The Malawi Priorities Project

Cost-Benefit Analysis of Fisheries Management in Malawi - Technical Report

National Planning Commission Report with technical assistance from the Copenhagen Consensus Center and the African Institute for Development Policy

COPENHAGEN CONSENSUS CENTER

NATIONAL PLANNING COMMISSION

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Malawi Priorities: Background

Malawi Priorities is a research-based collaborative project implemented by the National Planning Commission (NPC) with technical assistance from the African Institute for Development Policy (AFIDEP), and the Copenhagen Consensus Center (CCC) to identify and promote the most effective interventions that address Malawi's development challenges and support the attainment of its development aspirations. The project seeks to provide the government with a systematic process to help prioritize the most effective policy solutions so as to maximize social, environmental and economic benefits on every kwacha invested. Cost-benefit analysis is the primary analytical tool adopted by the project. Cost-benefit analysis will be applied to 20-30 research questions of national importance. Research will take place over the course of 2020 and 2021.

Research questions were drawn from the NPC's existing research agenda, developed in September 2019 after extensive consultation with academics, think tanks, the private sector and government. This sub-set was then augmented, based on input from NPC, an Academic Advisory Group (AAG) of leading scholars within Malawi, and existing literature, particularly previous cost-benefit analyses conducted by the Copenhagen Consensus Center. The research agenda was validated and prioritized by a Reference Group of 25 prominent, senior stakeholders. The selection of interventions was informed by numerous consultations across the Malawian policy space, and one academic and two sector experts provide peer review on all analyses.

Cost-benefit analyses in Malawi Priorities consider the social, economic and environmental impacts that accrue to all of Malawian society. This represents a wider scope than financial cost-benefit analysis, which considers only the flow of money, or private cost-benefit analysis, which considers the perspective of only one party. All benefit-cost ratios (BCRs) reported within the Malawi Priorities project are comparable.

The cost-benefit analysis considered in the project is premised on an injection of new money available to decision makers, that can be spent on expanding existing programs (e.g. new beneficiaries, additional program features) or implementing new programs. Results should not be interpreted as reflections on past efforts or the benefits of reallocating existing funds.

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Contents

Acronyms

AAG	Academic Advisory Group
AFIDEP	African Institute for Development Policy
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CCC	Copenhagen Consensus Center
CPUE	Catch per unit effort
DoF	Department of Fisheries
ESMF	Environmental and Social Management Framework
FAO	Food and Agriculture Organisation
FCMA	Fisheries Conservation and Management Act
FV	Future Value
GDP	Gross Domestic Product
GoM	Government of Malawi
MGDS	Malawi Growth and Development Strategy
MEY	Maximum Economic Yield
MSY	Maximum Sustainable Yield
NEP	National Environmental Policy
NFAP	National Fisheries and Aquaculture Policy
NPC	National Planning Commission
OLS	Ordinary Least Square
PV	Present Value

1. Introduction

Malawi's new long-term development plan, Malawi 2063 (MW2063), has earmarked the fishing sector as an important contributor to the country's "inclusive wealth creation" development agenda. Building on previous efforts in the sector, the MW2063 First Implementation Plan (MIP 1) places a particular emphasis on a set of progressive commercialization and diversification programmes in the fishing industry to boost incomes and spur growth for socio-economic transformation. Torell et al. (2020) point out that in 2017, the Malawian fishing industry contributed 7.2% to GDP. The sector directly employs nearly 63,000 fishers, and over 8000 fish farmers (De Graaf and Garibaldi, 2014). Indirect employment supports over 600,000 people who are engaged in various activities across the value chain including fish processing, fish marketing, as well as boat building and engine repair (Gumulira et al. 2019). Although a large quantity of fish produced within Malawi is consumed locally, the nation derives a significant amount of foreign exchange from exporting fish. The Malawi National Fisheries and Aquaculture Policy (GoM, 2016) estimated that more than 500 tonnes of fish are exported annually. The fisheries sector is therefore extremely important to the national economy.

In addition, the sector is important for nutrition and food security, especially in the poorer sections of the population for whom fish may be the only regularly available source of animal protein. Malawi has among the highest dependency on fish for animal protein in Southern Africa, with fish providing more than 70% of total animal protein (GoM, 2018). It is estimated that fish consumption per capita is about 8kg per person per year (FISH, 2015; GoM, 2016).

Lastly, the sector has an impact on biodiversity and the environment. Malawi has many waterbodies, which account for almost 21 percent of the country's total area. Lake Malawi, the largest water body in the country has been classified as one of the world's most important freshwater bodies, with between 700 to 1000 native fish species (Food and Agriculture Organization, FAO, 2020). Lake Malawi contributed about 94% of the nation's total fish production in 2019 (GoM, 2020). Other important water bodies include Lakes Malombe, Chiuta and Chilwa along with the Shire River – which is the only outlet of Lake Malawi. Fishing activities are prevalent in all these lakes and communities along the lake are predominantly fishing communities.

The importance of the fisheries sector to the economy, livelihoods, nutrition, and the environment makes it extremely important that the sector is properly managed. Unfortunately, there is evidence of extreme overfishing. In many fisheries, overfishing manifests as declining catch per effort over time – a pattern noticeable in Malawian data from 1993 to around 2005. This makes additional effort less profitable, and fisheries may reach a natural equilibrium where catch remains stable albeit not at maximum sustainable or economic yields without some credible government intervention. However, the data in Malawi show a potentially precarious trend where catch per unit effort has increased substantially from 2006 to 2018. Since Lake Malawi is a closed inland lake with no possibility of fish migration from another area, this suggests a change in technology that increased efficiency but likely in an unsustainable manner. As an example, the collapse and possible extinction of the chambo species, which was once prolific in Lake Malawi, demonstrates the challenge and results of overfishing. We attribute this to increasing and now predominant use of illegal unmeshed nets in the country, which capture juveniles and spawning fish, reducing the reproduction potential of the species.

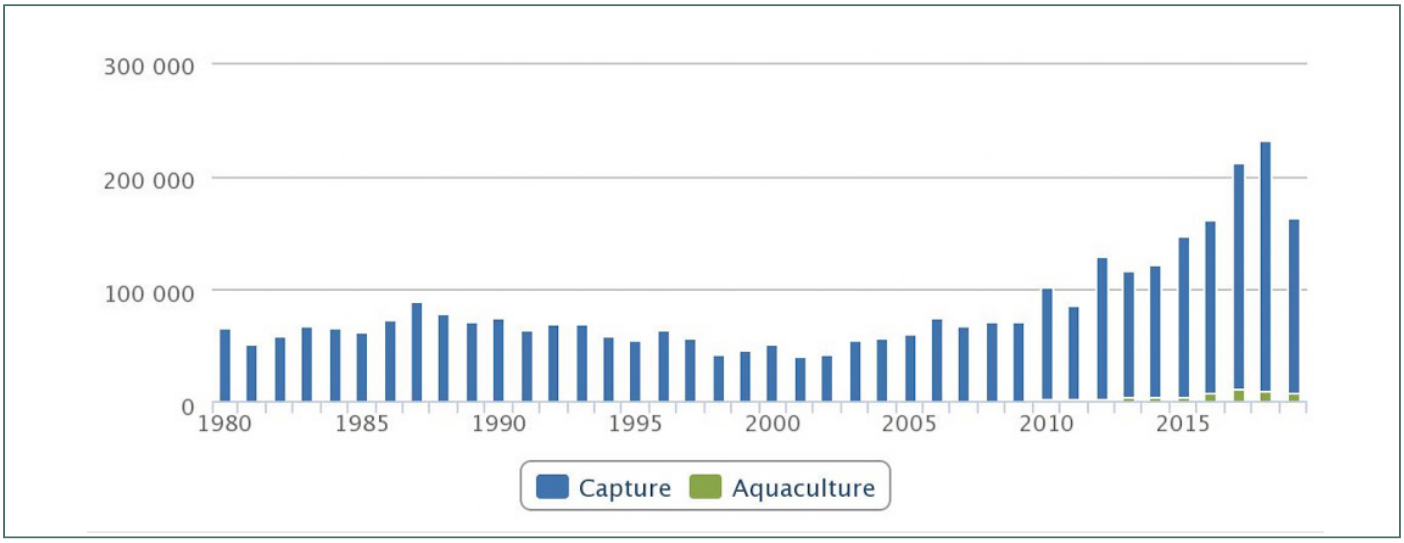
The analysis in this paper suggests that fisheries rents in 2018 – an estimated MWK 185.5 billion (USD 250 million), are around 5 times greater than the rent at maximum sustainable yield. A significant reduction in fishing effort is required to avoid a collapse of fishing stock. In conjunction with the Fisheries Department, we examine the costs and benefits of two potential strategies to address the challenge of overfishing – i) replacing illegal nets ii) fishing in rotation. The results indicate that fishing by rotation is the superior strategy from a cost-effectiveness standpoint. The upfront costs involve painting the boats to designate which days they are allowed to fish (MWK 0.3 billion), plus foregone revenue in the first year (MWK 164.3 billion). However, this would reduce effective fishing effort down to 2,475 'full time' craft and avoid a drastic reduction in the fisheries stock. In the long run this would lead to an extra MWK 53.7 billion in sustainable revenue and ongoing fishing costs of MWK 4.4 billion per year. The benefit-cost ratio is 2.8.

Replacing the illegal nets barely passes a cost-benefit test, and only at a 5% discount rate or lower. This is because the upfront costs of the intervention are very large – more than MWK 91.1 billion to replace the nets, plus foregone (unsustainable) revenues of MWK 180.1 billion for one year. Importantly, the intervention still leaves 18,000 vessels in the waters of Lake Malawi and surrounding water bodies, striving for the same limited pool of fish. While marginal revenues are MWK 55.4 billion annually, large operational costs of MWK 32.5 billion are incurred annually, making this intervention barely viable from a cost-benefit perspective.

1.1 Overview of The Fisheries Sector in Malawi

The fisheries sector in Malawi comprises two subsectors; (i) capture fisheries, which is the dominant sector and (ii) the aquaculture sector. For Capture fisheries, Lake Malawi is the foremost fishing area, responsible for most of the fish in the region along with Lake Chilwa. The capture fishery in Lake Malawi is highly diverse. It consists of large-scale commercial, small-scale commercial, and subsistence fisheries. Fishing methods include trawling, hook and line, and several others. The capture fisheries sector in Malawi is also classified as commercial fisheries, artisanal fisheries, and ornamental fisheries. The former two harvest most of the fish for food while ornamental fisheries are a crucial source of employment and revenue to the local economy (ESMF, 2019). The total number of estimated fishing vessels in 2020 was at 19,646 fishing crafts (2020 Frame Survey).

Figure 1: Total Capture and Aquaculture Production in Malawi (1980-2019) (Tonnes)



Source: http://www.fao.org/fishery/facp/MWI/en

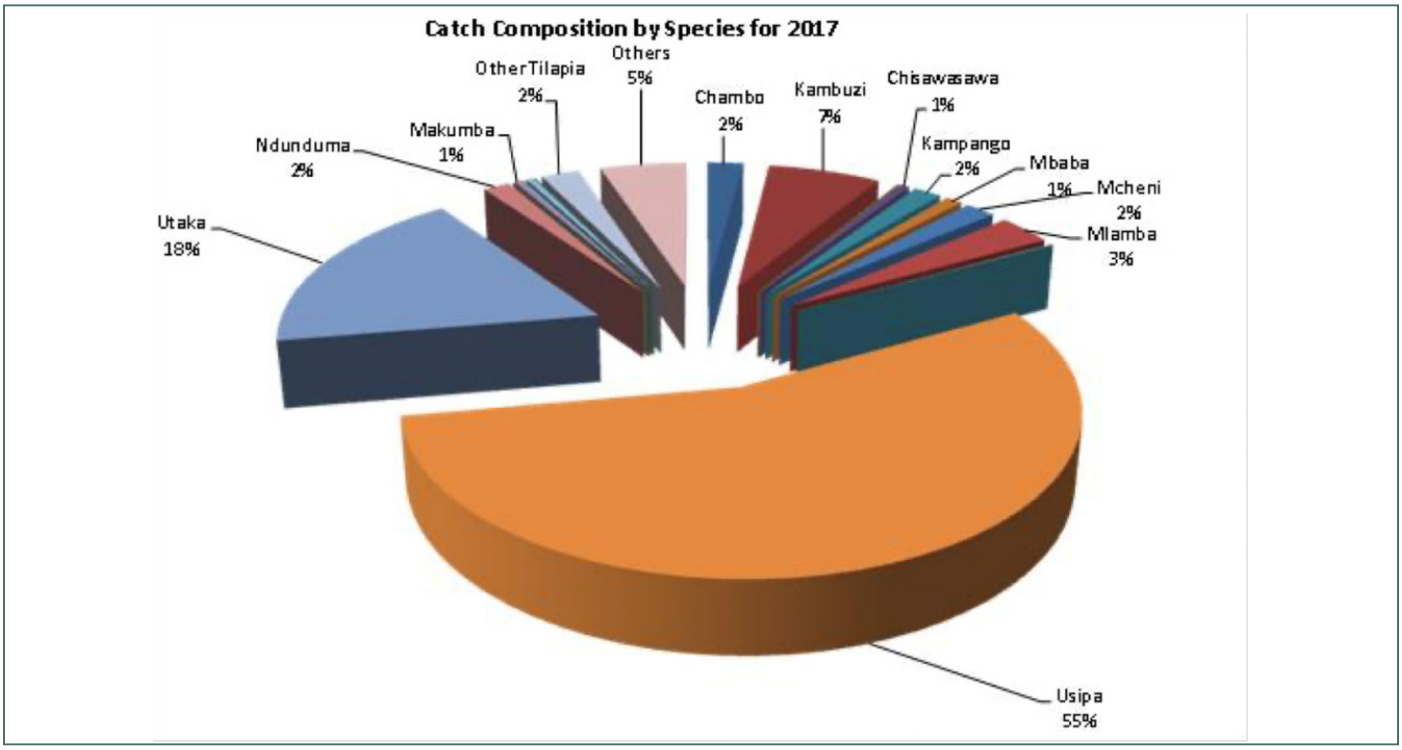
1.2 Issues and Constraints

While fish remains the cheapest source of animal protein for many rural Malawians, the stock and catch levels of edible fish are hard to predict over the last few years leading to biological overfishing and collapse of important fisheries such as Lake Malombe. The uncertainty is amplified by several factors including overfishing, weak governance structures and climate change (Limuwa et al. 2018).

Studies also indicate that governance and management of fisheries on Lake Malawi was weaker than on other water bodies in the country like Lake Chiuta (Nunan et al. 2015); Hara et al. 2015). The most significant difficulty identified in implementing any authority or control was that Lake Malawi is a large 'open access system'. This poses problems in creating secure geographic communal rights. The several challenges that arise due to a weak governance system in turn impact the fragile ecosystem in the lake. The most common problem faced is that of overfishing in localized fishing areas. Overfishing is aided by the prolific and extensive use of under-sized-meshed nets and trawling in areas that are not designated for fishing. This has a huge impact on the degradation of the environment. Further, the 'open access' nature of the fisheries leads to more and increased fishing efforts in terms of gears and fishers (Jamu et al., 2011; Donda et al., 2015).

Overfishing is another serious concern with Turner (1995) pointing out how changes in the species composition in Lake Malawi is a clear indicator of loss of species and replacement because of overfishing. Overfishing along with climate change is a major factor which impacts the productivity of the small pelagic resources. Looking at the species composition of total national catches (Figure 2), small pelagic fish have dominated to the extent that over 70% of the capture fisheries industry in Malawi consists of cyprinidae family, mainly Engraulicypris sardella which comprised of 55% of the total catch and Utaka 18%.

Figure 2: Percent species composition of total national catches for 2017



Source: Department of Fisheries, Malawi, 2019

1.3 Policy Framework

The Malawian government acknowledges the significance of fisheries for the country and the imperative and the necessity to increase productivity and consumption of fish to encourage economic growth and help foster food security in the country. The main objective of the National Fisheries and Aquaculture Policy (2016-2021) is to "sustainably increase fisheries and aquaculture productivity for accessible nutritious food and increased contribution to economic growth". The specific objectives include

- To increase annual fish production from capture fisheries from 90,000 tonnes to 110,000 tonnes;
- To increase small and large scale aquaculture production from 3,600 tonnes to 10,000 tonnes;
- To strengthen participatory fisheries management regimes;
- To reduce fish post-harvest losses from 40 to 20 per cent;
- To increase annual fish exports from 500 tonnes to 3,000 tonnes;
- To increase per capita fish consumption from 8.12kg to 10kg;
- To improve decent employment in fishing communities for youth, women and men and to reduce the number of child labourers;
- To promote applied research in fisheries and aquaculture and monitor the impact of pollution and environmental changes including climate change; and
- To develop capacity of the Government and local management institutions to serve the industry.

Other policies and acts which impact/impacted this sector include:

1. *Fisheries Conservation and Management Act (FCMA) of 1997 –* It regulates the utilization of fisheries and its preservation and also guides development of fish farming, promoting community participation in the protection of fish. This is significant as it reflects a shift in the fisheries management philosophy from the conservation paradigm.
2. *The National Fisheries and Aquaculture Policy (NFAP) -* approved in 2016 was formulated to revise the National Fisheries and Aquaculture Policy of 2001 in order to effectively contribute to sustainable economic growth in Malawi, as outlined in the Malawi Growth and Development Strategy II (MGDS II). The revised Policy sought to promote sustainable fisheries resource utilisation and aquaculture development.
3. *National Environmental Policy (2004) -* Within the NEP, the fisheries sectoral objective to manage fish resources for sustainable utilization and conservation of aquatic biodiversity is clearly highlighted.
4. *Fisheries Policy Implementation, Monitoring and Evaluation Strategy (IMES) (2016- 2020) -* developed to enable the implementation of the Policy for Fisheries and Aquaculture is approved by the Cabinet. Key priority areas, include (i) Capture Fisheries (ii) Aquaculture, (iii) Fish Quality and Value Addition, (iv) Governance, (v) Social Development and Decent Employment, (vi) Research and Information, and (vii) Capacity Development.

This analysis studied the cost effectiveness of 2 interventions aimed at reducing overfishing, namely replacing all Illegal Fishing Nets and fishing by Rotation (Fishing in turns). The analysis suggests that replacing illegal fishing nets will yield a central Benefit Cost Ratio (BCR) of 0.93, whereas fishing in turns or by rotation will yield a BCR of 2.8.

2. Research Process

The National Planning Commission (NPC), in collaboration with African Institute for Development Policy (AFIDEP), and the Copenhagen Consensus Center (CCC) have started the Malawi Priorities project – a research and advocacy exercise to identify the most effective ways to address the nation's challenges using the framework of cost-benefit analysis. The aim is to inform both short and long term development priorities for the country, acknowledging that there are insufficient resources to address all of Malawi's challenges and that maximizing outcomes requires careful, evidence-based consideration of the costs and benefits of all policies.

The starting point of all research questions is the NPC's existing research agenda, structured around the six thematic areas of Sustainable Agriculture, Sustainable Economic Development, Human Capital and Social Development, Sustainable Environment, Demography, Governance, Peace, and Security.

NPC's research agenda was developed by the commission in September 2019 after extensive consultation with academics, think tanks, the private sector and government. Consequently, the commission's research agenda, prima facie, contains questions of national importance. As a first step, Malawi Priorities drew questions from the NPC research agenda that could be answered by CBA. Then, additional research questions were added based on input from NPC, an Academic Advisory Group (AAG) of leading scholars within Malawi, and existing literature, particularly previous cost-benefit analyses conducted by the Copenhagen Consensus Center. This process of identifying research questions for investigation generated a total of 38 potential research questions across all 6 thematic areas.

The research agenda was validated and prioritized by a Reference Group of 25 prominent, senior stakeholders from government, civil society and the private sector. The outcomes of the Reference Group exercise were used to inform which research questions to prioritize and which interventions to focus on within those research questions. The validation process finished in July 2020.

2.1 Interventions Considered and Researched

The intervention selection process usually starts with a wide universe of potential interventions drawing from literature, stakeholder interviews and advisor input. From here, the prioritization of interventions takes in a number of considerations. Though there is no mechanical formula for selecting interventions, several important factors include:

1. **Sector expert priority –** An intervention is accorded higher priority if sector experts note that it is important. There are several avenues from which experts provide input into our process such as the Reference Group questionnaire, direct interview, inferences from the NPC research agenda, and via our academic advisory group.
2. **High benefit-cost ratio or cost-effectiveness in similar previous research –** The purpose of the Malawi Priorities project is ultimately to identify interventions of outsized benefits relative to costs. Input into this factor is determined from the economics literature, particularly previous research conducted by the Copenhagen Consensus Center. In the Center's experience BCRs above 15 are among the highest across all interventions. Due consideration is given to contextual differences between previous research and the current situation in Malawi in determining the effect of this criterion.
3. **Addresses a problem of sufficient size –** some interventions could be considered highly effective but only address a small percentage of a given problem, limiting the overall net benefits of the approach. To avoid focusing on solutions that are too small, each intervention must have the potential to address a problem that is significant.
4. **Significant gap in current coverage levels of intervention –** all analyses conducted in Malawi Priorities focuses on marginal benefits and costs. Therefore, if an intervention already has high coverage rates, then additional resources provided towards that intervention are unlikely to be effective, or will suffer from the 'small-size' problem.
5. **Availability of crucial data or credible knowledge of impact –** due to time and resource constraints, all analyses conducted by Malawi Priorities are based on secondary data. No primary research is conducted, such as field experiments or trials. Therefore, each intervention is constrained by the availability of data. In many cases, one key constraint is knowledge concerning the impact of a given intervention. It is typical to formally deal with uncertainty via sensitivity analyses. However, in some cases the uncertainty is so great that it precludes even researching the intervention at all.

In April 2021, as much of the research for Malawi Priorities was finalized or on the way to being finalized, the NPC requested Copenhagen Consensus to conduct a paper on fisheries specifically as this element was absent from project, yet was considered an important sector in Malawi. The Head of the Fisheries department, Government of Malawi suggested two policies that were under consideration. Since there was no ex-ante expectation or a good understanding on what the BCRs were going to be, the study chose these interventions for further cost-benefit analysis on the basis of policy relevance. They are:

1. 1.Replacing all illegal fishing nets
2. Fishing by rotation (also known as fishing in turns)[1]

It is noteworthy that a single intervention may not be the silver bullet, and each intervention can only generate the desired outcome if it is well implemented, and compliance is adequate. Replacing under-meshed nets, for example, will reduce fishing capacity and

[1] Rotation here simply means making fishers fish in rotation or in turns. It is not about allowing fishing grounds to fallow.

increase resource rents in the medium to long term but may not eliminate excess capacity in the fishery. Also, if fishers are made to fish in turns, it will reduce fishing pressure, and increase yield and resource rents. In addition to sensitizing fishing communities about the potential benefits of these interventions, when implemented, all stakeholders must ensure that fishers comply. Furthermore, for ease of analysis, we do not consider multiple interventions at the same time.

3. Methodology

To undertake cost-benefit analyses of the proposed interventions, a bio-economic model based on the Gordon-Schaefer harvest and cost functions was employed (Gordon, 1953, 1954; Schaefer, 1954). The model makes some assumptions: the biomass growth function is logistic, and catch is a linear function of fish stock and fishing effort. Let the growth and harvest functions -- equations 1 and 2, respectively -- be:

$$g(x_t) = rx\left(1 - \frac{x_t}{k}\right), \tag{1}$$

$$h(x_t, E_t) = qE_t x_t\ , \tag{2}$$

where x_t is the stock of fish (in biomass), k is environmental carrying capacity, r is the intrinsic growth rate, E_t is fishing effort, q is catchability coefficient, and t is a time variable. The stock dynamic equation associated with equations 1 and 2 is:

$$x_t = x_{t-1} + g(x_t) - h(x_t, E_t) \tag{3}$$

To maintain a given stock level (i.e., in steady state): $x_t = x_{t-1} = x^*$ and $g(x) = h(x_t, E_t)$. This implies:

$$x^* = k\left(1 - \frac{q}{r}E\right) \tag{4}$$

Substituting equation (4) into the Schaefer harvest function generates the sustainable yield (y) function is obtained if equation 2 is substituted in the Schaefer-harvest function. That is:

$$y_t = qkE_t - \frac{q^2k}{r}E_t^2 = \alpha E_t - \beta E_t^2,$$

$$\text{where } \hat{\alpha}(= qk) \text{ and } \hat{\beta}\left(= \frac{q^2k}{r}\right). \tag{5}$$

3.1 Maximum Sustainable Yield (MSY)

The maximum catch or predation that can sustain the stock in perpetuity (i.e., MSY) corresponds to the turning point of the quadratic function (i.e., equation 6). From the Sustainable Yield (SY) function (i.e., equation 5) the MSY and the corresponding fishing effort (i.e., number of fishing crafts) are calculated as equations 7 and 6, respectively:

$$\frac{\partial y_t}{\partial E_t} = 0 \Rightarrow E_{MSY} = \frac{\alpha}{2\beta}, \tag{6}$$

$$MSY = y(E_{MSY}) = \frac{\alpha^2}{4\beta}, \tag{7}$$

where $\frac{\partial y_t}{\partial E_t}$ is the first order derivative of the yield function with respect to the fishing effort (i.e., number of fishing crafts). Note that the MSY and the corresponding effort level do not depend on economic parameters such as the price of fish and cost of fishing.

3.2 Maximum Economic Yield (MEY) and Effort in a Timeless Situation

To determine the rents generated by a fishery, information on the price of fish (p) and cost of fishing (cost of operating a fishing craft (c)) are needed. Thus, py(E) represents total revenue from the catch obtained and cE is the total cost of fishing. The profit function for fishery is:

$$\pi(E) = py(E) - cE = p(\alpha E - \beta E^2) - cE \tag{8}$$

The maximum economic yield (MEY) and the corresponding effort level (E_{MEY}) are obtained if the profit function is maximized with respect to the fishing effort (i.e., number of crafts).[2]

$$\frac{\partial \pi(E)}{\partial E} = 0 \Rightarrow E_{MEY} = \frac{\alpha}{2\beta} - \frac{c}{2\beta p} = \left(E_{MSY} - \frac{c}{2\beta p}\right) \tag{9}$$

and

$$MEY = Y(E_{MEY}) = \left(\frac{\alpha p - c}{2\beta p}\right)\left(\frac{\alpha p + c}{2p}\right) \tag{10}$$

[2] If $\hat{\alpha}(= qk)$ and $\hat{\beta}\left(= \frac{q^2k}{r}\right)$ are substituted into equations (9) and (10) we have $E_{MEY} = \frac{r}{2q}\left(1 - \frac{c}{2pk}\right)$ and MEY= $\frac{r}{4}\left(k - \frac{c^2}{p^2q^2k}\right)$, respectively. Note that when calculating E_{MSY}, MSY, E_{MEY} and MEY we do not have to explicitly estimate q, k, and r.

To empirically estimate equation (5) a normally distributed error term ε_t is added to the equation so that it becomes equation (11).

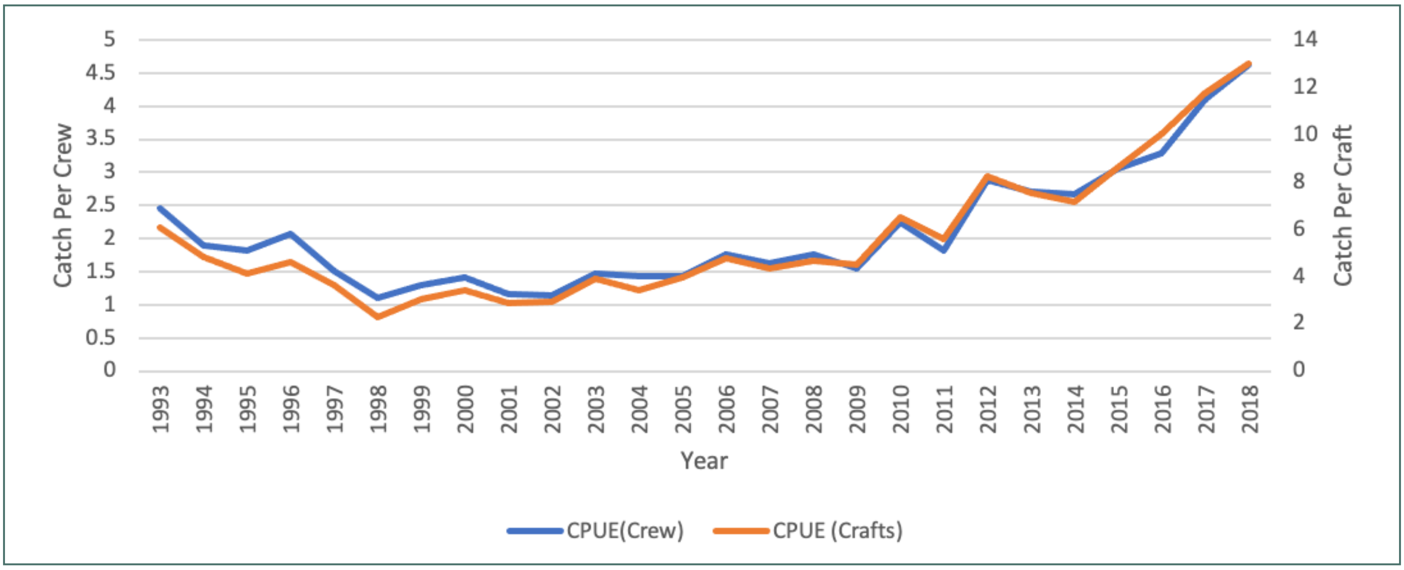
$$y_t = \hat{\alpha} E_t - \hat{\beta} E_t^2 + \varepsilon_t, \tag{11}$$

Note that $\hat{\alpha}$ and $\hat{\beta}$ are two estimated parameters based on time series data on catch and fishing effort (# of crafts); ε_t denote a normally distributed error term.

4. Data analysis

The empirical estimations require catch and effort data. The catch represents the total landings from all lakes within the country. The data was obtained from the World Bank.[3] The corresponding series for all the fishing crafts (i.e., canoes and boats) fishing within the country were extracted from *2020 Annual Frame Survey Report of The Small-Scale Fisheries* (page 15, figure 11). Figure 3 illustrates the catch per crew member and catch per craft (i.e., catch per unit effort (CPUE) from 1993-2018.

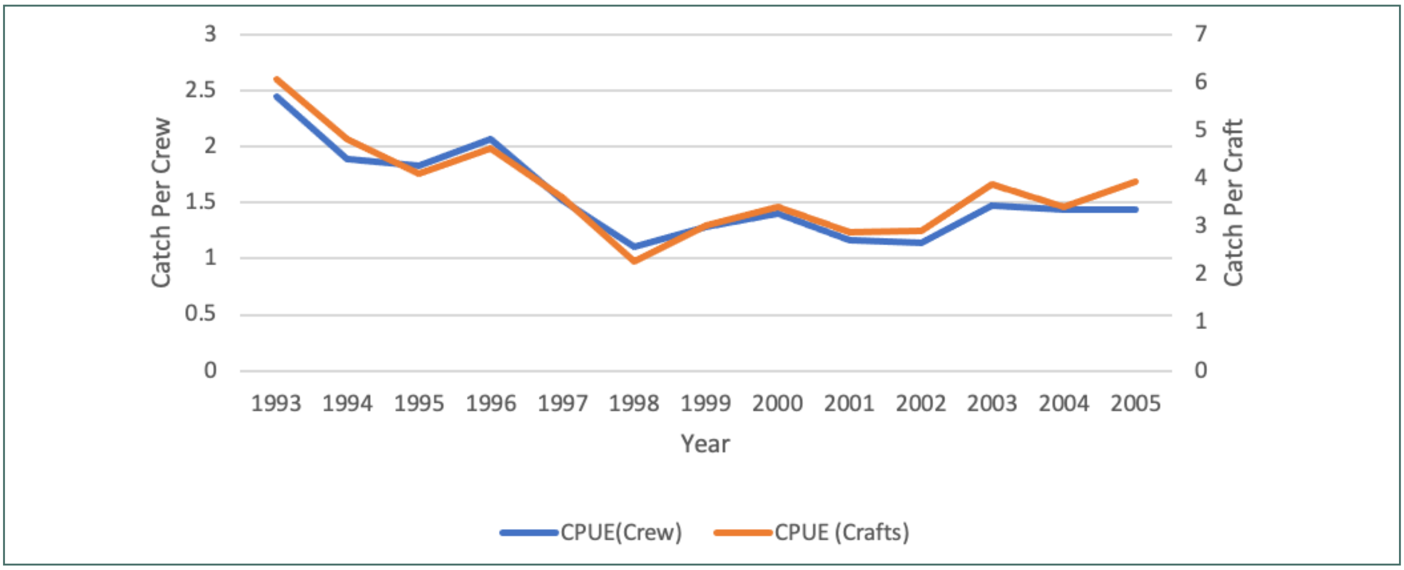
Figure 3: *Catch Per Crewmember and Craft (1993-2018)*



As shown in the figure, the CPUE exhibits an unusual pattern. It declines from 1993 through 2005, indicating overfishing but starts to rise from 2006 through 2018. The rising trend consists mainly of Engraulicypris sardella (usipa) catch, which peaked at 72% and averaged over 60% of total catch between 2010 and 2018. It has been argued that the collapse of the Oreochromis spp. (chambo) fishery owing to overexploitation created a conducive environment for the small zooplanktivorous usipa to thrive (FISH, 2015). Yet in the late 1980s and early 1990's when champo catches were high, usipa already constituted a significant proportion of total landings. Specifically, for 1989 and 1996, usipa landings exceeded 50% of total catch, and the landings in 2003 and 2004 exceeded those of 2006 and 2007.

The use of under-meshed nets is associated with high rate of exploitation of juveniles and spawners, leading to the collapse of the chambo stock (Mangochi District Profile, 2014; FISH, 2015). Fish (2015) noted that, since 2005, "The use of inexpensive small meshed illegal gillnets, which are locally referred to as 'ngongongo,' have risen markedly". Because there is no evidence of recovery of collapsed fish stocks, the increasing total catch, and the significant share of usipa in total landings can be attributed to the intense use of under-meshed nets (i.e., enhanced catchability coefficient). Thus, since no closed season was observed in 2005/6, the only plausible reason for the rising total catch trends is increased gear efficiency, which is unsustainable. To estimate the sustainable yield function, only the segment of the series that reflects decreasing CPUE was considered (i.e., 1993-2005). The Figure 4 shows the evolution of CPUE for the time span considered for the study.

Figure 4: *Catch Per Crewmember and Craft (1993-2005)*

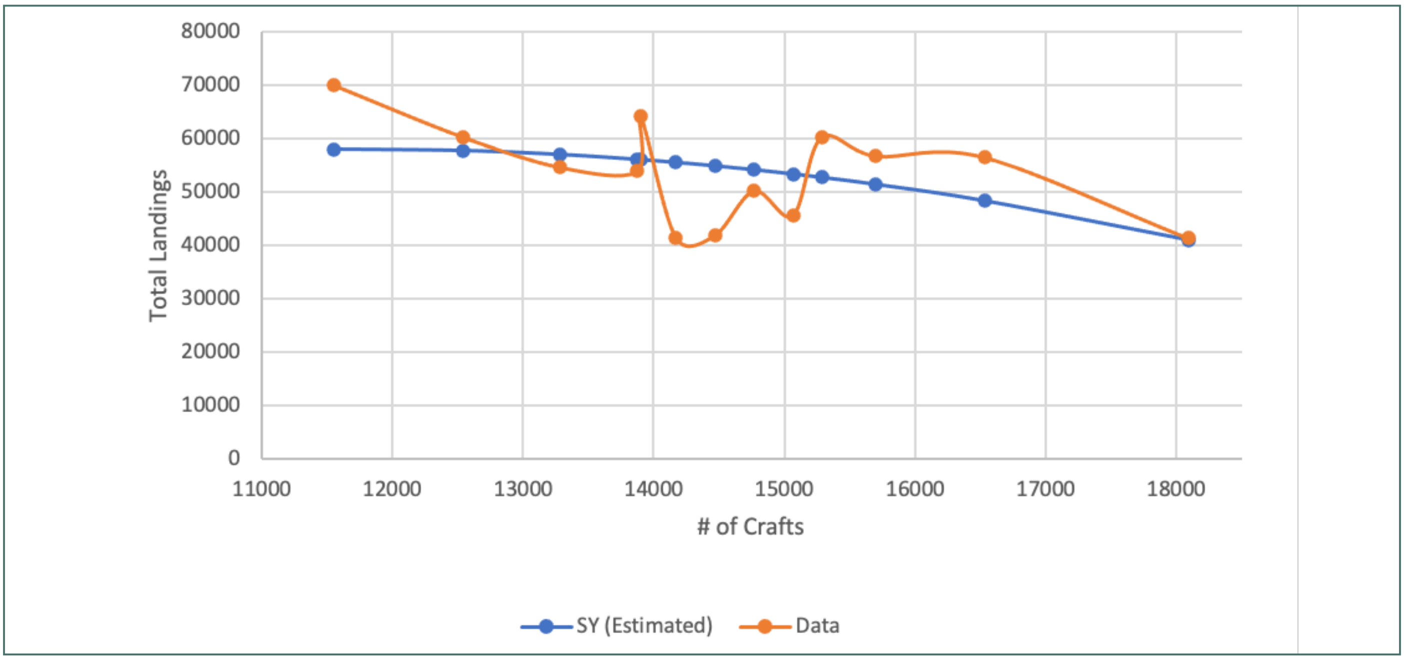


[3] https://data.worldbank.org/indicator/ER.FSH.CAPT.MT?locations=MW

4.1 The SY and MSY Estimation

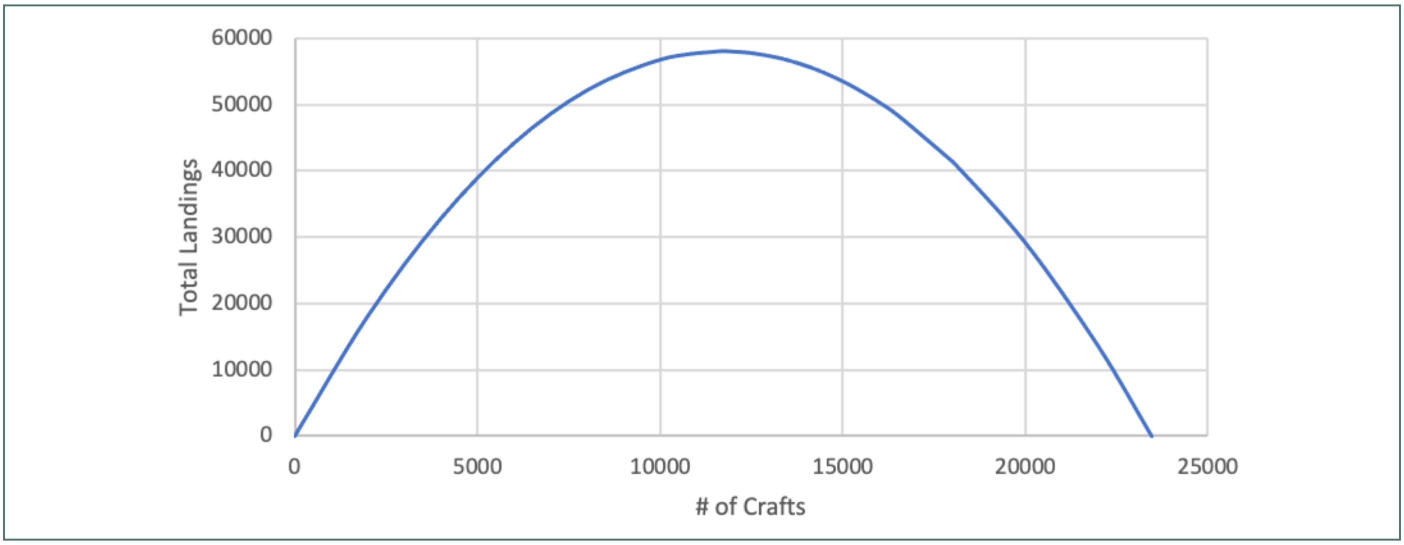
Since the evolution of the catch per crew member and catch per craft were similar, the SY function was estimated using data on total landings and the corresponding number of fishing crafts. The F-statistic shows that the Ordinary Least Square (OLS) regression line fits the data at 1% significance level. In addition, the two parameters (i.e., $\hat{\alpha}$ = 9.893695 and $\hat{\beta}$=0.0004217) estimated were also statistically significant an 1% level and took the right signs. Figure 5 illustrates the goodness of fit of the estimated sustainable yield curve. This is consistent with the results obtained from the regression analysis.

Figure 5: Goodness of Fit of Estimated Sustainable Yield Function (1993-2005)



The complete sustainable yield function is shown in Figure 6. Based on equations (5) and (6), the MSY and the corresponding number of crafts are about 58,000 tons and 11,700, respectively. This signifies the maximum potential catch that can be sustained in perpetuity, if the 11,700 crafts fish at the intensity of 1993-2005 levels.

Figure 6: Sustainable Yield Function (1993-2005)



The obvious task is how to account for the intensified fishing efforts (i.e., the use of under- meshed nets) spanning 2006 through 2018. Using the estimated parameters for the sustainable yield function, we calculated catches and the corresponding efforts along the function. Thus, using the estimated parameter values (i.e., $\hat{\alpha}$ and $\hat{\beta}$) in equation (11), the effort values for 2006 through 2018 are substituted in the equation to generate the corresponding catch and CPUE values represented by the blue bars (Fig. 7). Conversely, using the actual values from 2006 through 2018, we generated the corresponding effort levels based on the parameter values estimated (Fig. 8). As expected, the observed catch per fishing craft, on average, far exceeded the 'adjusted' CPUE. This is illustrated in Figure 8. By 2018, the percentage difference between the adjusted CPUE (2.26) and observed CPUE (12.98) was almost 500%. Conversely, by adjusting for the gear efficiency, the estimated number of fishing crafts far exceeds the observed values (see Figure 8). The implication is that the fishery is highly overcapitalized and heavily overexploited. Evidently, beginning 2018, both the total catch and the catch share of the most abundant species (usipa) started to decline. From Fig. 9, the total catch peaked at approximately 157,000MT in 2018, but reduced to 105,000MT in 2020. Similarly, from Fig. 10, between 2018 and 2020, the catch share of usipa reduced by 10 percentage points (i.e., from 72% to 62%).[4]

[4] https://www.voazimbabwe.com/a/overfishing-in-lake-malawi-creates-scarcity-overpricing/5126298.html.

Figure 7: Adjusted CPUE Using Catch and Effort Data from 1993-2005

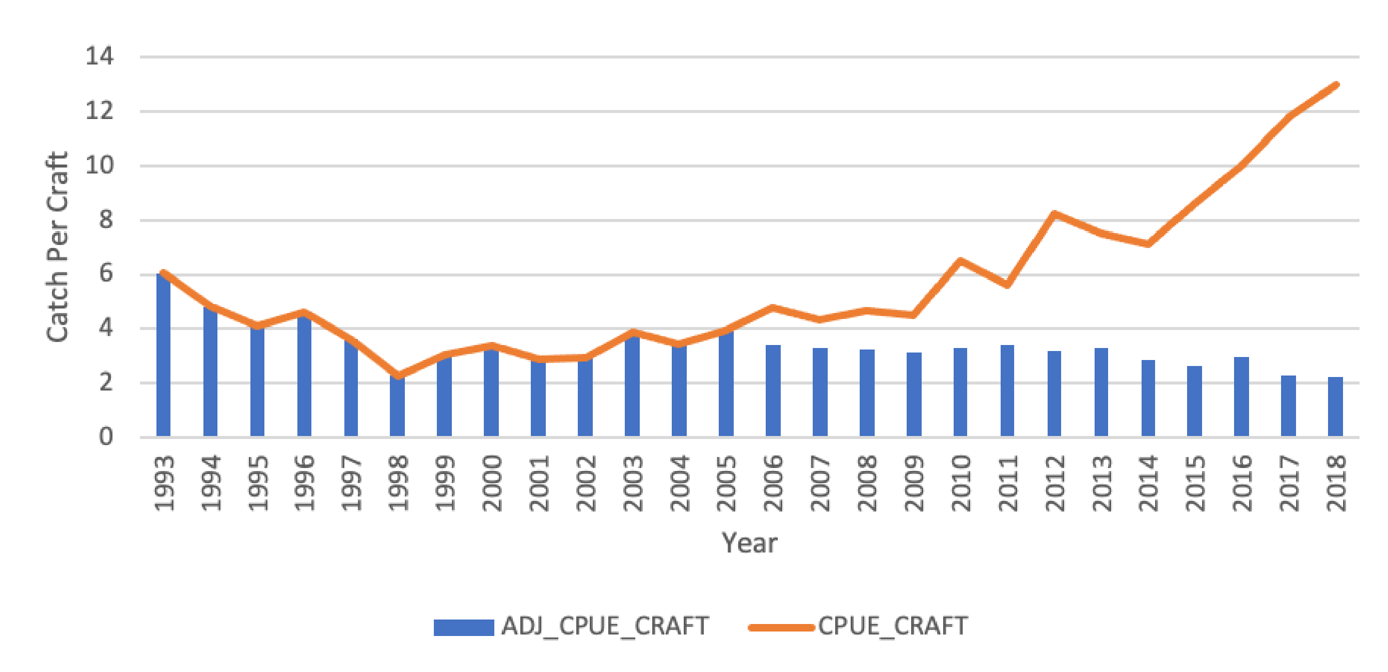


Figure 8: Actual and Adjusted # of Crafts (1993-2018)

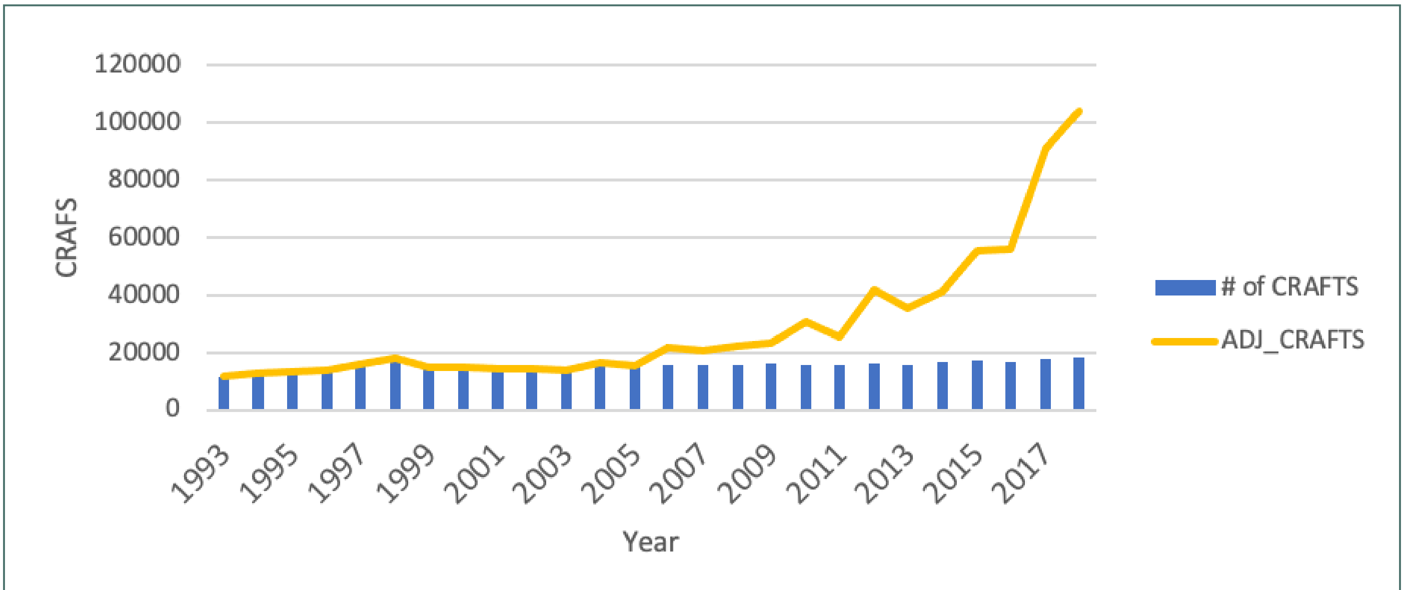


Figure 9: Total Catch of Usipa in Malawi (2010-2020)

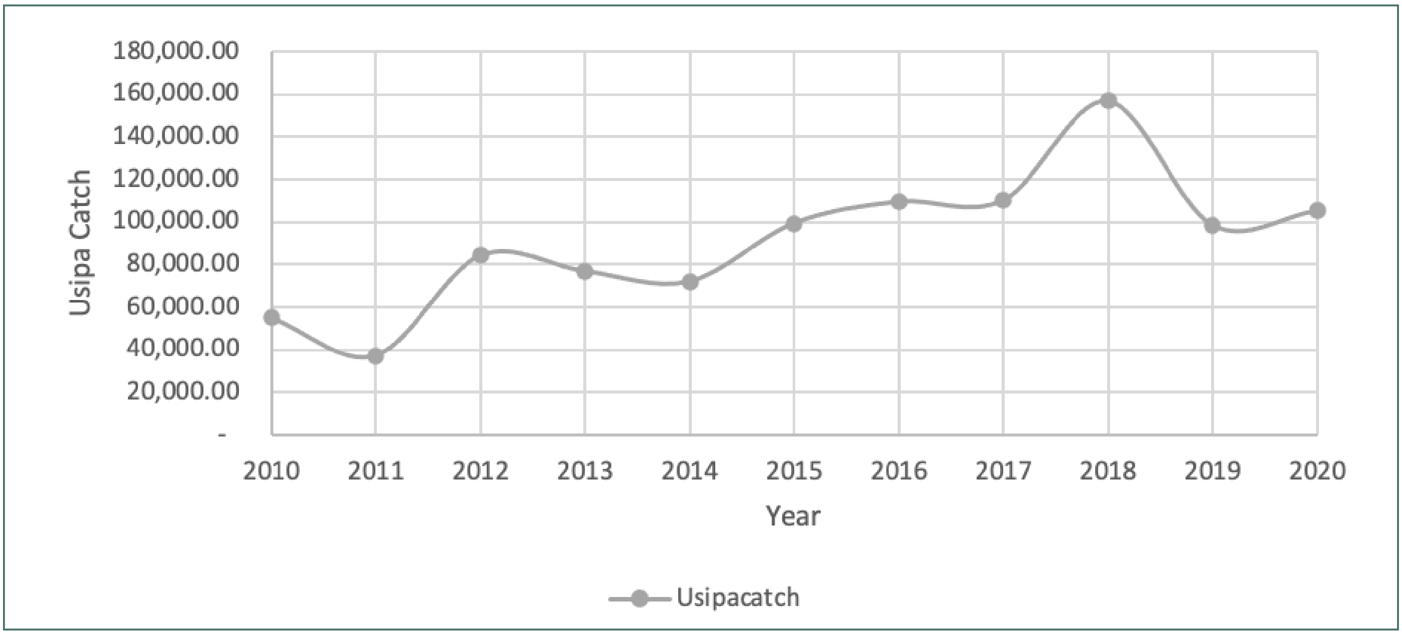
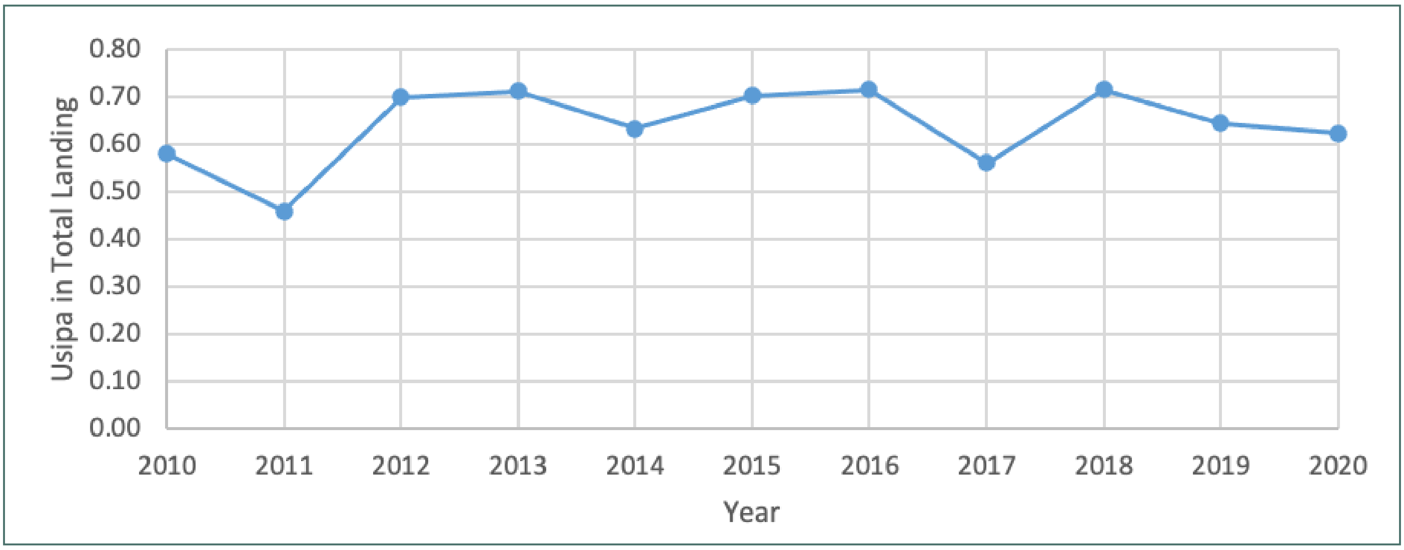


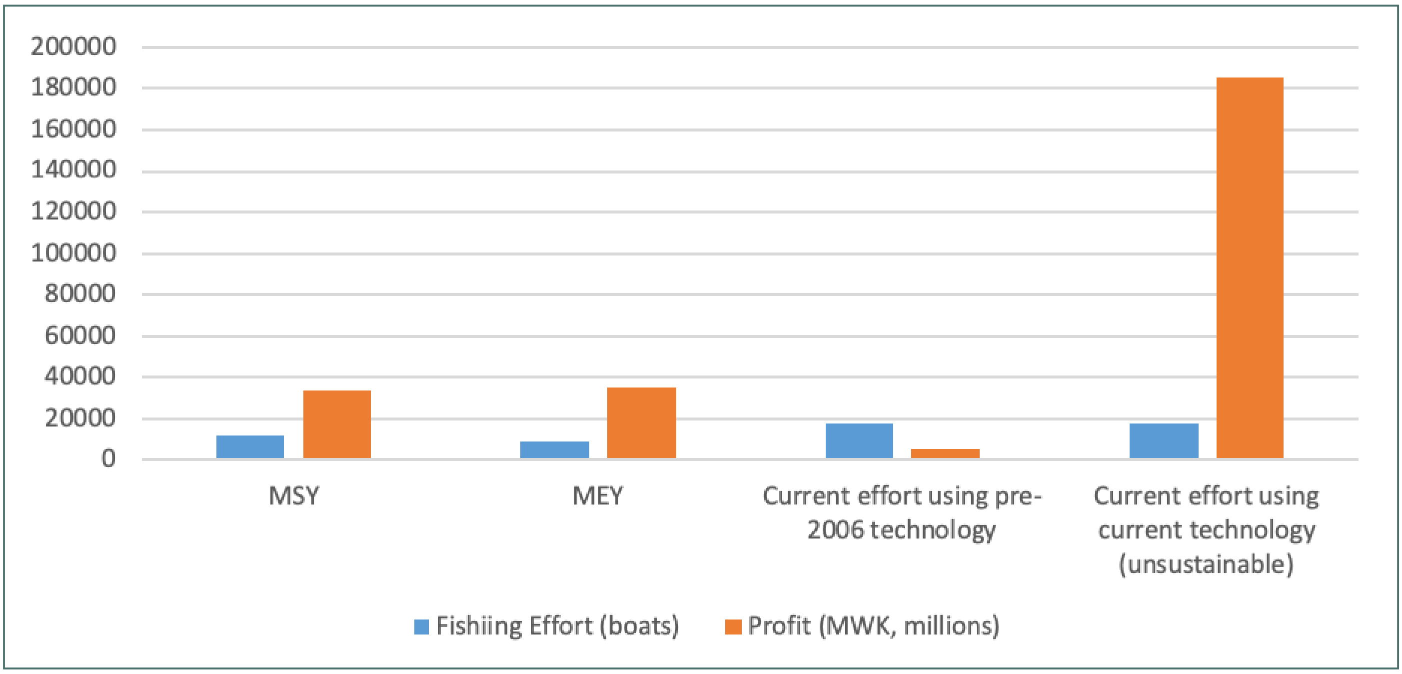
Figure 10: Catch Share of Usipa in Malawi (2010-2020)



4.2 Profitability of the Fishery

The current levels of effort coupled with the enhanced technology in the fishery is unsustainable. The fishery is highly likely to collapse within a noticeably short period if immediate measures are not taken. Gumulira et al (2019), for example, noted that even the most abundant species in lake Malawi (usipa) is overexploited. They recommended more than halving the fishing effort to maximize rents. To calculate the rents from the fishery, we need the price of fish and the cost of fishing. Following the literature, the price per kg of fish in the local market is MWK 925 (USD 1.26) (Malawi Nation, Oct 25, 2019),[5] and the average cost of operating a fishing craft per year is MWK 1.82 million (USD 2,445, Winston et al., 2019). The annual maximum potential rent/profit from the fishery, based on the price and cost of fishing figures, is estimated at MWK 35 billion (USD 47 million, i.e., at the MEY) and the corresponding number of fishing crafts is 9,400 crafts (see Figure 11). If the current fishing effort in the fisheries is adjusted based on the parameter estimates of equation (11) (i.e., assuming that fishing technology is at pre-2006 levels), the associated rent would have been MWK 5.6 billion (USD 7.47 million), which is much lower than the potential value. However, the intensified fishing effort following the use of illegal fishing gears (monofilament nets and ngongongo) generated a false (unsustainable) rent of MWK 185.5 billion (USD 249 million). Figure 11 shows the various profit and effort levels.[6]

Figure 11: Rents at MSY, MEY, and Current Effort Levels (1993-2018)



[5] Source: http://www.channelafrica.co.za/sabc/home/channelafrica/economy/details?id=22ac07c2-f98f-48d9-a21e-028f7c51557a&title=Malawi%20fish%20output%20decline%20pushes%20up%20prices (retrieved on 11/08/2021).

[6] Some have argued that the high CPUE and the corresponding elevated profit margins are due to increased usipa stock levels following the collapse of the chambo stock. The counterargument is that this is a multispecies fishery where fishers target all species including usipa since the 1980s. Moreover, the sudden spike in usipa catch from 2006 corresponds with the escalation of the use of under mesh nets in the fishery, As a result, the only plausible explanation for the sharp increase in usipa landings, hence total catch, beginning 2006 is the escalation of the use of illegal gears.

5. Benefit-cost Analysis

To determine whether (or not) an intervention in the fisheries is socially beneficial, the benefits and the costs associated with each intervention must be computed. Following the prescription by the Copenhagen Consensus Center (CCC), the stream of costs and benefits are discounted at annual rates of 5%, 8% and 14%. The benefit-cost ratios (BCR) are calculated as:

$$BCR = \frac{PV_0(Benefits)}{PV_0(Costs)} \quad (12)$$

where $PV_0 = \sum_{t=0}^{T} FV_t(1+r)^{-t}$. The variable *PV* represent the Present Value, *FV* is the Future Value, *r* is the chosen discount rate and *t* is the time ranging from *0* to *T*. The calculated BCR is non-negative. If it is greater (less) than 1, for an intervention, then society gains (losses) from that intervention. The benefits fully compensate the costs if BCR=1. Thus, interventions for which the BCR>1 should be implemented whilst those with BCR<1 discarded. Since fish stocks are renewable and can be extracted in perpetuity, the period for this analysis is assumed to be 25 years. The baseline from which the interventions are compared is a collapse of the fish stock by 2023. There is already emerging evidence that since 2019 artisanal fishers are either making losses or just breaking even (i.e., making no economic profits).[7]

Interventions

Given the current state of the capture fisheries in the country, two interventions are proposed: (1) replacing all illegal nets with legal ones, and (2) making crafts fish in turns (i.e., fishing by rotation). Research has shown that rotation can substantially reduce the risk of local depletion of stocks (Hart 2003; Kaplan et al., 2010; Plagányi et al., 2015). To operationalize the fishing-in-turns intervention, fishing crafts could be marked or painted with different colors and rotation should be based on color codes. These two interventions are considered below.

5.1 INTERVENTION 1: Replacing Illegal Fishing Nets

As indicated earlier, the illegal nets are made up of monofilament nets (47%) and other under-meshed (illegal) gillnets (40%). Thus, any net with mesh size smaller than 3.75 inches (i.e., 92.25 mm) in stretched diagonal is illegal. According to the '2020 Annual Frame Survey Report of The Small-Scale Fisheries', this accounts for 87% of all gillnets (69,817), implying that 60,741 nets are supposed to be replaced. It has been estimated that Lake Malawi recorded about 80% of the under-meshed gillnets (DoF, 2020). Comparing the effectiveness of fishing effort for 2018 and 1993-2005, when the catch per unit effort was declining, the catchability coefficient will reduce by 83% if the illegal fishing nets are replaced.[8] The corresponding estimated total catch is about 41,000 tons, and the average local price (per kg) of fish is MWK 925.[9] Working with the price ratios of 2:3 for small/juvenile relative to matured sized fish (i.e., MWK 925 and MWK 1,410), the annual total revenue is estimated at MWK 55.4 billion after replacing the nets.

The cost of replacing each net of 1000m length, 100m depth with the approved mesh size of 3.75 inches is estimated at about MWK 1,500,000. The total cost of replacing the illegal nets is MWK 91.1 billion. In addition to this cost, the fishing community must be sensitized about the intervention to achieve high level compliance (FAO, 2001). The proposed one-time cost is MWK 367 million. The largest cost is the foregone revenue in the first year where, instead of yielding MWK 218 billion revenue, fishers only yield 38 billion for a one-off net loss of MWK 180 billion. In addition, operational cost of the fishing craft is MWK 33 billion per year. This calculation is based on approximately18,000 crafts currently in the fishery.

The benefit is the revenue from fishing with the legal nets, which will be lower in the first year compared to a counterfactual of illegal net use because of the bigger mesh size. However in subsequent years the marginal revenue is positive given the assumed counterfactual of the collapse of the fish stock. Additionally, beginning the second year, the fishers will catch bigger sized fish selling at a higher value MWK 1,410 per kg. Table 1 presents the benefit-cost ratios for discount rates of 5, 8 and 14%; and for a 25-year period. At 5% discount rate, the intervention will generate benefits that is just approximately the cost.

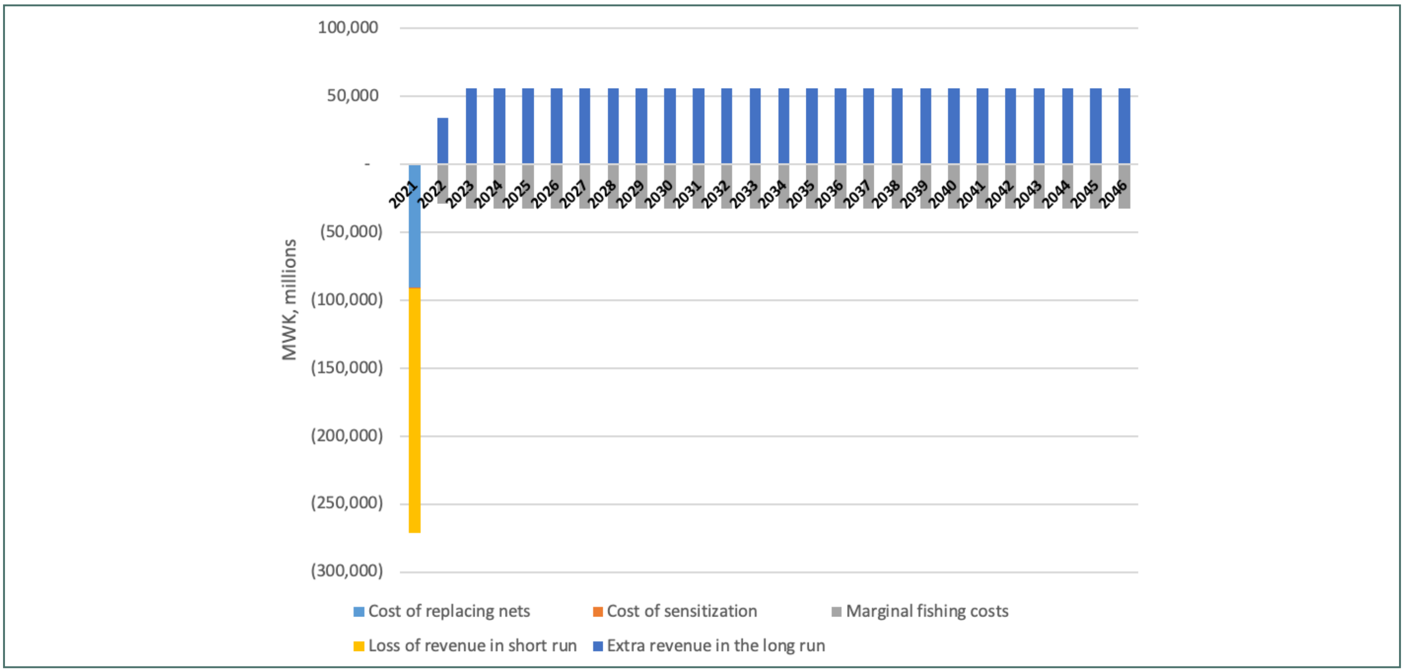
Table 1: Summary of Costs and Benefits of Replacing Illegal Fishing Net

Discount Rate	Benefit (MWK, millions)	Cost (MWK, millions)	BCR
5%	760,432	726,604	1.05
8%	571,492	615,566	0.93
14%	361,826	492,163	0.74

[8] This based on comparing actual catch, given the current fishing effort, with catch along the sustainable yield curve, using the estimated parameter values in equation (11).

[9] The price of fish may vary depending on many variables including the species. This is just an average figure obtained from MalawiNation (2019): http://www.channelafrica.co.za/sabc/home/channelafrica/economy/details?id=22ac07c2-f98f-48d9-a21e-028f7c51557a&title=Malawi%20fish%20output%20decline%20pushes%20up%20prices

Figure 12: Stream of costs and benefits of replacing illegal nets



5.2 INTERVENTION 2: Fishing in Turns (Fishing by Rotation)

As noted earlier, making crafts fish in turns is a feasible policy to halt the depletion of the capture fish stocks, if the illegal nets are not replaced. Given the current levels of technology (i.e., gear efficiency), to operate the level of maximum sustainable yield, only 2,475 crafts should be allowed in the fishery each period, catching 58,000 tons of fish. Note that with the fishing intensity as of 2018, the 2,475 crafts have the capacity of approximately 11,731 crafts as per 1993-2005 estimates. This will generate annual rent of about MWK 49,915 million, owing to the relatively low total cost of operating fewer crafts with high fishing intensity. But for easy monitoring, each craft must be painted to make it visible from a distance and the total cost of doing so is MWK 271 million. In addition, the fishers will be sensitized at a cost of MWK 485 million.

The cost of fishing in turns (fishing by rotation) includes the cost of painting/marking all fishing crafts, the cost of sensitizing the fishing community and the loss in instantaneous rent owing to the intervention (MWK 164,346 million). This is one time cost, which will occur in the first year. From the second year, the fishery is expected to generate profit at the MSY level. Thus, within the first year, the cost elements will include operating cost of the fishing crafts, the cost of painting the crafts and sensitization cost. The benefit will be the revenue accruing to the crafts as they operate at the MSY level. In the second year and beyond, the only cost is the operational cost (see Figure 13). Table 2 contains the Benefit Cost Ratios for the three discount rates. Making the fishing crafts fish in turns, could generate benefits that exceed the cost by a factor of approximately 3.

Figure 13: Stream of costs and benefits for fishing by rotation

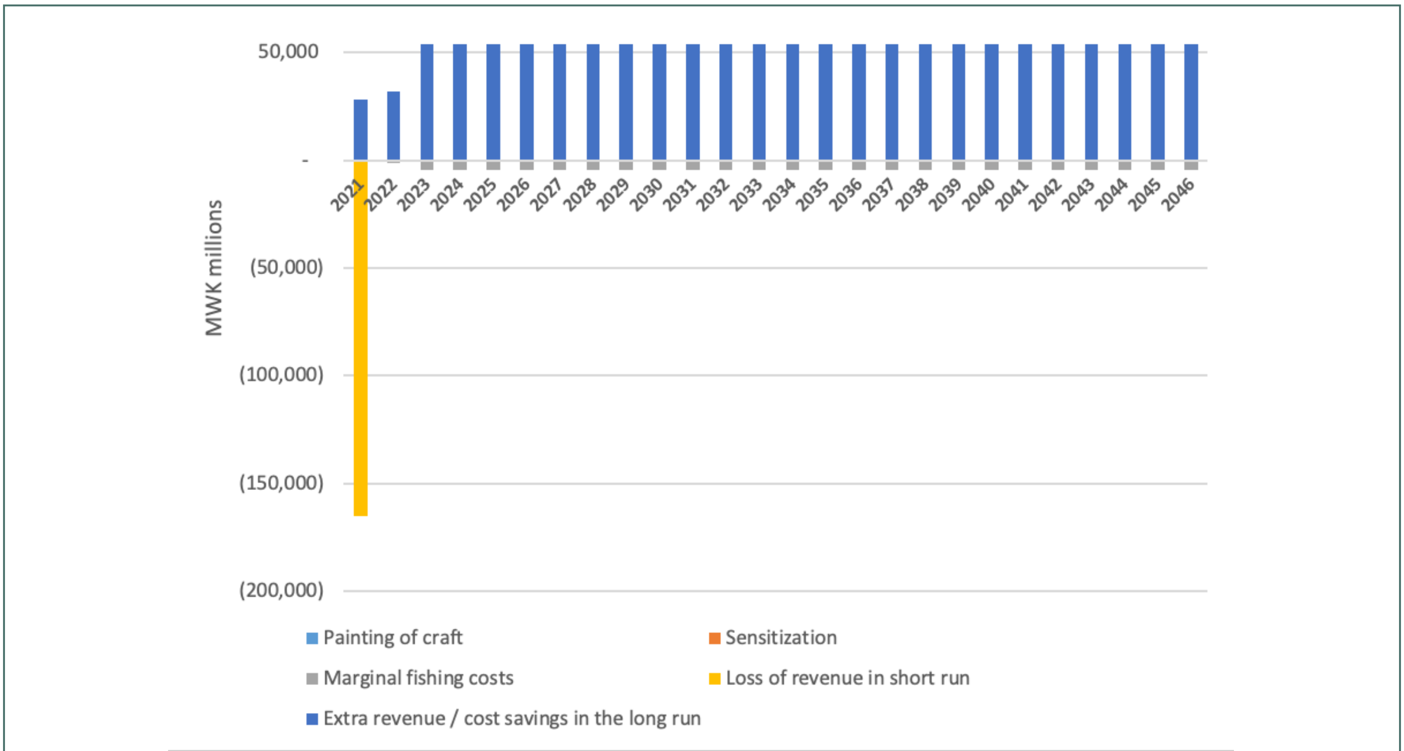


Table 2: Summary of Costs and Benefits of Fishing by Rotation

Discount Rate	Benefit (MWK, millions)	Cost (MWK, millions)	BCR
5%	763,950	224,648	3.4
8%	580,963	209,537	2.8
14%	377,916	192,798	2.0

Similarly, Table 2 presents the benefit-cost ratios for discount rates of 5, 8 and 14%; and for a 25-year period. At 8% discount rate, the intervention will generate benefits that is almost 3 times the cost.

6. Conclusion

The capture fisheries sector in Malawi provides employment, income, and food and nutrition for communities around lakes, major rivers and beyond. Yet the use of destructive fishing gears and methods, which has resulted falsely in rising trends in total catch and catch per unit effort beginning 2006 is severely endangering the sustainability of the industry. The most common illegalities in the fishing industry are the use are monofilaments and under-meshed nets. Evidently, rents in the fishery are dissipated as some fishers have started complaining about making loses when they go on fishing expeditions. By estimating the sustainable yield function and using the parameters to adjust the intense fishing efforts accordingly, we found evidence of severe overcapitalization and biological overfishing, with a high likelihood of immediate stock collapse.

Two interventions have been proposed: replacing the illegal fishing nets and making the fishers fish in turns (fish by rotation). If all illegal nets are replaced, whilst maintaining the current number of fishing crafts, the potential social benefits are expected to equal the social costs at a discount rate of 5%. Secondly, if the fishing crafts are made to fish in turns, without replacing the fishing nets, whilst maintaining the fleet capacity at the MSY levels, the social benefit can exceed the associated cost by around 3 times. The efficacy of these interventions, like any others, depends on the extent to which fishers comply with them.

This study has a few limitations. Owing to the lack of data on each lake in Malawi, the analyses is based on total landings from all lakes, and the fishing effort consists of all fishing boats and canoes (i.e., crafts), motorized or not and dugout or planked. Secondly, we assume the bio-technical parameters in our model (i.e., q, r, and K) are time invariant, hence sustainable yield is not a function of time. Furthermore, we have not considered combinations of interventions, which in most cases is necessary to achieve first best outcomes. Notwithstanding these limitations, the findings point to the direction of severe overfishing and the need to introduce a few drastic measures/interventions to rescue the industry. Notwithstanding these limitations, the findings point to the direction of severe overfishing and the need to introduce a few drastic measures if Malawi is to reap the anticipated gains from the fishing sector as espoused in MW2063.

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The Malawi Priorities Project

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