Improving Technical Efficiencies of Small-scale Commercial Fish Farmers in Malawi – Lessons Learned from 9 Farmers

FISHERIES INTEGRATION OF SOCIETY AND HABITATS (FISH) PROJECT

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Farm manager of Grace kumvenji Fish Farm.
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Abbreviations

AEM	Aquaculture Enterprise Malawi
ABW	Average Body Weight
BMPs	Best Management Practices
BMZ	The Federal Ministry of Economic Cooperation and Development
CRSP	Chambo Restoration Strategic Plan
DFO	District Fisheries Officer
DoF	Department of Fisheries
EPA	Extension Planning Area
FCR	Feed Conversion Ratio
g	Grams
GIZ/GTZ	The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GoM	Government of Malawi
ICLARM	The International Center for Living Aquatic Resources
Kg	Kilograms
Km	Kilometres
m	Meters
MWK	Malawi Kwacha
NAC	National Aquaculture Centre
SADC	Southern African Development Community
SHASP	Small-scale Hatchery Seed Production
SWOT	Strengths, Weaknesses, Opportunities, Threats
T	Tonnes
T/ha	Tonnes per Hectare
USAID	The United States Agency for International Development

Executive summary

As a component of the “Fisheries Integration of Society and Habitats” project (FISH), Imani Consultants Ltd. (ICL) were commissioned by Pact Malawi to identify and work with existing, semi/commercial fish farmers to identify barriers that inhibit their production and over the course of a single production cycle implement mitigation measures enabling them to improve their productivity and profitability. It was anticipated that these “collaborators” would represent the group who, given small changes to their system and access to improved inputs, could significantly increase aquaculture production in Malawi. This was considered a pilot-scale intervention, with a view to the findings being made available and therefore replicable throughout Malawi to assist in wider growth of aquaculture in the country.

The study’s methodology used a phased approach, first through a review of available literature, exploring the current bottlenecks that prevent the progression of commercial aquaculture in Malawi. Findings of this review indicated: lack of education in farm and business management skills; poorly developed supply chains for key inputs - feed, fingerlings and fertiliser/manure; lack of sales and marketing knowledge; and limited access to credit facilities. To identify suitable participants, Department of Fisheries (DoF) datasets informed a preliminary list of 25 farmers who were visited through a scoping mission, which informed a detailed selection process involving 9 farmers (hereafter collaborators) using topic guides and farm inspections. A specific implementation plan was then developed for each collaborator, which sought to enable use of commercial inputs and improved practices to increase both productivity and profitability over a single cycle (i.e. 4-5 months during 2018/19). The collaborators were provided with key inputs, including formulated feed from National Aquaculture Centre (NAC) and feeding trays; inorganic fertiliser (NPK and Urea sourced from Yarra); weighing scales and seine nets to enable sampling and input adjustments. Based on the production guidelines of NAC, a cycle plan was designed for each farmer to ensure improved production and profitability (i.e. known application rates of fertiliser and feed in accordance with monthly sampling). The application of inputs was monitored, and each farmer received bi-weekly training and guidance on best management practices (BMPs).

The selection process found that most farmers do not adhere to BMPs as they have not seen benefits in the past. This in part contributes to the low incidence of farms that are truly commercial in their approach. Furthermore, farmers that do show commercial intent typically lack access to good quality inputs. Farmers indicated that previous average productivity was ~1.2 T/ha/year and profitability ~1,600,000 MWK/ha/year. However, the majority of collaborators reported that only a small portion of their total profit came from grow-out (<100,000 MWK/year) and instead, the majority came from the sale of fingerlings - an interesting finding and indicator of the need for wider discussion regarding the development of supply chains for quality seed.

The results from the production cycle show that all collaborators succeeded in achieving higher production and productivity than the previous cycle (average of 46.77 to 79.08 Kg and 1.2 to 2.2 T/Ha), thus demonstrating that the use of shortened cycles and orientating production towards profitability rather than maximum fish size can improve average annual productivity to >4 T/ha/year. However, despite adherence to BMPs, fish growth rates varied greatly, and this is likely attributable to various factors (e.g. stocking size, genetic quality etc). Similarly, in terms of profitability, all but two collaborators secured positive net profit, with five achieving higher net profit than the previous cycle, though high incidence of theft affected two collaborators. Furthermore, though fish sales values vary by geographical area, this is likely linked to fresh fish availability among other factors, since there is no clear price-premium by fish size and small-sized fish is viable at this scale (≤100g). In terms of input usage, inorganic fertiliser is seen to be a suitable alternative to animal manure with all collaborators highlighting its use as a key learning outcome for this study. Moreover, all but two collaborators achieved a lower feed conversion ratio (FCR) than the previous cycle (average of 2.1 from 8.8 - SD 13.7). This demonstrates the important gains that can be made when using formulated feed such as that produced by NAC in combination with BMPs, though the results of proximate analysis indicate that NAC feed is suboptimal in terms of key nutrients when compared with other feed options that are available within the region. Therefore, it is advised that the improvements seen for productivity - including feed use - and profitability

may be increased further through use of various imported feed options. Further exploration of options for importing high quality, formulated feed found that the process for import is currently complicated, and it is suggested that this likely plays a role in these feeds not being available in Malawi at present. However, it has been demonstrated here by scenario analysis, that improved profitability is attainable when the cost of imported feed - including import VAT - is used in place of the costs incurred by using domestically produced feed for these collaborators, thus showing that the current VAT cost is not a barrier to expansion of commercial aquaculture in Malawi if BMPs are upheld, though it is recommended that, temporary wavering of VAT over a short and defined time period would likely catalyze expansion of the sector in the short term, until a domestic demand reaches critical mass of production, creating a viable case for domestic feed supply.

These findings demonstrate that it is possible for semi-commercial fish farmers - like the collaborators of this study - to produce fish that are suitable for markets in under 24-weeks and be profitable using commercial inputs and more specifically this key finding highlights the need for revising approaches towards the length of production cycles as it has been shown that optimum cycle lengths of 13-19 weeks can be achieved with growth rates of 0.8 ABW increase per day and adherence to BMPs, allowing for two cycles per annum (see Annex 6: Projected change in net profit (MWK) in relation to cycle length (n) for 2018/19). Therefore, to increase the production of aquaculture in Malawi, farmers like the collaborators in this study must have access to high quality inputs and should be encouraged to utilise BMPs.

1. Introduction

Despite Malawi's aquaculture sector receiving considerable attention over recent decades, the sector has failed to develop to scale. As such, the majority of farmers still operate low-input, low-output systems and face a wide range of challenges that prevent their system's reaching maximum productivity and profitability – perhaps most notably the lack of supply chain development which hinders farmer's access to core inputs. In response to this issue, Pact Malawi, with funding from USAID as part of the "Fisheries Integration of Society and Habitats" project (FISH), launched this aquaculture component, to identify the barriers that inhibit production for semi/commercial fish farmers and to promote mitigation measures to enable collaborator farmers to improve the productivity and profitability of their systems.

1.1 Historical Context: Aquaculture in Malawi

Though various indigenous and exotic species have been cultured in Malawi, since the mid-1950's production has been focussed towards indigenous tilapias from genera *Oreochromis* and *Tilapia* (e.g. *O. shiranus, O. karongae* and *T. rendalli*). This was spurred by the creation of the "Experimental Fish Farm" in Domasi, which later became the National Aquaculture Centre (NAC) during the ICLARM/GTZ Aquaculture Project of the 1980-90's. The centre's primary role was to breed improved strains and to distribute these fingerlings to farmers.

During this time period (1970-present), the development of aquaculture has coincided with many donor-funded projects, with these largely focussing on the development of low-tech farming technologies and the promotion of smallholder integrated systems, in attempts to boost animal protein available to resource-poor and food-insecure people. This cycle of events may have restricted the developing sector, since now the majority of fish farm throughout Malawi are either smallholder or small-scale, low-input and low-yielding ponds (average of <1-2 T/ha/annum).[i] As is the case with many commodities when produced at smaller scales, these individuals typically lack the funds to purchase commercial inputs, and instead rely almost exclusively on recycled seed (i.e. from neighbours or own ponds), family labor and green-water ponds, fertilised with manure (e.g. poultry) and supplemented with various locally-available foodstuffs.[ii] Despite this, semi-commercial farmers do exist and utilise commercial inputs as available.

Since the year 2000, several large, commercial-scale farms have been established in Malawi to produce indigenous species in cages and ponds (Maldeco Fisheries Ltd in Mangochi) and recirculating aquaculture systems (RAS) utilising intensive biofloc (Chambo Fisheries Ltd in Limbe). As of 2018/19 there are plans for multiple new cage farms to be developed in Lake Malawi, close to Salima.

In general, fish farms in Malawi can be classified into three commonly agreed categories in which the first two typically overlap, depending on the portion of production sold, as illustrated in Table 1.

Table 1: Categorising scales of Aquaculture Enterprises in Malawi[iii]

Category	% of Fish Farmers	Description
Subsistence / Small-scale Farm	**≥85%**	**1-3 ponds** with total area **≤500m²**, managed by **household, no formal employees, quality inputs or credit.** Harvest on continuous basis (over 1-2 years), **primarily home consumption with few sales at farmgate**, **no records or business planning**. **Extensive systems,** yield of **<1 T/ha/annum.**
Semi-commercial Farm	**≤10%**	**>3 ponds** each with area **500-1000 m²**, owned by **household** but **employ few staff**, access to **some quality inputs and credit.** Harvest every 6-8 months and **sell most fish outside home village. Some financial records and business planning**. **Semi-extensive** and average yield **±1-4 T/ha/annum.**
Large-scale Farm	**≤5%**	**>10 ponds** each with area **>1000m²**, owned by **individual/s or business,** with **many employees**, use of **commercial inputs**, **access to**

		loans and credit, harvests at least once every 6-8 months, selling **majority of fish to urban markets** with value-chain stakeholders, **comprehensive records**, **concrete business plans**. **Intensive** and therefore yields **>5 T/ha/annum.**

2. Methodology and Approach

The study aimed to gain a better understanding of the current challenges/barriers and system inefficiencies that hinder increased production and profitability for semi-commercial fish farmers in Malawi. As such, the study sought to select and work closely with existing, semi-commercial/commercial fish farmers (hence forth "collaborators") over a single production cycle to introduce implementable mitigation measures that can assist these individuals in overcoming the challenges/barriers that they face. It was anticipated that these challenges/barriers may include technical expertise, on-farm management and husbandry skills; market identification and utilisation; and access to supplies of affordable inputs, such as feed, seed and manure. The implementation of this methodology was achieved through a phased approach.

2.1 Inception Meeting

An inception meeting took place between the Team Leader from Imani and Pact Malawi staff (Chief of Party, Deputy Chief and Party and Finance Manager). The inception meeting provided an opportunity to refine and confirm the project plan, activities and timescales, as well as discussing the background to the broader project aims and objectives and to clarify any outstanding questions.

2.2 Literature Review and Desk-based Study

During this stage, the consultants reviewed available literature, including key studies and reviews for commercial aquaculture production and fish marketing systems in Malawi (see Annex 1: Literature Review – Commercial Aquaculture in Malawi). The literature review presents the key issues and barriers for aquaculture in Malawi from a historical perspective and formed the foundations on which the intervention process was built, by identifying gaps in available data (e.g. production data: productivity and economic feasibility, cost-benefit analyses, profit and loss for different pond production models) which could then be filled where possible in the subsequent phase of the project. This desk study also sought to review approaches in other Sub-Saharan African countries, since the growth, or not, of aquaculture in these countries can provide valuable insight into what may or may not be successful in Malawi.

2.3 Identifying Collaborator Farmers

Since this study aimed to work with semi-commercial/commercial fish farmers and sought to collaborate with these farmers to improve system efficiencies over the course of a production cycle (i.e. up to 8 months including preliminary preparation and training), it was important that sufficient time was given to selecting suitable farmers who could work well with technicians. Therefore, a phased selection process was used.

2.3.1 Dataset Review and Discussion

This initial stage involved reviewing existing datasets from Department of Fisheries (DoF) for fish farmers. Individual farmer details were sorted so that farmers could be compared and contacted for initial scoping. At this stage, it was important to discuss the validity of the data used and to compare this with the personal experiences of the consultancy team. Categorising fish farmers is a key challenge due to the consistency of data and varying pond management techniques, as well as the availability of inputs in the different areas of Malawi. For this reason, the farmers scale of production was used alongside considerations of those who are known to demonstrate semi/commercial activities rather than subsistence farming, and those who can operate without assistance from NGOs of GoM. During this stage of the process 25 farmers were selected for scoping.

2.3.2 Scoping Mission & Initial Farm Visits

The scoping mission was intended to secure a better insight and understanding of the 25 farms, in order to inform and guide the subsequent deep dive selection process. As such, the scoping mission sought to understand the historic and present realities for the selected sample of fish farms. The consultants assessed the level of management being employed in operations (e.g. how fish farming contributes to the livelihood of the farmer to determine whether it is a truly “commercial activity”), including existing infrastructure (e.g. pond design, inflow and outflow piping, devoted water sources, equipment etc.), as well as gaps in any previous technical assistance and training received by the farmer. It was also important at this stage to assess the willingness of farmers to participate in the study and to ensure that those chosen would be able to meet the demands of ongoing monitoring. The output for this stage was a SWOT analysis for each farm, showing the specific strengths, weaknesses, opportunities and threats (see Annex 2: Swot analysis for the 25 farmers included in scoping). Following the scoping mission and the second stage of the selection process, 12 farmers were selected for further investigations and 9 farmers were chosen as collaborators.

2.3.3 Deep dive Systems Analysis

For this stage, Topic guides were used (see Annex 3: Collaborator Farmer Topic Guides) including questions relating to previous production cycles. This served as baseline data which could later be used for comparison throughout the intervention and final reporting. Furthermore, data relating to production costs was used to complete a gross margin analysis for each farmer. Following this deep dive, three of the 12 farmers were removed for various reasons:

- farms that needed vital, structural changes to ponds which rendered the farm unviable for this cycle;
- farmers who were unwilling to commit to the ongoing monitoring that would be required in the study;
- farms exhibiting very low profitability and no clear evidence of recent commercial intent;
- farms exhibiting little to no infrastructure to allow filling and draining ponds; and
- farms with very poor access

2.4 Implementation Plan

The output of this stage was a specific plan for a single, “project” pond for each collaborator that would be used for this production cycle. This plan detailed key implementable recommendations that would seek to improve this project pond’s production and profitability. Rather than targeting a maximum biomass or maximum individual fish size as seen in previous, similar projects, each plan sought to ensure increased productivity (T/Ha), whilst maintaining commercial viability and increased net profitability. This approach was taken because though in many cases, these alternative aims have led to high production figures and large fish sizes, they have failed to register net profit as production costs soon outweigh the value of harvest (i.e. exceeding the stage in the cycle where it is more expensive to feed the fish than the value of fish at harvest). Additionally, within the overarching implementation plan, training regimes were developed to improve BMPs throughout the course of the production cycle (see Annex 7: Best Management Practices - SOPs).

2.4.1 Fertiliser

In previous years, all collaborators fertilised their ponds using animal manure (e.g. poultry) from a range of different sources and applied on an *ad hoc* basis. However, all collaborators highlighted that the consistency of supply was a key challenge during previous cycles, both in terms of cost, access and availability. For the majority, purchasing manure requires hiring a private vehicle and procurement of significant quantities to meet the needs of pond fertilisation throughout a production cycle. Furthermore, it was noted that in the previous cycle (2017-18), collaborators did not apply manure efficiently. Five individuals recorded application rates varying between 9.9-27.2 T/Ha/annum and the remaining four stated that they used manure produced by their own poultry on an *ad hoc* basis. This indicates that the collaborators were not applying fertilizer efficiently.

To improve the process of pond fertilisation for this production cycle (2018-19) and to ensure that the collaborators had consistent supplies of inputs throughout, the collaborators were provided with a combination of Yarra inorganic fertilisers (NPK and Urea) sourced from Southern Flue Ltd, at a cost of MWK 22,000/50kg of NPK and MWK 21,000/50Kg of Urea. This fertiliser was applied using BMPs/SOPs, at 33.3 Kg/ha/week of NPK and 44.4 kg/ha/week of Urea, though the need for application was assessed through ongoing, daily monitoring of "greenwater" using BMP methods (see Annex 7: Best Management Practices - SOPs). The initial, planned amount of total fertiliser required for each collaborator is shown in Table 2 below. Inorganic fertilisers offer multiple benefits, firstly the greater concentration and consistency of nutrients compared to poultry manure (i.e. animal manures exhibit variable C:N ratios and release nutrients slower as this can only occur after microbial breakdown, resulting in unpredictable primary and secondary production) and secondly, due to significant reduction in effort required for future cycles since affordable inorganics are widely available from agro-dealerships in the region.

2.4.2 Feed

In previous years, all collaborators used locally sourced madeya and home garden vegetables in combination with either, on-farm feed formulations (e.g. soybean, cottonseed, fish sweepings and chicken feed) or Novatek Zambia floating feed. Novatek feed was sourced from the AEM/SHASP project office in Blantyre, on credit basis and with cost varying between 575-960 MWK/Kg depending on the quantity required, the loan structure and the cost of logistics. Unfortunately, the AEM/SHASP project finished in 2018 and therefore this feed was no longer available for this study. Records from the previous cycles indicated that the collaborators have been feeding very erratically, as FCRs ranged between 0.4-48:1 – in comparison with recommended FCRs of 1.5-1.8:1 - though all collaborators struggled to confirm the final yields from the previous cycle since all used partial harvesting methods (i.e. fish removed on *ad hoc* basis depending on the demands of the market/household).

Therefore, to improve the feeding process, each collaborator was provided with seine nets and manual weighing scales, to be used for monthly, sampling sessions and for measuring quantities of fertiliser and feed. To ensure that the collaborators had a consistent supply of feed throughout the cycle, various sources of formulated feed were explored, including various imported options (e.g. feed from Zambia – Novatek, Skretting Zambia and Aller-aqua Zambia). As a first option, Maldeco Fisheries were approached and asked whether they would be a supplier of these feed types as an agent. Unfortunately, it was not possible to secure supply within the timeframe of the study. Similarly, it was not possible to procure feeds from any of the three Zambian companies directly since at the time of request these producers stipulated a minimum quantity of 10-30 tonnes per consignment - a higher figure than the total demand of this study. In light of this and as a "best" alternative that could demonstrate the best possible production cycle for each collaborator, a formulated, sinking feed was sourced from NAC (see Figure 1). This feed is formulated using soya among other ingredients (e.g. fish meal, wheat bran, maize flour, mineral mix, vitamin mix and oil). Each collaborator used a feeding regime that was designed in accordance with NAC feeding guidelines and assumptions:

- **The quantity of feed provided should correlate with the standing biomass of stocked fish and subsequent sampling (i.e. feeding rate of 3% biomass), using feeding trays for monitoring**

- **The feed nutritional protein profile should exhibit 25-30% crude protein, depending on availability of ingredients in local markets**
- **NAC feed should cost MWK 30,000/50 Kg bag (i.e. MWK 600/Kg)**
- **Feed is to be used in combination with fertilization or manuring**
- **When combined with good quality fingerlings and feed trays, average daily growth rates of 0.8g should be achieved (i.e. a target production of 6 T/ha)**
- **A consistent average mortality rate of approximately 5% is expected, due to mode of stocking (i.e. using fingerlings from own production reducing stress) and ongoing water quality**

As part of the wider research for this study, the use of different feeds from various foreign suppliers (i.e. Zambian companies: Novatek, Skretting and Aller-aqua) was assessed through an academic exercise including two hypothetical scenarios that would assess the impact on net profit for each collaborator, when the cost of these feeds replaced the cost of the NAC feed used. Though these three feed companies produce a wide range of feeds, only those feeds that offer comparable nutritional specifications (as advertised) to the NAC feed were used for comparison, since the other, more expensive/premium options are specifically designed for cage farms systems and hatcheries (e.g. fry starter and broodstock) rather than greenwater, earth ponds. Two scenarios were compared (accounting for minimum consignment size (e.g. 10-30T), transport cost (USD 3,000 per consignment) and currency conversion (i.e. MWK 730 – USD 1):

1. Incorporating costs associated with transportation, VAT and a 30% mark-up
2. Incorporating costs associated with transportation, ex VAT and a 30% mark-up

Though mark-up would typically be 10-15% in Malawi, an inflated mark-up of 30% was used for calculations since this accounts for the anticipated risk that may be encountered by an agent selling a new product, with a limited shelf life (e.g. 4-6 months). It was anticipated that the mark-up would be reduced as a critical mass of buyers is achieved to reduce the risk for the agent.

Furthermore, to better understand the nutritional composition, profile and therefore quality of the NAC feed, a small sample of the feed underwent proximate analysis at the University of Stirling (Institute of Aquaculture), Scotland. This facility was selected to conduct the analysis because of its international reputation for providing high quality analysis and to provide objective results. To investigate the nutritional composition of the feed the proximate analysis measured the feed for moisture, oil/fat, protein and ash, using LM016.R01, LM003.R03, LM004.R03, LM023.R03, LM019.R01 methods and Soxhlet - acid hydrolysis.

Figure 1: Formulated, soya-based, sinking feed produced by NAC and used by all collaborator farmers

2.4.3 Productivity and Profitability

Production projections were developed to determine optimal production cycle length in relation to ongoing operational costs and the net profit that could be achieved at harvest, in accordance with the anticipated growth rate of 0.8 g/day (as per NAC guidance). Consideration was also given to the assumption that little to no price-premium can be attained by growing fish to larger sizes. These projections demonstrated that extending the growth-cycle to the traditional 24-weeks (i.e. 6 months), would render the cycle less profitable than a shorter cycle period for each collaborator (see Annex 6: Projected change in net profit (MWK) in relation to cycle length (n) for 2018/19). Factors influencing cycle length included the size of the project pond (m^2), ongoing operational cost and the sales value that could be achieved in local markets at harvest (MWK/Kg).

It was also anticipated that many of the collaborators would encounter difficulties in adjusting to the methodologies demanded by this stricter cycle period, due to their shared experiences of longer, partial harvest cycles which are known to attribute low importance to profitability. More specifically, though the majority of the collaborators have previous experience of monitoring the use of inputs (e.g. weighing and recording quantities of feed and fertiliser and sometimes practising grading/sampling sessions), the approach used here encouraged collaborators to assume greater autonomy over calculating input use throughout the cycle, in response to changing biomass (e.g. feeding at 3% of standing biomass as per the results of monthly sampling).

2.4.4 Fingerlings

Since the majority of collaborators are small-scale Hatchery Operators, they were advised to stock fingerlings from either their own hatcheries or a suitable alternative, with fingerlings of 5-10g average - as available - to maintain consistency with the best practices of the DoF extension staff and previous projects and to reduce confusion. Therefore, the production cycle projection assumed that the achievable growth rate of 0.8g/day increase would allow for fish to grow to approximately 100g average in 18 weeks from stocking and therefore, each collaborator would aim to produce fish of between 73-106 g ABW depending on the profitability projection.

Table 2 below shows the anticipated input quantities that would be required by collaborators to achieve the optimal net profit for their production cycle, whilst

Table 3 below shows the anticipated costs and profitability. It was anticipated that the actual quantities of inputs used throughout, and the yields achieved at harvest would be dependent on several factors: the actual growth rate of fish would affect the amount of feed required; weather related issues (e.g. high cloud cover) may affect the application frequency of fertiliser; pond soil, water chemistry and water availability (i.e. allowing for ongoing water transfer); and the accuracy of measurements made by collaborators using scales.

Table 2: Planned input amounts for cycle in the implementation plan projection (2018/19 cycle)

Name	Pond size (Ha)	Fingerlings (n)	Fertiliser (Kg)		Feed (Kg)
			NPK (Kg)	Urea (Kg)	
Chilomoni	0.052	1569	31.3	41.8	292.2
John	0.075	2250	45.0	59.9	419.0
Friday	0.036	1092	21.8	29.1	203.4
Charles	0.020	600	12.0	16.0	111.7
Matias	0.024	720	14.4	19.2	134.1
Rajab	0.060	2250	36.0	48.0	419.0
Willy	0.040	1200	24.0	32.0	223.5
Grace	0.040	1200	24.0	32.0	223.5
Kondwani	0.012	360	7.2	9.6	67.0

Table 3: Anticipated production costs and profit from projection for each collaborator (2018/19 cycle)

Name	Pond size (Ha)	Costs (MWK)				Profit (MWK)	
		Fingerlings	Fertiliser	Feed	Total cost	Gross	Net
Chilomoni	0.052	31,380	31,349	175,329	238,058	354,790	116,732
John	0.075	45,000	44,955	251,428	341,383	508,781	167,398
Friday	0.036	21,840	21,818	122,027	165,685	276,560	110,875
Charles	0.020	12,000	11,988	67,048	91,036	162,810	71,775
Matias	0.024	14,400	14,386	80,457	109,243	195,372	86,129
Rajab	0.060	45,000	35,964	251,428	332,392	508,781	176,389
Willy	0.040	24,000	23,976	134,095	182,071	217,080	35,009
Grace	0.040	24,000	23,976	134,095	182,071	238,788	56,717
Kondwani	0.012	7,200	7,193	40,229	54,621	97,686	43,065
Average	**0.040**	**24,980**	**23,956**	**139,571**	**188,507**	**284,516**	**96,010**

Using the planned input guide and assuming that actual fish growth rates coincided with the guidance of NAC, all farmers anticipated a significant increase in both production amount (Kg) and productivity (T/Ha) from the project pond, as shown in Table 4 below. The decrease in projected production/productivity for Friday can be attributed to the significant variation in the production that he was able to achieve between different ponds in the previous cycle and it was therefore not possible to disaggregate production for each pond, instead production for the project pond was calculated as a percentage of the total. It is assumed that the projected production/productivity would correlate with an increase for the project pond.

Table 4: Projected 2018/19 production for project pond compared with previous cycle for project pond (2017/18)

Name	2017-18 (Kg)		2018-19			
	Production (Kg)	Productivity (T/Ha)	Projected Production (Kg)	Projected production difference (Kg)	Projected Productivity (T/Ha)	Projected productivity difference (T/Ha)
Chilomoni	72.69	1.39	127.66	+54.96	2.44	+1.05
John	56.14	0.75	183.07	+126.93	2.44	+1.69
Friday	183.59	5.04	98.77	-84.82	2.71	-2.33
Charles	26.32	1.32	57.03	+30.71	2.85	+1.54
Matias	14.69	0.61	68.43	+53.74	2.85	+2.24
Rajab	33.10	0.44	183.07	+149.96	2.44	+2.00
Willy	22.86	0.57	80.72	+57.86	2.02	+1.45
Grace	7.69	0.19	86.43	+78.74	2.16	+1.97
Kondwani	3.82	0.32	34.22	+30.40	2.85	+2.53
Average	**46.77**	**1.18**	**102.16**	**+55.39**	**2.53**	**+1.35**

2.5 Ongoing On-farm Monitoring

Throughout the production cycle (i.e. Nov-Jan 2018/19 to Mar-May 2019), each collaborator was visited on a bi-weekly basis, to ensure that the proposed mitigation measures and best practices were being followed (e.g. basic spot checks including: monitoring of notebooks and assessment of reliable record keeping; assessing the correct use of inputs, including the amount of feed and fertilizer). To increase the validity of these assessments, some visits were not pre-arranged so as to discern the level of commitment shown by the farmer. These visits also included overseeing monthly sampling, as well as capacity building (see Annex 7: Best Management Practices - SOPs), including various, vital pond management activities:

- Application of lime/ash – in pond preparation, all collaborators applied lime/ash to kill pathogens in the pond and to assist in neutralizing the pond soil prior to the application of water and fertiliser.
- Pond water filling – initially, ponds were partially filled only, with fertilizer added to promote a quick reaction. On average, green water was seen within three to five days, and ponds were then filled.
- Fertilizer application – add in pond preparation and then applied weekly at consistent rate. The fertilizers were dissolved in water and then broadcasting method ensured even spreading over pond.
- Stocking of fingerlings – the farmers stocked on different dates according to their own schedules. Fingerlings stocked ranged in size between 5-10g/fingerling - as available. Stocking was done after the water colour changed to green and within two weeks of the first pond fertilization.
- Feed and feeding – the feed purchased from NAC had no specific or comprehensive nutritional information. Under guidance from NAC, the collaborators fed their fish at 3% total biomass, informed by monthly sampling. The fish were fed twice per day, though a satiation method was advised.
- Sampling and grading – Monthly sampling sessions informed accurate feed adjustment, allowed for grading and assessed fish growth rate, to determine the cycle stage in relation to harvest. Grading involved transferring fry/fingerlings into hapas and tanks where they could be grown and sold to other farmers – including government and NGO-funded projects – within close proximity.

2.6 New Findings Meeting

This meeting took place during March 2019, with two separate groups of stakeholders. This meeting coincided with the Malawi Aquaculture Round table meetings (e.g. Outreach and Research Expert Working Groups). This ensured that individuals from other organisations who are currently engaged in aquaculture projects were present to offer their input and to discuss the outcomes of the study, as well as providing further recommendations for the sector.

3. Results and Discussion

3.1 Initial Findings from Selection Process

- **In general, farmers do not adhere to BMP such as recorded feeding, sampling and grading**
- **Farmers lack access to good quality fingerlings and feed, though fingerlings are available throughout the Southern Region as a result of projects such as SHASP**
- **Generally low incidence of farms that are truly commercial in their approach at present**

During the deep dive analysis process, it was noted that farmers face a number of common challenges that are largely applicable to the majority:

- **Technical expertise and Best Management Practices (BMPs)**: despite the presence of a strong institutional structure through the DoF - supporting a myriad of extension staff in district-level offices - "semi-commercial", smallholder farmers like these collaborators have relied heavily on development projects (i.e. both Local Government and International donors) for technical support. Unfortunately, due to the nature and mandate of these projects, capacity building has largely been geared towards low-input, low-output, integrated systems that do not prioritise sustainable income generation. As such, these projects have not developed basic business skills and strategy, such as enabling farmers to calculate the real cost of production; the real value of their fish prior to harvest; and a range of different management practices that allow for more choice and improved production with corresponding increase in profit margin. In contrast, it was observed that many farmers simply regurgitate what they have been told by DoF and NGO extension staff rather than being able to show a comprehensive understanding and critical thinking about the best approach for their cycle. Though the collaborators were able to demonstrate good, well-rounded knowledge regarding basic fish farming principles, it was noted that prior to this study the majority did not adhere to practices such as good feeding, sampling and grading methodologies.

- **Supply chain identification and development (Feed and Seed)**: local supplies of formulated fish feed are limited to several Government-managed institutions (e.g. NAC and LUANAR). These centres typically produce "sinking" feed forms with irregular-sized pellets and exhibiting suboptimal traits (e.g. low crude protein, irregular form and texture, unproven palatability). The alternative, imported, "floating/extruded" feeds are difficult to access - long lead times, high overland transportation fees and the possibility of import duty and VAT charges (see Profitability Comparison with Imported Feed Options). Though all of the collaborators have used these feeds in the past through various projects, they currently have no access. Similarly, though many of the collaborators are small-scale Hatchery Operators, they are restricted to using fingerlings of suboptimal quality (e.g. mixed-sex, size and non-improved selection) leading to a range of difficulties during grow-out (e.g. early maturation, breeding and stunting) as will be discussed further.

- **Business planning and tracking**: many fish farmers are often not aware of the benefits that even basic record keeping (e.g. input record and bookkeeping) can have on the cost efficiency of their farm activities. As such, it is important to demonstrate how keeping track of key figures can and should inform future decision making. For example, many farmers do not track the weight of fish throughout the cycle and therefore struggle to calculate how much feed should be fed at different stages of the growth cycle. Furthermore, without consistent monitoring of the standing biomass, it is not possible for farmers to organise harvests effectively, and an "*ad hoc*" approach will be adopted instead.

3.2 Input Use

- **Use of inorganic fertiliser is a suitable alternative to animal manure and reduced demand and all collaborators highlighted this as a key learning outcome for this study**
- **Use of NAC feed, when combined with BMPs led to reduction in overall feed demand and FCR on average, when compared with previous cycle**
- **NAC feed found to be suboptimal in terms of key nutrients through proximate analysis**

As shown in Table 5 below, all but two of the collaborators used less feed and fertiliser during this cycle than the previous cycle. However, the two, Charles and Matias were known to use very low quantities of feed previously due to lacking personal funds. Similarly, when comparing with the original plan, all collaborators but Rajab used less fertiliser (NPK and Urea) and all, excluding Grace and Kondwani used less feed than originally anticipated. **This indicates that the farmers were able to achieve good, greenwater conditions faster than anticipated – an observation that was supported by the accounts of each collaborator throughout the cycle**. Unfortunately, several collaborators experienced difficulties with pond fertilisation due to heavy rainfall during January, which led to increased turbidity and a loss of algal bloom.

Similarly, all farmers used less feed than anticipated in the production plans, though this can be attributed to lower than anticipated fish growth rate seen by most farmers (see Fish Growth Rate). As aforementioned, the projection figures were calculated on the assumption that 0.8 g/day increase in ABW should be expected, though the actual feed amounts were calculated and adjusted by using monthly sampling.

Table 5: Total actual input amounts used compared with previous cycle (2017/18 and 2018/19 cycles)

Farmer	Previous cycle (Kg) (2017/18)		This cycle (Kg) (2018/19)					
	Fertiliser (various type)	Feed (various type)	Planned			Actual		
			NPK	Urea	Feed	NPK	Urea	Feed
Chilomoni	2000	800	31.3	59.9	292.2	15.7	20.9	164.9
John	2445	350	45.0	29.1	419.0	25.0	33.3	209.0
Friday	N/A	1020	21.8	16.0	203.4	16.3	19.3	111.0
Charles	N/A	19	12.0	19.2	111.7	9.5	11.0	65.0
Matias	N/A	50	14.4	48.0	134.1	10.4	13.9	123.0
Rajab	1440	485	36.0	32.0	419.0	45.0	59.0	272.0
Willy	N/A	330	24.0	32.0	223.5	22.6	30.2	125.4
Grace	2000	1200	24.0	9.6	223.5	24.0	32.0	223.4
Kondwani	6000	650	7.2	41.8	67.0	7.2	9.6	67.0
N.B. N/A in previous fertiliser application shows *ad hoc* application (i.e. irregular application of poultry manure from household chickens.								

As shown in Table 6 below, all but two of the collaborators achieved a lower FCR than they saw during the previous cycle (average of 2.1:1 down from 8.8:1). Furthermore, it is important to highlight that the FCR achieved by John and Grace would likely be much lower had they not experienced theft (±1.5:1 using average and projection prior to theft). Also, it is also shown that the average actual FCR achieved by all nine collaborators were significantly lower than both the previous cycle and the projected FCR. **These findings indicate a positive uptake in the BMP's and SOP's that were promoted and implemented as part of this study.**

A possible explanation for two of the collaborators not achieving a decrease in FCR (Charles and Matias) is that they both used significantly lower quantities of feed than any other collaborator in the previous cycle. Instead of using high quantities of feed, these farmers used a low-input, low-output, extensive, long-cycle-length that did not require the addition of feed in order to keep costs low. This being said, Charles achieved the anticipated FCR through the plan (2.0:1).

In order to improve these FCR's further, it would be important to maintain sampling methods and to develop improved feeding skills, so as to ensure the fish are being fed the correct amount (i.e. satiation). This is a difficult skill that can take farmers several production cycles and sometimes years to master. The importance of feed efficiency becomes one of the determining factors in ensuring increased profitability. Additionally, the type of feed being used is of upmost importance. **For farmers to attain FCR of 1.5:1 and below, feed must comprise sufficient amounts of vital nutrients, such as protein and fats.**

Table 6: Comparing the difference in FCR between previous cycle (2017/18) and this cycle (2018/19)

Farmer	Previous FCR (2017/18)	Projected FCR (2018/19)	Actual FCR (2018/19)	Difference in FCR (Actual – Previous)
Chilomoni	4.4	2.3	1.5	-2.90
John	3.5	2.3	3.1	-0.38
Friday	1.4	2.1	1.1	-0.25
Charles	0.4	2.0	2.0	+1.59
Matias	1.7	2.0	3.4	+1.75
Rajab	7.6	2.3	1.9	-5.71
Willy	3.3	2.8	1.3	-2.02
Grace	48.0	2.6	3.4	-44.56

Kondwani	9.3	2.0	1.1	-8.17
Average	**8.8**	**2.3**	**2.1**	**-6.74**
SD	**14.11**	**0.27**	**0.91**	**13.72**

The results of proximate analysis for the feed produced by NAC can be seen in Table 7 below. These results demonstrate that the levels of oil/fats, protein and ash (~4, 17 and 5% respectively) are very low for a fish feed, and it is likely that this exacerbates any potential amino acid deficiencies. The lack of protein and fat is of particular concern, since both are needed for fish to build muscle and fat tissue, and fat is a predominant source of energy. **These results suggest that this feed does not offer an optimal nutritional profile when compared with imported options.**

It is probable that these deficiencies can be attributed to poor availability of suitable ingredients in close proximity to NAC, in particular fishmeal or other sources of crude protein for the feed. This also highlights a challenge for the wider development of domestic fish feed production in Malawi, since it is unlikely that emerging producers would be able to source and process/mill suitable ingredients at a price that is competitive with international options.

Table 7: Nutritional composition of NAC feed, compared with industry standard ranges

% Composition	NAC feed (%)	Typical range (%)
Moisture	11.79	8-10
Oil/Fat	3.69	10-30
Protein	17.70	15-25 (supplement) 30-50 (complete)
Ash	5.32	6-10

3.1 Production and Productivity

- **Eight collaborators able to achieve higher production/productivity than previous cycle (2.2 T/ha/cycle from 1.2 T/ha/year), using shortened cycles and orientating production towards profitability, rather than maximum fish size can improve average productivity to >4 T/ha/year**
- **Theft can have significant impact on cycle production and therefore profitability**
- **Fish growth rate highly variable and likely to correlate with stocking size, genetic quality, pond depth, feeding efficiency and feed quality and the need for more grading**

As shown in Table 8, with the exception of Friday, all collaborators succeeded in achieving a higher production for the project pond than the previous cycle in 2017/18. However, as aforementioned, this can be attributed to Friday's reported yield for the previous cycle not being disaggregated to pond level and therefore not reflecting a realistic production. Furthermore, four of the collaborators were able to achieve a higher production than the projection (i.e. Chilomoni, Friday, Willy and Kondwani).

This demonstrates a significant improvement on previous cycles and indicates that the BMP/SOPs and methods encouraged during this cycle contributed to these improvements. More specifically, this highlights the importance of sufficient feeding and ongoing grading of new recruits at regular intervals throughout the cycle to reduce competition in mixed-sex ponds.

In contrast, the remaining six farmers did not achieve the projected production amount (i.e. John, Charles, Matias, Rajab and Grace). However, two of these, John and Grace both suffered significant losses from theft (213.9 and 55.2 Kg respectively according to comparison with final monthly sampling prior to harvest). Had both of these not suffered theft, they would both have achieved significantly higher yields (280.9 and 120.2 Kg respectively), as well as a positive "actual difference 17/18vs18/19" and "difference projection vs actual 18/19" (John: +224.76 and +97.84 Kg, and Grace: +112.51 and +33.77 Kg respectively). These findings highlight the significant impacts that can be caused by theft.

Table 8: Actual production of project ponds compared with the projected production (2018/19 cycle)

Farmer	Previous Production 2017/18 (Kg)	Projected Production 2018/19 (Kg)	Projected difference 17/18 vs 18/19 (Kg)	Actual Production 2018/19 (Kg)	Actual difference 17/18 vs 18/19 (Kg)	Difference (Projection vs actual 18/19)
Chilomoni	72.69	127.66	+54.96	107.00	+34.31	-20.66
John	56.14	183.07	+126.93	67.00	+10.86	-116.07
Friday	183.59	98.77	-84.82	100.00	-83.59	+1.23
Charles	26.32	57.03	+30.71	33.00	+6.68	-24.03
Matias	14.69	68.43	+53.74	36.00	+21.31	-32.43
Rajab	33.10	183.07	+149.96	145.75	+112.65	-37.32
Willy	22.86	80.72	+57.86	98.00	+75.14	+17.28
Grace	7.69	86.43	+78.74	65.00	+57.31	-21.43
Kondwani	3.82	34.22	+30.40	60.00	+56.18	+25.78
Average	**46.77**	**102.16**	**55.39**	**79.08**	**+32.32**	**-23.07**
SD	**55.97**	**52.74**	**66.62**	**36.58**	**54.95**	**41.16**

Figure 2 below shows that all of the collaborators succeeded in achieving higher productivity (T/Ha) for this production cycle than the previous cycle and a higher productivity than the national average for smallholder farmers (average of >4 T/Ha/year with SD 1.2, compared with 0.75-1.2 T/Ha/year[iv]). However, only three of the collaborators managed to achieve productivity that was higher than or equal to the projected productivity from the projection (Friday, Willy and Kondwani). This being said, the productivity seen by John and Grace would have been higher had they not encountered theft. It is also important to note that the production and productivity recorded in the previous year (2017/18) accounted only one production cycle (6-8months or more), where the approach used here (2018/19) will allow for each farmer to complete two production cycles each year, thus providing the opportunity for increasing production by >100%. Therefore, assuming that the same productivity could be replicated through a second cycle in 2019, the average productivity would increase to 4.53 T/Ha/year (SD 2.36). **These findings indicate that the production methodology used by this study improved the existing system for the collaborators.**

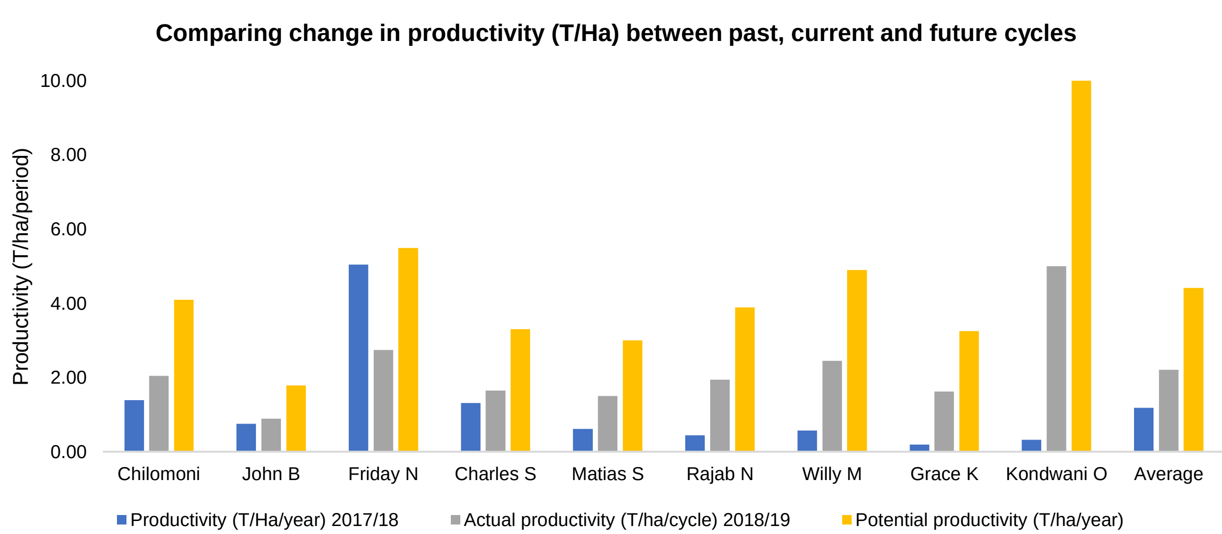

Figure 2: Comparing productivity (T/ha/year): previous cycle, projection and actuals

3.1.1 Fish Growth Rate

As shown in Figure 3, the growth rates achieved by each of the nine collaborators varied quite significantly. The collaborators who stocked larger fingerlings (approx. 10g/ABW) achieved the highest ABW at harvest (Chilomoni, John and Grace – 136, 140 and 120g/ABW respectively), where in contrast those who stocked smaller fingerlings (e.g. varying between 3-7g/ABW) achieved lower final ABW at harvest (Charles, Matias, Rajab and Willy). However, suprisingly the collaborator who stocked the smallest fingerlings (Friday – 3g/ABW) was also able to achieve a higher than average final ABW at harvest (103g/ABW). It is also possible that the genetic quality and therefore growth potential of the fingerlings used by Chilomoni, John, Grace and Friday were superior to those of other farmers, thus highlighting the importance of consistent quality and the need for improved fingerlings to be available.

As shown here, the difference in growth rate between all collaborators starts to increase at the 11 to 12-week point in the cycle. This can be seen most clearly when comparing the distribution of markers before week 8 and then beyong week 12. The range of growth rates seen not only indicates the varying quality of fingerlings, but also the importance of growth during early stages of the cycle and therefore the importance of stocking good quality fingerlings of slightly larger sizes when using this approach.

When these findings are compared with the anticipated length of cycles according to the cycle projection, one can see that in reality all but one of the collaborators extended their cycle period beyond the planned harvesting date, though the variance observed ranges between one and six weeks. The main reasons for this are likely to be: the slower than anticipated fish growth rate seen by some collaborators; the ocurrence of heavy rains during January which had a significant impact on the turbidity in some ponds; a 2-week delay in food supply during the middle of the cycle between Feb-Mar 2019; and the hard-held belief of farmers that the key to profitability is the size of fish instead of measuring of net profit.

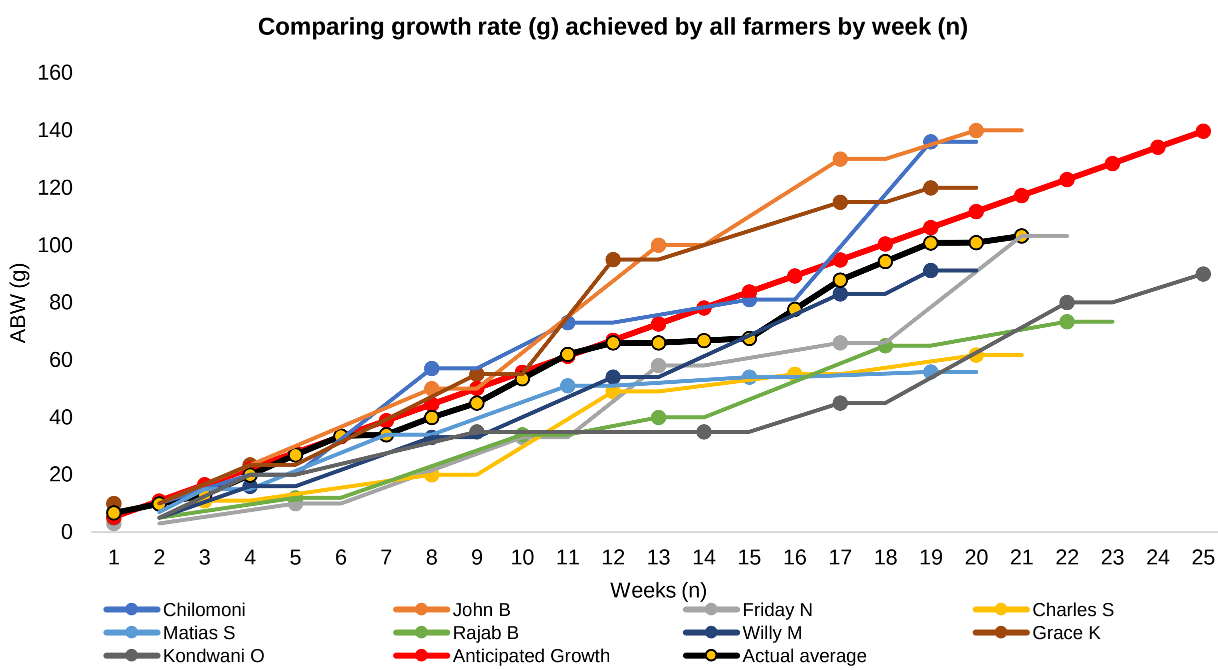

Figure 3: Comparison between fish growth rates (ABW - g) of all collaborators over time (weeks)

This trend can be seen more clearly in Table 9 below, as it compares the actual ABW increase for the fish of each farmer collected through sampling sessions, compared with the expected trend of the initial growth projection (control/projection - 0.8g ABW increase/day). As shown here, three of the collaborators succeeded in achieving a growth rate higher than or equal to the original projection (i.e. Chilomoni, John and Grace). Though for each of these farmers, the growth rate between sampling sessions still varied quite significantly. As such, the growth rate can be seen to spike at either the 2nd or 3rd sampling session. In contrast, the remaining six collaborators were unable to achieve an average growth rate comparable with the anticipated projection.

This finding adds further weight to the claim made above with regards to **Error! Reference source not found.**, where it is argued that the collaborators who stocked larger fingerlings (approx. 10g/ABW) were able to produce fish of larger size at harvest, though again, this could also be attributed to the fingerlings used by these collaborators exhibiting superior genetic quality. However, in addition to fingerling size and quality, pond depth and water transfer may have also contributed to the growth rates observed. For example, John's pond has greater depth than other collaborators (e.g. >1.5-2m average) and his fish had the highest growth rate of all (140 grams within four months of stocking), thus supporting the findings of research which has shown that fish grown in deeper ponds can attain significantly higher overall mean final weight.[v]

Table 9: Change in ABW increase (g) by sampling week (n)

Farmer	Sample week (n)					Average over cycle	Difference from Projection
	1	2	3	4	Harvest		
Projection	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.00**
Chilomoni	0.4	1.4	0.6	0.3	2.4	1.07	0.27
John	0.7	1.4	1.2	0.5	0.5	0.94	0.14
Friday	0.2	0.7	1.0	0.3	1.7	0.77	-0.03
Charles	0.3	0.3	1.2	0.2	0.3	0.44	-0.36
Matias	0.4	0.6	0.7	0.1	0.1	0.38	-0.42
Rajab	0.2	0.6	0.3	0.7	0.3	0.43	-0.37
Willy	0.4	0.5	0.9	0.9	0.5	0.64	-0.16
Grace	0.5	0.9	1.6	0.7	0.3	0.80	0.00
Kondwani	0.2	0.4	0.4	1.1	0.5	0.68	-0.12
Average	**0.4**	**0.8**	**0.9**	**0.5**	**0.7**	**0.68**	**-0.12**

3.1 Profitability

- **All but two collaborators achieved higher net profit than the previous cycle**
- **The sales value varies by geographical area but are likely influenced by fresh fish availability, though there is no clear price-premium by fish size and therefore small-sized fish is viable (≤100g)**
- **If alternative commercial feeds are available, multiple options would provide more profitable alternative to NAC when VAT included, and more offer comparable profitability when VAT removed.**

As shown in Table 10 below, all but two of the collaborators succeeded in making positive net profit, with an average of >MWK 60,000. When compared with the projection shown in

Table 3, the average net profit was lower in reality (~MWK 30,000), though the total cost was also significantly lower (~MWK 50,000) since the cost of feed was lower than anticipated for reasons explored previously. The total cost of the production cycle varied for each collaborator, depending on the size of ponds and therefore input use (fingerlings, fertiliser and feed). Similarly, the sales values seen also varied by location (2,000-3,000 MWK/Kg or 2.7-4.1 USD/Kg).

As anticipated, the highest sales values were seen in Phalombe, Thyolo and Machinga (2,800-3,000 MWK/Kg) and this may be attributed to lower levels of competition with fresh fish from capture fisheries (e.g. Lakes Chilwa, Malombe and Malawi). In contrast, lower values were seen by those located closer to urban areas around Blantyre and Zomba with markets that exhibit higher quantities of fresh fish. The lowest sales values were seen in Chingale (2,000 MWK/kg) - a remote, rural area within Zomba, Machinga and Balaka districts - where customers typically exhibit low purchasing power and the fish found in markets are typically small and processed (e.g. *usipa, utaka* small, silver fish from L. Malawi and *mlamba*, catfish from L. Chilwa and R. shire). The cost of transportation, poor road quality and lack of suitable preservation techniques limit the potential to explore more lucrative markets that are located in Limbe fresh fish market (i.e. the most lucrative market in the region, but highly competitive with fresh produce from L. Malawi) or Phalombe.

Table 10 also highlights the impact of the theft experienced by John and Grace. More specifically, had these collaborators harvested the amount that was predicted from their final sample, they would have received MWK 486,895.00 and MWK 82,424.00 positive net profit respectively. In this case, John would have been the most profitable rather than the least, since his operation costs were low considering the scale of his production.

Figure 4 below shows that five of the collaborators made a higher net profit during this production cycle (2018/19) than the previous year (2017/18). More importantly, this demonstrates that these collaborators could increase their annual net profit further, if the number of cycles is increased to two - which is made more possible when cycle lengths are shortened to <24 weeks. For those who saw a reduction in net profit, this can be attributed to several factors. The highest decrease was seen for Friday, though again this can be attributed to the distribution of profit made throughout his entire farm of eight ponds during the previous year. For Charles and Matias, the decrease in net profit may be attributed to the increase in total cost of production, due to higher inputs costs than the previous cycle.

Table 10: Actual production costs and profit for each collaborator (2018/19 cycle)

Farmer	Costs (MWK)				Profit (MWK)		
	Fingerlings	Fertiliser	Feed	Total	Sales (MWK/Kg)	Gross	Net
Chilomoni	31,380.00	15,660.00	98,940.00	145,980.00	2,500	267,500.00	+121,520.00
John	45,000.00	44,955.00	125,400.00	215,355.00	2,500	167,500.00	-47,855.00
Friday	21,840.00	21,818.16	66,600.00	110,258.16	2,800	280,000.00	+169,741.84
Charles	12,000.00	11,988.00	39,000.00	62,988.00	3,000	99,000.00	+36,012.00
Matias	14,400.00	10,418.20	73,800.00	98,618.20	3,000	108,000.00	+9,381.80
Rajab	45,000.00	44,955.00	163,200.00	253,155.00	2,500	364,375.00	+111,220.00
Willy	24,000.00	22,644.00	75,240.00	121,884.00	2,000	196,000.00	+74,116.00
Grace	24,000.00	23,976.00	134,040.00	182,016.00	2,200	143,000.00	-39,016.00
Kondwani	7,200.00	7,192.80	40,200.00	54,592.80	3,000	180,000.00	+125,407.20
Average	**24,980.00**	**22,623.02**	**90,713.33**	**138,316.35**	**2,611.11**	**200,597.22**	**+62,280.87**

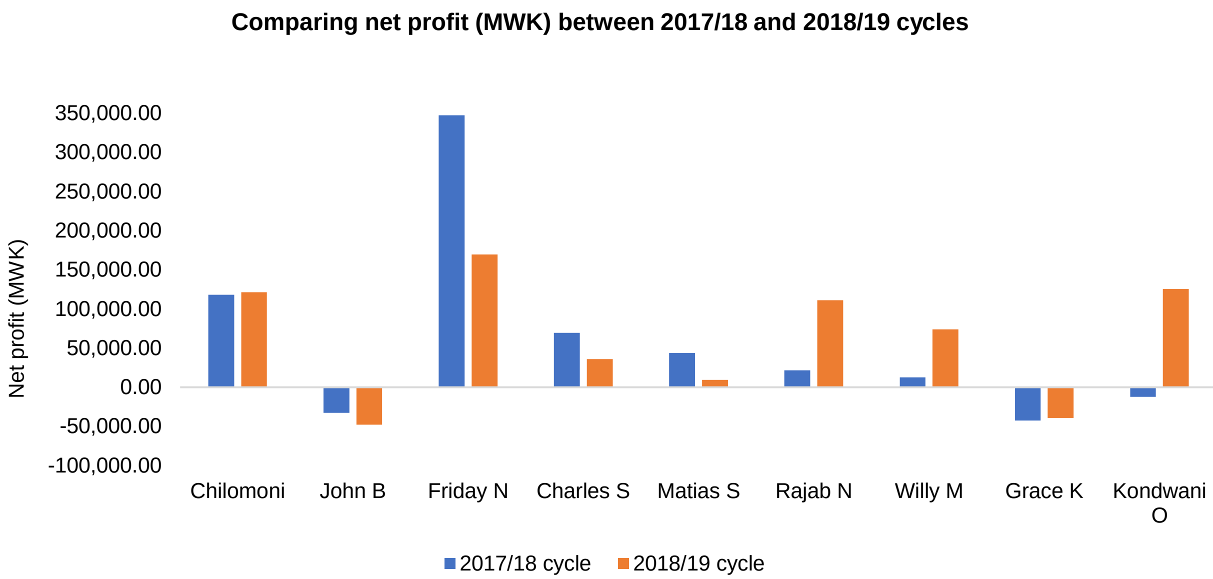

Figure 4: Comparing between net profit achieved in project pond between 2017/18 and 2018/19 cycle

3.1.1 Profitability Comparison with Imported Feed Options

As aforementioned, with the exception of very few individuals and companies (e.g. Maldeco Fisheries Ltd), it is currently not feasible for fish farmers - of all scales - to access high quality, floating/extruded, formulated, fish feeds such as those produced in neighbouring countries (e.g. Zambia), or further afield (e.g. Mauritius, Brazil and China etc).

The key barriers to these feeds being made more easily available within Malawi, and indeed the process of importing these feed options is: the costs and timescales attributed to this process (see Figure 5): the lack of diversification from existing feed suppliers to begin formulating fish feeds alongside existing production (e.g. poultry and livestock feed suppliers: CP, Kamponji, Crown Feeds etc); and no emergence of entrepreneurial agents with either, the capital or interest to invest in importing a relatively large consignment of these feeds (e.g. 10-30T if organised directly through the feed producer). Figure 5 below shows this process divided into nine different steps for ease of viewing, as some of these steps can occur in parallel.

Firstly, it is important to highlight that none of the collaborators – alone, nor together as a group/cluster – would be able to import feed themselves and therefore rely entirely on an existing company, agents, institutions or project to manage and fund the import process. Though there are individuals, companies and projects who have purchased consignments of feed from Novatek, Skretting and Aller-aqua in the past (e.g. Maldeco Fisheries Ltd, Luanar, ANR, AEM/SHASP etc), and there are recent accounts in 2019 of individual agents procuring Novatek feeds for distribution out of Lilongwe, these feed options have still not reached any of the collaborator farmers outside of part or fully subsidised project activities.

As indicated in the Figure, completion of an order and its delivery is dependent on the speed at which each respective institution can process the relevant documents (e.g. temporary import permit and veterinary clearance, DFO recommendation and duty waiver). It is also important to note that feed suppliers accept minimum orders for export (e.g. 10-30T), unless one is buying smaller consignments and can organise all logistics, and only when all of the relevant documents are provided by the buyer. Furthermore, the documents listed here are required for each separate consignment imported. For example, a new, Temporary Import Permit must be issued and stamped by veterinary staff from Ministry of Agriculture, Department of Animal Health and Livestock for each and every consignment of feed that is imported, irrespective of whether the feed type or the company that it is sourced from have been given recent clearance for entry (e.g. during the same year or less). In practice, this means that the same feed, from the same factory, may require many import permits throughout a single year.

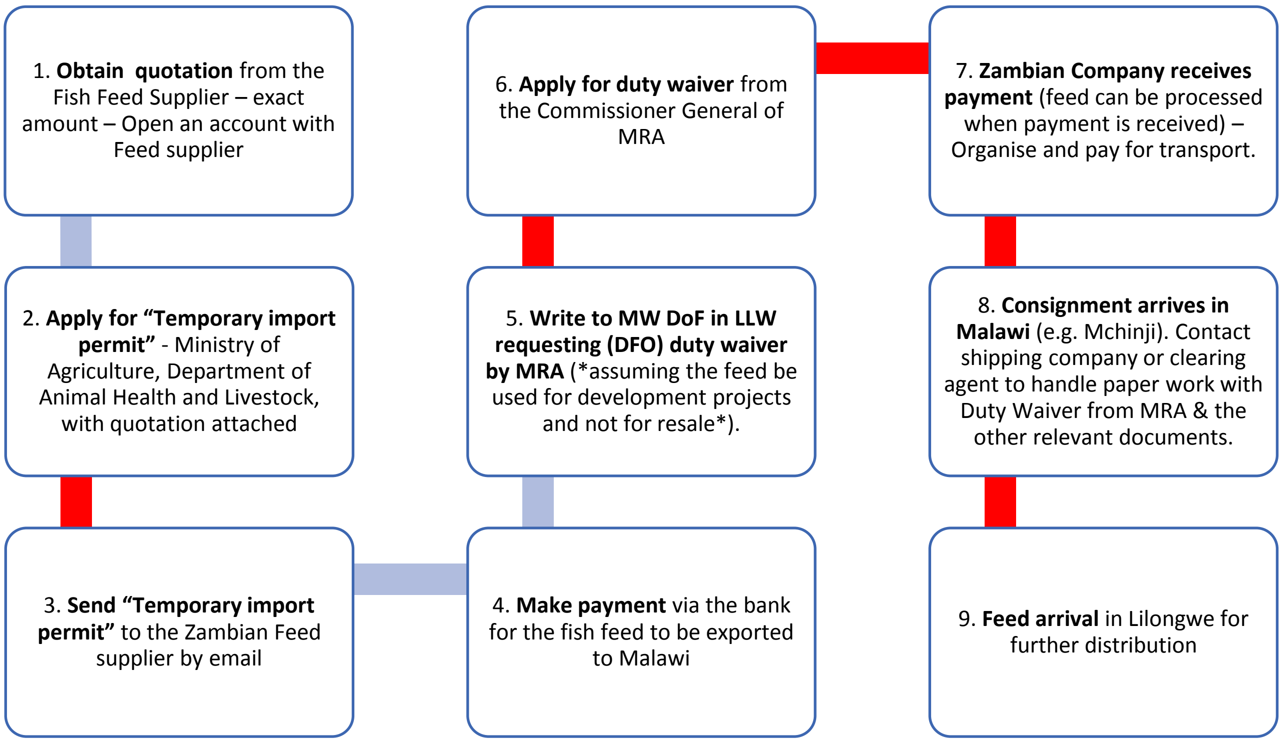

Figure 5: Procurement process for importing fish feed into Malawi from Zambia (step-by-step) red links connecting stages indicate possible delays (1-2 business weeks)

It is anticipated that **if it had been possible to access imported, floating/extruded feed it would have had a positive impact on fish growth and therefore productivity**, though doubts were raised regarding whether it would improve profitability, due to the perceived cost of these imported options being high. However, the results of this cost comparison demonstrate that for both scenarios, the price of all of the feed options would have fallen within the price range that has been paid by the collaborators for Novatek feed in previous cycles (~500-900 MWK/Kg).

For the first scenario, in which **VAT is included (see Figure 6 and Table 11), using four of the alternative feed types would have led to an increase in the net profit seen by all farmers when compared with NAC feed**. These feeds like the NAC feed all exhibit low crude protein content (15-24%) and are intended for use as a supplementary feed in combination with fertilisation. In contrast, the other six feed types would all lead to a reduction in net profit. However, these more expensive feeds would contribute to different factors which could translate to financial benefit. For example, the **more expensive feed types exhibit higher crude protein content (>25%) and would therefore likely achieve improved growth rates and final fish size**.

For the second scenario where **VAT is removed (see Figure 7 and Table 11), in almost every case, a further three feeds offer comparable net profitability with that of NAC feed**. Moreover, the anticipated improvements to growth rate would see viability for the two most expensive feed options (i.e.

Skretting feeds). When considering the operational benefits of these feed options, it is important to note that these **companies advertise that their feeds can achieve an average FCR of 1-1.5, which are lower than the average FCR's achieved using NAC feed for this study** (see Table 6).

Temporary removal of VAT on imported fish feed has often been highlighted by experts as a potential catalyst for stimulating the growth of Malawian aquaculture as it would reduce production costs, as well as the discrete potential to improve growth rates of farmers, including the collaborators for this study.

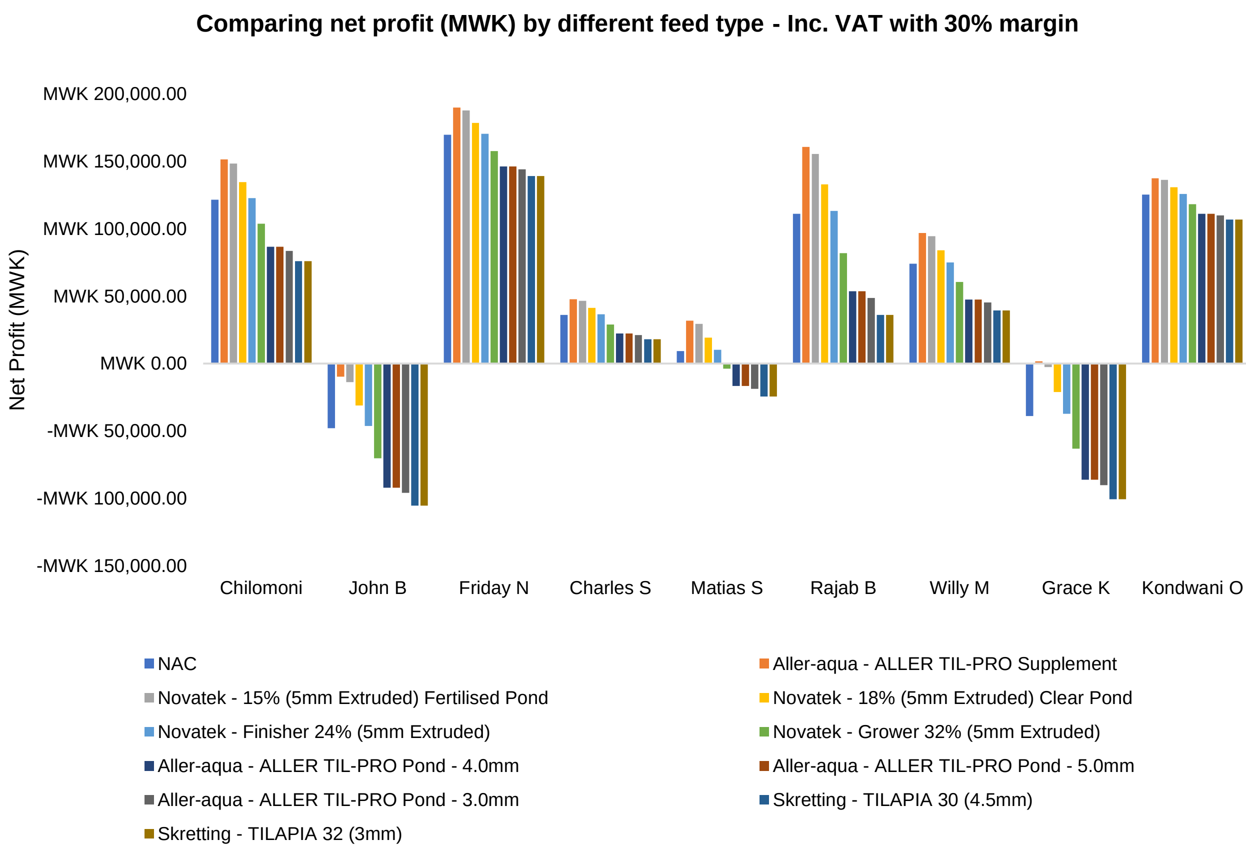

Figure 6: Comparing the impact of using imported feeds on net profit (MWK)

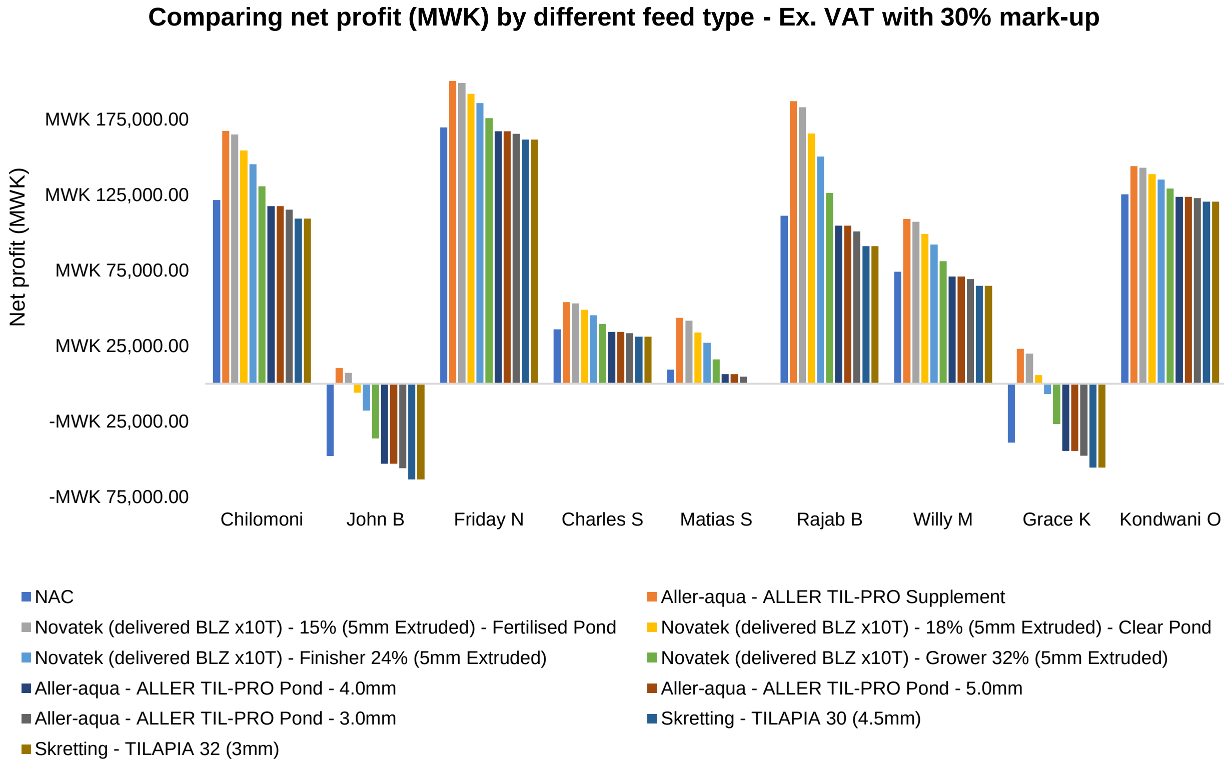

Figure 7: Comparing the impact of using imported feeds on net profit (MWK)

Table 11: Comparing cost of imported and NAC feed (MWK/Kg) through value chain

Feed name	Ex-factory cost (MWK/Kg)	Ex-factory + transport cost (MWK/Kg)	Final cost Inc VAT (MWK/Kg)	Final cost Inc VAT +30% mark-up (MWK/Kg)	Final cost Ex VAT +30% mark-up (MWK/Kg)
Aller-aqua PRO Supplement	202.85	275.85	321.36	417.77	358.60
Novatek 15% (5mm) - Fertilised	288.35	288.35	335.93	436.71	374.86
Novatek 18% (5mm) - Clear	343.10	343.10	399.71	519.62	446.03
Novatek 24% (5mm) - Finisher	391.28	391.28	455.84	592.59	508.66
NAC soya-based feeds	600.00	600.00	600.00	600.00	600.00
Novatek 32% (5mm) - Grower	467.20	467.20	544.29	707.57	607.36
Aller-aqua PRO Pond 4.0mm	462.69	535.69	624.08	811.30	696.40
Aller-aqua PRO Pond 5.0mm	462.69	535.69	624.08	811.30	696.40
Aller-aqua PRO Pond 3.0mm	474.73	547.73	638.10	829.53	712.04
Skretting TILAPIA 32 (3mm)	505.20	578.20	673.61	875.69	751.66
Skretting TILAPIA 30 (4.5mm)	505.20	578.20	673.61	875.69	751.66

3.2 Wider Findings

3.2.1 Management and Record Keeping

As anticipated, despite the general trend of improvement there was a clear correlation between the quality of records and an individual's literacy level. As such, six of the collaborators were able to capture more comprehensive records than those remaining. In contrast, two encountered ongoing challenges due to their low literacy level and inexperience of recording this type of information. Though the third was literate, this individual was seldom involved in farm activities, and instead, employs an on-site farm manager to oversee all activities (i.e. wider agricultural production, of which aquaculture is a small part). In this example, the farm manager who was responsible for all activites and records is illiterate but was often able to secure assistance for writing records. This increased the risk of information being lost and therefore demanded greater support. Similarly, other collaborators who have are literate sometimes forgot to write important records for up to one week, though this certainly improved throughout the cycle through ongoing encouragement and supervision.

Furthermore, technicians noted that it was the first time that many of the collaborators had been responsible for taking greater control of their cycle planning and implementation. More specifically, the action of calculating and weighing feed in response to changes in standing biomass, as well as calculating and applying inorganic fertiliser in accordance with pond area. Prior to this study - and as evidenced through the deep dive process - feed adjustments were not the norm, since the collaborators did not recognize the benefits. As such, activites such as sampling would only be done during projects and the value of these results would not be relayed to the farmer. A key aspect of this study's ongoing training was the use of manual weighing scales which could be easily maintained and replaced. Many of the collaborators had previously used digital scales, though these were now - in all cases - either broken or without batteries. Since the collaborators had not seen the importance of using scales, the equipment was not maintained and fell into disrepair.

3.2.2 Marketing and Sales

It was noted that though all of the collaborators were previously able to roughly assess the suitable time for harvest based on fish size, they could not relate this to making net profit. Instead, they would aim towards growing the largest fish possible to attract customers, without considering the length of the production cycle or the impacts that this would have on operational costs. As such, despite their best efforts, at least three of the collaborators were unable to acknowledge that they had made a loss for their grow-out ponds during the previous cycle. This also links back to findings relating to productivity and profitability, since a farmer's preference towards growing the largest fish possible (e.g. >200g) does not coincide with market preferences in the areas that these farmers sell their fish. This is evidenced by the fact that all of the collaborators were able to achieve a sales value based on price per kilogram (MWK/Kg) irrespective of fish size, rather than price per individual piece as would be seen in larger, formal, fresh fish markets in the region (e.g. Limbe or Blantyre). This indicates that there is no strong price premium on fish of larger sizes or against fish of smaller sizes in these markets (e.g. <100g average). This adds further weight to the argument that cycle lengths can be shortened without having a negative impact on profitability.

4. Conclusions

4.1 Input Use

4.1.1 Fertiliser

Prior to this study, none of the collaborators had any notion of using inorganic fertilizer as a replacement for manure, nor did they know about the positive impacts that it could have for their ponds. Instead, in previous cycles the collaborators would source manure, often over great distances, expense and effort. Furthermore, without fully understanding the demands of manure use (e.g. the importance of tilling in the manure prior to pond filling etc), they were not aware that their method of manure application contributed to their ponds being buried or exhibiting high turbidity. The project introduced the use of inorganic fertilizer which has proven to be both cost effective and more efficient/quicker to react than the manure used previously. As such, all collaborators noted that use of inorganic fertiliser as an alternative to manure was a key learning outcome for them as evidenced by their comments shown in Table 12 below.

Table 12: Comments made by collaborators regarding the benefits of this study's approach

Comment/quotes
"In the past we did not know how to calculate the feed requirement, but now we do. The feed we are using now is not as good as the feed from Zambia that we have used before, but we hope that maybe we will still benefit because of the use of fertilizer which we think is responsible for making our fish growing faster"
"I do not think I will use manure again in future, because inorganic fertiliser is better in terms of cost and impact. I hope to buy more land near to my ponds to increase my production, because I am now assured that I will be make large profits by following the management practices I have learnt from this technicians"
"I have been a fish farmer for over 25 years and though I knew about inorganic fertiliser, I have not used it like this in my ponds before and I did not think it would have the effect that it has had"
"Many thanks to this project, for I have learnt a lot, including the use of fertilizer and the use of manual scales for sampling. I now have learned how to make my own calculations and feel more experienced"
"I did not know that I could do sampling using manual scales, I have only used digital in the past. I now know how to adjust the feed required…I hope to have two production cycles per year since I now know that fish can be harvested in four months with best management practices as demonstrated here"
"In previous production cycles, the pond has been difficult to fertilize properly to reach algal bloom, but during this cycle the pond turned green very quickly. I have never seen this before. I have benefited more from this project, I understand you were doing research, but know that I have personally learnt a lot and I hope to produce more and make more profits in this production and my other upcoming cycles"
"The idea of raising fish for only 4 months is new to me, but now I hope to make more profits each year since I will be able to have two production cycles. I also did not know that inorganic fertilizer can work better than manure, I hope to use it from now onwards. I have used it on my crops but did not know this"
Since I started working on the fish farm, I have never seen the pond turn this green within such a short time period and I am sure that this is one of the reasons for fish growth being good"

Therefore, it is recommended that extension workers and others who provide technical advice to farmers to advocate the use of inorganic fertiliser as a suitable alternative to manure. This is particularly relevant for farmers who have poor access or cannot afford the cost of procuring manure. Though the collaborators indicated that they would choose to use inorganic fertiliser during future production cycles, for them to improve efficiency further it will be important for them to experiment with varying application rates in accordance with their unique farm systems, so that they can discern the optimal application in relation with soil type and water and weather conditions.

4.1.2 Feed

The results from this study have shown that it is possible for semi-commercial fish farmers to generate net profit using commercially produced, formulated feed from NAC in combination with fertilisation and the

BMP's and SOP's used during this study cycle. Additionally, these collaborators have shown that by using this feed, it is possible to achieve lower FCR than during previous cycles (average of 2.1:1 down from 8.8:1). These findings indicate a positive uptake in the BMP's and SOP's that were promoted and implemented as part of this study, as well as the importance ongoing sampling to track growth rate as a means of adjusting feed use.

Additionally, these findings highlight the importance of using formulated feed and if possible, the best quality feed available. In this instance, proximate analysis showed that the feed produced by NAC exhibits a deficit of key nutrients, most importantly protein. However, as demonstrated through cost comparison, it may be possible for these farmers to improve their productivity and profitability further if they have access to imported floating/extruded, formulated feeds (i.e. imported feeds from Zambia – Novatek, Skretting and Aller-aqua), though this is dependent on the emergence of more outlets and agents who will distribute this feed from locations that are accessible to the farmers (e.g. Blantyre, Zomba, Mulanje and Phalombe). The profitability of cycles may be improved further if the VAT addition on imported feed is relaxed.

Therefore, it is recommended that there is need to advocate for import of these feed options, and for this to be viewed as a priority by decision makers. Furthermore, the potential gains of waiving duty/VAT obligations should be considered, as this may act as a catalyst in stimulating development of the fish feed supply chain and the range of different actors who stand to benefit.

4.1.3 Fingerlings

As aforementioned throughout this report, the importance of fingerling quality cannot be understated as it can have a notable impact on growth rate and FCR achieved by fish, as demonstrated by the collaborators who stocked larger fingerlings (±10g) and were able to achieve superior growth. This indicates that it is preferable to stock larger fingerlings for grow-out cycles. However, it must be noted that in most cases, the fingerlings used by collaborators during this production cycle were sourced from the collaborator's own hatcheries and transferred over short distances between ponds. Transporting fingerlings of larger sizes (±10g) can lead to significant mortalities, both through transportation itself, but also stocking. Therefore, though it is preferable to stock larger fingerlings, this should be approached with caution and on a case-by-case basis, considering the quality of storage (e.g. oxygenated bags, stocked with low densities of fingerlings), the handling that is required by both fingerling producer/provider and the fish farmer, as well as the distance between the two locations to mitigate against losses.

Though seven of the collaborators in this study are small-scale Hatchery Operators, the quality of the fingerlings produced in their systems may be a cause of the difficulties that they face improving their productivity and therefore profitability in the future. During the deep dive phase of this study, it was found that these hatchery operators produced 28,000 fingerlings on average last year (ranging between 6,500-65,000 in 2017/18), earning approximately MWK 650,000 from sales on average. Furthermore, in almost every case, the farmers made more money from producing fingerlings than they did grow-out fish sales (approx. MWK 400,000), though one collaborator earned significantly more than others, thus increasing the average by approximately MWK 200,000. What is perhaps more concerning is that these hatcheries claimed that their main customer is normally the government (e.g. DoF and NAC), who procure fingerlings to be distributed to other fish farmers in the region. Though the distribution of fingerlings in this way does have positive benefits for fish farmers who would otherwise not be able to afford to buy them, it undermines the development of these hatcheries, as they cannot receive objective feedback to enable further improvement of their produce (e.g. in terms of both quality and price). Since Hatchery Owners are given a recommended fixed price, this does not necessarily coincide with their cost of production nor account for inconsistencies in quality.

To remedy this issue, Hatchery Operators require ongoing technical support to assist in improving their methods and cost efficiencies further, but at a sector-wide level, a concerted effort is needed from a range of stakeholders (e.g. government, NGOs and donors, research organisations and importantly the private sector) to increase the supply of quality fingerlings from selected breeding programs that will help to ensure improved traits for optimal production.

Therefore, it is recommended that existing hatcheries are supported to produce improved quality, monosex fingerlings that can be accessible and affordable for farmers as they reach the next stage of commerciality, since this will reduce the operational demands associated with grading activities throughout production cycle. However, in the absence of monosex fingerlings, the results seen from these collaborators demonstrate the importance of stocking larger-sized fingerlings where possible, supported by ongoing grading sessions to ensure that fish populations exhibit consistent sizes throughout the cycle period.

4.2 Production and Profitability

The results from this study demonstrate that fish farms of this scale can be profitable when using commercial inputs and cycle periods that are shorter than the traditional 6-month period (24 weeks), thus allowing for a second cycle for many farmers. Furthermore, these collaborators were able to grow fish to an average size of approximately 100g (range of 56-140g - SD 30.7) within an average of 20 weeks (range of 119-172 days - SD 15.3), though several of the farmers who stocked larger sizes (approx. 10g) were able to achieve >100g average in 18.5 weeks. These findings also demonstrate the importance of having a cycle plan that includes the projected use or cost of all actions and places importance on executing BMPs, including ongoing record keeping and grading sessions throughout the cycle to monitor and regulate the fish population at all times during the cycle.

Therefore, it is recommended that extension staff who interact and advise this type of fish farmer, are trained to better understand basic business management skills and therefore to be able to train farmers using participatory approaches that are suited to the individual, focused on generating profitable production.

4.3 Management and Record Keeping

The lack of record keeping highlights a systemic issue for many farmers - represented here by the collaborators. Prior to this study - and as evidenced through the deep dive process - feed and other input adjustments were not the norm, since the collaborators did not recognize the benefits of these actions. As such, for example sampling would only be done during projects and the results/information would only be deemed important for project teams, rather than for the farmer. However, through this study, the technicians were able to demonstrate how record keeping and other BMPs/SOPs could assist the collaborators in making informed decisions (i.e. the relationship between cycle length and profitability) so that the collaborators could harvest in conjunction with net profit. Through adopting this approach, all of the collaborators were convinced that keeping records of production costs is the best way for them to easily know the performance of their business.

Therefore, it is recommended that greater effort is required to improve farmers' understanding regarding the need for records, the type of information that is important to capture, and the way that this information can assist in informing farmers' cycles and cost management when attempting to adopt a more commercial approach. It is also anticipated that this would not only benefit the fish farming aspect for smallholders, but also their wider agricultural activities (e.g. household food crops and cash crops), and the way in which these income generation streams can interact.

4.4 Marketing and Sales

The findings of this study indicate that there is minimal price premium associated with fish size, for the context in which these collaborators reside (i.e. the markets and individuals that they sell fish to). Instead, the most significant factor that influences both price and market demand is the availability of fresh fish sourced from capture fisheries. It is therefore important for fish farmers - like the collaborators of this study - to coordinate their harvests with others who may compete for the demand, and where possible to plan ahead to ensure they are able to secure the sales needed to ensure profitability, or alternatively, to seek the best possible market prices within their area, or travel to areas where sales values are higher. This being said, this may not be possible for many farmers since transport costs may outweigh the additional profit gained. In contrast, as aquaculture develops and for farms of larger scales with greater overall production (i.e. many tonnes per cycle), formal markets are a necessity to ensure consistent demand and sales price.

Therefore, it is recommended that farmers - in accordance with cycle planning - are encouraged to consider their route to market ahead of sales, to enable them to realise the optimal revenue for their production, to ensure profitability and to sustain their fish farming.

5. Annex

5.1 Annex 1: Literature Review – Commercial Aquaculture in Malawi

Historical record of commercial aquaculture

The term 'commercial' aquaculture refers to systems that are market-led, private sector driven and for profit.[1] In Malawi, commercial aquaculture is largely nascent, though private sector investors have made various attempts to start larger-scale, ventures. The first attempts of 'commercial' production were demonstrated by estate managed systems (i.e. 1970's-2000), though these claims have been disputed since these farms were focussed on providing sustainable, subsidised protein supplies for estate workers rather than truly commercial operations.[2] Prior to this, between 1900 and 1940, aquaculture had involved the breeding and stocking of rainbow trout (*Onchorhynchus mykiss*) in the upland streams of Zomba, Mulanje and Nchenachena. Though, following the Second World War, the then colonial government instructed that fish farming should be developed as a means of improving fish availability for communities inland, away from the active fishery in Lake Malawi. From the 1950's, studies led by the trout warden of Nchenachena sought to better understand the potential of indigenous tilapias (*Oreochromis shiranus* and *Tilapia rendalli*). These trials proved successful in producing reasonable yields varying between 1.4-2.8 T/ha/year using either manuring or basic supplementary feedstuffs and sparked the interest of surrounding communities who saw this as an exciting prospect. This interest merited the creation of a training and research centre, and by the end of the 1950's, there were over 50 established, smallholder fish farms throughout the Northern region.

Towards the end of the 20th century in the 1980-90's, research projects sought to better understand and define the parameters for culture of existing, indigenous species that were typically utilised by smallholder farmers. One such project, The Central and Northern Regions Fish Farming Project (CNRFFP) demonstrated how it could be possible to improve the production generated during the 1950-60's (approx. 2-3 T/ha/year), over shorter culture periods and utilising a range of different system types (monoculture, polyculture and varying input usage). Among the most important findings from this research was the results of economic analysis for smallholder farmers, which showed that – using the appropriate methods – fish farming could provide higher financial returns than all other crops, excluding tobacco (i.e. return on labour and land etc).[3] Furthermore, during this period there was a significant increase in the number of ponds constructed throughout the Central and Northern regions.

In 2003, Press Corporation (Press Holdings - Malawi's largest conglomerate) bought Maldeco Fisheries from Malawi Development Corporation and in order to diversify fish production, established a cage fish farm in Lake Malawi, under the name Maldeco Aquaculture Limited. The initial plans involved a cage site of 48-salmon-type cages, located approximately 25km north of Mangochi town, land-based ponds for hatchery production and feed mill for the production of formulated feed.[4] More recently, in 2012 the company began expanding the land-based activites by constructing more ponds in order to increase land-based production, though in recent years these ponds have suffered from significant theft and as such the company adopted a change in strategy, now focussing exclusively on cage culture. Though the company originally targeted production of 3,000 T/annum, recent accounts suggest that production is less than one third of this target (<1000 T/annum).[5] However, this can be attributed to the farm experiencing a range of challenges to date, including poor feed conversion, as a result of using sinking feed through previous

1 SADC (2016) SADC Regional Aquaculture Strategy and Action Plan (2016-2026). Available: https://extranet.sadc.int/files/9514/6522/0178/SADC_FTC_1_2016_5a_Aquaculture_Strategy_English.pdf

2 SSC (2005) Master Plan Study on Aquaculture Development in Malawi Main Report. p-3. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

3 Brooks et al (1995) The Central and Northern Regions Fish Farming Project (C&NRFFP) [no online source available]

4 Worldfish (2008) Feasibility Study for a community driven fish cage model in Lake Malawi. [no online source available]

5 Maldeco (2019) Pact: Fish aquaculture component final stakeholders workshop June 2019. [no online source available]

production cycles; theft by fishermen and birds from cages and the high cost of importing formulated feed from Zambia.[6]

At a similar time to the beginnings of Maldeco Aquaculture Ltd, another large-scale, pond farm was established in Kasinthula, Chikwawa on the site of the FAO Kasinthula Project (1970-1976). This project sought to conduct research on various species (e.g. *C. carpio, O. mossambicus, O. shiranus, T. rendalli* and *O. karongae*) to investigate suitable candidates for aquaculture.[7] GK Aquafarms Ltd, leased 18 ha of pond area from the Government of Malawi (GoM) for 10 years. During the lease period, the farm sourced water from the River Shire and produced *O. mossambicus* and *C. carpio* (under license), among other indigenous species.[8] GK Aqua stated that the farm was geared to produce 12 T/ha/year, however, despite reporting successful yields and good growth rates as a result of the consistent conditions (e.g. water temperature and availability), there are no published records about the actual productivity and therefore profitability of the venture.[9] The business closed within the first lease period as the owner relocated to India, and the scheme is now under the management of the Department of Fisheries (DoF). Other examples of past attempts include the Liwonde fish farm (Nu-Line Foods Fish Farm) and the Benthos fish farm, owned by Club Makakola and located in Mangochi. Liwonde fish farm had >10 ha available for fish production and primarily *C. gariepinus*; However, no records were produced documenting the productivity and the farm closed within several years of opening. Similarly, Benthos fish farm which was initially built to supply fish for the restaurant at high-end lodges along the southern lakeshore has not reported data regarding production.[10][11]

More recently, several other examples have emerged: Chambo Fisheries in Limbe (Rift Valley Fisheries), supporting the largest tank-based, recirculating aquaculture system (RAS) in Africa.[12] The farm utilises hyper-intensive, Biofloc Technology (BFT) (i.e. protein-rich macro aggregate of organic material and micro-organims, including: diatoms; bacteria; and algae on which fish feed). This farm was opened in 2006 and original plans claimed an estimated production of approximately 800 T/annum of tilapia (e.g. *O. shiranus, O. karongae* and *T. rendalli)*. The farm also includes an indoor hatchery, feed processing facilities and breeding tanks. Despite this significant infrastructure and investment, the original production estimates have not been achieved to date, due to a number of technical issues, including inconsistent water temperature and operating costs. African Novel Resources (ANR) established in 2014 and situated in Chipoka, Salima combines 6 land-based, earthen ponds (approx. 1 ha total) and 8 cages in Lake Malawi (4-8km from Chipoka). The farm produces multiple tilapia species and *C. gariepinus* and has the potential to produce significant quantities. In addition to the grow-out systems, the farm includes an indoor hatchery and breeding ponds. Despite this infrastructure, the farm has faced ongoing challenges relating to the growth rate of species and the cost of imported feed from Zambia (i.e. feed cost including import tax).

Besides these examples of larger systems, the remaining aquaculture activities can be classified into two distinct categories. Smallholder farmers generally comprise 1-3 earthen ponds, with total area <500m^2. These small units are typically run by a single household, family members or a group, without any structured requirement for paid employees. In these systems, harvests are typically carried out on a continuous or partial basis and restocking may not occur for up to three years or at unstructured intervals in accordance with needs. Due to restrictions on funds for travel and transportation, sales that do occur will be made at either the farmgate or within the adjacent village. Due to the inherent simplicity of operations, the majority of these farmers do not practise record keeping or execute business plans for future. Due to their scale and available finance, these farms have limited access to quality inputs and

6 Personal communication (2018) Mr Bvunzawabaya, On-grower Manager Maldeco Aquaculture Ltd

7 SSC (2005) Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

8 Breuil, C. and Grima, D. (2014) SmartFish: Baseline Report Malawi. Available: http://www.fao.org/3/a-br797e.pdf

9 SSC (2005) Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

10 SSC (2005) Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

11 ADiM (2005a) Working Paper No.2. Situation analysis of aquaculture in Malawi. Available: [no online source available].

12 Kourie, R. (2017) Large-Scale Biofloc Tank Culture of Tilapia in Malawi. Available: https://sustaquafishfarms.co.za/pdf/Large-Scale%20Biofloc%20Tank%20Culture%20in%20Malawi%20-%20a%20technical%20success%20story%20-%20June%202017%20issue%20of%20WA%20magazine.PDF

financial services due to their unattractive risk profile for investors (e.g. credit and loan facilities) and therefore struggle to expand, improve efficiency or in many cases, become profitable.

In contrast, small to medium-scale, semi-commercial enterprises are typically larger with more three ponds each with area 400-1000 m^2 (although not exclusively). These farms may still be owned by individuals or a single household but are more likely to employ one or more staff due to the scale of operations and the likely integration with agriculture. These features are also indicative of the farmers investable income, as they are typically able to access and afford some commercial inputs; feeds, fingerlings and fertilisers. Furthermore, at this level, the individual may be able to access financial services, linked to alternative collateral. These farms will execute a more robust plan for cycle management, including harvesting and be able to demonstrate some financial records and future business planning. It is likely that if these farmers have access to water throughout the year, they will harvest fish at least once every 6-8 months and plan multiple cycles each year. It is also more likely that these farmers will sell most, if not all, of the fish harvested outside the adjacent village and in peri-urban or urban areas, or for higher prices.

Combined, it is likely that these two categories represent >90% of the fish farmers in Malawi.[13] Despite the existing body of literature, the productivity of this subsector remains in dispute, with some sources suggesting as low as 0.04-0.2 T/annum, whilst others suggest 2-4 T/annum.[14][15] Some sources report that the over-estimation of reports on the production from the smallholder and small-scale subsector can be attributed to the small sample sizes of target groups (i.e. from which harvests have been measured), and the significant resource demand required by Government to conduct accurate, regular censuses.[16][17][18]

Policy and Official Documents

The **Fisheries Conservation and Management Act 1997** serves as a guide to those aspiring to begin an aquaculture enterprise. This includes the application process for establishment and operation of aquaculture through permits and rights to water usage, under the Water Resources Act.[19]

The first edition of the **National Fisheries and Aquaculture Policy 2001 (NFAP)** stipulated that the main national goal for aquaculture was to increase and sustain fish production from smallholder and large fish farming operations in order to improve fish supply in Malawi.[20] As such, this document outlined specific objectives, which focussed on developing solutions relating to then current issues through bio-technical research (i.e. including prohibiting the introduction of live exotic fish species unless and until scientific evidence justifies otherwise),[21] and economic analysis of different systems at varying scales. However, no specific production targets were provided at this time, to guide this development.

Following the original NFAP document, the **Master Plan Study on Aquaculture Development in Malawi** or **National Aquaculture Strategic Plan (NASP) 2006-2015** (2005) comprised five separate sub-documents, and the NASP's primary function was to provide a road map for the sector (i.e. aquaculture development strategies and action plan). It promoted small-scale systems in rural areas as a means of reducing poverty and improving food security, as well as highlighting that "commercial

13 Brummett, R.E., Gockowski, J., Bakwowi, J. and Etaba, A.D. (2004) Aquaculture Economics and Management 8 (5-6): 319-328.

14 ADiM (2005a) Working Paper No.2. Situation analysis of aquaculture in Malawi [no online source available].

15 AgriTT (2017) How can smallholder aquaculture producers in Malawi improve their yields and profitability? Available: http://knowledgeshare.sainonline.org/wp-content/uploads/2017/04/How-can-smallholder-aquaculture-producers-in-Malawi-improve-their-yields-and-profitability.pdf

16 ADiM (2005b) Working Paper No.6. Commercial aquaculture development [no online source available].

17 Personal Communication (2018) Multiple District Fisheries Officers: Zomba, Thyolo, Mulanje, Chikwawa – July 2018. [no online source available]

18 Phiri *et al.* (2018) Economic Profitability of Tilapia Production in Malawi and China. Available: https://www.researchgate.net/publication/325847537_Economic_Profitability_of_Tilapia_Production_in_Malawi_and_China

19 Government of Malawi (1997) Fisheries Management & Conservation Act. Available: https://cepa.rmportal.net/Library/government-publications/Fisheries%20Conservation%20and%20Management%20Act%201997.pdf/view

20 Government of Malawi (2001) National Fisheries and Aquaculture Policy. Available: https://cepa.rmportal.net/Library/government-publications/National%20Fisheries%20and%20Aquaculture%20Policy%202001.pdf

21 Government of Malawi (2001) National Fisheries and Aquaculture Policy. Available: https://cepa.rmportal.net/Library/government-publications/National%20Fisheries%20and%20Aquaculture%20Policy%202001.pdf

aquaculture has the ability to significantly improve the cash economy in certain areas of the country and to contribute towards economic growth and job creation".[22] Furthermore, as a plan for enhanced economic opportunities for commercial fish farmers (Strategic Theme: 2) the plan outlined five clear strategies with measurable outcomes.[23] Part of the strength of this overarching plan is that it provided a comprehensive account of all information available at the time in 2005, regarding the situation of commercial aquaculture in Malawi, mostly compiled by the JICA ADiM Study Team.

The NASP also flagged a number of notable constraints to the growth of the commercial sector. These included: the poor growth potential of indigenous tilapia strains and the need for hybridisation and development of faster growing strains and monosex; the need for improved technical expertise to complete basic on-farm operations (e.g. feeding, fertilisation and population control); the DoF's role in prioritising a move away from old-fashioned technologies and improved dissemination of research results; and addressing fish farmers inability to access credit to develop their systems and increase their production.[24] It can be argued that several of the constraints raised regarding rural aquaculture can also be related to the commercial sector (e.g. the scarcity of input commodities etc.) since emerging, small to medium-scale, 'commercial' fish farmers fall within the rural, smallholder classification.

The NASP also highlights the opportunities for commercial aquaculture. These included: building knowledge on fast growing technologies and the introduction of alternative, indigenous species, monosex technology and developing improved strains of indigenous tilapia; and accumulation of economic information, including price information and cost information (e.g. gross margin analysis), which could be disseminated to farmers.[25] A key legacy of the project's pilot was the establishment of the Innovative Fish Farmers Network Trust (IFFNT), a group of "lead, innovative farmers" who were identified as being more advanced in their productivity and therefore given responsibility of representing the interests of fish farmers as an organisation.[26]

The revised **National Fisheries Policy (NFP) 2012 – 2017** (2012) stipulated that the main policy target should be to increase production to 10,000 tonnes by 2017 and increasing to 50,000 tonnes as a long-term measure. To make this a reality, the NFP promoted Government and private sector investment in aquaculture development, and a focus on promoting aquaculture as business at various operation levels (small, medium or large).[27]

The newest edition of the **National Fisheries and Aquaculture Policy (NFAP)** (2016) is the current policy document and aims to address critical issues affecting aquaculture development in Malawi.[28] Within this document, the Government of Malawi aims to increase aquaculture production from 3,600 tonnes to 10,000 by 2020, and 50,000 tonnes by 2029, as well as increasing fish exports to 3,000 tonnes from the current 500 tonnes to targeted markets within the region, for both high and low value fish products.[29] Echoing the aforementioned documents, the most recent policy highlights the main constraints to aquaculture development including: inadequate policies, limited technological advancement and weak institutional support. The policy issues mainly deal with hatchery development,

22 SSC (2005) Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

23 SSC (2005) Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

24 SSC (2005) Master Plan Study on Aquaculture Development in Malawi Main Report. Constraints to Commercial Aquaculture. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

25 SSC (2005) Master Plan Study on Aquaculture Development in Malawi Main Report. Constraints to Commercial Aquaculture. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

26 SSC (2005) National Aquaculture Strategic Plan (NASP) 2006-2015. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

27 Government of Malawi (2012) Fisheries Policy. Available: https://www.unpei.org/sites/default/files/event_documents/FISHERIES%20POLICY%20FINAL%2013.11.2012.pdf

28 Government of Malawi (2016) Fisheries and Aquaculture Policy. Available: http://www.unpei.org/sites/default/files/dmdocuments/Government%20of%20Malawi%20National%20Fisheries%20and%20Aquaculture%20Policy-%202016.pdf

29 Government of Malawi (2016) National Fisheries and Aquaculture Policy. Available: https://cepa.org.mw/Library/government-publications/National%20Fisheries%20and%20Aquaculture%20Policy%202016.pdf/at_download/file

tenure issues in cage culture, security problems; catfish fry survival, feed production and weak institutional collaboration.

As part of the **Malawi Growth and Development Strategy (MGDS) III**, the Government of Malawi has highlighted aquaculture as an important sector for growth. This strategy document details ambitious policies targeting a significant increase in aquaculture production to 8,000 tonnes by 2020 (increasing to 50,000 tonnes by 2029).[30,31] To make this a reality, and as demonstrated by regional examples, there is a need for the development of large, commercial-scale actors producing upwards of 10,000 t/annum, as well as continued development of the complex value chain, which will also help to support improved production and efficiency for existing small-scale smallholder systems. This will require greater collaboration between existing stakeholders involved in the sector and the rise of new and varied opportunities for supply chain expansion. Furthermore, it is critical that in support of these ambitious production targets, enabling policies are instituted to further develop production by large-scale commercial and current, smaller scale, 'semi-commercial' farmers.[32]

Key Constraints

As demonstrated above, the issues facing the aquaculture sector in general are well documented and understood by policy makers. Historically, research and respective literature has focussed on barriers that continue to prevent consistent increases in production for the Malawian aquaculture context. However, little has been added to this pool of knowledge in recent years. The two main barriers that are often cited include: the lack of high production technologies (i.e. a poor-quality, formulated feed), and the use of species that cannot attain comparable, maximum, harvest size with international competitors (i.e. fish are harvested at <100 g individual body weight in the majority of small-scale systems and ≤300g for commercial-scale systems in six to eight months). However, there is a need to investigate all factors.

Farm and Business Management

Despite ongoing efforts by Government District Fisheries Officers and their team of extension staff (i.e. providing training in best practise methods and fish husbandry), there remains a lack of sufficient technical expertise in the aquaculture sector for it to fully commercialise. Similarly, the majority of farmers can rarely demonstrate sufficient financial records (e.g. bookkeeping and production plans) to show whether their pond-based production systems are financially viable and have been historically successful. For this to change, there is a need for Government extension services and donor-funded projects to promote training courses with a focus on budgeting and financial management prior to start and throughout grow-out cycles, to ensure effective business management and personalised business models that can assure farmers of the maximum commercial viability and profitability for their systems.

Effective farm management involves a range of different activities and processes. For fish farmers, there is a need to understand the biological processes that determine optimal productivity for fish growth. A key feature of this is the growth rate of fish and also stocking density. This is considered a distinguishing feature of commercial operations as the farm owner must be able to set specific production targets within the available water body, utilising pre-determined numbers of stock (i.e. the correct number of fingerlings which can demonstrate uniform growth rates).[33]

In addition, farmers must also monitor the economic processes that determine the profitability of their farm business. This requires ongoing financial planning, analysis and evaluation.[34] In the Malawian

30 Government of Malawi (2017) The Malawi Growth and Development Strategy iii. Available: https://cepa.rmportal.net/Library/government-publications/the-malawi-growth-and-development-strategy-mgds-iii

31 Government of Malawi (2016) Fisheries and Aquaculture Policy. Available: https://cepa.org.mw/Library/government-publications/National%20Fisheries%20and%20Aquaculture%20Policy%202016.pdf/at_download/file

32 Jamu, D. and Brummett, R. (2008) ICLARM - Opportunities and Challenges for African Aquaculture. Available: http://pubs.iclarm.net/Pubs/alien_species/pdf/01.pdf

33 SSC (2005) The Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

34 Engle, C. R. and Niera, I. (2005)) Tilapia Farm Business Management and Economics: A Training Manual. Available: http://pdacrsp.oregonstate.edu/pubs/engle_manual.pdf

context, this means that farmers must demonstrate a clear understanding of seasonal price fluctuations for fish (e.g. determined by supplies of fish from capture fisheries in different geographical regions), and the impact that this may have on harvest schedules, as well as an understanding of the relationship between fish price and size, so as to schedule their production and harvesting cycles to coincide with optimal profitability.[35] Therefore, management is one of the most important factors for success, since this will play a significant role in determining a fish farm's profitability in years where profit margins are reduced (i.e. in years where the price of inputs and operations appears to exceed the potential market opportunities). For any commercial, business activity to be profitable, it is essential that revenue gained surpasses the operational cost of production and other expenses (e.g. taxes).[36]

Furthermore, like any other business that is to remain commercially viable and therefore profitable, fish farmers must apply the universal rules of financial management, if they are to remain viable and sustainable. Unfortunately, the majority of fish farmers (i.e. smallholders) have been the recipients of poorly managed subsidies and hand-outs without sufficient financial training - this is thought to have led to the collapse of many fish farms that could have become profitable and commercially viable.[37] These farmers may have received various inputs (e.g. high quality feed and fingerlings) enabling them to conduct several consecutive successful rearing cycles, however, in subsequent years of poorer productivity (i.e. if they are unable to maintain production with these inputs due to lack of finance and instead return to low-input methods) the farm will falter, and likely be abandoned.

A significant factor in this cycle of events is the lack of re-investment into the fish farming business (i.e. revenue from fish sales). Unfortunately, this is a theme for many agricultural MSMEs, which demonstrate a tendency to grow "too big, too fast", for reasons that not related to the fish farm at all (e.g. increased social obligations which require scheduled payments, such as school fees, wider family issues and basic, incremental additions to physical capital and family wealth).[38][39] Farm management and technical expertise is also intrinsically linked to broodstock and hatchery management, where the application of improved techniques is vital to prevent reversal of valuable progress: inbreeding, interspecific hybridization, and contamination of the newly developed improved strains (i.e. introgression).[40]

Fingerlings (seed)

Excluding *O. niloticus* and *C. gariepinus,* most other species that are currently used in African aquaculture have seen negligible genetic improvement and are insufficiently domesticated due to a lack of coordinated selective breeding programmes. As a result, their capacity to compete under improved management is inferior to better performing species and strains.[41] A recurring theme in the recommendations given by experts is emphasis on the need to develop strains with more desirable traits (i.e. through genetic enhancement). Methods for genetic enhancement have been applied to a vast array of species and indeed, most livestock strains. Similarly, in pisciculture methods such as those used to produce the GIFT strain Nile tilapia and various salmonids of the Atlantic industries, should be used as a catalyst to accelerate genetic enhancement programmes at national levels.[42][43]

35 SSC (2005) The Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

36 Engle, C. R. (2010) Aquaculture economics and financing: Available: http://www2.hcmuaf.edu.vn/data/nmduc/Aquaculture%20Economics%20and%20Financing%20-%20Management%20and%20Analysis.pdf

37 Russell *et al.* (2008) Recommendation Domains for Pond Aquaculture. Country Case Study. Available: http://aquaticcommons.org/1692/1/9789832346654.pdf

38 Winkelmann (1998) CGIAR Activities and Goals: Tracing the Connections. Available: http://documents.worldbank.org/curated/en/930591468765601820/pdf/multi0page.pdf

39 Brummett (1998) SmartLessons: Growing Fish to Make Money in Africa. Available: http://documents.worldbank.org/curated/en/356011468192850439/pdf/677090BRI00PUB0htoMakeMoneyinAfrica.pdf

40 Jamu *et al.* (2003) Potential for the development of aquaculture in Africa. Available: http://pubs.iclarm.net/Naga/na_447.pdf

41 Brummett (2008) Genetic quality of cultured tilapia stocks in Africa. Available: https://www.was.org/magazine/ArticleContent.aspx?Id=498

42 Eknath *et al.* (2007) Genetic improvement of farmed tilapias. [no online source available].

43 Ponzonia *et al.* (2008) Genetic Improvement of Nile Tilapia (O. Niloticus). Available: https://cals.arizona.edu/azaqua/ista/ISTA8/Ponzoni.pdf

Due to the aforementioned ban imposed by the Malawian Government, which prohibits the use of exotic species,[44] Malawian fish farmers must slow-grow, indigenous strains.[45] The alternative is to embrace the longer process of decentralized genetic improvement (i.e. the development of improved strains through ongoing selective breeding programmes in the home country, rather than importing superior broodfish from stock in a different country) to avoid the cost of replicating centralized improvements.[46][47] Not only does this require a significant capital outlay and coordination between stakeholders (e.g. Government, international donor, private investor), it also requires a sustainable approach to reduce the risk of abandonment. Furthermore, human capital and skilled experts capable of maintaining the management strategy are required (e.g. the importance of avoiding inbreeding) to ensure the survival of new strains.[48] Despite these hurdles, experts suggest that where possible, regular and well-managed outcrossing of wild strains with hatchery populations can see effective enhancement of desirable traits and can be a successful alternative to the introduction of exotic species (i.e. even improved, fast-growing strains from abroad). Some argue that this practise can be more effective than the import of broodfish, countering the effects of deterioration caused by poor genetic management.[49]

As previously discussed, the National Aquaculture Centre (NAC) was established so that it could be responsible for initiating selective breeding programmes, to investigate the potential for improving growth rates of indigenous species (including stocking densities) in particular *O. shiranus*.[50] The centre succeeded in rearing fish to F^6 (6th generation) with an improved growth of 25.2%, lower feed conversion ratio (FCR), higher efficiency at utilizing feed and growing better than alternative, unimproved strains at stocking densities of 5 fish/m^3.[51] Despite this early success, the centre has struggled to sustain this programme and the current status of the fish generations is unconfirmed.

Today, fingerling production in Malawi is disorganised and is not sufficiently sensitive to quality. The market is also skewed by the Government practice of distributing free fingerlings through their own programmes and on behalf of NGOs, which acts as a disincentive to private producers (both large and small-scale). The lack of regulation of fingerling production in Malawi negates any gains made through breeding programmes.[52] This being said, recent developments in hatchery management have started to see improvements. The Aquaculture Enterprise Malawi (AEM) project (2013-16) sought to understand the status of fingerling supplies and worked with fish farmers in Malawi's Southern region to develop small-scale hatcheries.[53] More recently, the Scottish Government funded 3-year SHASP project (2016-19) has sought to develop the technical expertise of small-scale Hatchery Operators producing tilapia (*T. rendalli and O. shiranus*) fingerlings using various methods (e.g. ponds, hapas and concrete hatchery tanks).[54]

There remains a need to focus efforts on improving systems to produce monosex fingerlings to farmers. Monosex culture is considered the most effective method for controlling reproduction and size uniformity within aquaculture.[55] Unfortunately, the situation regarding the feature of fish farming in Malawi has seen little to no improvement despite research programmes in the last decade.[56] This was a focus of the AgriTT

44 Government of Malawi (1997) Fisheries Conservation & Management Act. Available: https://cepa.rmportal.net/Library/government-publications/Fisheries%20Conservation%20and%20Management%20Act%201997.pdf/at_download/file

45 Ambali (2001) Aquaculture Genetics Research in Malawi. Available: http://pubs.iclarm.net/Pubs/Fish_Genetics/chapter%209.PDF

46 Government of Malawi (1997) Fisheries Conservation and Management Act. Available: https://www.elaw.org/system/files/mw.fisheriesmanagementandconservationact.doc

47 SNDP (2008)) State of Environment Report for Malawi. Available: http://www.sdnp.org.mw/enviro/soe_report/chapter_7.html

48 Brummett (2017) Genetic quality of cultured tilapia stocks in Africa. Available: https://www.was.org/magazine/ArticleContent.aspx?Id=498

49 Brummett (Unknown) Genetic quality of cultured tilapia stocks in Africa. Available: https://www.was.org/magazine/ArticleContent.aspx?Id=498

50 Ambali (2001) Aquaculture Genetics Research in Malawi. Available: http://pubs.iclarm.net/Pubs/Fish_Genetics/chapter%209.PDF

51 M'balaka *et al.* (2012) The effect of stocking density on the growth and survival of improved and unimproved strains of Oreochromis shiranus. Available: https://core.ac.uk/download/pdf/82802688.pdf

52 AgriTT (2017) Policy Briefing: Why invest in African aquaculture? Available: http://knowledgeshare.sainonline.org/wp-content/uploads/2017/04/Why-invest-in-African-aquaculture.pdf

53 AEM (2015) Developing commercial aquaculture in Southern Malawi. Available: http://www.ccardesa.org/media/1/uploads/ppt_presentations/youth_summit_2015/napuru.ppt

54 Sustainable Aquaculture Stirling (2017) Scottish Govt SHASP Hatchery Project Malawi. Available: http://www.susaquastirling.net/blog/2017/11/9/scottish-govt-shasp-hatchery-project-malawi

55 SSC (2005) The Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

56 SSC (2005) The Master Plan Study on Aquaculture Development. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

project (2016), as it sought to improve infrastructure at government hatcheries and to promote monosex fingerling production using the hybridisation methods.[57] Though it was highlighted that for this to prove sustainable, a long-term strategy would be needed to address challenges relating to technology adoption and production procedures.[58] It is unconfirmed whether these facilities are fully functional two years after the project ended, but anecdotal evidence suggests that Public-Private partnership (PPP) options are being explored.

Feeds

Anecdotal accounts from farmers and recent unpublished reports suggest that feed represents one of the most significant barriers for Malawian fish farmers. Furthermore, research from recent decades suggests that 90% of all fish farmers in Malawi use maize bran or *madeya* as a primary feed.[59] Sadly, this remains the current condition for the majority of farmers who continue to struggle in accessing improved feed options, even for those who identify themselves as being 'semi-commercial' and can afford more improved options. Maize exhibits poor nutritional profile. Published accounts have shown that maize exhibits low gross protein content of <5% and sub-optimal feed conversion ratio of 12-20:1.[60] Additionally, the volumes of maize required to provide optimal feeding rates (i.e. 5% body weight per day) are typically too high for farmers to access.[61]

The alternative for farmers is to utilise on-farm formulations including local ingredients. Studies and projects through the last decade have highlighted the need for improved farmer awareness of opportunities that exist with on-farm feed formulations.[62] The Master Plan Study on Aquaculture Development in Malawi (2005) stated that this must include a focus on formulating recipes using ingredients that can be found locally (e.g. soya, maize and rice brans, brewers waste etc.) and plants which can be grown in integrated systems that can be utilised as either food or fertiliser (i.e. plants with high Carbon-Nitrogen ratios such as: Vetifer grass, black jack, cassava leaves, papaya leaves, sweat potato leaves, coco-yam leaves).[63]

Recent reports have suggested that the lack of improved, formulated feed options is a direct result of poor private, commercial activity in the Malawian aquaculture sector.[64] There is evidence of farmers importing from Zambian suppliers (e.g Novatek, Skretting and Aller-Aqua), though the current cost of import is too high for the majority of small-scale and indeed semi-commercial farmers (i.e. cost of feed to Malawi including transport and VAT tax). This has led to recent calls for the need to develop alternative, low-cost options that can be developed within Malawi.[65] The AgriTT project (2016) suggested that, if 20% of the fish farmers in Malawi are willing and able to purchase feed, then the current potential market volume is 210 MT feed per annum, with a value of approximately 61.8 million Malawi Kwacha (MK) (US$ 86,000).[66] However, project outputs also suggested that the critical mass of fish currently produced does not justify investment in the production of high quality fish feeds. As an alternative, the project promoted local

57 AgriTT (2017) Commercialising the aquaculture sector in Malawi. Available: http://knowledgeshare.sainonline.org/wp-content/uploads/2017/04/Commercialising-the-Aquaculture-Sector-in-Malawi.pdf

58 AgriTT (2017) Challenge of producing high quality fingerlings in Malawi. Available: http://knowledgeshare.sainonline.org/wp-content/uploads/2017/04/The-challenge-of-producing-high-quality-fingerlings-in-Malawi.pdf

59 Hecht (1999) Border Zone Aquaculture Development Project and NARMAP Fisheries Management Project [no online source available]

60 Hecht (1999) Border Zone Aquaculture Development Project and NARMAP Fisheries Management Project [no online source available]

61 Hecht *et al.* (2003) Situation analysis of aquaculture in Malawi. [no online source available]

62 SSC (2005) The Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

63 SSC (2005) The Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

64 AgriTT (2017) Commercialising the aquaculture sector in Malawi. Available: http://knowledgeshare.sainonline.org/wp-content/uploads/2017/04/Commercialising-the-Aquaculture-Sector-in-Malawi.pdf

65 Singini *et al.* (2014) Development of quality and affordable fish feed for small scale fish farmers in Malawi. Available: https://www.researchgate.net/publication/319257065_Development_of_quality_and_affordable_fish_feed_for_small_scale_fish_farmers_in_Malawi

66 AgriTT (2017) Commercialising the aquaculture sector in Malawi. Available: http://knowledgeshare.sainonline.org/wp-content/uploads/2017/04/Commercialising-the-Aquaculture-Sector-in-Malawi.pdf

production of mid-range feed (i.e. cost approx. 359 MWK / US$ 0.5)/kg),[67] though the project was unable to secure the setup of these schemes within the project period. Despite these findings, anecdotal accounts have claimed that there are existing animal feed companies in Malawi who would be interested in investing in the necessary infrastructure to produce extruded fish feeds, if the critical mass required can be met by commercial farmers.

Sales and Marketing Development

Large-scale fish farms (Maldeco Fisheries Ltd. and Chambo Fisheries Ltd.) are able to deliver fish to distant consumers in major district centres (e.g. Lilongwe, Blantyre, Mangochi).[68] Reports indicate that Maldeco remains the only company capable of transporting frozen fish to these markets, since they own the necessary facilities, ice plants and chill storage facilities.[69] Recent observations in 2018-19 found that Maldeco is able to attain prices for retailed farmed fish from MWK 3,000/kg (low grade; 100-200 g) to MWK 4,000/kg (high grade; >300 g), equivalent to USD 4-6/Kg, thus demonstrating that it is possible for fish farms to succeed in reaching high market values, comparable with, if not higher than regional competitors.

The alternative for other farmers is to sell their fish fresh either from farmgate or local trading centres. Challenges exist for the majority to reach urban centres where prices may be better than their local setting. However, discussions with fish farmers in 2018-19 indicated that many are not aware of the best market options within their local area, or regional markets (e.g. price and distribution networks). There is little published information regarding recent pricing structures for fish from farms. However, reports from the past decade have found a correlation between price and market type, showing that urban centres typically exhibit higher prices on average than rural markets.[70] Despite these ongoing challenges, anecdotal evidence from fish farmers in 2018 suggest that small to medium-scale, 'semi-commercial' producers sell almost exclusively at either farmgate (i.e. if they are able to charge optimal price), or district-level trading centres. The price varies depending on fish size and quality, between MWK 1,500-3,000/Kg, equivalent to USD 2-4 (in 2018).

Value chain linkages must be improved if more farmed fish are to reach the desired marketplace in significant volumes and of acceptable freshness. Although the value chain for capture fisheries is relatively well established, there is a need to develop a similar model for aquaculture produce, where farmers can be assured access to markets through structured and un-structured actors (i.e. vendors and traders who currently trade fresh fish on ice and dried fish from capture fisheries), thus demanding stronger, reliable relations between fish farmers and market committee members. More importantly, if these effective marketing channels to attractive urban and peri-urban markets are not created, there is a significant risk that the efforts of fish farmers in Malawi will be undermined by competition from neighbouring countries, such as Zambia and Zimbabwe (e.g. Yalelo and Lake Harvest, with the latter already established with franchise outlets in Lilongwe, Blantyre and other urban centres), or Asia.[71]

Access to Credit, Finance and Related

The Master Plan Study on Aquaculture Development in Malawi (2005) highlighted fish farmers' inability to access credit and institutional support as being a major constraint to development within the sector.[72] This remains a key barrier for small to medium scale 'semi-commercial' farmers who demonstrate potential. Medium to large-scale commercial investors are similarly constrained as reports suggest that many are not aware that high interest rates and uncompetitive investment incentives, such as tax breaks as well as the high import duties on raw materials and machinery/equipment do not apply to aquaculture.

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67 AgriTT (2017) Commercialising the aquaculture sector in Malawi. Available: http://knowledgeshare.sainonline.org/wp-content/uploads/2017/04/Commercialising-the-Aquaculture-Sector-in-Malawi.pdf

68 LTS (2017) Sector Analysis Studies (CASA) Available: http://value-chains.org/dyn/bds/docs/949/Component%20A%20and%20C%20-%20Annex%20A%20-%202%20%20Malawi%20Sector%20S.pdf

69 Kapute (2008) Fish Quality and Processing in Malawi. Available: http://www.unuftp.is/static/fellows/document/fanue08prf.pdf

70 Matiya *et al.* (2005) Factors Influencing the Prices of Fish in Central Region of Malawi. Available: http://docsdrive.com/pdfs/ansinet/jas/2005/1424-1429.pdf

71 WorldFish (2008) Market, policy, infrastructural and institutional support requirements for the successful introduction of a small cage fish farm model in Malawi. [no online source available].

72 SSC (2005) Master Plan Study on Aquaculture Development in Malawi. Available: http://open_jicareport.jica.go.jp/pdf/11802675.pdf

More specifically, the majority of farmers are not aware that it is possible to apply for duty-free import status, if tax-exemption is applied for through the DoF. However, this reluctance demonstrated by investors is not unfounded, as there has been limited demonstrable evidence of successful commercial aquaculture enterprises in the country to date.[73] There are a number of commercial banks that provide various funding to private sector investment, although these typically charge high interest rate at 32%. In addition, anecdotal reports suggest that banks are reluctant to provide financing to agricultural enterprises due to high-risk profiles. If farmers are to attain loans, they must provide demonstrable evidence in the form of viable business plans with collateral.[74]

As aforementioned, another factor that inhibits growth of the aquaculture sector is the high cost of import duty for selected equipment and other items. Most recently, at the GIZ Aquaculture Value Chains Programmes (AVCP) stakeholder's meeting (2018), a spokesperson from the IFFNT highlighted the challenges faced by fish farmers relating to import duty and Value Added Tax (VAT), to which the Director of Fisheries stated publicly that the government is investigating the matter to ensure Malawi effectively competes with other countries such as Zambia which are advanced in fish farming.[75] This dispute is largely due to the notable disparities between fisheries and aquaculture in policy documentation. For example, investors in the capture fisheries industry are not subject to import duty, import excise or import VAT on key items and materials (e.g. aerators, pumps, mesh, nets, measuring equipment, tanks etc.) provided they receive a letter of recommendation from the DoF.[76][77][78]

In summary, a range of sector-wide issues exist which currently inhibit growth of the sector as well as the efforts of individual farmers. To mitigate these barriers there is a need for specific strategies: **Farm and Business Management**: In order to maximise the productivity of a specific system, it is important to ensure that farmers are able to accurately track their cycle activities, including financial outgoings and eventual turnover at harvest and marketing. Through this consultancy, there will be an opportunity to work closely with farmers, to develop monitoring plans alongside farmers' existing cycle plans, to schedule key cycle events and monitor the impact (e.g. sampling, grading, feed schedules, water quality, harvest weighing, market and sales pricing etc.). **Fingerlings**: In order to maximise growth of fish (i.e. as a result of genetic quality), it will be important to source fingerlings (seed) from reliable sources with superior quality. Through this consultancy, there will be an opportunity to assist farmers in locating seed of improved quality where possible. **Feed**: In order to maximise growth of fish post-stocking, it will be essential to ensure that feed is of a viable nature – both in terms of quality and price. As such, this consultancy will provide an opportunity to assess the quality of on-farm formulated feed types, the source of ingredients and to track the feed conversion rate through ongoing monitoring. Working with collaborators, this study will seek to improve feed efficiency, and demonstrate to collaborators the benefits of improved feeding best practices. **Access to Credit**: In order for individual farmers to access credit facilities, there is a need for them to produce robust business plans and accounts which demonstrate profitability and therefore a guarantee of return on investment. Through this consultancy, there will be an opportunity to develop such business plans with individual collaborators. Furthermore, the ongoing work and monitoring involved in this study will provide case study evidence to support developing advocacy for fish farmers in Malawi.

73 Kapeleta (2008) Aquaculture Development in Malawi. Available: http://www.fao.org/tempref/docrep/fao/007/y2277b/y2277b04.pdf

74 LTS (2017) Sector Analysis Studies (CASA). Available: http://value-chains.org/dyn/bds/docs/949/Component%20A%20and%20C%20-%20Annex%20A%20-%202%20%20Malawi%20Sector%20S.pdf

75 Zodiak Malawi (2018) Farmers Decry Tax on Fish Feed. Available: https://zodiakmalawi.com/malawi-national-news/farmers-decry-tax-on-fish-feed

76 MRA (2018) Incentives for the agriculture sector. Available: http://www.mra.mw/tax-update/incentives-for-the-agriculture-sector

77 Nsiku, N. (2012) Assessing Investment Incentives in Malawi. Available: https://www.iisd.org/pdf/2013/assessing_investment_incentives_malawi.pdf

78 MRA (2016) Tax Incentives in Malawi: Volume 1. Fishing Industry. Available: http://www.mra.mw/assets/upload/downloads/TAX_INCENTIVES_IN_MALAWI_HANDBOOK_2016.pdf

5.2 Annex 2: Swot analysis for the 25 farmers included in scoping

Strengths	**Description**
Entrepreneurial skills and dedication	This trait distinguishes farmers who typically focus on fish farming as a business activity with an implementable/trackable plan, rather than those who see fish farming as an "*ad hoc*" source of income and more importantly household food security.
Well-trained and experienced	This trait confirms that the farmer has received training (e.g. project activities and extension), which might cover topics like, water quality management, feeding methods, basic fish handling, some understanding of cycle planning and harvesting methodologies.
Preferable Location (water, soils, road, market & drainage)	Key to reducing cycle costs incurred (e.g. cost of transport and ease of access, water inflow, inputs, maintenance, reconstruction and harvesting). Farmers with permanent water supplies can manipulate the pond more easily and without additional cost incurred. Likewise, access to good roads will increase the likelihood of further market opportunities
Own equipment (e.g. net, scales etc.)	Owning or having easy access to equipment will improve the farmer's ability to conduct sampling and grading, to control the population within the pond. This in turn will enable the farmer to monitor and track production through the cycle (e.g. feeding to harvest date)
Available capital to invest	Farmers must have funds for their activities without subsidies if they are to be sustainable enterprises. The amount required will depend on the scale of operations (e.g. farm size).
Employed staff if not living on-farm	This enables farmers to split their time between income generating activities. For the majority of farmers, the ability to employ casual labour for key activities in vital (e.g. sample/harvest), though some will also employ staff to oversee all of their farm operations.
Weaknesses	
Lack of entrepreneurial skill	As above, if a farmer lacks entrepreneurial skills it is unlikely that they will be able to sustain an income generating farming activity beyond periods of subsidy and ongoing support.
Over-dependence on assistance	This is common and unfortunately affects those who are able to operate without/with less assistance also (i.e. identifiable when projects/subsidies cease as farming will stop).
No access to quality inputs (feed, seed etc)	A key barrier to many farmers. Poor seed contributes to early maturation, in-pond breeding and stunted growth, where lack of feed may reduce total production (e.g. total yield is likely to be reduced). Likewise, a lack of core equipment will remove the farmers ability to control.
Inadequate funding	If a farmer does not have access to personal funds to invest in the production cycle it will be difficult to become commercially viable when using inputs that incur a cost.
No business plan / records in place	Farmers who neglect planning and monitoring are unable to plan and track their production cycle. This means that it is very difficult to confirm whether they are profitable or not. Also, if a farmer is to secure a loan/credit, they must be able to demonstrate accounts.
Opportunities	
Increase scale: space and water supplies	If land and water is available at affordable costs, farmers may be able to increase their productivity and ultimate profitability by expanding their farming operation. This can be seen for a number of farmers who have built new ponds in the last 1-3 years.
Cooperating with other farmers (buy and sell)	Working as a group may improve conditions for individuals as it can make it easier for them to access inputs (buying in bulk as a group) and to engage in well-coordinated group marketing, to ensure that fish can be sold at optimal rates (e.g. eliminate over-supply).
Use of commercial fish feeds if available	Farmers have shown a desire to use commercially produced, formulated, extruded feeds as these - when well managed - can lead to higher productivity and yields.
Threats	

Fish predation and theft: lack of defence/training	The loss of fish to various predators and theft from surrounding community members. Loss of significant quantities can lead to a production cycle making a significant net loss.
Disagreements in group / cluster / village	Often overlooked, many farmers can face a range of challenges when relationships with others in the community break down (e.g. competition for water - washing, irrigation, home).
Climatic shocks (e.g. drought)	In recent years, farmers have faced increasingly severe impacts of changing conditions (e.g. erratic rainfall patterns) which have negatively impacted production cycle length and water quality (e.g. rainfall leading to overland flow and increased turbidity of pond water).
Fluctuating fish price in local market	In some locations, farmers must compete with an abundance of fish from capture (e.g. areas surrounding L. Chilwa where fish prices are low due to over-supply). Therefore, it is important for farmers to plan their harvesting according to this competition in markets.

5.3 Annex 3: Collaborator Farmer Topic Guides

Date: ____

Interviewer(s): ____

District / TA: ____

Village: ____

Introduction

- Introduce self and project / Explain purpose of the project (FISH aquaculture).
- Explain how findings will be reported, and benefits shared back to individual farmer.

Background of Interviewee

- Name and contact for interviewee – farm owner
- History of aquaculture involvement and personal goals
- Existing productivity / activities
- Current constraints to improved productivity and profitability (from farmer perspective).
- Investment in Aquaculture.
    - Time - How much time does farmers spend on aquaculture compared with other work?
    - How much income compared to other work (per year / month / 6 month or cycle)

Sources of Inputs (Feed, Seed and other input costs)

1. Source of Feed

- What feed do you use for your fish farm?
    - Formulated feed purchased as completed diet?
    - Ingredients for on-farm recipes as supplement?
- How is it accessed and how often?
- How much do you spend on feed (weekly, monthly, cycle, annual)?
    - What is the cost of formulated feed to farm, OR how much do you spend on individual ingredients (as above) each time you purchase ingredients?
- Do you keep records so that you can calculate your feed conversation ratio (FCR)?
    - What is your current FCR?
- What are your main concerns / if any, regarding feed provision?
    - Price, quality, FCR achieved, On-farm or formulated feed (cost-benefit), affordability, experience of growth rates, cycle length comparisons, interest imported?

2. Current source of Seed (Fingerlings)?

- What seed do you buy?
    - Species, hatchery, number / stocking density?
- How do you access this seed?
    - How do you transport and what is the system?
- How much do you currently spend on seed?
- Main concerns / if any, regarding fingerling provision?
    - Fish disease, poor size and species, transport issues, correct numbers, price, mortalities in early stage (first week), seasonality of supply, communication with suppliers?

3. Current source of manure / fertiliser (if using fertiliser)?

- What type of fertiliser do you buy?
    - Type, frequency and source?
- How much do you currently spend on fertiliser?

Connectivity and Market segmentation

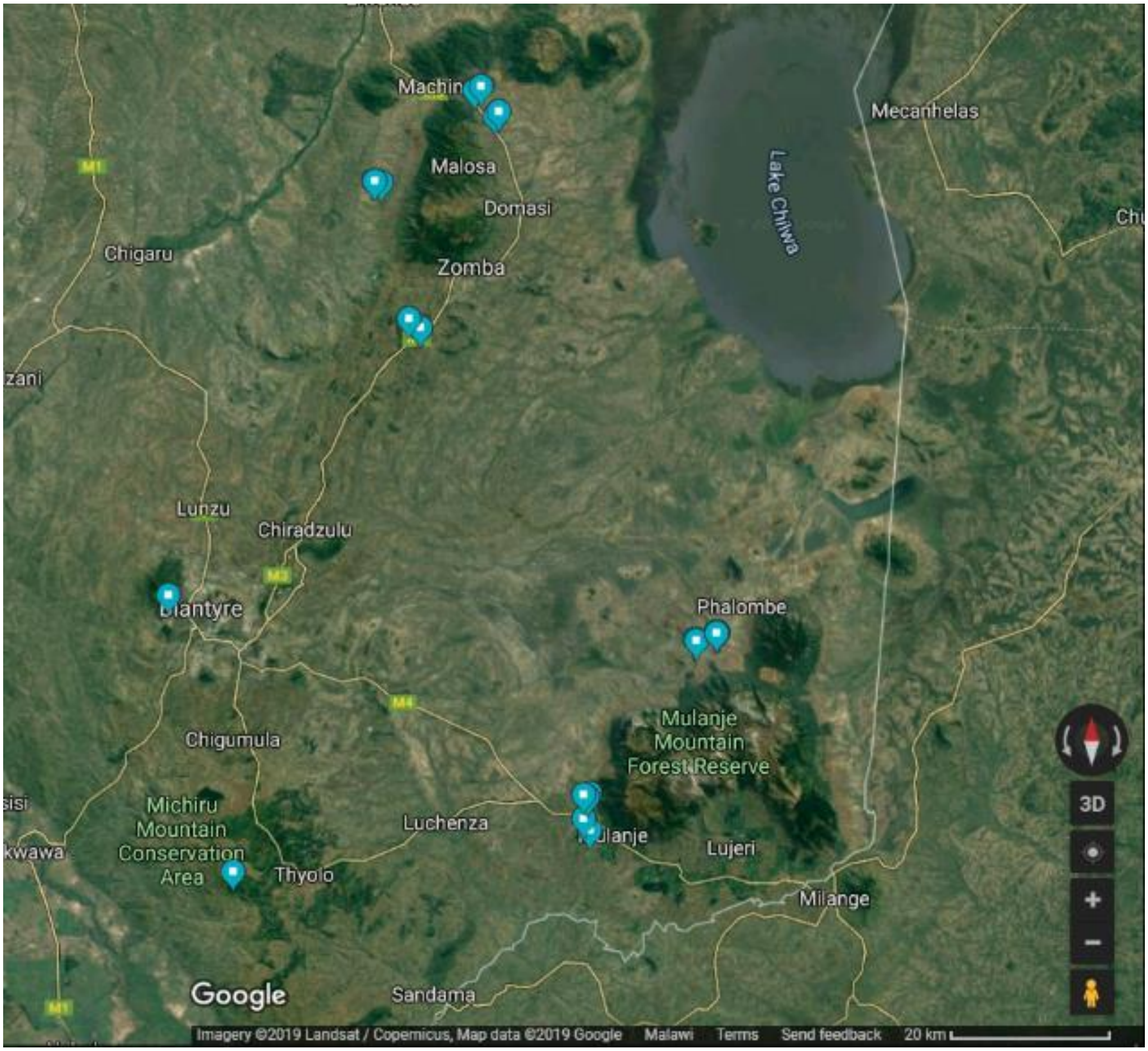
- How do you sell your fish?
    - Where do you sell?
    - How often do you sell?
        - How do you decide when to sell your fish?
    - # Total harvests in last year and Total Kg Harvested
- How does a harvest day work?
- How much do you know about current prices for farmed fish?
    - Do you do research in local / regional area?
    - Farmgate, Local village, near town, large markets (district and regional large towns)
- Do you keep records of sales and harvesting for comparisons?
- Do you connect with other farmers or other businesses for sales? FFs Association or grouping?
- What are other local fish farmers doing?

- How are their results, are they doing anything different?
  - Do they share information and skills or are they separate?
- What are some of the innovative ways and products of marketing fish?
- What are the main challenges you face in marketing fish?
  - Do you get support from Extension Officers, DFO, Donors? What support? Do they visit?
- How have you been involved in other projects in the past? Received in funding, who from?

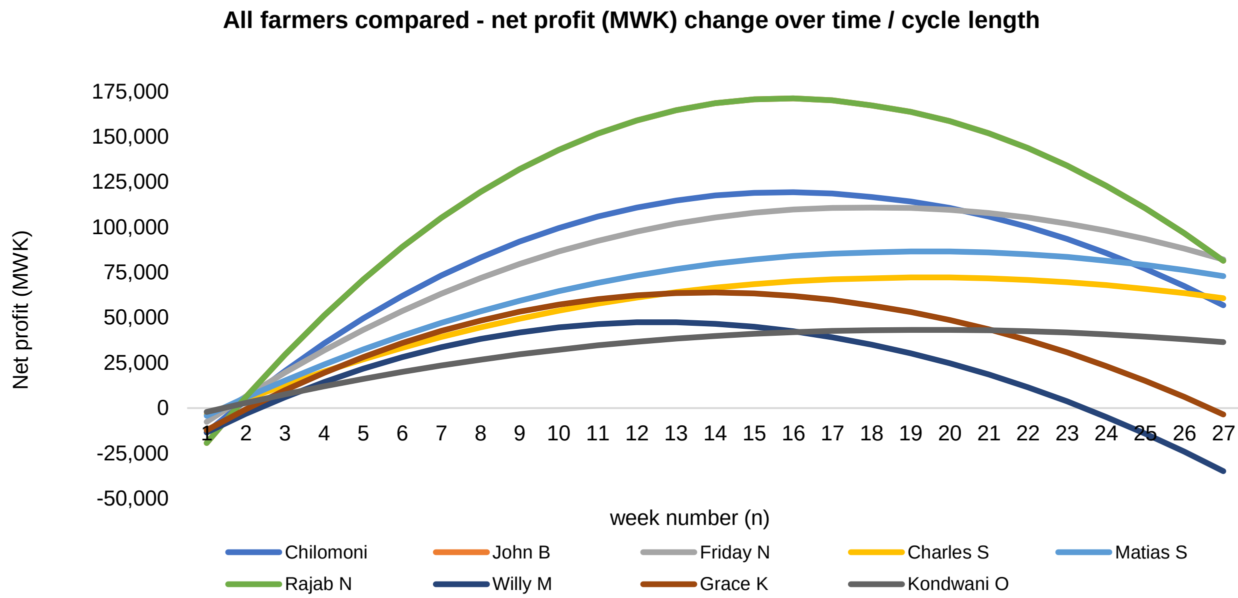
5.4 Annex 4: Key farm details for collaborator farmers

Name	Sex	District	No of Ponds	Total farm area (ha)	Grow out	Hatchery	Ongoing Production	Permanent source of Water
John	M	Mulanje	3	0.1336	Yes	No	Yes	Stream / Underground
Matias	M	Phalombe	2	0.049	Yes	Yes	Yes	Spring
Charles	M	Phalombe	2	0.22	Yes	Yes	Yes	Spring
Grace	F	Zomba	1	0.1487	Yes	No	Yes	Stream
Willy	M	Zomba	3	0.038	Yes	Yes	Yes	Stream / Spring
Rajab	M	Thyolo	2	0.13	Yes	Yes	Yes	Stream
Chilomoni	M	Blantyre	2	0.1295	Yes	No	Yes	Stream
Friday	M	Thyolo	8	0.175	Yes	Yes	Yes	Spring
Kondwani	M	Machinga	6	0.145	Yes	Yes	Yes	Stream

5.5 Annex 5: Location of Collaborator farmers



5.6 Annex 6: Projected change in net profit (MWK) in relation to cycle length (n) for 2018/19



Wk #		Projected net profit (MWK) by cycle length in weeks (n)								
	ABW (g)	Chilomoni	John	Friday	Charles	Matias	Rajab	Willy	Grace	Kondwani
1	5	-13,490	-19,345	-7,662	-3,577	-4,293	-19,345	-13,480	-12,215	-2,146
2	11	4,244	6,086	6,485	4,857	5,828	6,086	-3,221	-634	2,914
3	17	20,657	29,623	19,692	12,767	15,320	29,623	6,064	9,958	7,660
4	22	35,762	51,284	31,969	20,158	24,190	51,284	14,386	19,572	12,095
5	28	49,571	71,086	43,323	27,035	32,443	71,086	21,754	28,218	16,221
6	33	62,096	89,047	53,763	33,403	40,083	89,047	28,178	35,903	20,042
7	40	73,349	105,185	63,298	39,265	47,119	105,185	33,666	42,639	23,559
8	45	83,343	119,517	71,936	44,628	53,553	119,517	38,229	48,434	26,777
9	50	92,090	132,060	79,685	49,495	59,393	132,060	41,875	53,298	29,697
10	56	99,603	142,833	86,555	53,871	64,645	142,833	44,615	57,240	32,322
11	61	105,893	151,854	92,554	57,761	69,313	151,854	46,456	60,269	34,656
12	70	110,973	159,139	97,691	61,169	73,403	159,139	47,410	62,396	36,701
13	**73**	114,855	164,707	101,973	64,101	76,921	164,707	**47,485**	63,628	38,461
14	**78**	117,552	168,574	105,410	66,561	79,873	168,574	46,691	**63,977**	39,936
15	**84**	119,076	170,759	108,010	68,553	82,264	170,759	45,037	63,451	41,132
16	**89**	**119,439**	**171,280**	109,782	70,083	84,100	**171,280**	42,532	62,059	42,050
17	**95**	118,654	170,154	110,734	71,156	85,387	170,154	39,186	59,811	42,693
18	**101**	116,732	167,398	**110,875**	71,775	86,129	167,398	35,009	56,717	43,065
19	**106**	114,236	163,818	110,644	**72,199**	**86,639**	163,818	30,341	53,152	**43,319**
20	112	110,656	158,685	109,644	72,196	86,635	158,685	24,872	48,776	43,317
21	117	106,003	152,012	107,881	71,768	86,121	152,012	18,611	43,596	43,061
22	123	100,286	143,813	105,362	70,919	85,102	143,813	11,563	37,618	42,551
23	129	93,513	134,101	102,094	69,652	83,583	134,101	3,737	30,850	41,791
24	134	85,695	122,889	98,082	67,972	81,566	122,889	-4,862	23,299	40,783
25	140	77,081	110,536	93,522	65,992	79,191	110,536	-14,079	15,133	39,595
26	145	67,445	96,719	88,239	63,610	76,332	96,719	-24,053	6,201	38,166

27	151	56,798	81,450	82,236	60,828	72,994	81,450	-34,777	-3,490	36,497

Annex 7: Best Management Practices - SOPs

The Best Management Practices (BMP) and Standard Operating Procedures (SOPs) outlined here were developed in accordance with the system type that will be used by "all" 9 collaborator farmers. This being a "greenwater" system where in-pond phytoplankton is encouraged through the use of inorganic fertilisers (NPK and Urea) and a formulated diet is provided in the form of sinking, soya-based feed, produced by NAC in Domasi. This feed comprises soya, fish meal (fish sweepings), wheat bran, maize flour, mineral mix, vitamin mix and oil and is formulated at the centre's feed mill. This system type has been selected as it avoids the use of retrogressive practices, such as the use of madeya for feed and utilises the "most advanced" feed type available, in the absence of easy-to-access, import options. The specific application rate of inorganic fertiliser and formulated feed was detailed in the specific "Implementation plan" for each collaborator farmer and monitored through ongoing checks on a daily basis by each farmer being responsible for his/her farm. These checks are outlined and discussed below. The records kept were assessed on a bi-weekly basis by a field technician and compared against the implementation plan for each farmer. The average body weight (ABW) of fish was assessed through monthly sampling, as this informed the feed demand and ultimate cycle length and profit generated.

Preparing the Ponds

There are **FOUR TASKS** to be done before the ponds can be stocked with new fish:

Drying the ponds

1. Open the outlet and drain all the water from the ponds.
2. Remove top layer of soil and transfer to agricultural fields for fertiliser.
3. Leave the ponds to dry in the sun for up to 14 days.
4. If a grown man can stand in the middle of the pond without sinking, the pond is dry.

Filling the ponds

1. Attach mesh over inflow to prevent introduction of self-recruiting fish into the pond (this inlet must be checked each time the inflow is opened).
2. Turn the inlet on.
3. Fill the pond to approximately 50cm in the shallow end and approximately 100cm in the deep end. If it is possible to fill with more water (e.g. 100cm – 150 cm), this may improve productivity.
4. Turn the inlet off.

Fertilising the ponds

1. Using a bucket, combine NPK, Urea and cold water (this can be pond water) as per application guide.
2. Wearing gloves, or using a stick, stir until the fertiliser has dissolved.
3. Wearing gloves, spread evenly over pond surface from pond dykes.
4. Do not stock pond with fish until the ponds have turned green, usually within 14 days.
5. Once the ponds are stocked, apply fertiliser twice a week at the same time each week (1/2 portion per application). It is important that the farmer keeps a record of application
    a. Fertiliser should be applied on days when there is intense sunlight – this will improve the process of fertilisation and improve algal growth through photosynthesis.

Ongoing Checks – Secchi disk or arm tests

The transparency of pond water varies from almost zero (in the case of very turbid water) to very clear water, and depends on the amount of water turbidity, which is caused by suspended matter such as phytoplankton, soil particles and so forth. Phytoplankton blooms generally change the colour of the water to green. To determine the need for fertiliser application and to assess plankton turbidity, the farmer should either use a **Secchi disk** (if available) or **their arm**. With a Secchi disk, when the disk is submerged:

- If at 25 cm or less the disk is still visible, no fertiliser should be applied. In this instance, it is also important to observe fish behaviour (fish at the surface, gulping for air) as there may be low dissolved oxygen. If fish are gulping at the surface, the inflow should be opened to allow fresh water into the pond.
- If at 25-40 cm the disk is still visible, no fertiliser should be applied. It is also best practise to observe fish activity and behaviour that indicates low levels of dissolved oxygen.
- If at 40 cm and above the disk is still visible, fertiliser should be applied as per schedule, and if above 60 cm, application should be increased (apply 2 x per week until the depth of visibility is reduced).
- In the absence of a Secchi disk, the farmer should use their arm instead.

If a Secchi disk is not available, the farmer can use their arm:

- Submerge arm in water vertically and if hand is not visible when the elbow is at the surface, there is no need for fertilization.

Figure 8: Secchi disk (left), aquaculture specialist demonstrating arm test (centre and right)

Stocking

The method used for stocking will depend on the source of fry/fingerlings:

1. If the fry/fingerlings are transferred from hapas on-farm, fingerlings should be counted into a bucket of water and transferred into the designated pond. This process should be repeated until the pond is fully stocked (with known stocking density – number of fingerlings/pond area, e.g. 2,100 fingerlings / 700m = stocking density of 3).
2. Alternatively, if the fingerlings are bought from an external source (e.g. other hatchery, NAC, Maldeco, LUANAR etc) and transported using oxygenated bags:

Preferably, **THREE** people are required to stock the ponds correctly:

- Count the correct number of bags into each pond – remember, there should be a specified number of fry per bag.
- Leave the bags unopened in the ponds for 20–30 minutes (allowing the fish to acclimatise to the new water temperature).
- Cut the zip tie and slowly open the bag.
- Lower the bag into the water gently and allow the fry to swim freely out of the bag.
- One person should count fry as they leave the bags.
- One person should collect the dead fry.
- One person should record the number of fry in the pond and mortalities.

NB. Do not feed the fish for 72 hours after successfully stocking the ponds as they will be stressed. Monitor the ponds for fish behaviour over the next 72 hours and remove any mortalities.

Sampling the fish

MONTHLY sampling of the fish has a number of benefits as it allows the farmer to estimate biomass; to change the amount of feed to give the fish; and ensures all fish grow in a uniform size. You will need the following equipment to sample the fish:

- 1x large bucket
- 1x small bucket
- 1x seine net
- 1x scoop net
- 1x hanging scales
- 1x record book

Follow these guidelines to successfully sample the fish:

1. Starting at the deeper end of the pond, guide the seine net to the shallow end to concentrate the fish.
2. Using scoop net, transfer 5 fish to 50l bucket. Repeat process until you have 25 fish in the bucket.
3. Fill 25l bucket with water and weigh the bucket. Record the figure.
4. Using scoop net, transfer 5 fish to the 25l bucket and weigh on the scales. Record the figure.
5. Using the scoop net, transfer the 5 fish to the second 50l bucket.
6. Repeat the process until you have five individual measurements.
7. Using the scoop net, carefully transfer the fish back into the pond.

NB. It is important to choose fish at random (fish may vary in size). The farmer must discern whether the fish chosen were part of the same population that were stocked originally. It is important to not choose the biggest fish only, as this will give an unrealistic picture of the total biomass.

Even when fish are stocked at similar sizes they can grow at different rates. Due to the variability in their growth fish may need to be graded several times during the production cycle. Since these farmers stock mixed-sex fingerlings, the fish will breed inside the pond. This results in an abundance of new fry/fingerlings on a bi-monthly basis throughout the growth cycle. During monthly sampling these small fish can either:

- be removed and sold to local markets
- reserved for additional home consumption
- stocked into other ponds in known quantities to enable another cycle in this pond.

It is the responsibility of the farmer to discern whether small-sized fish are merely stunted (i.e. they represent a portion of the stocked population) or were the result of in-pond breeding.

How to calculate the weight of an individual fish?

1. Fill a bucket with water, weigh and take note of the weight
2. Place five fish in bucket, weigh and take note of the new weight
3. Subtract the weight of the bucket and water. This will tell you the weight of five fish.
4. Divide that figure by five to find the average weight of the fish.
5. Repeat this process until you have five separate averages.
6. Add these averages and divide by five (giving the average body weight of the fish in the whole sample)

Feeding the Fish – Sinking, soya-based feed

For the fish to grow to a marketable size of 100g, they will be fed with sinking, soya-based, pellet feed alongside the aforementioned inorganic fertiliser. **THREE** considerations need to be made:

1. Feed should be supplied to the feeding tray at the same time each day.
2. The fish should be fed the correct amounts depending on their size.
3. The amount given should be recorded and the amount not eaten should be recorded.

NB. It is important that the feed tray is checked for feed that is not eaten. If the amount remaining is significant, the feed schedule should be adjusted and reduced to reduce waste.

What is the correct amount of fish feed for the fish?

- Fish are fed as a percentage of their overall biomass (3% biomass for NAC feed, as per guidance).
- Fish should be fed according to feeding schedule, but records should be kept regarding uneaten feed.

How do I feed the fish?

Feeding fish can be a **MANUAL PROCEDURE** done by hand. Farmers must be prepared to feed both manually and using feed trays. Follow the guidelines to successfully feed the fish using feeding trays:

1. Weigh the correct amount of feed for each pond using scale
2. Disperse known quantity of feed on the surface of water, over the feeding tray.
3. Observe feeding behaviour around the feeding tray to ensure fish are feeding normally.
4. Lift the tray two to three hours after the feed was supplied to check how much of it has been consumed.

NB. Empty feeding trays may indicate that the quantity given is inadequate and may have to be increased. Conversely, full or slightly touched trays indicate excessive feed quantities. The feeding ration should be adjusted accordingly to optimize feed utilization.

Testing water temperature

To measure the water temperature, a manual thermometer must be used. To check the water temperature, follow the below procedure:

1. Submerge thermometer in pond water for 5 minutes until the temperature reading is stable.
2. Record the temperature reading
3. Clean the thermometer for next use.

What to do if temperature is high or low (Above 35°C or below 25°C)

1. If the temperature is too high turn the inlet on and allow fresh new water into the pond - At the same time, open the outlet and remove some of the old water.
2. If the temperature is too low stop feeding the fish as they will not want to eat.

How often should the temperature of pond water be measured

1. The temperature of each pond should be taken twice daily.
2. The temperature should be taken at same time every day. At 06:00-08:00 and 14:00-15:00.

Harvesting the ponds

The following equipment is required for harvesting the ponds:

- seine net
- scoop net/s
- buckets (large and small buckets)
- weighing scales

Fish have fragile scales on their outer surface which can become easily damaged if the fish are mishandled. Damaging the skin will cause unnecessary stress to the fish. It can also look unattractive to a buyer, and the price of the fish must be reduced. Handling the fish should be kept to an absolute minimum. Apart from monthly sampling sessions, the fish have not been handled throughout the production cycle. When holding a fish, a damp towel can be used to protect the outer surface and allow better grip. Fish should be held upright, cupping the sides to prevent the fish escaping. Never handle more than one fish at a time.

For smaller-scale production, manual harvesting is a best practice using a seine net. First, the pond should be drained to half empty, which ensures the process of harvesting is easier. Four people are required to use a seine net. Harvesting should start in the deep end and work towards the shallow end to make access easier, holding the net on the bottom of the pond and slowly moving it along its length. Tilapia will actively burrow and jump over the net to escape; it is therefore essential that movement is slow and precise. Once the net has reached the shallow end the fish should be scooped out of the water using a hand net, then placed in buckets to retain freshness. This process should be repeated at least four times to ensure all fish have been removed.

NB. When using a seine net, a 30% catch should be assumed each time – always seine early in the morning when temperatures are low to reduce stress levels for the fish.

Removal of fish from the ponds

1. Depending on the pond size, approximately 3-4 people should enter the deep end of the pond with the seine net held on the bottom of the pond; holding net with feet to prevent fish swimming under.
2. All should move slowly towards the shallow end.
3. Once at the shallow end, one person on the dike should guide the net towards the other. This will bring the 3-4 people in the pond close together and the seine net will be in the corner of the pond.
4. The fish will try to jump out of the net, so it should be held high to reduce the number of escapees.
5. Others should use dip nets to remove the fish from the seine net and place them in to the 50L buckets.
6. Once all the fish have been removed, the process should be repeated to ensure the pond is emptied.

Business Management: Marketing and Sales

A fish farm must have a business plan; whether the farm will produce fish for the direct community through farmgate sales, a local market, or simply be designed to improve food security within a small community. Deciding on a business plan requires careful market research and a basic understanding of the inputs and outputs required to run a farm operation. In this instance, the farmers and the Imani team will discuss the budget / plan for the production cycle within the study pond.

Prior to harvest, it is important to advertise the fish. This can either be done using word-of-mouth or posters / social media advertising (in some cases). If using posters, it is important to advertise in workplaces where your target buyers are located. It is important to advertise: your name, contact details, basic location information (do not provide all information as this may lead to theft of your fish), cost / kg of fish and the date and time that you plan to harvest.

If fish are to be sold at farmgate, it is important to establish a list of known buyers in advance to reduce wastage (post-harvest losses). Prior to harvesting, buyers must register their demand. Buyers must arrive on time and should make an orderly queue at the farmgate so that they can collect their known quantity of fish. Operating in this way means that the farmer can predict the total sales and plan harvesting accordingly. If the farmer only manages to sell a small portion in advance, it demonstrates the need to secure alternative markets and possibly to stagger harvesting to reduce wastage.

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