International Journal of Fisheries and Aquaculture

Full Length Research Paper

Bioeconomic analysis of *Engraulicypris sardella* (USIPA) in South east arm of Lake Malawi

Innocent Gumulira[1*], Graham Forrester[2] and Najih Lazar[3]

[1]Monkeybay Fisheries Research Station P. O. Box 27, Monkey Bay, Malawi.
[2]Department of Natural Resources Science, University of Rhode Island, Kingston, USA.
[3]Coastal Resources Centre, 220 South Ferry Road, Narragansett, USA.

Usipa *Engraulicypris sardella* is the most abundant small pelagic species in Lake Malawi. It plays an important part in the lake communities' economy and food security. However, much remains unknown on their stock status and bioeconomic importance. This study is carried out to estimate the maximum economic yield and maximum sustainable yield for Usipa fishery in the South-east arm of Lake Malawi. Structured quantitative questionnaire was used to collect information from 139 informants on the price of usipa landings and cost of fishing effort. Catch and effort data for Usipa were used in a biomass dynamic model (ASPIC) to estimate key parameters (r, q and k). A bioeconomic model was further developed based on the Gordon- Schaefer model using cost and revenues of the Usipa fisheries to derive the Maximun Sustainable Yield (MSY) and the Maximum Economic Yield (MEY). Model estimates of MSY and MEY were 9,228.8 and 8,227.1 tonnes, respectively. The corresponding fishing effort was estimated to be 40,000 net-hauls and 30,000 net-hauls at MSY and MEY, respectively. Revenues at MSY were estimated at MWK42.280 billion, while at MEY the revenues were MWK39.309 billion. The analysis shows that the current effort of 65,232 net-hauls has a yield of 6,000 tonnes, indicating that the Usipa fishery is currently overexploited over the optimum bio-economic level and even beyond the open access yield. We recommend reducing the fishing effort by 54% to realize the best economic benefits (Production at MEY) and end overfishing to protect the fishery from biological and economic collapses.

Key words: Usipa, bioeconomic, chilimira, catch per unit effort, maximum economic yield, South east arm.

INTRODUCTION

Contributing about 4% to the gross national product for Malawi, the importance of the fisheries sector in Malawi cannot be overemphasized. With one third of the land covered with water, fishing is the mainstay of most rural communities adjacent to large water bodies (GoM, 2016). Lake Malawi fisheries are a source of employment for over 60,000 fishers directly and more than 600,000 people indirectly in fish ancillary activities, which includes boat building, engine repairs and fish processing.

Over 1.6 million people in the rural communities along the shores derive their livelihoods from the Lake Malawi fisheries sector. There is no doubt that the Lake Malawi

*Corresponding author. E-mail: igumulira@uri.edu. Tel: +265 999 241 051.

fishing industry supports food and nutrition security for the majority of the country's citizenry in both rural and urban areas (GoM, 2014).

Malawi has a total population of approximately 17.5 million people and a population growth rate of 2.9% (National Statistical Office, 2018). This high population growth rate, coupled with dwindling catches from Lake Malawi has pegged per-capita fish consumption for the country at 7.79 Kg/year in 2013 (GoM, 2014), which is much lower than the global average (currently more than 20 Kg/year) (FAO, 2018).

In recent years, fish landings have been dominated by a single species of cyprinid, *Engraulicypris sardella* (Usipa) with a contribution of over 70% of the total landings (Department of Fisheries, 2017). For instance, South east arm (SEA) area recorded total Usipa landings of about 18,000 tonnes in 2015 for an effort of approximately 65,000 net-hauls (Government of Malawi, 2016). Usipa is a small pelagic schooling species (Thompson and Bulirani, 1993), that feeds on plankton, and its small size (120-130 mm) makes it prey to many larger fish, including cichlids such as *Ramphochromis* spp. (Allison, 1996). Spawning in Usipa takes place throughout the year; however, the growth rate of juveniles hatched during the rainy season is faster than those hatched during the dry season (Morioka and Kaunda, 2003), suggesting that food abundance during the rainy season is high and supports faster growth for the juveniles hatched at this time of year. However, much remains unknown about the ecology and best management practices for Usipa, despite it being the main fishery in Lake Malawi since 2000.

Thompson and Allison (1997) suggested that only limited management of the Usipa fishery was necessary based on their understanding that the fish has high reproductive output, high natural mortality and its survival is much more dependent on environmental factors rather than fishing mortality. However, such natural resources still need to be managed in some way so as to avoid depleting the stocks to levels that they may not be able to repopulate again. Currently, there is limited management of the Usipa fishery in Lake Malawi (Makwinja et al., 2018). Gear License fees, imposed by the Malawi government through the Department of Fisheries are not prohibitive enough, and enforcement measures are not strong enough to limit access. Usipa landings continue to increase with increased effort (Government of Malawi, 2016) and there is no scientific information to identify sustainable levels of exploitation (personal Observations). There is, therefore, an urgent need to provide these sustainable yield and effort figures upon which to base management decisions for the fishery.

Several authors have advocated for Bioeconomic modelling as a better tool for managing fisheries resources because of its ability to help understand the effects between resource exploiters, economic structures and the dynamics of the ecosystem (Nielsen et al., 2018). However, fisheries are complex management systems that rely on biological, ecological and socio-economic information, which is typically simplified using mathematical models (Jentoft and Chuenpagdee, 2009). This study used a simple biomass dynamic model; the ASPIC software and Schaefer (1954)'s model were used to provide the biological reference points: population instrinsic growth (r), carrying capacity (K) and catchability (q). A corresponding model framework was further developed based on the Gordon-Schaeffer bio-economic model to estimate the fishery (Maximum Economic Yield (MEY) and the Maximum Sustainable Yield (MSY). Data for the model were cost and revenues of the artisanal canoes collected through a field questionnaire. Using the model, optimum levels of effort to achieve MSY and MEY were estimated. The estimated biological and bio-economic reference points from this study are intended to help fisheries managers manage this fishery sustainably.

METHODOLOGY

Modeling overview

Gordon Schaefer model

The Gordon-Schaefer logistic model describes population growth based on the following mathematical equation:

$$\frac{dB}{dt} = rB_t \left(1 - \frac{B_t}{K}\right)$$

(1)

Where r is the intrinsic population growth rate, $B(t)$ is the population biomass and k is the carrying capacity of the environment, which corresponds to the unfished equilibrium stock size.

Under exploitation, Schaefer (1954) introduced the catch rate $Y(t)$,

$$Y_t = qf_tB_t$$

(2)

Where $F(t)$ is the fishing effort and q is the catchability coefficient which is the effectiveness of each unit of effort (Hilborn and Walters, 1992).

Therefore, biomass change through time is expressed as;

$$\frac{dB}{dt} = rB_t \left(1 - \frac{B_t}{K}\right) - qf_tB_t$$

(3)

Under sustainable level

$$rB_t \left(1 - \frac{B_t}{K}\right) = qf_tB_t$$

(4)

Dividing both sides by rB;

$$1 - \frac{B}{K} = \frac{qf}{r}$$

(5)

Then

$$B = K(1 - \frac{qf}{r})$$

(6)

Substitute B in the yield function to obtain the sustainable yield function

$$Y = qfk(1 - \frac{qf}{r})$$

(7)

Maximum sustainable yield (MSY)

Maximum sustainable yield (MSY) effort was obtained according to Seijo et al. (1998).

First derivative of yield function:

$$F_{msy} = \frac{r}{2q}$$

(8)

Substituting F_{msy} into sustainable yield function gives:

$$Y_{msy} = \frac{rK}{4}$$

(9)

First derivative of the logistic growth function

$$B_{msy} = \frac{K}{2}$$

(10)

Maximum economic yield

The level of harvesting which maximizes the profit to the fishery is determined by maximum economic yield (MEY). This yield can be obtained from the fishery when the difference between the total revenue earned by the fishery and total cost of fishing effort is at maximum. The marginal value of fishing effort was obtained by multiplying the average value of fishing effort with the average price (p).

$$MVE = pqK(1 - \frac{2qf}{r})$$

(11)

Fishing effort at MEY (f_{MEY}) was obtained by equating Equation 11 above to the unit cost of fishing effort (c) and solving for f,

$$f_{MEY} = \frac{r}{2q}\left(1 - \frac{c}{pqk}\right)$$

(12)

And Y_{MEY} was calculated as

$$Y_{MEY} = \frac{r}{4}\left(K - \frac{c^2}{p^2q^2K}\right)$$

(13)

Parameterizing the model

Study area

For monitoring purposes, all large water bodies including Lake Malawi are sub-divided into survey areas termed 'Strata' (FAO, 1993). This study estimated MSY and MEY for the fishery spanning 6 Strata in the South East Arm (SEA) namely; stratum 2.1 (South West Boadzulu), stratum 2.2 (South East Boadzulu), stratum 2.3 (North West Boadzulu), stratum 2.4 North East Boadzulu), stratum 2.5 (Makanjira) and stratum 2.6 (Fort Maguire) (Figure 1). All

artisanal landings and effort are monitored using a boat-based survey introduced in 1976 (Bazigos, 1974). It is based on a monthly random sampling of the landings by species and effort expressed in net-hauls following a data collection protocol by trained enumerators. Total landings are obtained by means of expansion to the total effort collected by the annual Frame survey (FS) and Catch Assessment Survey (CAS). The Frame Survey involves a census of the total boats and gears at each of the fishing sites, whereas the CAS is boat based and the recorder logs the number of craft at each fishing site. However, the CAS system was replaced with the Malawi Traditional Fisheries survey (MTF) in 2002 in all of the strata where the study was conducted (Manase et al., 2002). The MTF was designed by FAO with the aim of improving catch and effort estimates, and its sample units are items of fishing gear rather than boats (FAO, 1993).

Catch and effort data

Catch and effort data from 2000 to 2015 for SEA arm of Lake Malawi were obtained from Mangochi District Fisheries Office, and used to calculate catch per unit effort (CPUE). ASPIC software version 7 by Prager (1996) was used to estimate the three most important parameters of the dynamic model r, k and q from catch and effort data.

Socio-economic data

Quantitative secondary data were collected in 2015 using a structured questionnaire and was administered to the 139 Chilimira gear owners in SEA. The questionnaire was designed to collect information such as revenues of catch and costs of fishing effort. Fixed costs of fishing included the cost of engines, cost of Chilimira gears, cost of boats and license fees, whereas variable costs included wages for the crew members, costs of lighting, costs of fuel and maintenance costs for the boat, gear and engine. The total cost was calculated by adding the variable costs and the fixed costs. Similar questionnaire was successfully used to collect fisheries data (Hutchings and Ferguson, 2000; Singini, 2013).

A total of 139 gear owners were sampled. Snowball sampling (Goodman, 1961) was used to identify respondents. This sampling process helped target gear owners with the most experience in using Chilimira gear. The survey required respondents to recall historical information on the costs, prices and other important data on the fishery with the aim of assessing how the fishery catch, effort, costs of effort, and landing beach prices have changed over time. The responses were triangulated within strata, as well as across strata by visually comparing the responses from the fishers within strata and across strata, and were generally consistent.

Costs of boat and gear were also triangulated with figures from a few boat makers and net shop owners, and were also found to be consistent.

All the costs for the past years were standardised to the 2015 value using the annual inflation rate as reported in the Malawi Government Annual Economic Report (GoM, 2014). To estimate the annual variable costs for the Usipa fishery, this study assumed fishers fished on average of 12 days per month (144 fishing days per year). This estimate considers the following: (1) unfavorable weather conditions on the lake, (2) the lunar cycle (when the moon is full, fishing using light is ineffective) and (3) maintenance days, when fishermen must stay on the shore to maintain their nets or repair boats and engines.

Estimated costs included those of lights to attract fish at night and boat-crew wages. Fishermen use kerosene fuel lamps, but recently some are using solar LED bulbs that are more efficient than the lamps. The daily lighting costs from the survey were multiplied by 144 to get annual cost of lighting. The crew wages per

Figure 1. Study Area. South East Arm of Lake Malawi showing the six strata.

person per day were multiplied by 10 (number of crew per boat) and then by 144 (fishing days per year) to get the total annual wages per boat per trip. The analysis was done in microsoft excel, 2016 version and the data for the two time periods (2001-2010 and 2011-2015) were analysed separately. This period was chosen specifically because it is thought that during this period Usipa fishery developed into the major fishery in Lake Malawi. In survey pre-tests, respondents were also asked about two earlier time periods (1976-1990 and 1991-2000), but only 2 out of 8 respondents could recall estimates for these earlier periods so the data were not analysed.

RESULTS AND DISCUSSION

Landings

Data obtained from the Mangochi District Fisheries Office

show that the fish landing trends for Usipa in the SEA (Figure 2, Table 1) have been increasing slightly with fluctuations from the year 2000. However, a much more rapid increase in landings was observed from 2006 until 2015 (end of records for this study). The highest landings were reported in 2015. In 2009 there was significant decline in the landings as compared to 2008 and 2010. One possible reason for the apparently stable landings during the first six years (2000-2006) is that Usipa was not directly targeted prior to 2006. The economic potential of the fishery may not have been fully realized (personal observation) because Usipa was, and is still being used as a bait in longline fishing to catch *Ramphochromis* spp, *Bagrus meridionalis*, *Bathyclarius* spp. and other bigger fish in the cichlid and cyprinid families. Another possible reason for the low reported landings in 2012-2015 may be due to low data collection
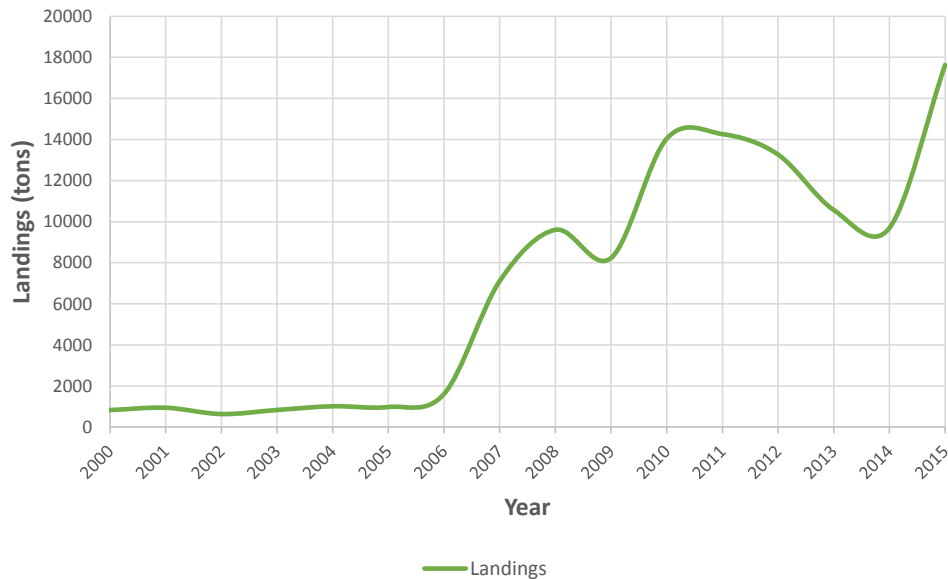
Figure 2. Usipa landings (metric tons) in south east arm of Lake Malawi from year 2000-2015.

Table 1. Observed landings, observed effort, catch per unit effort, adjusted beach price and Net Revenues for Usipa fishery in South East Arm of Lake Malawi.

Year	Obs. Landings (mt)	Obs. effort (net-hauls)	CPUE	Adjusted beach price (MWK)	Net revenues per boat/year (MWK)
2000	829	82123	0.01009	240	988,391.81
2001	944	79519	0.01186	208	1,034,147.22
2002	636	83112	0.00764	211	532,613.05
2003	835	89483	0.00933	264	1,066,383.86
2004	1017	73775	0.01378	280	1,321,077.49
2005	980	75299	0.01300	363	1,577,352.53
2006	1616	75299	0.0214	409	2,855,615.80
2007	7112	64017	0.1110	431	13,019,984.55
2008	9608	69725	0.13780	637	26,242,700.94
2009	8233	63960	0.12872	618	19,938,733.52
2010	14041	67973	0.20656	524	28,673,692.28
2011	14264	61716	0.2311	653	35,910,243.02
2012	13269	57487	0.23082	520	26,295,607.75
2013	10570	61078	0.17305	729	37,716,076.98
2014	9694	52611	0.18425	547	22,826,154.87
2015	17629	65232	0.27025	646	39,907,282.30

because of shortage of field staff, which was further exercerbated by inability of the few data collectors to get to some distant landing sites. Furthermore, The MTF method of data collection (currently being implemented in Mangochi District) is done at one beach for 4 days per month and so may not adequately sample landings that fluctuate from day to day. Figure 2 shows that landings are not stable.

Fishing effort

Figure 3 presents the changes in fishing effort for Usipa, which is showing a steady increase with a modest decline during the period 2000-2015. The recorded effort in the year 2000 was about 82,000 net-hauls, decreasing to about 65,000 in 2015. However, there is a significant increase in catch resulting from this effort, that is, an
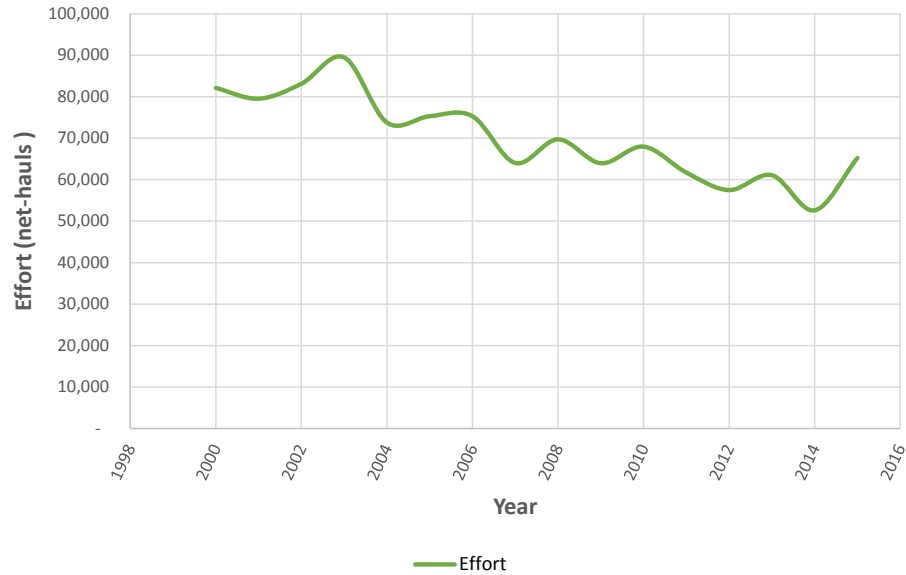
Figure 3. Usipa fishing effort in south east arm of Lake Malawi from year 2000-2015.

Figure 4. Catch[1] per unit effort[2] of Usipa in South east arm of Lake Malawi. [1]catch is measured in metric tons. [2]Effort is measured in number of net-hauls.

effort of 82,000 net-hauls landed 830 tons of Usipa in the year 2000 while 65,000 net-hauls landed about 17,000 tons in 2015 (in other words, a 20% reduction in effort resulted in a 2,000% increase in catch). This may possibly be attributed to several changes in the fishery that are not accounted for in the fishing effort data. These changes include more experience in catching Usipa gained over time by fishers, as well as a change in the fishing grounds. In addition, the gear used to target Usipa has greatly been modified as indicated by one of the respondents that the bunt diameter has been increased by 2 fold and others by 3 fold and that the size of the gear

has also been increased by simillar margin as the bunt (Sergrath et al., 2018).

Catch per unit effort

The CPUE showed a steady increase from 2006 until 2015, suggesting an increase in abundance of Usipa (Figure 4). From the year 2000, Usipa fishery had almost a constant CPUE in the SEA. This is probably due to early development of target fisheries for Usipa. Overall, the CPUE has been increasing steadily with the highest
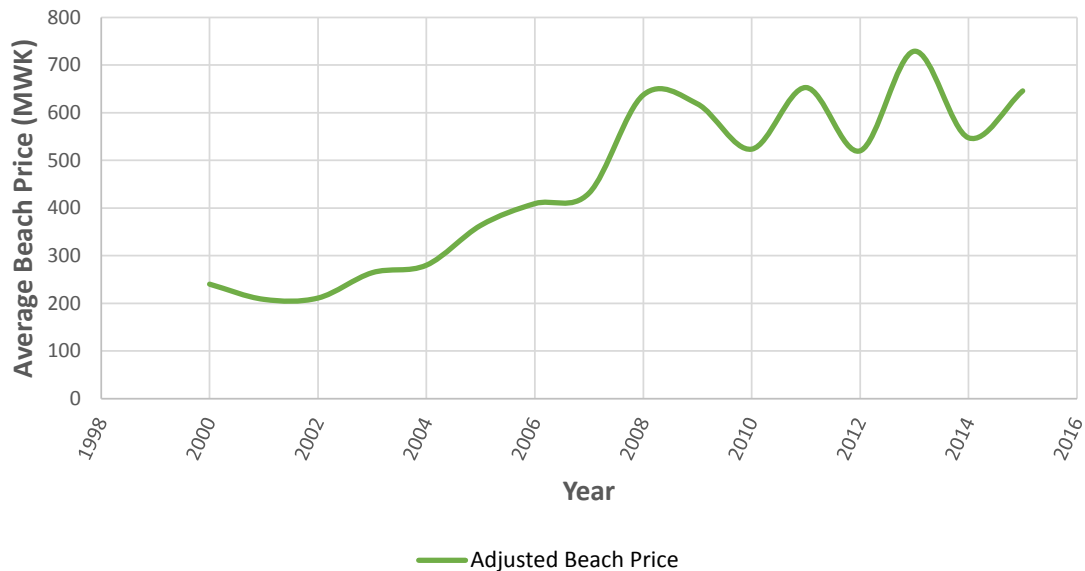
Figure 5. Average Beach Price[1] for usipa in south east arm of Lake Malawi from 2000-2015.
[1]The price is in Malawi Kwacha (2015: $US1=MWK715).

CPUE observed in 2015. This can be attributed to the use of modified gears which have become more effective. Furthermore, this could also be due to the the availability of better transportation of data collectors who took advantage of the motor cycles provided by the Fisheries integration of Society and Habitats (FISH) project which helped data collectors to easily get to landing sites which were very far away to be reached by foot. The effort in year 2000 to 2006 was markedly higher compared to the corresponding landings. This is likely a problem with recording of the effort or landings or both. A fishery with such fishing trends would be regarded as overexploited, and no fisherman would continue fishing unless there were fishing subsidies (Kelleher et al., 2009).

Landing beach prices

The adjusted landing beach prices as recorded by the Mangochi District Fisheries Office indicate that it has been increasing steady from 2000-2015 (Figure 5). Some price spikes were, however, recorded in 2008, 2011 and 2013. Some marked increase in the beach prices was observed in 2006 to 2008, and this may possibly be attributed to the increase in the investment in this fishery. This ended up causing the landing prices to go up as well. Another reason for this increase in the beach prices could be that there was no much alternative for fish due to the dwindling catches in the bigger fish like Chambo. And what was readily available was Usipa which fish mongers could easily access and bring to the markets. It is worth noting that this phenomenon corresponded well with the high landings (Figure 2). The average beach

prices are highly affected by the season, rainy season with the most negative impact. Usipa is processed by sundrying and during rainy season. This method of conservation is almost impsossible, because most of the sundrying is done on open drying racks (Banda et al., 2017). As such during the rainy season Usipa beach price is so low since very few fish mongers would be willing to buy the fish except for the few that use other fish processing methods such as the Solar tent drier or paraboiling (Njaya and Kachilonda, 2008).

Net revenue

Figure 6 illustrates the revenue fluctuations over the 15 years. From 2000-2015, the revenue was almost constant, registering less than 1 billion Malawi Kwacha. However, there was a rapid increase after 2006, with revenues thereafter fluctuating around MWK 30 billion. Fluctuations from year to year could be due to the unstable pricing of the Usipa, due to its unstable beach landings. When caught in large quantities, the price goes down and fishers are forced to sell at small profits and sometimes with a significant loss (personal observation) and hence low revenues in some years.

Biological equilibrium

Three parameters of the Gordon-Schaefer model (q, K and r) were estimated as follows: q= 4.6454E-06 (catchability coefficient), K= 98,000 (Carrying capacity) and r= 0.37928982 (intrinsic rate of increase). The model

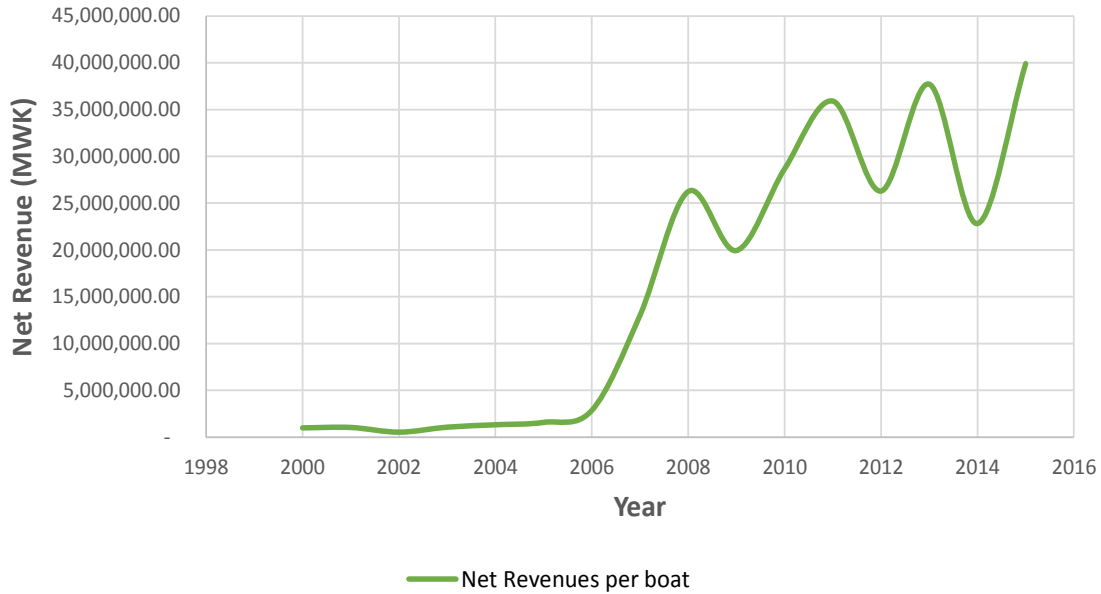**Figure 6.** Changes in total annual revenue per boat (MWK) for Usipa fishery in south east arm of Lake Malawi.
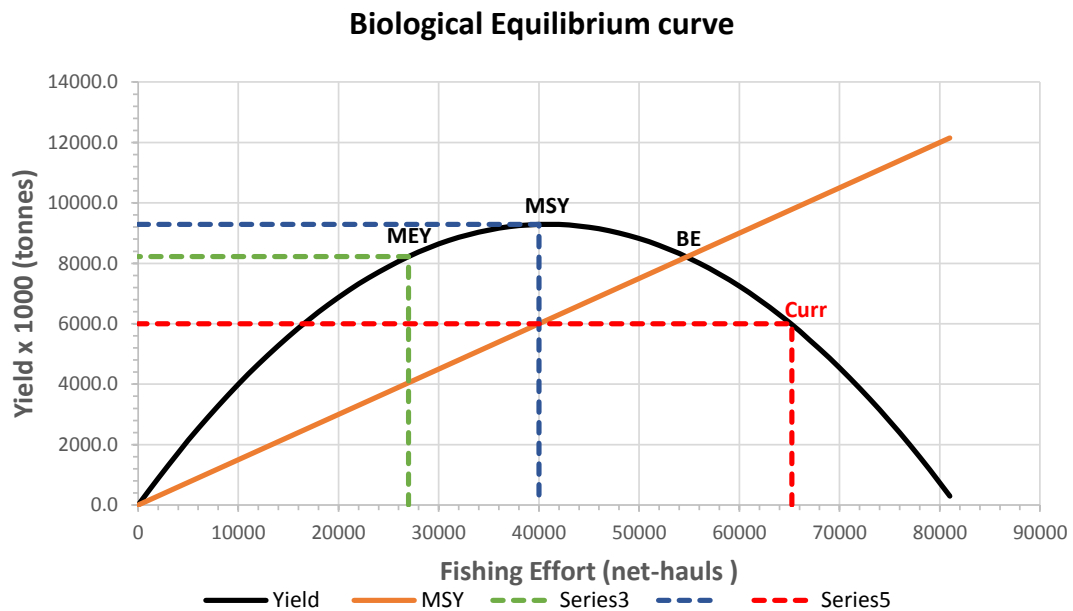
Biological Equilibrium curve

Figure 7. Gordon-Schaefer equilibrium curve, showing traditional reference points (maximum economic yield, MEY; maximum sustainable yield, MSY; bionomic equilibrium, BE) for Usipa fishery in south east arm Lake Malawi.

fit was significant (P<=0.05). The graph of yield (Yt) against effort (Ft) for the Gordon-Schaefer model fit to the data (using the method of least squares) is shown in Figure 7. From the figure, the estimated MSY for Usipa fishery in SEA was 9228.8 metric tons. This yield at MSY is almost 1000 metric tons higher than that for Maximum

Economic Yield (8227.1 metric tons). This result was expected because MEY is usually a more conservative reference point (Seijo et al., 1998). The corresponding efforts at MSY and MEY were 40,000 and 27,000 net-hauls. The model also estimated the bionomic equilibrium yield as 8200 metric tons and its corresponding effort of
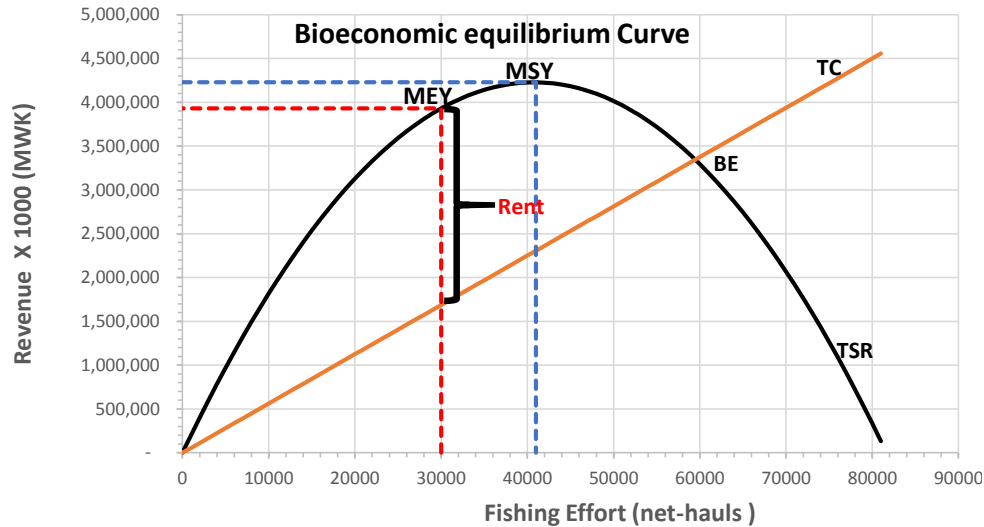
Figure 8. Gordon-Schaefer equilibrium curve, showing total sustainable revenue, (TSR) and traditional reference points maximum economic yield, (MEY); maximum sustainable yield, (MSY); bionomic equilibrium, (BE) in south east arm Lake Malawi.

54,000 net-hauls.

Bieconomic equilibrium

The total annual revenues realized from Usipa in SEA of Lake Malawi are presented in Figure 8 and Table 3. From the figure, the sustainable revenue at MSY was estimated to be MK42.280 billion realized with a corresponding effort of 41,000 net-hauls. At MEY the sustainable revenues were estimated to be lower than at MSY by a margin of MWK 2.971 billion while the corresponding effort for MEY was lower by 11,000 net-hauls as compared to that of sustainable revenues at MSY.

Most fisheries today aim to operate at MEY (Pradhan and Chaudhuri, 1999) because of the advantages over operating at MSY (Seijo et al., 1998). It is not only sustainable biologically to operate at MEY, but it also gives the maximum net revenue to the harvesters. For the Usipa fishery in SEA of Lake Malawi, the modeling results suggest that operating at MEY would come at a significant cost to the fishers. From the results in Figures 6 and 7 and Tables 2 and 3, managing the fishery using MEY as a reference point would require a reduction of effort by 54%, which of course by implication will correspond to higher rent than what the fishery is currently realizing. Although there is a small difference in landings and revenues between operating the fishery at MEY and MSY (1000 mt), it is still safer to operate at MEY than at MSY because MEY is both conservative and maximises resource rents (Seijo et al., 1998). However, effort reduction in the short term means a reduction in yield and revenues for the small-scale fisheries. This will

have significant socio-economic implications because of the livelihood and food security dependencies by the low income shore communities. Oftentimes, effort reductions must be done in step increments accompanied by safety net programs to ease the burden of economic and food loss of the low-income communities.

Models are never true but they are useful; however, they require adaptive management which gives us an opportunity to adjust the model so as to make sure that the model is not grossly wrong (Jentoft and Chuenpagdee, 2009). The results from Figures 2 and 3 indicate that the fishery is currently being fished at an effort of 65,232 net-hauls and a corresponding catch of 17,629 m.t. The model, however, predicts a lower catch of about 6,000 m.t. for the same effort (Figure 7), and model results suggest that the SEA is being fished above bionomic equilibrium (BE). It is however important to note that catch in purely schooling fish is a function of effort only and independent of the fish stock (Steinshamn, 2011).

The US Sustainable Fisheries Act (Office of Coastal Management, 2019) and United Nations Convention of the Law and Sea (United Nations, 1982) advocate the need to consider the economics, the environment and social implications when managing any fishery. Models must be inclusive by considering the three dimensions; the biology of the fish, the economics of harvesting as well as the environment; however, the current study did not consider the important environment component.

Although there is no published literature that quantified damage that predators cause to the Usipa, there is evidence from local fishermen that points to the fact that Usipa are preyed upon by *Ramphochromis* spp and other species that were once abundant but have dwindled

Table 2. Yield and fishing effort at maximum sustainable yield (MSY) and at maximum economic yield (MEY) for Usipa fishery in south east arm Lake Malawi.

Variable	MSY	MEY
Yield	9228.8	8227.1
Effort	40000	27000

Yield is in metric tons and Effort is in number of net-hauls.

Table 3. Revenue and effort at maximum sustainable yield (MSY) and at maximum economic yield (MEY) for Usipa in south east arm Lake Malawi.

Variable	MSY	MEY
Revenue	42.280	39.309
Effort	41000	30000

Revenue is in billion Malawi Kwacha and Effort is in number of net-hauls

(FAO, 1993). It is important to note that both the artisanal fishers and commercial fishers target these predators using long line fishing methods by artisanal fishers and as a bycatch by commercial fishers. These predators have a higher economic value as compared to Usipa (Kanyerere, 2001; Personal observation). Singini (2013) suggested that dwindling population of these bigger fish contributed to the increase in production of Usipa in SEA of Lake Malawi which may explain the past increases in landings of this fishery. The results of the model suggest that the Usipa fishery is over exploited and that catch from recent years is above the MSY and MEY. This neccesitates reducing the effort to as close as possible to the calculated Maximum Sustainabe Yield and better still to the effort predicted by the model at Maximum Economic Yield.

RECOMMENDATIONS

Replicating the study to include the environmental parameters and further standardizing the effort would be the next steps to improve the current predicted results. Reducing the effort levels in some way may be by introducing prohibitive license fees, which might result in rendering the fishery less of an open access could be a short and medium term goal to sustain this fishery.

ACKNOWLEDGEMENT

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Allison E (1996). Diets and food consumption rates of pelagic fish in Lake Malawi, Africa. Fisheries Research 35:489-515.
Banda J, Katundu M, Chiwaula L, Kanyerere G, Ngochera M, Kamtambe K (2017). Nutritional, Microbial and Sensory quality of Solar Tent Dried (Samva Nyengo) and Open sun Dried Copadichromis virginalis-Utaka (Pisces: Cichlidae). International Journal of Marine Science (May) 7(11):96-101.
Bazigos GP (1974). The Design of Fisheries statistical Surveys- In-land waters. FAO Fisheries Technical Paper 133. p 122.
Department of Fisheries (2017). Annual Economic Report 2017 Fisheries Sector Contribution. Lilongwe, Malawi: Department of Fisheries. Available online at www.agriculture.gov.mw/Profiles/Fisheries.pdf
Food and Agriculture Organization (2018). The status of World Fisheries and Aquaculture 2018. Meeting the sustainable development goals, Rome P 69.
Food and Agriculture Organization, (1993). Fisheries Management in South east Lake Malawi, the upper shire river and Lake Malombe with particular reference to Chambo (Oreochromis spp). CIFA Technical.Paper 21. Rome, Italy: FAO
Goodman LA (1961). Snowball sampling. The Annals of Mathematical Statistics 32(1):148-170.
Government of Malawi (2014). Annual Economic Report 2014. Ministry of Finance, Economic Planning and Development, Budget Document No. 2. Lilongwe, Malawi.
Government of Malawi (2016). Annual frame survey report of the small-

scale fisheries. Department of Fisheries, Lilongwe, Malawi.

Hilborn R, Walters CJ (1992). Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. New York: Chapman and Hall Press.

Hutchings JA, Ferguson M (2000). Temporal Changes in harvesting dynamics of Canadian in-shore fisheries for Northern Atlantic cod. Canadian Journal of Fisheries and Aquatic Sciences 57(4):805-814.

Jentoft S, Cheumpagdee R (2009). Fisheries and coastal governance as a wicked problem. Marine Policy 33(4):553-560.

Kanyerere GZ (2001). Spatial and temporal distribution of some commercially important fish in the southeast and southwest arms of Lake Malawi: A Geo-statistical Analysis. In Lake Malawi Fisheries Management Symposium P 173.

Kelleher K, Williman R, Amason R (2009). The sunken billions. The sunken billions: the economic justification for fisheries reform. The World Bank. p 108, doi: 10.1596/978-0-8213-7790-1

Makwinja R, Singini W, Kaunda E, Kapute F, M'balaka M (2018). Stochastic modelling of *Engraulicypris sardella* (Gunther,1868) catch fluctuation. International Journal of Fisheries and Aquaculture. 10(4):34-43.

Morioka S, Kaunda E (2003). Preliminary examination of lapillus utility for otolith increment analysis in Malawian cyprinid *Engraulicypris sardella.* Ichthyological Research 50(3):284-287.

National Statistical Office (2018). Population and Housing Census 2018 (Preliminary report), National statistical office, Zomba, Malawi, pp. 1-23. doi:10.1016/j.jtcvs.2012.11.079.

Nielsen JR, Thunberg E, Holland DS, Schmidt JO, Fulton EA, Bastardie F, Punt AE, Allen I, Bartelings H, Bertignac M, Bethke E, Bossier S, Buckworth R, Carpenter G, Christensen A, Christensen V, Da-Roch JM, Deng R, Ditchmont C, Doering R, Estaban A, Fernandes JA, Frost H, Garcia D, Gasche L, Gascuel D, Gourguet S, Groeneveld RA, Guillen J, Guyader O, Hamon KG, Hoff A, Horbow I, Hutton T, Lehuta S, Little LR, Lleonart J, Macher C, Mackinson S, Mahevas S, Marchal P, Mato-Amboage R, Mapstone B, Maynon F, Merzereaud M, Palacz A, Pascoe S, Paulrud A, Plaganyi E, Prellezo R, van-Putten EI, Quaas M, Ravn-Johnsen L, Sanchez S, Simons S, Thebaud O, Tomczak MT, Ulrich C, van-Dijk D, Vermard Y, Voss R, Waldo S (2018). Integrated Ecological-Economic Fisheries models-Evaluation Review and challenges for Implementation. Fish and Fisheries 19(1):1-29. https//doi.10.1111/faf.12232.

Njaya F, Kachilonda D (2008). Fish-value-chain analysis and vulnerability of actors in the marketing of usipa: case of Msaka and Msitiwere beaches on Lake Malawi, Mangochi. Unpublished report submitted to FAO Malawi Office.

Office for Coastal Management (2019). Magnusson-Stevens Fishery Conservation Act. From 2010-06-15. NOAA National centers for Environmental Information. https://inport.nmfs.noaa.gov/inport/item/48890.

Pradhan T, Chaudhuri KS (1999). Bioeconomic harvesting of a schooling fish. Korean Journal of Computer and Applied Mathematics 6(1):127-141.

Schaefer MB (1954). Some aspect of the dynamics of Populations important to the management of commercial marine fisheries. Bulletin of Mathematical Biology 53(1-2):253-279.

Seijo JC, Defeo O, Salas S (1998). Fisheries Bioeconomics: Theory, Modelling and Management. FAO Fisheries Technical paper 368. Rome, Italy. Food and Agriculture Organisation of the United Nations.

Sergrath JC, Gergel SE, Vincent ACJ (2018). Shifting gears: Diversification, Intensification and effort increases in small-scale fisheries (1950-2010). PLoS ONE 13(3). https//doi.org/journal.pone.0190232

Singini W (2013). Bioeconomic Analysis of Chambo (Oreochromis spp) and Kambuzi (Small Haplochromine spp) Fish stocks of Lake Malombe. Ph.D. Thesis, pp. 1-199, University of Malawi, Bunda College of Agriculture, Malawi.

Singini W, Kaunda E, Kasulo V, Jere W (2013). Wealth based fisheries management of Chambo (Oreocochromis spp) fish stock of Lake Malombe in Malawi. International Journal of Fisheries and Aquaculture 4(1):270-277.

Steinshamn SE (2011). A conceptual analysis of dynamics and population in bioeconomic models. American Journal of Agricultural Economics 93(3):799-808.

Thompson AB, Allison EH (1997). Potential yield estimates of unexploited pelagic fish stocks in Lake Malawi. Fisheries Management and Ecology 4(1):31-48.

Thompson AB, Bulirani A (1993). Growth of Usipa (Engraulicypris sardella) in Lake Malawi/Niassa. UK/ SADC Pelagic Fish Resource Assessment Project: In CIFA Occasional Paper NO. 19. FAO, Rome.

United Nations (1982). United Nations Convention on the Law of the Sea. Retrieved from http://www.org/Depts/convention_agreement/texts/unclose/unclos_e.pdf