NOTES AND COMMENTS

A note on recent advances in the genetic characterization of Tilapia stocks in Lake Victoria Region

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INTRODUCTION

Oreochromis esculenta, the original "ngege" is virtually extinct in Lake Victoria, and is limited to satellite lakes and reservoirs in the greater Lake Victoria region. *Oreochromis variabilis* can still be found in Lake Victoria and some satellite lakes in the Kyoga System, but in small numbers and only at a few localities (WANDERA and KAUFMAN, unpub. data). Little is known about the influence that species translocations have had on the genetic structure of these crucial fishery species, and even the source of the parent stocks for the introductions remain obscure. Genetic variability was examined within and among allopatric populations of three species in the tilapiine genus *Oreochromis*: *O. esculentus* (endemic to Lakes Victoria and Kyoga), and two exotic species introduced to Lake Victoria in the late 1950's to supplement the failing fisheries for native tilapiines, *O. niloticus* and *O. leucostictus*.

MATERIALS AND METHODS

Population samples were obtained (>10 individuals/species/locality) from Lake Victoria and eight satellite Lakes in the Victoria basin: Lakes Nabugabo, Kayugi, Kayanja, and Manywa in the Nabugabo System; Lake Kanyaboli in the Yala-Nzoia System, and Lakes Mburo, Kachira, and Kijanebalola in the Koki Lakes System. Of these, only Nabugabo contained Nile Perch (OGUTU-OWHAYO, 1993). Small bits of muscle tissue were removed immediately upon capture. Only those individuals that could be identified unambiguously in the field were taken for the study.

The tissues were placed in 95% ethanol in sample vials, and the alcohol changed after 1hr. DNA was extracted from the muscle tissue samples using a standard phenol/chloroform extraction procedure (SAMBROOKE, 1982). DNA samples were amplified through PCR using a Perkin-Elmer thermocycler using single short arbitrary 10-mer oligonucleotide primers. Amplification products were separated by electrophoresis in a 1.6% synergel agarose gel, stained with ethidium bromide, and viewed under ultraviolet light. Individual species were analyzed for species-specific markers (bands that occurred exclusively among individuals of a particular species, Table 1). Gametic diversity (Table 2) was calculated after LYNCH and MULLIGAN (1994), which is specific to the analysis of gene structure using RAPD data. Gene introgression (Table 4) was estimated .in terms of the proportion of RAPD alleles characteristic of a given taxon that appeared in congener populations. Cladograms (using maximum parsimony) were constructed with the aid of the program PAUP 3.1, with analyses conducted under highly stringent condiltions. The outgroup chose *Tilapia zillii*, a tilapiine cichlid assumed to be phylogenetically basal to the general *Oreochromis* and *Sarotherodon* based on the work of Trewavas and others (TREWAVAS, 1983).

RESULTS

All species exhibited a relatively high number of species-specific alleles, with *O. leucostictus* exhibiting the highest number followed by *O. niloticus*, and *O. esculentus* with the least

(Table 1). *O. niloticus* exhibited the highest mean within population gene diversity, and *O. esculentus* the lowest (Table 2). *O. esculentus* exhibited the highest degree of population subdivision, but statistically it did not differ significantly in this regard from *O. niloticus*, both of which displayed remarkably high levels of population distinctness.

O. leucostictus was unusual in its low degree of population subdivision, and *T. zillii* for its relatively high within-population genetic diversity (Table 3). All six of the *O. esculentus* populations examined exhibited evidence of *O. niloticus* alleles (Table 4). The most highly introgressed population was that of Lake Mburo, and the purest was Lake Kanyaboli. The three Nabugabo satellite Lakes and Lake Kachira showed similar, moderately high levels of introgression from *O. niloticus* into *O. esculentus*. Gene introgression from *O. esculentus* into *O. niloticus* was generally lower than the reverse. Lake Victoria *O. niloticus* showed little evidence of *O. esculentus* alleles, though Lake Nabugabo, where *O. esculentus* has been extirpated, displayed surprisingly high levels of introgression and retention of *O. esculentus* alleles.

Table 1. Total number of population-specific bands within the three species of the genus *Oreochromis*.

Population	O. esculentus	O. niloticus	O. leucostictus
Lake Kanyaboli	6	–	–
Lake Manywa	4	–	–
Lake Kijanebalola	4	–	–
Lake Kayugi	9	–	–
Lake Kayanja	2	–	–
Lake Kachira	5	6	21
Lake Mburo	13	7	9
Lake Victoria	–	5	8
Lake Nabugabo	–	7	9
Lake Edward	–	9	–
Lake Albert	–	5	–
Species (total)	43	39	47
Total bands	140	115	105
Proportion of unique bands	0.31	0.34	0.45

Table 2. Estimates of mean within-populations gene diversity (H_w) for three species belonging to the genus *Oreochromis*.

Species	n	H_w	SE	Var H_w	$Var_I H_w$	$Var_L H_w$	$Var_P H_w$
O. niloticus	5	0.213	0.031	0.00095	0.000038	0.000085	0.00083
O. esculentus	6	0.152	0.020	0.00042	0.000025	0.000035	0.00036
O. leucostictus	4	0.202	0.019	0.00034	0.000038	0.000071	0.00023

n= number of populations studied
Var H_w = sampling variance
$Var_I H_w$ = sampling variance due to finite number of individuals
$Var_L H_w$ = sampling variance due to finite number of loci
$Var_P H_w$ = sampling variance due to finite number of populations

DISCUSSION

The genetic distinctness of both *O. esculentus* and *O. niloticus* populations is of an order normally associated with subspecies (Table 3). Even the comparatively low values found in *O. leucostictus* were higher than expected. We attribute this to founder effect, due either to natural or artificial seeding of these populations by a very few individuals in each case. Introgression between the endemic *O. esculentus* and the introduced *O. niloticus* is rampant. Gene flow has been predominantly, though not exclusively, from *O. escu-*

Table 3. Estimates of genetic diversity for within (H_W) and between (H_B) populations and Wright's measure of population subdivision, F_{ST}, among Tilapiine populations from Lake Victoria Basin.

Species	n	H_W	H_B	F_{ST}
O. niloticus	5	0.213	0.605	0.740
O. esculentus	7	0.152	0.613	0.801
O. leucostictus	4	0.202	0.539	0.686
Tilapia zillii	2	0.222	–	–

n= number of populations studied

lentus into *O. niloticus*. It is distinctly possible that no pure stocks of *O. esculentus* are existent today. The best remaining hope lies in two disparate localities: the Nyumba ya Mungu Reservoir in Tanzania, where the source stock of *O. esculentus* may have been relatively pure, and various satellite Lakes of Lake Kyoga, where we have discovered astonishingly rich remnant communities resembling those of Lakes Victoria and Kyoga prior to the huge ecological changes of the past four decades. For centuries, *O. esculentus*

Table 4. Estimate of gene introgression based on proportions of species specific 'fixed' allele harbored by a congener.

	fixed alleles	O. niloticus	O. esculentus
O. esculentus			
Lake Kanyaboli	–	6.72	–
Lake Kayugi	–	14.39	–
Lake Kayanja	–	12.94	–
Lake Manywa	–	13.73	–
Lake Kachira	–	14.11	–
Lake Mburo	–	35.27	–
O. niloticus			
Lake Victoria	–	–	0.91
Lake Mburo	–	–	6.67
Lake Nabugabo	–	–	21.10
Lake Kachira	–	–	8.20

was among the most prized food fishes in East Africa, and it was the staple fish on Lakes Victoria and Kyoga in pre-colonial and early colonial times (BALIRWA, 1992). This was on account not only of its abundance, but also its excellent taste, firm meat, and suitability for sun-drying. Nonetheless, *O. esculentus* was never taken up by aquaculture scientists during the "blue revolution" that led to the current popularity of other tilapiines as targets in aquaculture. Now that the species has disappeared from Lakes Victoria and Kyoga and there is a real possibility of its biological extinction, reconsideration of its status, and its future in East Africa is long overdue.

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Methodology for valuing Wetlands in Uganda

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INTRODUCTION

The wetlands in Uganda are undergoing rapid degradation. Swamps provide a habitat for birds, fishes and other animals. They have many ecological functions and, furthermore, supply people with multiple resources, such as reeds, herbs, fish and agricultural products. Although some uses of wetland are sustainable, others lead to rapid deterioration. The main threat to swamps are human activities. One reason for the progressive destruction of wetlands is that the people may not appreciate the existence of and the treasures represented by wetlands even if they live in arm long distance from them. Another reason is that the two most important user groups of wetlands, farmers and fishermen, although having conflicting interests concerning the wetlands, hardly interact.

A study, done as part of the Ecotone Project at the Fisheries Research Institute (FIRI), tries to evaluate in monetary terms how much Uganda loses with progressive destruction of wetlands. The study looks first at which uses of the wetlands are of importance and thereafter it examines, what data is needed and available to calculate the values of those uses.

METHODOLOGY

The methods used in the study assess the value of wetlands through cost- benefit analysis. This consists of adding up the various benefits coming from sustainable uses of wetlands and comparing them with possible profits from converted wetlands. The sustainable benefits a wetland provides are: erosion and flood control, water purification and wildlife habitat. Furthermore, wetlands can attract tourism and provide goods like medicinal herbs and raw materials for craftmakers. Uses which alter a wetland are agriculture and waste disposal.

This research concentrates on the non- sustainable agricultural use of the wetland area on the one side and on the filtering capacity, the existence value and the importance of the swamps as breeding place for fishes on the other side.

The profit P of wetland area used for cultivation is easy to assess. Shortly after clearing a swamp the area seems to be slightly more productive than further inland. The yield y per area on dryland soil is well known for various crops. The profit, therefore, can be calculated by multiplying the yield with the prices of the crop and subtracting the costs C which go into producing this yield. The production costs consist mainly of wages. Hence:

$$P = y \times p - C$$

The value of the filtering capacity of the wetland can be assessed by comparing the filtering capacity of a natural wetland with an appropriate wastewater treatment facility, e.g. waste stabilisation ponds. By discounting both the operation costs and the depreciation of such waste stabilisation ponds, we can attribute a value to this facility. If a wetland does the same to the wastewater, therefore, we can attribute the same value to the wetland too. However, this value is optional. That means this value can be realised by passing wastewater through the swamp. By doing that the costs of constructing and maintaining a wastewater treatment facility can be saved. If there is no wastewater passed through the wetland, this special value is not realised but still remains an option. By destroying a wetland this value is lost.

The concept of the existence value has been developed in industrialised countries where nature in all its aspects (wildlife, plants, scenery) are presently rare. Existence values refer to the fact that individuals attach value to goods only by

knowing that such goods (e.g. rare and diverse species, unique natural environments etc.) exist, even if the individuals do not intend to make an active use of these goods. Such goods are usually public goods which means that no one can be excluded to use them. Therefore, no market can be established for such goods and by that no price can be attributed to them. Although they have a value, traditional cost-benefit analysis could not handle them because such calculations have been biased.

The concept of the existence value provides a possibility to make the economic analysis accessible for public goods. The method to estimate existence values involves willingness to pay (WTP) studies. A possible form of such a study is to ask people directly what amount of money they would pay to support a policy which protects wetlands. WTP studies, therefore, reflect the people's perception of the value of wetlands. WTP studies have proved appropriate for the calculation of existence values in industrialised countries (PORTNEY, 1994). In developing countries they have been found practicable for estimating the cost recovery capacity of large public sponsored investments (e.g. water and sanitation). It is an open question, therefore, whether WTP studies are suitable for the estimation existence values in developing countries.

In the present situation in Uganda it is most likely that the greatest importance of wetlands in monetary terms comes from their contribution as breeding places and refuge for fishes. The value V of a wetland can be described as a product of the marginal productivity of the function of fish harvest Q(H,W) and the dockside price p of the fishes, hence:

$$V = q_w Q(H,W)*p$$

The harvest function Q(H,W) is dependent both on the human effort H needed to catch the fish and the wetland acreage W (COSTANZA et al., 1989). LYNNE et al. (1981) developed a model of catch in which catch depends on swamp acreage, catch in the former year and effort:

$$Q_t = b_0 + b_1 \ln W_{t-1} * H_t + b_2 \ln W_{t-1} * H_t^2 + b_3 Q_{t-1} + e_t$$

To estimate the parameters β_0, β_1, β_2 and β_3, we need statistical data about human effort H (measured in days or canoes) and covered wetland area, which both contribute to the harvest Q. Once the parameters are estimated, the marginal productivity can be estimated. Hence,

$$q_w Q = (b_1 + b_2 * H) * \frac{H}{W}$$

With appropriate statistical data about fish catches, therefore, a simple model of a harvest function can be calculated and by that a value of the wetlands can be estimated.

CONCLUSIONS

The research described here is an attempt to evaluate the contribution of some of the various functions of a wetland to its overall value. It furthermore takes into consideration that the benefits of wetland protection are mainly social benefits whereas the profits of non-sustainable used wetland area can be privatised. By that, the study may provide some hints concerning the rationale behind the progressive wetland degradation. However, the analysis is purely economic and, therefore, excludes the intangible value wetlands have for society.

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