Impact of Nile perch (*Lates niloticus*) overfishing on fishers' income: Evidence from Lake Victoria, Tanzania

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Abstract

Despite the crucial role played by Nile perch in the income of fishers around Lake Victoria, Tanzania, fishing pressure has increased in recent years and has led to overfishing and, consequently, a risk to the lake's future sustainability and the fishers' livelihoods. This study used data collected in 2018 from 268 randomly selected sample fishers at 10 landing sites across Lake Victoria. In conjunction with the endogenous switching regression model, the potential impact of Nile perch overfishing on the fishers' income per fishing trip in Lake Victoria was evaluated. The results show that there is a significant difference in the socio-economic, institutional and fishing effort characteristics of Nile perch fishers who overfish and those who do not. In particular, Nile perch fishers who overfish earn significantly higher incomes per fishing trip than fishers who do not overfish. The study recommends the need for policy makers to develop policies that acknowledge the dynamics of socio-economic, institutional and fishing effort factors. In addition, more flexible fish quota restrictions and consistent fishing patrols need to be enforced to ensure compliance with fishery regulations. These measures should promote a balance between the sustainability of fishery resources and an improved income for Nile perch fishers in Lake Victoria.

Key words: overfishing; income; poverty; Nile perch; Lake Victoria

1. Introduction

Fishing has been one of the significant sources of income, employment and food security among people living around fishery resources (Onyango & Jentoft 2010; Martin *et al*. 2013; Solaymani & Kari 2014). However, communities around fishery resources are still poor, despite the fact that these resources generate substantial incomes at both the micro- and macro-level (Béné 2003; Béné *et al*. 2004; FAO 2005; Omwega *et al*. 2006; Onyango 2011; Olale & Henson 2013). Poverty in small-scale fishing communities is also caused by several other socio-institutional factors, such as education, financial capital and marginalisation as a result of political decision-making (Béné & Friend 2011).

Previous studies have argued that a lack of investment in the upgrading of regulatory institutions and governance might hinder poverty-reduction strategies in fishing-dependent communities (Carbonetti *et al*. 2014, Nunan 2014; Nunan *et al*. 2015). Moreover, studies have shown the significant role of government institutions in an attempt to improve food security and eradicate income poverty among fishing-dependent communities (Cinner *et al*. 2012; Nunan 2014; McClanahan *et al*. 2015).

In Tanzania, for instance, the government introduced the Nile perch (*Lates niloticus*) species in the 1950s to feed on small fishes like haplochromines in order to increase fishing activities and the income of fishers around Lake Victoria (Acere 1985; Ogari 1985; Kudhongania *et al*. 1992; Nkalubo *et al*. 2014). Since the introduction of the Nile perch, there has been an increase in the number of fish-processing factories dealing in the export of fish fillets, with an increased demand for raw material around the lake. The increase in fish exports is closely linked to an increase in fishers' income and, therefore, in poverty reduction (Nyeko 2004).

Nile perch is a predatory fish of high commercial and recreational value that can grow to a length of 2 m and weigh up to 200 kg (Aloo *et al*. 2017). This has consequently attracted a number of fishers to the fish industry due to the high demand by local and export markets for Nile perch (Ogutu-Ohwayo 2004; Geheb *et al.* 2008). Despite the crucial role played by Nile perch in the income generation of fishers around Lake Victoria, the lake has been faced with increasing fishing pressure in recent years, leading to overfishing. A stock assessment survey report provides evidence of the declining trend in Nile perch biomass over the past two decades (Balirwa *et al*. 2003; Odongkara *et al*. 2009). Thus, a decline in fish yields will have far-reaching socio-economic consequences, including a loss of income and livelihood, employment, and food and nutritional security (Odongkara *et al*., 2009).

On the other hand, there are limited empirical studies on the impact of Nile perch overfishing on fishers' income around Lake Victoria. Several studies conducted on Lake Victoria (Ogutu-Ohwayo 1990; Kudhongania *et al*. 1992; Witte *et al*. 1992; Balirwa *et al*. 2003; Lowe-McConnell 2010; Njiru *et al*. 2014; Taabu-Munyaho *et al*. 2016) focused on the impact of overfishing on the reduction in the stock of several species, the biodiversity, and ecological, eutrophication and environmental changes. In addition, most of these studies used biological and ecological indicators to predict biomass dynamics and trophic levels, particularly biomass trends, growth and mortality, feeding and reproductive characteristics of the stock, catch rates and catch per unit efforts.

This study, assessing the impact of Nile perch overfishing on the income of Lake Victoria fishers, was therefore a necessity. In addition, it also contributes to the existing knowledge in the literature on Lake Victoria's fisheries in terms of the interrelationship between the regulations on current Nile perch slot size and the income of fishers; and will inform policy on the sustainable management of Lake Victoria's fishery resources in order to reduce fishers' income poverty.

2. Conceptual framework

The conceptual framework of this study hinges on the literature of Béné (2003, 2009), Béné *et al.* (2009) and Olale & Henson (2013) regarding the interrelationship between income poverty and fish dependency. It is argued that the major reasons for income poverty among fish-dependent communities are: a) open access to fishery resources, which, in the absence of effective fishery management and governance, leads to declining fish resources; and b) the lack of income-diversification activities, which makes fishing their "last resort". This implies that, as catch returns fall with continued over-exploitation, fishers are unable to realise sufficient income to maintain an acceptable standard of living, unless they can find alternative income-generating opportunities. Figure 1 below illustrates the interrelationship between income poverty and Nile perch overfishing in the study region.

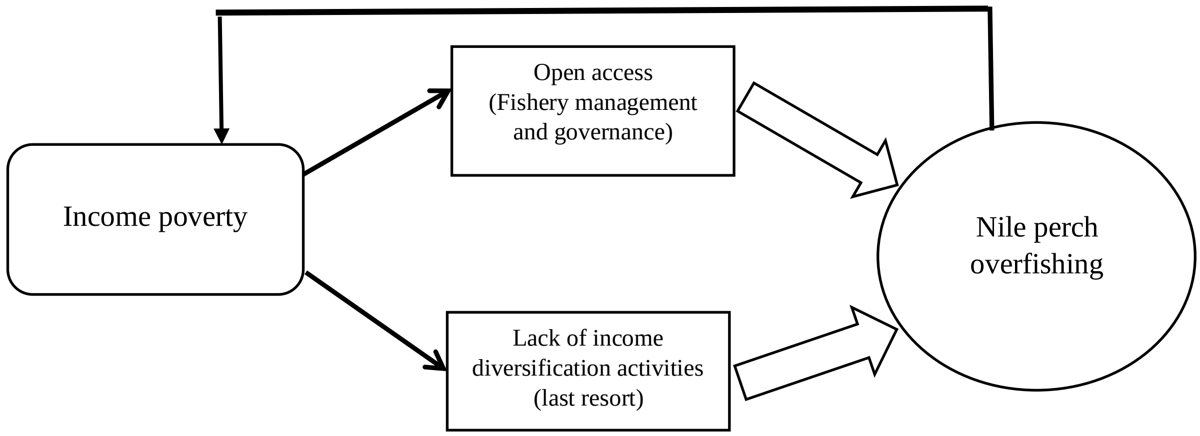

Figure 1: Conceptual framework of interrelationship between income poverty and Nile perch overfishing
Source: Authors' conceptualisation

Fishers' income is determined by the quantity of fish they catch and the price obtained for it; thus, if the fishery is managed well, it will contribute to driving income poverty down (Nyeko 2004; Bavinck 2009; McGregor 2009; Coulthard *et al*. 2011; Weeratunge *et al*. 2014). Building on these facts, Lake Victoria provides open access to anyone to fish in it, subject to existing fishery regulations (Ntiba *et al*. 2001; Eggert & Ellegård 2003; Ogello *et al*. 2013). This study therefore conceptualises that the existing income poverty among communities in Lake Victoria will lead to Nile perch overfishing because of the open-access nature of the lake and the lack of income diversification activities. The increasing rate of overfishing leads to the depletion of fishery resources, which in turn leads to fishers' income poverty.

3. Methodology

3.1 Study area

This study was conducted in Lake Victoria, Tanzania, Africa's largest freshwater fishery. The lake covers an area of 68 000 km^2 and has a catchment area of 193 000 km^2. The lake is shared among Uganda (43%), Kenya (6%) and Tanzania (51%). It has a shoreline of 3 450 km and is relatively shallow, with a mean depth of 40 m and a maximum depth of 84 m. The lake is also the source of the Nile River and its resources contribute directly to supporting the livelihoods of over two million people through income, food and the generation of employment (Kolding *et al*. 2014). Lake Victoria is the most important source of affordable animal protein in the form of fish in East Africa. The fisheries are diverse, highly dispersed and fragmented, with about 1 500 landing sites and more than 120 000 fishers (Cowx *et al*. 2003).

3.2 Sampling and data collection procedure

Major Nile perch fish-landing sites around Lake Victoria were selected in consultation with the Tanzania Fisheries Research Institute (TAFIRI), leaders of the Beach Management Unit (BMU), landing sites and fishery officers within the districts. For the purpose of this study, four districts were initially selected (Magu, Ilemela, Nyamagana and Misungwi) because they had the highest number of Nile perch fishers, and also because of their proximity to town centres and their different socio-economic characteristics in terms of level of development, livelihood strategies and service provision. Of these districts, Magu and Misungwi were relatively far out of Mwanza town compared to Ilemela and Nyamagana. Ten landing sites were selected in these four districts, with at least two landing sites per district. Landing sites were selected that had more Nile perch fishers, namely Chole, Igombe, Kigangama, Kayenze Zamani, Kayenze Ndogo, Kigongo Ferry, Luchelele, Mihama and Shadi.

A total of 268 Nile perch fishers from the 10 landing sites (at least 26 per landing site) were selected using a random sampling technique. The study employed different data collection methods, namely a questionnaire for Nile perch fishers, focus group discussions and key informant interviews. The focus group discussions were moderated by the researchers and conducted by BMU leaders to obtain the different views of fishers on fishery management practices in the lake. With the assistance of TAFIRI staff, the names of landing sites and districts were identified. Key informants, such as BMU leaders at the landing sites, were also approached to provide a general overview of landing site operational activities, current challenges and opportunities. Data was collected on various aspects of Nile perch fishery from January to March 2018. Survey data included information on the socio-economic characteristics of the fishers, institutional factors and fishing efforts.

3.3 Determination of Nile perch overfishing and income per fishing trip

Nile perch overfishing was measured by using the slot size regulation of 50 cm to 85 cm total length (TL). This slot size was introduced to protect immature fish and large adults so that the stock could be replaced while mature fish are being harvested (Msuku *et al*. 2011). Fishers were asked about the average weight in kilogram (kg) of individual Nile perch harvested by them per trip. The conventional measurement of weight and length was then done, following studies by Ogutu-Ohwayo (1999) and Yongo *et al.* (2017), who found that a Nile perch with an average length of 55.38 cm TL weighs 2 355 g (2.4 kg). Using this length-weight relationship would imply that the minimum slot size of 50 cm TL will weigh 2 141 g (2.1 kg). Therefore, every fisher who fished an average weight of less than 2.1 kg per individual fish and thus a TL below 50 cm was considered to have overfished. However, the baseline survey could not find fishers who caught above a TL of 85 cm. Nile perch fishing income per trip was determined by asking fishers about the average income they receive per trip. Further calculations were done at the landing sites by multiplying the number of fish caught per trip by the market price.

3.4 Endogenous switching regression model

In order to measure the impact of Nile perch overfishing on fishers' income, the endogenous switching regression model, developed by Lokshin and Sajaia (2004), was employed. In the first stage, the probit model was used to determine the socio-economic factors influencing Nile perch overfishing. In the second stage, an ordinary least squares (OLS) regression with selectivity correction was used to examine the relationship between the outcome variables (Nile perch income per fishing trip) and a set of explanatory variables conditional on fishers' overfishing status.

The observed outcome of Nile perch overfishing can be modelled by following the random utility formulation. With regard to the expected benefits, a fisher evaluates whether or not to overfish on the basis of fishing gear and available inputs. The expected utility of overfishing (U_0) is compared to the expected utility of not overfishing (U_s), i.e. $I_i^* = U_o - U_s > 0$. A fisher will have overfished if $U_0 > U_s$ or will not have overfished if $U_0 \leq U_s$. The benefit (I_i^*) that the fisher derives from overfishing is a latent variable determined by observed characteristics (Z_i) and an error term (ε_{it}), and can be estimated with a probit model that is calculated as follows:

$$I_i^* = \gamma Z_i + \varepsilon_{it} \qquad I_i^* = \begin{cases} 1\, if & I_i^* > 0 \\ 0 & otherwise \end{cases}, \qquad (1)$$

where I_i^* is a binary indicator variable that is equal to 1 if a fisher has overfished, and 0 otherwise; γ is a vector of unknown parameters to be estimated; Z_i are socio-economic, institutional and fishing effort variables that affect the probability of overfishing or not overfishing to be estimated; and ε_{it} is an error term.

In the second stage of the model, two regimes of income per fishing trip were assumed for Nile perch fishers who overfished and those who did not, expressed as follows:

Regime 1: $y_{1i} = x_1\beta_1 + \mu_{1i}$ if $I_i = 1$ (2a)

Regime 2: $y_{2i} = x_2\beta_2 + \mu_{2i}$ if $I_i = 0$, (2b)

where y_{1i} and y_{2i} are the Nile perch fishers' income per fishing trip in regimes 1 (overfishing) and 2 (not overfishing); β_i represents a vector of parameters to be estimated; x_{1i} and x_{2i} are vectors of exogenous covariates that influence income per fishing trip; and μ_{1i} and μ_{2i} are random disturbances associated with the income level per fishing trip. Following Akpalu and Normanyo (2014), Khonje *et al*. (2015) and Lokshin and Sajaia (2004), the error terms in equations (1), (2a) and (2b) are assumed to have a tri-variate normal distribution with a zero mean and a covariant that can be expressed as:

$$\Omega = \text{cov}(\varepsilon_i, \mu_1, \mu_2) = \begin{bmatrix} \sigma_\varepsilon^{\ 2} & \sigma_{\varepsilon 1} & \sigma_{\varepsilon 2} \\ \sigma_{\varepsilon 1} & \sigma^2{}_1 & \\ \sigma_{\varepsilon 2} & . & \sigma^2{}_2 \end{bmatrix}, \quad (3)$$

where $\sigma_\varepsilon^{\ 2}$ = var(ε); $\sigma_1^{\ 2}$ = var(μ_{1i}); $\sigma_2^{\ 2}$ = var(μ_{2i}); $\sigma_{\varepsilon 1}$ = cov(ε, μ_{1i}); and $\sigma_{\varepsilon 2}$ = cov(ε, μ_{2it}). Also, $\sigma_\varepsilon^{\ 2}$ is assumed to be 1 because it is estimable only up to a scale factor of 1 (Maddala 1983). Following Asfaw *et al.* (2012), Akpalu and Normanyo (2014) and Khonje *et al*. (2015), it is further assumed that, since the error term of the probit (selection equation) (1) is correlated with the error terms of the income per fishing trip functions (2a) and (2b), the expected values of μ_{1i} and μ_{2i}, conditional on the sample selection, are non-zero and are expressed as follows:

$$E(\mu_{1i} | I_i = 1) = \sigma_{\varepsilon 1} \frac{\phi(Z_i\gamma)}{\Phi(Z_i\gamma)} = \sigma_{\varepsilon 1}\lambda_{1i} \quad (4a)$$

$$E(\mu_{2i} | I_i = 0) = \sigma_{\varepsilon 2} \frac{\phi(Z_i\gamma)}{1 - \Phi(Z_i\gamma)} = \sigma_{\varepsilon 2}\lambda_{2i}, \quad (4b)$$

where $\varphi(\cdot)$ and $\Phi(.)$ are the standard normal probability density function and normal cumulative density function respectively, thus $\lambda_{1i} = \frac{\phi(x_i\beta)}{\Phi(x_i\beta)}$ and $\lambda_{2i} = \frac{\phi(x_i\beta)}{1 - \Phi(x_i\beta)}$ are the inverse Mills ratio, calculated from the selection equation, and are included in equations (2a) and (2b) to correct for selection bias in an endogenous switching treatment regression model. Also, if the estimated covariances, $\sigma_1^{\ 2}$ = var(μ_{1it}) and $\sigma_2^{\ 2}$ = var(μ_{2it}), are statistically significant, then the decision to overfish and the Nile perch income per fishing trip are correlated (Di Falco *et al*. 2011).

In order to estimate the endogenous switching regression model, the full information maximum likelihood (FIML) method was used, expressed as:

$$\ln L_i = \sum_{i=1}^{N} \left\{ I_i \left[\ln \phi\left(\frac{\mu_{1i}}{\sigma_1}\right) - \ln \sigma_1 + \ln \Phi(\theta_{1i}) \right] + (1 - I_i) \left[\ln \phi\left(\frac{\mu_{2i}}{\sigma_2}\right) - \ln \sigma_2 + \ln(1 - (\theta_{2i})) \right] \right., \quad (5)$$

where $\theta_{ji} = \frac{\gamma Z_i + \rho_j \mu_{ji} / \sigma_j}{\sqrt{1 - \rho^2}}$, with j = 1,2 and ρ_j denotes the correlation coefficient between the error term ε_{it} of the selection equation (1) and the error terms μ_{jit} of equations (2a) and (2b) respectively.

3.5 Conditional expectations and treatment effects

The endogenous switching regression model was used to compare observed and counterfactual catch values (Akpalu & Normanyo 2014). Therefore, it is possible with this model to estimate and compare the income of fishers who overfish if they have not overfished before, and fishers who do not overfish if they have overfished before (see Table 1). Following Jaleta *et al*. (2015), the structure of the expected conditional and average treatment effects under an actual and counterfactual given scenario is expressed as:

Fishers who overfish (observed from the sample):

$$E\left[y_{1i} \middle| x_i, I_i = 1\right] = x_1 \beta_1 + \sigma_{\mu 1i} \hat{\lambda}_{1i} \quad (6a)$$

Fishers who do not overfish (observed from the sample):

$$E\left[y_{2i} \middle| x_i, I_i = 0\right] = x_2 \beta_2 + \sigma_{2\mu i} \hat{\lambda}_{2i} \quad (6b)$$

Fishers who overfish if they have not overfished before (counterfactual):

$$E\left[y_{2i} \middle| x_i, I = 1\right] = x_1 \beta_2 + \sigma_{2\mu i} \hat{\lambda}_{1i} \quad (6c)$$

Fishers who do not overfish if they have overfished before (counterfactual):

$$E\left[y_{1i} \middle| x_i, I = 0\right] = x_2 \beta_1 + \sigma_{1\mu i} \hat{\lambda}_{2i} \quad (6d)$$

Thus, the average treatment effect on the treated (ATT) is computed as the difference between (6a) and (6c):

$$\begin{aligned} ATT &= (y_{1i} | I_i = 1; x) - (y_{2i} | I_i = 1; x) \quad (7) \\ &= x_{1i}(\beta_1 - \beta_2) + \lambda_{1i}(\sigma_{\mu 1i} - \sigma_{\mu_{2i}}), \end{aligned}$$

while the average treatment effect on the untreated (ATU) is computed by the difference between (6b) and (6d):

$$ATU = (y_{1i} | I_i = 0; x) - (y_{2i} | I_i = 0; x) \quad (8)$$
$$= x_{2i}(\beta_1 - \beta_2) + \lambda_{2i}(\sigma_{\mu 1i} - \sigma_{\mu_{2i}})$$

Table 1: Conditional expectations, treatment and heterogeneity effects

	Probability		Treatment effects
	To overfish	**Not to overfish**	
Nile perch fishers who overfish	(6a) $E[y_{1t} \| x_i, I_i = 1]$	(6c) $E[y_{2t} \| x_i, I_i = 1]$	TT
Nile perch fishers who do not overfish	(6b) $E[y_{1t} \| x_i, I_i = 0]$	(6d) $E[y_{2t} \| x_i, I_i = 0]$	TU
Heterogeneity effects	BH_1	BH_2	TH

Source: Field survey (2018)

3.6 Foster-Greer-Thorbecke index

In this study, the Foster-Greer-Thorbecke (FGT) index (Foster *et al*. 1984), was adopted to measure the incidence, depth and severity of overfishing of Nile perch, based on Lake Victoria's slot size regulation of 50 cm TL. The FGT-weighted poverty index is well known for its use in different studies of quantitative poverty assessment, particularly to measure poverty incidence, depth and severity.

The FGT method has been used widely, also in nutrition and food security studies (Bose & Dey 2007; Nigussie & Alemayehu 2013; Dube *et al*. 2018; Sinyolo & Mudhara 2018). Different studies in fishery science have also applied the method to measure fishers' income, livelihood and poverty status (Abbas & Ahmed 2016; Amankwah *et al*. 2018). Moreover, the sensitivity analysis in this study was conducted to evaluate how the incidence, depth, severity and income per fishing trip of overfishing would change with an increase or decrease of 5% in the minimum slot size of 50 cm TL.

The FGT index can be decomposed and expressed as:

$$P_\alpha = \frac{1}{N} \sum_{i=1}^{h} (g_i)^\alpha \quad (9)$$

$$g_i = \left(\frac{z - y_i}{z}\right), \quad (10)$$

where *N* represents the number of sampled Nile perch fishers; *h* signifies the number of Nile perch fishers who overfish; z denotes the cut-off between overfishing and not overfishing (50 cm TL slot size of Nile perch); y_i represents the individual actual Nile perch average length in cm TL; and α denotes the FGT index, taking values 0, 1 and 2 to indicate overfishing incidence, depth and severity respectively.

Adopting the definitions of Foster *et al.* (1984) and Gao *et al*. (2015), we define overfishing as the percentage of Nile perch fishers (headcount from the sample) who on average caught Nile perch below the minimum slot size of 50 cm TL. Overfishing depth is defined as the extent (actual cm TL) to which the average Nile perch catch falls below the minimum slot size and is expressed as a percentage of the minimum slot size of 50 cm TL. Overfishing severity is defined as the weighted sum of overfishing gaps, i.e. the square of each fisher's overfishing gap, to assess how severe the rate of overfishing is. It also gives greater weight to fishers who fall far below the minimum slot size of 50 cm TL than to those who are closer to it.

4. Results and discussion

4.1 Socio-economic characteristics of the sample of Nile perch fishers

The socio-economic characteristics of the fishers are presented in Table 2 below.

The results presented in Table 2 show that the average age of the sampled Nile perch fishers was 36 years and the average number of years spent in formal education was seven, indicating that most of them had only a primary education. The fishers had an overall average fishing experience of 12 years, although fishers with more experience (13 years) were the ones who overfished. In addition, the results show that the average quantity of Nile perch catch per trip was 27 kg; fishers who overfished had larger fish catches (29 kg) than those who did not overfish (24 kg). The overall average crew size per trip was three, spending an average of nine fishing hours per trip. The overall average size of the mesh gillnet was 6.7 inches, while the average size of longline hooks was 11. Fishers who overfished had larger size hooks (11) than those who did not overfish (10). The overall average number of sampled fishers who used non-motorised boats was 56.7%; 63.7% of fishers who overfished used non-motorised boats versus the 46.3% who did not overfish. The overall average quantity of bait used per trip was 516. Fishers who overfished used 515 baits versus the 517 baits of fishers who did not overfish. The overall average number of mesh gillnets used per trip was two; fishers who overfished used less (1.9) than those who did not overfish (2.1). Fishers undertook an overall average number of five fishing trips per week. Furthermore, the overall average costs of bait used per trip was 63 177.24 TZS (27.7 USD). Fishers who did not overfish spent more money on bait, viz. 64 569 TZS (28.31 USD) than fishers who overfished, viz. 62 238 TZS (27.29 USD).

The results of the t-test show no statistically significant differences in most socio-economic, institutional and fishing effort characteristics of fishers who overfish and those who do not. A possible reason for this is that the majority of Lake Victoria's fishers do not own boats or fishing gear and are therefore hired by boat owners in different landing sites to fish for them, with the profits being divided among the crew and the boat owner (Odongkara *et al*. 2005, 2009). This assumption indicates that the same fishers can overfish or not, depending on the fishing gear allocated to them at a given time by the boat owner hiring their services. Therefore, for this study, Nile perch fishers were asked about the fishing gear that they were using at the time of the interview but also about the gear they use when hired by other boat owners. It was found that the majority of fishers were skilled in the use of both gillnets and hooks. This result is consistent with Nunan (2010), who found that most of the migrations of Lake Victoria's fishers are characterised by movement between landing sites in response to localised changes in fish productivity. Fishers use social networks to identify better fishing grounds and areas of higher fish prices. However, the most significant factors that are different between fishers who overfish and those who do not are the number of mesh gillnets and the cost of bait.

Table 2: Overall descriptive summary of variables used in estimations (n = 268)

		Overfishing = 1		Not overfishing = 0		Overall pooled data		
Variable	**Description**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**	**t-test (p-value)**
AGE		36.762	10.78	36.556	11.187	36.679	10.928	0.5603
EDU	Years spent in formal education system	7.43	1.399	7.556	1.578	7.481	1.472	0.2494
EXP	Years in Nile perch fishing	13.256	9.011	12.139	9.896	12.806	9.376	0.8302
MRT	Marital status of a fisher (1 = married, 0 otherwise)	1.875	0.384	1.907	0.350	1.888	0.370	0.2417
QTY	Quantity of catch per trip (kg)	29.445	27.726	24.144	24.808	27.405	26.716	0.9372
CST	Crew size per fishing trip	3.288	0.586	3.361	0.571	3.317	0.581	0.1548
HFT	Hours spent on fishing per trip	9.0126	9.169	9.673	4.289	9.278	7.588	0.2438
SGG	Size of mesh gillnet (inches)	6.75	0.847	6.870	1.006	6.799	0.914	0.1456
SGH	Size of longline baited hooks	11.075	1.426	10.926	1.125	11.015	1.312	0.8186
MOP	Mode of propulsion[1] (1 = non-motorised, 0 otherwise)	0.637	0.482	0.463	0.501	0.567	0.496	0.9977
BQT	Quantity of bait (hooks are baited with natural bait, e.g. small live fish, slices of meat, earthworms)	515.313	232.230	517.130	246.106	516.045	237.465	0.4756
NGT	Number of mesh gillnets	1.944	0.865	2.088	0.758	2.002	0.825	0.0804*
FTW	Number of fishing trips per week	5.075	1.707	5.148	1.645	5.104	1.679	0.3636
BCT	Costs of bait used per trip (in Tanzanian shillings)	62 237.52[2]	76 946.50	64 569.44	75 146.35	63 177.24	76 093.24	0.0637*

* statistically significant at 10%
Source: Estimated from sample survey data (2018)

[1] The actual number of Nile perch fishers who were using motorised boats was 116 versus the 152 who were using non-motorised boats.
[2] 1 USD = 2 281 Tanzanian shillings in August 2018.

4.2 Results of the endogenous switching regression model

The results of the estimation of the endogenous switching regression model are presented in Table 3. The estimations were implemented in STATA using the *movestay* command, following Lokshin and Sajaia (2004).

Table 3: Full information maximum likelihood estimates of the switching regression model

		FIML endogenous switching regression	
Variable	**Probit model for overfishing (1/0)**	**Overfishing = 1**	**Not overfishing = 0**
AGE	-0.007 (0.008)	-0.002 (0.006)	-0.002 (0.009)
EDU	-0.224 (0.053)***	0.114 (0.038)**	0.184 (0.051)***
EXP	-0.000 (0.009)	-0.002 (0.007)	0.001 (0.010)
MRT	-0.273 (0.177)	0.419 (0.129)***	0.032 (0.197)
QTY	0.007 (0.003)**	0.001 (0.002)	0.013 (0.003)***
CSW	-0.005 (0.120)	0.107 (0.087)	-0.060 (0.132)
HFT	-0.013 (0.009)	-0.002 (0.007)	0.047 (0.010)***
SGG	0.0279 (0.078)	0.007 (0.057)	-0.033 (0.085)
SGH	0.116 (0.049)**	-0.061 (0.036)*	0.098 (0.056)*
MOP	0.574 (0.149)***	-0.222 (0.109)**	0.468 (0.175)***
BQT	-0.000 (0.000)*	0.000 (0.000)	0.000 (0.000)
NGT	-0.157 (0.085)	0.024 (0.063)	-0.331 (0.099)***
FTW	0.022 (0.042)	-0.039 (0.031)	0.063 (0.047)
BCT	-0.166 (0.073)**	-0.001 (0.053)	-0.233 (0.081)***
Constant	2.958 (1.233)	11.347 (0.914)	12.814 (1.374)
/lns1	-0.311 (0.058)***		
/lns2	0.097 (0.089)		
/r1	-6.80 (1.088)***		
/r2	7.139 (1.375)***		
sigma_1	0.732 (0.042)		
sigma_2	1.103 (0.099)		
rho_1	- 0.9999975 (5.35e-06)***		
rho_2	0.9999987(3.47e-06)***		
LR test of independent equations: $chi^2(1) = 103.34$; Prob > $chi^2 = 0.0000$			

Notes: *, ** and *** denote 10%, 5% and 1% levels of significance respectively
Source: Estimated from sample survey data (2018)

The results indicate that the correlation coefficients of the two groups, *rho_1* and *rho_2*, are both statistically significantly different from zero. Since *rho_1* is negative, the model suggests that a fisher who overfishes would earn more income per fishing trip than a random fisher from the sample group. Likewise, since *rho_2* is positive, the model suggests that a fisher who does not overfish would earn less income per fishing trip than a random fisher from the sample group. The likelihood ratio test for the joint independence of the three equations is statistically significant, implying that the three models (probit and OLS of two groups) are not jointly independent and should not be estimated separately. Variables */lns1*, */lns2*, */r1*, and */r2* are ancillary parameters used in the maximum likelihood procedure. Moreover, s*igma 1* and *sigma 2* are the square roots of the variances of the residuals of the regression part of the model. In addition, */r1* and */r2* are the transformation of the correlation between the errors from the two equations of those who overfish and those who do not overfish.

4.3 Results of the determinants of Nile perch overfishing

The results of the selection model (probit) in column 2 of Table 3 show that the coefficient of education has a negative effect on the probability of Nile perch overfishing. This implies that fishers with a better education are likely to reduce the probability of overfishing because they are probably capable of better understanding and complying with fishery regulations. Also, the coefficient of the quantity of Nile perch catch per trip has a positive effect on the probability of Nile perch overfishing, implying that an increase in the quantity of Nile perch catch per trip will likely increase the chances of overfishing. The coefficient of longline hook size has a positive effect on the probability of Nile perch overfishing, indicating that the larger the size of the longline hook, the more likely it is that the probability of overfishing will increase. In addition, the coefficient of the mode of propulsion has a positive effect on the probability of Nile perch overfishing, which implies that an increase in the number of fishers who use non-motorised boats is likely to increase the probability of overfishing. The quantity of bait used per trip and bait cost per fishing trip also have a negative and significant effect on the probability of Nile perch overfishing.

4.4 Results of the determinants of Nile perch income per fishing trip

The results presented in columns 3 and 4 in Table 3 show that the coefficient of fishers' level of education is statistically significant and has a positive effect on income per fishing trip of both fishers who overfish and those who do not. This implies that fishers with a higher education are capable of earning more income per fishing trip, probably because education provides skills via which knowledge of the best fishing techniques can be generated for larger catches and hence more income. The coefficient of marital status of fishers who overfish was also found to be statistically significant and positively related to income per fishing trip. The reason may be that Lake Victoria is surrounded by fishing-dependent societies, therefore a married fisher will overfish to increase the catch to obtain a larger income in order to meet the household's needs. The coefficient of quantity of Nile perch catch per fishing trip was also found to be significant and had a positive influence on the fishing income per trip for fishers who do not overfish. The reason may be that fishers who do not overfish catch larger fish (more weight, in kg) within the slot size, leading to increased income.

The coefficient of fishing hours per trip was found statistically significant and had a positive influence on income from fishing per trip for those who do not overfish. A possible reason may be that, in order to fish within the slot size, fishers are required to sail for long distances to reach an adequate depth in the lake. This takes time and, once they arrive at the fishing ground, they spend more time waiting for the catch. The coefficient of size of mesh gillnet was found to be statistically significant for both fishers who overfish and those who do not. However, for fishers who overfish, the size of mesh gillnet was negatively related to the fishing income per trip, implying that the larger the size of mesh gillnet, the lower the fishing income per trip. The reason may be that fishers who overfish target more of their catch in the near inshore waters, irrespective of the size, hence a large mesh size may not catch smaller sized fish. On the other hand, for fishers who do not overfish, the size of mesh gillnet was positively related to the fishing income per trip. This result implies that the larger the size of the mesh gillnet, the larger the fish caught within the slot size and, as they have more weight, it leads to a higher fishing income per trip.

The coefficient of mode of propulsion was statistically significant for both fishers who overfish and those who do not. However, for fishers who overfish, the mode of propulsion was negatively related to the fishing income per trip. This implies that the fishing income per trip decreases with the continued use of non-motorised boats. On the other hand, the mode of propulsion was positively related to fishing income per trip for fishers who do not overfish. A possible reason for this is that the majority of fishers who do not overfish tend to use motorised boats to sail for longer distances, and hence it is possible for the income per fishing trip to increase due to the larger catch from the deep parts of the lake.

The coefficient of the number of hooks used per fishing trip by fishers who do not overfish was statistically significant and negatively related to the income per fishing trip. This suggests that an increasing number of hooks per fishing trip reduces the income per fishing trip. A possible reason for this is that more hooks require longlines, making it difficult to manage large fishes, resulting in low catches and income per fishing trip. Lastly, the coefficient of cost of bait used per trip by fishers who do not overfish was statistically significant and negatively related to the income per fishing trip. This suggests that, with an increase in the cost of bait used per fishing trip, the income per fishing trip reduces. This may be because increasing bait costs imply increasing operational costs per trip, which reduces the income per fishing trip for fishers who do not overfish.

4.5 Results of average treatment and untreated effects

The results of average treatment and untreated effects are presented in Table 4.

Table 4: Treatment and heterogeneity effects

	Probability		Treatment (*return*) effects
	To overfish	Not to overfish	
Expected income of Nile perch fishers who overfish	13.03	11.96	1.07 (0.04)***
Expected income of Nile perch fishers who do not overfish	11.68	13.97	-2.30 (0.04)***
Heterogeneity (*level*) effects	1.35***	-2.01***	3.36***

*** statistically significant at 1%

The result of the treatment effect, measured by the switching regression model, indicates that fishers who overfish have a positive and significant effect on the log income per fishing trip versus fishers who do not overfish. It is clear from this result that the mean income per fishing trip of fishers who overfish is 1.07,[3] while that of fishers who do not overfish is -2.30.[3] This is equivalent to an increase in income of 192%, i.e. 411 644 TZS (180.47 USD),[4] per fishing trip for fishers who overfish and a decrease of 89.97%, i.e. 210 147 TZS (92.13 USD), for fishers who do not overfish. On the other hand, the transitional heterogeneity effect on income per fishing trip is positive, which indicates that the effect is bigger for fishers who overfish than for fishers who do not overfish. The reason may be that fishers who overfish rather target a catch of different composition (small and large) so as to maximise their income. They can catch more by purposely using illegal fishing gear and violating several fishery regulations. This result is consistent with Cowx *et al*. (2003), Odada *et al*. (2004), Matsuishi *et al*. (2006) and Geheb *et al*. (2008), who found that, due to poorly regulated fishery regulations, fishers move towards smaller meshed nets, outlawed fishing techniques and the use of illegal gear that exploit smaller fish. In addition, since the majority of fishers use non-motorised boats, fishers may not be able to sail more than 5 km for a more diversified catch composition. This result supports the findings of Cabral and Geronimo (2018), namely that the lack of motorised boats in small-scale fishing suggests that fishers are highly dependent on easily accessible fish catches in the near inshore[5] waters of the lake.

4.6 Nile perch slot size and sensitivity analysis

The results of the FGT index for overfishing are presented in Table 5. In order to understand the relationship between the slot size and the income per fishing trip, a sensitivity analysis was done by adjusting the slot size, i.e. in turn increasing and decreasing the slot size by 5% and then comparing the results with the income per fishing trip.

[3] Since the values for income per fishing trip were log-transformed, following Asfaw *et al.* (2012), the exact percentage difference is given by $100(e^{ATT} - 1)$ and $100(e^{ATU} - 1)$ respectively, where e is the exponential natural logarithm, ATT is the average treatment effect and ATU is the average treatment effect of the untreated, both provided by the analysis of the log-transformed variable.
[4] 1 USD = 2 281 Tanzanian shillings in August 2018.
[5] Inshore waters represent the lake water that serves as breeding and nursery grounds for most fish in the lake, thereby comprising fish recruitment (Njiru *et al*. 2005; Aloo *et al.* 2017).

Table 5: FGT overfishing index and sensitivity analysis

Overfishing	Current slot size	Sensitivity analysis	
		i. 5% increase	ii. 5% decrease
	50 cm TL	**52.5 cm TL**	**47.5 cm TL**
Incidence	59.701	99.9	38.806
Depth	6.052	10.526	3.456
Severity	0.839	1.537	0.422
Overfishing average income per trip	214 398	225 118	203 678
Not-overfishing average income per trip	171 975	180 574	163 376
Overall average income per trip	189 070	198 523	179 617

Source: Estimated from sample survey data (2018)

The results presented in Table 5 show that, with the current minimum slot size of 50 cm TL, overfishing incidence, depth and severity based on the FGT index are 60%, 6% and 0.8% respectively. Moreover, within the recommended minimum slot size of 50 cm TL, the overall average income of fishers who overfish and those who do not is 189 070 TZS (82.89 USD). This implies that the proportion of fishers who overfish below the minimum slot size of 50 cm TL is higher, while the overfishing intensity and the degree of severity is low. This result is consistent with studies by Medard (2015) and Kayanda *et al*. (2017), who point out that there has been a significant increase in fishing pressure in Lake Victoria. However, the sensitivity analysis shows that an increase of 5% in the minimum slot size (alternative i) (i.e. from 50 cm to 52.5 cm TL) will increase the overfishing incidence from 60% to 99.9%, while the depth, severity and fishing income per trip will increase from 0.8% to 2%, 6% to 11% and 189 070 TZS (83 USD) to 198 523 TZS (87 USD) respectively. This result suggests that, if the minimum slot size is increased, fishers will benefit more by having more income per fishing trip; however, the intensity of overfishing will increase as well.

On the other hand, a decrease of 5% in the minimum slot size (alternative ii) (i.e. from 50 cm to 47.5 cm TL) will cause a decrease from 60% to 39% in overfishing incidence, while the depth, severity and fishing income per trip will decrease from 6% to 3%, 0.8% to 0.4% and 189 070 TZS (82 USD) to 179 617 TZS (78.74 USD) respectively. This result suggests that, if the minimum slot size is decreased, the income of fishers will be reduced but the intensity of overfishing will decrease as well.

5. Conclusions

This study evaluated the potential impact of Nile perch overfishing on fishers' income in Lake Victoria, Tanzania. The study used cross-sectional data collected from January to March 2018 via a baseline survey among 268 Nile perch fishers, a randomly selected sample across ten landing sites along Lake Victoria. The endogenous switching regression model was also used to measure the causal impact of Nile perch overfishing on fishers' income per fishing trip. This model was used due to its ability to control the selection problem between the two groups, i.e. fishers who overfish and those who do not, and each group's effect on fishing income per trip.

The study concludes the following: a) that different socio-economic, institutional and fishing effort factors influence the probability of Nile perch overfishing; b) that Nile perch fishers who overfish have systematically different socio-economic, institutional and fishing effort characteristics than fishers who do not overfish. These differences confirm the variation between the two groups as per the OLS model used in the study; c) that the results of the switching regression model suggest that Nile perch fishers who overfish earn significantly higher income per fishing trip than fishers who do not overfish, even after controlling for all the confounding factors; d) that the sensitivity results of the FGT index for overfishing suggest that, if the minimum slot size is increased, the fishing income per trip will increase. However, this will be at the expense of increasing pressure on and intensity of overfishing. Likewise, if the minimum slot size is decreased, the fishing income per trip will reduce but at the expense of decreasing pressure on and intensity of overfishing.

In order to address these issues, policy makers should develop policies that acknowledge the dynamics of socio-economic, institutional and fishing effort factors, such as fishers' level of education, the quantity of Nile perch catch per trip, the size of mesh gillnets, the mode of propulsion and the cost of bait used per trip, in order to reduce the chances of Nile perch overfishing. In addition, a more flexible restriction on fish quotas and consistent fishing patrols to control and ensure adherence to fishery regulations should be emphasised, as this will help to eliminate the gap between fishers who overfish and those who do not. Moreover, with regard to the slot size sensitivity analysis of the two alternatives, (i) and (ii), in Table 5, policy makers can develop a policy based on the objectives to increase fishers' livelihoods by reducing their income poverty, or reducing overfishing and promoting sustainable fishery resource management. However, the policies have different outcomes; for instance, when focusing on sustaining fishery resources and neglecting fishers' livelihoods, it is likely that the extent of overfishing will increase as fishers will strive to sustain their livelihood through illegal fishing practices. Likewise, if policies focus on eradicating fishers' income poverty and neglect the lake's sustainability, it is likely that the lake's resources will be at risk of future depletion. Therefore, it is important that the policies that are developed should balance the two scenarios, i.e. sustaining the lake's resources while improving the livelihoods of fishers.

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References

Abbas AM & Ahmed B, 2016. Poverty reduction potential of fish farming in Ondo State, Nigeria. Scientia 14(3): 306–13.

Acere TO, 1985. Observations on the biology, age, growth, maturity and sexuality of Nile perch, *Lates niloticus* (Linne) and the growth of its fishery in the northern waters of Lake Victoria. FAO Fisheries Report 335, 42–61.

Akpalu W & Normanyo AK, 2014. Illegal fishing and catch potentials among small-scale fishers: Application of an endogenous switching regression model. Environment and Development Economics 19(2): 156–72.

Aloo PA, Njiru J, Balirwa JS & Nyamweya CS, 2017. Impacts of Nile perch, *Lates niloticus*, introduction on the ecology, economy and conservation of Lake Victoria, East Africa. Lakes and Reservoirs: Research and Management 22(4): 320–33.

Amankwah A, Quagrainie KK & Preckel PV, 2018. Impact of aquaculture feed technology on fish income and poverty in Kenya. Aquaculture Economics and Management 22(4): 1–21.

Asfaw S, Shiferaw B, Simtowe F & Lipper L, 2012. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. Food Policy 37(3): 283–95.

Balirwa JS, Chapman CA, Chapman LJ, Cowx IG, Geheb K, Kaufman L, Lowe-McConnell RH, Seehausen O, Wanink JH, Welcomme RL & Witte F, 2003. Biodiversity and fishery sustainability in the Lake Victoria basin: An unexpected marriage? AIBS Bulletin 53(8): 703–15.

Bavinck M, 2009. Interactive governance and the wellbeing of the coastal poor. Paper prepared for the ESPA Workshop 1 on Building Capacity for Sustainable Governance in South Asian Fisheries: Poverty, Wellbeing and Deliberative Policy Networks, 4 April, Institute for Ocean Development, Chennai, India.

Béné C, 2003. When fishery rhymes with poverty: A first step beyond the old paradigm on poverty in small-scale fisheries. World Development 31(6): 949–75.

Béné C, 2009. Are fishers poor or vulnerable? Assessing economic vulnerability in small-scale fishing communities. The Journal of Development Studies 45(6): 911–33.

Béné C & Friend RM, 2011. Poverty in small-scale fisheries: Old issue, new analysis. Progress in Development Studies 11(2): 119–44.
Béné, C, Bennett E & Neiland A, 2004. The challenge of managing small-scale fisheries with reference to poverty alleviation. In Bene C & Neiland A (eds), Poverty and small-scale fisheries in West Africa. Dordrecht: Springer.
Béné C, Steel E, Luadia BK & Gordon A, 2009. Fish as the "bank in the water" – Evidence from chronic-poor communities in Congo. Food Policy 34(1): 108–18.
Bose ML & Dey MM, 2007. Food and nutritional security in Bangladesh: Going beyond carbohydrate counts. Agricultural Economics Research Review 20(2): 203–25.
Cabral RB & Geronimo RC, 2018. How important are coral reefs to food security in the Philippines? Diving deeper than national aggregates and averages. Marine Policy 91: 136–41.
Carbonetti B, Pomeroy R & Richards DL, 2014. Overcoming the lack of political will in small scale fisheries. Marine Policy 44: 295–301.
Cinner JE, McClanahan TR, MacNeil MA, Graham NAJ, Daw TM, Mukminin A, Feary DA, Rabeariso AL, Wamukota A, Jiddawi N, Campbell SJ, Baird AH, Januchowski-Hartley FA, Hamed S, Lahari R, Morove T & Kuange J, 2012. Co-management of coral reef social-ecological systems. Proceedings of the National Academy of Sciences 109(14): 5219–22.
Coulthard S, Johnson D & McGregor JA, 2011. Poverty, sustainability and human wellbeing: A social wellbeing approach to the global fisheries crisis. Global Environmental Change 21(2): 453–63.
Cowx IG, Van der Knaap M, Muhoozi LI & Othina A, 2003. Improving fishery catch statistics for Lake Victoria. Aquatic Ecosystem Health and Management 6(3): 299–310.
Di Falco S, Veronesi M & Yesuf M, 2011. Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. American Journal of Agricultural Economics 93(3): 829–46.
Dube AK, Haji J & Zemedu L, 2018. Determinants of food insecurity and coping strategies of rural households: The case of Shalla District, West Arsi Zone, Oromia Region, Ethiopia. Journal of Development and Agricultural Economics 10(6): 200–12.
Eggert H & Ellegård, A. 2003. Fishery control and regulation compliance: A case for co-management in Swedish commercial fisheries. Marine Policy 27(6): 525–33.
FAO, 2005. Increasing the contribution of small-scale fisheries to poverty alleviation and food security. FAO Technical Guidelines for Responsible Fisheries No. 10, Rome, Italy.
Foster J, Greer J & Thorbecke E, 1984. A class of decomposable poverty measures. Econometrica 52: 761–6.
Gao Q, Yang S & Li S, 2015. Welfare, targeting, and anti-poverty effectiveness: The case of urban China. The Quarterly Review of Economics and Finance 56: 30–42.
Geheb K, Kalloch S, Medard M, Nyapendi AT, Lwenya C & Kyangwa M, 2008. Nile perch and the hungry of Lake Victoria: Gender, status and food in an East African fishery. Food Policy 33(1): 85–98.
Jaleta M, Kassie M & Marenya P, 2015. Impact of improved maize variety adoption on household food security in Ethiopia: An endogenous switching regression approach. International Conference of Agricultural Economists, August, Milan, Italy.
Kayanda RJ, Chande AI, Mgaya YD, Mlaponi E & Mkumbo OC, 2017. Stock assessment of commercial fish species of Lake Victoria. In Mgaya YD & Mahongo SB (eds.), Lake Victoria fisheries resources: Research and management in Tanzania. Cham: Springer.
Khonje M, Manda J, Alene AD & Kassie M, 2015. Analysis of adoption and impacts of improved maize varieties in eastern Zambia. World Development 66: 695–706.
Kolding J, Modesta M, Mkumbo O & Van Zwieten, PAM, 2014. Status, trends and management of the Lake Victoria fisheries. In Inland fisheries evolution and management. Case studies from four continents, FAO Report No. 579, FAO, Rome.
Kudhongania AW, Twongo T & Ogutu-Ohwayo G, 1992. Impact of the Nile perch on the fisheries of Lakes Victoria and Kyoga. Hydrobiologia 232(1): 1–10.
Lokshin M & Sajaia Z, 2004. Maximum likelihood estimation of endogenous switching regression models. Stata Journal 4: 282–9.

Lowe-McConnell R, 2010. The changing ecosystem of Lake Victoria, East Africa. Freshwater Forum 4(2): 76–89.
Maddala GS, 1983. Limited dependent and qualitative variables in econometrics. Cambridge, UK: Cambridge University Press.
Martin SM, Lorenzen K & Bunnefeld, N, 2013. Fishing farmers: Fishing, livelihood diversification and poverty in rural Laos. Human Ecology 41(5): 737–47.
Matsuishi T, Muhoozi L, Mkumbo O, Budeba Y, Njiru M, Asila A, Othina A & Cowx, IG, 2006. Are the exploitation pressures on the Nile perch fisheries resources of Lake Victoria a cause for concern? Fisheries Management and Ecology 13(1): 53–71.
McClanahan T, Allison EH & Cinner JE, 2015. Managing fisheries for human and food security. Fish and Fisheries 16(1): 78–103.
McGregor JA, 2009. Human wellbeing in fishing communities. Paper prepared for the ESPA Workshop 1 on Building Capacity for Sustainable Governance in South Asian Fisheries: Poverty, Wellbeing and Deliberative Policy Networks, 4 April, Institute for Ocean Development, Chennai, India.
Medard M, 2015. A social analysis of contested fishing practices in Lake Victoria, Tanzania. Doctoral dissertation, Wageningen University, Wageningen, The Netherlands.
Msuku BS, Mrosso HDJ & Nsinda PE, 2011 A critical look at the current gillnet regulations meant to protect the Nile perch stocks in Lake Victoria. Aquatic Ecosystem Health and Management 14(3): 252–9.
Nigussie Z & Alemayehu, G, 2013. Levels of household food insecurity in rural areas of Guraghe Zone, Southern Ethiopia. Journal of Agricultural Research 2(1): 8–14.
Njiru M, Van der Knaap M, Taabu-Munyaho A, Nyamweya CS, Kayanda RJ & Marshall BE, 2014. Management of Lake Victoria fishery: Are we looking for easy solutions? Aquatic Ecosystem Health and Management 17(1): 70–9.
Njiru M, Waithaka E, Muchiri M, Van der Knaap M & Cowx IG, 2005. Exotic introductions to the fishery of Lake Victoria: What are the management options? Lakes & Reservoirs Research & Management 10(3): 147–55.
Nkalubo W, Chapman L & Muyodi F, 2014. Feeding ecology of the intensively fished Nile perch, *Lates niloticus*, in Lake Victoria, Uganda. Aquatic Ecosystem Health and Management 17(1): 62–9.
Ntiba MJ, Kudoja WM & Mukasa CT, 2001. Management issues in the Lake Victoria watershed. Lakes and Reservoirs Research and Management 6(3): 211–6.
Nunan F, 2010. Mobility and fisherfolk livelihoods on Lake Victoria: Implications for vulnerability and risk. Geoforum 41(5): 776–85.
Nunan F, 2014. Wealth and welfare? Can fisheries management succeed in achieving multiple objectives? A case study of Lake Victoria, East Africa. Fish and Fisheries 15(1): 134–50.
Nunan F, Hara M & Onyango P, 2015. Institutions and co-management in East African inland and Malawi fisheries: A critical perspective. World Development 70: 203–14.
Nyeko JI, 2004. Co-management and value chains: The role of Nile perch exports in poverty eradication in Lake Victoria fishing communities. United Nations University Fisheries Training Programme – Project Report, Reykjavik, Iceland.
Odada EO, Olago DO, Kulindwa K, Ntiba M & Wandiga S, 2004. Mitigation of environmental problems in Lake Victoria, East Africa: Causal chain and policy options analyses. Ambio: A Journal of the Human Environment 33(1): 13–23.
Odongkara K, Abila RO & Luomba J, 2009. The contribution of Lake Victoria fisheries to national economies. African Journal of Tropical Hydrobiology and Fisheries 12(1): 47–51.
Odongkara K, Abila R & Onyango P, 2005. Distribution of economic benefits from the fisheries of Lake Victoria. The State of the Fisheries Resources of Lake Victoria and their Management: Proceedings of the Entebbe Regional Stakeholders' Workshop, 24–25 February, Entebbe, Uganda.
Ogari J, 1985. Distribution, food and feeding habitats of *Lates niloticus* in Nyanza Gulf of Lake Victoria (Kenya). FAO Fisheries Report 335: 68–80.

Ogello EO, Obiero K & Munguti JM, 2013. Lake Victoria and the common property debate: Is the tragedy of the commons a threat to its future? Lakes Reservoirs and Ponds 7(2): 101–26

Ogutu-Ohwayo R, 1990. The decline of the native fishes of lakes Victoria and Kyoga (East Africa) and the impact of introduced species, especially the Nile perch, *Lates niloticus*, and the Nile tilapia, *Oreochromis niloticus*. Environmental Biology of Fishes 27(2): 81–96.

Ogutu-Ohwayo R, 1999. Deterioration in length–weight relationships of Nile perch, *Lates niloticus* L. in lakes Victoria, Kyoga and Nabugabo. Hydrobiologia 403: 81–6.

Ogutu-Ohwayo R, 2004. Management of the Nile perch, *Lates niloticus* fishery in Lake Victoria in light of the changes in its life history characteristics. African Journal of Ecology 42(4): 306–14.

Olale E & Henson S, 2013. The impact of income diversification among fishing communities in Western Kenya. Food Policy 43: 90–9.

Omwega RN, Abila RO & Lwenya C, 2006. Fishing and poverty levels around Lake Victoria (Kenya). In Odada E & Olago DO (eds.), Proceedings of the 11th World Lakes Conference 2: 178–85.

Onyango PO, 2011. Occupation of last resort? Small-scale fishing in Lake Victoria, Tanzania. In Jentoft S & Eide A (eds), Poverty mosaics: realities and prospects in small-scale fisheries. Dordrecht: Springer.

Onyango P & Jentoft S, 2010. Assessing poverty in small-scale fisheries in Lake Victoria, Tanzania. Fish and Fisheries 11(3): 250–63.

Sinyolo S & Mudhara M, 2018. The impact of entrepreneurial competencies on household food security among smallholder farmers in KwaZulu Natal, South Africa. Ecology of Food and Nutrition 57(2): 71–93.

Solaymani S & Kari F, 2014. Poverty evaluation in the Malaysian fishery community. Ocean and Coastal Management 95: 165–75.

Taabu-Munyaho A, Marshall BE, Tomasson T & Marteinsdottir G, 2016. Nile perch and the transformation of Lake Victoria. African Journal of Aquatic Science 41(2): 127–42.

Weeratunge N, Béné C, Siriwardane R, Charles A, Johnson D, Allison EH, Nayak PK & Badjeck MC, 2014. Small-scale fisheries through the wellbeing lens. Fish and Fisheries 15(2): 255–79.

Witte F, Goldschmidt T, Wanink J, Van Oijen M, Goudswaard K, Witte-Maas E & Bouton N, 1992. The destruction of an endemic species flock: Quantitative data on the decline of the haplochromine cichlids of Lake Victoria. Environmental Biology of Fishes 34(1): 1–28.

Yongo E, Outa N, Kito K & Matsushita Y, 2017. Some aspects of the biology of Nile perch, *Lates niloticus*, in the open waters of Lake Victoria, Kenya. Lakes and Reservoirs: Research and Management 22(3): 262–6.