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霞ヶ浦における湖岸植生帯の現状について

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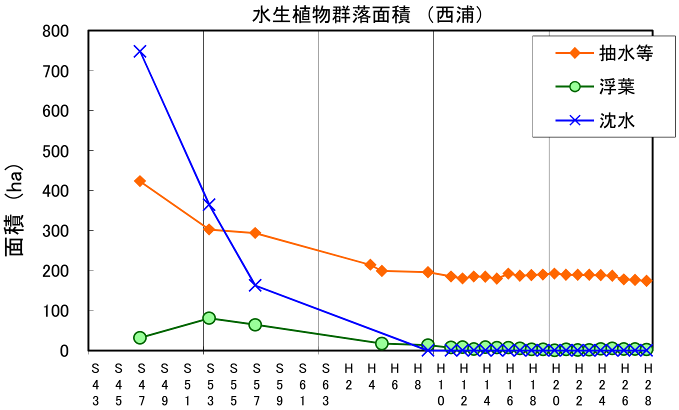
抄録

霞ヶ浦の湖岸植生帯は，昭和 40 年代からの水質悪化や湖岸堤の整備等により，平成 9 年頃にかけて大幅に減少したことから，消波施設や養浜の整備等，様々な保全対策を行ってきたところである。しかし，ヨシ等の抽水植物は，その後も現在に至る約 20 年間において減少傾向が続いている。このため本研究では，霞ヶ浦（西浦）を対象とし，最近の約 20 年間の植生図を用いて，湖岸植生帯の面積や群落構成の変化，特徴などについて整理し，その要因について考察した。その結果，西浦では全体として湖岸植生が減少，樹林化が進行している傾向が見られ，植生面積は，保全対策箇所は維持されているが，未対策箇所では減少しているなど，箇所毎の状況にもいくつか特徴が見られた。今後は，これまでに得られた成果を踏まえ，減少傾向を解消しつつ良好な水辺環境を創造，維持するための手法を導き，さらに保全対策を推進していく必要があると考えられる。

1.　はじめに

霞ヶ浦の湖岸には，かつて抽水植物，浮葉植物，沈水植物など多様な植生帯が形成されていたが，昭和 40 年代からの流域の人口増加に伴う水質悪化や霞ヶ浦開発事業（H8 年 3 月完成）による湖岸堤築造等により，S47 年から H9 年の 25 年間で，沈水・浮葉植物はほぼ消滅し，抽水植物は約半分程度まで減少した（図1）。

また，植生帯面積は，H8 年からの霞ヶ浦開発事業の管理開始に伴う水位運用後も減少が確認されたため，各機関では消波施設整備や前浜造成などによって植生帯を復元し，保全対策を継続的に行っているところである（表 1，図 2）。しかし，抽水植物は H8 年から現在にかけても約 29ha と少しずつであるが減少傾向が続いている（図1）。



注）1　昭和47年、53年の値は、妙岐の鼻地点の抽水植物を幅50mとして算出。
注）2　抽水等：抽水植物等（沈水・浮葉を除く主に抽水状体の堤外地植物群落）、
浮葉：浮葉植物群落、沈水：沈水植物群落

図 1. 霞ヶ浦（西浦）の湖岸植生面積の変化

表 1. 湖岸植生帯の主な保全対策施設　（西浦）

対策手法		整備内容・地区数（完成年度）	整備事例
国土交通省	波浪対策	・治水対策として石積や篭による消波施設の整備 ・25 地区（H3-H26）	
	湖岸植生緊急保全対策	・粗朶や石積による消波施設，養浜による多様な湿地環境整備 ・8 地区（H10-H23）	
	植生保全対策	・粗朶，篭，袋詰め根固めによる消波施設の整備 ・12 地区（H11-H24）	
水資源機構	前浜造成	・浚渫土による前浜の造成，突堤の整備 ・15 地区（H14-H24）	
茨城県	水生植物帯造成	・消波施設の設置と養浜による静穏な浅場造成 ・5 地区（H14-H23）	

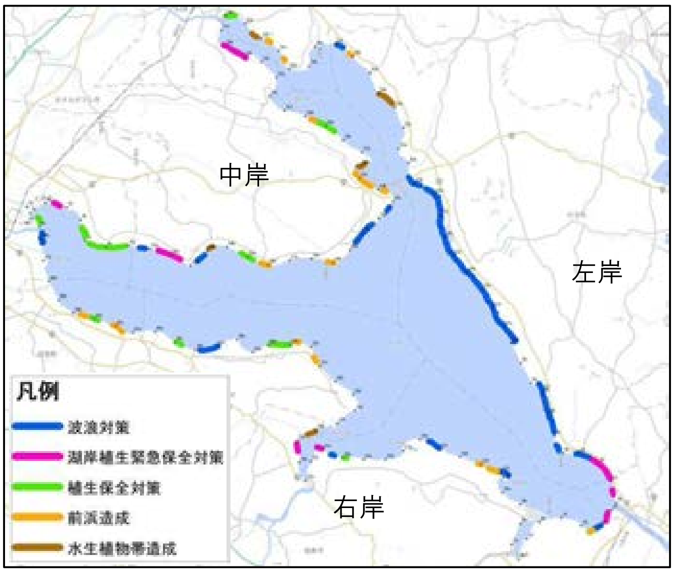


図 2. 対策施設の位置図（西浦）

本検討では今後の霞ヶ浦の湖岸植生帯の保全・再生のあり方を検討するための基礎資料とすることを目的に，H8 年から H28 年までを対象に，蓄積された植生図，水位や波浪等のデータから，霞ヶ浦全体の植生変化の現状とその特性を捉えることを主眼に整理を行った。

2. 方法

対象地区は霞ヶ浦の西浦とし，航空写真の判読により群落区分を行った植生図を用いて湖岸植生の面積を計測した。本検討で整理対象とした植生は，植生図のうち湖岸堤の護岸前面から沖側の範囲（Y.P.+1.5m 以下）とした（図 3）。

植生面積は，霞ヶ浦の距離標を基準に 1km 区間ごとに整理した上で，前述の保全対策施設（表 1，図 2）の有無で区分した（図 4）。

なお，植物群落のうち，航空写真の撮影時期等により精度が大きく異なる可能性がある浮葉・浮遊植生は整理対象外とした。

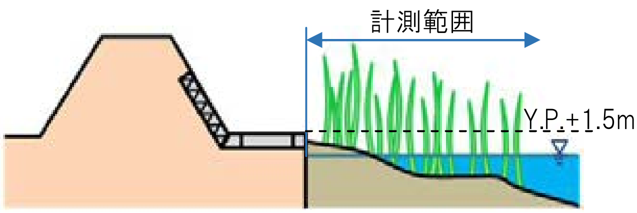


図 3. 植生面積の計測範囲（横断面）

図 4. 植生面積の計測方法（平面イメージ）

3. 結果

3.1 西浦における植生面積の変化

H8 年から H28 年の約 20 年間における変化量について，以下のとおり整理した。

(1)ヨシ等抽水植生について（図 5）

西浦全体では，H8 年が約 112.3ha であったが H28 年は約 82.9ha となり，約 74%にまで（約 29ha）減少した。

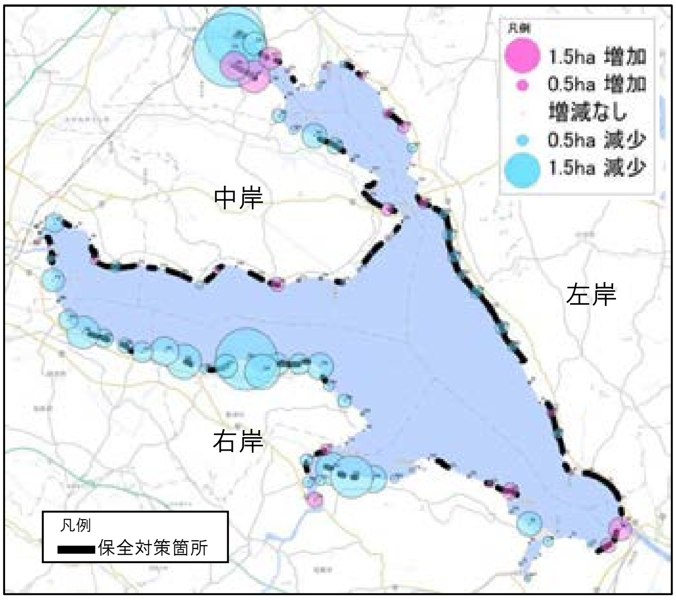


図 5. ヨシ等抽水植生の面積変化

箇所別では，主に右岸側や中岸湾奥部の対策施設がない区間において減少量が比較的多かった。一方，対策施設が連続的にある左岸側では，減少量は比較的少なかった。また，養浜等の保全対策により増加している区間も見られた。

(2)低木・亜高木について （図 6）

西浦全体では，H8 年が約 5.6ha であったが H28 年は約 18.4ha となり，約 327%にまで（約 13ha）増加した。

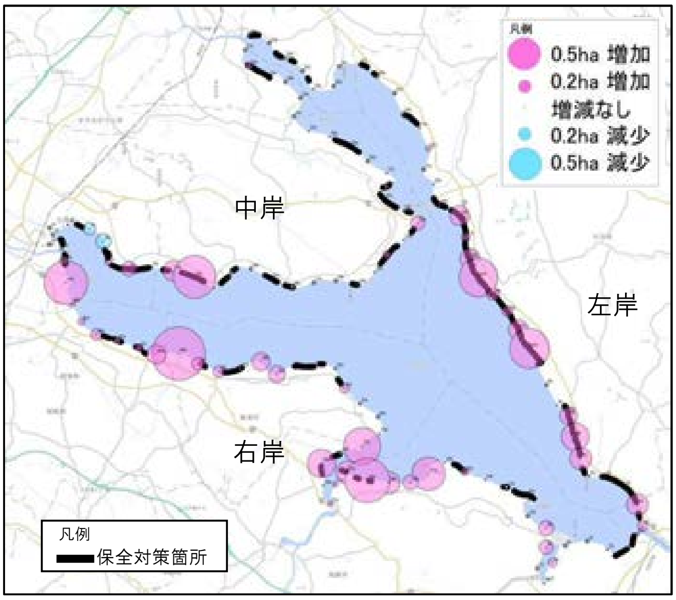


図 6. 低木・亜高木の面積変化

箇所別にみると，低木・亜高木は対策施設の有無に係らず，維持または増加している区間が多く，減少している区間はほとんどなかった。

3.2 対策手法別の植生変化

図 7 に対策手法別の植生面積の増減状況を示す。

波浪対策は，主に離岸堤による波浪対策を実施した箇所であるが，全体として植生面積は増加傾向であった。ただし，ヨシ等抽水植生が減少し，20 年間で低木・亜高木の面積が約 10 倍にまで増加しており，樹林化が著しかった。

湖岸植生緊急保全対策では，養浜などにより H8 から H18 で主にヨシ等抽水植生が大きく増加したが，その後，一部で樹林化が進行した。

消波施設を施工した植生保全対策では，植生面積（主にヨシ等抽水植生）が減少している。

前浜造成，水生植物帯造成は，養浜等によりヨシ等抽水植生は増加傾向で，樹林化も比較的進んでいない。

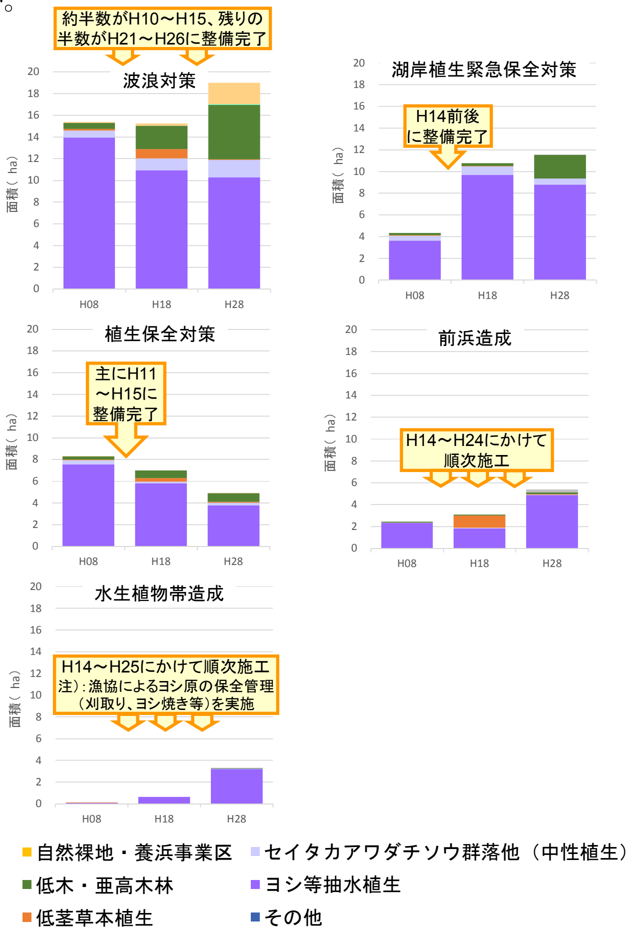


図 7. 対策手法別の植生変化（西浦）

4. 考察

4.1 西浦における湖岸植生の変化

近年の西浦では，保全対策によりヨシ等抽水植生が増加している箇所も見られ，一定の効果は発現していると考えられるが，対策施設が施工されていない区間では減少量が比較的多く，樹林化は対策施設の有無に係らず，左右岸で進行している。

また，対策施設のタイプにより植生の変遷が異なり，「前浜造成」「植生帯造成」ではヨシ等抽水植生の増加が見られたが，「植生保全対策工」では植生面積が減少し，「波浪対策工」では樹林化の進行が著しかった。

4.2 湖岸植生の変化要因

H8 年からの水位運用前後の水位を比べてみると，西浦では，S51～H7 年度の平均水位（各年度の 11-3 月の平均水位の平均値）は Y.P.+1.014m であるのに対し，H8～H22 年度（水位運用を休止していた H12-H15 年度除く）では Y.P.+1.178m と，約 16cm 上昇している。これを踏まえると近年約 20 年間では，以下のような事が変化要因の一つとして推定される。

- 「施設なし区間」では，水位上昇による冠水深の増大，波高の増大およびそれに伴う生育基盤の侵食により，ヨシ等抽水植生が減少。
- このようなヨシ等抽水植生の衰退箇所への樹木の侵入や，経年的な遷移などにより低木・亜高木が増加。
- 緊急保全対策箇所を代表とする「施設あり区間」では，水位上昇により冠水深が増大するが，施工直後は消波施設により波高が減少するとともに，生育基盤の造成等により，ヨシ等抽水植生が増加。
- その後，造成地盤の裸地などに侵入した樹木が，消波施設による陸域の安定化の影響もあり，生長・拡大し，ヨシ等抽水植生を被圧。

5. 今後の方向性

今回，西浦の植生変化について，約 20 年の時間スケールでの全体的な傾向について概ね把握することができた。

今後は，施設の有無と植生の増減との関連性等について代表的箇所を選定し，より詳細に要因分析を進める必要がある。併せて，現在の霞ヶ浦の水位や波浪等の環境特性を踏まえた上で，抽水植物の減少傾向を解消しつつ良好な水辺環境を創造，維持するための具体的な手法の検討，及び将来的な霞ヶ浦の自然再生のあり方や方向性についてもとりまとめていく予定である。

多種多様な生物の生息基盤となる湖岸植生帯は，霞ヶ浦の生態系サービス（基盤サービス）として非常に重要な存在であるので，引き続き関係機関とも連携・情報共有し，保全に努めていきたい。

O1-17

題名：琵琶湖における冬季の水位と沈水植物群落の変遷に関する考察

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キーワード：琵琶湖開発事業, 水位管理, 沈水植物, 冬季の水位低下, 生物多様性評価

抄録

水資源機構は，琵琶湖総合開発事業の一環として，水資源開発と琵琶湖沿岸及び下流淀川の治水を目的に琵琶湖開発事業を実施し，1992 年 4 月より管理を開始した。これによる水位変動が沈水植物の生育などへ与える影響を把握することを目的として，1997 年から毎年，湖北の早崎，湖西の安曇川，湖南の赤野井の 3 測線で潜水目視観察等の調査を行っている。本稿では，2002 年の秋季から冬季にかけての水位低下以降，クロモとセンニンモの平均被度の優先順位に変化がみられたことに着目して考察を行った。その結果、秋季から冬季の水位低下が南湖に生育するセンニンモの平均被度に影響を与えたことが推察できた。

*B.S.L.±0.0m＝T.P.（東京湾平均海面）＋84.371m

1. はじめに

琵琶湖における水資源開発と治水を目的に実施された「琵琶湖開発事業」が 1992 年 3 月に終了し 4 月から管理に移行したことにより，国土交通省(当時「建設省」)による瀬田川洗堰のルール化した操作（図1）が開始された。水資源機構(当時「水資源開発公団」)では，事業の実施による琵琶湖沿岸生態系への影響を把握するため，1997 年から毎年，早崎，安曇川，赤野井の 3 測線において，潜水目視観察により，植被率，種別被度階級，群落高などの沈水植物調査（以下「定期調査」という。）のほか，節目調査として,約 6 年に 1 回の頻度で「沈水植物季節変化調査」を実施している。本稿では，2002 年の秋季から冬季にかけての水位低下以降，クロモとセンニンモの平均被度の優先順位に変化がみられたことに着目して考察するものである。

2. 琵琶湖の水位低下の状況

琵琶湖の水位は 1874 年より観測されているが,管理開始以降に発生した渇水のうち，1994 年 9 月に観測史上最低水位となる B.S.L.（琵琶湖基準水位）−1.23m を記録したほか，2000 年 9 月には史上第 5 位となる B.S.L.−0.97m を記録した。これらは沈水植物の生育が著しい夏季に発生していることから，第 9 回世界湖沼会議において「夏渇水による琵琶湖の水環境への影響」と題して報告されている[1]。その後に発生した記録的な渇水として，2002 年 10 月に史上第 2 位の B.S.L.−0.99m が挙げられる。この渇水は秋季から冬季にかけて発生したものであり，図 1 に示すように長期間に渡って水位が低い状態が続く傾向が見られた。また，1994 年の水位は，最低値を記録後，一時的に上昇しているが，再度，冬季に低下していることから，1995 年にまで影響していることが考えられた。これらを踏まえ、管理開始以降の水位低下の状況を表 1 にとりまとめた。なお,秋季から冬季にかけて琵琶湖水位が B.S.L.−0.8m 以下で長期間続く時期の沈水植物に与える影響が,これまで取り上げられていなかったことから，表 1 の「日数」は B.S.L.−0.8m 以下の日を対象として算出した。その結果、これまで着目されていなかった秋季から冬季にかけて約 50 日から 100 日間，水位が低い時期があることを整理した。

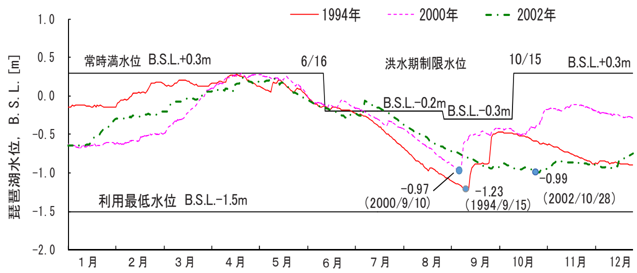

図 1 管理開始以降に発生した渇水時の琵琶湖水位

表 1 管理開始以降の水位低下状況

西暦	最低水位 (B.S.L.m)	B.S.L.−0.8m以下の期間	日数	時期
1994年	−1.23	1994/08/11 ～ 1994/09/29	50日間	夏季～秋季
1994年～1995年	−0.90	1994/11/26 ～ 1995/01/13	49日間	秋季～冬季
1995年～1996年	−0.94	1995/10/31 ～ 1996/01/14	76日間	秋季～冬季
2000年	−0.97	2000/08/29 ～ 2000/09/11	14日間	夏季～秋季
2002年	−0.99	2002/09/15 ～ 2002/12/26	103日間	秋季～冬季

3. 調査方法

3.1 定期調査(沈水植物調査)

図 2 に示す琵琶湖の三大ヨシ帯の 3 測線(北湖 2、南湖 1)を設定した。沈水植物調査は，毎年 8～9 月に各調査測線において、水際線から幅 2m、長さ 10m のベルトトランセクト法による潜水目視観察を実施した。調査範囲は、北湖の早崎・安曇川測線においては群落生育下限までとし，南湖の赤野井測線においては群落生育下限に達しないため対岸までとした。潜水目視観察により、植被率，種別被度階級、群落高を調査した。また併せて水深、底質の計測を行った。

3.2 沈水植物季節変化調査

1999 年，2005 年，2011 年，2017 年には，定期調査の 3 測線を含む 12 測線(図 2)において，沈水植物の季節的な生育状況の変化等を把握することを目的として，定期調査と同様に潜水目視観察調査(植被率，種別被度階級、群落高)及び、水深、底質の計測を行った。各年 8 月の定期調査以外に年 3～5 回実施した。

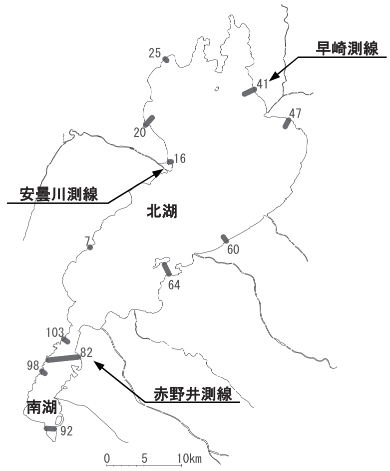

図 2 調査測線位置図(定期，季節変化)

4. 結果

4.1 定期調査(沈水植物調査)の結果

1997 年から 2018 年まで実施した調査結果のうち，表 1 に示す秋季から冬季にかけての水位低下と気象や水質データなどを水植物の生育状況と比較するために 2007 年までの調査結果を対象とした。平均植被率(測線上の同水位帯における植被率の合計を調査区画数で除した値)を図 3～5 に示す。各測線とも、水深帯別の植被率では、水位変動の大きい B.S.L.-2.0m 以浅に比べて B.S.L.-2.0m から B.S.L.-5.0m の植被率が高い。また、植被率の変動については、2003 年は 3 測線ともに低下したが，2 年後以内に回復しているほか，赤野井測線の B.S.L.-2.0m 以浅は、1999 年から 2007 年まで，常に増加を示している。

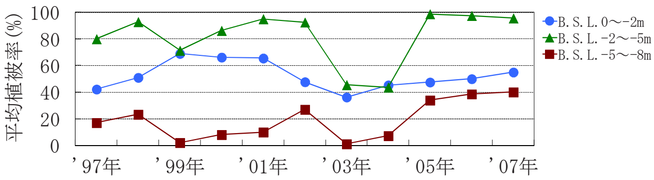

図 3 安曇川測線における水深帯別平均植被率

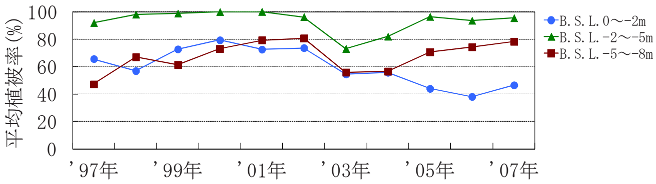

図 4 早崎測線における水深帯別平均植被率

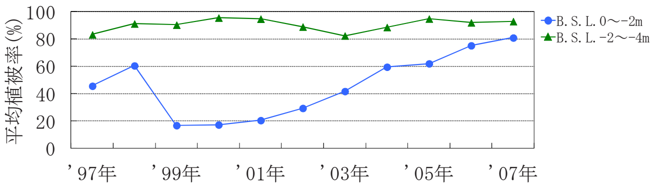

図 5 赤野井測線における水深帯別平均植被率

4.2 沈水植物季節変化調査の結果

沈水植物の季節変化を，冬季に植物体（地下部分除く）が見られたか否かとういう調査結果と，繁茂する時期などの生育情報を基に 4 群に区分とした。(表 2) また，季節ごとの植被率に群落高を乗じて求めた体積により群落占有体積図(図 6)を作成した。

表 2 沈水植物の季節変化類型区分

区分	季節変化の特徴	種名
・在来種 I 群	冬に植物体がほとんどみられず，夏から秋に繁茂	・クロモ ・コウガイモ ・ネジレモ ・ササバモ ・ヒロハノエビモ ・オオササエビモ ・イバラモ ・オオトリゲモ
・在来種 II 群 ・外来種 II 群	冬でも植物体がみられ，夏から秋に繁茂	・センニンモ ・サンネンモ ・ヒロハノセンニンモ ・マツモ ・ホザキノフサモ
		・オオカナダモ（外来種）
・在来種 III 群	冬に植物体がほとんどみられず，春に繁茂	・ホソバミズヒキモ ・エビモ
・外来種 I 群	冬でも植物体がみられ，初夏に繁茂	・コカナダモ（外来種）

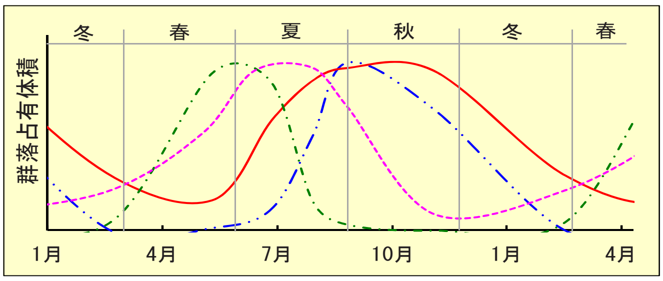

図 6 季節ごとの群落占有体積図

5. 考察

考察に先立ち，琵琶湖水位，日照，水質のほか，「在

来種Ⅰ群」のクロモと「在来種Ⅱ群」のセンニンモの平均被度（測線上の同水位帯における各種ごとの被度の合計を調査区画数で除した値）などを比較するため図7を整理した。

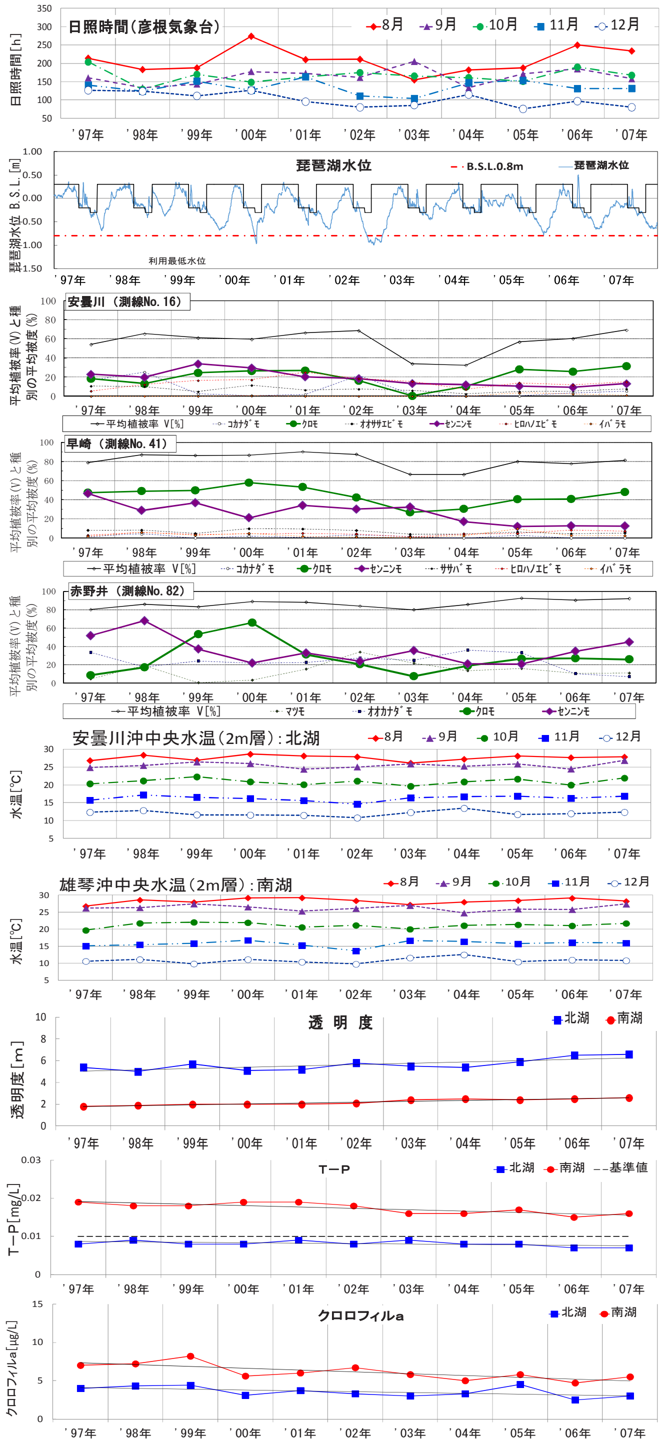

図 7 琵琶湖水位と定期調結果・日照・水質との比較

冬季に植物体が枯れるクロモは 8～9 月に現存量が最大に達し、冬季に植物体が枯れない常緑のセンニンモでは 8～11 月に現存量が最大に達する[3]といわれていること，2002 年の水位低下は 12 月まで続いたことを考慮し，日照時間と水温は 8 月から 12 月の 5 ヶ月間のデータを採用した。また，比較する対象期間は，秋季から冬季にかけて水位が低下した 2002 年の前後 5 年間（1997 年から 2007 年）とした。

光，水温特性についてクロモとセンニンモを比較すると，高水温（23～29℃），強光下ではクロモの成長速度が速く，低水温（11～17℃），弱光下ではセンニンモの成長速度が速くなることが実験により確かめられている[3]。2002 年 9 月から 12 月にかけて水位が低下した時の日照時間を見ると、11 月，12 月が，それ以前の年よりも短くなっている傾向がうかがえる。また，2003 年は冷夏であったことから，8 月の日照時間が短くなっている。これ以降の南湖（赤野井）では，クロモの減少に対してセンニンモが徐々に増加している。よって，南湖は，2002 年の水位低下で，低水温・弱光下が長期間継続されたこと，翌年が冷夏だったなどからセンニンモが生育しやすい環境になったと推察される。北湖（安曇川，早崎）でも 2003 年付近でクロモと，センニンモの平均被度が逆転しているが，これは，南湖（赤野井）と反対の現象を示している。安曇川沖中央の 11 月，12 月水温が，13～15℃あり，北湖は透明度も高いことから，クロモの生育が多く確認されている沿岸部の水深 6m 以浅は，クロモの生育にとって好条件となっていることが推察される。また，水質では，富栄養化の改善による透明度の上昇，植物プランクトンの減少により，栄養塩の競合が有利になったことなどが，複合的に影響していると考えられる。

6. 結論

本稿では，2002 年の秋季から冬季にかけての水位低下以降，クロモとセンニンモの平均被度の優先順位に変化がみられたことに着目して考察を行った。その結果、秋季から冬季の水位低下が南湖に生育するセンニンモの平均被度に影響を与えたことが推察できた。水資源機構では，事業の実施による琵琶湖沿岸生態系への影響を把握するため,これからも琵琶湖沿岸域環境調査を継続する。今後、これらの調査結果が，事業影響評価のためだけではなく，学術的な基礎資料としても活用され，琵琶湖の環境保全に役立つことを願う。

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O1-18

On Inhabitation of Birds Belonging to the Family Charadriformes and Scolopacidae in Lotus Fields on the Shore of Lake Kasumigaura

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Keywords: Endangered Species, Lotus Fields, Plover, Sandpiper

ABSTRACT

Birds which belong to the family Charadriformes and Scolopacidae inhabit depending on shores, in particular mudflats. On the other hand, there are a lot of lotus fields, which provide mudflats, in the alluvial lowlands on the shore of Lake Kasumigaura. It got confirmed by observations for 11years that 28 species of the families including ones registered on the Red List of Japan's Ministry of the Environment inhabit in the lotus fields, and most of them were observed there through almost a year except June and July or several months.

1. INTRODUCTION

The alluvial lowland along a part of the shore of Lake Kasumigaura - the second largest lake in Japan, of which length is about 20km from the west end to the east end, mainly consists of lotus fields (figure.1). The lotus fields provide mudflats suitable for the habitat of birds belonging to the Charadriforms –hereafter "Plover", Scolopacidae –hereafter "Sandpiper"(figure.2).

Concerning this area, observations on these birds have been conducted by members of the Wild Bird Society of Japan. However, the times of the observation are twice par a year, that is to say, the end of Apr and Aug, so that their inhabitation through a year was not obvious.

Therefore, in order to clarify what kinds of plovers and sandpipers inhabit there throughout a year and that the lotus fields provide good habitats for them, I have conducted multiple observations par a year for 11 years.

Figure.1 Target Area; In the area surrounded by a yellow line, green patches are lotus fields, white ones are rice paddies.

Figure.2 A mudflat in a lotus field on 20 Aug 2017

2. METHOD

(1) Method of observations

A. By driving a small car, so-called "k-car" through narrow trucks among the fields in order to seek birds more thoroughly.

B. By using binoculars to seek them and a digital camera with a 500mm telephoto lens to judge the kinds of species.

C. Seeking in some parts of the area or the whole area par an observation.

(2) Times of observations

The first observation was on 11 Nov 2007 and the last one was on 31 Mar 2018. The times of observations reaches 226 times including the first and last one.

(3) Target Fields

The lotus fields. Though I observed not only in the lotus fields but also in other lands such as rice paddies in this area, I don't discuss the results in this paper.

3. RESULTS

(1) Overview (table.1)

A. 6species of plovers, 22species of sandpipers have been observed. According to "Check-List of Japanese Birds 7th Revised Edition", there inhabit 15species of plovers and 58species of sandpipers in Japan. It means that 40% of Japanese species of plovers and 38% of those of sandpipers have been observed in the lotus fields in the area.

B. There were 5species registered on the Red List of Japan's Ministry of the Environment - hereafter "the Red List". That is to say, the wood sandpiper, the spotted redshank and the common redshank are registered in the rank of "VU" (vulnerable), the Dunlin is in "NT" (near threatened)

And the Grey-headed Lapwing is “DD” (data deficient). “VU” is the category, which is considered that it will be shifted to the category of "endangered " species in the near future ,if the stress factors that have brought the present state continue to work

C. Some species were observed almost through a year except Jun and Jul (Type.1). This category includes the wood sandpiper, the ruff as well as the little ringed plover. Others were observed mainly in winter (Type.2). This category includes the ringed plover, the terminck’s stint, the long-toed stint as well as the snipe. Others are migratory such as the pacific golden plover, Rufous-necked Stint (Type3). The others are accidental such as the bar-tailed godwit (Type.4).

D. 18species were observed in winter. The lotus fields probably provide the environment suitable for wintering of plovers and sandpipers.

Table.1 Times observed of each species par each months

			month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			observations in the month		32	20	11	23	13	1	1	29	27	16	27	26
Type.1	Little Ringed Plover	p			22	11	5	19	7			24	21	13	16	15
	Marsh Sandpiper		s		3	1		1	1			2	9	6	5	1
5sp	Wood Sandpiper 【VU】		s		20	16	6	14	5			13	15	15	16	14
	Common Sandpiper		s		15	6		11	4			22	19	7	6	7
	Ruff		s		5	4	2	3	3			1	3	2	2	6
Type.2	Northern Lapwing	P			19	11	4							1	9	19
	Ringed Plover	p			7	7	2						2	2	5	4
9sp	Long-billed Plover	p			6	4						6	1	1	2	2
	Snipe		s		19	14	8	18	5				13	9	12	18
	Long-billed Dowitcher		s		5	2		2						1	4	3
	Green Sandpiper		s		20	6	4					19	18	9	16	8
	Terminck's Stint		s		21	14	4	6				2	5	7	12	11
	Long-toed Stint		s		4	1	1					2	3	3	2	1
	Dunlin 【NT】		s		25	11	3	4					1	4	10	12
Type.3	Pacific Golden Plover	p						5	1			1	1			
	Black-tailed Godwit		s										4	4	4	
7sp	Spotted Redshank 【VU】		s					1	1				3	1		1
	Common Greenshank		s					1				4	7	1	2	
	Rufous-necked Stint		s				1		1			4	16	5	2	1
	Little Stint		s		7							1	1	1	1	
	Sharp-tailed Sandpiper		s					1	1					4	3	
Type.4	Grey-headed Lapwing【DD】	p			1											
	Bar-tailed Godwit		s											1		
7sp	Eurasian (or Eastern)Curlew		s										1			
	Common Redshank 【VU】		s										1			
	Terek Sandpiper		s									2	2			
	Ruddy Turnstone		s					1								
	Great Knot		s									1	1			
	p; plovers, s; sandpipers	6	22													

(2) Noticeable Species (Table.2)

A. **Little Ringed Plover;** Though it is said that they are generally summer residents in Japan, they usually wintered in this area.

B. **Marsh Sandpiper;** Though it is said that they are generally migratory, several of them sometimes wintered.

C. **Wood Sandpiper;** They are very common in the lotus fields in this area, instead of their being registered in the rank "VU" in the Red List.

D. **Ruff;** Though it is said that they are generally migratory, a few of them sometimes stayed through winter.

E. **Ringed Plover;** Though it is said that they are rare in Japan, a few of them usually stayed mainly in winter.

F. **Long-toed Stint;** Though it is said that they are migratory in Japan's main islands, a few of them often stayed in this area in winter.

G. **Dunlin;** Though they are registered in the Red List, they stay in this area by large flocks mainly in winter. The average of individuals of the dunlin observed par an observation dominates obviously among those of the other species.

H. **Pacific Golden Plover;** Though they stayed in a flock consisting of tens of individuals in rice paddies in this area, they stayed alone in the lotus field.

Table.2 The Average of Individuals Observed par an Observation

	month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Type.1	Little Ringed Plover	2.5	3.0	6.8	2.3	2.3			6.2	13.1	7.9	5.8	4.5
	Marsh Sandpiper	1.3	1.0		2.0	2.0			2.0	1.8	8.2	2.2	1.0
	Wood Sandpiper	2.5	2.6	4.3	5.0	1.2			6.1	8.1	8.3	6.9	4.5
	Ruff	1.8	2.0	3.5	1.3	1.3			1.0	1.0	2.0	1.0	3.0
Type.2	Ringed Plover	1.4	2.0	2.5						1.0	3.0	2.8	2.3
	Long-toed stint	1.0	3.0	3.0					1.0	1.3	1.3	1.5	1.0
	Dunlin	36.8	57.9	51.0	42.3					1.0	6.5	61.3	71.8
Type.3	Pacific Golden Plover				1.0	1.0			1.0	1.0			

3. DISCUSSION

Further researches would be required as follows, in order to clarify the value of lotus fields as the habitat of plovers and sandpipers.

(1) Researching trends in the number of the species and individuals over the longer term

The observations were conducted within continuous 11years. However, it is not long enough to confirm the trends in the number of species and individuals of plovers and sandpipers. The further long-term observation is required.

(2) Researching influences of the environmental change in the lotus fields on the number of the species and individuals

Nets to prevent birds damaging crops began to be installed in the lotus fields around 2002, and a new method to water the fields began to be adopted mainly in spring and winter. Gaining the data before the events is required in order to clarify the influences of the events on plovers and sandpipers.

4. CONCLUSION

Facts as follows show that the lotus fields provide habitats suitable for plovers and sandpipers. Remaining the lotus fields suitable for their habitat is required.

A. 28species have been observed.

B. 3species of them are rather rare species registered in the rank "VU" which is just lower than the rank "Endangered" species in the Red List.

C. 18species were observed in winter.

D. Most were observed through almost a year except June and July or several months.

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O1-19

Species Richness and Endemism of Vertebrate Fauna In and Around Four Lakes in Agusan del Sur, Philippines

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Keywords: bat, birds, diversity, herpetofauna, wetlands

ABSTRACT

Lakes are important wetlands that provide critical habitats for vertebrates. In this study, species richness and endemism of vertebrates were assessed in four lakes of Agusan del Sur. Cruising, mist netting, and McKinnon's List methods were employed to document vertebrates in the area. Forty-eight vertebrate species comprising 38 birds, three bats, and seven herpetofauna (three anurans and four reptiles) were recorded in the four lakes of Agusan del Sur. A low endemism of 29% was documented consisting of 10 species of birds, one bat, and three herpetofauna. Two Philippine endemic species have vulnerable status, namely, *Anas luzonica* (Philippine duck) which was only recorded in Oromica Lake and *Oreophryne anulata* (Mindanao Cross Frog) which was only found in Nato Lake. The endemic bat species, *Ptenochirus jagori* (Greater Musky Fruit Bat) was the only bat species found in all lakes sampled. A high species diversity with even distribution of species was recorded in the lakes of Agusan del Sur where Nato Lake had the highest vertebrate species richness (S=41) and diversity (H'=3.714). Bray-Curtis cluster analysis showed that Lakes Oromica, Nato, and Los Arcos had high similarity percentage in terms of birds while Lakes Himbang and Nato had high similarity percentage of herpetofauna. Lakes Oromica and Nato were more similar in bat composition. Conversion of forest surrounding the lake into agricultural purposes was observed as threat to the vertebrate fauna in the area. The presence of three vulnerable species indicates the need for conservation of the four lakes in this study.

1. INTRODUCTION

The Philippines, a tropical country, is one of the most biologically rich regions in the world[1]. The country's biodiversity includes at least 206 species of mammals of which 117 (57%) are endemic [2]; 102 amphibian species[3] with 78 endemic [4]; 258 reptile species with 170 (66%) endemic[4], and 695 species of bird species with 241 endemic[5]. However, with the discovery that several subcenters of endemism exist within islands and that species have varied patterns and range of distribution, there is still a need to conduct more surveys in many areas and on different habitat types[6] and one of these habitats is lakes. Lakes are among the most important of wetlands[7] that provide critical habitat for an amazing array of animals including amphibians, reptiles, birds and mammals[8]. Yet, lakes have been subjected to various pressures resulting from the increasing need of people and communities for food, fuel, water, and many other products and services. Thus, surveys on vertebrate fauna in lakes are needed to be able to assess the status of distribution and conservation of species. This study was conducted to determine the species richness and endemism of vertebrate fauna in and around the lakes of Agusan del Sur.

2. METHOD

Sampling Area

This research was conducted in the selected lakes of Agusan del Sur, the seventh largest province of the Philippines with a land area of 8,568 square kilometers located in the Caraga region of Mindanao[9] on November to December 2016. Four sampling sites were surveyed in lakes situated in the municipalities of Esperanza and Prosperidad.

Collection of Samples, Processing, and Identification

The birds and bats were sampled by mist netting. McKinnon's List was used to supplement mist netting data on birds. Morphological measurements were recorded and photographs were taken. Birds were identified using Kennedy *et al.*[10] and Fisher and Hicks[11] while Ingle and Heaney[12] for bats. For herpetofauna, modified cruising method was done and morphometrics were recorded. Identification was based on Alcala and Brown[13], Brown *et al.*[14], Nuñeza[15]. The conservation status of the vertebrates was determined based on the IUCN Red List of Threatened Species[16].

3. RESULTS

Forty-eight vertebrate species of which 14 species are Philippine endemic (10 birds, one bat and three herpetofauna) with 29% endemism were recorded in the four lakes of Agusan del Sur (Table 1). The 48 species comprised 38 species of birds, three bats, and seven herpetofauna (three anurans and four reptiles).

Table 1 Vertebrate fauna recorded in and around four lakes in Agusan del Sur

Vertebrate Fauna	Sampling Sites				Total
	1	2	3	4	
Birds	36	20	24	26	38
Bats	3	1	3	2	3
Herpetofauna					
Amphibians	2	1	2	1	3
Reptiles	1	1	2	3	4
No. of Vertebrate Species: 48					
No. of Endemic Vertebrate Species: 14					
No. of Threatened Vertebrate Species: 3					

Legend: 1-Nato Lake; 2-Himbang Lake; 3-Oromica Lake; 4-Los Arcos Lake

The Philippine endemic species with vulnerable status, *Anas luzonica* (Philippine duck) was only recorded in Oromica Lake while *Oreophyne anulata* (Mindanao Cross Frog) was only found in Nato Lake. The Philippine coucal (*Centropus viridis)* was observed to be in pairs perching on a tree branch on the side on Lake Nato. In addition, the rarely seen wading birds such as the Grey heron (*Ardea cinerea*) and the Great-billed heron (*Ardea sumatrana*) were also recorded in Lake Nato.

Three bat species namely, *Cynopterus brachyotis* (Lesser Short-nosed Fruit Bat), *Eonycteris spelaea* (Common Nectar Bat), and *Ptenochirus jagori* (Greater Musky Fruit Bat) belonging to one order and one family were recorded in the four lake sites of Agusan del Sur. The endemic bat species, *Ptenochirus jagori* (Greater Musky Fruit Bat) was the only bat species found in all lakes sampled.

For herpetofauna, *Rhinella marina* (Cane Toad) and *Eutropis multicarinata* (Northern Two-striped Mabuya) were the most distributed herpetofauna species found in all sampled sites. The Philippine endemic and vulnerable species *Oreophryne anulata* (Mindanao Cross Frog) and *Hydrosaurus pustulatus* (Sailfin Water Lizard) were only present in Nato and Los Arcos Lakes, respectively.

Table 2 shows that the lakes of Agusan del Sur had a high number of vertebrate species with high species diversity and even distribution. Among the sampled sites Nato Lake had the highest number of vertebrate species.

Table 2 Biodiversity Indices of the four lakes in Agusan del Sur

Indices	Sampling Sites			
	1	2	3	4
Taxa (S=48)	41	23	32	31
Dominance	0.02439	0.04348	0.03125	0.03226
Shannon H’	3.714	3.135	3.466	3.434
Evenness	1	1	1	1

Legend: 1-Nato Lake; 2-Himbang Lake; 3-Oromica Lake; 4-Los Arcos Lake

Of the four lakes in Agusan del Sur, Lakes Oromica, Nato and Los Arcos had high similarity percentage (>78%) in terms of birds. Lakes Oromica and Nato had high similarity percentage in bat composition (>96% similarity), while Lakes Himbang and Nato are more similar in terms of herpetofauna.

4. DISCUSSION

The species richness and diversity in and around lakes of Agusan del Sur could be attributed to the varied vegetation types of area and the presence of the food availability for vertebrate species. According to Jones *et al.*[17] vegetation type, temperature, humidity, rainfall, latitude, and altitude, as well as food availability are factors which may contribute to the presence of the species in an area. The presence of endemic species and threatened species in the lakes of Agusan del Sur indicates that lakes are important habitats for the vertebrate fauna. The Philippine endemic and vulnerable *A. luzonica* thrives in Lake Oromica since it has larger land area with patches of vegetation cover allowing bird species to disperse. Additionally, plant species and vegetation structure (density and coverage) provide an explanation for bird species dispersal and richness[18, 19]. In addition, *A. luzonica* frequents most freshwater and saltwater habitats, including mangroves, open sea, and watercourses inside forest[20] thus implying that this species favors areas that are larger with widely open patches. Meanwhile, the recorded Philippine endemic species with vulnerable status, *O. anulata* (Mindanao Cross Frog) and *H. pustulatus* (Sailfin Water Lizard) in Nato Lake showed that this lake is an important habitat for herpetofauna species despite the conversion of the surrounding land area into agricultural fields. The similarity of sites in terms of faunal composition was seen to be due to the presence of fruiting trees or food sources, microhabitats, and breeding sites which meet the requirements of the species.

5. CONCLUSION

The four lakes surveyed in Agusan del Sur have a relatively high species richness and species diversity. Among the sampled sites, Nato Lake had the highest vertebrate species richness (S=41) and diversity (H'=3.714). Two Philippine endemic species with vulnerable status, *Anas luzonica* (Philippine duck) and *Oreophyne anulata* (Mindanao Cross Frog) were notable species recorded. The presence of endemic species and three threatened species indicates that the lake ecosystem provides favorable habitats for vertebrates. Conversion of forest into agriculture was observed as threat to the vertebrate fauna in the area.

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O1-20

霞ヶ浦における淡水二枚貝類の生息状況と遷移

鈴木　興道

キーワード:ドブガイ、イシガイ、イケチョウガイ

抄録

霞ヶ浦（西浦・北浦）の湖内およびその周辺の流入河川において、1994 年以降、二枚貝類を採取し、生息状況の遷移を調査してきた。結果として湖内では、ドブガイ、マルドブガイ、イシガイ、イケチョウガイ、マシジミ、カワヒバリガイの6種類が確認され、流入河川では上記の他に、カラスガイ、ヨコハマシジラガイ、ヒレイケチョウガイの 3 種類が確認され、計 9 種類となった。 イケチョウガイは 2009 年まで断続的に 9 個体確認されてきたが、それ以降は確認されていない。ヒレイケチョウガイは真珠生産の母貝として養殖されているが、2011 年に桜川中流で 1 個体の成貝が確認され、自然繁殖の可能性が示唆される。カラスガイは湖内では確認されず、2013 年に恋瀬川上流の釣り堀から大量の老貝と 2018 年に桜川で成貝 1 個体が確認された。ヨコハマシジラガイは湖内では確認されず、川尻川で少数ながら生息している。総じてカワヒバリガイや肉食魚類など外来種の繁殖と食害が続き、在来種の生息量が低減している。

1.　はじめに

霞ヶ浦には古来より豊かな水環境と生態系が有った。著者は 1995 年開催「第 6 回世界湖沼会議」にて、霞ヶ浦の魚種組成の遷移を下記のように報告[(1)]した。

“湖内：1885 年以降 34 種 80 種→1973 年以降 21 科 51 種。流入河川（花室川）：1991 年以降 7 科 29 種”。

しかし、その後も在来魚類の生息種数および現存量は低下傾向が続き、特に外来肉食魚のバス、ブルーギル、ナマズ類の増加に相反して、二枚貝類の産卵床となるチチブ、ヨシノボリ、ウキゴリなど在来の小型魚類が捕食され低減している。貝類も同様な傾向が著しい。

2. 方法

貝類の調査範囲は、霞ヶ浦の湖岸及びその流入河川である花室川や川尻川などであった。湖底は砂泥質で歩きやすく、湖岸沿いに水深 1m程度の沖合を素足で探りながら歩き、足裏に貝殻の感触がある所をタモ網で掬い取るラインセンサスを行った。流入河川では貝採り器（目合 5mm）を用いた。採取した貝類は、殻長、殻高、殻幅、質量を測定し記録した。調査頻度は冬期を除き各年2～3日であった。1999～2001 年は調査を休止した。

3.　結果

1993 年の調査当初は貝類の生息密度が高く、写真1に示すように多くの個体が採取された。湖内では、写真2に示すイケチョウガイ *Hyriopsis schlegeli* (Martens) とドブガイ *Anodonta woodiana*(Lea)、写真3に示すマルドブガイ *Anodonta calipygos* Kobelt、写真 4 に示すイシガイ *Unio douglasiae nipponesis Martens*、マシジミ *Corbicula leana Prim*e、写真5に示すカワヒバリガイ *Limnoperna fortune* (Dunker)の6種類が確認された。

流入河川では上記貝類の他に、写真2に示すカラスガイ *Cristaria plicata plicata (Leach)*とヒレイケチョウガイ *Hyriopsis cumingi* [Unionidae]、写真4に示すヨコハマシジラガイ *Inversiuno jokobamensis* (Ihering)の 3 種類が確認され、合計9種類であった。

図1に主な貝類の各年の測定個体数と国交省霞ヶ浦河川事務所が管理する湖心水質自動監視所における年間の上層平均水温の遷移を示した。変動範囲は 15.5～17.3℃で弱い上昇傾向にあるが、貝類への影響はない。しかし、現実には貝類の測定個体数に大きな増減が認められ、特に 2013 年以降の減少が危惧される。

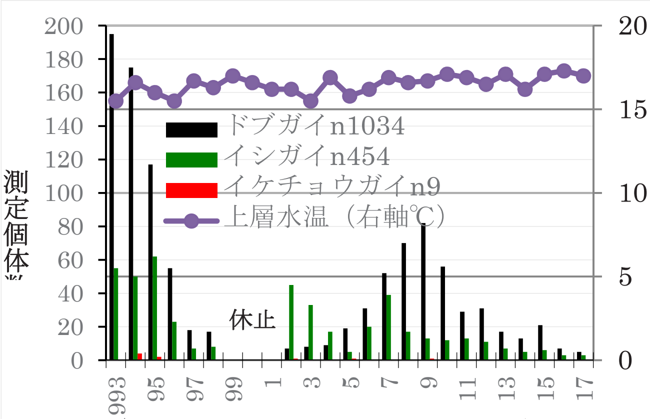

図１　主な貝類の測定数の推移

写真1　霞ヶ浦西浦（土浦市石田地区）の採取状況(1994.7.6)。イケチョウガイ（写真下の大2個体）、ドブガイ（左～上側の中粒）、イシガイ（右側の細粒）。イケチョウガイは桜川の河口で6個体が確認された。

写真3　マルドブガイ。沖合の一部に生息が認められた。殻長に対する殻幅が厚く、殻幅比の上限領域が 0.55（ドブガイは 0.50）程度までである。ドブガイに比較して形態がボール状に丸みを帯び殻頂部の発達が著しい。

写真5　カワヒバリガイ（殻長 20～30mm）。足糸で瓦礫や排水管に強力に密着群生する。水質汚濁にも強い。

写真2　左上：イケチョウガイ(殻長 235mm)。左中：ヒレイケチョウガイ(240)。左下：カラスガイ(262)。右上：マルドブガイ(175)。右中：ドブガイ型(186)、下がヌマガイ型(164)。右下4個体：タガイ型(46～90)。

写真4　左側5個体：イシガイ(殻長 72～26mm）。中央5個体：ヨコハマシジラガイ(64～35)。右側上 4 個体：マシジミ(34～19)。右側下2個体：タイワンシジミ。

4.　考察

・　ドブガイは湖内及び流入河川に広く生息分布している。図2に殻長に対する殻高と殻幅、図 3 に質量の関係を示した。当種には歯がない。殻高が高く卵円形のものをヌマガイ型、殻高が低く卵形のものをドブガイ型、田の側溝等に群生し長卵形小型のものをタガイ型と呼

ばれる。しかし、この3型の間には中間的な形態のものが極めて多く、殻長に対する殻高の割合及び殻幅の割合はいずれも漸移・重複して3型を区別する境界は生じず、3 型の呼び名は典型的なものにしかあてはまらない。

- マルドブガイは、全体がボールのように丸く膨らみ、殻頂部が著しく発達して蝶番線から突出する。霞ヶ浦の当種は、琵琶湖や木曽川のものと比較すると、殻長に対する殻高、殻幅、質量の分布は全く重複分布する。霞ヶ浦では湖内では採取されたが、流入河川では確認されなかった。
- イケチョウガイは、1930 年代初めに琵琶湖から霞ヶ浦に移入繁殖した。2009 年まで断続的に 9 個体が確認されてきたが、それ以降は確認されず、今日では絶滅したと思われる。なお 1966 年に霞ヶ浦から青森県の姉沼へ移入した当種は、今日最大の繁殖集団となっており、著者はこれを再び霞ヶ浦へ80 個体試験放流した。1～2年後には全て死滅したことから、当種復活の可能性は低い。ヒレイケチョウガイは真珠の母貝として養殖されているが、2011 年に桜川中流で 1 個体の成貝が確認され、自然繁殖の可能性が示唆される。
- カラスガイは 1994 年の沼沢氏の調査[2]でも確認されなかった。しかし当種は 2013 年に恋瀬川の川又川上流に在る釣り堀から多数の老貝と、2018 年に桜川で成貝 1 個体が確認されており、流入河川の溜池に生息している可能性が示唆される。
- イシガイは湖内及び流入河川で広く確認された。ヨコハマシジラガイは湖内では確認されず、川尻川など里山の流入河川で少数ながら生息している。

- 表1　霞ヶ浦における二枚貝類の調査結果

種類	霞ヶ浦湖内	流入河川
ドブガイ	全域に生息	
マルドブガイ	生息	なし
カラスガイ	なし	一部に生息
イケチョウガイ	2009 年まで確認	なし
ヒレイケチョウガイ	生息（養殖）	一部に生息
ヨコハマシジラガイ	なし	一部に生息
イシガイ	全域に生息	
シジミ類	マシジミの他に外来種が繁殖	
カワヒバリガイ	全域に繁殖	

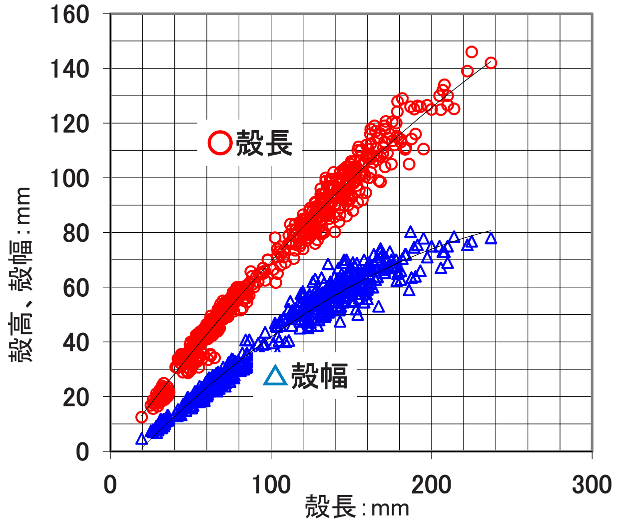

図2　ドブガイの殻長に対する殻高と殻幅

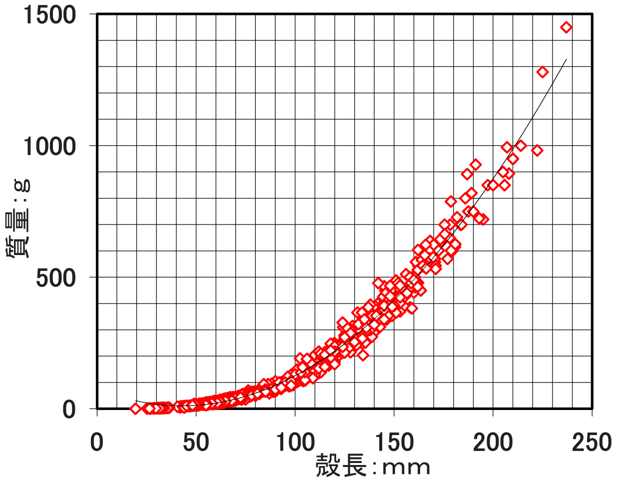

図3　ドブガイの殻長と質量の関係

5　結論

- 水温は弱い上昇傾向にあるが貝類への影響はない。底泥の堆積は少ないが、2013 年以降、貝類の確認量の減少が続いており、畜産排水が危惧される。
- 近年、タイワンシジミや朝鮮シジミ、カワヒバリガイの外来種が繁殖し、種の攪乱が進行している。
- ナマズ類の外来種魚類が繁殖し、在来種が減少している。特にヨシノボリ等の小型魚が捕食されている。彼らの生息域となる葦原の復元が望まれる。
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O1-21

Spatial Analysis of Macrophytes Diversity and Distribution in a few Selected Lakes and Reservoirs in Southeast Asia; with Special Reference to Malaysia, Indonesia and Myanmar

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Keywords: Biodiversity evaluation, ecosystem functions, invasive alien species

ABSTRACT

Southeast Asian inland lakes and reservoirs are important ecosystem which functioning in both ecological and economical services. The primary factor that distinguishes wetlands from other land forms is the characteristic vegetation of aquatic macrophytes, adapted to the unique hydric habitat. Therefore, the objective of this study is to analyze the macrophytes diversity and distribution represented in a few selected lakes and reservoirs of Malaysia, Indonesia and Myanmar. The field survey were carried out from February 2015 until April 2018 in eight selected lakes, namely Chini Lake, Bera Lake, Chenderoh Reservoir, Temengor Reservoir (Malaysia), Tempe Lake, Jatiluhur Reservoir, Saguling Reservoir (Indonesia) and Inle Lake (Myanmar). There were four natural lakes and four man-made reservoirs. All of them play multi-functional roles including as a source of fisheries and tourism, power plant, as well as water sources for irrigation. In Malaysia, there are four consecutive reservoirs along Perak River, whereas in Indonesia, there are three consecutive reservoirs along Citarum River. The result showed relatively high in diversity of macrophytes in natural lake compared to man-made reservoir. Subsequently, the characteristics of the lakes are the most important aspect for macrophytes distribution. A better understanding of spatial patterns of macrophytes diversity and distribution would help to improve conservation efforts as well as for the invasive alien species monitoring program because prevention is the most effective method to control the invasive species.

1. INTRODUCTION

Aquatic macrophytes plays vital role in a healthy wetland ecosystem. They serves as primary producers of oxygen through photosynthesis, provides substrates for algae and shelters for many invertebrates, sediment nutrient cycling and helps in stabilizing river and stream banks. Aquatic macrophytes are also a good bio-indicator for water quality monitoring. By its nature, eutrophication could results in a progressive change of species composition and a loss of species diversity.

Climate changes and human activities would lead to a devastating effect on aquatic macrophytes community. According to Seshavatharam (1990), human activities would lead to an uncontrolled growth of aquatic vegetation. Anthropogenic pressure such as sewage inputs and agriculture run off could cause significant changes in abundance and composition of macrophytes (Lind and Cottam, 1969). Meanwhile, climate change will affect aquatic systems by warming the water temperatures, altering stream flows pattern, and increasing storm events (Poff *et al*., 2002). These changes are expected to have profound effects on the distribution and phenology of species and the productivity of aquatic ecosystems (Parmesan, 2006).

Several studies were conducted to examine the relationships between macrophytes and environmental factors. The following studies were carried out to determine the relationships between macrophytes and chemistry of water variables (Heegard *et al.,* 2001; Meerhoff *et al*., 2003; Capers *et al.,* 2010; Akasaka and Takamura, 2011; O'Hare *et al.,* 2012). In addition, macrophytes community composition and distinct in distribution with hydrology, climate, substrate type and nutrient availability (Cronk and Fennessy, 2001) and can be affected by geology, water, land use and sediment chemistry (Koch, 2001; Lougheed *et al*., 2001; Hansel-Welch *et al*., 2003; del Pozo *et al*., 2011).

Characteristics of sediments such as chemical compound and physical properties have important role in aquatic vegetation distribution (Misra, 1938). Aspects that influenced the growth and distribution of macrophytes have long been interested by ecologist (Pearsall, 1920; Misra, 1938; Moyle, 1945; Peltier and Welch, 1970; Barko *et al.,* 1986).

This study will be focusing on providing a better understanding of macrophytes diversity and distribution represented in a few selected lakes and reservoirs of

Southeast Asian region. A better understanding of spatial patterns of macrophytes diversity and distribution would help to improve conservation efforts as well as for the invasive alien species monitoring program because prevention is the most effective method to control the invasive species.

2. METHOD

The field survey were carried out from February 2015 until April 2018 in eight selected lakes, namely Chini Lake, Bera Lake, Chenderoh Reservoir, Temengor Reservoir (Malaysia), Tempe Lake, Jatiluhur Reservoir, Saguling Reservoir (Indonesia) and Inle Lake (Myanmar)(Table 1). The characteristics of sampling sites are as being explained in Table 2.

Table 1. The lists of sampling sites for macrophytes diversity and distribution

Site/ criteria	Location	Impoundment
Chenderoh	Perak, Malaysia	Man-made; Perak River (1930)
Temengor	Perak, Malaysia	Man-made; Perak River (1978)
Chini Lake	Pahang, Malaysia	Natural, Floodplain
Bera Lake	Pahang, Malaysia	Natural, Floodplain
Jatiluhur	West Java, Indonesia	Man-made; Citarum River (1967)
Saguling	West Java, Indonesia	Man-made; Citarum River (1981)
Tempe Lake	Sulawesi, Indonesia	Natural, Floodplain
Inle lake	Shan State, Myanmar	Natural, Solution

Table 2. The characteristics of sampling sites for macrophytes diversity and distribution

Site	Surf. area (km2)	Elev. (m)	Max. Depth (m)	Human impact	Fish industry
Chenderoh	25	45	25	Domestic waste	Yes
Temengor	152	245	100	-	Yes
Chini Lake	2.02	11.9	4	Domestic waste	Yes
Bera Lake	61.5	43.9	7	Domestic waste	Yes
Jatiluhur	83	107	90	Domestic waste	Yes
Saguling	56	650.5	92	Domestic waste	Yes
Tempe Lake	130	5	5	Domestic waste	Yes
Inle lake	47	1000	7	Domestic waste	Yes

The diversity and distribution of macrophytes is being analyzed by using the geographical information system. The diversity of species in distinct subunits within a study area (known as *alpha* diversity) is the principal subject of the spatial analysis of diversity. The most direct measurement of *alpha* diversity results from counting the number of observed diversity units (the number of species).

In the process of selecting areas for conservation, emphasis is most often placed on conserving the highest number of species (Petit et al. 1998). It is, however, important to realize that focusing conservation only on those sites with the highest levels of diversity may lead to a failure to identify threatened species found only at sites with generally low levels of diversity (e.g. high mountain ecosystems which reveal a low number of species, but where such species are unique and not found in other ecosystems).

3. RESULTS

The result showed relatively high in diversity of macrophytes in natural lake compared to man-made reservoir. Subsequently, the characteristics of the lakes are the most important aspect for macrophytes distribution.

4. CONCLUSION

A better understanding of spatial patterns of macrophytes diversity and distribution would help to improve conservation efforts as well as for the invasive alien species monitoring program because prevention is the most effective method to control the invasive species.

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O1-22

Habitat conditions and structures of rare riverside grassland plant communities on the Tenryu-gawa River system in the Nagano Prefecture, Japan

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Keywords: endangered species, invasive alien species, floodplain vegetation, semi-natural grassland

ABSTRACT

Recently, populations of river-specific plants and herbaceous perennial species in Japan have decreased and extinct. However, in a preliminary investigation, we confirmed the presence of rare plant communities in the Tenryu-gawa River system. And, alien plants such as *Coreopsis lanceolate* and *Robinia pseudoacacia* invaded and established in the natural grassland in Tenryu-gawa River system. Therefore, the purpose of this study was to explore the habitat conditions and structures of these rare plant communities on the riverside grassland vegetation in this area to conserve these endangered species. Vegetation and environmental conditions of the riverside communities were investigated in the summer of 2017.All investigation plots were 28, and the area of one quadrat was 2m×2m. Five types of communities were distinguished by a TWINSPAN classification. These were primarily classified into three high-water channel site types and two low-water channel site types. The endangered herbaceous perennials, such as *Cynanchum paniculatum* or *Ixeris chinensis* subsp. *strigosa*, appeared in high-water channel site types, whereas the river-specific plants, such as *Potentilla chinensis* or *Artemisia capillaris*, dominated in low-water channel site types. On the other hand, alien plants such as *Coreopsis lanceolate* invaded in all types. It was thought that many alien plants had a negative influence on the growth of the rare plant communities.

1. INTRODUCTION

Recently, it becomes the problem that river-specific plant and herbaceous perennial plants decreased and extinct in Japan [1]. And, alien plants established semi-natural grassland communities in the river side [2]. Also, alien plants such as *Corepsis lonceolata* and *Buddleja davidii* invaded and established in the southern part of Nagano prefecture [3] [4]. However, the rare plant communities such as *Ixeris tamagawaensis* and *Orostachys japonicas* were comfermed [5] [6]. So, the riverside and semi-natural grassland communities have remained in the southern part of Nagano prefecture. In preliminary investigation, we were able to confirm those rare plant communities in the Tenryu-gawa River system. And, alien plants such as *Coreopsis lanceolate* and *Robinia pseudoacacia* invaded and established in the natural grassland in Tenryu-gawa River system. Therefore, the purpose of this study was to explore the habitat conditions and structures of these rare plant communities on the riverside grassland vegetation in this area to conserve these endangered species.

2. METHOD

The present study was conducted on the river side and semi-natural grassland on Tenryu-gawa river system in Nagano prefecture, Japan. Vegetation and environmental conditions of the riverside communities were investigated in the summer of 2017. All number of investigation plots were 28 (high water channel; n=22 , low water channel; n=6), and the area of one quadrat was 4 ㎡(2m×2m). For the vegetation survey（Braun-Blanquet 1964) , plot cover and maximum high of each species were recorded in each plot. To explore environmental conditions, we recorded RPPFD(Sep.), soil hardness(Sep.) and grain ingredient of sand(Nov.).

Statistical analyses

TWINSPAN classification was used as species composition and structure of communities. Furthermore, a detrended correspondence analysis (DCA) was performed with the species incidence matrix.

3. RESULTS

The number of appearance species was 72. To know the species composition and structure of communities, all plots were analyzed by TWINSPAN. And, appearance species were classified by TWINSPAN, too. So, five type communities were distinguished by TWINSPAN classification. And mainly, all plots were classified in the group of 3 high water channel site types and 2 low water channel site types. *Corepsis lonceolata* was common species in all types. *Z.japonica, I.pseudo-tinctoria, R.lucia* was common species in high water channel. *Cynonchum ponlculatum* dominated in Cp-Zj type. The endangered plants such as *Orostachys japonicas* or *Ixeis chinensis*, *Lespedeza tomentosa* appeared in Ic-Lt Rp type. The herbaceous perennial plants such as *Cymbopogon tortilis* or *Dianthus superbus* constituted grassland vegetation in Ds-Ct type. *Artemisia princeps* and *Artemisia capillaris* were common species in low water channel. *Artemisia capillaris* dominated in Ac-Pj type. And *Lespedeza tomentosa* appeared too. *Potentilla chinensis* and *Robinia pseudoacacia* dominated in Pc- Rp type.

Environmental conditions

In Cp-Zj type, the soil hardness and community height were lower than other. Community height and RPPFD of Ic-Lt-Rp type were highest. The ratio of alien plants of the communities on low water channel site was higher than others.

DCA ordination of the river side grassland community

The same date of TWINSPAN was utilized by DCA ordination. The all plots were arranged high water channel site types and low water channel site types.

4. DISCUSSION

The river specific plants and herbaceous perennial plants appeared in high water channel. So, these were grassland vegetation indigenous to river side. Cerepsis lonceolata dominated in Cp-Zj type. We thought that Cerepsis lonceolata impacted on other herbaceous plants. And, it seemed that dominance of Robinia pseudoacacia impacted on herbaceous plants in Ic-Lt-Rp type. We thought that grassland communites were decreased by dominated Amorpho futiacasia in Ds-Ct type. For this reason, the problem of high water channel were dominace of Cerepsis lonceolata and alien plants such as Robinia pseudoacacia or Amorpho futiacasia impacted on herbaceous plants and decreased grassland. The river-specific plants such as Potentilla chinensis or Artemisia capillaris and Lespedeza tomentosa appeared low water channel. So, it was thought that the disturbance with the river was necessary for conservation of the low water channel grassland communities. Robinia pseudoacacia dominated in Pc-Rp type. In this type, the rare river-specific plants and R. pseudoacacia were maintained under the same condition by the disturbance of the river. For this reason, the ratio of alien plants of the communities on low water channel site was higher than others.

5. CONCLUSION

It was thought that many alien plants had a negative influence on the growth of the rare plant communities. We thought that immediately, it was necessary to exterminate of the alien plants to conserve rare plants.

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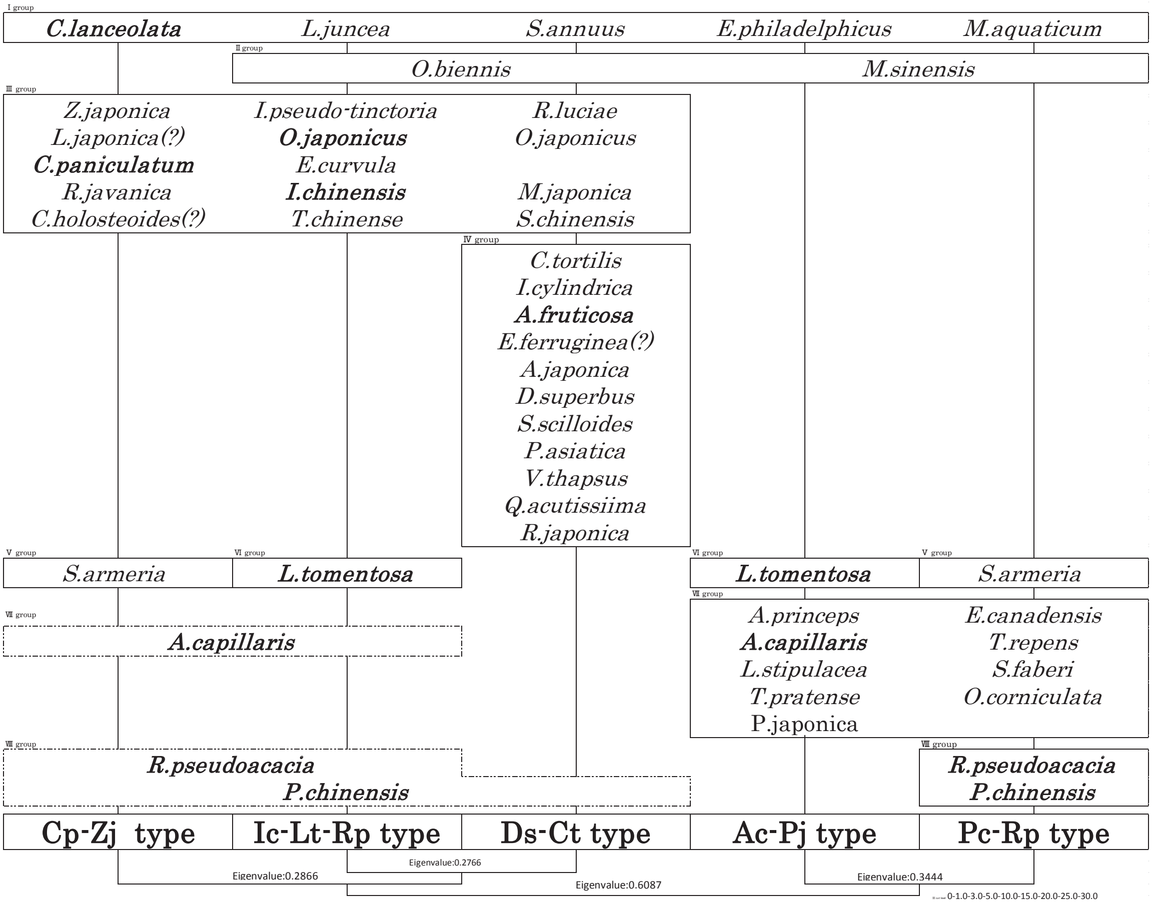

Fig.1 Species composition and structure of communities by TWINSPAN

Table 1. Environmental conditions

	type	Cp-Zj type	Ic-Lt-Rp type	Ds-Ct type	Ac-Pj type	Pc-Rp type
Plot cover(%)	mean	70.56	64.00	66.25	76.67	60.00
	SD	14.02	12.45	11.26	2.89	10.00
Number of species	mean	10.67	19.00	18.50	16.67	12.00
	SD	2.693	1.732	2.619	0.577	1.732
High of community(cm)	mean	74.90	153.80	109.00	94.33	114.00
	SD	17.62	101.13	27.96	12.50	39.85
Alien plants percentage(%)	mean	19.84	23.00	21.37	44.00	46.97
	SD	6.60	4.63	8.25	2.95	2.62
Soil hardness(mm)	mean	11.67	13.04	13.17	18.60	17.47
	SD	4.39	4.31	5.45	5.51	4.73
RPPFD(%)	mean	53.62	31.75	46.35	48.43	65.10
	SD	16.02	22.25	10.28	10.94	14.24

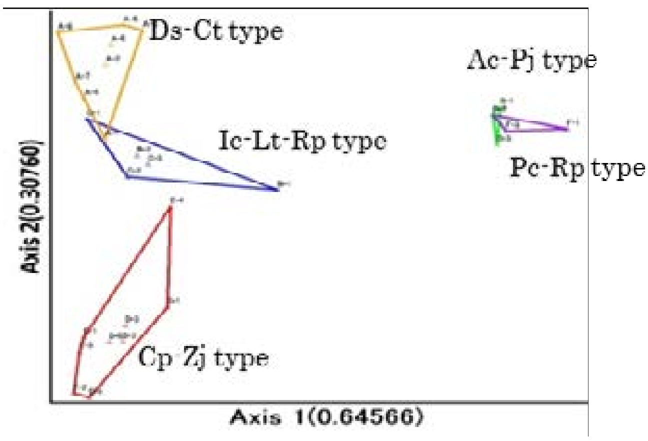

Fig.2 DCA ordination of the river side grassland communities

O1-23

急拡大する侵略的外来水生植物オオバナミズキンバイ等への対策：琵琶湖における取組事例

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キーワード：侵略的外来植物、オオバナミズキンバイ、外来種対策、琵琶湖、霞ヶ浦

抄録

琵琶湖では2009年に初確認されたオオバナミズキンバイは，先行して琵琶湖に侵入・定着していたナガエツルノゲイトウに置き換わるように分布範囲と生育面積を急速に拡大し，生態系への影響や漁業被害，航行障害などが懸念され，2013 年度から本格的な対策事業が始まり，2014 年度からは建設機械や水草刈取り船など機械力を導入した大規模駆除が行われている。一旦はリバウンドを経験しながらも，駆除に際しては機械駆除と人力駆除を併用しできるだけ取り残しがないようにし，駆除済みの区域における巡回・監視を徹底して群落の再生を抑えることで，年度末の水域全体の生育面積は過去2カ年減少傾向を続けることができた。本発表では，琵琶湖で試行錯誤を重ねて確立された駆除方法を中心に，駆除個体の処分には過大な手間暇と経費がかかることなど対策の概要について紹介する。本種は近年，関東地方の霞ヶ浦，手賀沼，印旛沼への侵入が確認され早期対応が求められる。

1.　はじめに：琵琶湖での対策の始まり

オオバナミズキンバイ（写真①：以下「オオバナ」と略記。）*Ludwigia grandiflora* とナガエツルノゲイトウ（写真②：以下「ナガエ」と略記。）*Alternanthera philoxeroides* は，わが国ではともに外来生物法の特定外来生物に指定されている侵略性の高い外来植物である。近年，オオバナとナガエ（以下，「オオバナ等」と略記。）は，琵琶湖をはじめ日本の複数水域への侵入・定着が確認されつつある。


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琵琶湖では，まずナガエが 2004 年時点で北湖東岸の内湖への侵入が確認され，その後，北湖南部から南湖にかけて分布範囲を拡大し，一部の内湖や河川，琵琶湖の内湾などでは大規模な群落を形成し始めた。続いて，2009 年に南湖北部の東岸でオオバナが確認され，南湖全域の湖岸へ急速に拡大し，先行したナガエに置き換わる形で大増殖するに至った。

オオバナとナガエはともに水陸両生の抽水植物であり，葉や茎の断片から発根するという栄養繁殖または種子繁殖（オオバナのみ）により分散するため，分布域は水際線沿いにときに急速に拡大する。オオバナ等は生育面積が水際から沖合いに向けて大規模に拡大するため（写真③），希少種を含む在来他種の植物を競争的に排除し，大規模に水面を覆う群落下では特に高水温期に著しい酸素欠乏が予測されるなど，在来の動植物の生息・生育に対して深刻な影響を与えるものと考えられる。また，大規模な群落の生育状態は，漁業の操業への支障や船舶の航行の阻害となるほか（写真④），琵琶湖から下流域への分布拡大や，琵琶湖周辺の農地への侵入など，数々の懸念は次第に現実化しつつある。


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滋賀県では，2013 年度からオオバナを対象とした本格的な駆除事業を開始したが，この年度は外来種調査を主課題とした緊急雇用対策事業（エイリアン・ウォッチャー事業）による対応であったため，内湖の一部において人力による駆除が年度を通して実施された。その結果，オオバナの生育規模と増殖速度を考えると，オオバナ等への対策は機械力を用いないと対応不能な状態に陥っていることが

明白となった。そこで，2013 年度末には滋賀県は関係市や団体とともに「琵琶湖外来水生植物対策協議会」を結成し，2014 年度から環境省の交付金と県からの補助金により，機械力を駆使したオオバナ等の大規模な駆除事業に着手することとした。

2. 琵琶湖における大規模駆除事業の展開

(1) 2014 年度：大規模機械駆除の開始

2013 年度末の時点で，琵琶湖および周辺水域におけるオオバナ等の生育面積は合わせて約 78,000 ㎡(うちオオバナ約 65,000 ㎡。以下，同じ。)に達していた。2014 年度を迎え初めての機械力を導入した大規模駆除を実施するに当たり，駆除作業で大量の植物片が発生し，それらが栄養繁殖して広域分散する原因となる可能性を憂慮する専門家からの意見もあり，その一方でオオバナ等の生育面積は増加を続けていることが確実であることから，県議会の 9 月定例議会で補正予算を確保し，駆除事業は年度後半からの実施となった。

まず，オオバナ等を掴み取ることができる特殊な林業用の建設機械，スイングヤーダ(写真⑤)を用いた駆除事業は 10 月末から始まった。続いて，琵琶湖の沈水植物の刈り取りに用いられてきたハーベスター形式の水草刈取り船(写真⑥)も操作方法を工夫することでオオバナ等の駆除にも使用可能であると確認されたため，年末からは水草刈取り船による駆除事業も始まった。


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岸から沖合いに向けて広がる大規模なオオバナの純群落の大部分を完全に除去する方針として駆除を進めた結果，年度内には最大約 176,00 ㎡(157,000 ㎡)に達したオオバナ等の生育面積は，年度末には約 62,000 ㎡(46,000 ㎡)にまで縮減させ，初めて前年度末の値よりも減らすことができた。

(2) 2015 年度：大規模リバウンドと分布拡大

2015 年度は，前年度に補正予算まで投入し大規模な駆除が実施されたことから当初予算は潤沢ではなかったが，前年度に機械駆除を実施した箇所では，その後地元の漁協や NPO が巡回・監視を行うことで，群落の再生がほぼ抑えられている区域も確保され，駆除後の丁寧な巡回・監視が有効であることが明らかとなった。しかし，その一方で，夏以降，特に秋になってから群落が想定を超える規模で再生した区域もあり，その原因として駆除せず残存した他の抽水植物群落の中に混生して残存したオオバナ等からの再生が示唆された。そこで，同年度の駆除事業においては，機械による大規模な駆除と人力による取り残しのない丁寧な駆除を併用し，駆除実施後の箇所では巡回・監視により群落の再生を抑えることを試行した。その結果，全体としては生育面積が大規模にリバウンドして最大約 306,000 ㎡(271,000 ㎡)に達し，年度末にも約 229,000 ㎡(200,000 ㎡)が残存する結果となった。さらに，この年度には，これまでオオバナが確認されていなかった琵琶湖の北湖周辺水域においても 4 箇所で相次いで小規模なオオバナ群落が確認されたが，北湖ではオオバナの生育しない状態の復元・維持を目標として緊急の駆除を行った。

(3) 2016～2017 年度：丁寧な駆除と巡回監視の徹底

2016 年度は，過去最大規模の当初予算を確保し，「できるだけ取り残しのない丁寧な駆除」と「駆除後の巡回・監視の徹底による再発防止」を基本方針とし，巡回・監視は当該事業による駆除が済んだ区域だけでなく，過去に駆除をした周辺区域にも拡大して，群落の成長開始に先んじて年度開始直後から駆除事業に着手した。しかし，年度当初の生育面積が膨大で，シミュレーションを行った結果，当初予算による駆除事業だけでは年度末に残存する生育面積から次年度の群落の成長速度が既存の事業者による駆除能力を上回り「制御不能な状態」になると予測されたため，県議会 9 月定例会議での補正予算を確保し当初予算と合わせて 3 億円を超える規模での駆除が実施されることとなった。なお，事業は上記の基本方針に沿って行うものとし，分散拡大のリスクや保全の必要性に応じた優先度を評価し，優先順位の高い箇所から順に駆除事業の対象とした。その結果，大規模群落のなかには優先順位が高くないと判定され，「順番待ち」となる群落も出てきたことから，その一部には群落の辺縁部から離脱が起こらないよう，拡大防止のためのフェンスの設置も試みられた。


⑦

このようにリスクや必要性に応じた優先順位に基づいた大規模かつ丁寧な駆除を実施した結果，年度内の最大生育面積が過去最大の約 348,000 ㎡(299,000 ㎡)に到達すると推定されたものの，年度末の残存生育面積は約 156,000 ㎡(131,000 ㎡)にまで減少させることができた(図 1)。

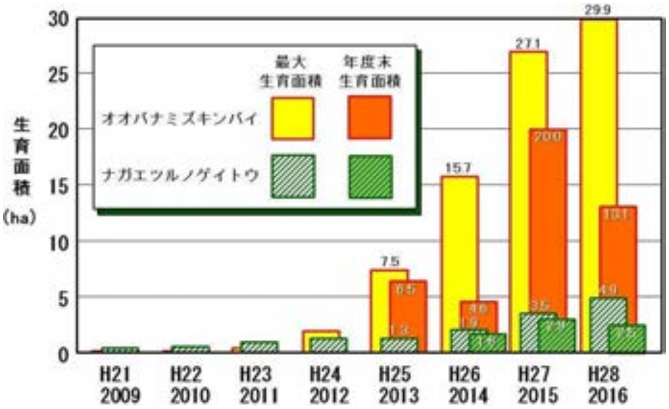

図1. 琵琶湖および周辺水域におけるオオバナ等の年度内最大生育面積と年度末残存面積の経年的変化.

2018 年度も前年度の枠組みを継承して取組を進めており，年度末の残存生育面積は本要旨の投稿時点では 100,000 ㎡程度となる見通しとなっており，その後の進捗については，発表の際に追加するものとする。

3. 対策を進めるうえでの課題

(1) 駆除から処分に至る過程の効率化・円滑化

現場から除去したオオバナ等は，その瞬間から生きた状態の特定外来生物であることに加えて，事業系一般廃棄物となるため，その適切な処分に至るまでは外来生物法だけでなく廃掃法の適用も受けることになる。現時点では，オオバナ等は焼却処分または埋設処分をする必要があるため，除去作業を行った基礎自治体において仮置きする場の確保し，除去したオオバナ等の軽量化や乾燥を行ってから，処分場へと運搬して処理を行っている。すなわち，オオバナ等の駆除事業には，現場での除去作業に加えて，その後の過程にも相当な労力と経費を要しており，その効率化・円滑化を図ることが必要である。また，処分方法を抜本的に改める新たな処理技術の開発にも期待が寄せられている。

(2) 難駆除群落に対する対策手法の確立

駆除の優先順位の高い箇所は水際から沖合いへ向かって群落が成長している箇所であるが，オオバナ等は水陸両生の植物であり，かつての高水位時に漂着したり，水際から陸上へ伸長したりして陸域にも生育している。これらは分散・拡大等のリスクが比較的低いとはいえ，石組み護岸の間や土中深くに根を張り，取り残しのない除去を行うことがきわめて難しい状況にある。こうした難駆除の群落に対しても，順次駆除を進めていくことが必要であり，新たな対策手法の検討・開発が求められている。

(3) 駆除後の管理体制の確立と継続

事業の進展により，駆除済みの箇所が増加することは，巡回・監視を行う必要のある地域の拡大を意味する。駆除跡地での巡回・監視に必要な労力と経費は，駆除の実施直後から継続して実施することで次第に縮減できるものと予測されるが，一方で，当面の間，その努力を継続させる必要のあることも確実なことである。そのための効果的かつ持続可能な巡回・監視の手法と体制を確立することが必要である。

4. 他の水域への警鐘

琵琶湖および周辺水域では現在，年度当初に機械駆除を必要とする大規模群落が存在しない「管理可能な状態」にその全域を置くことを当面の目標として対策事業を進めており，2 年連続で年度末の残存面積を縮減させることができ，諸課題が残されているとはいえ，やっとその目標の実現に向けての道筋が付けられたところである。これまでの経緯を振り返ると，対策がこれまでの規模となってしまった背景としては，行政施策的には十分とは言えないまでもかなり順応的な対処が採られてきたとはいえ，特にオオバナは素性のよくわからない新たな植物でもあったことから，結果として対策が後手に回ってしまい，分布範囲と生育規模の著しい拡大を許容してしまったことが挙げられる。

本会議の開催地である茨城県霞ヶ浦をはじめとする関東地方の水域ではすでにナガエが侵入しており，うち一部の水域では生育規模に拡大し，被害対策も採られてきている。近年，霞ヶ浦と千葉県の印旛沼，手賀沼において新たにオオバナが確認された。これらの水域においては，琵琶湖では先行して生育していたナガエの群落が次々にオオバナに置き換わり，はるかに大規模な群落へと成長したことを，ぜひとも教訓としてもらいたい。オオバナの発見箇所では，それぞれ緊急の対応が試みられたが，たまたま確認された見つけやすい箇所以外にもすでに群落が拡大していることを想定し，大規模な拡大を招くことのないよう，できるだけ先手を打つ対応が採られることを願ってやまない。

O1-24

霞ヶ浦周辺地域における特定外来生物カワヒバリガイの現状と対策

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キーワード：外来種，分布拡大，水利施設

抄録

カワヒバリガイ *Limnoperna fortunei* は中国・朝鮮半島を原産とする淡水二枚貝であり、現在はアジア各国と南米に広く分布している。本種は固い基質に固着する性質を持ち、水利施設の配管等に付着してその運用に悪影響を及ぼす。茨城県の霞ヶ浦とその周辺地域でカワヒバリガイの生息状況の調査を行ったところ、霞ヶ浦では 2006 年から 2012 年までの間に湖岸の 46%から 83%まで分布を拡大し、採集個体数は約 3.8 倍に増加した。霞ヶ浦から取水する水利施設(水路・貯水池)とその流入河川においてカワヒバリガイの生息が確認され、分布データと遺伝解析の結果から、これら侵入の少なくとも一部は水利施設を経由したものと推察された。霞ヶ浦から取水する水利施設の管理組織では，貯水池や水路等のモニタリング調査や落水による駆除などを通じ，水利施設を経由したカワヒバリガイの分布拡大と被害抑制の試みを進めている。

1. はじめに

カワヒバリガイ *Limnoperna fortunei* は中国・朝鮮半島を原産とする淡水性二枚貝であり、現在はアジア各国と南米に広く分布している[1-4](図 1)．本種は繊維状の分泌物である足糸により岩などの基質に固着する性質を持ち、水利施設の配管内部に付着して水の流れを妨げるなど施設の運用に悪影響を与えることが知られている[5]．また、本種の侵入によって、侵入先の在来生態系に大きな変化が生じることが報告されている[6]。

図 1 貯水池のバースクリーンに付着したカワヒバリガイ

霞ヶ浦は日本で二番目に大きい湖であり、その水は飲料水や農業用水・工業用水など、様々な目的の水源として使われている。2005 年以降、霞ヶ浦ではカワヒバリガイの生息が確認されており、自然環境への影響や水利施設での被害が懸念されている。

本稿では、霞ヶ浦とその周辺地域におけるカワヒバリガイの現状を概観すると共に、その分布拡大と被害対策の取り組みについて述べる。

2. 方法

霞ヶ浦におけるカワヒバリガイの分布状況を明らかにするために、湖岸の全域を対象にカワヒバリガイの目視調査を 2006 年と 2012 年に行った。調査では、水深の浅い湖岸を主な対象として、調査員 1 人が 10 分間当たりに採集できた個体数を密度の指標として記録した。得られた分布データを元に、霞ヶ浦湖岸における本種の分布拡大速度の推定と将来予測を行った。

カワヒバリガイの分布拡大経路を検討するために、霞ヶ浦の周辺河川と、霞ヶ浦から取水している水利施設を対象とした生息状況の調査を行った。また、一部の貯水池では落水(水抜き)を行い、カワヒバリガイの侵入状況の調査をおこなった。

3. 結果

2006 年から 2012 年までの間に、カワヒバリガイは霞ヶ浦湖岸の 46%から 83%まで分布を拡大し、採集個体数は平均で 3.8 倍に増加した(図 2)。解析の結果、2012 年における霞ヶ浦湖岸における生息の有無は、2006 年における生息地点からの距離によって最もよく説明されることが示された。この生息分布マップを元に霞ヶ浦におけるカワヒバリガイの分布拡大速度を推定したところ、6 年間に約 11km の速度で分布拡大が進行していることが明らかになった(定着確率が 50%を越える距離を拡大距

離として推定)。この拡大速度を元にすると、霞ヶ浦では遅くとも 2018 年には湖岸全体にカワヒバリガイが生息するようになると推定された[7]。

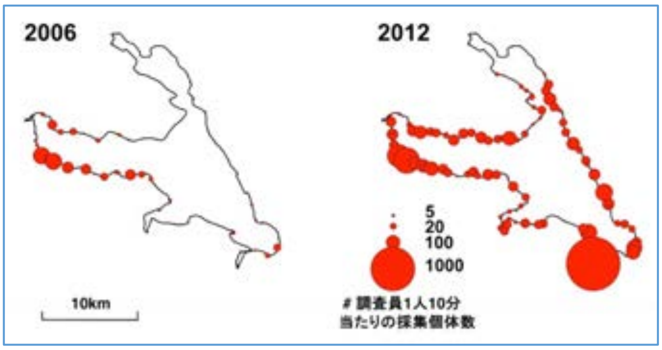

図 2 霞ヶ浦におけるカワヒバリガイの分布拡大(伊藤・瀧本 2013 より作図)

小貝川は関東平野を流れる全長 118km の一級河川であり、2008 年以降カワヒバリガイの生息が確認されている。分布調査の結果、小貝川では、カワヒバリガイは霞ヶ浦から取水している水利施設の分水工(水を分ける施設)よりも下流でのみ採集された(図 3) [8]。この水利施設(霞ヶ浦を水源として 1988 年以降一部通水・1994 年から本格通水を開始)では、2006 年から施設の中でカワヒバリガイの生息が確認され [9]、水路や貯水池の水からはカワヒバリガイの浮遊幼生が確認された。遺伝子解析の結果、小貝川で採集されたカワヒバリガイには、霞ヶ浦から採集されたカワヒバリガイと共通するハプロタイプが高頻度で含まれていた[10]。

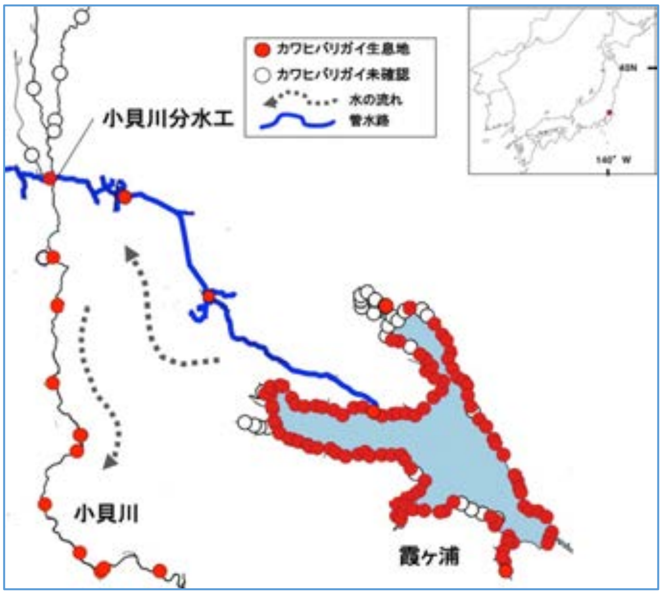

図 3 小貝川と霞ヶ浦、水利施設(管水路・貯水池)におけるカワヒバリガイの分布(Ito 2015 より作図)

利根川水系に隣接する那珂川水系では、2009 年から 2013 年までの調査ではカワヒバリガイの生息が確認されていなかった[11]。しかし、2014 年以降、那珂川水系内の霞ヶ浦から取水している貯水池において、新たにカワヒバリガイの生息が確認されるようになった(図 4)。カワヒバリガイの駆除を目的として貯水池の落水を行ったところ、カワヒバリガイは貯水池の約半分の範囲から採集され、特に流入口と取水口に近い部分で密度が高い傾向を示した。採集個体のサイズと過去に報告された成長データから、この貯水池には遅くとも 2013 年にはカワヒバリガイが侵入していたと推察された[12]。那珂川水系全体では、カワヒバリガイの生息が確認された地点はごく限られており、侵入の段階としてはまだ初期の状態である可能性が高いと推察された。

図 4 霞ヶ浦から取水している水利施設(管水路)と、那珂川水系内でカワヒバリガイの発見された貯水池(青矢印)の位置関係(伊藤 2016 より作図)

4. 考察

調査の結果、霞ヶ浦ではカワヒバリガイの分布拡大と密度の増加が進行しつつあることが示された。近年、霞ヶ浦から取水する一部の水利施設ではバースクリーンの閉塞や死貝の堆積などによる通水障害が発生しており[9]、今後霞ヶ浦から流出する河川や、そこから取水する水利施設では、カワヒバリガイが侵入・定着することを想定する必要があるだろう。

小貝川と水利施設に生息するカワヒバリガイの分布データ(図 3)、並びに遺伝解析の結果は、小貝川に生息するカワヒバリガイの少なくとも一部が、水路や貯水地を経由して霞ヶ浦から分布を拡大したことを示している。現在明らかになっている那珂川水系内のカワヒバリガイの生息地点も、霞ヶ浦から取水する水利施設とその周辺、もしくはその下流に限られている [12]。水路や導水路を経由したカワヒバリガイの分布拡大を示唆するデータは日本国内の複数の地域で明らかになっており[8,13]、水利施設を経由する

本種の拡大は国内でもごく一般的に生じているものと推察される。霞ヶ浦の水は茨城県南部を中心に広い範囲で利用されており(図 4)、その中には調査の行われていない河川や水利施設が数多く含まれている。今後、これらの地域でも新たにカワヒバリガイの侵入が確認される可能性は高いと考えられる。

那珂川水系でカワヒバリガイの生息が確認されている貯水池は涸沼(2015 年ラムサール条約登録)に流入する河川の上流部に位置しており、この地域での対策は生物多様性保全を考える上でも重要である。現在、水利施設の管理組織では通水障害への対策に加え、貯水池や水路、周辺河川でのモニタリング調査や非灌漑期に行う貯水池の落水などを通じて，用水を経由したカワヒバリガイの新たな分布拡大と被害を抑制する試みを進めている(図 5)。

図 5 霞ヶ浦から取水する水利施設の管理組織によるカワヒバリガイ対策：左上：貯水池の落水による駆除，左下：浮遊幼生調査，右：トラップと目視観察によるモニタリング調査

5. 結論

カワヒバリガイの浮遊幼生は 100-200μm と小さく[14]、本種の発生した水源の水を大量に利用することを前提とした侵入防止は極めて困難である。当面はモニタリング調査を通じてカワヒバリガイが発生した地点を明らかにするとともに、その地域の水利施設の管理や駆除を積極的に行うことで被害の拡大や未侵入地域への移動を減らしていく必要があるだろう。水路を経由した外来種の意図せぬ分布拡大は、様々な分類群で報告がある[15,16]。今後，水利整備事業の運営や開発を行う上で，これら外来種の問題への配慮が求められるだろう。

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O1-25

Trophic status of *Chitala ornata* (Osteichthyes; Notopteridae), an invasive fish species in Sri Lanka and impacts of its invasion on Fish diversity in tributaries of Bentota River

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Key words: Invasive, *Chitala ornata*, Stomach contents, Biodiversity, Bio volume.

ABSTRACT

Fish were sampled using gill nets, seine nets, cast nets and some were also collected from fishermen's catches at the tributaries of the Benthota River in Katapola, Ganegoda, Avitthawa, Yagirala and Galatara from August to December 2016. To investigate the potential threats from *Chitala ornata*, its stomach contents were analyzed and quantified using the Point method based on the percentage of bio volume per food category. Ten species of fish were recorded from all five sites, including two endemic species, *Clarias brachysoma, Channa orientalis*. Some indigenous species such as *Puntius vittatus* (n=371), *Rasbora daniconius* (n=120), *Puntius dorsalis* (n=33) and *Trichogaster pectoralis* (n=52) were also caught in reasonable number. Parts of fish (scales, fins and flesh), mollusks, adult insects, insects larvae, macrophytes and digested/detritus matters were observed in the stomach. Among the stomach contents of *C. ornata* larger than 15 cm, highest bio volume (72%) comprised of parts of fish which was significantly higher ($p < 0.05$) than other food categories. Macrophytes accounted for the lowest biovolume (6.5%) which was significantly lower ($p < 0.05$) than the other food categories. However gut contents of *C. ornata* smaller than 10 cm comprised of a higher percentage of algae and plant materials (60%). Remains of fins of *Channa orientalis*, and *Rasbora daniconius* and some invertebrates observed in stomach contents of *C. ornata*, indicated its negative impacts on biodiversity in study sites. Therefore urgent attention should be paid to population control of *C.ornata* and to prevent its further invasion into new habitats.

1. INTRODUCTION

Invasive Alien Species (IAS) are species, native to one area or region, that have been introduced into an area outside their normal distribution, either by accident or on purpose, and which have colonized or invaded their new home, threatening biological diversity, ecosystems and habitats, and human well-being. *Chitala ornata* is one of the major IAS in Sri Lanka, a primarily carnivorous species and hence threatening biodiversity. At present, IAS introduction is considered as one of the major direct driver of erosion or devastation of the biodiversity in freshwater ecosystems[1] [2].

It is believed that the introduction of *C. ornata* (Family: Notopteridae), which is native to the Mekong basin in Laos, Thailand, Cambodia and Viet Nam[3] was through a negligence of aquarists and ornamental fish traders[4]. This species is now found in the Diyawanna Oya and the Bolgoda Lake in the western province of the country as well as in Bentota River of Sri Lanka.

Stomach content analysis is a better tool to predict possible predation, competition and feeding habit of particular species. A stomach content analysis of an endangered clown knife fish *C. ornata* from different wild population indicated that this species was primarily predatory and carnivorous in nature, indicating differences in the diet in different wild populations[5]

However, so far no detail ecological and biological studies on possible impacts assessments of *C. ornata* in freshwater bodies of southern region of Sri Lanka has been carried out, but some studies on ecological, biological and reproductive studies had been carried out in western province of Sri Lanka[6].

Present study was carried out mainly to investigate the possible competition for food among the *Chitala* spp. and other indigenous fish species inhabiting Bentota River and to investigate ontogenetic diet shift in *C. ornata* as a sub objective.

2. MATERIALS AND METHODS

Five sampling sites i.e. Katapola, Ganegoda, Avitthawa. Galatara and Yagirala associated with tributaries of Bentota river were selected in the suburbs of Elpitiya area in Sri Lanka. Fish were sampled using gill nets, seine nets, and cast nets. In addition some *C. ornata* were collected from fishermen.

Maximum number of 10 individual belonged to different length classes of each fish species caught were preserved in formalin in order to carry out gut content analysis. Fishes larger than 10 cm were preserved by injecting 10% formalin into the body cavity immediately after capture to prevent deterioration of stomach contents and then were put in formalin bath. Prior to the gut content analysis total length and body weight of each individual were measured. For gut content analysis the point method based on the percentage of bio volume per food category was used[7]. Gut contents were analyzed according to different length classes i.e. below 15 cm, 15-30 cm and larger than 30 cm, in order to assess ontogenetic diet shift.

Diet overlaps were calculated on the basis of the gut contents of species concerned. Diet overlap (S) between each pair of species was determined using Schoener's (1970) formula;

$$S = 1- 0.5 (\Sigma_{ai=1}^{n} | P_{xi}-P_{yi} |)$$

Where S= the dietary overlap coefficient of fish species x and y.

Pxi = proportion of food category "i" in the diet of species "x"

Pyi = proportion of food category "i" in the diet of species "y"

n = number of food categories

The values for this similarity index ranged from 0.00 to 1.00, with 1.00 indicating complete overlap and 0.00 indicating no overlap.

The diet/niche breadth was calculated for each fish species using the niche breadth coefficient, Bi[8].

$$B_i = -\Sigma^{n}_{j=1} P_j * \log Pj$$

Where Pj = the proportion of food category "j" consumed by species "i".

Bi = the niche breadth coefficient of a fish species "i"

n = the number of resource states available

For the data that exhibited normal distribution, One-way ANOVA was carried out to check the significantly different food items among and between the different size classes of fish using SPSS ver 17 statistical package.

3. RESULT AND DISCUSSION.

Fish species richness was reasonably high in all selected five sites. Ten fish species were collected from three sites out of five sites sampled and included some endemic species such as *Clarias brachysoma, Channa orientalis.* Some indigenous species such as *Puntius vittatus* (n=371), *Rasbora daniconius* (n=120), *Puntius dorsalis* (n=33) and *Trichogaster pectoralis* (n=52) were also caught in reasonable numbers. Highest abundance of *Chitala ornata* was recorded in Katapola site. Length of the smallest *Chitala ornata* recorded is 7.2 cm while the largest one measured 42 cm when pooled together irrespective to the sites.

Results of the gut content analysis of *C. ornata* are shown in Table 1. The main food items recorded in *C. ornata* irrespective to sites are parts of the fish (flesh, scales, parts of fins and bones), mollusk, adult insects, insects larvae, macrophytes, and digested/detritus matters.

Table 1: Gut contents of *Chitala ornata* per different size classes irrespective to the sampling sites.

Food item	Size classes (cm)		
	0-10	10-15	> 15
Parts of the fish	05	32*	72*
Mollusk	04	18	07
Adult insects	17	12	04
Insects larvae	02	09	03
Macrophytes	60*	15	6.5
digested/detritus matters	12	14	7.5

Small *Chitala ornata* (less than 10 cm) mainly depended on macrophytes and adult insects, but when they attained to the large size (more than 15 cm) their food habits shifted to carnivory from herbivory, by feeding mainly on parts of fish and mollusks. Consumption of adult insects gradually decreased with increasing body size. These data clearly reveals ontogenic diet shift. Some fresh fish remains that are not digested were identified as small cyprinids like *Puntius vittatus, Rasbora daniconius* and endemic fish *Channa orientalis.*

Results of the one way ANOVA reveals significant difference ($P< 0.05$) of food items such as parts of the fish and macrophytes among different size classes. Shirantha (2016) recorded same situation in research carried on Size-dependent dietary shifts in *Chitala ornata* in Bolgoda Lake, Western province, Sri Lanka [9]. Their research outcomes revealed clear ontogenetic variations of relative abundance of different food categories based on stomach content analysis. It showed strong ontogenetic diet shifts from omnivory in 30-35 cm fish to carnivory in fish larger than 35 cm and exclusively piscivory when it was larger than 50 cm.

Diet/niche overlap values for possible fish species pairs are given in Table 2.

Table 2: Diet/niche overlap values for possible fish species.

Fish species	CO	PV	RD	PD	TP	OG	CHO
CO	-	0.15	0.24	0.37	0.29	0.19	***0.812***
	PV	-	0.37	0.41	0.49	***0.56***	0.165
		RD	-	***0.62***	***0.68***	0.36	0.418
			PD	-	***0.53***	0.32	0.472
				TP	-	***0.57***	0.359
					OG	-	0.204
						CHO	-

Note: CO- *Chitala ornate* PV- *Puntius vitatus* RD- *Rasbora daniconus* PD- *Puntius dorsalis* TP- *Trichogaster pectoralis* OG- *Osporonemus goramy* CH0- *Channa orientalis*

High diet/niche overlap value was exhibited by fish species pair CO-CHO. This revealed high competition for food among *Chitala ornata* and *Channa orientalis*, an endemic species.

The diet/niche breadth values of the species considered in this research are shown in table 3.

Table 3: Diet/niche breadth values of fish species considered.

Fish species	Overall
Chitala ornata	2.67
Puntius vitatus	2.88
Rasbora daniconus	***4.02***
Puntius dorsalis	***4.93***
Trichogaster pectoralis	***4.73***
Osporonemus goramy	3.18
Channa orientalis	2.96

Rasbora daniconus, Puntius dorsalis and *Trichogaster pectoralis* showed a relatively large niche breadth based on food resources used and thus are more generalised feeders. In contrast, *Chitala ornata* recorded a narrow niche breadth value ($B_i < 2.75$) indicating specialised feeder. *Puntius vitatus, Osporonemus goramy* and *Channa orientalis* are moderately specialised feeders.

4. CONCLUSION

Remains of body parts of *C. orientalis*, which is an endemic fish species found in guts of *C. ornata* indicates threats to the endemic fauna of Sri Lanka. Presence of flesh and parts of fins of *R. daniconius* and some invertebrates in the gut contents of *C. ornata*, indicates the negative impacts on native fish as well as on other aquatic fauna. Size distribution of *C. ornata* ranging from 8 cm to 42 cm indicates reproduction within the introduce habitat and successful colonizing nature. Therefore urgent attention should be paid to population control of *C.ornata* and to prevent its further invasion.

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O1-26

Are Japanese Rice Fields threatened by the New Invasive Alien Species of Tadpole Shrimp (*Triops strenuus* Wolf, 1911) from Western Australia?

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Keywords: invasive alien species (IAS), rice fields, ecosystem management, consensus building, nature conservation

ABSTRACT

Three species of tadpole shrimp, i.e., *Triops sinensis* (Uéno, 1925) (resurrected by Naganawa in 2018, previously synonymized erroneously in Japan with *Triops granarius* (Lucas, 1864)), *Triops longicaudatus* (LeConte, 1846) and *Triops cancriformis* (Bosc, 1801-1802), have been known from Japan. The author described a fourth *Triops* species (= *Triops strenuus* Wolf, 1911) living in the rice fields of Shirahama and adjacent area of Wakayama Prefecture (a southern area of Honshu, the largest of the four main islands of Japan). This species was probably endemic to the Australian continent, and no habitat distribution outside of Australia has been reported so far. The impact on the existing ecosystem of Japan is quite unknown, and therefore, it is necessary to announce this intrusion into Japan in order to clarify the invasion route, habitat ecology, and the future measures against this new alien species. This invasion is considered to be caused by the resting eggs brought together with silica sand (imported from Western Australia into Japan for the large-scale beach improvement). There are two possible routes of dispersal from the coastal sand to the rice fields where *T. strenuus* had been found in Japan: (1) windborne dispersal and (2) dispersal by human activities (i.e., tourism) and/or animal vectors (e.g., water birds and crows). The results presented here also describe the phylogenetic relationship with all the Australian species described so far, but also all the known *Triops* species of the world, based on the nucleotide sequences of mitochondrial DNA.

1. INTRODUCTION

About 50 living tadpole shrimp species are known from the world, all belonging to the single family Triopsidae Keilhack, 1909. They are subdivided in two genera (*Lepidurus* Leach, 1819 and *Triops* Schrank, 1803) and are around the recent world except Antarctica. Tadpole shrimp are limnophilous crustaceans that adapted their way of life to natural temporary waters; however, we can find them in Japan in rice fields only. The first discovery of a tadpole shrimp in Japan was by Professor Chiyomatsu Ishikawa (Tokyo Imperial University) in August of 1916, from the locality of Kagawa Prefecture of Shikoku, the smallest of the four main islands of Japan. Yatsu stated in 1916 [1] that tadpole shrimp inhabited Japan, and then Kawamura also referred to it in brief [2]. Later, Uéno reported on Japanese and Chinese tadpole shrimps in detail, entitled “*Apus* from eastern Asia” [3]. This was the first academic description on tadpole shrimp published in Japan.

As for tadpole shrimp at present, four species, i.e., (1) *Triops sinensis* (Uéno, 1925), called “Tairiku Kabuto-ebi” in Japanese (formerly “Asia Kabuto-ebi”); (2) *Triops longicaudatus* (LeConte, 1846), “America Kabuto-ebi”; (3) *Triops cancriformis* (Bosc, 1801-1802), “Europe Kabuto-ebi”; and (4) *Triops strenuus* Wolf, 1911, “Shirahama-Australia Kabuto-ebi” (**Fig. 1**) have been reported from three main islands of Japan, except Hokkaido [4-6]. This report is an updated version of the author’s paper published in *Crustaceana* in February of this year [7].

2. METHODS

Newly collected samples from Japan, Siberia and Mongolia, and also ethanol-fixed specimens on loan from the Western Australian Museum were used to sequence 658 bp of mitochondrial cytochrome *c* oxidase gene subunit I (COI), following the methods described in Naganawa [7]. The sequences were compared with ones retrieved from GenBank in a phylogenetic analysis. All newly generated sequences were deposited in GenBank.

3. RESULTS & DISCUSSION

The most important facts are as follows. First, silica sand of Australian origin has been imported into Japan for beach improvement about 25 years ago. Second, the present author found the resting egg of *Triops* from the coastal sand of the area in Japan. And third, the *Triops* specimens collected from Japanese rice fields in the area, cluster within Australian *Triops* in the phylogenetic analyses (DNA barcoding approach). The individuals from Japan add a fifth hitherto unknown lineage to *T. strenuus*. On the one hand, this result shows that the genetic diversity in Australia is even greater than shown by Meusel & Schwentner [8], but unfortunately, also does not allow verifying the precise source population genetically. In addition, unrecognized Australian *Triops* populations may have been present in between the coastal area and the rice fields, may work as potential dispersal agents. Formerly recognized Japanese tadpole shrimp as “Asia Kabuto-ebi” are all to be *T. sinensis* correctly.

Fig. 1 New invasive alien tadpole shrimp of Australian origin, *Triops strenuus* Wolf, 1911 [7] (＊ in Fig. 2)

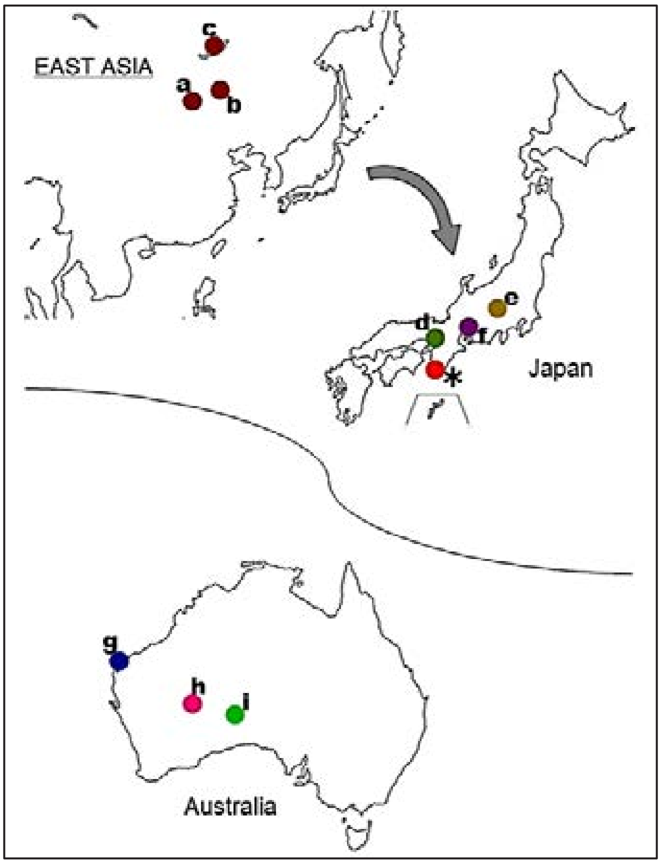

Fig. 2 Distribution map of newly recognized *Triops* [7]

The author’s findings are listed below, under trying to describe each as new formal species, except one (*Triops sinensis* (Uéno, 1925)). At least, *Triops* sp. Learmonth could be a new species; *Triops* sp. Mistake Creek and *Triops* sp. Great Victoria Desert are newly recognized Australian lineages (see also **Fig. 2**).

(a) *Triops* sp. Mandalgobi (Gobi, Mongolia)
(b) *Triops* sp. Choir (Gobi, Mongolia)
(c) *Triops* sp. Baikal Olkhon Is. (Siberia, Russia)
(d) *Triops sinensis* (Uéno, 1925) (western Japan)
(non *Triops granarius* (Lucas, 1864), misidentified)
(e) *Triops* sp. Shigeno (Nagano Prefecture, Japan)
(f) *Triops* sp. Kakigase (Gifu Prefecture, Japan)
(g) *Triops* sp. Learmonth (Western Australia)
(h) *Triops* sp. Mistake Creek (Western Australia)
(i) *Triops* sp. Great Victoria Desert (Western Australia)

4. CONCLUSION

The scope of this article is to report the occurrence of an Australian *Triops* in Japan. Additionally, it provides nine new COI sequences, some of which coincidently suggest the presence of new genetic lineages.

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カブトエビ

豪州産が紀南に定着

京大の長縄さん　国内で初確認

白浜町にある京都大学瀬戸臨海実験所の長縄秀俊さん(54)＝京大大学院理学研究科動物学教室＝は、同町や上富田町の水田で、オーストラリア原産のカブトエビが生息していることを確認した。国内で豪州産が確認されたのは初めて。今後、生息域が広がる可能性があるという。シラハマオーストラリアカブトエビと命名。研究成果は近く、甲殻類研究の国際誌に掲載される。

カブトエビは、全長2～4㌢ほどになる小形の甲殻類。「トリオプス」や「生きた化石」などとも呼ばれ、飼育セットが販売されている。国内では、アメリカ、アジア、ヨーロッパの3種が知られている。

流れに逆らって泳ぐシラハマオーストラリアカブトエビ
（白浜町才野で）

長縄さんは3年前、白浜町の水田や周辺の水路で、既知種と色や形の違ったカブトエビを確認。その正体を解明するため、世界各地からカブトエビのサンプルを集めるなどして研究を続けてきた。顕微鏡による形態観察やDNA解析などから、豪州大陸の固有種である可能性が高いことを突き止めた。

1905年に豪州中部のウルル（エアーズロック）付近から発見され、11年に報告のあった種と共通の祖先を持ち、約3400万年前に枝分かれしていた。ただ、ウルルのカブトエビは雌雄があるが、白浜の種は雌だけで増えている。その繁殖のメカニズムや進化の過程は分かっていない部分が多いという。

白良浜の養浜事業か
日本への侵入経路

生態系への影響などを考えるため、日本への侵入経路の究明にも取り組んできた。侵入経路は1989年から数年間行われた白良浜の養浜事業が有力とみている。カブトエビの卵は直径0・3～0・4㍉ほどで、乾燥した状態だと50年以上生き続けられる。西オーストラリア州から日本へ輸入された白砂に卵が紛れ込んで白良浜に持ち込まれ、風や人の移動によって拡散した可能性が考えられるという。

2016年の調査で、白良浜から卵の殻と思われるものも見つけている。

長縄さんは「今後はオーストラリアの研究者らと共同で、今回のものも含めカブトエビの進化についてさらに詳しい調査を展開していきたい」と話している。

カブトエビ　南極大陸を除く世界各地から約50種が知られている。これらのほとんどが絶滅の危機にひんしている。日本でカブトエビが初めて発見されたのは1916年。降雨や雪解けの後に一時的にできる天然の水たまりが主な生息地だが、日本では水田やその周辺以外から発見されたことがない。

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今日のニュース

8面
「本宮大社の記念切手」
日本郵便が販売開始

9面
「奥田氏インタビュー」
上富田町長選の当選者

Appendix 1 Article on this invasive alien species (IAS) problem reported on Kii Minpo news, Japan

O1-27

The widespread of the redclaw, *Cherax quadricarinatus* in Indonesia

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Keywords: Redclaw; biological invasion; non-indigenous species; Parastacidae; aquaculture; pet trade

ABSTRACT

Redclaw (*Cherax quadricarinatus*, von Martens) is a crayfish native to north-eastern Australia and southern New Guinea, being found for the first time west of the Wallace Line in Java in 2016. Following introductions for aquaculture purposes, it escaped from culturing facilities, exhibiting invasive habits in various tropical and subtropical countries. Based on climate matching, its further spreading within Indonesian territory was predicted. We surveyed selected localities within Indonesian territory to check the species occurrence. Redclaw crayfish were found in numerous rivers, lakes, ponds and reservoirs in Batam and Bintan Islands, Java, Sulawesi, and Sumatra. Some stocks were apparently well established, providing a food source for locals and sustaining catching for pet trade purposes. Since there are no effective regulations of this crayfish introductions and exploitation in Indonesia, its further dissemination and spread to new localities is expected. This will lead to the devastating consequences toward often endemic freshwater biota in this prominent biodiversity hotspot. Increased attention to this issue, especially at the level of wildlife management and national environmental policy, is urgently needed.

1. INTRODUCTION

In Indonesia, *Cherax quadricarinatus* is native only to the Papua province but it was previously recorded as non-indigenous and established at two localities west of the Wallace Line in Java[1]. The lobster is increasing in popularity for human consumption in Indonesia[2]. Moreover, this country was previously identified as one of the leading exporters of ornamental crayfish, especially of the genus *Cherax*[3]. The production of *C. quadricarinatus* for ornamental purposes was also recorded there[1]. Nevertheless, information about the method of farming and harvesting in this region are just anecdotal[2] and detailed monitoring is lacking.

Based on climate matching between the native range and entire Indonesian territory, it was predicted that this species has a high potential to become established when introduced[1]. *Cherax quadricarinatus* is a relatively large and highly fecund species[4], known to be a successful invader in warm climatic conditions. Its spread may have devastating consequences to numerous Indonesian endemic crustaceans including shrimps, crabs and other freshwater biota, potentially affecting the functioning of entire ecosystems. This assumption is supported by a recent event in the Lido Lake, Java: *C. quadricarinatus* together with the invasive shrimp *Macrobrachium lanchesteri* (de Man) caused a dramatic decline of the native shrimp *M. sintangense* (de Man) leading to its extinction at this locality (Aprila, Wowor and Farajallah, unpublished data). Since there are no effective legislative measures of non-native crayfish introductions in Indonesia, the further spread of *C. quadricarinatus* to new localities was expected. This is the highly alarming scenario, given that the region is a prominent global biodiversity hotspot[5].

2. METHODS

During June 2016 – August 2017 we surveyed selected localities within Indonesian territory to ascertain *C. quadricarinatus* presence. Crayfish were collected at each locality during one-night sampling with use of bamboo or foldable net traps baited with fish and gastropod meat. We found populations of *C. quadricarinatus* in various waterbodies including natural lakes, artificial ponds and reservoirs, and also rivers in Batam and Bintan Islands, Java, Sulawesi, and Sumatra (Fig. 1). Identification of captured crayfish was based on morphological characteristics according to Holthuis[6] and Souty-Grosset et al.[7]. If ovigerous females are observed in a population, the population is considered established.

Fig. 1 Map of Indonesia with localities where *Cherax quadricarinatus* was recorded, localities indicated by red circles of different sizes indicating number of sites.

3. RESULTS AND DISCUSSION

C. quadricarinatus was imported into Indonesia in 2003 for the establishment of aquaculture industries[2]. But based on information obtained from local people, the crayfish in Kemang Lake were produced for the pet trade in net cages in 2002 (Fig. 2), escaping from the facility the same year. Currently, crayfish are captured by local hunters using bamboo traps in the lake. We assume that this was the starting point for the dissemination of the species in the entire Indonesia.

Fig 2. Net cages used for culture of ornamental fish and crayfish in Kemang Lake, West Java – Indonesia.

Cherax quadricarinatus was also recorded to be commonly advertised for trade as an ornamental animal in local pet shops in Jakarta and Bogor, Java, being offered under the general local name "lobster air tawar" (freshwater crayfish) and in one case under misnomer C. albertisii. Based on information from pet shop owners, the traded crayfish originated from Kemang Lake.

In addition to previous records in Cilala and Lido Lakes, Java[1], we report 32 additional established populations of *C. quadricarinatus* widespread within Indonesian territory outside its native range (Table 1). The only national regulation of non-native species in Indonesia is Regulation No. 41/PERMEN-KP/2014 banning the import of 152 selected non-native fish. In this law, fishes are defined as "all types of organism in which all or part of its life cycle is in an aquatic environment". There are only four crayfish listed and banned: *Faxonius rusticus* (Girard), *F. virilis* (Hagen), *Pacifastacus leniusculus* (Dana), and *Procambarus clarkii* (Girard). Generic names were updated according to the recent taxonomic revision (Crandall and De Grave 2017).

Table 1. Established populations of *Cherax quadricarinatus* in Indonesia: locality name; type: artificial (pond, reservoir), natural (lake), river; island; GPS coordinates. Localities marked by an asterisk were adopted from the previous study[1]

Locality	Type	Island
Sei Ladi Reservoir	artificial	Batam Island
Buaya River	river	Bintan Island
Bagendit Lake	natural	Java
Borcess Lake	natural	Java
Burung Lake	natural	Java
Cilala Lake*	natural	Java
Ciburuy Lake	natural	Java
Cirata Reservoir	artificial	Java
Darma Reservoir	artificial	Java
Gede Lake	natural	Java
Kemang Lake	natural	Java
Kemuning Lake	natural	Java
Lengkong Lake	natural	Java
Lido Lake*	natural	Java
Panjang Lake	natural	Java
Saguling Reservoir	artificial	Java
Tonjong Lake	natural	Java
Bantimurung Pond	artificial	Sulawesi
Bonto Jolong Pond	artificial	Sulawesi
Lekoala Pond	artificial	Sulawesi
Tondano Lake	natural	Sulawesi
Tempe Lake	natural	Sulawesi
Laut Tawar Lake	natural	Sumatra
Maninjau Lake	natural	Sumatra
Manna River	river	Sumatra
Teluk Lake	natural	Sumatra
Sipin Lake	natural	Sumatra
Kerinci Lake	natural	Sumatra
Atas Lake	natural	Sumatra
Bawah Lake	natural	Sumatra
Talang Lake	natural	Sumatra
Toba Lake	natural	Sumatra
Batang Lembang River	river	Sumatra
Batang Ombilin River	river	Sumatra

It is obvious, that *C. quadricarinatus* is popular for exploitation and, since release of this crayfish to the wild is not illegal in the country, we assume that more waterbodies are or will be used for its culture. In addition, more unintentional escapes might also be expected. Local people have very poor knowledge about risks related to invasive species (Patoka J., pers. observ. 2017) and since the eradication of established crayfish is impossible without dramatic disturbance of the whole ecosystem, further education of the general public seems to be crucial for prevention of new introductions. Therefore, we strongly recommend this situation to the attention of wildlife managers and national policymakers.

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O1-28

Ecological Barriers and Aquatic Ecosystem isolation – The effect on mosquito populations and their natural enemies in Chiang Mai City, Thailand

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Keywords: ecological fragmentation, population, mosquito born disease, predator-prey and habitat

ABSTRACT

Rapid urbanization is the main reason of habitat isolation and fragmentation in many city area of the world. Extinction, decreasing of biodiversity and balancing of community lost were the effect of habitat isolation. Mosquitos (Diptera: Culicidae) are the vector of many pathogen disease. Mosquito larva as prey in aquatic ecosystem could got some effect on unbalancing of community by Ecological Barriers and Aquatic Ecosystem isolation. There are many small wetland, freshwater Lakes and ponds in Chiang Mai, Thailand. Sixteen observation sites were selected by grid sampling method (3x3 km^2). The physicochemical data and biological data were analyzed and compared between every isolated area and main area. For the result, the newly created small canal, ponds that isolated from the main of larger habitat and ecological barriers as a water gate are inducing unbalancing of community, increasing number of mosquito larva and increasing pond breeding site of mostly *Culex* species mosquito. Result of physicochemical and biological parameters show dissolve oxygen (DO), Evenness of aquatic organism and percentage of predator were negative correlation between number of mosquito larva. Moreover, good water quality was positive correlation between number of predator. From the result, the biological barriers and aquatic environment isolation by human urbanization was indirect effect of the mosquito born disease in many countries of tropical zone. Therefore, every construction and city management have to concern with the biological barriers and isolation.

1. INTRODUCTION

Cities have emerged on the banks of rivers throughout history[1]. Rivers are multi-faceted ecological, cultural, economic, and political agents, providing resources such as food, water, irrigation, sanitation, and transportation. Urban growth is most rapid in the developing world, where cities gain an average of 5 million residents every month[2]. Man made construction such as pond, water gate, pipe line and rode are ecological barriers that isolated the habitat of aquatic organism. Population and community were got effect from ecological barriers. The role of barriers as "filters" structuring population and community in each environment[3].

Many mosquito larva species (Diptera: Culicidae) be as a prey in food chain[4]. One of the ecological barriers effects is community change. The reduction of predator in isolated area can be cause of increasing prey population[5]. Many species of mosquito are the pathogen of many vector borne disease. Dengue fever transmitted by *Aedes* mosquito, is one of the important vector born disease that occur in the city of tropical area[6]. The number and severity of dengue infections has been increasing since the Second World War, culminating in a 30-fold increase between 1960 and 2010. It is now 20 times more common than the flu[7]. Because of global warming, pesticide use, and the *Aedes* mosquito's preference for urban environments[8], the insect – and the virus it carries – are rapidly spreading around the world.

Mosquito Larva observation is the simple way to determine the mosquito population in environment. Before the 1940s, control actions had been directed specifically at the aquatic ecosystem. The focus was on eliminating larvae, and there was a growing interest in applying biological strategies to reduce mosquito populations at the breeding sites[9]. The mosquito larva predator was interested.

Over 3,520 mosquito species that recognized in the world and 459 species in Thailand[10]. There are many aquatic ecosystem isolations such as small wetland, freshwater

Lakes, ponds, retention areas and paddy field in Chiang Mai. In this study, we focus the effect of habitat isolation on the abundance of mosquito larvae in aquatic environment in Chiang Mai. The relation between main area and isolation area with predators and mosquito larva were analyzed. Moreover, water quality was estimated to find out the relation between the predator and mosquito larva.

2. METHOD

Study site

Sixteen observation sites around Chiang Mai city were chosen base on fresh water habitat applied from Williams and Feltmate 1994 [11] by using grid sampling method (3x3 km^2) (figure 1).

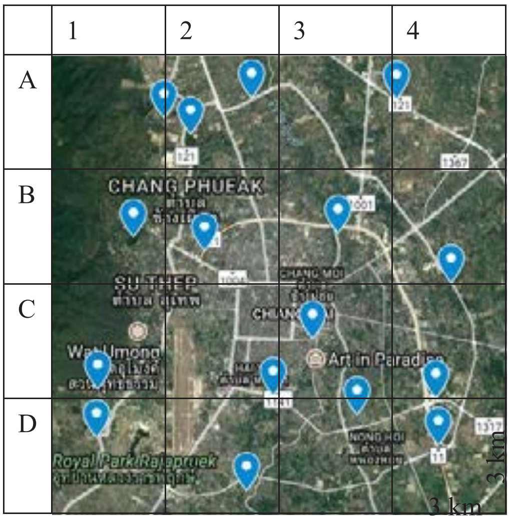

Fig. 1 Sixteen sampling area around Chiang Mai city

Data and sampling method

Samples were collected in dry season before the first rain conning in Chiang Mai (1st April 2018 – 30th April 2018). The physicochemical parameters in 8 parameter including water temperature, pH, ORP, Conductivity, Salinity, Total dissolve Solid, Dissolve oxygen and turbidity were measured using handheld HORIBA U52 equipment. Hydraulic characteristic water velocity was measured by measuring velocity meter. Light Intensity (Lux) was measure by using Lux meter. Riparian and habitat characteristic (stream bed, aquatic plant, deposits and stream bank) were scored follow by The National Institute of Water and Atmospheric Research (NIWA) New Zealand[12]. Macroinvertebrates were collected by kick and pick method[13] from several habitats of each sampling site. Samples were preserved in 70% ethanol prior to transport to laboratory. After the cleaning and sorting process, macroinvertebrate samples were identified to family level under stereomicroscope.

Analysis

The environment data were used to calculate Habitat score that applied from NIWA organization New Zealand. The macroinvertebrate and other mosquito predator were collected in qualitative sampling method. Macroinvertebrate were identified, and No. of individual predator and mosquito were count. The correlation in each factor and biological data were used PAST3

3. RESULTS AND DISCUSSION

From 16 study sites, 12 sites were found mosquito larvae. Ten sites were pond isolation. After analyzed with Mann-Whitney U test, mosquito abundance of isolation and main side were significantly different ($p<0.01$). The pond sites have higher mosquito abundance than the flow sites ($\bar{X}=98.2\pm115.0$, 12.9 ± 20.3 respectively). Highly mosquito larvae abundance was presented in pond side because most of mosquito larvae prefer standing water or slow water flow.

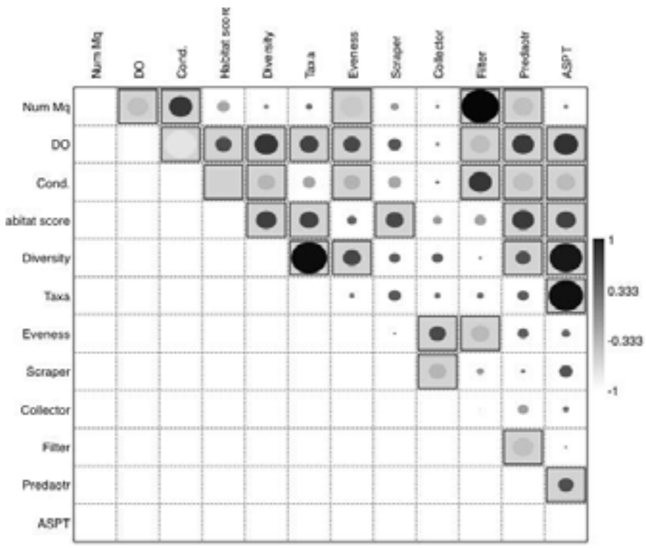

Fig.2 Correlation between mosquito larvae and factors

(Grey box showed p<0.05 significant)

Correlation between mosquito larvae and influent factor showed as figure 2 The mosquito larvae abundance showed significantly negative correlation with dissolved oxygen, predator ($p<0.01$) and evenness ($p<0.001$) and showed positive correlation with conductivity and functional feeding group of filter feeder ($p<0.001$). The water flow can increase the dissolved oxygen in the water. Thus, standing water (that mosquito lives in) have low oxygen. Moreover, ASPT score that higher for represent good water quality was show the positive correlation with diversity and percentage of predator.

4. CONCLUSION

Isolation of aquatic habitat have effected to the mosquito population especially in larva stage. The stream that changed to standing water by human activity are suitable habitat for mosquito may increase the mosquito borne diseases in urban area. Therefore, every construction and city management should concern with the biological barriers and isolation.

5. ACKNOWLEDGEMENT

Special thanks are extended to the staff of Freshwater Biomonitoring Research Laboratory (FBRL). We would like to express my very great appreciation to Environmental Science Program, Chiang Mai University, Thailand and Center of Excellence on Biodiversity, Thailand for facility and financial support.

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O1-29

The state of Ghana's Aquaculture Production on the Volta Lake at a Glance

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Keywords: Volta Lake, Tilapia production, Nutrient discharge, Site selection, Carrying capacity

ABSTRACT

This present study was conducted to establish the number of tilapia farms on the Volta Lake, their farm size, employees experience in nutrient discharge and pollution control, annual production and feed used. Owners of 129 farms (83 small, 32 medium and 14 large scale) were interviewed using qualitative and quantitative questionnaires. The 129 farms employed 1,379 permanent and 1,200 causal workers with 3,392 cages (59% in used). The owners had no experience in tilapia farming and selected their sites based on physical characteristics without in-depth research. Only 3% had legal documents to operate on the Volta Lake. The 129 farms produced 18,632.27 metric tons of fish in 2015 and 14,711.82 metric tons in 2014. Fifty-Eight percent fed based on stock density, 20% used body weight while 16% used the age of the fish. Ninety five percent do not measure water quality parameters, engage in any kind of pollution control and know the amount of phosphorus being deposited in the lake. Ninety percent had no knowledge about the carrying capacity and zonation of the lake. All the farmers use between 70 and 90 bags (25kg per bag) of feed to produce 1 metric ton of fish. Based on that, the author estimated that about 31,674.74 metric tons of feed were used in 2015 and 25, 010.09 metric tons in 2014 with FCR of 1.7. The findings led to the conclusion that Ghana's aquaculture development on the Volta Lake needs to be better planned to prevent negative environmental impacts in the future

1. INTRODUCTION

The study was aimed to establish the number of tilapia farms operating on the Volta Lake, their locations, farm size, employees experience, annual production, feed used and workers knowledge on nutrient discharge, pollution control, carry capacity, disease and bacterial control.

2. STUDY AREA

Volta Lake is about 394,000 km2 and runs through six countries: Mali, Benin, Togo, Burkina Faso, Ivory Coast and Ghana. In Ghana, it covers 4% land area with a volume of 149 km3 and a depth of 19 m (MOFAD, 2016). It is divided into eight strata and surrounded by 1250 communities as shown in Figure 1.

Figure 1 B and B: Volta Lake view and the strata map.

3. APPROACH AND METHODOLOGY

Both qualitative and quantitative questionnaires were used to collect the needed data from the famers, chiefs', elders and the community members.

Figure 2: Retailers loading the fish for the market.

4. RESULTS AND DISCUSSIONS

A total of 129 tilapia cage farms were interviewed, 17% from the strata I - Afram River arm (Kwahu-Adowso), 57% in strata II - Lower section (Dzemeni,Akosombo) and 25% in strata III-Middle section (Kpando). Fourteen percent (14%) were established between 2001 and 2010, 5% in 2011, 16% in 2012, 18% in 2013, 24% in 2014 and 23% in 2015. This implies that interest in aquaculture farming continues to grow in Ghana each year with an average growth rate of about 16% (Kassam, 2014). The increasing number of farms is very significant. As suggested by Asmah et al (2016), the increasing number of farms on the Volta Lake would contribute to food and nutrition security; create more jobs for unemployed youth and save Ghana an amount of US$ 200 million from fish importation per year. From the survey, majority of the farms were concentrated in strata II. This implies that there is more surface area for aquaculture development in other strata's. However, the water quality and aquaculture impact on communities around the strata II should be controlled to prevent conflict and health problems.

Of the 129 farm owners, 5% were females and 95% were males. Setboonsarng (2002), observed a low participation of women in aquaculture in some Asian countries. However, women not been owners, 92% women engaged in postharvest activities such as processing and marketing of aquaculture products as reported by Akrofi (2002). It could be said that, the number of female owners in current aquaculture production in Ghana is opposite of what were reported by Amsah (2008) and Chirindza (2010). Both Asmah (2008) and Chirindza (2010) focused on pond aquaculture as compared this study on cage aquaculture. The reason for the decline of women owners in aquaculture could be attributed to the introduction of cage culture in Ghana. The cage aquaculture farming is more intensive, expensive and is done in deeper. The annual production yields from the 5% female fall within the larger scale farm classification as confirmed by a similar study by Nandeesha and Heng (1994) in Cambodia ponds.

The age range was from 28 years to 85 years, 51% did not disclose their level of education, 10% had no basic education, 12% attended only Junior High School, 22% held bachelor degrees, and 5% had earned a master's degree. This could be suggested that in the future more youth and educated people would be interested to invest in aquaculture farming to enhance food security and focus on ecosystem approach (Soto et al, 2007).

The majority (80%) had no experience before starting their farms, 97% indicated did no research but based on advice from friends and expected high profit returns. This implies owners had various reasons for starting their aquaculture farms (Adeleke and Omoboyeje, 2016).

Only 3% had acquired legal documents to operate a fish farm on the Volta Lake.Most farms belong to associations. It implies that the farms could form one strong association to assist farmers to acquire permits, advocate for enabling policies and compile with responsible code of conduct.

Sixty-four percent (64%) small-scale, 25% medium-scale and 11% large-scale farms were recorded. Sixty-three percent (63%) purchased fingerlings or brood stock from other farms, 1% sourced from Water Research Centre, 22% produced own fingerlings and 14% got from their own farm and other farms. Out of 129 farms, only 9% farms measured and sorted fish every two weeks. The remaining 91% said they do not measure and sort, in order to avoid causing mortalities.

The total fish stock in cages and ponds of 108 farms was 2,667.296 metric tons. Ninety-four percent (94%) were table size and ready to be sold during the Christmas period, 4% were fingerlings, 1% fry and 1% brood stock.

The number of cages recorded was 3,392. Fifty-nine percent (59%) were in use, while 41% cages were in the river but empty. Two cage sizes were very standard: 5x5 and 6x6 meters. Only four farms had larger sized cages. It could be said, the size of cages used had contributed to the slow growth of aquaculture production in Ghana. This is because; the average stock density (fingerling per cage) for 5x5x5m was 10,000 as compared to 500,000 for 16 or 19 diameter cage.

The total fish production from 88 farms (68%) in 2015 was 18,632.27 metric tons while 14,711.82 metric tons was produced by 56 farms in 2014. Ghana have had higher aquaculture production yield of 44,610 tons (FAO, 2017) as compared to Tanzania, and Rwanda. Brummett et al. (2008) suggested that Ghana has the potential to produce more fish as Volta Lake has about 140 species of fish (Braimah, 2001).

Majority do not use feed conversion ratio (FCR). The farms used between 70-90 bags (25kg) feed to produce 1 metric ton of fish. It was estimated that approximately 31,674.74 and 25, 010.09 metric tons of feed were used in the upstream of the Volta Lake during 2015 and 2014.

Almost all do not know the amount of nitrogen and phosphorus that is being deposited in the lake. The average oxygen level in the Lake had dropped from 8.6 mg/L to 7.8 mg/L. Some farmers had measured oxygen levels of 0.4 mg/L inside the cages and 0.6 mg/L outside the cages in 2015, which falls below what Alabaster and Lloyd (1982) suggested as the suitable conditions for fish growth.

Figure 3 presents the some challenges faced by the aquaculture farmers on the Volta Lake.

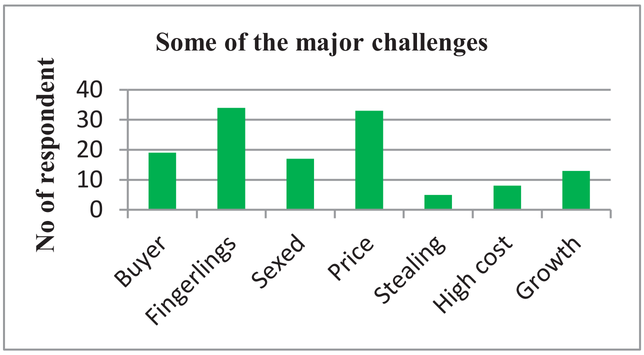

Figure 3: Some challenges faced by the aquaculture farmers on the Volta Lake.

5. CONCLUSION

The study revealed that there is an increasing trend of aquaculture farming activities on the Volta Lake mainly on strata II. The Ministry of fisheries and Aquaculture and Environmental protection agency are dialoguing with the farmers and the communities to develop responsible and sustainable ecosystem approach to ensure safe aquaculture production for human consumption, clean and quality water for community's members' living around the lake as well as easy passage for local canoe operators.

6. RECOMMENDATIONS

1. Farmers should move the cages to deeper waters to avoid massive mortalities during low oxygen periods (January-February and July, August to September).
2. There should be a peace dialogue to resolve the conflicts between the fish farmers, the communities, local fishermen and canoe operators on the user righ.
3. The farmers should be educated on feeding methods and feed conversion ratio to enable them maximize profits and minimize mortality rates.
4. Entrepreneurship, budgeting, marketing, productivity, human resource and cage management training should be organized for the farmers to see fish farming as a business. The small and medium farms workers should be taught in basic numeracy and literacy skills to enable them keep records
5. Government should support fish farmers to establish their own feed mill and provide them water and sediment quality equipment to enable the farmers to monitor water and sediment quality.
6. The farmers should form strong local Associations to enable them to collaborate for more success. For example, working together they could agree on a common price system, set-up sales outlets, cold stores and fingerlings production centers for farmers in all the regions.
7. Government (to include all ministries and agencies responsible for aquaculture production) should ensure and enforce a strict policy on importations of tilapia into Ghana to encourage local investors to increase production and create jobs for the youth in Ghana

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O1-30

Spatial and Temporal Variation of Length-Weight Parameters and Condition Factors of Commercial Fish Species in Lake Nasser, Egypt

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Keywords: Length-Weight parameters, Condition Factors, Spatial and temporal variation, Lake Nasser

ABSTRACT

Length and weight data of fish populations are necessary in stock assessment models and ecosystem modelling. Also, they could be used to spatially compare between different fish populations under different environmental conditions. This study provides an updated information on the length weight relationships and condition factors of six fish species in Lake Nasser, Egypt. It also investigates how these parameters are affected by variation in environmental characteristics of the Lake, therefore it presents the first reference on the spatial and temporal variation of these data in Lake Nasser. More than 13,000 fish were collected on monthly basis to cover different geographical zones and seasons of the lake. The values of the growth coefficient *b* obtained in this study were very close to the values recorded by previous studies with slight inconsistency while the average condition factors, *K,* were generally lower than that reported for 1984 - 2000. Moreover, results indicate overall statistically significant differences in seasons and locations for total length, total weight and condition factor means. The results obtained from this study are contributing to the knowledge of fish populations in Lake Nasser and highlighting the spatial and temporal variation of fisheries biological parameters in such large lake system. This variation should be considered by fisheries scientists and managers for future studies.

1. INTRODUCTION

Length and weight data of fish populations are useful for estimation of growth rates, length and age structures, and other components of fish population dynamics. This information is necessary in stock assessment models and ecosystem modelling approaches [1]. Moreover, length and weight data could be used to spatially compare between different fish populations under different environmental conditions [2] and temporally to track seasonal variations in fish growth [3]. The condition factor is used in order to compare the “condition”, “fatness” or wellbeing of fish. It is strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live [4].

Lake Nasser is a huge water body with a surface area of 5,237 km^2 at its highest water level (180 m above sea level) that now provides an important source of fish for Aswan governorate and the rest of Egypt [5]. Despite the importance of investigating the spatial and temporal variation of different biological parameters of fish populations in such a huge water body, which extends for 291.8 km from South to North, information about the spatial and temporal variation of length-weight parameters and condition factors of fish species in Lake Nasser is absent. All available information on these parameters are of the lake as whole without considering any variation in environmental conditions through different regions of the lake and over different seasons.

This study contributes to available length- weight and condition factor data for the most economically and ecologically important fish species inhabiting Lake Nasser. Also, this study investigates how these biological parameters are affected by variation in environmental characteristics of the Lake, therefore it presents the first reference on the spatial and temporal variation of these data in the Lake.

2. METHOD

Sampling Area:

The Aswan High Dam was constructed in the 1960s creating a huge water body, Lake Nasser, which contains three regions: the riverine southern part; the lacustrine northern part; and a region in between that has riverine conditions during the flood season and lacustrine characteristics in the remainder of the year [6] (Figure 1).

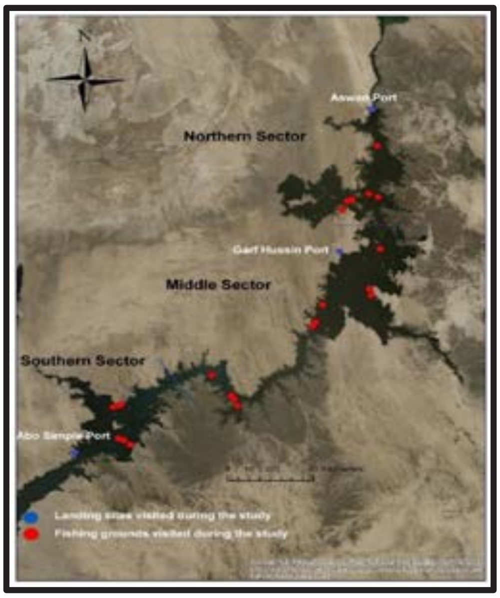

Fig. 1 Map of Lake Nasser showing sampling sites and different sectors of the lake.

Sampling of Fish:

Sampling was carried out during the period between October 2016 and September 2017. Monthly landing surveys of fishing ports (Aswan in the North, Garf Hussin in middle, and Abo Simbel in the South) have been conducted, in addition to bimonthly spatial surveys to cover the entire lake. A total of 13,091 fish belonging to six fish species (three families) were collected. Total length of each fish was taken to the nearest millimetre from the tip of the snout (mouth closed) to the extended tip of the caudal fin using a measuring board. Body weight was measured to the nearest 0.1 gram using a top loading balance.

Data Analysis:

Parameters of the length-weight relationship (LWR) of identified fish species were estimated using the equation:

$W = a L^b$ [7]; where, W = Weight of fish (g), L = Length of fish (cm), *a* = y-intercept or the initial growth coefficient, *b* = Slope or the growth coefficient.

The values of constants *a* and *b* were estimated after total weight (TWt) was plotted against total length (TL) and a power trend line (curve) of the form $y = a\,x^b$ fitted to the data using Microsoft Excel. Only extreme outliers attributed to data error were omitted from analyses. Condition factor (K) was calculated by the formula: $K = 100W/L^3$ [8]. Variations in TL, TWt, LWR (represented by '*b*') and K of the individual fish living in the lake's three regions during different seasons were analysed with one-way analyses of variance (ANOVA) with subsequent Tukey's honestly significant difference (HSD) tests using Xlstat software. All the statistical analyses were considered at significance level of 5% ($p<0.05$). Due to statistical constraints, only those species represented by at least 20 individuals in each season and sector of the lake and with a relatively wide size range were considered for ANOVA and Tukey's (HSD) tests. Therefore, *Alestidae* species were excluded from these analyses.

3. RESULTS

The species, number of specimens, LWR parameters *a* and *b*, correlation coefficient (r^2), condition factor, mean length of fish species, mean weight of fish species and growth type (allometric or isometric) are presented in (Table 1).

The family with the highest number of species was *Cichlidae*, which had three species (*Oreochromis niloticus*, *Sarotherodon galilaeus* and *Tilapia zillii*) and two species were recorded for *Alestidae* (*Alestes baremoze* and *Hydrocynus vittatus*), while, the last family *Latidae* had one species *Lates niloticus*. The sample size for the fish species varied from 375 in *A. baremoze* to 4562 in *S. galilaeus* while the value of *b* ranged from 2.92 in *S. galilaeus* to 3.29 in *A. baremoze*. The lowest condition factor (K) (0.57) was recorded in *H. vittatus* while the highest value (2.06) was observed in *O. niloticus*. The values of correlation coefficient (r^2) varied from 0.9396 in *T. zillii* to 0.9885 in *O. niloticus*. All *Alestidae* species had positive allometric growth while all *Cichlidae* species had negative allometric growth except *O. niloticus*, which had isometric growth similar to *L. niloticus*. An ANOVA revealed significant differences ($P<0.0001$) in all tested biological parameters among various seasons and locations for the four investigated species except for *b*. As ANOVA has shown an overall statistically significant difference in seasons and locations TL, TWt and K means, Tukey's (HSD) test was done to confirm where the differences occurred by pairwise comparisons for seasons and locations. The results of both statistical analyses are shown in Table 2.

4. DISCUSSION

This study provides an updated information on LWR of six fish species in Lake Nasser, Egypt. Unfortunately, the available literature on LWR parameters in Lake Nasser is outdated and limited to Nile tilapia (*O. niloticus*) as it was the main commercial fish species, besides few studies on mango tilapia (*S. galilaeus*) [9-11]. Nevertheless, the values of *b* obtained in current study for these two species (3.04 and 2.92 respectively) are very close to the values recorded by those studies where it ranged between 2.6 and 3.02 for Nile tilapia and 2.5 and 3.12 for mango tilapia. It is likely that this slight inconsistency is due to seasonal variability of the environment, food availability [12], sampling size and the length interval within different areas or habitat suitability [13].

K of the six fish species ranged between 0.57 and 2.06 which is generally lower than that reported by Adam, 2004 [14] for the years between 1984 and 2000. This suggests that the current condition of Lake Nasser, in comparison to its former status, may be becoming unfavourable to fishes. Therefore, there would be need for more studies on the physico-chemical properties and the condition factors of other fish species to be able to establish the sustainability of the lake for fish.

Table 1. Estimated parameters of the length-weight relationships (LWR), growth type, condition factors (K) and growth performance (total length & total weight) for six fish species in Lake Nasser.

Family	Species	N	Length (cm)			Weight (g)			K	Parameters of the LWR			Growth type
			Min	Max	Mean	Min	Max	Mean		a	b	r^2	
Alestidae	*Alestes baremoze*	375	21	47	29.3982	48.8	758.4	175.206	0.59255	0.0022	3.2915	0.9617	P
	Hydrocynus vittatus	606	21.4	78	37.7711	45.9	3042	362.89	0.56516	0.0021	3.2751	0.9788	P
Latidae	*Lates niloticus*	2278	13.5	160	30.2517	26.8	43000	458.421	1.15231	0.0116	2.9968	0.9763	I
Cichlidae	*Oreochromis niloticus*	2874	14	54.7	28.7166	54.8	3384.3	600.033	2.0594	0.0177	3.0447	0.9885	I
	Sarotherodon galilaeus	4562	10.6	38	21.6902	24.5	1011.3	225.045	2.05335	0.0257	2.9249	0.9562	N
	Tilapia zillii	2302	11.5	30.5	20.3957	39	632	181.779	2.0453	0.0244	2.9404	0.9396	N

N= number of samples, K= condition factor, a= intercept of regression line, b= slope of regression line, r^2 = regression coefficient, P= positive allometric , N= negative allometric ,I= isometric

Table 2. Results of ANOVA and Tukey's (HSD) tests of studied biological parameters among various seasons and locations in Lake Nasser.

	Oreochromis niloticus			*Sarotherodon galilaeus*			*Tilapia zillii*			*Lates niloticus*		
(ANOVA)												
	T.L.	**T.Wt.**	**K**	**T.L.**	**T.Wt.**	**K**	**T.L.**	**T.Wt.**	**K**	**T.L.**	**T.Wt.**	**K**
R^2	0.057	0.057	0.074	0.162	0.164	0.113	0.040	0.050	0.061	0.022	0.006	0.047
F	34.791	34.544	45.578	175.767	179.248	115.833	18.938	24.207	30.019	10.271	2.682	22.597
Pr > F	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.020**	**< 0.0001**
Tukey's HSD (LS means) - Seasons and Sites												
Autum	28.957 a	599.413 b	2.061 b	22.117 b	235.046 b	2.027 b	20.751 a	189.682 ab	2.023 b	32.083 a	623.566 a	1.128 b
Winter	29.901 a	687.274 a	2.130 a	22.313 b	250.415 a	2.137 a	20.771 a	195.584 a	2.101 a	30.737 ab	525.006 ab	1.194 a
Spring	29.667 a	653.363 ab	2.010 c	22.690 a	256.143 a	2.035 b	20.198 b	182.886 b	2.076 a	29.102 c	359.691 b	1.179 a
Summer	27.372 b	522.441 c	2.014 c	19.939 c	168.336 c	2.016 b	19.920 b	162.460 c	1.992 c	29.725 bc	383.852 b	1.125 b
Pr > F	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.020**	**0.000**
North	27.858 b	530.394 b	2.061 a	20.537 c	182.487 b	2.002 c	20.460 b	180.906 b	2.026 b	29.718 b	443.114 a	1.137 b
Middle	31.278 a	758.423 a	2.033 b	22.576 a	253.408 a	2.038 b	20.825 a	195.369 a	2.047 b	29.698 b	439.360 a	1.154 b
South	27.787 b	558.052 b	2.067 a	22.181 b	246.558 a	2.122 a	19.946 c	171.684 c	2.071 a	31.820 a	536.611 a	1.178 a
Pr > F	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.020**	**0.000**

T.L.= total length, T.Wt.= total weight, K= condition factor

This study reveals, for the first time, the geographical and seasonal variations of the studied parameters in Lake Nasser. All investigated species showed different mean TL, mean TWt and mean K in different geographical areas of the lake and through different seasons. These differences could be related to spatially different environmental and biological conditions. This variation is related to many factors such as temperature, salinity, food (quantity, quality and size), habitat and gonad development, spawning period season, sex. Fishing time, fishing gear and area may be additional causes of such variation [3, 7].

5. CONCLUSION

The results obtained from this study are contributing to the knowledge of fish populations in Lake Nasser, as a large lake system, and highlighting the spatial and temporal variation of fisheries biological parameters in such large lake system. This variation should be considered by fisheries scientists and managers in informing future studies, and preparation of fisheries management plans. This is especially necessary for the heavily exploited populations, as well as those under stock recovery plans or other management and conservation programmes.

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O1-31

霞ケ浦のワカサギ資源変動要因の抽出及び早期資源評価モデルについて

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キーワード：ワカサギ，*Hypomesus nipponensis*，水産・漁業，生物利用

抄録

茨城県水産試験場では霞ケ浦のワカサギ（*Hypomesus nipponensis*）の資源を管理し，持続的に利用できるよう，本種の資源評価及び資源変動要因の解明に取り組んでいる。本種の資源変動に影響している要因を抽出するため，これまでに蓄積された資源評価結果や餌生物，水質など 18 項目 212 種類のデータを用いて，無相関検定に供した。その結果，資源変動は「①親の資源水準」「②ふ化初期時点の餌料生物の発生量」「③気象要因」と比較的強い相関があることが判明し，湖内環境や漁業の影響だけでなく，気象要因も無視できないことが示唆された。これらの要因を説明変数にして GLM 解析を試み，早期資源評価モデルを作成した。

1. はじめに

霞ケ浦（ここでは単体呼称を「西浦」及び「北浦」，西浦と北浦を合わせた水域全体を「霞ケ浦」とする。）のワカサギ（*Hypomesus nipponensis*）は，重要な水産資源であり，全国屈指の漁獲量を誇る。漁業を安定的かつ持続的に営むためには，その資源量が再生産可能なレベルで安定させることが望ましいが，霞ケ浦の本種資源量は増減を繰り返しており，変動要因として，漁法の変化や常陸川水門の閉鎖による淡水化や富栄養化など，社会・物理・生物的要因が複合的に作用していると考えられる。一方，当場のこれまでの知見から，本種の資源量は，ふ化初期段階での生残，特に餌生物の発生量と関係が深いことが分かっている[1]。変動する本種資源に対し，漁業者は持続的利用を図るため，操業調整やふ化増殖活動などに取り組んでおり，特に若手漁業者を中心として積極的な増殖手法の改善が進められている。水産資源を管理し，持続的に利用できるよう，当場では本種の資源評価及び資源変動要因の解明を進めている。

本研究では，これまでに蓄積された資源評価結果や餌生物，水質など，霞ケ浦の各要因を取りまとめ，本種資源変動の関係性解析，および早期資源評価に向けた指標作成（モデル化）を試みた。

2. 方法

(1) 資源評価モデルの作成及び応答変数

本研究では，本種の早期資源評価を目的とし，一般化線形モデル（GLM: Generalized Liner Model）解析によって資源評価モデルを作成した。本種資源量の指標として応答変数には，資源水準値（PLI: Population Level Index）を用いた。PLI は当場が漁業協同組合とともにワカサギ漁開始直前の 6-7 月に実施している定点での曳き網調査の漁獲尾数を基に，単位面積密度法を用いて求める値であり，ワカサギ漁開始直前の資源評価に利用している[2]。PLI は尾数を基礎としているため，確率分布は Poisson 分布に従うと仮定した。link 関数は log を指定した。なお，PLI の西浦と北浦の母集団の差は Mann-Whittny の U 検定に供して判断した。

(2) 説明変数

本種資源変動には，広く様々な要素が影響を与えていると見込まれる。そこで，可能な限り網羅的に比較検討するため，本研究では当場で調査・収集している水質などの物理的要素，動物プランクトンや前年親魚資源水準などの生物的要素，霞ケ浦周辺観測所で記録・公表している気象要素など，説明変数候補（以下「要素」）は西浦，北浦ともに Table1 に示す 18 項目 212 種類のデータを用いた。説明変数は全て数値型である。

霞ケ浦では 7 月 21 日にワカサギ漁が始まり，また応答変数とする PLI の値が 6，7 月には定まるため，7 月以降の要素と比較しても変動要因の探索には意味を成さない。そこで，漁期中の 7-12 月の値については全て前年のものを用いた。また，水産関係者の操業調整や経営判断材料として資源評価情報の提供を考えたとき，実務上は漁開始の 2 カ月より前（5 月）に評価を示す必要がある。そこで本研究では，4 月時点で確定値が得られない要素はモデル作成から除外した。なお，本種の資源変動に対する遺伝的影響は，事前に霞ケ浦各水域の本種ハプロタイプ分析を実施し無視できると示唆されたため本研究では考慮していない[3]。

説明変数の選択は，応答変数と各要素を無相関検定に供して関係を判断した。欠測値は検定時に除外した。

要素が多量であり，変数全ての特性を把握することは難しいことから，相関係数は Spearman の順位相関係数を選択した。併せて，以下の条件を設定することで,多量のデータの中から簡便に説明変数を選択できるか試みた。

1）応答変数との相関係数が $\rho > |0.4|$である。

2）西浦と北浦共通で 1)を満たし，かつ符号が等しい。

3）2）を満たし，かつ検定結果が $p<0.01$ で有意である。

本研究では本種生息水域が比較的近く,また遺伝的にも同様の系群傾向であったことから，水域の違いはあるが西浦と北浦とも基本的には同じ要素に資源変動が左右されていると仮定し，2)の条件を含めた。 両湖の値を全てまとめて解析処理に供するかは，（1）の検定結果を踏まえて判断した。

Table1 Response variable and Candidate explanation variables

Name		Period	n
PLI:	Population level index	2001-'17	17
PY.PLI:	Previous year PLI	2000-'16	17
SAL:	Spowning adult stock level	2000-'16	17
AEL:	Aboundance of Egg-laying level	2000-'16	17
IFL:	Initial feed level	Mar.1st.week until Apr.1st.week in 2001-'17	17
IFL-*Syn* .:	*Synchaeta* sp. in the IFL	Mar.1st.week until Apr.1st.week in 2001-'17	17
IFL-*Pol* .:	*Polyarthra* sp. in the IFL	Mar.1st.week until Apr.1st.week in 2001-'17	17
IFL-*Bra* .:	*Branchionus* sp. in the IFL	Mar.1st.week until Apr.1st.week in 2001-'17	17
IFL-*Ker* .:	*Keratella* sp. in the IFL	Mar.1st.week until Apr.1st.week in 2001-'17	17
ZLm*1:	Zooplankton level at the offing	Jan. until Jun. in 2001-'17	17
ZLmP:	Previous year ZL	Jul. until Dec. in 2000-'16	17
RLm:	Rotifer level in the ZL at the offing	Jan. until Jun. in 2001-'17	17
RLmP:	Previous year RL	Jul. until Dec. in 2000-'16	17
NLm:	Nauplius larva level in the ZL at the offing	Jan. until Jun. in 2001-'17	17
NLmP:	Previous year NL	Jul. until Dec. in 2000-'16	17
CLm:	Small crustacea level in the ZL at the offing	Jan. until Jun. in 2001-'17	17
CLmP:	Previous year CL	Jul. until Dec. in 2000-'16	17
CLLm	Chironomidae sp. larva level	Jan. until Jun. in 2001-'17	17
CLLmP	Previous year CLL	Jul. until Dec. in 2000-'16	17
OLm	Oligochaeta sp. level	Jan. until Jun. in 2001-'17	17
OLmP	Previous year OL	Jul. until Dec. in 2000-'16	17
WTSm:	Water temprature at the shore	Jan. until Jun. in 2001-'17	17
WTSmP:	Previous year WTS	Jul. until Dec. in 2000-'16	17
WTOm:	Water temprature at the offing	Jan. until Jun. in 2001-'17	17
WTOmP:	Previous year WTO	Jul. until Dec. in 2000-'16	17
TRm:	Trancparency at the offing	Jan. until Jun. in 2001-'17	17
TRmP:	Previous year TR	Jul. until Dec. in 2000-'16	17
SSm:	Suspended solid level at the offing	Jan. until Jun. in 2002-'17	16
SSmP:	Previous year SS	Jul. until Dec. in 2002-'16	15
VSSm:	Volatile suspended solid level in the SS at the offing	Jan. until Jun. in 2002-'17	16
VSSmP:	Previous year VSS	Jul. until Dec. in 2002-'16	15
FSSm:	Fixed suspended solid level in the SS at the offing	Jan. until Jun. in 2002-'17	16
FSSmP:	Previous year FSS	Jul. until Dec. in 2002-'16	15
Tm:	Monthly average temperature	Jan. until Jun. in 2001-'17	17
TmP:	Previous year T	Jul. until Dec. in 2000-'16	17
Dm:	Sunshine duration	Jan. until Jun. in 2001-'17	17
DmP:	Previous year D	Jul. until Dec. in 2000-'16	17
Wm:	Monthly average wind speed	Jan. until Jun. in 2001-'17	17
WmP:	Previous year W	Jul. until Dec. in 2000-'16	17
Rm:	Monthly average rainfall	Jan. until Jun. in 2001-'17	17
RmP:	Previous year R	Jul. until Dec. in 2000-'16	17
SRm:	Monthly sum rainfall	Jan. until Jun. in 2001-'17	17
SRmP:	Previous year SR	Jul. until Dec. in 2000-'16	17

*1 "m" is month. Ex. ZL1, ZL12P.
*2 T,D,W,R,SR data by the Tsuchiura（Nishiura） or Hokota(Kitaura) AMeDAS observatory

（3）統計解析

検定・解析など計算処理は，全て R Ver.3.4.3（ https://cran.r-project.org, R Development Core Team）を使用した。解析用データセット作成，表の整理やグラフ描写は MS-Excel （Microsoft Corporation）を用いた。

3. 結果

（1）応答変数

西浦の PLI（NPLI: Nishiura PLI）と北浦の PLI（KPLI: Kitaura PLI）は，同じ母集団に属するとは認められなかったことから（$p<0.05$），西浦と北浦のデータはまとめず個別に解析を進めた。

（2）説明変数

西浦北浦共通でかつ有意な相関が認められる要素として，Table2 に示す 5 項目 14 種類を選択し，説明変数とした。ただし，4 月時点で得られない要素は除外するとともに，餌料要素の IFL-*Bra*. 及び IFL-*Ker*.は，IFL に内包されており，IFL と RL3 は，ともに 3 月時点のワムシ類発生量を示していることから，影響の重複を防ぐため，代表して IFL のみ説明変数とした。

Table2 Candidate explanation variables and Test for no correlation results

Factor	Correlation ρ Nishiura		Kitaura		
PY.PLI	0.801	***	0.620	**	Previous Year PLI
IFL	0.831	***	0.784	***	Initial feed level
IFL-*Bra* .	0.868	***	0.853	***	*Branchionus* sp. in the IFL
IFL-*Ker* .	0.723	**	0.647	**	*Keratella* sp. in the IFL
ZL5	0.831	***	0.618	**	Zooplankton level at the offing in May
RL2	0.660	**	0.612	**	Rotifer level in the ZL at the offing in Feb.
RL3	0.636	**	0.721	**	RL in Mar.
RL5	0.635	**	0.632	**	RL in May
D5	0.738	**	0.672	**	Sunshine Duration in May
W2	0.695	**	0.646	**	Monthly average wind speed in Feb.
W3	0.736	**	0.608	**	W in Mar.
W4	0.711	**	0.685	**	W in Apr.
W9P	0.764	***	0.683	**	Previous Year W in Sept.
W10P	0.767	***	0.748	***	Previous Year W in Oct.

Signif. codes: '***' $p<0.001$, '**' $p<0.01$, '*' $p<0.05$

（3）資源評価モデル

選択された説明変数及び GLM 解析に供した結果は Table3 に示す。NPLI を応答変数とする西浦のモデルを「Nmodel」，KPLI を応答変数とする北浦のモデルを「Kmodel」とした。なお，モデル毎に分散拡大要因を，vif 関数を用いて確認をしたところ，多重共線性は疑われなかった（vif<10）。併せて Stepwise 関数を用いて変数選択（AIC 基準変数増加法）したところ，AIC の改善は全ての説明変数を選択して止まったため，Full モデルを採用した。モデルによる PLI 推定値（N，Kmodel）と PLI（N，KPLI）とをグラフにした結果は Fig.1 に示す。

4. 考察

本種資源変動に影響を与えている要因として，本研究から「①親の資源水準（PY.PLI）」，「②ふ化初期時点の餌料生物の発生量（IFL,RL2）」，「③気象要因

Table3 Explanation variables and GLM coefficients

Factor	Estimate	Std. Error	z value	Pr(>|z|)
Nishiura Model name "Nmodel"				
Intercept	3.007000	0.016600	181.17	***
PY.PLI	-0.000003	0.000000	-69.61	***
IFL	0.001417	0.000007	214.96	***
RL2	-0.005336	0.000041	-130.05	***
W2	0.158500	0.015310	10.35	***
W3	1.065000	0.009869	107.92	***
W9P	1.958000	0.013700	142.99	***
W10P	0.269300	0.010900	24.70	***
Kitaura Model name "Kmodel"				
Factor	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	4.891000	0.058360	83.80	***
PY.PLI	0.000018	0.000001	13.18	***
IFL	0.000383	0.000006	64.79	***
RL2	-0.000271	0.000029	-9.39	***
W2	0.517500	0.028120	18.41	***
W3	0.167800	0.026280	6.39	***
W9P	1.426000	0.023220	61.43	***
W10P	-0.291900	0.035560	-8.21	***

Signif. codes: '***' p <0.001

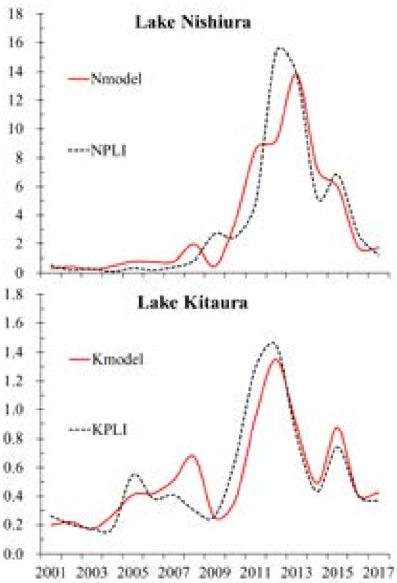

Fig.1 N,Kmodel (GLM estimate) **and PLI** (response variable)

（W2,3,9P,10P）」の 3 要因が示された。各要因を説明変数に用いた資源評価モデル（GLM）の結果も，応答変数とした PLI の変遷を十分描写できていると見込まれるものであった。4 月時点で確定値が得られるものから当モデルを作成したことで，実運用においては漁開始前に定量的な資源評価が可能となり，これまでの実漁獲に基づく 7 月時点の資源評価より早期に，操業調整や経営判断材料として活用できるものと期待できる。しかし，Nmodel と Kmodel とで係数符号が一致しない説明変数があること（PY.PLI，W10P），RL2 の係数符号が負の値を示す理由などは，本稿執筆時点では検討課題となっている。また，当モデルの検証・精度向上は，実運用と併せて毎年継続していく必要がある。これらについては今後解決すべき課題として，引き続き取り組んでいく。

各要因についてみてみると，「①親の資源水準」は，親の多寡が仔の資源に影響を与えるのは，当然妥当なものと考えられた。「②ふ化初期時点の餌料生物の発生量」も，本種の初期生残に餌料条件が関係していることなどを示した過去の当場の研究結果と合致するものであり，妥当と考えられた。一方で，「③気象要因」が本種資源変動と高い相関を示したことは興味深い結果であった。これまで，本種の資源変動を考える際には，湖内環境や漁業の影響など，湖内要因についてのみ着目しており，気象要因を加味したものは無い。しかし，本研究の結果は，気象の影響も無視できないことを示唆するものであった。気象要因が直接的又は間接的に，本種資源変動にどのような影響を与えているかは，本研究のみでは解釈できないが，引き続き解析を進めることで，新たな視点からの本種資源特性が明らかになる可能性がある。

5. 結論

（1）霞ケ浦のワカサギ資源の変動は「①親の資源水準」「②ふ化初期時点の餌料生物の発生量」「③気象要因」と比較的強い相関があることが示唆された。

（2）本研究からワカサギ資源変動を考えるうえで，湖内環境や漁業の影響だけでなく，気象要因も無視できないことが示唆された。

（3）（1）の要因を説明変数として GLM 解析を試み，早期評価資源評価モデルを作成した。

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O1-32

Paper title : "Fish Conservation Areas as a tool to strengthen freshwater community fisheries: Project experience from the Tonle Sap"

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Keywords: fish conservation area, community fisheries, common-pool resource management, sustainable conservation and livelihood benefits

ABSTRACT

As one of the world's most unique freshwater ecosystems, the Tonle Sap lake is a dynamic socio-natural system. It is also a system under threat by rapid environmental change and weak governance. Not only does this have implications for the wider Tonle Sap ecosystem, but for the livelihoods of millions of Cambodian citizens, who depend on the resources provided by this natural ecosystem. To address this, the EU-funded Non-State Actors project, implemented by the International Union for the Conservation of Nature (IUCN) and the Fisheries Action Coalition Team (FACT), sought to improve the livelihoods of fishing communities at three target sites in the Tonle Sap: Kampong Phluk, Boeung Chhmar, and Phlov Touk. In collaboration with the target communities and relevant authorities, each site implemented a fish conservation area (FCA) where fishing is prohibited year round to protect key fish refugia, benefitting both the aquatic ecosystems and productivity of community fisheries. The project applied an ecosystem-based management approach, combined with common pool resource management principles and a highly participatory approach to achieve sustainable conservation and livelihood benefits in these communities. This paper outlines key elements with the intention of providing flexible guidance for other projects working for sustainable and conservation based community fisheries management in the Tonle Sap and beyond.

1. INTRODUCTION

The freshwater fisheries of the Tonle Sap and Mekong River form the foundation of Cambodian livelihoods and the economy (Baran and Gallego 2015). The Tonle Sap lake is a critical component of fisheries productivity, both within the lake itself and throughout the Mekong, due to the dynamic flood-pulse system and the importance of spawning grounds within the lake. The biodiversity of this system is internationally recognised as a biodiversity hotpot, being designated as a UNESCO Biosphere reserve.

The ecosystems and social systems of the Tonle Sap are facing increasing and unprecedented challenges. These arise from population growth, climate change, land use change, over exploitation of resources and modifications to river flows and fish migration resulting from hydropower development on the Mekong and tributaries (Ratner et al. 2017). Fish yields and diversity within the lake and inundation zone are plateauing and declining, reducing both the biodiversity and socio-economic values of the systems (Chap, Touch, and Diepart 2016).

The EU-funded Non State Actors project, "*Community-based Small-scale Fish Conservation Area Management in the Tonle Sap lake, Cambodia*" strengthened and empowered established Community Fisheries Committees to manage and improve fish stocks through the implementation of fish conservation areas (FCAs).

2. METHOD

Please describe the method you have chosen for your research here [3]. Apply (1) left- and right-justification, (2) automatic hyphenation as well as (3) spell check to all the text you write.

The conceptual basis of the project was to empower communities to create a sustainable resource management system supported and respected by external stakeholders. The concept of the project was developed based on three fundamental principles:

- o use of an ecosystem-based approach to achieving livelihood benefits and conserving a critical natural resource through establishment and management of Fish Conservation Areas (FCAs)
- o considering common pool resources as complex socio-ecological systems in determining an intervention strategy aimed at long-term change
- o "*giving people voices"* through a participatory approach to project development, monitoring and implementation, ensuring a focus on post-project commitment by communities and other stakeholders.

Development of the intervention strategy was informed by both scientific and local knowledge of ecological systems and theories for sustainable management of natural resource management (Cox, Arnold, and Tomás 2010).

Three sites were selected: Kampong Phluk, Boeung Chhmar and Phlov Tuk. These sites were selected based on clear opportunities to have a positive social and environmental impact through the establishment of FCAs in critical dry season fish refugia; having dry season refugia that were small and close to communities to enable cost-effective management, and in order to build on existing relationships and initiatives by the project partners.

The following objectives were used as a framework for the development of intervention activities:

- o Capacity of CFs to negotiate, demarcate, and manage FCAs is strengthened.
- o Capacity of CFis to network with other CFis managing FCAs is enhanced.
- o Value of FCAs demonstrated and management costs are included in CDFs.

Specific interventions included, but were not limited to, demarcation of the resource, establishing rules and regulations for the CFis, ensuring clear user rules, ensuring equity amongst community members and empowering communities to work with local authorities to enforce the user rule. All interventions were adapted at each site to be context specific based on an independent situation analysis and ongoing adaptive response to community input collected through the ongoing engagement.

The project adopted a multi-level engagement strategy, with local communities as a core, integrating strategic and planned engagement with local and national authorities. Communities and local authorities were regularly engaged during the course of monitoring, workshops, practical works, and site visits. Establishment of relationships between communities and authorities was key.

The monitoring process was highly participatory, comprising of quarterly focus group discussions, and monthly collection of fisheries data by communities. Information collated was used to directly inform project implementation. The monitoring process doubled as a recourse mechanism for conflict resolution.

3. RESULTS

Communities strongly supported the establishment of FCA's based on the traditional understanding of the need for 'mother-fish' to be protected during the dry season. The physical demarcation of the FCAs had a positive impact on local support and participation. With the demarcation established, CFi rules and regulations established and with an on-going knowledge campaign regarding the benefits of ecosystem-based conservation, the FCAs became operational. CFi rules around FCA use were policed by local community members and local authorities in 2015. Since then, communities have reported remarkable increases in the amount of fish that have spawned and harvested for subsistence and income.

Joint enforcement activities greatly improved relations between local authorities and the CFis; local authorities became increasingly involved in law enforcement in collaboration, rather than in conflict with, the communities. The CFi committees are now confident enough to seek external assistance.

Incorporation of management costs in commune development funds as determined to be impractical on a large scale, and the need for a broader range of financing options was identified. The following major long-term financing opportunities were identified include: sourcing money from CFi membership fees, defining a buffer zone payment, receiving funding from ecotourism, and receiving funding from community savings group.

The project monitoring was an instrumental component in establishing effective and trusting relationships not only between project staff and communities, but within communities and between communities and local authorities; and also of developing the skills and confidence of local community members.

4. DISCUSSION

The use of small community managed Fish Conservation Areas to protect critical dry season fish refugia not only protected an important and highly threatened component of the lifecycle of fish species, but also generated a high value resource during the wet season, around which fisheries were substantially more productive. This motivated communities and local authorities to invest energy in the protection and management of these areas, independently of project support.

The high degree of involvement by the local community in influencing the design and ongoing implementation of the project, both through the initial consultation and the ongoing engagement, resulted in exceptional to the project by communities. This also facilitated development of relationships with authorities and with other communities. Linking scientific knowledge with traditional knowledge, enabled communities to have strong understanding of the project basis and to be highly committed.

The focus on creating conditions conducive to self-organisation of management of common pool resources ensured that the project took a long term approach to the problem, ensuring that interventions were targeted to creating the motivational, economic social and governance conditions required for ongoing management of the resource by communities following project conclusion.

5. CONCLUSION

Overall, this project has demonstrated that in the complex socio-ecological system of the Tonle Sap, ecosystem based intervention through the establishment of Fish Conservation Areas can result in the successful achievement of both ecosystem conservation objectives and livelihood development activities.

The short term project interventions can assist in the generation of the physical, economic, social and governance conditions which support local communities to effectively manage valuable natural resources to deliver both both conservation and livelihood benefits in the longer term. With proper co-management, conservation, securing sustainable financing, and due care of the ecosystem services, contested fisheries can be effectively managed by local communities resulting improvements in both fisheries and the underlying aquatic ecosystems.

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O1-33

Application of a model for carrying capacity for aquaculture to a big overexploited lake

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Keywords: cage aquaculture; trout re-stocking; assimilative capacity; water level; anthropogenic pressure.

ABSTRACT

Lake Sevan in Armenia is one of the most overexploited freshwater mountain ecosystem in the world. Over the long term, severe and diverse anthropogenic pressures have converted it from an oligotrophic ¨trout¨ lake into a mesotrophic ¨carp¨ reservoir. Water level lowering during decades, drying out of the spawning grounds of endemic trout, illegal fishing, insufficient control of organic and pollutant input from catchment, occasional introduction of alien species, current water level fluctuations has caused significant changes in the limnosystem. The current situation is characterized as a disturbed ecosystem stability as evidenced by species succession at all trophic levels, intensification of bioproduction in the lake, shift of production-destruction processes. A recent governmental program for the restoration of the endemic Sevan trout stock though a cage-based aquaculture in the lake could be an effective intervention to re-stock the lake with valuable trout species and improve its ecosystem services. However, it is needed to estimate the carrying capacity of the lake given its current vulnerability and instability. In this work, we estimated the capacity of the lake to assimilate organic input from aquaculture with the maximum precaution, taking into account its historical trends and the current state.

1. INTRODUCTION

Freshwater resources have been severely overexploited by humans and the decline in biodiversity in freshwater systems are greater than in the most affected terrestrial ecosystems (Dudgeon, 2005; Sala et al., 2000). However, freshwater provides water for human consumption and biodiversity losses may cause water quality degradation (Cardinale, 2011).

Lake Sevan, a big alpine lake situated in Armenia, is one of the examples of the most overexploited limnosystems in the world. Long term, severe and diverse anthropogenic pressures have converted the lake from an oligotrophic ¨trout¨ lake into a mesotrophic ¨carp¨ reservoir (Gabrielyan, 2010). Recently, a governmental program for the restoration of the Sevan trout stock (through a cage-based aquaculture in the lake) has been adopted. It can be an important step toward re-stocking of the lake with a valuable trout species taking into account the dramatic state of the fish community. However, given the current state of the ecosystem and diversity and intensity of anthropogenic pressures, the aquaculture and re-stocking operations should be carefully monitored by science-based methods. Aquaculture is known to release solid and dissolved phosphorus and nitrogen that change the balance of nutrients and alters their life cycle in the environment (Azevedo et al., 2011; Canadian Science Advisory Secretariat, 2015). In this work, we aimed to assess the volume of aquaculture that Lake Sevan can safely support by applying a model of carrying capacity for aquaculture.

2. METHOD

2.1 Study area

Lake Sevan consists of two morphologically different parts which differ by morphology, size and depth: deeper Small Sevan (SS) and shallower Big Sevan (BS) (Fig.1). Before the anthropogenic lowering of the water level Lake Sevan was oligotrophic, hosting three endemic fish species: polymorphic Sevan trout *Salmo ischchan* with 4 races differing in a number of biological and morphological traits, barbell *Barbus goktschaicus* and khramulia *Varicorhinus capoeta sevangi*.

Fig. 1 Lake Sevan (Armenia) and location of aquaculture facility.

In the 20s, two species of whitefish (*C. lavaretus ludoga* and *C. lavaretus maraenoides*) were being gradually acclimatized to fill the empty niche of pelagic consumer in the lake's food web. The main primary producers were macrophytes (7000 g/m^3), the share of phytoplankton was low (0.3 g/m^3) and the lake had high phosphorus concentration and nitrogen limitation in all seasons (0.32 g/m^3 and 0.003 g/m^3, correspondingly) (Ecology…, 2010).

Regular and increasing water extraction since the 30s have resulted in a reduction of the water level by around 18.5 m by 1980 (Fig. 2), surface area reduced by 12.2% and volume by about 42.2% (Gezalyan, 1983; Hovhanisyan, 1994). This caused the destruction of the macrophyte zone and of the spawning sites of two races of Sevan trout, barbell and khramulia. Fish catches significantly decreased by the 50s (Fig. 2).

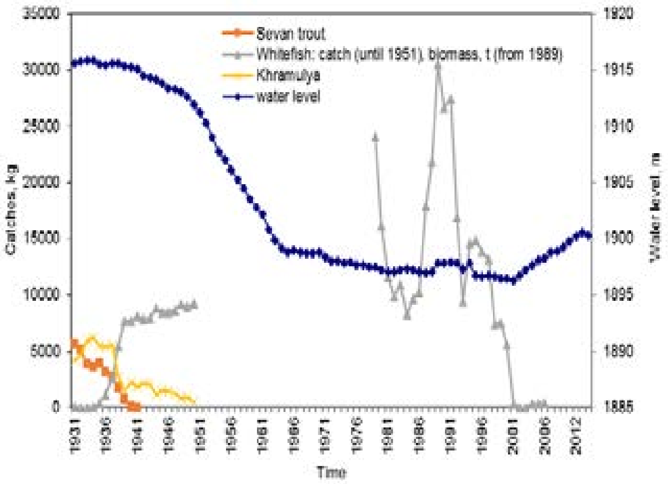

Fig. 2 Dynamics of water level drop, fish catches and whitefish biomass in Lake Sevan, Armenia.

In addition, nitrogen content has gradually increased due to the watershed development. As a result, phytoplankton has become the primary producer in the lake (Hovhanisyan, 1994). At the beginning of the 80s the status of the lake was estimated as euthropic with later shift towards mesotrophy (Ecology..., 2010). The whitefish stock reached ca. 30,000 t by the end of the 80s (Gabrielyan, 1998; Gabrielyan and Khosrovyan, 2006; Gerasimov et al., 2006). However, by 2001 it was overfished and depleted (Fig. 2). Currently, the ecosystem shows signs of instability such as unpredictable successions of phytoplankton species and main groups, shifts in production-destruction processes in the lake, changes in the composition and horizontal distribution of zooplankton, trends towards increasing phytobenthic forms (Ecology…, 2010; Lake Sevan…, 2016).

2.2 Aquaculture in the lake

In August 2016, a pilot aquaculture facility for breeding Sevan trout was installed in BS. According to December data (after 5 months) on feed distribution, around 50,013 kg of feed was applied and the biomass increment approached to 50 t. The emanation of nutrients from aquaculture during the 5 months is estimated by the company as 1.7 t of nitrogen and 0.25 t of phosphorus.

2.3 Model of the carrying capacity of a lake for aquaculture (Legovic et al., 2008)

The detailed description of the model can be found in (Legovic et al., 2008). Briefly, the model is based on the following equation:

$I_a = X_c - I_0$ (1),

where I_a - concentration of nutrients in water contributed by aquaculture, X_c - critical concentration of nutrients in phytoplankton (which leads to critical phytoplankton growth), I_0 – concentration of nutrients in water contributed by background sources (external to aquaculture). As fish cultures emanate nutrients and foster phytoplankton growth, it may reach such a growth that can effectively consume available oxygen in water, creating inappropriate conditions for oxygen-sensitive fish.

2.3 Maximum fish stock in aquaculture

The maximum fish stock in aquaculture can be estimated:

$S_{nut} = a * S_{max}$ (2),

where S_{nut} – nutrient mass emanated from aquaculture in a unit of time, a – nutrient mass from aquaculture by production of 1 t of fish, S_{max} – maximum standing stock of fish in aquaculture (t). The equivalent increase of nutrients in the lake from aquaculture can be expressed as:

$I_a = S_{nut} / (V * D)$ (3),

where V – lake's volume, D – flushing rate of the lake. For Lake Sevan, the flushing rate was estimated 0.04 /year (Hovnanisyan, 1994) and the volume 38.1 * 10^9 m^3 (Lake Sevan…, 2016).

2.4 Chlorophyll-a (Chl-a) – nutrient interrelationship

The components of the model are expressed in mass of nutrient per volume and we translated the mass of nutrient unit into phytoplankton-related Chl-a concentration to facilitate comparison with the critical Chl-a level in lake, suggested by Florida Lakewatch (2000) and Legovic et al. (2008) – 100 mkg Chl-a /l. For the Chl-a and total phosphorus (TP) relationship, the equation based on 19 Canadian lakes was used (Dillon and Rigler, 1974):

log10 (mkg Chl-a/l) = -1.134 + 1.5383 log10 (mkg TP/l) (4).

In these lakes, the ratio N:P ≥ 12, which is also characteristic for Lake Sevan. For estimation of critical Chl-a concentration in Lake Sevan, historical nutrient loads and the trends in the ecosystem state were taken into account (Hovhanisyan, A.S. Parparov, 1983; Nikoghosyan, 1979).

3. RESULTS AND DISCUSSION

The carrying capacity of Lake Sevan has been considered to be reached at 0.1 mg/l of TP and 88 mkg Chl-a /l. Using equation (4), nutrient loads were translated into Chl-a concentrations and these values were imposed into equation (1). Thus, the Chl-a concentration attributable to the additional input of nutrients from aquaculture was estimated:

88 mkg Chl-a/l. – 75 mkg Chl-a/l = 13 mkg Chl-a/l.

This level of Chl-a corresponds to TP = 0 .029 mg/l (the mass of nutrient per volume that can be contributed by aquaculture). From the data provided by the aquaculture company, the emanation of nutrients from growing 1 t of fish was estimated: 0.082 t/year of nitrogen and 0.012 t/year of phosphorus (a=0.012 t/year of phosphorus). By using equation (3) and imposing I_a (phosphorus contribution from aquaculture, mg/l), the mass of nutrient (phosphorus) emanated by the aquaculture in a unit of time (1/year) can be calculated as follows:

S_{nut} = 0.029 mkg/l * 0.04 /year * 38.1 * 10^9 m^3 = 44.196 t of phosphorus/year.

Lastly, from equation (2) the maximum fish stock in aquaculture (S_{max}) can be calculated:

S_{max} = S_{nut} / a = 44.196 / 0.012 = 3683 t.

Hence, at the present volume of water, flushing rate and the estimated level of organic input from external sources, Lake Sevan would support aquaculture with the maximum standing biomass of 3683 t without jeopardizing its water quality. This stock is considerably smaller than the wild stock existed in the past (e.g., ca. 30,000 t of whitefish at the end of the 80s) (Fig. 2). However, the present condition of the lake is different from the past, anthropogenic pressures are diversified and intensified, fish community is disturbed, water level fluctuates, the ecosystem shows signs of instability. Moreover, for the estimation of the carrying capacity of Lake Sevan, the Chl-a-TP equation for Canadian lakes was used. This is the first estimation of the carrying capacity of Lake Sevan and it can serve as a starting point for a scrutinized scientific monitoring of the effects of aquaculture activity on the health of the lake's ecosystem.

4. CONCLUSION

The acquisition of data for investigating the key impacts of fish farming is not easy and the use of proxies in the lack of appropriate data may be required. As aquaculture is an intensive pressure on the natural ecosystems, a cautious derivation of estimates of the carrying capacity is necessary. The estimates of phosphorus load from aquaculture and the maximum standing fish stock for Lake Sevan were derived taking into account historical characteristics and the current state of the limnosystem. However, proxies and alien equations were also used. Thus, the results obtained should be carefully verified by a constant monitoring program of the ecosystem health to ensure the protection of ecosystem services and provision of economic benefits.

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O1-34

Mass Balanced Model of Lake Volta Fisheries: The use of Ecopath Model

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Keywords: ecotrophic efficiency, functional groups, mass balanced model, trophic interaction

ABSTRACT

A mass-balanced model of trophic interactions among 10 key functional groups of Lake Volta was constructed using the Ecopath software to analyze the interactions and energy flows within Lake Volta. The study was based on secondary and primary data on fish catch, diet composition, phytoplankton and zooplankton biomasses, collected in 2015 and 2016. An additional information on growth parameters of major species required for balancing the Ecopath model were obtained from FishBase. The functional groups were detritus, phytoplankton, zooplankton, benthos, prey fish, *Tilapia*, *Bagrus*, *Chrysichthys*, *Alestes* and *Synodontis*. In this ecosystem, four trophic levels were identified and the energy flow mainly occurred within the first three levels. The calculated ecotrophic efficiency value of the primary producers (phytoplankton: 0.075; detritus: 0.090) showed that they were least exploited compared to the zooplankton (0.80) and benthos (0.50), the secondary producers. The main energy flows in the ecosystem were from detritus and phytoplankton at trophic level 1 with *Bagrus* species being the top predator at level of 3.30. The connectance index (0.44) and system omnivory index (0.06) indicated that the ecosystem was unstable, immature and still at a developing stage.

1. INTRODUCTION

Construction of dams for hydropower, water supply, flood control, aquaculture and agricultural irrigation is one of the major human disturbances in river ecosystems. Such constructions result in habitat changes from lotic to lentic conditions and the existing ecosystem exhibits multiple ecological stressors impacting the dynamics of fish stocks and community composition, leading to eutrophication, changes in zooplankton, aquatic vegetation, as well as invasion of species [1]. Such changes influences aquatic populations, trophic relationships and food web structures. Interaction between fish species has been a continued discussion with focus on best practice in managing fisheries resources, taking, where necessary, biological interaction into account [2]. The objective of the study was to construct a mass-balanced trophic model of Lake Volta using Ecopath model to reveal the trophic interactions and energy pathways in the food web and to analyze the ecosystem maturity using an ecosystem characterization index resulting from network analysis.

2. METHOD

The model area, Lake Volta, formed by damming River Volta for hydropower (Figure 1) has a surface area of 8,500 km^2 and a shoreline of 4,880 km with a maximum depth of 75 m and a mean depth of 14 m. The reservoir's fisheries, provide 90% of the national freshwater fish production [3]. The Ecopath software version 6.5 was used to construct the model. Parameters included for each group in order to develop a mass balanced model were biomass (*B*), production/biomass ratio (*P/B*), consumption/biomass (*Q/B*), diet composition and ecotrophic efficiency (*EE*). The model assumes an equilibrium condition such that the inputs to any functional group are equivalent to its outputs.

In the study, 10 functional groups were identified, these included 6 fish species (*Chrysichthys nigrodigitatus, Tilapia zillii, Bagrus bajad, Alestes baremoze, Syn-*

odontis ocellifer and prey fish). The fish species were selected based on catch landings in 2015 and 2016 and its economic value. In addition, the following food sources for fish were considered: zooplankton, phytoplankton, benthos and detritus groups which form the remaining 4 groups. A diet matrix was constructed based on the stomach content data of fish species sampled in the lake. Basic estimations were independently made for *EE* values of prey fish, zooplankton and benthos. Where three of the four basic input parameters (typically *B*, *P/B*, *Q/B*) of the model are provided for a group (from sampling and FishBase), Ecopath estimate the missing parameter (typically *EE*) for each group in the model.

After a preliminary run of the model, the ecosystem stability and degree of system maturity were analyzed by various system statistics and network flow indices in accordance with [4].

3. RESULTS

The output parameters (mass-balanced model) are summarized in Table 1. *Chrysichthys* and Tilapias had high biomasses of 3.94 and 3.75 t km^{-2} $year^{-1}$, respectively among fish groups. The *EE* values for the top predators (*Bagrus* and *Chrysichthys*) and primary producers (phytoplankton and detritus) were low as compared to the primary consumers (*Alestes*, Tilapia, Prey fish, zooplankton). Analysis of the trophic structure showed that the lake can be divided into 4 main trophic levels (Figure 2). Most of the functional groups were confined to trophic level II and III. The highest trophic level was 3.3 for *Bagrus* which is typical of top predators described as low-order secondary consumer. *Chrysichthys*, *Alestes*, *Synodontis*, and prey fish were between 2.5 and 3.0 belonging to high-order primary consumers. The low-order consumers with trophic levels 2 to 2.5 were tilapias, benthos and zooplankton whilst the main primary producers, phytoplankton and detritus in trophic level I.

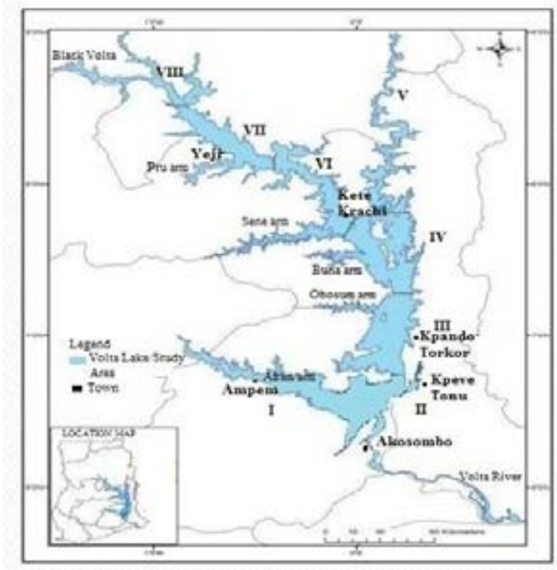

Figure 1: Map of the model area, Lake Volta.

Table 1: Basic estimated parameters generated after the mass-balance process in Lake Volta.

Group name	*TL*	*B* (t/km²)	*P/B* (/year)	*Q/B* (/year)	*EE*	*P/Q*
Bagrus	3.30	1.82	1.00	18.5	0.126	0.054
Chrysichthys	2.96	3.94	2.50	16.5	0.231	0.152
Alestes	2.80	1.18	2.60	17.4	0.786	0.144
Synodontis	2.59	0.87	1.50	20.9	0.463	0.072
Tilapias	2.03	3.75	2.00	113.0	0.762	0.018
Prey fish	2.50	5.76	4.00	20.00	0.900	0.200
Zooplankton	2.00	5.09	17.58	58.61	0.800	0.300
Benthos	2.00	17.40	10.00	33.33	0.500	0.300
Phytoplankton	1.00	41.90	200.00		0.075	
Detritus	1.00	10.00			0.090	

Note: TL = Trophic level; B = Biomass; P/B = Production biomass; Q/B = Consumption biomass; EE = Ecotrophic efficiency; P/Q = Production consumption

The system characteristics and degree of ecosystem maturity is shown in Table 2. A TPP/TR value of 8.98 was recorded indicating that the lake system is still in a developmental stage. CI and SOI values were 0.44 and 0.06 respectively which shows that the complexity of feeding activity of different trophic levels in the Lake are at a low level.

4. DISCUSSION

The *EE* values of detritus and phytoplankton suggest that their resource was not utilized adequately and their supply exceeded the demand of consumers in the food web.

This is an indication that the food availability in the lake is mainly primary producers based. The *EE* value for the top predator, *Bagrus* indicating that they experienced low predation as most of the stocks have been exploited as shown by their reduced biomass level. Detritus and phytoplankton in the food web played an important role in the ecosystem and considered dominant components in the energy structure. This is consistent with the natural feature in aquatic environments as suggested by [2].

The four trophic levels identified in the lake is typical of other reservoir ecosystems in tropical lakes such as Lakes Awassa, Kariba, Victoria and Malawi [5] suggesting that species in these lakes exhibit similar feeding patterns. Fish groups were composed of three main feeding habits: carnivorous/piscivorous, omnivorous and herbivorous and fish species (e.g. *Bagrus*, *Chrysichthys*, *Synodontis, Alestes*) have the ability to switch to different feeding behaviour depending on food availability. The biomasses of functional groups at the base of the trophic level also conformed to the rules of the biomass distribution pyramid [1; 2] and this formed the basis of energy flow. The ecosystem statistics generated by the model indicated a total sum of production of 8690.12 t/km/yr. which is similar to most lake in Africa Lakes (Kariba, Awassa). This indicates a high productivity but not fully utilized by the fish species. The lake is considered in developmental stages as their TPP/TR ratios are above 1. Values of the SOI was low suggesting that the complexity of feeding activity of different trophic levels in the lakes are at a low level [2; 4].

5. CONCLUSION

The structure of the food web comprised four trophic levels with *Bagrus* species feeding at the highest trophic level. Network analysis showed that detritus and phytoplankton groups formed an important component of the food chain and are more susceptible to predation changes by fish functional groups at higher trophic levels. The lake is described as being at an immature stage.

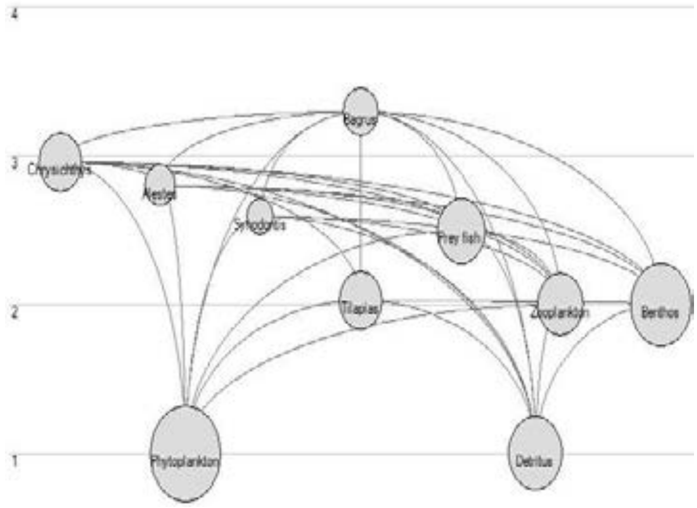

Figure 2: Flow diagram of the trophic structure and the functional groups in Lake Volta.

Table 2: System statistics estimated by the Ecopath model in Lake Volta.

Parameter	Value	Units
Sum of all consumption	1554.84	t/km^2/yr.
Sum of all production	8690.12	t/km^2/yr.
Mean trophic level of the catch	2.70	t/km^2/yr.
Calculated total net primary production	8380.00	t/km^2/yr.
Total primary production/total respiration (TPP/TRP)	8.98	
Connectance Index (CI)	0.44	
System Omnivory Index (SOI)	0.06	

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O1-35

The evaluation of the fulfilment of the obligations under the Convention on Biological Diversity in the South Caucasus

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Keywords: CBD, commitment to the Convention, freshwater biodiversity, protected area.

ABSTRACT

In the South Caucasus region, severe pressures were exerted on the water and biological resources of freshwaters that resulted in biodiversity decline or even extirpation of native populations. This work analyzed the state of the freshwater biodiversity in the selected countries of the region (Armenia, Azerbaijan, Georgia and southern Russia) before and after ratification of the Convention on Biological Diversity. A critical assessment of the level of the fulfilment of commitments to the Convention after ca. 20 years of ratification was conducted. Instruments or mechanisms that can improve the implementation of the provisions of the Convention were discussed.

1. INTRODUCTION

Biodiversity conservation and management is an important task for every nation as biodiversity resources provide means for country development, growth and self-reliance. However, about 60% of all surface waters have been lost in Asia and Europe, according to the Wetlands Extent Index. As 4/5 people live downstream of the freshwater or are served by renewable freshwater services (Millennium Ecosystem Assessment, 2005), freshwaters are threatened by pollution from watersheds and competitive water demands by urban, industrial and agricultural users. In the South Caucasus region, where biodiversity contained high endemism (Fig.1), severe pressures on freshwaters have resulted in biodiversity decline or even extirpation of native populations. Now, the region is part of Caucasian "biodiversity hotspot". Some of the countries of the region are part of WWF's "priority places" (Greater Black Sea Basin). The whole Caucasus is included in the list of Global 200 Ecoregions by WWF.

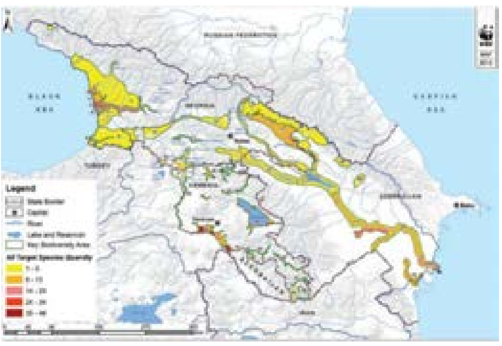

Fig. 1. Freshwater Key Biodiversity Areas with species richness in the South Caucasus (Freyhof et al., 2015).

This work aims to evaluate the level of the fulfillment of the commitments of the national governments to the provisions of the Convention on Biological Diversity (CBD) after ratification.

2. METHOD

For the assessment of the progress of the fulfillment of obligations under CBD the national reports of study countries (Armenia, Azerbaijan, Georgia and southern Russia), national strategies for biodiversity and actions plans and supplementary materials were analyzed and compared. A special focus was given to the biodiversity issues in inland freshwaters that include all permanent or temporal, deep or shallow water bodies within the territory of a country (e.g., lakes, rivers, reservoir/ponds, springs, floodplains, bogs, marshes, and swamps). A consolidated information such as the total area of protected sites or the number of animals in the Red Books was also used. The failures and successes of the national actions are compared and the causes of failures are discussed. The main threats to biodiversity addressed are: resource overuse, pollution, habitat destruction, species invasion, climate change. The assessment also covered the state of biodiversity in inland freshwaters of the South Caucasus region before and after ratification of the CBD. Often, the comparison of the national reports was complicated due to the differences in data presentation and the level of details provided. Commonly accepted taxonomy for describing the actions in a consistent way would allow a robust content management for reporting and would also facilitate learning from each other (UNDP, 2016).

3. RESULTS

Before ratification of the CBD agriculture, urban and industrial development and unsustainable natural resource management and low environmental awareness resulted in significant diverse pressures on inland freshwater ecosystems. For example, artificial lowering of the water level of Lake Sevan (Armenia) by about 20 m by 2003 has led to a disappearance or drastic decline of endemic species due to the degradation of spawning grounds (1st NRCBD Armenia, 1999). In Georgia, sturgeon numbers reduced several times by 2007 and numbers of trout declined by 30% from 1995-2005 (4th NRCBD Georgia, 2010). 29.2%

of land in the Caucasian Russia is completely transformed for cattle grazing and mineral resource extraction (1st NRCBD Russia, 1998). Construction and industrial development on Absheron Peninsula, where about 40% of population and 70% of the industrial potential of Azerbaijan is concentrated, resulted in a reduction of natural habitats, pollution of lakes by oil and domestic waste and biodiversity decline (1st NRCBD Azerbaijan, 2004). Currently, many of native fish species are red-listed: e.g., all endemic fish of Lake Sevan, river/lake trout and salmon entering rivers of Western Georgia from the Black Sea, all species of anadromous sturgeon in river waters of Georgia (4th NRCBD Georgia, 2010; 5th NRCBD Georgia, 2015).

There are 6 species occasionally introduced into formerly "trout" Lake Sevan. In 30 years the Crucian carp has become a common fish that negatively affects native fish population in Georgian inland waters (5th NRCBD Georgia, 2015). In Russia, 120/380 freshwater fish species are alien (3rd NRCBD Russia, 2007).

During 1993-2000 all the study countries ratified the CBD. Since then national biodiversity strategies and action plans were submitted to the CBD Secretariat. These documents allowed environmental issues including biodiversity conservation to receive importance at the level of political decisions. All the study countries are involved in the Emerald Network. Several RAMSAR sites were designated: 3 in Armenia, 2 in Azerbaijan and Georgia, and 35 in Russia (www.ramsar.org). Cooperation for transboundary ecosystem conservation or restoration within the South Caucasus has started. The establishment of the Caucasus Nature Fund in 2008 provided funding opportunities for effective regional cooperation for the protection of the Caucasus Ecoregion. As a result, biodiversity inventories have been implemented in key areas, protected areas have been defined and monitoring systems have been elaborated. By 2014, protected areas system covered 13% of total land of Armenia and 9 % of Georgia. In Azerbaijan, terrestrial protected areas covered 12% and marine 6% of the country's land by 2008 (5th NRCBD Armenia, 2014; 5th NRCBD Georgia, 2015; UNDP, 2011). In Russia, biodiversity and spatial conservation management operations were intensively decentralized, facilitating creation of new protected areas. There are 740 protected areas in Russia.

Substantial progress is made toward meeting Aichi targets by 2020. In particular, for Aichi target 5 (to half the rate of loss of habitats and reduce degradation and fragmentation) Armenia has implemented measures on the increasing of the water level of Lake Sevan. The benefits are already seen: improved water quality and living conditions of fish, benthic and planktonic communities. Bird fauna around the lake has also benefitted from newly formed shallow areas. Russia eliminated the number of species in the Red List due to improvement of their conservation status. However, the Georgian and Azerbaijan lists were expanded by the inclusion of endangered and critically endangered plant species. Pollution issues are also handled although from different aspects. For instance, Russia will achieve this by creation of economic motivation for a gradual diminution of emissions. Armenia has responded by the implementation of a regular chemical monitoring of key water bodies (39 risky rivers, 5 risky reservoirs and 2 lakes) and rehabilitation of sewage system. Georgia has developed actions for the mitigation of inland water pollution. Azerbaijan reported 25-50% progress in pollution reduction (from the 5th national reports).

4. DISCUSSION

The ratification of the CBD and integration of biodiversity vales into national programs were dictated by the obvious diminution of ecosystem services, globalization of economies and increased international cooperation. Nevertheless, despite this, insufficient and inefficient control over the use of bioresources is common. In Armenia, only 40% of waste water is treated and only mechanically (5th NRCBD Armenia, 2014). Adequate human resources and efficient mechanisms of control are not in place (5th NRCBD Russia, 2014). Although protected areas exist, they are not connected through ecological corridors regardless of the key importance of the areas (5th NRCBD Georgia, 2015). The lack of regular monitoring in Georgia and Azerbaijan prevents information update on the dynamics of populations or systematic reporting on the progress towards achieving the national targets (5th NRCBD Azerbaijan, 2014; 5th NRCBD Georgia, 2015).

Conservation status of the most fish species remains unclear. Fish surveys for assessing the health of ichthyofauna are not conducted since 1991, except for the Black Sea salmon and sturgeon. Many fish species are endemic species and have economic value, but data on their populations are missing and specific conservation needs are not identified. Inventory and ecological assessments of freshwater ecosystems have not been done and many are not protected. Meantime, unregulated anthropogenic activity modifying water levels or habitat integrity is carried out (4th NRCBD Georgia, 2010). Biodiversity conservation is implemented mainly in specially protected nature areas of Armenia (5th NRCBD Armenia, 2014).

Conservation success highly depends on anti-poaching. However, fishery bans and fish re-stocking activities in Armenia have been carried out for a long time but were inefficient. In Russia, strengthening of anti-poaching efforts and the expansion of state surveillance are needed (5th NRCBD Russia, 2014).

Still, the integration of biodiversity conservation into socio-economic development is not sufficient. The importance of biodiversity and ecosystem services is not adequately appreciated by decision makers and their value and benefits are not assessed (Protocol of the session of the Government of the Republic of Armenia, 2015). Ecosystem services concept is not integrated into conservation practice and research funding is not adequate to ensure comprehensive science-based evaluation of the impacts (5th NRCBD Russia, 2014).

Aichi targets are not adequately addressed. In Armenia with relevance to target 7 (sustainable management of areas under aquaculture) the use of natural resources is not managed. For example, aquaculture in Armenia is solely demand driven and resource-exhaustive (3 R STRATEGY, 2011). For target 8 (reduction of pollution and nutrients to non-detrimental level), measures are constrained to the monitoring of chemical parameters in Armenia. Municipal waste water remains the main source of pollution in Georgia. Also, 18 critical freshwater habitats only 25.81% are included in the protected category (5th NRCBD Georgia, 2015). The impacts of species invasion (target 9) are declared indirect in Armenia (5th NRCBD Armenia, 2014). In Russia, the establishment of a centralized system of monitoring of biotic invasions and control of aquatic organisms has failed. Azerbaijan fulfilled this target by 25-50%. Climate change impacts on the stability of ecosystems have not been sufficiently assessed. In response to Aichi target 15 (enhancing the contribution of biodiversity to carbon stocking thereby addressing climate change mitigation and adaptation) Armenia declared these impacts as indirect and not visible. Azerbaijan reported 50-75% progress. In Georgia, the main focus of climate change mitigation measures is put on the management of grasslands. Meanwhile, national goals for this target are not set in Russia (5th NRCBD Russia, 2014).

Transparency problems such as insufficient access to information, low public participation, problems in effective implementation of the State control are issues to be solved in the South Caucasus countries to satisfactory fulfill the commitments under the CBD.

5. CONCLUSION

Obvious improvements have been achieved in the biodiversity conservation and protection and conditions for the rehabilitation of disturbed populations in key freshwaters are being created. However, socio-economic situation in all the countries (poverty, poor political will, lack of sufficient control instruments) impede prioritization of biodiversity values in the national economic development programs. Participation in international treaties related to biodiversity evidently helps address national, regional and global environmental issues.

Nevertheless, executive agencies in each country should increase the efficiency and transparency of their work on biodiversity conservation and protection. Undoubtedly, the improvement of organizational and institutional capacities will require governance reforms to better regulate surveillance, monitoring, anti-poaching efforts to avoid further impoverishment or loss of biodiversity. Ecological state on inland waters is determined by the condition of their watersheds. Until the socio-economic improvement is achieved and adequate political decisions and human resources are available, realistic biodiversity conservation and protection cannot be achieved.

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O1-36

環境保全型農業がもたらす水田の生物多様性の保全効果の検証

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キーワード：生物多様性評価，環境保全型農業

抄録

農地の拡大・集約化にともなう生物多様性の減少を食い止めるため、近年では世界中で環境保全型農業の生物多様性保全効果の検証が進められている。しかし水稲の主要生産地であるアジアでの検証例は未だに少なく、環境保全型農業の有効性を議論するための知見が不足している。そこで今回は、水田の有機栽培や特別栽培などの環境保全型農業が、日本の代表的な生物相（植物、節足動物、カエル、魚、鳥類など）にもたらす保全効果について、本研究所のこれまでの取り組みを中心に紹介する。特に、2013–2017年度にかけて実施された農林水産省受託プロジェクトの研究成果など、最新の知見を紹介したい。またこれらの成果にもとづき、環境保全型農業の保全効果を今後より高めるために考えるべきことについても議論したい。

1. はじめに

農業の拡大・集約化は世界中で生物多様性における最大の脅威の一つとなっている。この減少を食い止めるため、欧州を中心に環境保全型農業が導入され、その効果が検証されてきた[1]。その一方、日本を含むアジアの主要作物である水稲については、環境保全型農業の導入および効果検証が遅れている。そこで本研究は、これまでの本研究所の取り組みを中心に、日本の環境保全型農業が水田の代表的な生物相（植物、節足動物、カエル、魚、鳥類など）にもたらす保全効果について議論する。

2. 農業に有用な生物多様性の指標及び評価手法の開発(2008-2011)

このプロジェクトは、水田の生物相を全国規模で調査した初めての取り組みといえるだろう。水田の有機・特別栽培の取り組みの効果を評価するうえで、クモ類、トンボ類、水生昆虫類およびカエル類が指標となりうることを明らかにした。さらに、これらの生物の簡便な調査法や、個体数にもとづく水田のスコア（点数）化によって、農業者への普及を促した[2]。これらの成果はマニュアルとして、無償で研究所HPからダウンロード可能である。また農業害虫の有用な天敵であるアシナガグモ属については、周囲の森林の豊かさや気候条件によって、減農薬の効果が左右されることも明らかになった（図1）[3]。

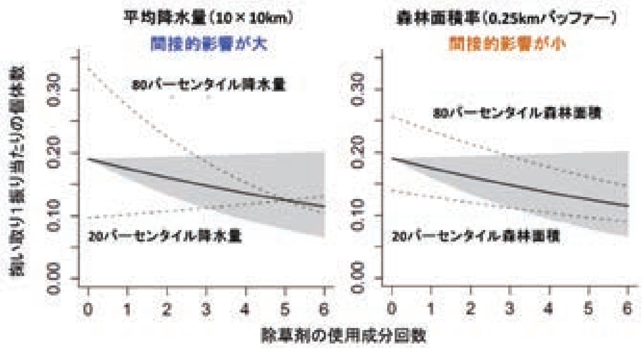

図1 除草剤の使用成分回数がアシナガグモ属の個体数に与える影響は降水量・森林面積にともない変化する[4]。（左）降水量が多い地域ほど減農薬の効果が高い。（右）森林面積が多い地域ほど個体数が多い。

3. 生物多様性を活用した安定的農業生産技術の開発(2013-2017)

本プロジェクトは、先のプロジェクトよりもさらに数多くの生物群（植物、クモ類、トンボ類、水生コウチュウ類、カエル類、ドジョウ、鳥類）を対象とし、環境保全型農業（有機栽培・特別栽培）の取り組みの効果を全国規模で評価した。700以上の圃場を調査し、一般化線形混合モデルで解析した。

その結果、特別栽培は植物種数およびアシナガグモ属・アカネ属の個体数を増やす効果があることがわかった。また有機栽培は、これらの種群に加えて、ダルマガエルおよびドジョウの数も増やしていた。また個々の農薬や畦管理など個々の農法の影響も調

べた結果、生物群によって異なる農法から影響を受けていることがわかった。具体的には、農薬（植物、アシナガグモ属、アカネ属）、畦管理（カエル類）、水管理（ドジョウ）といった差がみられた。これらの成果はマニュアルとして公開する予定であるとともに、現在学術論文としても投稿中である。

4. 結論

日本の水田においても、環境保全型農業、とりわけ有機栽培は様々な生物群の種数・個体数を増やす高いポテンシャルを持っていることが明らかになってきた。しかし、有機栽培は一般的に収量の低下を伴うことから、大規模に普及させることは現実的ではない。一方、特別栽培は収量の低下度合いも少なく、より広範囲に普及可能なオプションになるだろう。ただし、増加する生物群が有機栽培よりも限定されることは知っておくべきである。ただしこれも、実際にどういった農法を実施するのか、によって大きく効果は変わる。

もう一つの重要な知見として、生物の種数・個体数には農薬・畦・水管理などの圃場内の条件だけなく、森林・気候などの周囲の条件も重要であることが分かってきた。これは、同じ取り組みでも地域によって取り組みの効果が異なることを示唆する。今後、各地域で環境保全型農業の効果が高いと見込まれる生物群を事前に特定したがうえで、その種の保全に有効な農法を実施することで、最大の保全効果を発揮できるだろう。これにより、害虫抑制などの生態系サービスの最大化も期待される。

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O1-37

Restoration of a metapopulation of *Aster kantoensis* Kitamura, an endangered floodplain plant endemic to Japan

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Keywords: endangered species, nature restoration, gravel, extinction, collaboration

ABSTRACT

Aster kantoensis Kitamura is an endangered plant species, endemic to the gravelly floodplains of a few eastern central Japanese rivers, and a flagship species for gravelly floodplains. Reduction in habitat could accelerate the decline of *A. kantoensis* metapopulations. To avoid extinction, seven restoration programs were initiated along the Tama River in the 1990s and 2000s. However, only two programs, including our experiment, currently continue. We examined the effect of human-aided seed dispersal in 2002 on an artificial gravelly floodplain in the Nagata Area. After 15 years, the metapopulation was still thriving, as flooding created new safe sites for seed germination and seedling establishment. Furthermore, small populations of *A. kantoensis* were found to be thriving in the lower course of the Tama River. The institutional administration added 90 000 m^3 of gravel to the upper course of the Nagata Area. A large flood occurred in 2007 after which the population of *A. kantoensis* declined, before recovering in 2008. The dynamic aspects of this metapopulation may have recovered. Since maintenance of the first artificial floodplain was difficult, other plants have been growing densely in the area, which has reduced in 1/8 reduction in the original area. This experiment was conducted in collaboration with institutional administrators, citizens, and scientists. The restoration success of *A. kantoensis* in the artificial gravelly floodplain has led to similar restoration efforts near other rivers in Japan.

1. INTRODUCTION

Aster kantoensis Kitamura is an endangered plant in Japan. It has a narrow distribution range on the gravel floodplains of three rivers (Fig. 1), although its population was sometimes large before the 1990s. Following a rapid population decline, many citizen scientists tried to cultivate *A. kantoensis* to reintroduce it to the floodplains. While it was easy to cultivate the plant in a farm, it was difficult to reintroduce it to the floodplains. Professional scientists studied the ecology of *A. kantoensis*, including its distribution[2], demography[5], photosynthesis[4], seed dispersal[2], seed germination[6], and genetics[1,3]; *A. kantoensis* life history is easy to study. As the population of *A. kantoensis* declined, restoration studies were conducted[7, 8].

Fig. 1 The distribution of *A. kantoensis* populations

Reduction in habitat might accelerate the decline of this *A. kantoensis* metapopulation. To avoid extinction of this species from the Tama River, seven restoration programs were initiated in the 1990s and 2000s (Fig. 2). However,

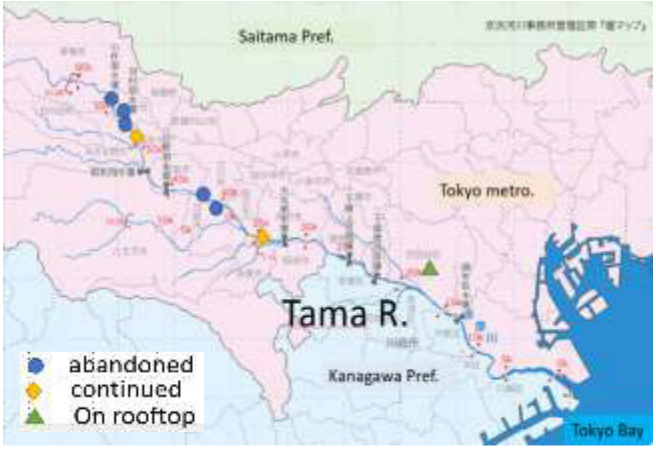

Fig. 2 Restoration activities for *A. kantoensis* in the Tama River

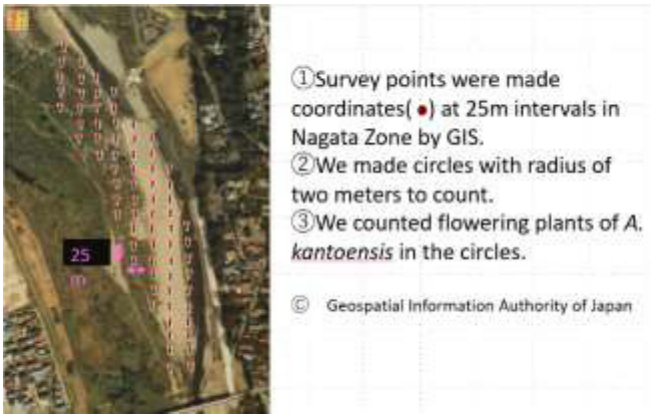

Fig. 3 Methods to count the number of *A. kantoensis* in the Nagata area.

only two programs, including the present experiment, have continued to date.

Our objective is to restore the local metapopulation dynamics of *A. kantoensis*.

2. METHODS

We surveyed the population and distribution of *A. kantoensis* on an artificial gravelly floodplain (Fig. 3) that was created in 2002 in the Nagata Area, Japan to conserve *A. kantoensis*, and assessed the ability of the floodplain to support a new metapopulation.

We examined the effects of human-aided seed dispersal.

3. RESULTS

Fifteen years after the creation of the artificial floodplain, the metapopulation of *A. kantoensis* was still thriving as flooding created new safe sites for seed germination and seedling establishment. However, maintenance of the artificial gravelly floodplain was difficult and other plants have been growing densely in the area, which has caused a one-eighth reduction in the management area.

The population of *A. kantoensis* had increased to 50,000 by 2010 but declined to 9,500 in 2017 (Fig. 4). A large flood occurred in 2007 and the population of *A. kantoensis* declined, followed by a recovery in numbers in 2008 (Fig. 5). Furthermore, small populations of *A. kantoensis* thrived in the lower reach of the Tama River (Fig. 6).

4. DISCUSSION

The dynamics of the metapopulation of *A. kantoensis* may

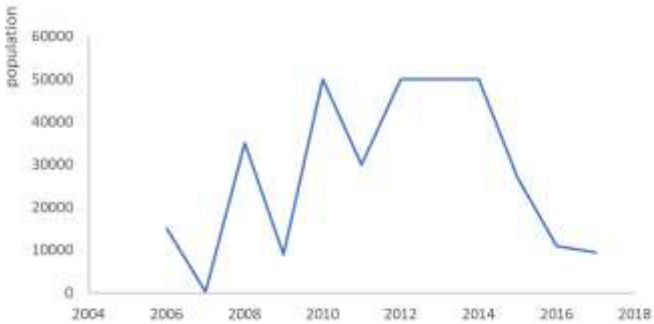

Fig. 4 The population of flowering plants of *A. kantoensis* in the Nagata area.

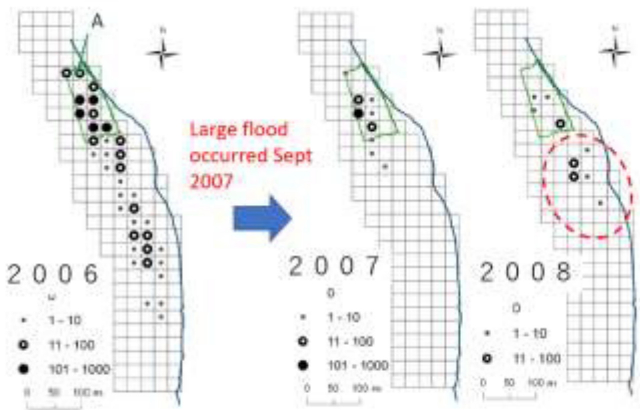

Fig. 5 Distribution and number of flowering plants of *A. kantoensis* in the Nagata Area 2006 to 2008.

Fig. 6 The distribution of flowering plants (●) of *A. kantoensis* below the Nagata Area.

have been restored. Maintenance of a gravelly floodplain is important for retaining the seed source of *A. kantoensis*. The Keihin River Office, one of the river authorities of the Ministry of Land, Infrastructure, Transport and Tourism added about 90 000 m^3 of gravel to the upper course of the Nagata Area, which created a new gravel floodplain in the Nagata Area. As many seeds were produced after 2010, small populations might thrive in the lower reach.

Our objective has been achieved to some extent. However, after 2013, large levee construction and levelling of the gravel floodplain destroyed small populations of *A. kantoensis* and restoration actions must be continued.

5. CONCLUSION

This experiment was conducted in collaboration with institutional administrators, citizens, and scientists. The coordinator of the collaboration is a scientist from Meiji University. The coordinator develops the plans and objectives for the year and maintains contact with the river manager and leader of the citizens. The collaboration and coordinated system have contributed to successful restoration efforts.

Successful restoration of the *A. kantoensis* population on an artificial gravelly floodplain has led to similar restoration efforts near other rivers in Japan. However, there are few floodplain endemic plants thriving in the restored flood plains. Therefore, inspection of all possible effects and identification of more efficient means of implementing the existing restoration methods is necessary.

Fig. 7 Collaboration in Aster Project

(from the leaflet of Aster Project 2018)

Citizen is the citizen group involved in the conservation and restoration of *A. kantoensis* in the Tama River. The local government is Fussa City. The river manager is the Keihin River Office. Scientists were from Meiji University and the coordinator is a scientist from Meiji University.

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O1-38

A proposed application of tributaries for aquatic plant restoration on the lake basin scale

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Keywords: Aquatic plant, restoration, basin scale, tributaries into lake

ABSTRACT

In this study, we surveyed the potential of the tributaries of Lake Kasumigaura to serve as aquatic-vegetation-restoration areas. Our results show that although red-listed species of aquatic vegetation grow in these tributaries, and invasive species grow in some of these tributaries as well. Therefore, careful selection of tributaries will be important for planning the meta-population network.

1. INTRODUCTION

Lake Kasumigaura was dammed to serve as a water resource, and the water levels there have increased. The lake is used as both a daily human water resource and an industrial water resource and provides important ecosystem services. However, the increase in the water levels has influenced the growth conditions of the aquatic plants in the lake.

Submerged aquatic plants and floating leaf plants have been particularly influenced by the increase in the water level. The increase in the water level decreases the water light conditions, which influence the growth of submerged plants that depending on the water light conditions. In addition, the increase in the wave conditions directly influences the floating leaf plants and emergent plants via increased disturbances.

To study the response to these aquatic plants to the changes in their growth conditions and to restore the growth conditions of the aquatic plants, a trial restoration controlling the water level of Lake Kasumigaura has been successfully conducted. However, the yearling control is difficult due to water resource management.

To improve this difficult condition, we need to enlarge the field of view, to recognize the area not only inside the lake but also in the tributaries as restoration fields. For example, the tranquil areas spread around the river mouths of tributaries are areas preferred by aquatic plants. However, the trial study did not focus on the aquatic plant conditions in tributaries. With this background, this paper aims to report on the aquatic plant growth conditions and discuss the potential of tributaries as aquatic plant growth preference areas and the potential of the ecological network of Lake Kasumigaura.

2. MATERIALS AND METHODS

2.1 STUDY AREA

This study was conducted in Lake Kasumigaura. Lake Kasumigaura is the second largest lake in Japan. The area of Lake Kasumigaura is approximately 220 km2, and the average water depth is approximately 4 m. Lake Kasumigaura is comprised of Lake Nishiura, Lake Kitaura, and Lake Sotonasakaura. This study primarily focused on Lake Nishiura. A total of 22 tributaries flow into Lake Nishiura. Around the river mouths of these tributaries are agriculture fields such as paddy field areas that form stable water. The area is thought to be a preference area for aquatic vegetation. This study primarily investigated the growth conditions around the river mouth areas and the paddy fields.

2.2 FIELD SURVEY AND DATA ANALYSIS

Two field surveys were conducted in FY 2015 and FY 2016. The field surveys were conducted for 15 tributaries (Fig. 1).

From the river mouths along the tributaries to approximately 4 km upstream, the growth conditions of

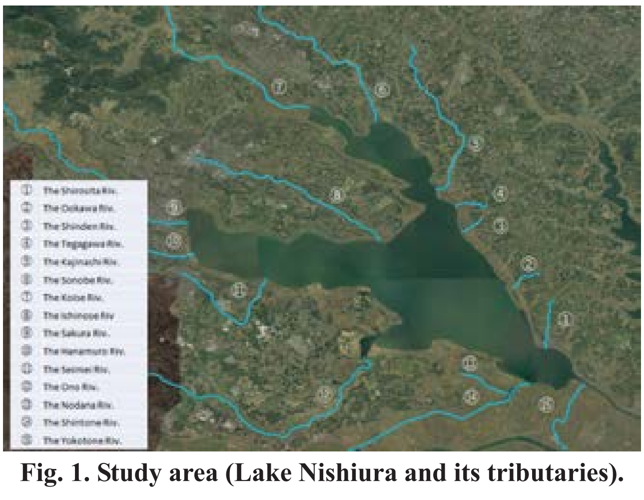

Fig. 1. Study area (Lake Nishiura and its tributaries).

the aquatic plants (emergent plants, floating leaf plants, submerged plants, and free-floating plants) were recorded and summarized into Geographic Information Systems. The summarized data for the two FY were classified into three groups comprised of red-listed species, invasive species defined by the Ministry of the Environment, and “standard species” not belonging to either of the other two species groups.

3. RESULTS

Figure 2 indicates the total area of the red-listed species and invasive species for the two years. Even though most tributaries showed a coexistence of red-listed species and invasive species, the percentages differed between individual rivers. In the Shintone, Hanamuro, Koise, Tegagawa, and Okawa rivers, there were extremely small levels of invasive species growth.

Figure 3 indicates the correlation between the area of the standard species, the area of invasive species, and the area of the red-listed species. Corresponding to increasing areas of standard species, the area of red -listed species decreased, and the area of invasive species increased. At approximately 10,000 m^2, the curves of the areas of the red-list species and the invasive species crossed.

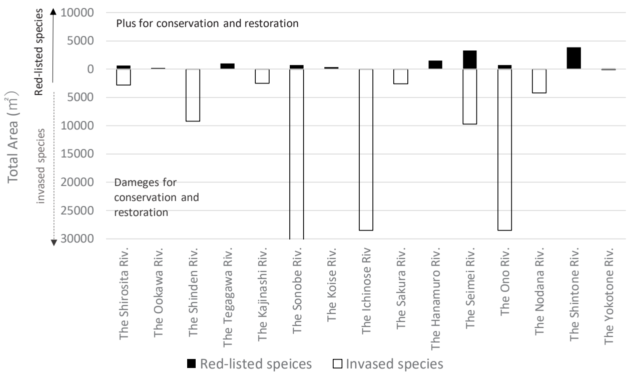

Fig. 2

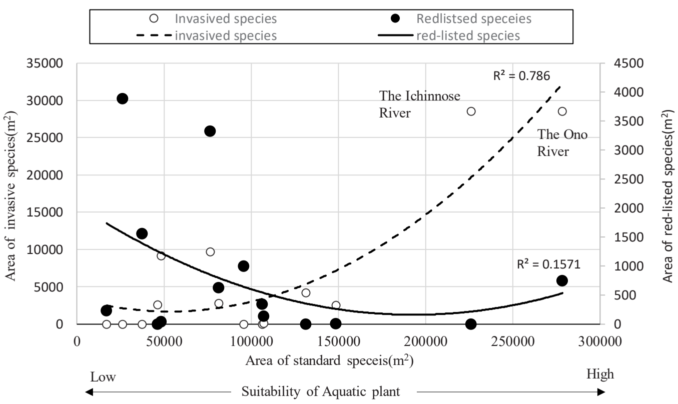

Fig. 3

4. DISCUSSION

Figs. 2 and 3 indicate the importance of tributaries for conservation and restoration of aquatic vegetation; in particular, Fig. 2 shows that many red-listed species grow there. Thus, it is important to incorporate these tributaries into conservation and restoration of red-listed species in terms of increasing metapopulations. In addition, the existing study indicates that channels foot of levees are important areas of aquatic-vegetation growth[1]. If we can form a metapopulation network between lakes, dike-foot water ways, and tributaries, it would create a vast network in basin scales.

However, we must carefully select tributaries in view of controlling invasive species (Fig. 2). We must prioritize tributaries where only standard and red-listed species grow. It is also important to consider the characteristics of basins wherein only red-listed species grow. Fig. 3 indicates interesting considerations for the conservation and restoration of aquatic plants. The results of Fig. 3 indicated that the exceeded suitable condition wherein standard species’ growth or stable water areas are not good for the control of invasive species and restoration of red-listed species. Rivers in which standard species occupy an area of more than 200,000 m2 such as the Onogawa and Ichinose Rivers are very suitable for aquatic-vegetation growth in their mouth areas due to a very low riverbed slope. These stable conditions enhanced the growth of standard and red-listed species, on the other hand they permitted growth of invasive species. This hypothesis suggested important direction for the conservation and restoration plan of aquatic vegetation in the basin scale, though quantitative analysis will be needed in the future works.

5. CONCLUSIONS

This study revealed the potential of tributaries of Lake Kasumigaura to serve as aquatic-vegetation-restoration areas. Our main results were as follows: red-listed and invasive species of aquatic vegetation were both found to grow in tributaries. The tributaries highly suitable for standard species were also appropriate for red-listed species; however, invasive species also tended to inhabit there. Although tributaries have the potential to serve as effective conservation and restoration areas for aquatic vegetation, careful selection of tributaries will be important for the control of the metapopulation network.

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O1-39

Mainstreaming Biodiversity into Inland Fisheries and Aquaculture (with special focus on wetlands) – scopes and challenges

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Keywords : Biological resource use, Fisheries, Ecosystem services, Ecosystem management

ABSTRACT

Mainstreaming of biodiversity is basically the process of integrating biodiversity concerns into policies and practices that impact and work on biodiversity. The Convention of Biological Diversity (CBD) advocated for this in its Article 6(b), which has also been reflected in Biological Diversity Act, 2002 of India. India has developed 12 national biodiversity targets, as per the directives from CBD, which are to be met by 2020, in line with National Biodiversity Strategy and Action Plan. The targets (5, 6 & 8) related to inland fisheries emphasize to achieve sustainable fisheries, conservation of ecologically representative areas and to safeguard areas of ecosystem importance (*e. g*., inland water bodies, wetlands and aquatic fauna). India is endowed with vast inland resources which includes rivers, lakes, reservoirs, estuaries, wetlands lagoons, etc., that are providing habitats for some thousands of aquatic animal and plant biodiversity, along with various ecosystem services. These resources play a significant role in providing food, nutrition, and livelihood security of millions of people across the country, through different forms of inland fisheries and aquaculture. The present paper analyses the scopes and challenges for mainstreaming biodiversity concerns into inland fisheries and aquaculture (including wetlands) in Indian context and throws light on the present scenario and gives some recommendation in achieving this objective towards compliance to National Biodiversity Targets, Aichi Targets and Sustainable Development Goals.

INTRODUCTION

The inland fisheries and aquaculture plays a significant role in providing food, nutrition, and livelihood security for millions of people around the globe. Fish is a highly nutritious food item as it provides protein, essential micro nutrients, vitamins, minerals and polyunsaturated omega-3 fatty acids. The inland water resources (*viz.* lakes, rivers, canals, reservoirs, ponds, streams, groundwater, springs, cave waters, floodplains, estuaries, coastal lagoons, mangrove creeks, marshes, backwaters and swamps) provide habitat for fishes, amphibians, water birds, semi-aquatic animals, plants apart from supporting highly endemic and endangered taxa (CBD, 2017). These dynamic ecosystems provide an array of ecosystem services such as climate regulation, flood mitigation, nutrient recycling, water purification, waste treatment, etc.

INDIA'S INLAND WATER RESOURCES AND BIODIVERSITY

India's inland water bodies comprise of 29,000 km of rivers and canals, 0. 202 million hectare (ha) of floodplain wetlands, 0,3 million ha of estuaries, 40,000 ha of estuarine wetlands, 0.19 million ha of lagoons, 0.356 million ha of mangroves, 2.43 million ha of (potential) freshwater ponds, 1.14 million ha of (potential) brackish water ponds, 3.15 million ha of reservoirs (Draft NIFAP, 2017), 1.667 million ha of large and medium reservoirs and 1.485 million ha of small reservoirs (Ayyappan and Sugunan, 2009). India has a rich aquatic genetic resources, which includes 9.456 species representing approximately 9.7% of the total number of animal species (*i.e*.. 97,708 species). The Indian fish diversity comprises of 113 brackish water, 936 freshwater and 462 exotic finfishes.

Wetlands in India is bestowed with a rich diversity, ranging from high altitude lakes of the Himalayas, floodplains and marshes of the Gangetic - Brahmaputra alluvial plains, saline flats of Green Indian desert to extensive mangroves marshes bordering the country's East and West coastline. India has total of 7,57,060 wetlands covering a total area of 15.26 million ha, roughly equal to 4.6% of its land area. Of this, inland wetlands constitute 69.22% (10.56 m.ha) (SAC, 2011). Inland wetlands are also reservoirs of biodiversity, it supports unicellular algae, bryophytes, mosses and ferns to woody angiosperms. The wetland ecosystem is contributing widely for the societal development and well-being. Many cities (like New Delhi, Kolkata, Bhopal, etc.) depend on wetlands for their water supplies. The wetland water is used for agriculture, horticulture, pisciculture and other livelihood activities of the local people. Dal Lake (Kashmir), Khajjar Lake (H.P), Nainital Lake (Uttarakhand) and Kodaikanal (Tamil Nadu) are important places for tourism. India's inland aquaculture production basically consists of freshwater and brackish water production along with small contribution from cold water.

CONCERNS

The fresh water habitats are under increasing threats and pressures due to the discharge of industrial wastes, sewage and agricultural runoff with chemical wastes and excessive nutrients. The other concerns includes: over exploitation, flow modification, degradation of habitat, eutrophication, siltation, macrophyte infestation, swampification, spread of, lack of river flows due to fragmentation of cascade by dams/ barrages and Invasive Alien Species. Many of the inland wetlands have been invaded by exotic species which have acquired nuisance proportions threatening the very existence of many of the habitats, and have considerably affect the native species. Some of the plant invasive recoded are water hyacinth, *Salvinia molesta*, *Ipomoea carnea spp* and *Alternanthera philoxeroides* (MoEFCC and GIZ, 2014). It was also reported that the Ornamental alien fish species hybridize with indigenous species in the wild and diluting the wild genetic stock leading to long term introgression of gene pools (Pimentel, D *et al*, 2001).

Majority of the estuarine ecosystems have become hyper-saline due to less ingress of freshwater from rivers, while few have lost their estuarine character due to excess ingress of freshwater. Estuaries are subjected to oil spill, which leads to the loss of economically important fish species such as hilsa, mullets, sea bass, pearl spot, prawns, etc. The mangrove vegetation spread over the estuarine areas are undergoing degradation and shrinkage due to increased biotic pressure and growing demand for timber, fuel wood and fodder. The degradation of reservoirs is increasing due to pollution from thermal power plants, siltation and poor environmental management of the varied catchment areas. The other biodiversity related concerns includes over-stocking, illegal introduction of exotic species, use of shore seines, use of small-sized mosquito nets, irrational lease policies, juveniles fishing and mining of ornamental fishes for export. Similarly, the wetland habitat is lost at an alarming rate due to changing land use pattern and reclamation for urban development. As per various estimates, nearly 30% of the natural inland wetlands in the country have been lost due to fragmentation of hydrological regimes, catchment degradation, pollution and spread alien species.

MAINSTREAMING BIODIVERSITY

Mainstreaming is an important policy tool which helps in strengthening the linkages between biodiversity and other sectors. The Convention on Biological Diversity has urged parties to develop national and regional biodiversity targets, using the Strategic plan and its global Aichi targets. Accordingly, India has developed 12 national biodiversity targets and these national targets need to be achieved by 2020. The targets (5, 6 & 8) related to inland fisheries emphasise achieving sustainable fisheries, conservation of ecologically representative areas and to safeguard areas of ecosystem importance (eg. Inland water bodies, wetlands and aquatic fauna). Some of the approaches suggested for mainstreaming biodiversity into inland fisheries includes: a) ecosystem approach; b) access & user rights; c) marketing incentive & export; d) policy & institutional strengthening.

INTERNATIONAL AND NATIONAL INITIATIVES

India is a signatory to several international conventions towards conserving biodiversity in the inland related biodiversity resources *viz* Convention on Biological Diversity (CBD)1992, the Convention on Conservation of Migratory Species (CMS), 1982, Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1975 and Ramsar Convention on wetlands, 1982. At present there are 26 Ramsar sites have been identified in India. To implement the objectives of the convention, a regulatory mechanism was put in place through Wetlands (Conservation and Management) Rule, 2017. The rule stipulate prohibition and regulation of range of developmental activities within a wetland notified areas. The Ministry of Urban Development has issued an advisory on conservation and restoration of water bodies in urban areas. A river conservation programme was initiated with the launch of Ganga Action Plan (GAP) in 1985. The GAP was expanded to cover other rivers under National River Conservation Plan (NRCP) in the year 1995. The objective of NRCP is to improve the water quality of rivers, which are major water sources in the country through implementation of pollution abatement works in various towns along identified polluted stretches of rivers. The National Plan for Conservation of Aquatic Ecosystems (NPCA) is implemented for a holistic conservation and restoration of lakes and wetlands for achieving the desire water quality enhancement, beside improvement in biodiversity and ecosystem through an integrated and multidisciplinary approach and a common regulatory frame work. In 2001, National Lake Conservation Plan (NLCP) was introduced to address pollution issues in urban and semi-urban environment through interception, diversion and/or treatment of pollution load entering the lake. In 2013, the Ministry has since launched the National Programme on

Conservation of Aquatic Ecosystem (NPCAE) for conservation of both lakes and wetlands with a significant increase in allocation of resources (NR5, 2014).

CHALLENGES

It has been found that a number of Ministries and Departments at National and sub-national level are contributing directly or indirectly for biodiversity cause. All these departments are also making a considerable amount of expenditure every year to address different biodiversity related issues pertaining to their respective department. It is observed that there is a lack of cohesiveness among all these activities. The major reason for this is lack of a clear cut synergic roadmap. Every related government department should have a clear idea on their department specific responsibilities vis-a-vis deliverables towards biodiversity conservation, its sustainable utilisations aiming at livelihood promotion for the poor.

RECOMMENDATIONS

This study gives some policy recommendations along with implementation plan and clarifies the specific responsible national and sub-national level organisations for this. Such as, for Conservation and restoration of inland aquatic ecosystems – Water quality health card to be prepared for the river stretches and other inland water bodies by Ministry of Environment, Forest and Climate Change (MoEFCC), National Bureau of Fish Genetic Resources (NBFGR) and Central Inland Fisheries Research Institute (CIFRI), ii) Banning of riverbed and boulder mining by National River Conservation Directorate (NRCD), iii) Making environmental flows mandatory under the Environmental Impact Assessment (EIA) clearance by State/UT Governments, Ministry of Water Resources and NRCD, iv) Destructive fishing gears to be banned by State/UT Governments, v) Institutional and governance mechanisms for community-based management for the open water fisheries need to be strengthened by State/UT Governments, vi) Strategic Environmental Assessment (SEA) need to be carried for the developmental projects by MoEFCC. Likewise detailed policy recommendation along with responsible departments or institutions have been given for a) conservation of fish genetic resources, b) developing a database on fisheries biodiversity and their habitats, c) valuation and documentation of ecosystem services of fishery resources, d) developing regulatory mechanism to stop unsustainable practices, hatchery development, ornamental fish culture, d) diversifying the species mix, e) incentivising ecosystem based culture, f) managing Invasive Alien Species, g) promoting of green certification and eco-labelling of fish and fishery products, h) liking market for ecosystem based culture products, i) strengthening the implementation of the BD Act.

CONCLUSION

The current study reviews the existing policy, schemes, and programmes of the inland fisheries sector to know the scopes and challenges for mainstreaming biodiversity concerns into inland fisheries and aquaculture in Indian context, and brings out a set of recommendations to address the biodiversity concerns. The proposed policy interventions are expected to help in achieving the goal of enhancing fishery diversity as well as contributing to sustained biodiversity wealth of the country through complying National Biodiversity Targets, Aichi Targets and Sustainable Development Goals.

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O1-40

琵琶湖の湖辺域における二枚貝を評価指標とした水環境改善手法の検討について

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キーワード:生態系機能, 生態系管理, 自然再生

抄録

琵琶湖では、COD の高止まり、水草の過剰繁茂、在来魚介類の減少等の新たな課題が生じている。特に減少が著しいシジミ類等の二枚貝は、湖内では大きく移動せず、生息環境としての水質や底質、餌環境としての植物プランクトン群集等、湖辺環境を構成する多くの因子の影響を受ける。すなわち、二枚貝の生息状況は、水質や生態系の状態を総合的に評価する上で重要であり、地域住民にも分かりやすく、優れた指標として活用できる可能性がある。生き物がにぎわう湖辺域の浅い砂地の再生に向け、環境省と滋賀県では、2017 年度から、二枚貝等の底生生物の良好な生息環境を評価するための調査解析と、地域住民等との協働による現地での実証事業を実施している。また、有識者等による検討会を設置し、湖辺域の水環境改善に向けた手法の検討を進めている。本発表では、実施している調査解析や実証事業、手法検討の全体概要と途中経過を報告する。

1. はじめに

日本最大の湖、琵琶湖では、これまでの水質保全対策により流入負荷量は減少傾向にあるものの、環境基準 COD の高止まり、特に南部の浅い水域(南湖)における沈水植物(水草)の過剰繁茂、在来魚介類の減少等の新たな課題が生じている[1]。こうした中、2015 年に「琵琶湖の保全及び再生に関する法律」が公布・施行され、国民的資産である琵琶湖を、健全で恵み豊かな湖として保全・再生を図ることが求められている。

琵琶湖では、湖岸線総延長の 32%、南部の浅い水域である南湖では 72%が緩傾斜であった従前の地形から改変されている[2]。改変後の急傾斜断面は、湖辺の流れを停滞させやすく、湖底の低酸素化、泥質の堆積の原因となると考えられる[3]。中でも泥質の堆積は、二枚貝等の底生生物の生息環境悪化や、嫌気的な底質から発芽し餌となりにくい藍藻類の増加につながることが分かってきた(図 1)[4]。

底生生物は、湖内では大きく移動せず、生息環境として水質や底質、餌環境として植物プランクトン群集等、湖辺環境を構成する多くの因子の影響を受ける。中でも、比較的ライフサイクル(寿命)が長いシジミ類等の二枚貝の生息状況は、水質や生態系の状態を総合的に評価する上で重要であり、地域住民にも分かりやすく、優れた指標と考えられ[5]、地域の保全活動の目標として活用できる可能性がある。二枚貝等の底生生物の生息

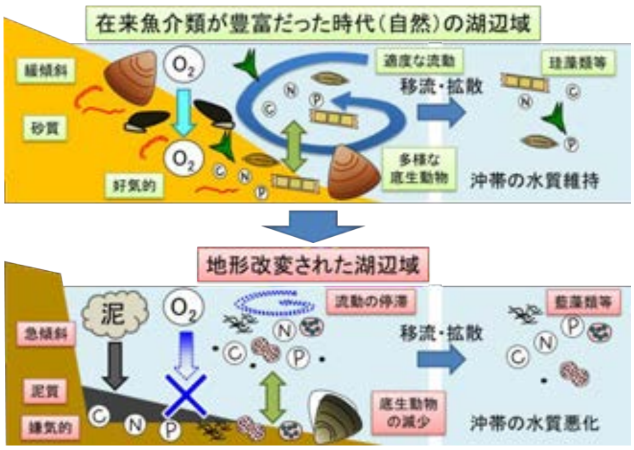

図 1 湖辺域における地形改変と水環境の変化(イメージ)

環境・餌環境の視点から、かつて在来魚介類が豊かであった時代の琵琶湖の水環境への回復に向けた改善策の検討が必要と考えている。

環境省と滋賀県は、生き物がにぎわう浅い砂地の再生に向け、琵琶湖の湖辺域において2017年度から、二枚貝等の良好な生息環境を評価するための現状把握調査、水環境を構成する要因間の影響評価とともに、地域住民等との協働による実証事業を実施している。また、行政担当者、研究者からなる検討会を設置し、湖辺域の水環境改善に向けた手法検討を進めている(図 2)。本発表では、これらの調査解析や実証事業、手法検討の全体概要と途中経過を報告する。

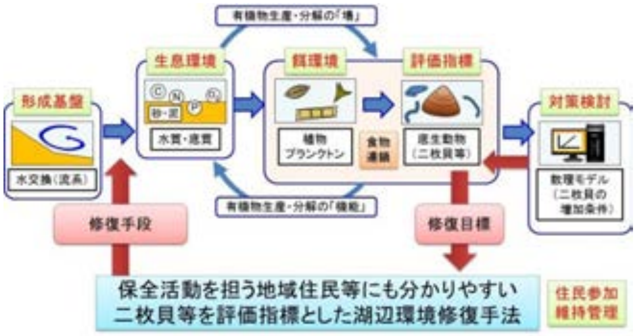

図 2 湖辺域の水環境改善に向けた手法検討に関する調査解析内容の構成

2. 水質・生態系に関する現状把握と影響要因の評価

湖辺域において望ましい水環境の状態を目指す上で、生物の生息環境・餌環境に着目する必要がある。このために、湖辺域での湖水の流れや波浪を考慮した湖底の地形、良好な底質（粒径等）の状態の知見を得る必要があることから、まず、水質や生態系を構成する複雑な要因間の関係把握を行うこととした。

検討にあたり、2017 年 12 月から 2018 年 1 月の間、琵琶湖湖辺域の 10 地点（北湖 6 地点、南湖 4 地点）において現状把握調査を実施した。

（調査項目）評価指標：二枚貝等の底生生物の生息状況、生息環境：水質と底質、餌環境：湖水中の植物プランクトンと底質中の藻類、生息環境や餌環境の形成基盤：水交換（流動、波浪）と湖底断面地形

底生生物の生息密度は、全地点の合計では水生貧毛類（ミミズ類）が 40.9%を占め最も高く、次いでユスリカ類（19.9%）、センチュウ類（19.3%）、シジミ類（10.6%）の順であった。生息環境との関係では、底質の粒径中央値が大きいほど、強熱減量が低いほど、ミミズ類とシジミ類の生息密度が高い傾向がみられた（図 3）。

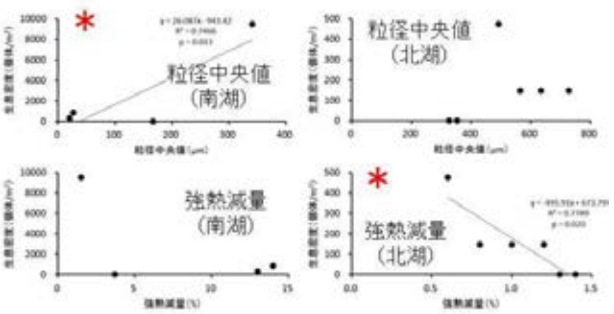

図 3 琵琶湖湖辺域における底質の粒径中央値・強熱減量とシジミ類生息密度の関係（＊$p < 0.05$）

餌環境では、湖水中の植物プランクトン、底質中の藻類量は、全体に北湖より南湖の地点で高く、シジミ類の肥満度も南湖の地点で高い傾向がみられた。また、脂肪酸をマーカーとした餌源分析により、シジミ類は餌として主に珪藻類、緑藻類、藍藻類を同化していたこと等が分かった。これらの現地調査は、地点・方法等を検討しつつ、季節変動も踏まえるため、2018 年夏季・秋季にも実施予定である。

また、特に南湖における近年の水草過剰繁茂は、湖底の低酸素化等を生じさせ、底生生物の生息環境悪化につながることが指摘されている[5]。南湖湖内の 9 定点において 2011 年から毎年夏季に実施している水草繁茂量と底生生物生息密度の調査結果では、2017 年夏季は、過去 7 年間で水草繁茂量が最も少なく、生息密度で優占するミミズ類の生息密度は 2 番目に高かった（図 4）。南湖の水草繁茂状況は年変動が大きく、湖辺域においても湖内の繁茂状況を反映すると考えられることから、今後もモニタリングを継続しつつ、水草が二枚貝等の底生生物の生息環境に及ぼす影響についても評価する必要がある。

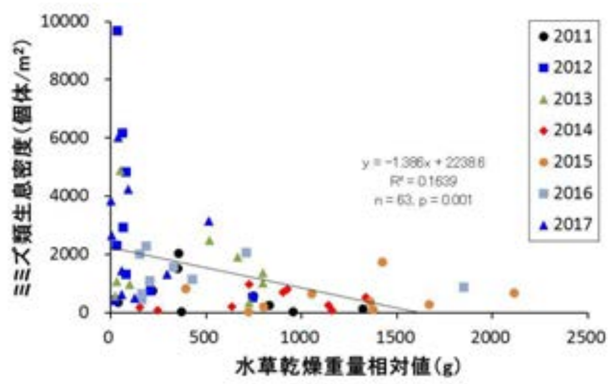

図 4 琵琶湖南湖湖内の 9 定点における水草繁茂量（相対値）とミミズ類生息密度の関係（2011 年～2017 年）

二枚貝等の生息に及ぼす影響要因の評価を行うため、シジミ類を対象とした調査結果等に基づく数理モデルの構成を検討した。作用機序を明示的に表現する物質収支モデルとして、大きくは個体成長モデルと個体群挙動モデルで構成するものとし、今後、調査結果や既存知見等に基づくモデルパラメータの調整とともに、理論式の構築を進める予定である。

3. 持続的・効果的な住民等との協働に向けた取組

地域住民や漁業者等との協働により湖辺域で行う実証事業として、琵琶湖南湖の湖辺域に設定した試験区（約 300 m^2; 滋賀県大津市柳が崎）において、人力およ

び小型船舶による水草除去・湖底耕耘を実施している。この活動は、2017年7月から、夏季の水草伸長期となる7月～9月は毎月2回、その他の期間は毎月1回実施している。また、活動の効果を検証するため、2017年7月から3か月毎に1回、水草除去・湖底耕耘を実施した耕耘区および隣接する対照区において、住民等との協働による貝類調査と、研究者による底生生物調査を実施している。各回の活動および調査活動には、住民および住民団体、漁業者、滋賀県職員等の計20名程度が参加し、持続的な活動の目標として、目指すべき湖辺域の水環境のあり方を検討するため、作業後に参加者の意見交換の場を設けるとともに、意識評価のためのアンケート調査を実施している。

2017年7月から2018年3月までの計12回の活動では、計3,260 kgの水草を除去・回収した。貝類の生息状況については、耕耘区・対照区のいずれも、シジミ類の殻長中央値は2017年7月の5～6 mmから2018年1月の9～10 mmとなり、シジミ類稚貝の成長が確認された（図 5）。生息密度については、各回の調査において耕耘区と対照区の間に有意な差はみられなかったが、2018年1月時点では、殻長10 mm以上の個体は耕耘区の方が多い傾向がみられた。また、20 mm以上の個体がほとんど採集されなかったことから、現在生息している個体の生残と成長が、今後の重要な視点と考えられる。

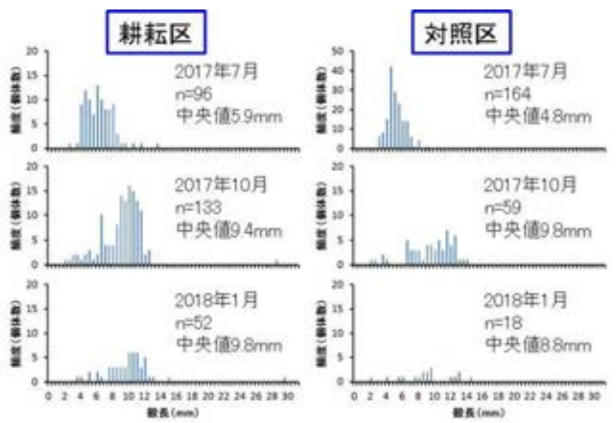

図 5 耕耘区・対照区におけるシジミ類の殻長分布

参加者の意識に関しては、活動の初期には水草の多さに驚いていたが、回数を重ねるにつれて作業中に二枚貝が発見されるようになったことから、活動の効果を実感してきていること等が分かった。

なお、湖辺域の底質環境保全の観点で重要と考えられている流入河川からの継続的な土砂供給機能の回復に向けた試みについても、2018年度から住民等の参加による取組を検討している。

4. 効果的な湖辺域の水環境改善手法等の検討

上記の調査解析、実証事業等の結果を踏まえて、湖辺域の水環境改善に向けた手法を検討していくため、学識経験者、自治体の環境行政担当者で構成する検討会を設置した。2018年3月に開催した第1回検討会において、住民等による持続的・効果的な湖辺の環境改善活動への活用を想定した手引き資料のとりまとめに向け、検討を開始した。また、二枚貝等の底生生物を指標に、場の特性に合わせた湖辺域の環境改善手法を検討することに対しては、①過去からの歴史的な経緯等を含めた状況や課題の整理、②現状把握、③改善目標の設定、④対策手法の選択、⑤モニタリング調査・維持管理活動の流れで取り組むこととし、現時点における課題・論点を整理した。引き続き調査解析、実証事業を行うとともに、検討会を継続していく予定である。

5. 結論

「琵琶湖の保全及び再生に関する法律」で目指す「健全で恵み豊かな湖」とは、水質と生態系が総体として良好に維持された状態と解釈できる。湖沼の水質・生態系の形成において重要な湖辺域[3]で、生息環境・餌環境の現状評価、因子間の関係評価を踏まえた「二枚貝の増加」という目標を設定し、湖沼生態系の機能を回復させ、良好な水質が保たれるよう、効果的な手法を確立したいと考えている。加えて、地域住民に分かりやすい二枚貝等の底生生物を指標とすることで、人と湖との関わりも回復させ、水質と生態系を総体として良好に維持することができるモデルを、全国の湖沼に先駆けて構築していく。その成果について、他の湖沼においても活用できる手引き資料としてとりまとめる。

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O1-41

Habitat restoration for Shijimi clam using local knowledge in the brackish lagoon Kugushi-ko

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Keywords: habitat loss, habitat restoration, nature restoration, Shijimi clam, local knowledge

ABSTRACT

Local knowledge (LK) is the knowledge that developed in a given region with histories of interaction with their natural environments, and had been historically used for resource use and conservation practices in estuaries and coastal habitats. However, it is overlooked recently in reliance on scientific knowledge and new technological ability. In this study, we identified local practices using LKs for conserving commercial bivalve Shijimi clam and verified whether the restoration practices resulted in the improved clam habitat in the brackish lagoon Kugushi-ko, in western Japan. It is demonstrated that elderly fishermen recognized that recent decrease in the clam harvest in the lagoon was mostly due to habitat loss, since the harvest declined after coastal revetment project in the late 1970s. On the assumption that the clam resource is under habitat limitation, they initiated habitat restoration practices recently using two different methods: modern method depending on engineering techniques using allochthonous sediments, and traditional method using LKs which depends on riverine sediment loads. The clam density was higher in the restored habitats than unrestored sites, and highest in the traditionally restored habitat using LKs, suggesting the effectiveness of the traditional restoration. These results suggest that approaches to nature restoration can be determined by using LKs even in less ecologically studied regions.

1. INTRODUCTION

Estuaries and coastal seas have been focal points of human settlement and marine resource use throughout history. In consequence, habitat loss is occurring rapidly in the ecosystems worldwide recently [1]. With recognition of their essential role for human and marine life, estuaries and coastal habitats have become the focus of efforts for conservation and restoration. To be successful, these approaches require historical references [2], including local knowledge.

Local knowledge (LK) refers to the understandings, skills and philosophies developed in a given region with long histories of interaction with their natural environments. LKs had been historically used for resource use and conservation practices in estuaries and coastal habitats [3], whereas it is overlooked recently in overreliance on scientific knowledge and new technological ability [4].

The aim of this study was to identify local practices using LKs for conserving commercial bivalve Shijimi clam (*Corbicula japonica* Prime, 1867) in the brackish lagoon Kugushi-ko, a part of the Mikata-goko (i.e., five lakes) (Fig. 1). In the lakes, Shijimi clam has been harvested from ~6,000 years ago [5], and recent (from ~350 years ago) major habitat of the clam has been in the Kugushi-ko lagoon. Recently, increased human activities resulted in local resource depletion, likely due to habitat loss. According to the Mikata-goko Nature Restoration Committee (since 2013), local efforts have been made to restore the clam's habitat using scientific knowledge [6], whereas the local practices using LKs have also been underway in recent decades. In this study, first, we conducted interviews with fishermen and residents in the region to identify local recognition on habitat status and practices for restoring the clam's habitat using LKs. Second, we verified whether the restoration practices resulted in the improved habitat using field census data.

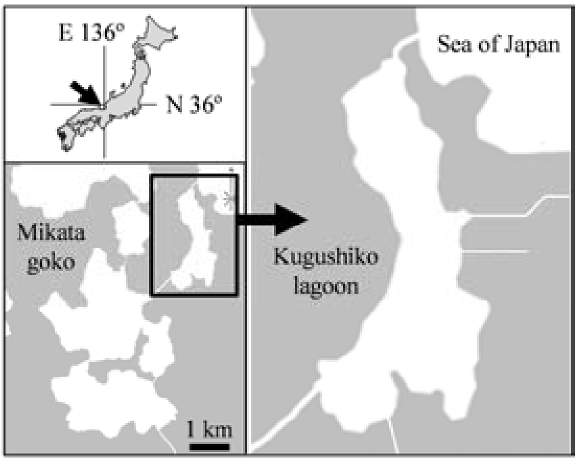

Fig. 1 Map of the present Kugushi-ko lagoon

2. METHOD

Shallow sandy coasts of the brackish lagoon Kugushi-ko

(Fig. 1) have been major harvested sites of Shijimi clam in the Mikata-goko, at least since the early 1600s [7]. In the late 1600s, developing new paddy fields projects decreased surface area of the lagoon by ~30% [8], resulting in a significant habitat loss of the clam [9]. Further, from 1976 to 1978, coastal revetments were installed along ~60% of coastline [10], linking further loss of the clam habitats.

In order to identify local recognition on habitat status and practices for restoring the clam's habitat using LKs, interviews were conducted with fishermen and residents in the region by showing past aerial photo images and landscape photos, and descriptions of ancient documents for the Kugushi-lagoon. In particular, we interviewed with people elder than 70 years old who possesses more LKs. To verify whether the restoration practices resulted in the improved clam habitat, we compared the clam density among restored and unrestored habitats using field census data conducted in 2017. Restored habitats were classified into two categories: using LKs or not.

3. RESULTS

Before the early 1970s when coastal revetments were not installed, Shijimi clams inhabited widely along west and southeast coasts of the Kugushi-ko lagoon (Fig. 2A). In the periods, the southeast coasts were still huge sandy shallows. However, after the 1980s, most of the clam's habitats were lost due to the coastal revetment project (Fig. 2B), and the amount of the clam harvest decreased.

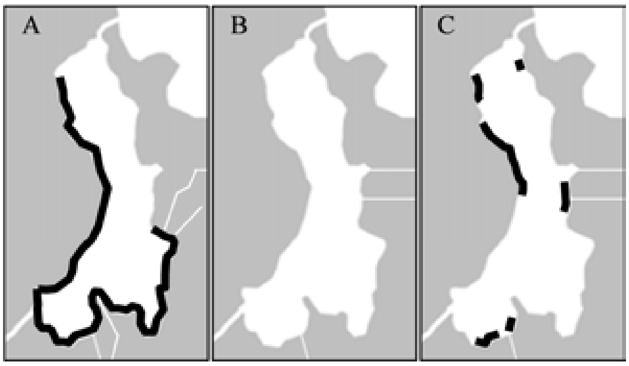

Fig. 2 Reconstructed clam habitats basing on interview results. A: ~1970s; B: 1980s-early 2000s; C: present.

Since the 2000s, habitat restoration (i.e., restoring sandy shallows) initiated by local fishermen (Fig. 2C). And in 2007, habitat restoration using LKs started at south coast; jetty was constructed at the small-river mouth aiming to enlarge sandy shallow along coastline of the lagoon (Fig. 3). After 10 years (2017), ~5,000m^2 of sandy shallows were successfully restored (Fig. 3). Shijimi clam density was higher in the restored habitats than unrestored sites, and the highest density was detected in the restored habitat using LKs (Table 1).

Fig. 3 Restored clam habitat using LKs. Jetty was build up at a river mouth in 2007.

4. DISCUSSION

Elderly fishermen recognized that recent decrease in the clam harvest in the Kugushi-ko lagoon was mostly due to habitat loss, since the harvest declined after coastal revetment project in the late 1970s. Huge sandy shallows at the southeast coast that used to be good clam-harvesting sites disappeared during the project. Considering the lagoon bottoms deeper than 1m depth were not preferable habitats for Shijimi clam in the past [11] and present, it seems plausible that habitat loss due to the artificial modification is a major factor for the decreased clam resources. Increase in the clam harvest after initiating habitat restoration practices since the 2000s further strengthened this fishermen's recognition.

To date, two different methods have been used in restoring the clam habitat practices. Modern method is a placement of sand covers on the coastal bottoms in a short time by engineering techniques, using allochthonous sands due to a scarcity of autochthonous materials. Traditional restoration, in contrast, depends on sand supply from rivers and on its dispersion by winter storm, thus taking a longer time. Traditional method is an application of ancient new-paddy development using river-supplied sediment, which has at least 300 years history in the region [12]. Interestingly, the clam density was higher in the traditionally-restored habitat than the

Table 1 Shijimi clam density in each habitat type in 2017. Errors are 95% confidence intervals.

Habitat type	N	Density (CPUE)
Restored (using LKs)	1	475.0
Restored (not using LKs)	7	169.7±39.7
Not restored	9	87.3±40.2

restored habitat using modern method, suggesting the effectiveness of the traditional restoration.

Habitat restoration using LKs has advantages and disadvantages. Lower cost is an economic advantage of the method; it costs only one-tenth of modern method to restore the same area of habitat. Furthermore, using autochthonous sediments supplied by river may be its ecological advantage, contributing inhibition of exotic benthic species invasion. The main disadvantage of traditional restoration is more consumption of time; it took 10 years to restore 5,000m^2 of habitat using traditional method (Fig. 3), whereas one year is sufficient to finish the same area of restoration using modern engineering method. Additionally, lesser feasible sites for restoration may be a disadvantage. Traditional restoration can be applied only near river mouth. However, considering that sandy shallows mostly forms near river mouth and the clam density was higher in traditionally restored habitat in such location (Table 1), the lesser feasible sites may not be a disadvantage if compared in terms of the productivity per restored area.

Unfortunately, the LKs for restoring Shijimi clam habitat have already been forgotten by many fishermen, whereas modern engineering method has been becoming popular in the region recently. However, in the 21st century, declining Japan's populations will result in reduced tax revenue, therefore, expensive public works projects such as modern engineering restoration of coastal habitat will likely be less feasible. On the other hand, frequency of heavy precipitation events which link to sediment supply into lagoons is increasing recently [13], suggesting that application of traditional habitat restoration depending on riverine sediment loads is becoming more feasible. These suggest that LKs concerning ecosystems would shed some light on future approaches to conservation and restoration practices.

5. CONCLUSION

We illustrated an example of coastal habitat restoration practice for Shijimi clam resources using LKs in the Kugushi-ko lagoon. The traditional restoration method is proven to have some advantages (e.g., low cost, low impact on ecosystem) and to be adaptive to recent economic and climatic changes. These suggest that approaches to nature restoration can be determined by using LKs even in less ecologically studied regions.

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「里浜づくり」で泳げる霞ヶ浦を

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抄録

(一社)霞ヶ浦市民協会は、1995（平成7）年開催の第6回世界湖沼会議にて採択された『霞ヶ浦宣言』の精神を理念に据え、1996（平成8）年に設立された。市民・行政・研究者・企業のパートナーシップのもと、霞ヶ浦という風土の中で培ってきた市民の英知を結集し、『泳げる霞ヶ浦』を目指して水質浄化の推進・啓発活動を続けている。『泳げる霞ヶ浦2020市民計画』は、2020年を目標に生活文化、水辺交流、環境保全、生態系保全、歴史文化、地域経済、啓発・環境学習など多岐にわたる分野での事業展開を示したもので、なかでも湖岸の整備、特に前浜再生に関わる「里浜づくり」事業を継続的に実践している。「里浜」とは、人の住む「里」と、自然の成す「浜」を合体させた造語だが、人と湖をつなぐ里浜（砂浜）をつくり維持管理しながら利活用することで、霞ヶ浦に対する人々の関心と、水質浄化への意識と行動を促すと考え、これを提案し事業として推進するものである。

1. 里浜の提案まで

1995（平成7）年に茨城県で開催された第6回世界湖沼会議は、学術会議にもかかわらず、多くの一般市民が参加したことでも記憶に残る。また、水環境保全を願う各国参加者の強い意志と決意の結晶である『霞ヶ浦宣言』がまとめられ、その宣言内容を設立理念とする社団法人(当時)霞ヶ浦市民協会が、1996（平成8）年に発足した。

2001（平成 13）年5月、当協会は 2020 年を目標に、『泳げる霞ヶ浦』の実現を目指すための『泳げる霞ヶ浦 2020 市民計画 基本構想』を、翌年には『同行動計画』を策定した。当時、20 年先の 2020 年は子どもたちが大人になり社会を担う時代であり、さらにその先へもつながる計画として、21世紀にふさわしい環境型循環社会の構築を背景にしたものである。これは、人と自然の共生を前提に、湖沼や河川の流域住民が、常に流域全体を視野に生活し、水系と関わっていることを自覚することで成り立つ、いわば『霞ヶ浦市民社会』とも言うべきネットワークの確立を目指したものでもある。

同計画の基本フレームは5つのプロジェクトから構成された。①暮らしのプロジェクト／新しい生活文化の創造…インフォメーションセンター「水の交流館」運営・夏休み教室・霞ヶ浦ジュニアレンジャー養成講座・自然観察会・環境学習・生活排水事業等 ②身近な川プロジェクト／生物多様性への模索…水質調査（地域・一斉）・新川クリーンアップ・どんぐり里子作戦・生物調査・河川清掃等 ③水辺交流プロジェクト／人と自然の回廊づくり…泳げる霞ヶ浦市民フェスティバル・水辺ふれあい事業・景観づくり等 ④地域経済プロジェクト／食に始まる霞ヶ浦ブランドづくり…土浦ビオパーク・新川浄化実験場・エコビジネス・地場産品の利活用 ⑤人とひとプロジェクト／プロジェクトの総括集結…シンポジウム・地域懇談会・世界湖沼会議・広報出版・交流会・研究など。これらの事業を市民、行政、研究者、企業、農林漁業者、学校、各種団体とともに協同・協働していく。

この5つのプロジェクトが相互に関連し合う、具体的な事業として辿り着いたのが、水辺の砂浜づくりである。昭和 40 年代初期までは霞ヶ浦沿岸に複数の遊泳場があり、人々は水に触れ、入り、泳いでいた。その泳げた時代をイメージしつつ掲げられた『泳げる霞ヶ浦』は、霞ヶ浦と流域住民の結びつきのもとで成立するものである。砂浜は、水辺の浄化機能を果たすのはもとより、親水空間としての利用価値がある。そこで、日常的に人々が集まり、水質浄化の意識行動のきっかけになる場としての砂浜を、人々の暮らす「里」と、霞ヶ浦の「浜」の結びつきを象徴する『里浜』という言葉で表した。しかし、同時

に維持管理が整わなければ砂浜は消失しかねない。

当協会は、多様な効用を持つ里浜の造成から維持のために、市民の立場で何をすべきか、何ができるかを考え、この里浜づくりを提案し、実践する。

2. 活動経過

『泳げる霞ヶ浦 2020 市民計画』策定後、里浜づくりに向けたシンポジウムやサマースクール等を開催、2006（平成 18）年3月には「第4回霞ヶ浦市民博覧会 2006」において、㈶土木研究センターなぎさ総合研究室長（当時）の宇多高明氏を講師に迎え、主に土浦市蓮河原・滝田地区の湖畔を対象に、現地視察と勉強会を行った。

宇多氏からは、養浜計画では、地形、地質、水深、汀線の角度、卓越風の方向、波の入射方向等の十分な事前調査が重要であることや、砂質、砂の安定のための方策、ヨシ浜との関係性が教示された。さらに、波のエネルギーを干さず、程よく浜に当てること、その地域にふさわしい姿にすることなどが浜づくりには重要であり、「相手は生きている湖」であることを忘れず、段階的な計画が必要であることを学んだ。

第6回世界湖沼会議後、旧建設省は、霞ヶ浦浄化の試みとして土浦市手野町石田地先に大量の砂を投入し、砂浜を造成していた。しばらくは前浜の形態を保ったものの、その後の管理が追いつかず、ヨシ等の植物繁茂、樹木の生長などで足を踏み入れる場もないほど荒れた。しかし、この湖岸は土浦の中心市街地からも近く、人々が利用する砂浜再生の場所としては適している。当協会では、この前浜をどうにか復活させ、里浜をつくろうということになった。

写真1 アシなどの草刈り

以降、年に数回、特に植物が繁茂する夏場には毎週のように、機械と人力による地道な草刈りと清掃作業を続け、各種イベントにも利用してきた。だが、整備エリアにもパワーにも限界は見えた。

2015年2月、事情を聞きつけた地元建設機械メーカーの全面協力のもと、約600 ㎡にわたる前浜部分のヨシを抜根した。根と砂を振るい分け、水辺近くでは浸出水に阻まれながらの大がかりな作業を終えると、地面に砂が見え始め、広々とした前浜が現れた。以降は人の手による継続的な整備作業が砂浜維持のための動力となっている。

写真2 前浜の草刈り作業

前浜の整備および利活用の一環としては、『水辺の楽校』と『砂浜の楽校』を年2回ずつ実施している。水辺の楽校は、主に子どもたちを対象に清掃活動と遊びを組み合わせたもので、自分たちできれいにした砂浜でペットボトル・ロケットを作り飛ばし、前浜にある流木でおこした焚き火で地元産サツマイモの焼き芋を作り食べるなど、水辺で遊び楽しんでもらう目的を持つ。

写真 3 砂浜でのペットボトル・ロケット飛ばし

砂浜の楽校は、建設会社関係者の協力による本格的な清掃作業で、不法投棄された大量のゴミや、漂流物、流木を除去する。景観の維持はもとより、霞ヶ浦の状況を目の当たりにすることで、浄化への意識啓発につなげることも目的のひとつとなる。こちらも作業後にはレンコンやサツマイモなど地元産の食材で作った総菜や菓子で一服する。

いずれにせよ、当協会会員のみならず、地域の団体・市民、企業等の協力を得ながら続けるこの活動に終止符はなく、人力による定期的な維持管理が常に欠かせない。

写真4　前浜の整備

3.　課題と展望

砂浜は造成しただけでは維持できない。ヨシなど植物が繁茂し、ゴミが溜まることで、人は訪れずに荒れていく。しかしながら、維持のためだけに活動を続けていくのにも限界がある。望ましいのは、日常生活の中で利活用しながら維持管理していくことであり、それが里浜の理念でもある。

かつて、人々は集落をつくり、霞ヶ浦沿岸には多くの漁村があり、遊泳場があった。霞ヶ浦と日常生活は同じ線上にあり、水辺は自ずと管理されていた。すなわち、そこにこそ里浜の原型があり、地域と住民の関わりが果たす役割の大きさに気づく。とはいえ、昔のように自立的持続的な水辺との関わりを求めても不可能に近い。現状を鑑みるならば、必要なのは、新たな循環型社会、持続的な水循環の構築ということになろう。

もともと砂浜には、有機物の分解やろ過などの水質浄化機能、そして消波作用や魚類の産卵場所などの機能がある。里浜は、こうした生物の営み、生態系保全の場でもなくてはならないが、地域住民の理解と協力があってこそ、これらの環境も維持される。さらに、その理解と協力を長期的に得るためには、人々にとっても何らかのメリットが必要だろう。人々の暮らしに役立ち、生物の営みにも役立つ場としての水辺空間たる里浜が求められる。

2003（平成 15）年施行の「自然再生推進法」に基づき、当地における「霞ヶ浦田村・沖宿・戸崎地区自然再生事業」には当協会ほか多数の団体・市民が参加し、『里と湖』の接点たる湖岸帯の保全・再生、生態系の維持に向けた活動を継続、年々成果を収めている。石田地区においても、子どもたちの環境学習、レクリエーションの場としての利活用が増えてきた。

写真5　子どもたちによる砂浜づくり

この前浜を砂浜として再生し維持していくことは生態系サービスの「調整」「文化的」観点にも貢献する。茨城県が「霞ヶ浦に係る湖沼水質保全計画」の長期ビジョンに掲げる『泳げる霞ヶ浦・遊べる河川』実現のためにも、この前浜の整備、砂浜化は有効と考える。

前出の宇多氏の弁を借りれば、里浜づくりは、かつて霞ヶ浦で泳いだ世代だけが満足するものではなく、多世代の共感を呼び、理念哲学を持つことが不可欠である。「人と生き物の共生を基本とし、暮らしの中で親しみながら守り育てる浜辺」としての里浜を、『泳げる霞ヶ浦』実現のための指標と位置づけている。