# Role of policies in the sustainability of fish species in Lake Victoria: A pathway to the green economy in Tanzania

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*Abstract:* - Tanzania has made efforts to transit to a green economy through policies, among other instruments that the country identifies to have green economy elements. This work studies the effectiveness of fishery policies in achieving green economy transitions in the country using the presence of Beach Management Units (BMUs) in the fishing site as a major policy element, acknowledging other control variables. The study uses cross-sectional data from the districts around Lake Victoria, which is the major fish zone of the country, to determine the impact of policies on the sustainability of the dominant species in the lake. Results from multiple linear regression analysis indicate that the presence of BMUs in the fishing site has a positive significant effect on the abundance of Nile perch and sardine (*dagaa)* species while having an insignificant impact on the abundance of other species. The work concluded that policies are siding on the Nile perch and sardines because of their economic importance. Therefore, the study recommends more studies on the maintenance of sustainability and productivity of the stock in the lake, as well as reforming policies that accommodate all species and important sectors.

*Key-Words:* - policies, green economy, fishery species, sustainability, Lake Victoria,

## 1 Introduction

The green economy concept focuses on how to achieve economic growth and growth in environment-dependent sectors without harming the environment [1, 2]. The term green is analyzed based on sustainability of three sectors that are; environmental (sustainability of natural resources), economic and social well-being of the people [3-5]. The concept came out with initiatives, programs, and projects that ensure sustainable consumption of natural resources. For the case of developing regions as sub-Sahara Africa, more attention has been made on renewable natural resources due to the region's unique features of high dependence on the resource.

Fishery resources are among of the resources that were highly exploited in the area. In past decades, these resources were mentioned to be renewable natural resources, environment-dependent that were exploited unsustainably in the region [6, 7]. Moreover, the demands for fish and fishery products were also expected to increase in the future due to population growth in the region and other developing countries [8]. Based on that, responsible authorities took actions to conserve the resources. In recent years, management of the fishery has been incorporated into different sustainable development pathways such as green economy initiatives to restore its ecology and value [9-12].

According to Asche, Garlock [13], the ecological approach to sustainability in fishery resources mainly focuses on the healthy state of the ecosystem; and therefore, often measured by the strong ecological health. As a result, will increase economic profits for fishers and country; also improve the social wellbeing of the surrounding fishing communities. Actions done to maintain fish stock will also improve and ensure the sustainability of the ecosystem balance in the water bodies. Therefore, the main aim is achieved through reduction in overcapacity as well as investment in the rebuilding of fish stocks [10].

Tanzania as one of the developing countries with abundant fishery resources, has also made an effort to ensure the sustainability of the resources through different policies [14]. On the implementation of the policies, the government is also implementing the green economy initiative [15]. As the government indicates that green economy transitions in the country may be achieved through other implementations that have the elements as policies [16], with no specific green economy strategy or policy. Thus, this study aims to provide the impact of the fishery policies in protecting the ecosystems as an objective of green economy transitions by studying the impact of the major policies elements, on the abundance of important fish species in the lake zone of Tanzania.

Lake Victoria is the largest freshwater tropical lake in the world, and source of the world's largest freshwater [17], with a total surface area of 68 800 km$^2$ [18]. The lakeside of Tanzania is the most fishery active area in the country, providing more than three-quarters of the fishes and fishery products (figure 1).

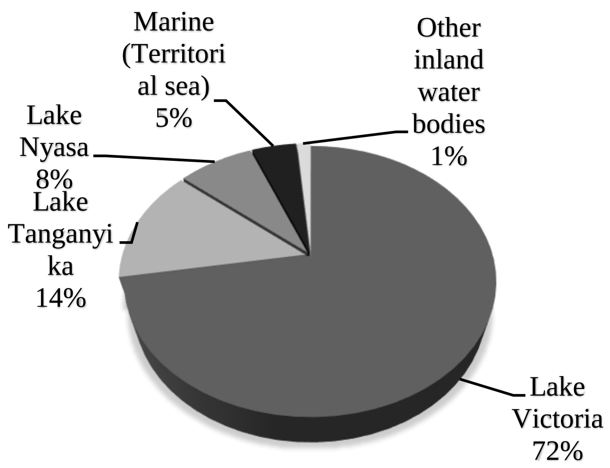


**Fig 1**: Estimated fish Biomass from different water bodies in Tanzania. Source: [14]

The current fisheries of Lake Victoria have a significant economic contribution in Tanzania as it contributes over 60% of the total fishery contribution [19, 20]. The Lake Victoria basin is one of the most densely populated regions in Africa [21] supporting livelihoods of millions of people by providing formal and informal employments to surrounding communities [22, 23]. With all these, the state of Lake Victoria's fisheries has to be a matter of great concern to management authorities, and therefore it is of importance to know the achievement of established management plans such as policies and regulation. Taking into consideration that The lake is reported to have depletion of the fish stocks [24], caused by overfishing to meet increasing local, regional and global demand for the lake fish and its by-products. [25]. Studying the effectiveness of the implemented policies in achieving the targeted goals will provide decision-makers with necessary knowledge that will enable them to understand better the policies and act accordingly. Thus, carefully manage the resource for the sustainable use of current and future generations.

Therefore this work intends to analyze the achievement of the policies in maintaining the sustainability of fishery resources by studying the three groups of fish species in the lake; that are Nile perch (*Lates niloticus*), a native sardine-like cyprinid locally called *Dagaa* (*Rastrineobola argentea*) and other species. Nile perch and *Dagaa* have been chosen because Nile perch is the highest valued species in the lake's fishery [26], and *Dagaa* is the most important catch from the lake in terms of weight [27-29]. The study uses cross-sectional data of the districts surrounding the lake.

# 2 Methodology

## 2.1 Study area

Lake Victoria is located at latitude 31°39' E–34°53' E and at longitude 0°20' N–3°S, 1135m above mean sea level. The lake is bordered by Kenya (6%) to the East, Uganda (43%) to the North-West and Tanzania (51%) to the South [30], with a catchment area of 184,000 km$^2$ [31]. Lake Victoria basin has an estimated volume of about 2750 km$^2$, and an average and maximum depth of 40 m and 80 m, respectively [32]. The climate of the Lake Victoria basin is generally tropical humid, with temperatures ranging from 15 $^0$C, in the highlands, to 28 $^0$C, in the semi-arid areas [33]. The mean annual rainfall varies from 886 mm to 2600 mm; the mean evaporative rate over the Lake is in the range 1100–2040 mm, which decreases with increasing altitude, but in some months exceeds rainfall [34].

In Tanzania, the lake is surrounded by five regions that are Mwanza with the largest part, kagera, Mara, Geita and Simiyu with the smallest part [35]. The major rivers draining into, and forming up part of, the Lake Victoria basin, based on geopolitical sources, are Mara, Kagera, Grumeti, Issanga, Mirongo, Mbalageti and Simiyu (Tanzania) [34].

## 2.2 Data and methods

Generally, the overall goal of both Tanzania National Fisheries Policy and Fishery act of 2015 and 2003 respectively, is to promote conservation, development and sustainable management of the Fisheries Resources for the benefit of present and future generations. [14, 36]. In support of the implementation and the agreement done by the countries surrounding Lake Victoria, the fisheries Act No. 22 of 2003 has led to the reformation of Beach Management Units (BMUs) in 2006, with all fishermen incorporated in the system [37]. Through this, the government and the riparian communities share responsibilities and authority in the management of the fisheries resources [29].

The reformation of BMUs were also supported by the principal Fisheries regulation of 2009 and have clear operational guidelines and institutional framework in the National BMU Guideline. The BMU guideline supports the national government development objective of sustainable use of natural resources and livelihood of people dependent upon these resources through empowering the fisheries communities in fisheries planning, management, and development [38]. The policies also have encouraged and promote recruitment of more staff with enough knowledge to ensure all the regulations and laws are well enforced, the control of fish and fish products, and provide education and necessary assistance [36]. Thus, this study uses number fishing sites with BMUs and the number of fishing staff as determinants of fishery abundance with the policy elements.

Also, interactions between and within fish species determine their abundance. Feeding interactions connect all species within an ecosystem to each other. Because of these connections, the population dynamics of one species can affect the dynamics of many other species [25]. Understanding these interactions can provide a context for interpreting stock assessment results. For example, Nile perch leave mainly on feed on other fish species like tilapia, *dagaa*, and haplochromines [39]. Therefore, the interaction of the species is also incorporated in the study.

Population growth is indicated to increase burden on the limited and continually degrading natural resources [40]. Even though natural resources are under increasing strain, human population growth tends to accelerate the rate of extinction. Lake Victoria has experienced extreme ecological stresses over the past century from different anthropogenic activities, influenced mainly by population growth, which includes intense fishing and increased industrial pollution [22, 41]. The direct impacts of higher human populations will likely increase demand for fish, also driving an increase in the number of people seeking to make a living from fishing [42], and thus putting the fishery resources at a vulnerable state. Ostrom [43] observed that the worsening ecological conditions of Lake Victoria are due often to increased human activity seeking for better livelihood options. Also, if other livelihood options are not working could drive more people to seek a living from fishing, thereby increasing fishing effort even further. Based on that, Human population's impact on the fish has also been analyzed.

## 2.3 Multiple linear regression analysis (MLRA)

Multiple linear regression analysis (MLRA) is among the most widely used statistical techniques to understand the relationship between several independent variables and a dependent variable, as explained by Abdipour, Younessi-Hmazekhanlu [44]. The general expression for standard MLRA is given by:

$$Y = \beta_0 + \beta_1 X_1 + \ldots \beta_n X_n + \varepsilon \quad (1)$$

Where Y is the dependent variable, x and n are independent variables, $\beta_s$ are the coefficients, and ε is the random error.

Therefore based on the backdrop, this study uses multiple linear regression analysis to determine the impact of BMUs, number of professional fishery staffs, amount of fishes caught in the district, population density, and interactions among the fish species on abundance of the dominants species in the lake. The study uses fish abundances of the three groups of fish species of 20 districts around the lake. Data are from Tanzania National Bureau of Statistics, ministry of natural resources and tourism, Tanzania fishery Research Institute (TAFIRI)-Mwanza centre, and respective districts in the lake zone.

Following the research and theoretical basis of this study, the model specification for the analysis is shown in equation 2:

$$F_i = \beta_0 + \beta_1 F_j + \beta_2 BMUs + \beta_3 CAS + \beta_4 staff + \beta_5 Pop + \varepsilon \quad (2)$$

Where:

- F is fish stock of *i* fish species in the district in metric tons
- BMUs is the number of fishing sites with BMUs in the district
- Staff is the number of professional fishery staff the district
- CAS is the amount of fishes caught in the district in metric tons
- $F_j$ is the fish stock of $j$ fish species that impact *i* fish species.
- *Pop* is the population density in $i$ district measured by a number of inhabitants in $km^2$
- and $\varepsilon$ is the error term.

# 3 Results

## 3.1 Descriptive statistics

Description of data is required to know the average rate of the data, including the variation of the variables around their averages, as well as to know the distribution pattern of the investigated variables. Table 1 describes the descriptive analysis of the variables. The descriptive analysis shows several statistics of all the variables in this study.

### 3.2 Preliminary Analyses

A correlation matrix was done to determine perfect relationships among the independent variables. Results are showing that a number of professional fishery staff is highly correlated with BMUs and the human population in the district at a 0.05 level of significance (table 2). This might be because the presence of BMUs in the fishing sites may lead to increasing number of professional staff to ensure the implementation of the regulations and policies; therefore, BMUs will reflect the same results as number of professional staff would. Moreover, a higher human population reflects a high number of fishers and, therefore staffs to manage and assist them. These results indicate a sign of multicollinearity, and this was confirmed by the after regression variation inflation factor (VIF) test whose values were higher than 10. Based on that, number of professional staff was removed from the regressors.

Table 1: Summary statistics of the variables

| | Variables | Description and measuring type | Mean | SD | Variable type |
|---|---|---|---|---|---|
| Dependent variables | Nile Peach | Nile perch stock in metric tons per square kilometre | 8.03 | .92 | Continuous |
| | Sardines | The stock of Sardines in metric tons per square kilometer | 8.11 | 1.64 | Continuous |
| | Others | The stock of Haplochromines and other species in metric tons per square kilometer | 7.46 | 1.08 | Continuous |
| Independent variable | Staff | Number of fishery profession staff in the district | 2.89 | 1.24 | Continuous |
| | BMUs | Number of fishing sites with Beach Management Units | 2.92 | 1.12 | Continuous |
| | Population | population density in *i* district measured by a number of inhabitants per square kilometre | 12.64 | .43 | Continuous |
| | Catches of Niles perch | Nile perch fishes caught in metric tons. | 16.35 | .94 | Continuous |
| | Catches of sardines | sardines caught in metric tons | 16.53 | 1.75 | Continuous |
| | Catches of other fishes | Haplochromines and other species caught in metric tons | 16.48 | 1.16 | Continuous |

Table 2: Correlation matrix of the variables

| SN | variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Nile perch | 1 | | | | | | | | |
| 2 | Sardine | 0.689* | 1 | | | | | | | |
| 3 | Others | 0.269 | 0.115 | 1 | | | | | | |
| 4 | Staff | 0.590* | 0.505* | 0.484* | 1 | | | | | |
| 5 | BMUs | 0.613* | 0.567* | 0.509* | 0.954* | 1 | | | | |
| 6 | Population | 0.172 | 0.136 | 0.621* | 0.600* | 0.491 | 1 | | | |
| 7 | Catches of Nile | 0.860* | 0.474* | 0.255 | 0.360 | 0.372 | 0.114 | 1 | | |
| 8 | Catches of Sardines | 0.718* | 0.743* | 0.126 | 0.319 | 0.365 | 0.135 | 0.784* | 1 | |
| 9 | Catches of Others | 0.178 | 0.203 | 0.582* | 0.124 | 0.212 | 0.252 | 0.073 | 0.038 | 1 |

*P<0.05

### 3.3 Factors affecting Nile perch species' population

Results are showing that the number of fishing sites with BMUs has a positive significant impact on Nile perch population, whereby an increase in 10 percent of number of sites with BMUs increases Nile perch population by 2.1 percent, as indicated in table 3. The human population was found to have an insignificant impact on the Nile perch population. Human population was expected to have a negative impact here as natural resources are expected to be under pressure from the increasing population growth [45]. On the contrary, Nile perch population is not affected; this might be because the species is mostly for the external market, exported because of its size with substantial foreign exchange [22, 23, 26]. The amount of Nile perch caught was found to negatively impact species population at 0.01 level of significance, whereby a 10 percent increase of the amount of species caught will decrease the amount of species by 3.3 percent. The amount of other species have a positive significant impact on the species at 0.1 level of significance, as increase of other species increases the species population by 1.3 percent. Nile perch is indicated to be an ecologically important species in the lake [46] because of its predation features, especially to haplochromines. Therefore, presence of prey species is expected to increase Nile perch population.

Table 3: regression analysis on the factor affecting of Nile perch population

| Independent variable | coefficient | Std. errors | P-value | VIF |
|---|---|---|---|---|
| Constant | -2.687 | 3.574 | 0.466 | |
| BMUs | .2193 | .1077 | 0.061 | 2.02 |
| Population | -.1410 | .2306 | 0.551 | 1.37 |
| Catches of Nile | -.3379 | .1035 | 0.000 | 1.32 |
| Others | .1320 | .0685 | 0.075 | 1.73 |
| R-squared = 0.87 | | | | |
| F value = 25.56 | | | | |
| P = 0.0000 | | | | |

### 3.4 Factors affecting *dagaa*'s population

Results are showing that a number of fishing sites with BMUs and the human population have a significant impact on the *dagaa* population in the study area. The number of fishing sites with BMUs has a positive significant impact at 0.05 level of significance, whereby the increase of the in BMUs by 10 percent increases the species population by 6 percent. The human population has a negative impact on the species population at 0.05 level of significance, whereby the increase of human population by 10 percent decreases the sardines' population by 5 percent.

Table 4: Regression analysis on the factor affecting *dagaa's* stock

| Independent variable | coefficient | Std. errors | P-value | VIF |
|---|---|---|---|---|
| Constant | 4.194 | 8.223 | 0.617 | |
| BMUs | .6094 | .2634 | 0.035 | 1.50 |
| Population | -.5781 | .6429 | 0.002 | 1.32 |
| Catches of *Dagaa* | .5713 | .1490 | 0.383 | 1.16 |
| R-squared = 0.67 | | | | |
| F value = 10.21 | | | | |
| P= 0.0006 | | | | |

### 3.5 Factors affecting other species stock

Results are showing that the human population and amount of other species caught have a negative significant impact at 0.05 level of significance. Number of fishing site with BMUs was found to have an insignificant impact on the species. Results are showing that Increase in 10 percent of human population decrease the species population by 10 percent. Increase in amount of the species caught by 10 percent decrease the species amount by 4 percent. This might be because these species have been found to be highly consumed by the surrounding community and less attractive for the international market [23].

Table 5: Regression analysis of the factor affecting other species stock

| Independent variable | coefficient | Std. errors | P-value | VIF |
|---|---|---|---|---|
| Constant | -12.682 | 5.780 | 0.044 | |
| BMUs | .210 | .178 | 0.255 | 1.33 |
| Population | -1.015 | .467 | 0.046 | 1.36 |
| Catches of others species | -.4065 | .155 | 0.020 | 1.08 |
| R-squared = 0.61 | | | | |
| F value = 8.03 | | | | |
| P = 0.0020 | | | | |

## 4 Discussion

From the obtained result, fishery policies have somehow managed to secure sustainability of species population in the lake. Introduction of BMUs in the fishing sites has indicted to have a positive impact on Nile perch and *dagaa* (sardines) populations while being insignificant to other species populations. Obiero, Abila [22] indicate that BMUs have enhanced sustainable Lake's fishery management by improving community participation that in turn ensures enforcement and administration of fisheries rules and regulations by, and for, the fishers. Based on obtained results, implementation of BMUs and therefore the policies have sided on the important species and neglecting other species. Other species are also important in their perspective, as has been identified to be a source of foods (protein) to most of the local communities [23].

In line with the results, different studies have also indicate BMUs and other policy elements to relying more on Nile perch, which has been pointed out as economically the most important stock in the lake [47]. In fact, BMUs are indicated to be highly fishery-based, concentrating only on a single species (Nile perch), ignoring the native species upon which most poor people depend on [23, 48]. In addition, the Council of Ministers from the countries surrounding the lake (Kenya, Tanzania and Uganda) has given priority to this fishery and maintaining its productivity as the principal management objective on the lake [25]. Fishing that is, size-selective, removal of larger individuals can cut the size structure of a fish population that in turn cause recruitment failure, and therefore reduce the reproductive outputs. Nile perch species has been identified as a near-top level predator [49] with humans as its only effective measure of population control, so its selective control will have significant impact.

There are studies and literature indicating the overexploiting of the Nile perch in the lake [21, 50, 51], but this does not justify it being prioritized in the managements over other species. The ecosystem-based approach, which takes into account ecological factors that affect all fish populations, would be more appropriate as indicated by Kolding, Van Zwieten [52].

Despite the establishment of the BMUs, illegal and unsustainable fishing continues to be observed in the lake; there is still evidence of excessive fishing effort in recent years [53]. Lack of adequate financial and equipment resources for monitoring and control operations has been indicated as one of the hindering factors [22], making them unable to control illegal fishing in their areas of jurisdiction. Ineffective regulations are no better than no regulations, and without political and financial support, the fishery administrations and BMUs will be unable to implement any management plans. Given the fact that some methods suggested for decreasing effort, such as reducing the number of fishing boats or gear, changing net and hook sizes, or establishing quotas, which will have a serious effect on the incomes of many fishers.

Participation of all the stakeholders will improve the outcomes, as researches indicate no proper coordination between key stakeholders. Firstly, as indicated implementations of BMUs is of all the countries surrounding the lake, but management activities around the lake are mostly identified as nationally focused [23]; the nations' policies and regulations are disjointed with no proper coordination [29]. In addition, there is also no proper coordination between intergrading ministries, even within the same county [25]. Information sharing across countries will strengthen cross-border exchange visits and therefore learn from each other, raise awareness, and develop remedial measures to address resource exploitation and transboundary conflict issues. Secondly, there is no proper communication and integration between fishers and the government. There is a concentration of authorities at the top level as Njiru, van der Knaap [25] indicate that studies regarding the lake are showing that over two-thirds of fishers felt that the lake and fishery belonged to the government. This is proven by the country's management approach of the regulations and policies developed by the government for fishers to implement, an approach that has not entirely succeed in improving either the fish stocks or the health of the lake as indicated in the results.

Besides providing vital implications, this empirical study came across some limitations, as it could not explore the other relevant policies and its elements in the area. Apart from the main Nation fishery act and regulation, there are also bylaws in the local area that have not been analysed. This is because of unavailability of such data and unsystematic way of collecting them in the area, which makes obtained information somehow biases. Despite these pitfalls, the results of this study give out a clear picture of the role of the policies in achieving sustainable fishery abundance, using the BMUs. Thus, Government and other responsible authorities' cohorts should take actions accordingly, like reforming policies to meet all the demands.

## 5 Conclusion and recommendations

This study uses cross-sectional data to determine the impact of fishery policies on the sustainability of the dominant species in the Lake Victoria, Tanzania's part. This has been linked to the achievement of the green economy initiative of conserving natural resources, as the initiative is implemented through policies, among others. Number of fishing sites with BMUs has been identified as a major policy element and analyze its impact on the sustainability of the three groups of fish species that are Nile perch, *dagaa* and other species. The work used multiple linear regression analysis estimation on the districts bordering the lake zone of Tanzania and discussed some issues related to the determinants of sustainability of the mentioned species. Results are indicating that presence of BMUs in the fishing sites has a significant positive effect on the population of Nile perch and sardine species. While the population of other species is not affected by presence of BMUs in the fishing sites. The study concluded that policies through presence of BMUs prioritize on Nile perch and *dagaa* species, highly on Nile perch because of its economic importance. Thus, the policies have their challenges, which hinder the achievement of policies and, therefore, the green economy. The study recommends on more studies relating maintain sustainability and productivity of the stock in the lake. As maintaining productivity of this fishery is of vital importance, but accomplishing this is a major challenge given the size of the lake, the increasing number of fishers, and environmental conditions ecological changes, which affect fish populations and growth.

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