, beach dragnets, traps, etc.), perform strict fishery management to aid in the breeding and protection of main commercial fish; 3) strengthen the management of sewage discharged by residents and factories around Lake Erhai to prevent sewage discharge into Lake Erhai, and enhance the management of discharge of Lake Erhai water to maintain a normal water level.

2.4. Service function of tourism and recreation

Lake Erhai is one of the first places to engage in the tourism industry in Yunnan Province. It is the cradle of

politics, economy, and culture of Dali, with beautiful scenery and abundant historical culture. Surrounded by Cangshan to the west, which functions like a natural screen, and Yu'an Mountain to the east, the ecological environment here is very beautiful, earning it the monikers “Silver Cangshan and Jade Erhai” and “Plateau Pearl”. Tourism of Lake Erhai has become an important part of fiscal revenue and economic development of Dali City. The natural scenery of Lake Erhai can be summarized as four islets, five lakes, nine serpentine and eight sights. Places of interest mainly include Natural Bridge, Erhai Park, island resorts, Luoquan Temple, Little Putuo, and Nanzhao Island.

The Lake Erhai basin has enjoyed rich tourism resources and is a highly popular tourist destination. Over the past 30 years of reform and opening-up, and especially since the start of the 21st century, the development of the tourism industry of the Lake Erhai basin has made considerable progress. Figure 3 shows the number of tourists and total social tourism revenue of Dali City.

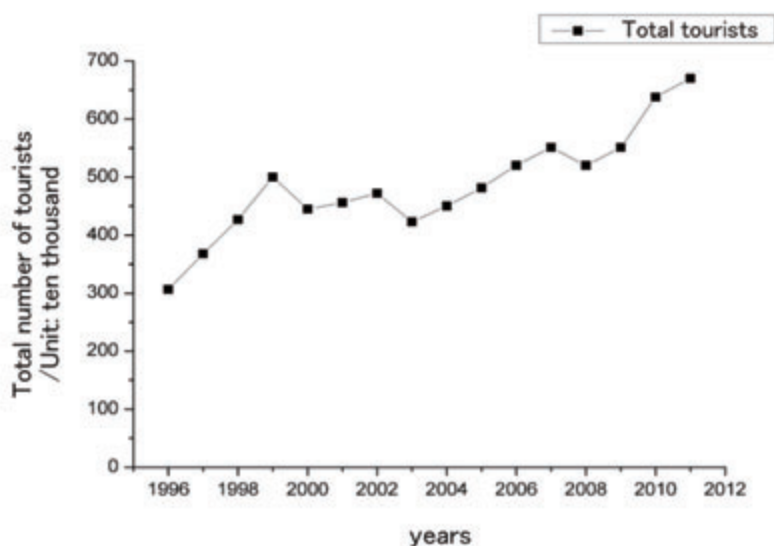


Figure 3 The number of tourists arriving in Dali City

We can see that the number of tourists and revenue of Dali City has been on the rise, with a slight drop during 2002-2003, and this may have resulted from the outbreak of cyanobacterial bloom in Lake Erhai in 2003.

The ecological environment of the community has improved due to strong government support of the environmental protection of Lake Erhai. For example, Xiangyang Village has established a sewage treatment plant, significantly improving the water quality of rivers of Xiangyang Village that flow into the lake. Also, mountain greening, scenic spot greening, greening of roads around the lake, and the construction of biogas all have made great progress. However, because of the blind pursuit of economic interests, the influence of traditional unsustainable living habits, and the ignorance of governmental administrative departments, great pressure has been exerted on the environmental protection of the tourism community, which indicates the likelihood of further deterioration.

2.5. Service function of water purification by lakefront

Roadway corridors are the main boundary markers of the Erhai littoral zone. According to a field survey,

the area of Erhai littoral zone is 63km².

The littoral zone can be divided into 4 subareas. Further, each subarea can be divided into several types of lakefront. The lakefront types in the river delta area in the north include river mouth, beach (including wetlands), farm and dike; the lowland and flat dam area in the west and southeast include farm, river mouth, fishpond, beach, dike, village and dock; the developed urban area and tourist area in the south mainly include dock, lakeside park, lake leisure, beach and farm; the low hill forest area in the east mainly includes steep shore-based, tourist attractions, dike and farm.

At present, the water level of the Erhai littoral zone has been falling. The conflict between water supply and demand has intensified; non-point source pollution is a serious threat to the ecosystem; the lakefront is being heavily encroached upon through activities such as invading beach areas to construct paddy fields, erecting fishponds, filling the homestead and building docks by filling in the lake; the ecological structure of natural communities on the lakefront of Erhai has been destroyed, which has resulted in reduced or completely destroyed lakefront usability.

The main functions of the Erhai littoral zone are the interaction of biotic and abiotic factors within the land-lake ecotone, and the adjustment of energy flow and material cycle within the ecotone. Enhua LI et.al. (Enhua LI: 2011) conducted a study of the vegetation on the Erhai lakefront three times from May to December in 2009, and identified a total of 47 families, 108 genera and 145 species of vascular plants, among which there were 15 species of trees and shrubs, 75 wet herbs, 15 emergent aquatic plants, 7 floating-leaved plants, 7 floating plants, and 26 submerged plants, and there were 15 plant communities, such as *Salix cavaleriei*, *Zizania latifolia*, *Trapanatans*, *Potamogeton maackianus*, etc. The cover area of aquatic plants accounted for 8% of the area of Lake Erhai. The average number of species of each point was 9 and the biomass was 12.5 kg (FW)/m², with the species richness index of submerged plant Margalef registering 1.8706. In conjunction with data analysis, we can see that plant diversity of Erhai has strengthened and the weakening of plant diversity in the north has improved through 10 years' management and restoration efforts. But there still exist some problems, such as a narrow lakefront, homogenous community types of emergent aquatic plants, vegetation cover areas, decaying natural flora composition, etc. The construction of buffer areas should be strengthened to enhance the function of the lakefront, improve the transparency of the water body, and enlarge the cover area of vegetation of Lake Erhai.

3. Conclusion

On the basis of review of relevant literature, we have discussed the ecological service value of Lake Erhai in the aspects of drinking water source, aquatic product supply, fish habitat, tourism and recreation, and water purification by lakefront.

After analysis of each index, we have come to the conclusion that Lake Erhai is of high value in ecological service function, and keeping good water quality of Lake Erhai is of great significance to the economic, social, and ecological development of Dali City. But in recent years, the water quality of Lake Erhai has been under constant threat and the overall ecological service function has declined year by year, for which the nitrogen pollution is mainly from the agricultural fields to the north of Lake Erhai. Therefore, it is of profound significance to carry out research on the management of these agricultural fields.

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水生植物改善湖滨带水质的现场实证性研究

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1. 研究背景

近年来,我国湖泊富营养化问题日益严重,湖泊环境保护工作任重而道远。

我国湖泊众多,且主要为不产生跃温层的浅水型湖泊。人们已经认识到浅水湖泊中存在着两种不同的稳态:草型清水稳态和藻型浊水稳态。这两种稳态之间可以相互转换(SCHEFER:1990,综合地球环境学研究所:2010),该转换过程具有两大特点。其一,前者转换为后者容易,而后者转换为前者很难;其二,沉水植物在决定稳态类型上具有重要作用(SCHEFER:1990)。然而,纵观前人的研究工作,可以发现在模拟生态系统里,水生植物改善水质的研究很多,尤其是水生植物的化感作用的研究很多(庄源益等:1995,胡洪营:2006,李锋民:2007)。但是在实际湖泊中,关于两者之间关系的报告很少。因为实验室研究属于半开放系统,温度、空气和光照等环境因子都可控,而实际湖泊却是完全开放系统,它的任何一个环境因子都与周围环境密不可分,而且环境因子复杂、时间和空间的变异性大。本文以云南两大高原湖泊—滇池和洱海为研究对象,在两大湖泊分别选取水生植物覆盖状况明显不同的地点,通过对不同季节水质的分析,通过现场实证性研究来证实水生植物对湖滨带水质的影响,为合理的湖泊综合管理和保护提供了科学依据。

2 采样点

我们确定滇池和洱海作为研究对象(谢杰等:2013),主要是基于以下几方面的原因:(1)气候相似;(2)面积差异不大:洱海 250.0 km²,滇池 298.4 km²;(3)污染程度不同,洱海处于富营养化初期,而滇池处于富营养化后期。(4)湖滨带水生植物覆盖度不同,洱海 50%以上,滇池仅 6.8%。(5)取样点分布有代表性。既有植物覆盖度较好的采样点,也有植物覆盖度较低甚至没有水生植物的采样点(表 1)。滇池与洱海的取样点见图 1。

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湖名	项目	1	2	3	4	5	6
洱海	植物数量	++	++	+++++	+	无	无
	植物种类	沉水植物	沉水植物	沉水植物为主 少量浮水植物	沉水植物	无	无
	地理坐标(°)	E100.2325 N25.6095	E100.1561 N25.749	E100.1037 N25.9266	E100.1714 N25.9345	E100.2138 N25.8563	E100.2763 N25.6639
滇池	植物数量	+++++	无	无	++	无	+++++
	植物种类	沉水植物为主 少量浮水植物	无	无	沉水植物	无	浮水植物为主 沉水植物为辅
	地理坐标(°)	E102.6494 N24.9757	E102.664 N24.8414	E102.6081 N24.7577	E102.6867 N24.6979	E102.7761 N24.8758	E102.6319 N24.996

*根据目测情况的估算，“+”符号越多，植物数量（密度）越高，+++++表示植物密度最高。

表 1 采样点位置及水生植物分布情况

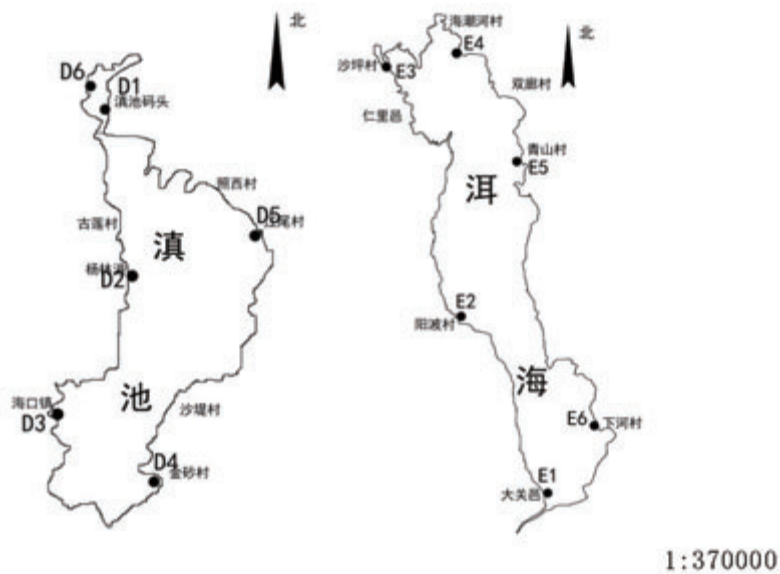


图 1 两湖的采样点示意图

3 . 结论与讨论

3.1. 2010 年夏季两湖的水质比较

滇池北部草海 (D1 和 D6) 具有最高的总氮(TN)和总磷(TP)浓度 (表 2)。洱海则除北部的沙坪湾 (E3) 外, 洱海西部的另外两个采样点 (E1 和 E2) 也具有比东部湖水更高的营养盐浓度。这一结果与最近尹延震等(2011)报导的结果一致, 反映了洱海生源物质污染负荷主要来自北部农业区和西部农业与旅游区, 而东部山区的污染负荷则相对较低。

从表 2 中我们可以看到滇池北部草海 (D1 和 D6) 以及洱海北部的沙坪湾 (E3) 在各自湖泊具有最高的营养盐浓度和电导率, 但叶绿素 a 含量却相对很低。而且, 这三个采样点的 pH 值也相对较低。夏季湖水 pH 的升高主要是由于藻类光合作用的结果, 因此低的叶绿素 a 浓度对应于低的 pH 值 (表 2)。但关键问题是, 为什么高总氮、高总磷浓度并没有导致高叶绿素 a 浓度? 由表 1 可知, 这一现象与采样点 (D1、D6 和 E3) 处大型水生植物覆盖度有密切的关系。也就是说, 大型水生植物的存在抑制了藻类的生长与繁殖。

在其它各采样点也具有大型水生植物覆盖度和藻类生物量之间的负相关关系。

采样点	pH	电导度	ORP	TN	TP	Chl-a	浮游动物数量	
		(mS/cm)	(mV)	($\mu\text{g}/\text{mL}$)	($\mu\text{g}/\text{mL}$)	($\mu\text{g}/\text{L}$)	(个/10ml)	
滇池	D1	7.56	0.6	231	9.54	0.175	59.1	2
	D2	9.55	0.43	207	4.85	0.139	60.9	0
	D3	9.52	0.44	204	4.70	0.118	78.4	1
	D4	9.96	0.46	190	6.23	0.118	148.5	0
	D5	9.54	0.41	203	4.48	0.142	87.5	0
	D6	8.85	0.66	226	8.92	0.319	87.3	33
	平均值	9.16	0.50	210	6.46	0.168	86.9	—
	标准差	0.86	0.10	15	2.25	0.077	32.6	—
洱海	E1	8.62	0.26	189	0.65	0.029	23.1	—
	E2	8.33	0.28	230	0.76	0.062	15.9	—
	E3	7.89	0.36	253	0.63	0.050	2.7	—
	E4	8.85	0.25	215	0.26	0.032	21.6	—
	E5	8.95	0.27	218	0.29	0.040	37.1	—
	E6	8.86	0.26	224	0.27	0.030	19.1	—
	平均值	8.58	0.28	222	0.48	0.040	19.9	—
	标准差	0.41	0.04	21	0.22	0.013	11.1	—

表 2 夏季两湖的水质比较

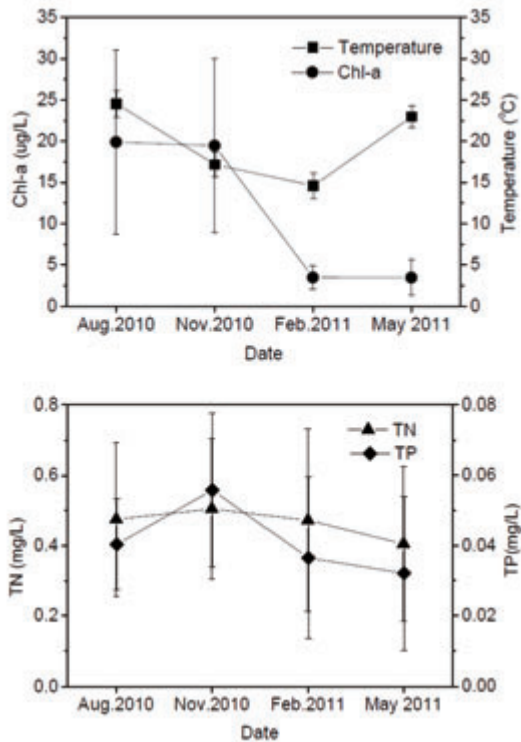


图 2 洱海湖泊水体总氮、总磷、温度及叶绿素-a 的季节变化（谢杰等：2013）

3. 2. 洱海水质的季节变化

除上述的水质调查外，为进一步了解高原湖泊的水质季节变化，我们继续于 2010—2011 年对洱海湖滨带的 6 个采样点进行了调查及取样分析(图 2)。不同采样点之间的水质差异较大。从不同季节来看（图 2），2 月和 5 月的氧化还原电位高于 8 月和 11 月，而 pH 及电导率不具有明显的季节间差异。总氮和总磷 8 月和 11 月高，而 2 月和 5 月低，全年以 11 月份的营养盐浓度最高。营养盐的这一季节变化规律与最近尹延震等（2011）报导的结果一致。反映藻类生物量的叶绿素 a 浓度也具有明显的季节变化，即 8 月和 11 月浓度高，而 2 月和 5 月浓度低。影响藻类生物量的主要因子为水温、光照及水中的营养盐浓度等。值得注意的是，11 月的水温明显低于 5 月，但 11 月的叶绿素 a 浓度却明显高于 5 月。因此我们认为：洱海湖滨带藻类生物量主要受营养盐浓度（TP）影响。

3. 3. 大型水生植物对藻类的抑制作用机制

大型水生植物对藻类的抑制作用机制如下（金相灿：2001）：（1）大型水生植物与藻类之间对营养盐的竞争作用；（2）遮光作用；（3）化感抑制作用；（4）水生植物创造出比较稳定的水体环境，抚育出高密度的浮游动物，大量捕食浮游藻类；（5）物理效应。在开放性、交换性强的湖泊现场，大型水生植物通过对营养盐的竞争作用抑制藻类不大可能（况且滇池北部草海以及洱海北部的沙坪湾具有最高的营养盐浓度）。除采样点 D6 外，采样点 D1 和 E3 处的植物种类主要为沉水植物，因此通过遮光作用的控藻效果也很有限。此外，沉水植物也不像挺水植物那样大量吸附藻类，因此物理效应并不起作用。初步估计，大型水生植物通过

分泌化感物质抑藻以及浮游动物的捕食作用可能是导致叶绿素 a 浓度较低的主要原因。在滇池草海，我们确实观察到了明显较高的水蚤类浮游动物密度（表 2）。洱海富营养化程度低，E3 采集的 0.5L 水样中虽未观察到浮游动物的出现，但该区域浮游动物密度高于无大型水生植物分布区是极有可能的。

湖名	采样点	CyHV 1	CyHV 2	CyHV 3
		Copies/L	Copies/L	Copies/L
滇池	D1	-	-	-
	D2	-	-	-
	D3	-	1608	-
	D4	-	433	-
	D5	688	-	-
	D6	-	-	-
洱海	E1	-	-	-
	E2	-	-	-
	E3	-	-	-
	E4	-	-	-
	E5	-	-	-
	E6	-	-	-

表 3 两湖不同地点的三种 DNA 病毒检测结果

3.4. 水生植物状况与病毒的关系

我们于 2010 年 8 月进行了水中 DNA 病毒的检测工作，结果发现，D1 和 D6 营养盐高的区域未发现病毒存在（表 3），但在 D3、D4、D5 这些沉水植物少的采样点却发现病毒。CyHV 1, CyHV 2 和 CyHV 3 都是 DNA 型病毒，在世界许多国家的淡水水体中具有较广泛的分布(DONG et.al. 2011, XU et.al. 2013)。CyHV 1 和 CyHV 3 专门感染鲤鱼(SANO et.al. 1985, HEDRICK et.al. 2000)，而 CyHV 2 则感染金鱼(JUNG and MIYAZAKI 1995)和鲫鱼(DOSZPOLY et.al., 2011)。

洱海西部 46km 湖滨带水生植被已经基本得到恢复，其东部的数个海湾及河口也具有良好的水生植被分布，因此洱海的湖滨带植被和水质状况远优于滇池。此次在洱海未检出三种病毒的存在，在滇池水质差但水生植物较为发达的草海也未检测出病毒。相反，检测出病毒存在的采样点都是位于滇池湖滨带中无水生植被分布或水生植被稀少的湖滨带。因此，我们的检测结果初步表明水生植物不仅能控藻，而且能控病毒。因此大型水生植物在清水型湖泊的建设中具有非常重要的作用。

4. 结论

- (1) 对滇池和洱海湖滨带的水质分析结果表明，污染负荷（营养盐浓度）高的区域，只要水生植物的覆盖度高，叶绿素 a 的含量很低，并伴随着低 pH 值。分析认为，大型水生植物通过分泌化感物质抑藻以及浮游动物的捕食作用可能是导致叶绿素 a 浓度低的主要原因。
- (2) 作为高原湖泊的洱海，其湖滨带营养盐及 ORP 的变化有着较明显的季节性规律。从不同季节的水质分析结果来看，水温和营养盐浓度是影响藻类生物量的重要因素。

- (3) 对两湖泊水体中病毒的初步分析结果表明,滇池湖滨带水生植物覆盖度低的三个采样点水体中检测出 CyHV1 和 CyHV2 病毒的存在,而洱海水体中未检测出受试 DNA 病毒。初步结果表明,水生植物具有控藻和控病毒作用。

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An On-Site Empirical Study on the Role of Aquatic Plants in Improving Lakefront Water Quality

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and Zen'ichiro KAWABATA⁶

1. Study background

In recent years, lake eutrophication has become increasingly severe in China, leading to a need for more efforts to be made in protecting lake environments.

There are many lakes in China, the majority of which do not generate thermo cline due to shallow lake. It has been recognized that there are two different kinds of stable states for shallow lakes: a clear state dominated by submersed plants and a turbid state dominated by phytoplankton. Conversion may occur between these two stable states (SCHEFER: 1990, Research Institute for Humanity and Nature: 2010), and the process of such conversion has two main characteristics. First, it is easy for submersed-plant dominated states to convert to phytoplankton-dominated states, while it is difficult for the reverse to occur. Second, submersed plants play an important role in determining the stable states (SCHEFER: 1990). By analyzing previous study results, we can find that in a simulated ecological system. Many studies have been carried out on the role of aquatic plants in improving water quality, and especially on the allelopathic effects of aquatic plants (Yuanyi ZHUANG et.al.: 1995, Hongying HU: 2006, Fengmin LI: 2007). But in studies of real lakes, there are few reports about the relationship between the two. This is because laboratory study belongs to a semi-open system, in which temperature, air, light and other environmental factors are all controllable; while a real lake is a completely open system, in which any of its environmental factors is inseparable with the surrounding environment, with complex environmental factors and great variability of time and space. In this paper, we take two plateau lakes in Yunnan, Lake Dianchi and Lake Erhai, as the subjects of study, to provide a scientific basis for the feasible comprehensive management and protection of lakes. An empirical study was carried out by choosing places with obvious differences in their coverage of aquatic plants, analyzing water quality during different seasons, and confirming the influence aquatic plants have on lakefront water quality.

2 Sampling points

On-site empirical study was carried out in Lake Dianchi and Lake Erhai (Jie XIE et.al.: 2013). These two lakes were chosen as the subjects of study for the following reasons: (1) similar climates; (2) no significant difference in size (298.4 km² for the former, and 250.0 km² for the latter); (3) different levels of pollution, with the former being at the later stage of eutrophication, while the latter at the early stage of eutrophication; (4) a difference in the coverage of aquatic plants in lakefront areas, with only 6.8% for the

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former, while over 50% for the latter; (5) the existence of a representative distribution of sampling points, including ones well covered by vegetation, and ones with either low coverage of vegetation or even without aquatic plants. The sampling points in both Lake Dianchi and Lake Erhai are shown in Figure 1, and the status of vegetation coverage was listed in Table 1.



Figure 1 Sampling points of the two lakes. (Redrawn from XIE et al. 2013).

Lake Name	Item	1	2	3	4	5	6
Lake Erhai	Quantity of Plants	++	++	+++++	+	None	None
	Plant Type	Submersed plants	Submersed plants	Mainly submersed plants A few floating plants	Submersed plants	None	None
	Geographical Coordinates	E100.2325 N25.6095	E100.1561 N25.749	E100.1037 N25.9266	E100.1714 N25.9345	E100.2138 N25.8563	E100.2763 N25.6639
Lake Dianchi	Quantity of Plants	+++++	None	None	++	None	+++++
	Plant Type	Mainly submersed plants A few floating plants	None	None	Submersed plants	None	Mainly floating plants A few submersed plants
	Geographical Coordinates	E102.6494 N24.9757	E102.664 N24.8414	E102.6081 N24.7577	E102.6867 N24.6979	E102.7761 N24.8758	E102.6319 N24.996

"It is estimated by visual inspection that the more the sign "+" shows, the larger quantity (higher density) of plants is, and +++++ indicates the highest plant density.

Table 1. Location of sampling points and distribution of aquatic plants

3. Results and discussions

3.1. Comparison of the water quality of the two lakes in summer, August 2010

Table 2 shows that total nitrogen (TN) and total phosphorus (TP) concentrations in Caohai (D1 and D6), which is in the north of Lake Dianchi, were the highest. As for Lake Erhai, the nutrient concentrations of the lake water at two sampling points (E1, E2) in the west was higher than that in the east, with the exception of E3 for TP. This result was in agreement with the one reported by Yanzhen YIN, et al. (2011), and indicates that the nutrients pollution load of Lake Erhai mainly comes from agricultural areas in the north and the agriculture and tourism area in the west, while the pollution load in the eastern mountain area is relatively lower.

Table 2 also shows that Caohai (D1 and D6) in the north of Lake Dianchi and Shaping Bay (E3) in the north of Lake Erhai had the highest electrical conductivity within their own lake areas, but D1 and E3 contained very low levels of chlorophyll-a. Moreover, the pH values of these three sampling points were comparatively lower, too. The increase of pH value of the lake water in summer is believed to be mainly due to algae photosynthesis, so the lower chlorophyll-a concentration corresponds to the lower pH value (Table 2). But the key question is: why haven't the high concentrations of total nitrogen and total phosphorus led to high chlorophyll-a concentration? As shown in Table 1 and Table 2, this phenomenon has a close relationship with the coverage of macrophytes at the sampling points (D1, D6 and E3). In other words, the existence of macrophytes inhibits the growth and reproduction of algae. The negative correlation between the coverage of macrophytes and the amount of algae also exists in other sampling points.

	Sampling Points	pH	Electrical Conductivity	ORP	TN	TP	Chl-a	Quantity of zooplankton
			(mS/cm)	(mV)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/L}$)	(/10ml)
Lake Dianchi	D1	7.56	0.6	231	9.54	0.175	59.1	2
	D2	9.55	0.43	207	4.85	0.139	60.9	0
	D3	9.52	0.44	204	4.70	0.118	78.4	1
	D4	9.96	0.46	190	6.23	0.118	148.5	0
	D5	9.54	0.41	203	4.48	0.142	87.5	0
	D6	8.85	0.66	226	8.92	0.319	87.3	33
	Average Value	9.16	0.50	210	6.46	0.168	86.9	–
	Standard Deviation	0.86	0.10	15	2.25	0.077	32.6	–
Lake Erhai	E1	8.62	0.26	189	0.65	0.029	23.1	–
	E2	8.33	0.28	230	0.76	0.062	15.9	–
	E3	7.89	0.36	253	0.63	0.050	2.7	–
	E4	8.85	0.25	215	0.26	0.032	21.6	–
	E5	8.95	0.27	218	0.29	0.040	37.1	–
	E6	8.86	0.26	224	0.27	0.030	19.1	–
	Average Value	8.58	0.28	222	0.48	0.040	19.9	–
	Standard Deviation	0.41	0.04	21	0.22	0.013	11.1	–

Table 2. Water quality of the two lakes in summer, August 2010

3.2. Seasonal changes of the water quality of Lake Erhai

In addition to the above mentioned water quality investigation, we continued our investigation and sample analysis of the 6 sampling points of lakefront areas of Lake Erhai during 2010 and 2011 (Figure 2). There was a great difference in the water quality of different sampling points. Judging from different seasons, the redox potential in February and May was higher than in August and November, while the pH value and electrical conductivity showed no obvious seasonal differences. Total nitrogen and total phosphorus were higher in August and November than that in February and May, and nutrient concentration reached to the highest in November. Such a pattern of seasonal change of nutrient concentration was in accordance with the results that were reported by Yanzhen YIN, et.al. (2011). The chlorophyll-a concentration that reflects the amount of algae also had obvious seasonal changes, with higher concentrations in August and November, and lower ones in February and May. The factors influencing the greater amount of algae are mainly caused by the higher water temperature, light and nutrient concentration in water. It is worth noting that the water temperature in November was clearly lower than that in May, but the chlorophyll-a concentration in November was significantly higher than that in May. Therefore, we believe that the amount of algae in the lakefront of Lake Erhai is mainly influenced by the nutrient concentration (TP).

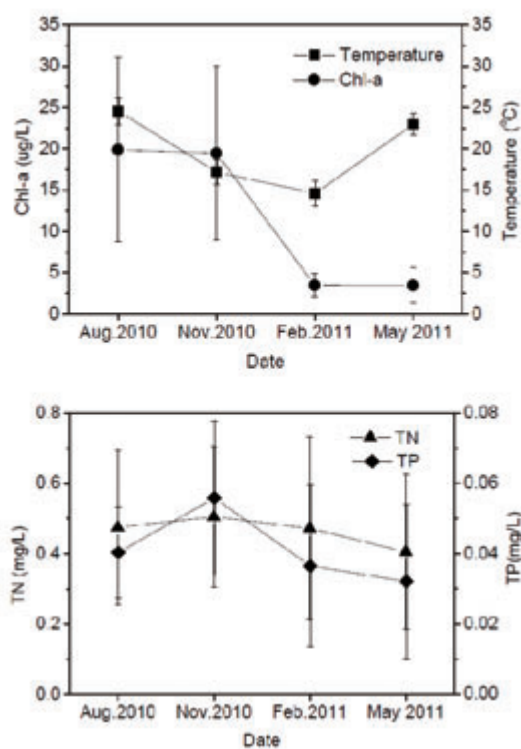


Figure 2 Seasonal changes of total nitrogen, total phosphorus, temperature and chlorophyll-a in Lake Erhai.

(Redrawn from XIE et al., 2013)

3.3. Inhibition mechanism that macrophytes perform on algae

The inhibition mechanism that macrophytes perform on algae is as follows (Xiangcan JIN: 2001): (1) the competition between macrophytes and algae for nutrients; (2) shading effects; (3) allelopathic inhibition; (4) aquatic plants are able to create a more stable water environment and nurture a high density of zooplankton, which then preys on large numbers of phytoplankton; (5) physical effects. In an open and changeable lake area, it is unlikely for macrophytes to inhibit algae through their competition for nutrients in Caohai in the north of Lake Dianchi and Shaping Bay in the north of Lake Erhai because they had the highest nutrient concentration. The plants in D1, D6 and E3 were mainly submersed plants, therefore, the effect of inhibiting the growth of algae through shading effect is believed to be limited. Moreover, submersed plants cannot absorb as much algae as emergent aquatic plants, so there is no physical effect. It is deemed that the main reasons for lower chlorophyll-a concentration are the secretion of allelochemicals by macrophytes to inhibit the growth of algae and the predation of zooplankton. Density of *Daphnia* zooplankton was clearly higher in Caohai of Lake Dianchi (Table 2). The degree of eutrophication of Lake Erhai was relatively low, and though zooplankton was not observed in the 0.5L water sample collected in E3, it is very likely that the density of zooplankton in this area was higher than that in the area without macrophytes.

3.4. Relationship between the condition of aquatic plants and viruses

DNA virus detection was performed at August, 2010, and no viruses were found in the D1 and D6 areas where the content of nutrients was high (Table 3), but they did exist in the D3, D4, and D5 sampling points where there were fewer submersed plants. *Cyprinid herpesvirus 1* (CyHV 1), *Cyprinid herpesvirus 2* (CyHV 2) and *Cyprinid herpesvirus 3* (CyHV 3) all belong to DNA viruses. CyHV 1 and 3 specifically infect common carp (SANO et.al. 1985, HEDRICK et.al. 2000), while CyHV 2 infects goldfish (JUNG and MIYAZAKI 1995) and *Carassius auratus gibelio* (DOSZPOLY et.al., 2011). The fish diseases caused by these viruses have been reported in many countries including China (DONG et.al. 2011, XU et.al. 2013).

The aquatic vegetation on the 46 km lakefront in the west of Lake Erhai has been basically restored, and the several bays and estuaries in its east also have a good distribution of aquatic vegetation. Because of this, the lakefront vegetation and water quality of Lake Erhai are far better than those of Lake Dianchi. These three viruses were not detected in Lake Erhai, and no viruses were detected in Caohai of Lake Dianchi either, which has poor water quality but more aquatic plants. On the contrary, the sampling points where viruses were detected are all located at the lakefront of Dianchi where there is no or very little aquatic vegetation. Therefore, our detection results probably suggest that aquatic plants can not only inhibit the growth of algae but also viruses. For this reason, macrophytes play a very important role in the makeup of lakes with clear water.

Lake	Sampling site	CyHV 1	CyHV 2	CyHV 3
		Copies/L	Copies/L	Copies/L
Lake Dianchi	D1	-	-	-
	D2	-	-	-
	D3	-	1608	-
	D4	-	433	-
	D5	688	-	-
	D6	-	-	-
Lake Erhai	E1	-	-	-
	E2	-	-	-
	E3	-	-	-
	E4	-	-	-
	E5	-	-	-
	E6	-	-	-

Table 3. Detection of the three DNA viruses at different locations of the two lakes

4. Conclusion

From these on-site empirical studies, we could obtain conclusions as below:

- (1) The results of water quality analysis of Lake Dianchi and Lake Erhai indicate that the areas with higher coverage of aquatic plants had lower content of chlorophyll-a and pH value with high nutrient concentration. The analysis suggests that the main reason for lower chlorophyll-a concentration that the macrophytes secrete allelo chemicals which inhibit the growth of algae and the predation of zooplankton.
- (2) For Lake Erhai, a plateau lake, the variation of nutrient concentration on its lakefront shows obvious seasonal patterns. Judging from the results of water quality analysis of different seasons, water temperature and nutrient concentration are important factors influencing the amount of algae.
- (3) The preliminary analysis of the tested viruses in these two lakes indicates that CyHV1 and 2 exist in the water bodies of the three sampling points with low coverage of aquatic vegetation and on the lakefront of Dianchi, while no these viruses were detected in Lake Erhai. The preliminary results suggest that aquatic plants have the effect of inhibiting the growth of algae and viruses.

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第四部 湖の環境ガバナンス

第四部 湖泊的环境治理

Part 4 Environmental Governance of Lake



太湖流域の水環境ガバナンス

—対話と協働による長期有効管理メカニズムの模索—

大塚 健司¹

1. 中国の水環境政策とガバナンス

中国における環境問題の解決に向けた取り組みについては、すでに 40 年近く経っている。また 1990 年代以降に工業汚染源に対する規制強化、政府、人民代表大会、報道機関の協調による上から下への監督検査活動の強化、水汚染物質の排出削減対策として流域単位での総量抑制策の導入などが行われてきた。それにもかかわらず、2000 年代に入っても環境関連法規に関する違法事件が多発し、各地で水汚染事故が絶えず、主要河川の地表水質指標においても楽観できる状況ではない（大塚：2010）。このような環境政策の失敗に対して、規制強化や公共投資の増強といった政府による一連の対応がみられる一方で、企業や政府に対して直接問題解決を迫る住民らによる集団抗議運動も散発している。こうしたなかで、企業のインセンティブや住民の参加をふまえた新たなガバナンスのあり方が模索されている（大塚：2011）。

しかしながら、中国において多様なステークホルダーの参加による流域ガバナンスを検討するにあたっては、中国における流域は、日本や他の先進諸国以上に、その空間のもつ政治的特質に十分留意する必要がある。流域は、上からの統治、地域間の権限の分散（分断）、そして下からの参加を制約する諸制度からなる重層的な政治空間である。中国における流域の環境保全・再生に向けて、政府、企業、住民など、異なる立場とインセンティブをもつステークホルダー間の利害調整と合意形成をもとにした制度構築を行うにあたって中国は、階層が多く、関係する主体が多数に及ぶだけでなく、中央・地方関係が複雑で、地方政府に経済成長志向が強いうえに、民主的な諸制度が十分整備されていないという諸条件を考慮に入れなければならない。すなわち、中国における水環境問題の解決に向けた流域ガバナンスの制度構築は、上からの統治システムの改革、下からの自発的な制度構築、そして地域間の交渉・調整・協力といった異なるベクトルが相互作用を繰り返しながら変容していく、複雑でダイナミックなプロセスとしてみていく必要がある。

以下では、2007 年水危機以降の太湖流域における水環境ガバナンスの特徴を概観し、そこに欠けている公衆参加のメカニズムのあり方を探るべく 4 年間にわたり流域一都市にて試行したコミュニティ円卓会議の到達点と課題を明らかにしたうえで、太湖流域におけるボトムアップ・ガバナンスの可能性と課題について述べる（大塚編：2010, 2012）。

2. 2007 年水危機以降の太湖流域における水環境ガバナンス

2007 年 4 月中下旬、太湖にて例年より早くアオコが異常発生し、5 月下旬には江蘇省無錫市最大の取水口のある貢湖水源地に大量に吹きだまったアオコを含んだ湖水が「黒水団」と化した。そして同月 29 日には市内上水道の水が異臭を放つようになり、約 200 万人の飲用・生活用水に影響を与えた。市は 6 月 5 日に安全宣言を出すまでの間、正常な給水

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を行うことができず、市民はボトルウォーターの買い占めに走った。市は各所にて純水供給拠点を設けるなどの措置をとって急をしのぐとともに、地元の報道機関を通して随時対応状況を報告してパニックの沈静化に努めた（楊：2008）。

太湖は1980年代から工場、農地、住宅地などから流入する汚廃水によって富栄養化が進行しており、アオコの大発生による上水供給危機も1990年以降、すでに複数回発生している（謝：2008）。そうしたなか2007年の水危機は、国内外のマスメディアを通して多くの衆目にさらされるなか、地方および国の指導層に緊急対応を迫るとともに、太湖流域の水環境政策を大きく転回させる契機となった。

太湖流域における水環境政策は国の重視のもとでの地方による事業実施および制度改革の先行的取り組み（地方イニシアティブ）をおもな流れとしながら、国と地方の重層的な政府構造のなかで、太湖流域の水環境政策が異なる階層の政府間で相互に影響を与えながら展開している。2007年の水危機から一定年数が経ち、また2011年から国の社会経済発展第12次5カ年計画が始動したことを受けて、太湖流域における水環境政策は、政策改革の段階から政策の実施・調整の段階に移りつつある。

しかしながら流域ガバナンスの視点からみると、太湖流域における水環境政策は、トップダウン的な政策改革と事業実施が中心であり、情報公開や公衆参加のようなボトムアップ的な取り組みは散発的にみられるだけである。また地方政府は、トップダウン的なガバナンスを補強するために、経済的手法や人事考課制度などの新たなインセンティブ・メカニズムを導入しているが、これらのメカニズムを有効に機能させるためには、広く人々からのモニタリングが必要であり、そのためには情報公開と公衆参加が欠かせない。さらには、日本の経験から見ても、湖沼のような閉鎖系水域の水環境改善には長期にわたる取り組みが必要とされており、それには政府のみならず、事業者、住民を含む多くのステークホルダー間の連携と協働が必要とされる。

3. 太湖流域におけるコミュニティ円卓会議の試行

太湖流域では2007年の水危機以降、国および地方各階層にてさまざまな政策改革や総合対策事業が進められているが、危機管理から政策改革の段階を経て、政策実施・調整段階に入りつつあるなか、政策改革や総合対策事業の実効性をいかに確保し、またその効果をいかに維持させていくのか、という長期持続的な環境管理のあり方が課題となっている。そうしたなか、基層レベルでの利害関係主体（ステークホルダー）の対話と協働を促進するための「コミュニティ円卓会議」の試みが重要な意味をもつ。

ここで、「コミュニティ円卓会議」とは、政府、企業、住民がひとつのテーブルに着き、地域の環境問題について対話を行う仕組みを指す。中国では環境政策における情報公開や公衆参加に関するさまざまな施策が試行あるいは制度化されつつあるなか（大塚：2010）、コミュニティ円卓会議については、江蘇省において世界銀行の協力を得て2006年より試行プロジェクトが開始され、2008年に「環境情報円卓対話制度業務ガイドライン」が策定された（WANG, BI and GE:2009）。この江蘇省における試行をふまえ、アジア経済研究所と南京大学環境学院環境管理・政策研究センターは、2008年度よりコミュニティ円卓会議の社会実験に関する共同研究を実施し、水環境保全をめぐる政府、企業、住民による対話の促進を試みてきた。

対象地域である宜興市は、太湖の流入河川を抱える工業都市であり、太湖へ流入する汚

染物質の削減が大きな課題となっている。また、コミュニティ円卓会議を実施している同市 Y 区は経済開発区として工業が集積しており、以前から周辺農村との間での紛争が発生していた。また企業用地の確保のために農村住民の新規造成住宅団地への計画的移転を行い、新たな「社区」建設が進められている。新社区では、開発区に立地する企業による環境汚染に加えて、インフラ整備の不備などによる環境問題も顕在化している。

2008 年度から 2009 年度にかけては Y 区にて 2008 年 12 月 3 日、2009 年 1 月 8 日、および 8 月 6 日の 3 回、G 社区にて 2009 年 12 月 8 日に 1 回、計 4 回にわたって会議を実施した。このうち、2009 年 1 月の会議は、前年 12 月のコミュニティ円卓会議のレビューを目的として行った。

2010 年度および 2011 年度は、現地にてコミュニティ円卓会議の社会実験を行うにあたり、南京市にて、日中双方の研究チームに加えて、現地にて円卓会議の組織化にかかわる関係者を交えたワークショップを 2010 年 9 月 24 日および 2011 年 8 月 10 日に開催し、筆者もこれに参画した。2 回のワークショップを通して、日中双方の研究チームと現地関係者の間でコミュニティ円卓会議の準備、実施、そしてフォローアップに至る一連のプロセスについて、日本の経験の紹介も交えながら意見交換を行い、問題点の発掘と共有を行うことによって社会実験の改良に努めた。（あわせて、ウッドロー・ウィルソンセンター中国環境フォーラムと南京大学環境学院環境管理・政策研究センター及びアジア経済研究所が共同で、2010 年 1 月南京、2010 年 8 月ワシントン D.C 及びシカゴ、2011 年 12 月東京及び諏訪湖にてスタディーツアーとワークショップを開催し、各国湖沼流域ガバナンスにおける公衆参加の経験共有を図った。）そして、2010 年 11 月 18 日に G 社区にて住民会議を開催し、2011 年 1 月 15 日に S 社区にて、同年 12 月 10 日および翌年 2 月 18 日には G 社区にてそれぞれ円卓会議を開催した。筆者は 2010 年 10 月の G 社区住民会議を参与観察するとともに、2010 年 11 月、2011 年 1 月および 12 月の会議開催後にそれぞれ現地にて環境問題の状況把握と参加者へのインタビュー調査を実施した（表 1）。

開催年月日	2008.12.3	2009.1.8	2009.8.6	2009.12.8	2010.11.18	2011.1.15	2011.12.10	2012.2.18
目的	円卓会議	レビュー会議	国家プロジェクトキックオフ/円卓会議	円卓会議	住民会議	円卓会議	円卓会議	円卓会議
テーマ	S川の環境整備	前回会議のレビュー	太湖流域水環境保全情報公開と公衆参加	G社区環境問題	G社区円卓会議の回顧と社区環境問題	S社区農業生産・農村生活様式と水環境問題	G社区第三期地区の秩序と環境	G社区円卓会議経験交流・社区公共環境問題対話
参加者	政府6(県2,区4)/企業4/住民4/南N大2/計16	政府6(県2,区4)/企業4/住民4/専門家1/N大2/計17	政府14(省3,市1,県5,区6),企業10,住民6,専門家1,メディア2,N大4/計36	政府11(県3,市1,県5,区6),企業4/住民12/メディア2/N大4/計33	住民15/N大1/DE 1/計17	政府2(市1,区1)/企業4/住民10(うち社区弁2)/他社区1/N大3/NGO1/計21	政府2(市1/区1)住民21他社区3N大3NGO1計30	企業3(サービス2)住民21N大3NGO1計28
議長	Y区安全環境保護局環境保護弁公室長	N大講師	N大講師	N大講師	G社区リーダー	G社区リーダー	G社区リーダー	G社区リーダー
参加者質問票調査	有効回答数: 14	—	有効回答数: 31	有効回答数: 26(同日住民調査、有効回答27)	有効回答数: 15(同日住民調査、有効回答16)	有効回答数: 16	有効回答数: 28	有効回答数: 26

表1 Y区コミュニティ円卓会議の概要

4. 太湖流域におけるボトムアップ・ガバナンスの可能性と課題

これまでの社会実験のなかで、コミュニティ円卓会議は、社区をベースにした住民、企業、政府の間での対話が可能であることが示された。表1にみるように、コミュニティ円卓会議のテーマは毎回少しずつ異なっている。太湖流域における水環境問題を住民参加のなかでどのように解決していくかということが一連の社会実験の目的として掲げられているものの、会議を成立させるためには何よりもまず住民との対話を優先することが必要である。そのなかで、住民や社区リーダーの関心は、企業による環境汚染問題と社区の公共管理問題にあることが明らかになってきた。

企業による環境汚染問題は、太湖流域の水環境問題の要因のひとつであり、2008年12月に開催された最初の円卓会議の時から話題となっている。しかしながら、住民の関心はむしろ地域環境への直接的な影響にあり、円卓会議では、水環境問題のみならず、悪臭や煤塵の問題に対する不満の声があがっている。また、2011年1月にS社区で行われた円卓会議では、テーマとして「農業・農村生活様式と水環境保護」が掲げられたものの、会議に参加した農民の関心は工場排水による水環境問題に集まった。円卓会議主催者側は、水環境保全のためには、工業排水や生活排水の処理に加えて、現在の多肥料・多農薬の投入による農業生産および農村生活様式の見直しも必要であるとの問題提起を行ったものの、農民のほうは、Y区に立地する化学肥料工場の排水による水産養殖被害をあげて、その解決過程に不満をあらわにした。

企業を含めた対話については、後述するように会議の組織化をめぐる政府、企業、社区リーダーの間の調整が問題となる。しかしながら、企業が集中立地する Y 区に居住する地域住民にとって企業の環境汚染問題に関心が高いものの、企業との直接対話には慎重であることがうかがえた。また、2011 年 12 月の G 社区円卓会議に参加した住民らは、以前から企業の環境汚染問題に対する不満はあったが、企業との対話は、「村幹部の役割」であるとして、自ら直接対話に臨むことには躊躇を示した。Y 区では企業と住民の間で環境紛争がしばしば発生しており、そうした紛争を未然に防止するためにも円卓会議が定期的に開催されることが望ましいと Y 区幹部も指摘していた。政府、企業、住民との間で対話を継続していくことが重要である。

他方で、G 社区での円卓会議で話題となった車庫改造による排水垂れ流しや居住地域での野焼きやゴミの散乱など、社区の環境衛生問題についても社区リーダーや住民の関心が高い。また、2011 年 12 月および 2012 年 2 月の G 社区円卓会議参加者の多くは、その原因を外地からの出稼ぎ労働者にあると考えているが、「住民の自覚的行動」にも原因があるという回答も少なくなかった（表 2）。2011 年 12 月および 2012 年 2 月に G 社区で開催された 2 回目の円卓会議はそこに焦点を当てたものであった。1 階の車庫の改造問題は、突き詰めれば設計段階でのニーズ把握の問題であるが、建設中の G 社区第三期小区では、車庫改造そのものは進められているものの、排水管への接続が必要であるとの認識が住民の間で共有されつつあることがうかがえた。これは円卓会議の成果のひとつと考えられる。

	2011年12月G社区円卓会議		2012年2月G社区円卓会議	
[居住するコミュニティに存在する環境衛生問題のおもな原因(複数回答)]				
政府が有効な措置をとっていない	6	(21)	8	(31)
企業行動が環境保護的ではない	2	(7)	3	(12)
現地コミュニティがうまく組織活動をしていない	5	(18)	6	(23)
外地からの出稼ぎ労働者に多くの問題がある	15	(54)	17	(65)
現地住民が自覚的に行動していない	12	(43)	10	(38)
その他	0	(0)	0	(0)
未回答・無効	4	(14)	0	(0)
回答数	44		44	
(出所)コミュニティ円卓会議質問票調査データより筆者作成。 (注)) ()内は %を示す。				

表 2 社区の環境衛生問題に対する意識

土地の集約化と効率的利用のために村から社区への移転を進める Y 区において、社区の公共管理問題は G 社区のみならず、共通の課題となっている。中国の他都市でも社区の公共管理問題は居住区におけるガバナンスの課題となっており（小嶋：2011）、住民の関与の方法はさまざま考えられる。社区の公共管理問題の有効な解決方法のひとつとしてコミュニティ円卓会議を位置づけることも可能であろう。

さらに、今回の共同研究を通して G 社区での会議に協力してきた同社区リーダーによると、2011 年 12 月の円卓会議の前に、共同研究における社会実験とは別に、社区独自で、同年 1 月、3 月、4 月、11 月の計 4 回にわたって「円卓会議」を開催し、社区内の環境・衛生・公共秩序に関する問題について住民、幹部、警察などを交えて対話を行ってきたという。同リーダーによると、当初は円卓会議への参加を求めると遠慮しがちであった住民が、会議を重ねるにつれて積極的な態度になってきているともいう。このことは、G 社区におけるコミュニティ円卓会議が共同研究による社会実験から、社区内の自立的な対話メカニズムに発展しつつあることを示している。

もっとも、G 社区におけるコミュニティ円卓会議の「成功」は、あくまで一事例に過ぎない。本共同研究の経験から、地域住民が切実に解決を必要としている問題があること、コミュニティ・リーダーがそうした問題について解決意欲があること、地元政府から一定の協力を得られること、そして多様なステークホルダーの参加をコーディネートすることのできる地元の専門家集団（本共同研究の場合は南京大学の研究チーム）が存在することなどが、コミュニティ円卓会議が成り立つための必要条件と考えられる。しかし、「組織化をめぐる正当性（SABATIER et. al. 2005）」をどう担保するかが大きな課題である。

5. 結語

対話と協働をめぐる日本や他国の経験からみると、太湖流域で展開されている水環境政策の各種プログラムには、「参加」の必要性は認められているものの、「ステークホルダーの協働による再生」という視点に欠いていることが指摘される。そして、「協働による再生」の必要性が政府を含めて主要なステークホルダーの間で共有されていないために、コミュニティ円卓会議のような試行的な取り組みを制度化していくことが困難になっていると考えられる。また、公衆参加を促進する仕組みとして円卓会議だけではなく、多様な仕組みを検討するとともに、専門家や NGO (NPO) の役割をどのように位置づけていくかという課題も残されている。

その仕組みの検討にあたっては、政府、研究機関、NGO だけではなく、地域の事情に明るく信望の厚いコミュニティ・リーダーが重要な役割を果たすことはコミュニティ円卓会議の試行経験からも明らかである。このように、さらなる対話と協働による新たな参加の段階を切り拓いていくためには、政策プログラムの改革、多様な仕組みの検討、コミュニティ・リーダーの育成など、多くの課題が横たわっている。

今後、太湖流域において長期持続的かつ順応的な環境再生が求められるなか、中国の環境政策におけるトップダウン型ガバナンスが抱える限界やそれを太湖流域において支える政治、経済、社会的基盤の変化に留意しつつ、そこにボトムアップ型の仕組みをどのように埋め込んでいくのが、制度構築の中心的課題となるであろう。

今後とも、コミュニティ円卓会議を、環境を共有する地域の公共的空間における参加と協働の仕組みを積み上げていくための相互学習の場として、継続していくことが望まれる。その試行錯誤によって、人々の間に参加と協働のための素養（literacy）と主体性（stewardship）が育成されていけば、自らの手で地域における「公共性」（齋藤：2000）の再構築が展望できるであろう。

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Governance of Water Environment in Taihu Lake Basin
—Pursuit of Effective Long-term Management Mechanism
Based on Dialogue and Collaboration—

Kenji OTSUKA¹

1. Policy and Governance of Water Environment in China

In China, nearly 40 years have already passed since the initial efforts to find solutions to environmental problems were launched. Since the 1990s, various measures have been taken, including the enforcement of stricter regulations against industrial pollution sources, reinforcement of the supervision and inspection against polluters and local governments through a top-down approach that involved the central government, People's National Congress and mass media, and the adoption of the scheme to control the total emission control of water pollutants in each of major river-lake basins. Despite of all these efforts, violations of environment-related laws and regulations were frequently detected even after entering the 2000s, and the problem of water pollution accidents recur in many parts of the country. Any optimistic view of seeing improvement in the surface water quality of main rivers seemed out of the question. (OTSUKA: 2010) While the government, in response to the failure with its past environment policies mentioned above, is taking a series of countermeasures to enforce stricter rules and expand the public investment, mass protests led mainly by the residents suffering from pollution are arising sporadically in the attempt to directly demand the industries causing the pollution as well as the government for immediate actions to solve the environmental problems. Under such circumstances, we are seeing a new move to pursue the establishment of a new type of governance over the water environment, based on the cooperation of incentivized enterprises and participation of local residents. (OTSUKA: 2011)

Nonetheless, to examine the possibility of establishing a “basin governance” in China based on the participation of diverse stakeholders, there is a need to keep in mind that the political aspects of Chinese basins have a lot more meaning than in Japan or other developed countries (TURNER and OTSUKA: 2005, OTSUKA: 2008, 2010, 2012). Each basin in China forms a complex multi-layered political arena. On the top layer is the state government that administers the basin. In the middle are local governments around the basin that respectively claim for their own authoritative rights, which are dispersed (split apart). In the bottom layer are various systems and regulations that impose restrictions on the participation of the residents living along the basin. In order to build a viable system to conserve and revitalize the environment around the basins in China, a complex set of considerations must be taken into account. The stakeholders range widely from the government, enterprises, residents, to other interest groups. They have different interests and incentives in realizing an improved water environment, which need to be carefully coordinated in order to reach a consensus about how to move on with the joint efforts to

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clean the environment. Not only are the stakeholders numerous, but they also represent many social classes. In addition, the relationship between central and local governments is complex, especially because the local governments are very strongly oriented toward growing their regional economies. Moreover, the country itself is still lacking in regulatory systems that work democratically. In other words, the institutional building for basin governance in China that functions as a driver to find possible solutions for the recovery of water environment in this country has to be a multi-faceted dynamic process that continues to evolve by transforming repeatedly while the government attempts to reform its administrative systems from the top, while voluntary actions emerge from the bottom seeking for self-governance(OSTROM:1990), and while the negotiations, coordination and cooperation between communities that work on different vectors come to mutual agreements, may they be interactive with each other.

In the following paragraphs, the overview of the characteristics of water environment governance established in Taihu Lake Basin after the water crisis occurred in 2007 will be introduced first. It will be followed by detailed description of the achievements and remaining issues identified in the pilot project to hold “community round-table meetings” in a county-level city nearby the lake that has been carried out for the last four years in an attempt to find a workable mechanism for the general public to participate in the making of a viable system for conservation and healthy use of their valuable water environment. Lastly, the feasibility of a bottom-up governance in Taihu Lake Basin and the challenges that need to be addressed to realize such form of governance will be discussed. (OTSUKA: 2010, 2012)

2. Water Environment Governance in Taihu Lake Basin Since the Water Crisis in 2007

In mid-April of 2007, blue-green algae bloom occurred in Lake Taihu earlier than usual. By the end of May that year, the surface of the water source of lake Gonghu where the largest intake to supply water to Wuxi City in Jiangsu Province is located was literally blackened with the abnormal massive bloom of blue-green algae. On May 29th, the tap water for drinking and other domestic use supplied to become stale, emitting abnormal odor, and affected the lives of approximately 2 million citizens to which this water was regularly supplied. Until the municipal authorities declared on June 5th that the city water is safe, speculative stocking of water spread among the citizens who rushed to the stores to buy bottled water because they could not receive their regular water supply from their faucets. As an ad-hoc countermeasure, the city selected several sites as tentative clean water supply centers, and the local media continued to report the latest progress in the recovery actions taken by the government to calm down the citizens from the panic mode. (YANG : 2008)

From the 1980s, the eutrophication of Lake Taihu accelerated as the amount of influent polluted wastewater discharged from plants, farmlands, and residential areas increased. Due to the massive blue-green algae bloom in the eutrophied lake, the local supply of tap water faced a critical state in several occasions in the 90s. (XIE: 2008) The water crisis that occurred in 2007 became widely known to the public as a social issue through the detailed coverage of both domestic and international media. This incident not only pressured the local and national leadership to take urgent actions, but also became a trigger for the water environment policy

implemented in Taihu Lake Basin to take a drastic turn.

The water environment policy implemented in Taihu Lake Basin is going through a dynamic process of adjustments made by different levels of complexly structured local and national government bodies that continue to affect each other, while local projects and attempts to reform the system set the mainstream approach to lead and drive the progress of necessary changes (as local initiatives) under the supervision of the state. (OTSUKA: 2010). During the several years that have passed since the water crisis in 2007, the water environment policy implemented in Taihu Lake Basin has gradually but definitely come to shift from policy reform planning stage to policy reform implementation and coordination stage. (OTSUKA: 2012)

However, when viewed from the standpoint of basin governance, the water environment policy implemented in Taihu Lake Basin is mainly based on top-down policy reform and project implementation, and bottom-up approach driven by disclosure of information and participation of the general public is limited to sporadic activities. Moreover, the local government is implementing new incentive mechanisms, such as, introducing economic incentives and performance assessment system, to reinforce the top-down governance. To make these new mechanisms function effectively, there is a need to monitor them extensively, and to do so, disclosure of information and participation of the general public are essential. Furthermore, past water conservation efforts in Japan suggest that the process to improve the water environment of a lake, which is a closed eco-system, will inevitably be long-term, and the success of such long-term approach will only come when, not only the government, but also all the other corporate and private stakeholders communicate and collaborate well. (OTSUKA et.al.: 2011)

3. Pilot Community Round-table Meeting in Taihu Lake Basin

Since the water crisis in 2007, various policy reforms and comprehensive countermeasures have been put into effect in Taihu Lake Basin by the national government and various groups in the local levels. Following the crisis management phase and policy reform phase, this region is now in the transitional phase where the activities are becoming more and more oriented toward the direction of new policy implementation and coordination. The current challenges are to figure out how to ensure the viability of policy reforms and comprehensive countermeasures, and maintain their effectiveness. In other words, there is a need to define the appropriate method of managing the environment sustainably for a long period of time. In this respect, one significant attempt to promote the dialogue and collaboration between key stakeholders in the basic level was the arrangement of “community round-table meeting”.

The term “community round-table meeting” refers to the mechanism to gather those representing the governments, enterprises and local residents around one table to discuss and exchange thoughts about local environmental issues. In China, various pilot projects and institutionalized mechanisms to promote disclosure of information and participation of the general public on environmental policies are being established (OTSUKA: 2010), and community round-table meeting is one of such initiatives that originally began as a pilot project in 2006 in Jiangsu Province under the cooperation of the World Bank, and was later defined more specifically in the “Working Guideline of Institution of Environmental Information Round-table Dialogue”

established in 2008(WANG, BI and GE:2009). Triggered by this pilot project in Jiangsu Province, the Institute of Developing Economies (IDE) and the Center for Environmental Management and Policy(CEMP), School of the Environment, Nanjing University launched a joint study on the social experiments carried out by the participants of the community round-table meetings with a common aim to promote the dialogue between the governments, enterprises and local residents on matters pertaining to environmental conservation.

A region where this joint study conducted was Yixing City, an industrial county-level city that was faced with a serious problem of polluted substances flowing through the waterways running through this city and eventually flowing into Lake Taihu. Selected as the site of the community round-table meeting in this city was Y District, which is an economic development zone that attracted numerous industrial players that have long been in dispute with the neighboring farming villages. This is also near the area where new “Shequ (urban communities)” are being built on the vacated farmland that were once inhabited by the farming villagers who have accepted the urban redevelopment plan to move to a newly developed residential apartment for the purpose of making more open lots available for corporate use. These new Shequ have also emerged as the center of attention for bringing about additional environmental issues that were attributable to poorly developed infrastructure, in addition to the environmental pollution caused by the enterprises operating in the economic development zone.

From 2008 to 2009, three community round-table meetings were held in Y District (on December 3rd, 2008, and on January 8th and August 6th, 2009), and one in G Shequ (on December 8th, 2009). Among them, the meeting scheduled in January 2009 was held mainly for the purpose of reviewing the matters discussed in the previous meeting in December 2009.

In the years 2010 and 2011, two workshops were held (one on September 24th, 2010 and the other on August 10th, 2011) in Nanjing City, where the members of Chinese and Japanese study groups, including the author (myself), and the local keypersons contributing to the building of community round-table meetings in their localities assembled to find ways to improve the pilot program for organizing community round-table meetings, and to identify and share the issues that needed to be addressed. Through these two workshops, the aforesaid participants exchanged opinions on the comprehensive process of how to make the community round-table meeting work, beginning from how it should be prepared, then implemented and finally followed up after holding the meeting. The opinions from the members of the Japanese study group included the introduction of similar experiences the local residents in various parts of Japan have gone through in the past. (Also, China Environmental Forum of Woodrow Wilson International Center for Scholars, based in Washington D.C. has co-organized with CEMP and IDE to hold study tours and workshops in Nanjing (January 2010), D.C. and Chicago in U.S.(August 2010), and Tokyo and Suwa in Japan(December 2011) for the purpose of studying three countries experiences on public participation in lake basin governance.) On November 18th, 2010, the residents in G Shequ organized a meeting of their own, followed by the community round-table meeting in S Shequ on January 15th, 2011. On December 10th, 2011 and February 18th, 2012, two community round-table meetings were held in G Shequ. The author participated in the G Shequ residents meeting held in October 2010 as an observer, and conducted post-meeting interview sessions to the participants of

the three meetings held in November 2010, and in January and December 2011, for the purpose of gaining hands-on information on the latest status of local environment issues. (Table 1)

Date	3 Dec 2008	8 Jan 2009	6 Aug 2009	8 Dec 2009	18 Nov 2010	15 Jan 2011	10 Dec 2011	18 Feb 2012
Objective	CRM	Review meeting	kick off meeting /CRM	CRM	Public meeting	CRM	CRM	CRM
Theme	Environmental issues along S river	Review meeting	Water environmental governance in the Tai Lake Basin: Information disclosure and public participation	Environmental issues in G community	Reviewing G community roundtable meetings and remained problems	Agriculture, rural lifestyle and water environmental conservation in S community	The third G community construction and its environment	Exchanging and sharing of experiences of G community roundtable meetings, dialogue on community environmental problems
Participants	Government 6 (county2/ district4) Industries 4 Residents 4 NU 2 Total 16	Government 6 (county2/ district4) Industries 4 Residents 4 Expert 1 NU 2 Total 17	Government 14 (province3/ city 1/county5/ district6) Industries 10 Residents 6 Expert 1 Media 2 NU 2 Total 36	Government 11 (county3/ district8) Industries 4 Residents 12 Media 2 NU 4 Total 33	Residents 15 NU 1 IDE 1 Total 17	Government 2 (city1/ district1) Industries 4 Residents 10 G-community 1 NU 3 NGO 1 Total 21	government 2 (province1/ district 1) residents 21 Other communities 3 NU 3 NGO 1 Total 30	Industries 3 (service 2) Residents 21 NU 3 NGO 1 Total 28
Chairperson	Chief of environmental division in Y district	Lecturer of NU	Lecturer of NU	Lecturer of NU	Deputy director of G community party	Deputy director of G community party	Deputy director of G community party	Deputy director of G community party

Table 1 Community Round-table Meetings in Y district

4. Possibility and Issues of Bottom-up Governance in Taihu Lake Basin

Among the various pilot programs carried out so far, community round-table meetings indicated that the residents and enterprises based in Shequ and the government can get into a constructive three-way talk. Table 1 shows that the theme selected for each community roundtable meeting differed slightly each time. Although these pilot programs have been aimed at making the residents involved in the process of finding solutions to the water environment issues in Taihu Lake Basin, the dialogue with the residents must be considered a top priority for any community event to be successful. Another thing that became increasingly clear was that the residents and the leaders of Shequ shared a common interest in investigating the problem of environmental pollution caused by the enterprises and poor public management in each Shequ.

One of the problematic factors that led to the water environment issues in Taihu Lake Basin was the environment pollution caused by the enterprises. Naturally, it was included as one of the agenda in the first community roundtable meeting held in December 2008. The residents who attended this meeting, however, were more concerned about the direct adverse effect on regional environment in general, rather than on the water environmental pollution itself. In the

roundtable meeting, they not only complained about the poor water environment, but also raised their angry voice on problems like bad odor and soot dust. Moreover, the theme selected for S Shequ round-table meeting held in January 2011 was “Agriculture, Lifestyle in Farming Village and Protection of Water Environment”. But the farmers in this district assembled to this meeting with the common interest on the problem of water environmental pollution caused by wastewater discharged from the local plants. The organizers of this roundtable meeting claimed that for conservation of water environment, the treatment of wastewater discharged from plants and households is not the only counteraction that must be considered, but also the farmers needed to re-examine and change their conventional methods of farming that relied heavily on the abundant use of fertilizers and agrochemicals. On the other hand, the farmers expressed their dissatisfaction in the way the problem of wastewater discharged from the plants manufacturing chemical fertilizers in Y District was handled by giving the damage of aquaculture caused by this wastewater as an example of how seriously their living environment is ill-affected.

For having a dialogue with the enterprises, the problem was how to coordinate between the government, enterprises and Shequ leaders to come up with an agreeable method to organize the round-table meetings, which will be discussed more in detail later on. Although the residents in Y District where many enterprises have gathered were very keen about the environmental pollution caused by these enterprises, they seem to be cautious about holding a direct dialogue with the enterprises. The residents who participated in G Shequ round-table meeting in December 2011 expressed the dissatisfaction they had been feeling for a long time about the environmental pollution caused by the enterprises, but also said that they were reluctant to talk directly to the enterprises because they thought that it was the “role of the village leaders” to hold a dialogue with the enterprises and not theirs. In Y District, the enterprises and the residents were frequently in dispute on who should be responsible of maintaining the environment. One of the leaders of Y district commented that holding a roundtable meeting regularly was a desirable solution to prevent such disputes from escalating, and that it was very important for the government, enterprises and residents to keep on communicating between each other.

Other issues of concern raised by the residents and the community leader in G Shequ round-table meeting were about the problems related to environmental sanitation, such as, draining of wastewater from a remodeled facility that originally designed as a garage, field burning and litter scattering in residential areas. Moreover, many of the participants of G Shequ roundtable meetings held in December 2011 and February 2012 believed that these problems related to environmental sanitation were caused mainly by the migrant workers who came from outside of the city. It should be also noted that there were not a few remarks that the “residents’ subjective behavior” might have also been the reason for such sanitary problems to arise. (Table 2) These points have been the focus of the second round-table meeting held in G Shequ in February 2012, following the first meeting in December 2011. Specifically, the problem of remodeling the 1st floor of the garage occurred as a result of the lack of understanding of the users’ needs in the design phase. In the residential area of 3rd term construction plan undergoing within G Shequ, the remodeling of the garage itself was underway. The problem was that the residents were not aware at first about the need of connecting the remodeled garage to the drainage pipe. The fact that this

recognition has started to spread among the residents can be perceived as one of the accomplishments of holding a roundtable meeting.

	community round-table meeting in Dec 2011 at G shequ		Community round-table meeting in Feb 2012 at G shequ	
[Major reasons of environmental sanitary problems in the community(plural answers)]				
Government does not take any effective measurements	6	(21)	8	(31)
Industries do not act pro-environmental protection	2	(7)	3	(12)
Local community does not organize residents well	5	(18)	6	(23)
Many problems owe to migrant labors	15	(54)	17	(65)
Local resident s act self-aware behavior	12	(43)	10	(38)
Others	0	(0)	0	(0)
No/not efficient answer	4	(14)	0	(0)
Total answers	44		44	
Source: compiled by the author based on results of questionnaire survey in community roundtable meetings. Note: () indicates % among total samples in each meeting.				

Table 2 Perception of environmental sanitary problems in the community

Y District is an area that is transforming from a village to a Shequ for the purpose of aggregating the blocks of land and using them more efficiently. The public management of Shequ is an issue for not having appropriate governance over the residential area. This problem is not only affecting G Shequ, but is also considered as one of the common issues affecting the urban communities developed in other cities of China. (KOJIMA: 2011) For an appropriate governance to work, the residents have to be involved and can do so in many different ways, including community round-table meeting, which can be considered as one of the effective means to solve the issue of poor public management of urban communities.

According to the leader of G Shequ who has cooperated with this joint study project in organizing the community roundtable meeting, this Shequ had voluntarily ran four separate round-table meetings of their own, prior to the community round-table meeting organized as a part of the pilot program for this joint project. In these voluntary meetings held in January, March, April and November of 2011, the residents, government officials and police officers discussed about various issues in G Shequ, including the environment, sanitation and social order. The leader of G Shequ said that the residents were hesitant at first about participating in this meeting, but became more actively involved as they got used to attending this meeting in subsequent rounds. This case example shows that community round-table meeting in G Shequ that initially started as a pilot program for this joint study is now gradually evolving into an autonomous dialogue mechanism within the Shequ.

The extensive development of community round-table meeting seen in G Shequ is still one of the few “successful” cases. For a community round-table meeting to work out successfully,

there apparently seem to be several requisites that need to be met: the experience of this joint study tells that there must be one or more serious issues in the community that the residents feel a desperate need for them to be resolved; the leader of the community must have a strong will to solve these issues; the community must be able to gain a certain level of support from the local government authorities; there must be a local group of experts that can coordinate the participation of all the different stakeholders that have an interest in these issues (in the case with this joint study project, the study team of Nanjing University served this role), among others. Nevertheless, even when these requisites are fully met, a large challenge yet remains, which is - how to secure the “legitimacy (SABATIER et.al.:2005) of organizing” the community round-table meeting in the context of current governance system in China.

5. Conclusion

Based on the past efforts and experience in promoting dialogue and collaboration in Japan and other developed countries, we can see that the various programs currently implemented to support the water environment policy enforced in Taihu Lake Basin have been effective in making the stakeholders recognize the necessity of “participation”. However, these programs have not been able to make the stakeholders realize the need for “restoration through their mutual collaboration”. And most probably, the reason why it is so difficult to institutionalize any experimental approach like the community roundtable meeting in this basin is because the key stakeholders including the local government do not share the need to “restore” the environment “by collaborating”. Moreover, other mechanisms to promote the participation of the general public should also be examined, besides the roundtable meeting. What kind of roles can the specialists on any given issue play to make the best use of their expertise? How can NGO (NPO) be involved in the overall process? These are some of the questions that still remain unanswered.

In examining which mechanisms are workable, one thing is clear from the experience of experimenting with the community roundtable meeting. It is not only the government, research institution or NGO that makes a mechanism work. It is the community leader who is knowledgeable about the actual conditions of the community and also trusted by the community that plays the key role in driving the mechanism. To elevate the level of participation to a new stage where dialogue and collaboration can be further induced, various challenges lie ahead, including the reform of policy support programs, examination of diverse workable mechanisms, and development of community leadership.

To seek for the restoration of the environment in Taihu Lake Basin that is adaptive and sustainable for a long term, there is a need to keep in mind that top-down form of governance has limitations in supporting the environment policy enforced in China. In the context of Taihu Lake Basin, the changes in the political, economic and social basins must also be taken into account. From here onward, the main theme to discuss and explore for new system building should be about how to incorporate bottom-up mechanism into the new system.

Going forward, it is desirable to continue holding community round-table meetings as a forum for mutual learning to build up a system of participation and collaboration for maintaining and enriching the public space in the community that shares the same environment. If the

participants of this meeting can nurture their literacy and stewardship necessary for the pursuit of participation and collaboration through trials and errors, they will most likely be able to project a more promising outlook toward reconstructing the publicness of their community (SAITO: 2000) with their own hands.

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流域ガバナンスの学際研究 - 琵琶湖の農業濁水問題を事例に -

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1. 流域管理の課題：階層性に着目した流域管理の視点

一般に、流域は水系に由来する入れ子状の構造（階層性）をもっており、そのような階層性と重なりあいながら人間の諸活動もおこなわれてきた。流域管理に関わる多様なステークホルダーは、異なる階層に分散している。階層が異なれば、流域の問題の「捉え方」に差異が生まれ、利害調整を含めた多様なコミュニケーションが阻害されるために流域管理がうまく進まない。本稿では、流域の階層性から生じるステークホルダー間のコミュニケーション阻害を流域管理の上での主要課題と位置づける（脇田：2005）。総合地球環境学研究所のプロジェクト研究 E-01(CR)『琵琶湖一淀川水系における流域管理モデルの構築（2002年度 - 2006年度）』の成果（和田：2009）をもとに、日本の琵琶湖における農業濁水問題を事例として、1）「人間と自然の相互作用環」の視点に立った「農業濁水問題」の全体像と、2）「階層化された流域管理」という考え方に基づいた流域ガバナンスを促進するためのコミュニケーション方法を紹介する。

2. 琵琶湖流域における農業濁水問題とは？

琵琶湖一淀川水系は、日本で人間活動によりもっとも大きな影響を受けている流域のひとつである。この流域は、大きく上流の琵琶湖流域と下流の淀川流域からなる。琵琶湖流域は、滋賀県とほぼ一致し、日本最大の淡水湖である琵琶湖を含み、特に湖東から湖北にかけての湖岸平野に稲作農業地帯が広がる。対照的に下流の淀川流域には、京都・大阪などの大都市を含む都市域が広がり、約 1400 万人が琵琶湖に水を依存している。琵琶湖流域では、1970 年代の富栄養化をきっかけに、陸域からの汚濁負荷に対して、環境基準による法的規制や下水道普及率の向上など技術的な対策を進めてきた。その結果、近年は、後述する農業濁水を含めた面源負荷の対策が相対的に重要課題となって浮上してきた。

水田稲作農業においては、水田の水持ちをよくし、耕作しやすいように水田を平らにすることを目的に、田植え前に水田に水を張って土を耕す（しろかき）。しろかき後の泥水は、ゆるやかに自然流下するが、泥の沈降を待たずに強制的に排水する場合もある（強制落水）。あるいは、田のあぜの穴から、また降雨によるあふれなどにより流れでる。これら排水路に流れた濁水は、地域の中小河川に集積し、最終的には、河口から琵琶湖へと流れ出る。「農業濁水問題」とは、4月から5月の連休の時期を中心に、特に琵琶湖湖東から湖北にかけての湖岸に、この濁水流入が視覚的に顕著に現れ、濁水に含まれる土壌粒子、窒素・リンなどの栄養塩が琵琶湖の環境に与える影響への懸念から、問題として認識されるようになったものである（図 1）。農業濁水は、典型的な面源負荷のひとつであり、農業濁水の影響を軽減するには、法的・施設の整備といったハード的な対策だけでは困難であり、農業の担い手である個々の農家とのコミュニケーションによるソフト的な対策が重要となる。

このような背景を踏まえて、本プロジェクトでは、階層性の視点からの流域管理研究、

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人間－自然相互作用系のモデルとして、琵琶湖流域における農業濁水問題に着目して研究を進めてきた。私たちは、琵琶湖流域を入れ子状の構造として捉えたうえで、琵琶湖流域における農業濁水問題に関わる、琵琶湖流域（滋賀県）：マクروسケール、滋賀県彦根市稲枝地域：メソスケール、稲枝地域内の集落群：ミクروسケールの3つの空間的な階層を便宜的に設定した（図2）。その上で、各階層における「物質動態」、「社会文化システム」、「生態系」、「流域情報モデリング」の4班の文理連携研究を進めてきた（谷内他：2007、和田：2009）。以下、第3節では農業濁水問題の影響について、第4節では濁水問題が生まれた社会的背景について説明する。

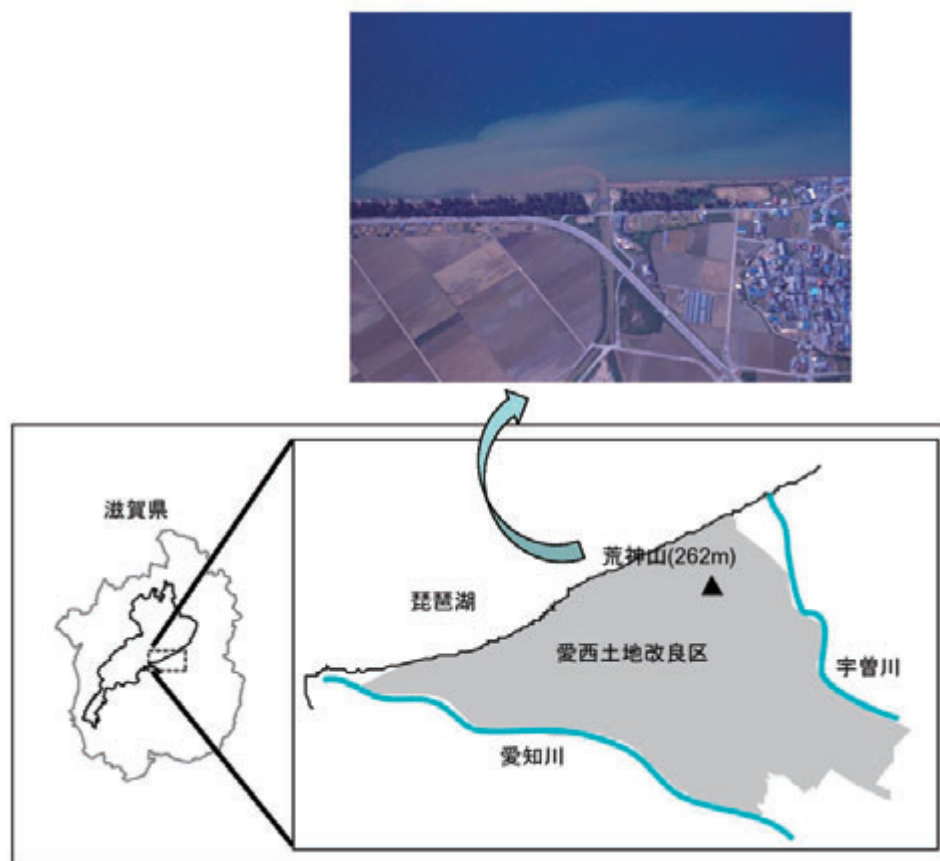


図1 湖岸から琵琶湖に流入する農業濁水（上）と彦根市稲枝地区の位置（下）
：（和田：2009）70頁 図2-2-1および76頁 図2-2-9より引用

3. 農業濁水問題の影響

まず、農業濁水が琵琶湖にどのような影響を与えるのかをさぐるため、各種の安定同位体や微量元素を、湖、川、人の質的なつながりを追跡する環境指標として利用した。琵琶湖流域というマクروسケールからの検討として、琵琶湖への流入41河川において、イオウ、ストロンチウムの安定同位体比を調査した結果、近年の琵琶湖における水質（安定同位体

組成) 変化の原因が、主に湖東地域の農業地帯を流域にもつ中小河川であることがわかった。農業肥料に含まれている硫黄の安定同位体組成および湖東平野の地層や土壌の交換性成分のストロンチウムの安定同位体組成は、中小河川の値と良い一致を示すことから、農業活動によって発生した各種の酸が平野の土壌や岩石からミネラル成分を溶脱したことにより湖水の水質が変化した、というシナリオが浮かび上がった。

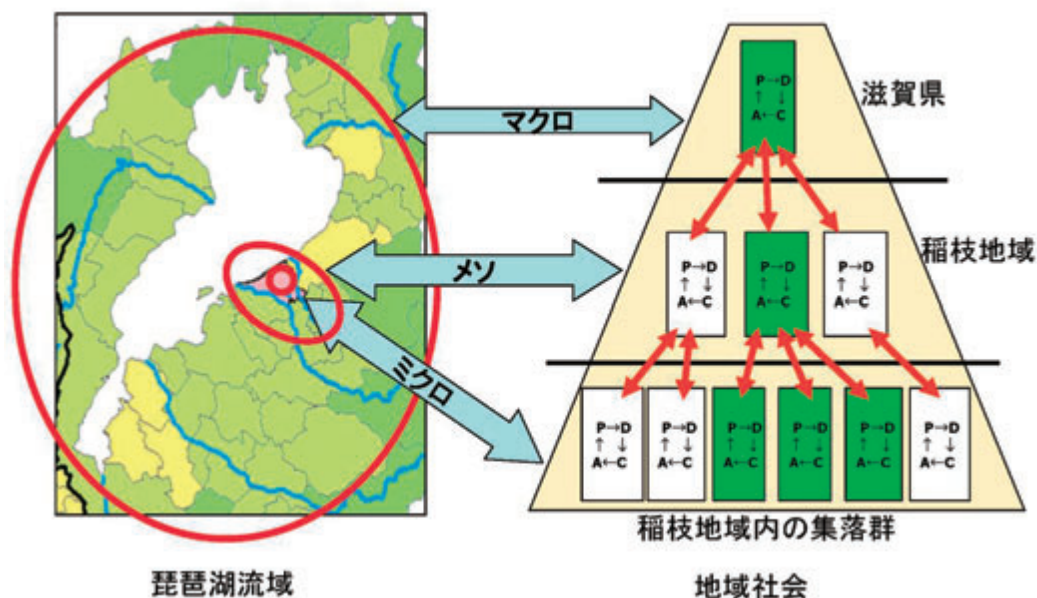


図2 琵琶湖流域の階層構造と「階層化された流域管理」

次に、琵琶湖の生物活動はリンによって規制されているため、湖東の中小河川が琵琶湖の富栄養化にどの程度影響しているのかを、現地農家の協力の下、圃場実験により検討した。中小河川の水質は、施肥や灌漑など周辺の水田の環境変化に応じて変化する。また、農業濁水に含まれているリンと窒素の濃度は、水管理のパターンにより大きく異なる。農業濁水の負荷を評価した結果、代表的な粗放的水管理である「強制落水」により、水田 0.3ha あたり、水田土壌 117kg、窒素 0.605kg、リン 0.146kg 流出することがわかった。この結果を琵琶湖北湖集水域の水田全体に適用すると、生活排水由来の窒素量の 11.4%、リンの 27.1%が、一回の強制落水で流出する。言い換えると、濁水の発生は短時間（1日程度）であるにもかかわらず、北湖に流入する窒素の 0.8-5.3%、リンの 13.5-42.3%が農業濁水によって説明できる。これらに代表される結果は、琵琶湖の水質形成・富栄養化に、湖東の中小河川への農業活動の潜在的インパクトが大きいことを示すとともに、地域住民によるボトムアップからのきめ細かい水管理や水路掃除などが、琵琶湖の環境保全において有効・必要であることを意味する。

一方で、このような濁水によって、水田からの土壌シルトの堆積により、中小河川の河床の溶存酸素濃度の減少やメタンガスの発生など、汚濁が進行することがわかった。言い換えると、マイクロレベルの空間的階層では、農家による農村集落の水辺環境の悪化が生じ

る「自己回帰型」として濁水問題が発現している。また主に漁業者への聞き取り調査から、濁水が沿岸漁民の漁撈活動への漁業被害を生み出す危険性が指摘された。つまり、メソレベルでは、原因者である農家と被害者である漁業者が分離する「加害・被害型」として濁水問題が現れる。さらに、このような地域社会からの濁水の流入が続くと、他の人間活動の負荷が複合的に働くことで、マクロレベルである琵琶湖全体の富栄養化を促進し、水質悪化が急激に進むレジームシフトが危惧される（「地球環境問題型」）。すなわち、濁水問題は、マイクロ、メソ、マクロとその空間的階層を移行するにしたがい、濁水問題のタイプを変化させ、問題が発生する空間スケールとタイムスケールを拡大していくことになる。濁水問題とは、連続するが異なるタイプやスケールをもつ「複合問題」なのである（表1）。

	富栄養化・レジームシフト	漁業被害	水辺環境の劣化
階層	マクロ	メソ	マイクロ
エリア	琵琶湖	湖岸域	水路等
原因者	農家を含む	農家	農家
被害者	湖水利用者	漁家	農家を含む地域住民
物質	DO, N, P	SS	SS, 泥
距離	大	中	小
タイムスケール	大	中	小
タイプ	地球環境問題型	加害・被害型	自己回帰型

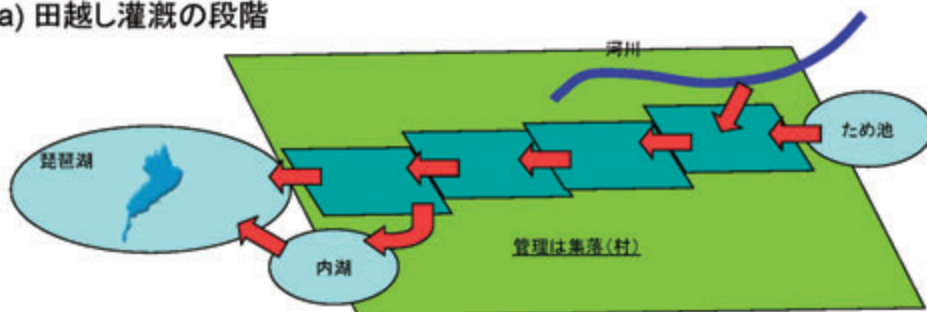
表1 濁水問題は「複合的問題」：(和田:2009) 80 頁 表 2-2-1 を一部改変して引用

4. 濁水問題が生まれた社会的背景

以上のような濁水問題の下流（影響）の分析とともに重要なことは、このような「複合問題」を生み出す「上流」の社会的・政策的背景の分析である。琵琶湖湖東においては、戦後日本の農業政策の下で、圃場整備と稲作の機械化・化学肥料・農薬の普及、琵琶湖からのパイプライン灌漑と用水・排水の完全分離（図3）など、一連の土地改良事業が進展した。その結果、水田の水管理主体がコミュニティから個人主体へと変化するとともに、農業用水・排水量が増加した。一方で、農家の第2種兼業化と高齢化・後継者不足が進行した結果、水管理が粗放化することで、農業濁水問題が顕在化した。この歴史的な濁水問題発現の過程で注意すべきことは、至近的には、地域の土地改良事業の推進に伴う、近代的な灌漑システムの導入が濁水問題を顕在化させたわけだが（図3）、その背景には、国策として進められてきた農業の近代化政策があることである。この近代化政策は、農業の生産性を向上させたものの、意図せざる結果として、コミュニティのもっていた水環境管理（水田を含む）を低下させたといえる。この農業濁水による琵琶湖への負荷は、外部不経済化されたままになり、実効性のある対策や取り組みが実現しているとは言いがたい。

土地改良事業が進行した日本の高度経済成長期の前後は、短い期間ではあるが、日本における、人間と自然の相互作用系が急激に変化した重要なフェーズである。特に、琵琶湖－淀川水系においては、下流淀川流域における水量変動の安定化と利水需要の要求を契機に、琵琶湖の多目的ダム化、その見返りとしての上流琵琶湖流域の総合的な開発がおこなわれ、人間と自然の相互作用系が、高度な人工系へと大きく変化した。琵琶湖の農業濁水問題とは、琵琶湖－淀川水系における大きな変化が、稲作農業地域において顕在化した問題の一端でもある。現在、琵琶湖では生態系の富栄養化による急激な変化の危険を含めて、レジリアンスの低下が進行しており、一方、湖東の農村地域に関しては、農業と地域社会ともに、大きな転換期にあり将来を模索している途上である。

(a) 田越し灌漑の段階



(b) 圃場整備後

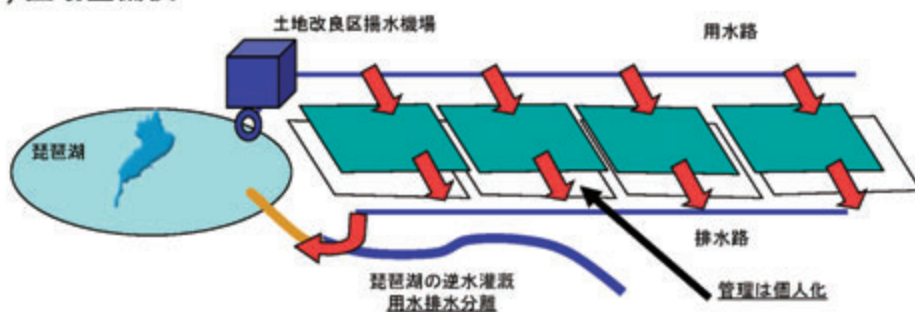


図3 灌漑システムの変化：(和田：2009) 76頁 図2-2-8を引用

5. 階層化された流域管理システムの提案

濁水問題の、階層によってその問題の発現の仕方が異なる「複合問題」としての性質は、階層間でコミュニケーションの阻害を引き起こす重要な要因の一例である。また、農村地域においては、後継者問題や農業の将来など、濁水問題だけでなく他にも切実な問題を抱えている。このような階層間での問題認識の違いもまたコミュニケーションの阻害を引き起こす。このような現実を前提としたとき、わたしたちが研究を進める上で提案し、指針としたのが、順応的管理を取り込んだ「階層化された流域管理システム」である(脇田：2005)(図2)。ここに、「階層化された」ということばは、流域管理システムが、階層構造を持つべきだと主張するために使われているのではない。そうではなく、流域は、ステークホルダーに異なる問題認識を生み出す原因となる階層性を持つこと、この事実を考慮して流域管理が考えられるべきだと注意をうながすためである。この「階層化された流域管

理」において重要となるのは、①「階層ごとの適切な順応的管理（PDCA サイクル）」と、②「階層間の双方向コミュニケーション」の2点である。

つまり、①階層ごとの順応的管理に必要な「流域診断」の具体的な方法を開発し、行政や地域住民による流域管理を支援するとともに、②そのような階層ごとの環境診断の方法を連関させ、同時に、階層間のコミュニケーションの回路を豊富化していくことで、個々の階層のもつ個別性に配慮した形での流域全体の管理の方法を発見していくこと、それが「階層化された流域管理」の基本的な戦略となる。「流域診断」の具体的な方法とは、指標、モデル、GIS（地理情報システム）、聞き取り調査、ワークショップ、アンケートなどである。これらの様々な「流域診断」の方法を有機的に連関させながら、階層間に分散した多様な利害関係者のコミュニケーションを促進することで、流域を共同管理していくための「ガバナンス」を確立し、「参加・参画」と「協働」による流域管理を構築していくわけである。次の第6節では、特にメソ・ミクロスケールにおいて重要なコミュニケーション手法について紹介する。

6. 地域社会と環境保全の接点を探る

調査地域の集落等 35 自治会において、水環境に関する管理や水利用の聞き取り調査をおこない、調査地周辺の詳細データ、琵琶湖流域に関するデータとともに GIS データベースに統合した。この結果をもとに、地域内の3集落においてワークショップを開催した。住民自らが、地図を使って、「美しい水辺・楽しい水辺」はどこかを議論し、そこから地域の水環境やその未来像について考える、住民自身による地域環境目標像作成を支援する試みである。また、農業経営や農業の未来に関しては、「農業センサス」を使った主成分分析をもとに、調査地域の29集落の農業経営再編と担い手の現状を類型化した結果、集落ごとに将来の営農の展開可能性に違いがあることがわかった。これらに代表される成果は、集落の個別性を前提としたコミュニケーション手法開発の必要性を示すものである。

また、調査地域の6集落において、当該地域での調査結果をもとに作成した水環境の現況や保全策に関する情報提供が、農家の環境配慮の意識や行動へ及ぼす影響を検証するワークショップを開催した。その結果、①合理的説得（水質汚濁をもたらす化学的物質とその生物的影響などの科学的情報を提示し、農家のリスク認知と一般的態度を促進）では、「環境を守らなければならない」という一般的態度の促進にはつながるものの、行動意図の促進にはつながらないことが示された。一方、②情動的説得（地域への愛着や生物への愛着などの情報を提示し、社会規範評価と行動意図を促進）では行動意図の促進に効果があることが示された。また、両条件を合わせた③合理・情動的説得では、濁水削減に対する一般的態度・行動意図の両方が促進されていた。特に情報提示をしない④統制群においても、現状に関する情報提示、参加者同士の話し合いが有効であったことが示され、ワークショップそれ自体の有効性が検証された。このように、濁水削減に対する農家の態度や行動が促進される上では、環境保全と地域社会固有の課題の接点ができるように、情報を多面的に提示することの重要性が示された。

これらの試みは、もちろん、農業濁水問題の即効的な解決にむすびつくものではない。しかし、まずメソスケール・ミクロスケールの地域住民が、農業経営・地域社会の将来という自らの切実な問題意識をもとに、地域の営農の将来像を考え、地域社会の身近な水環境の問題と重ねて、濁水問題を検討していける状況をつくることが、流

域ガバナンスに基づいた流域全体の濁水問題の解決につながると私たちは考えている。そのためには、地域の個別性を前提として、地域住民自らによる環境保全活動を支援するための、環境診断の方法論や、順応的管理、コミュニケーションを有効に促進する方法が必要となるのである。

謝辞

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Interdisciplinary Study of Watershed Governance

– Using the Agricultural Turbid Water Problem of Lake Biwa as Reference –

Shigeo YACHI¹

1. Watershed management issues: watershed management perspective with focus on hierarchy

Generally, watersheds have nested structure (hierarchy) originating from the water system, and human activities have been carried out overlapping such hierarchy. Diversified stakeholders related to watershed management are distributed in different hierarchical levels. When the hierarchical levels are different, differences in the “interpretation” of the problems of watershed surface occur, and the watershed management does not proceed well because various communications are obstructed including the control of interests. In this article, the communication obstruction between the stakeholders that originate from the watershed hierarchy is positioned as the most important issue in the watershed management (WAKITA: 2005). Based on the result of the Research Institute for Humanity and Nature’s research project E-01 (CR) Multi-disciplinary Research for Understanding Interactions between Humans and Nature in the Lake Biwa – Yodo River Watershed (FY2002 to FY2006) (WADA:2009), and using the agricultural turbid water problem in Lake Biwa of Japan as a reference, 1) the overview of the “agricultural turbid water problem” based on the “human and nature interaction loop” perspective and 2) the communication method to facilitate watershed governance based on the “hierarchical watershed management” perspective will be introduced.

2. What is the agricultural turbid water problem in Lake Biwa watershed?

The Lake Biwa – Yodo River watershed is one of the most impacted watersheds by human activities in Japan. This watershed is largely composed of the Lake Biwa watershed at the upstream and the Yodo river watershed at the downstream. The Lake Biwa watershed coincides nearly with Shiga prefecture, includes the largest freshwater Lake Biwa, and the rice growing farm belt stretches on the lakeside plain from the east to the north of the lake. By contrast, a metropolitan area including large cities such as Kyoto and Osaka stretches in the lower Yodo river watershed, and about 14 million people rely on the water from Lake Biwa. Triggered by the eutrophication in the 1970’s in Lake Biwa watershed, legal restrictions through environmental standards and technical measures such as the increase of the coverage of the sewage system were taken against the pollutant load from the land. As a result, in recent years, the countermeasures for non-point source load, including the agricultural turbid water, to be described later, have relatively gained attention as important issues.

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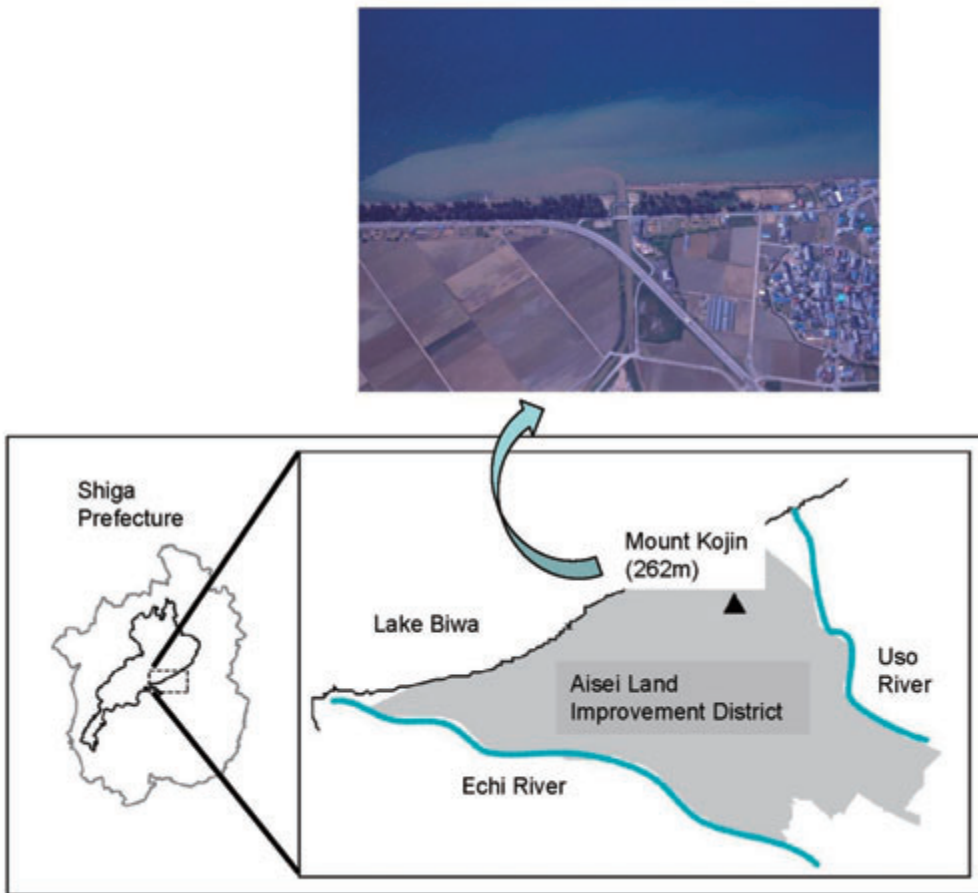


Figure 1 Agricultural turbid water flowing from lakeshore into Lake Biwa (top) and the location of Inae district of Hikone city (bottom) : excerpt from (WADA: 2009) p.70, Fig. 2-2-1 and p.76, Fig.2-2-9

In the rice growing agriculture, the rice paddies are irrigated and the soil is plowed (“shirokaki”) before transplanting the rice seedlings, in order to make the rice paddies flat so that the rice paddies hold water well and become easy to farm. The turbid water after the shirokaki slowly and naturally flows down, and sometimes is forced to drain without waiting for the mud to settle down (forced drainage). Or, it flows out through the holes in the ridges between rice paddies or overflows due to rainfall. This turbid water that flows out into the drainage is collected into the medium and small size rivers of the region and ultimately flows out from the mouth of the river into Lake Biwa. “Agricultural turbid water problem” is the concern, that people perceived as a problem, for the impact of this turbid water on the Lake Biwa environment when its inflow, containing nutrients such as the soil particles, nitrogen and phosphorus, was conspicuously seen visually around the holiday period of April to May, especially in the lake shore stretching from eastern Lake Biwa to the northern part (Figure 1). Agricultural turbid water is one of the typical non-point source loads and it is difficult to reduce the impact of the agricultural turbid water

through hardware type of countermeasures alone such as legal and facility preparations, and software type of countermeasures such as the communication with the respective farm households who undertake the actual farming is important.

In light of such background, this project has been conducting a research focused on the agricultural turbid water problem in Lake Biwa watershed as a watershed management study from hierarchy perspective and a model for human–nature interaction system. We have treated Lake Biwa watershed as a nested structure, and for convenience sake, established three spatial hierarchical levels for the agricultural turbid water problem in Lake Biwa watershed - Lake Biwa watershed (Shiga prefecture): macro scale, Shiga prefecture Hikone city Inae district: meso scale, the local communities in Inae district: micro scale (Figure 2). In addition, we have been conducting four groups of humanities and sciences interdisciplinary research in “material cycling,” “social cultural system,” “ecosystem,” and “watershed information modeling” for each of the hierarchical levels (YACHI et.al.: 2007, WADA: 2009). Below, the impact of the agricultural turbid water problem will be discussed in section 3, and the social background from which the turbid water problem originated in section 4.

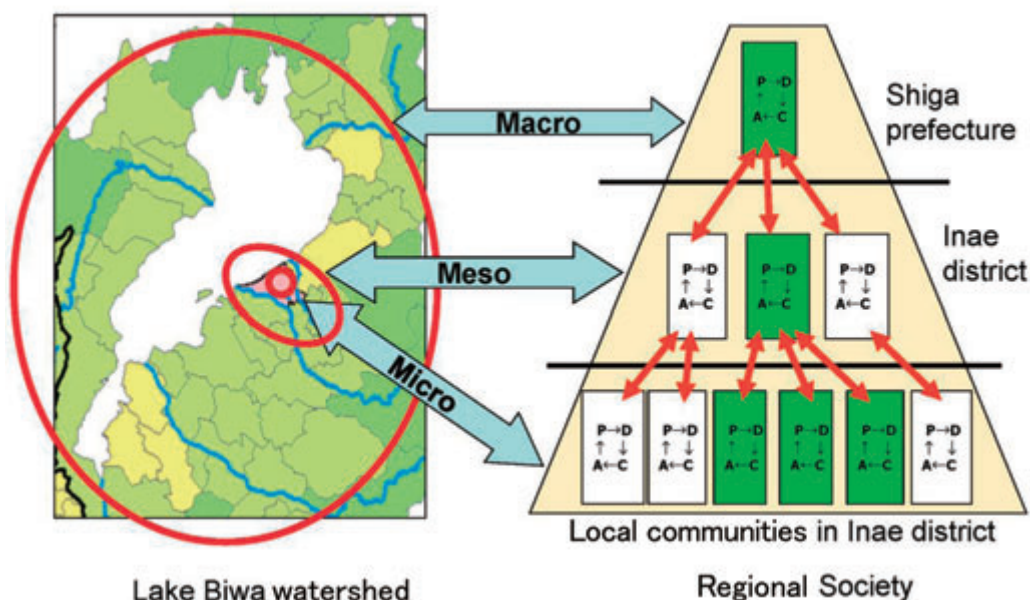


Figure 2 Hierarchy structure of Lake Biwa watershed and “hierarchical watershed management”

3. The impact of the agricultural turbid water problem

First, in order to investigate what the impact of the agricultural turbid water has on Lake Biwa, various stable isotopes and trace elements were used as the environmental index to track the physical relationships among the lake, rivers, and people. From an investigation at the macro scale level of Lake Biwa watershed, the results from inspection of the stable isotopes ratio of sulfur and strontium in the 41 rivers flowing into Lake Biwa indicated that the cause of the recent change in water quality (stable isotopes composition) lie mainly in the medium and small size rivers that

drains into the agricultural area in the eastern region of the lake. From the fact that the stable isotope of sulfur included in agricultural fertilizer and the stable isotope composition of strontium of the exchangeable component in the eastern lake plain strata and soil match the values from the medium and small rivers, a scenario has appeared where various acids generated from the agricultural activities leached the mineral components from the plain soil and rocks and caused the change in water quality in the lake water.

Next, because the activities of the organisms of the lake are restricted by the presence of phosphorus, the level of impact the medium and small rivers of the lake's eastside has on the eutrophication of Lake Biwa was investigated through field experiments with the cooperation of the farmers at the site. The water quality of the medium and small rivers changes with the environmental changes such as the fertilization and irrigation of the rice paddies in the vicinity. Also, the concentration of phosphorus and nitrogen in the agricultural turbid water changes greatly depending on the pattern of water management. As a result of evaluating the load of agricultural turbid water from a "forced drainage", which represents a rough water management, 117 kg of rice paddy soil, 0.605 kg of nitrogen, 0.146 kg of phosphorus per 0.3 ha of rice paddy were found to be discharged. When this result is applied to the entire rice paddies in the Lake Biwa northern lake catchment watershed, 11.4% of nitrogen and 27.1% of phosphorus originating from household wastewater is discharged in a single forced drainage. In other words, even though the turbid water occurs for a short period (about a day), it is responsible for the 0.8 to 5.3% of nitrogen and 13.5 to 42.3% of phosphorus flowing into the lake's northern part. The result represented by this fact indicates that the potential impact of the agricultural activities on the medium and small rivers of the east of the lake is enormous on the water quality and eutrophication of Lake Biwa, and that the bottom-up activities such as the detailed water management and the cleaning of the waterways by the local residents are effective and necessary for the environmental conservation of Lake Biwa.

On the other hand, it is found that there is increase in pollution such as the decrease in the dissolved oxygen concentration and generation of methane gas in the riverbeds of medium and small rivers due to the build-up of the soil silt from this type of turbid water. In other words, in the spatial hierarchy at micro level, the turbid water problem manifests as "autoregressive type" where the farmers cause the deterioration of the waterfront environment of the farming communities. Also, from the hearing investigation of mainly the fishermen, it was pointed out that there is a danger of the turbid water causing damages to the fishing activities of the fishermen of the coast. That is to say that at meso level, the turbid water problem manifests as "aggressor-victim type" in which the farmer, the cause, and the fishermen, the victim, are separate. Furthermore, when the turbid water inflow from local societies continue, and other human activity loads come into play in a compounded manner, then the regime shift becomes a concern in which the eutrophication of the entire lake at macro level is accelerated and the water quality is drastically degraded ("global environmental problem type"). Namely, the turbid water problem changes its type and increases the spatial and time scale in which the problem occurs as it moves through the micro, meso, macro and their spatial hierarchy. The turbid water problem is a "compound problem" that is continuous but has different type and scale. (Table 1).

	Eutrophication, Regime Shift	Damage to fishing industry	Degradation of lakeside environment
Hierarchy Level	Macro	Meso	Micro
Area	Lake Biwa	Lakeside district	Waterways, etc.
Originator	Farmers included	Farmers	Farmers
Victim	Lake water users	Fishermen	Local residents including farmers
Substance	DO, N, P	SS	SS, mud
Distance	Long	Medium	Short
Time scale	Long	Medium	Short
Type	Global Environmental Problem	Aggressor / Victim	Autoregressive

Table 1 Turbid water problem is “compound problem”: (WADA: 2009) edited excerpt from p.80 Table 2-2-12-1

4. The social background in which the turbid water problem occurred

The analysis of the social and policy background of the “upstream” that generates this type of “compound problem is just as important as the analysis of the downstream (impact) of the turbid water problem discussed above. Series of land improvement projects were advanced in the east of Lake Biwa under the postwar Japan agricultural policy such as the agricultural field improvement project, increased mechanization of rice farming, widespread usage of chemical fertilizers and pesticides, the irrigation pipeline from Lake Biwa, and the complete separation of irrigation and drainage (Figure 3). As a result, the water management entity of the rice paddies changed from the community to the individuals and the agricultural irrigation and drainage volume increased. On the other hand, as a result of the increase of the Type 2 farmers with side business, aging, and lack of successors, the water management becomes rough and the agricultural turbid water problem manifested itself. The point to note in the course of the occurrence of this historical turbid water problem is that, in close view, the introduction of the modern irrigation system accompanying the regional land improvement projects manifested the turbid water problem (Figure 3). In the background, however, there was a national policy for the modernization of agriculture. It can be said that despite the fact that this modernization policy has increased the agricultural productivity, it decreased the water management environment (rice paddies included) held by the communities as an unintended result. The burden on Lake Biwa from this agricultural turbid water has been left ignored as an external diseconomy, and it is difficult to say that there is any effective countermeasure or plan that has been put into practice.

The period before and after the high economic growth in Japan when the land improvement projects have been progressing was an important phase when the human and the nature interaction system drastically changed in Japan even though it was for a short duration. Especially in Lake Biwa–Yodo River watershed, the stabilization of the water volume change and the irrigation demand requests in the downstream Yodo river watershed were timely reasons to start the refurbishment of Lake Biwa as multipurpose dam and a compensating development of the upstream Lake Biwa watershed, and the human and the nature interaction system greatly changed

into an advanced artificial system. The Lake Biwa agricultural turbid water problem is also a part of the problem of a drastic change in the Lake Biwa–Yodo River watershed that manifested in the rice growing agriculture region. Currently, the resilience of Lake Biwa, including the danger of the drastic change in the ecology of the lake due to eutrophication, is progressively reduced, while in the agricultural district of the eastern part of the lake, both the agriculture and the local society are in a period of great transition and is in midst of searching for the right path to the future.

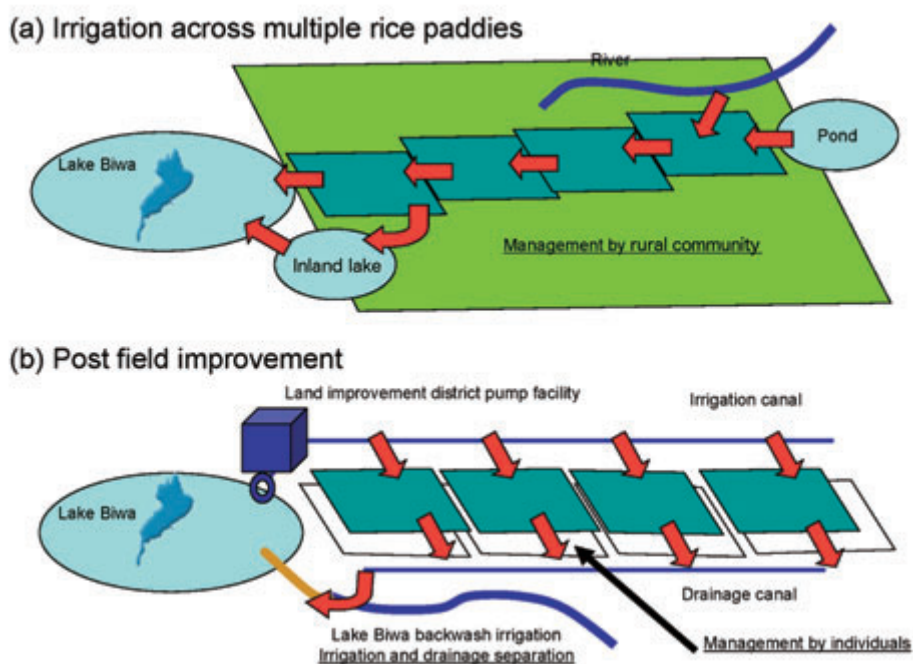


Figure 3 Change of Irrigation System: (WADA: 2009) excerpt from p.76, Fig. 2-2-8

5. Proposal of a Hierarchical Watershed Management System

The “compound problem” characteristic of the turbid water problem in which the problem manifests differently according to the hierarchical levels, is an example of the important factor in the obstruction of communication between the hierarchical levels. Also, in the agricultural district, there are other pressing problems aside from the turbid water problem such as the successor problem and the future of farming. This kind of difference in problem recognition between the hierarchical levels also causes the obstruction of communication. When this kind of reality is the premise, the proposal and the direction that we offered in the course of our research was a “hierarchical watershed management system” that incorporated an adaptive management (WAKITA: 2005) (Figure 2). The word “hierarchical” is not used to advocate that the watershed management system should have a hierarchical structure. Instead, it is to urge caution that the watershed has hierarchy that causes the stakeholders to have different recognition of problems, and that the watershed management should be thought through with this fact in mind. The two important points in the “hierarchical watershed management” are 1) “the appropriate adaptive

management (PDCA cycle) and 2) bidirectional communication between the hierarchical levels.

In other words, by 1) developing the detailed method for “watershed diagnosis” that is needed for adaptive management for each hierarchical level, and supporting the watershed management by the government and local residents, and by 2) connecting the environmental diagnosis methods for each of such hierarchical levels and, at the same time, by enriching the communication circuit, the process of discovering the management method for the entire watershed that takes into consideration the individuality of each hierarchical level becomes the basic strategy of the “hierarchical watershed management.” The detailed methods for the “watershed diagnosis” are index, model, GIS (Geographic Information System), hearing investigation, workshop, survey, etc. By linking these various methods of “watershed diagnosis” in a coordinated manner, and promoting the communication of the diversified stakeholders distributed in the hierarchical levels, the “governance” for the cooperative management of the watershed can be established and the watershed management through “involvement, participation” and “collaboration” can be constructed. In the next section 6, the important communication method especially at meso and micro scale levels will be introduced.

6. Probing the local society and environmental conservation connection

Hearing investigation was carried out in the 35 local communities of the investigated district for the management related to water environment and irrigation and the result was combined with the detailed data of the surrounding areas of the investigated district and the data related to Lake Biwa watershed and then stored into the GIS database. A workshop was held in the three communities in the district based on these results. It is an attempt to support the creation of the image of local environmental goal by the residents, themselves, using maps to discuss where the “beautiful shores, pleasant shores” are, and then think about the future of the local water environment. Also, in regards to the farm management and the future of farming, based on the principal component analysis utilizing the agricultural census, the results of the typification of the current status of farm management reorganization and successors in 29 communities surveyed indicated that there are differences in the future farming development possibility for each community. This representative result indicates the need for the development of communication method that assumes the individuality of the communities.

Also, workshops were held in 6 communities of the investigated district, to verify the effect of providing the information of water conservation status and conservation activities based on the investigation results of the said district on the farmers’ environmental conservation awareness and activities. As a result, although it was shown that 1) rational persuasion (the scientific information is presented, such as the chemical substances that cause water pollution and the biological impact, and risk recognition and typical attitude by the farmers are promoted) leads to the promotion of the typical attitude of “the environment needs to be protected”, it does not lead to the promotion of the will to act. On the other hand, 2) emotional persuasion (information such as the affection for the district and living things is presented and social norm evaluations and will to act are promoted) is shown to be effective in the promotion of the will to act. Also, for the combined condition 3) rational and emotional persuasion, both the typical attitude and the will to

act toward reducing the turbid water were promoted. In the 4) control group, to which no particular information was provided, the providing of current situation information and discussions among the participants were shown to be effective and the workshop itself was verified to be effective. In this manner, it is shown that is important to present information from various perspectives so as to make the connection between the environmental conservation and the problems specific to the local society when there is promotion of farmers' attitude and actions toward turbid water reduction.

These efforts, of course, do not lead to immediate solution to the agricultural turbid water problem. However, I think that when the local residents at meso and micro scale levels recognize their own pressing problems such as the farm management and the future of the local society, and think about the image of the future local farming overlapping with the local and immediate problem of water environment, and create an environment to investigate the turbid water problem, it will lead to the solution to the turbid water problem of the entire watershed that is based on watershed governance. In order to achieve it, with the local individuality as a premise, an effective method for the promotion of the communication, the environmental diagnosis methodology and the adaptive management to support the local resident-initiated environmental conservation activities becomes necessary.

Acknowledgement

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后记

孔海南¹

湖泊是人类赖以生存的重要自然水体生态系统之一。在数千年的人类文明发展过程中，湖泊为人类提供了各种生态服务功能，诸如工农业用水和饮用水源地、水产品供给、旅游与休闲娱乐、气候调节与水质净化等。可以说，湖泊因人类而体现其经济与文化价值，而湖泊的环境、功能与价值也因人类而改变。事实上，由于人类对湖泊流域的过度开发和湖泊生态服务功能的过度利用，以富营养化问题和灾害为代表的湖泊的加速生态退化与消亡正在严重威胁着全球的湖泊生态系统。在湖泊流域的经济社会发展和湖泊环境保护这一博弈中，如何构建和谐的人—湖关系，协调湖泊生态保护和生态服务功能的可持续利用，已经成为世界各国湖泊研究工作者十分关注的问题。

上海交通大学河湖环境工程研究中心于 2006 年起就和日本综合地球环境学研究所建立了合作研究关系，我的团队和该研究所川端教授的团队开展了多年的合作研究工作，主要涉及人类活动对湖泊环境的改变、湖泊环境与湖泊生态健康（特别是病原生物的发生与危害）的关系以及湖泊的保护对策等，我们的共同的足迹遍及琵琶湖、巢湖、太湖、西湖、滇池及洱海等，而琵琶湖和洱海是我们的重点研究对象。7 年多来，我们的合作研究取得了大量的创新性成果。

自然科学、人文社会科学和工程技术科学都是科学，在推动人类文明进步方面它们从来就没有孰重孰轻之分。复杂而艰巨的湖泊环境问题的治理更是离不开不同学科领域的科技工作者的共同努力。诸如湖泊生态学和水化学等理科方面的研究以及污染物减排和负荷削减的工科方面的研究固然重要，但对湖泊资源的不合理利用和湖泊环境造成破坏的正是环境意识和素养水平亟待提高的人类自身，掌握和处理好正确的人—湖关系，通过合理的湖泊管理手段建立相互协调的湖泊保护与利用的关系，离不开人文社会学方面的研究。正是基于这样的理念，2013 年 1 月上海交通大学和日本综合地球环境学研究所上海交通大学闵行校区联合举办了《湖泊的现状与未来可能性》国际研讨会，来自中日两国共十余所大学与研究机构的文科、理科和工科学者，从湖泊生态学、湖泊水环境修复、人文社会科学、预防医学等不同的专业角度，就湖泊环境修复与管理等方面的问题进行了学术讨论与交流。本书是在这次讨论会的基础上，由各位学者共同执笔完成的。

多学科的交叉融合是科技创新和发展的重要源泉。各位执笔者都是在某一学科比较精通，同时又都对湖泊的现状与未来比较关注。他们的视角各不相同，研究方法和内容互有差异，但研究目标又一致相同。尽管湖泊生态学理论和富营养化治理方面已有不少专著，但是对湖泊治理进行文、理、工科的综合研究应该得到我们的重视。从这个意义上讲，本书可以说是作了一个很好的尝试，我也期待着本书能起到一个抛砖引玉的作用。由于时间较为仓促，作者水平有限，本书难免存在不足和欠缺，希望大家指正。

本书在翻译和出版等经费方面得到了综合地球环境学研究所中国环境问题研究据点的大力支持，在本书的出版过程中松香堂出版社给予了大力协助，在此一并表示诚挚的谢意。

2013 年 7 月于上海

1 上海交通大学环境科学与工程学院

Epilogue

Hainan KONG¹

Lakes are among the most important natural aquatic ecological systems which the mankind depends on for living. In the course of thousand years of human civilization development, lakes have been providing a number of ecological service functions for people, such as serving as the source of water for industries and agriculture as well as drinking water, providing aquaculture products, tourism and amusement, and helping climate regulation and water purification. It can be said that, on one hand, lakes demonstrate their economic and cultural values for the mankind, and on the other hand, the environment, functions and values of lakes are being altered by the mankind. In fact, because of the overdevelopment of lake basins and the overexploitation of the ecological functions of lakes, as represented by eutrophication problems and disasters, speeding ecological degradation and disappearance of lakes are seriously threatening the global lake ecological systems. In the gaming of economic and social development with the protection of lake environment in lake basins, how to build a harmonized relation between human and lakes, coordinate the protection of lake ecology and sustainable service functions, has become a world-wide issue highly concerned by lake researchers in different countries.

Lake and River Environment Engineering Research Center of Shanghai Jiao Tong University (SJTU) has established partnerships with the Research Institute for Humanity and Nature (RIHN) in Japan since 2006, and my team has cooperated with the team led by Professor Kawabata from this Japanese Institute on research projects for years. Our cooperation covers changes of human activities on lake environments, the correlation of lake environments and lake ecological health (in particular the occurrence of pathogenic organisms and their hazards) and protection countermeasures for lakes as well as other topics. Our common presence includes Lake Biwa, Lake Chaohu, Lake Taihu, Lake Xihu, Lake Dianchi and Lake Erhai, with Lake Biwa and Lake Erhai being the two key lakes for our research. Over the past 7 years, we have achieved a number of innovative results in our cooperative research.

Natural science, human and social science and engineering science all belong to science in terms of an academic discipline, and they are equally important in pushing forward human civilization. Management of lake environment issues is a complex and difficult task, which cannot be achieved without common efforts by scientific and technical workers from different research fields. Scientific research programs in lake ecologies and aquatic chemistry, and Engineering research programs in reduction of pollutant emissions are very important. However, it is people that have been making improper use of lake resources and damaging lake environment and they need to improve their environmental awareness and education level. People need to well understand and deal with the relation of people and lake, so as to build a coordinated relation between lake protection and exploitation via sound lake management. And all of these cannot be achieved without humanistic and social researches. Based on this concept, in January 2013 SJTU and RIHN held an international workshop on the Current Situation and Futurability of Lakes in the Minhang Campus of SJTU, and liberal, scientific and engineering scholars from more than 10 universities

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and research institutions in both Japan and China conducted academic discussions and exchanges on lake environment restoration and administration from different disciplinary perspectives such as lake ecologies, lake water environment restoration, human and social science, preventive medicine. This book is written by all scholars based on this seminar.

Cross-link of different scientific disciplines is an important source for technical innovation and development. Each writer of this book not only excels in a certain fields but also pays close attention to the current situation and future of lakes. With different perspectives, research methods and contents, they have a common research target. Though there are a number of existing publications on lake ecological theories and eutrophication controls, we deem that comprehensive researches on lake restoration and management from liberal, scientific and industrial perspectives are of utmost importance. In this sense, it can be said that, this book has made a good try and I also hope this book may broaden this kind of research and inspire more people to participate. As both time and writers' knowledge level are limited, defects and shortcomings may be inevitable. Any comments and opinions will be highly appreciated.

In the course of translation and publication of this book, RIHN Initiative for Chinese Environmental Issues (RIHN-China) offered us great support in terms of fund, and in the course of its publication, Shoukadoh Book Sellers also offered great support to us. Here I would like to extend my sincere gratitude to both of them.

July 2013, Shanghai

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