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SOCIO-ECONOMIC AND BIOLOGICAL IMPACTS OF THE FISH-BASED FEED INDUSTRY FOR SUB-SAHARAN AFRICA



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4. A feed vendor selling feed ingredients to his customer. Pre-mixing of ingredients is avoided due to cheating, the United Republic of Tanzania. © Yahya Ibrahim Mgawe.

SOCIO-ECONOMIC AND BIOLOGICAL IMPACTS OF THE FISH-BASED FEED INDUSTRY
FOR SUB-SAHARAN AFRICA

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Preparation of this document

This document was prepared by Djiga Thiao, FAO consultant, and Stuart Bunting, Natural Resources Institute of the University of Greenwich. They led and coordinated the study that the document reports on, which was carried out within the framework of the FAO-Norad project “Empowering women in small-scale fisheries for sustainable food systems” and the EAF-Nansen Programme “Supporting the application of the ecosystem approach to fisheries management considering climate and pollution impacts” and the CGIAR Research Program on Fish Agri-Food Systems (FISH) led by WorldFish in close collaboration with the University of Greenwich. The study includes country surveys, and the authors are grateful for the important work done by the national consultants Cheikh-Baye Braham (Mauritania), Sidi Ndaw (Senegal), Ebou Mass Mbye (the Gambia), Thomas Aloysious Lebbie (Sierra Leone), Rebecca Sackey-Mensah (Ghana), Maurice Nkaya (the Congo), Yahya Ibrahim Mgawe (the United Republic of Tanzania), Frezar Trywell Chimaliro (Malawi) and Rhoda Tumwebaze (Uganda).

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Abstract

As populations grow and urbanize, demand also increases for animal-source foods, including farmed livestock and fish, and for feed products that can include fish-derived ingredients. Low- and middle-income countries are increasingly concerned about the fish-derived ingredient and fish-based feed industry, as many of the fish species used for fish-derived ingredients and fish-based feed production are important for communities as a source of livelihoods and food and nutrition security. Improved understanding of the fish-based feed industry, its stakeholders and the associated livelihood activities is timely to determine how these products fit in food systems that are transforming to more equitable and sustainable configurations. With the increase in the number and intensity of demands on these species comes concern for all aspects of sustainability, and trade-offs and opportunities that are experienced by different stakeholders. The objective of this study was to understand the drivers, outcomes and trade-offs of the fish-based feed industry for sub-Saharan Africa, focusing on nine countries (the Congo, the Gambia, Ghana, Malawi, Mauritania, Senegal, Sierra Leone, Uganda and United Republic of Tanzania). The study used various information sources and mixed methods for data collection and analysis, including a desk review of published and unpublished reports and data sets as well as country surveys consisting of background data collection, key informant interviews ($n = 122$) and focus group discussions ($n = 642$) which contributed to a stakeholder Delphi assessment (an iterative process of asking questions to identify preferences and trends amongst stakeholders). The study found that fish-based feeds are mainly exported, offering some economic benefits to governments and fishworkers throughout the value chain. At the same time, however, respondents suggested the industry constitutes a threat to the livelihoods and food and nutrition security of local communities. Looking to the future, stakeholders identified a range of actions that are required to ensure that the fish-based feed industry contributes to equitable social and economic development, nutritional benefits and environmental sustainability. The study prioritized these recommendations for decision-making and future research and these included the establishment of and/or compliance with regulations for environmentally friendly and healthy/safe fish-derived ingredients and fish-based feed production, as well as continued efforts to identify and promote alternative efficient to use feed products that do not rely (or rely less on) fish-based ingredients.

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Acronyms and abbreviations

AGORA	Access to Global Online Research in Agriculture
CECAF	Fishery Committee for the Eastern Central Atlantic
COMAPOPE	Compagnie Mauritano-Portugaise de Pêche
FAO	Food and Agriculture Organization of the United Nations
FBF	fish-based feed
FDI	fish-derived ingredient
ITC	International Trade Centre
LVFO	Lake Victoria Fisheries Organisation
MPEM	Ministère de la Pêche et de l'Économie Maritime
Norad	Norwegian Agency for Development Cooperation
RDM	Recommendation for Decision-Making
RFR	Recommendation for Future Research
SOMIP	Société Mauritanienne d'Investissement et de Pêche
SSF	small-scale fisheries

1. Introduction and general framework of the study

1.1 CONTEXT OF THE STUDY

Demands for foods are evolving with population growth, urbanisation and changing preferences of the growing ‘middle class’. These demands include animal-source foods, notably farmed livestock and fish, that rely on feed products that can include fish-derived ingredients. The use of fish-based ingredients for feeds is creating concern at local, national and international levels (Corten *et al.*, 2017; Avadí *et al.*, 2020; FAO, 2020b) due to potential issues regarding sustainability, nutrition and livelihood trade-offs involved in the sector. This report responds to demands of African nations for more information about what these trade-offs might be, where they are experienced, to what degree and by whom. With this information, private, public and civil society actors are in a better position to make informed governance decisions.

Despite the livestock sector being a large consumer of fish-based feed (FBF), aquaculture has dominated in recent years; increased demand for FBF has led to the growth of the FBF industry globally (Hecht and Jones, 2009; Mullon *et al.*, 2009; Fréon *et al.*, 2014). Since the 1970s, fishmeal and fish oil have increasingly been used in feed for the finfish and shrimp aquaculture sectors and are the main components of fish-derived ingredients (FDI) around the world. Whole fish and fish waste from poor handling, excess fish that remains unsold, and offal and other by-products are used to produce FDI.

Global assessments further demonstrate that food-grade fish represents the major portion of fisheries-derived products used in the FBF industry (Cashion *et al.*, 2017). Small pelagic species are targeted or caught as bycatch for FDI raw materials by specialized vessels in both large- and small-scale fisheries (New and Wijkström, 2002). Although these species are sometimes called low-value fish or “trash fish” (Edwards, Tuan and Allan, 2004), most species used as feed ingredients are in fact socially, nutritionally and economically essential for many local communities in developing countries, especially in Africa (Corten *et al.*, 2017; Avadí *et al.*, 2020). The growing use of small pelagic fish for FBF (Hua *et al.*, 2019) and the potential impacts on food and nutrition security, livelihoods, public health and national economies as well as the sustainability of these fishery resources have become a growing concern in sub-Saharan Africa.

Potential negative impacts of the FBF industry have been discussed at various forums, such as during multiple sessions and working group meetings of the Fishery Committee for the Eastern Central Atlantic (CECAF). At its seventh session in October 2019, the Artisanal Fisheries Working Group of CECAF called for an assessment of the socio-economic impacts of the FBF industry in West Africa. Similarly, the CECAF working group dealing with the assessment of small pelagic fish off Northwest Africa also expressed concern about and an interest in studying further the role of the industry in increased fishing effort on important small pelagic species, many of which are considered overexploited, and other related biological impacts (FAO, 2020b). The issue was also discussed at the inception workshop of the FAO-Norad small-scale fisheries project “Empowering women in small-scale fisheries for sustainable food systems”, held in Ghana in March 2020. The workshop included a discussion on the perceived negative impacts of the FBF industry on women in the post-harvest sector and subsequently on food and nutrition security (FAO, 2020c).

Globally, there is growing demand for FDI and FBF that are rich in protein and essential fatty acids. Consequently, market demand has resulted in a rapid increase in production of

FDI in some countries of sub-Saharan Africa. Historically, in most of the countries, the FBF industry relied essentially on fish processing waste and by-products, as well as on bycatch of fish species that were not locally consumed (Hecht and Jones, 2009; Cashion, 2016). In recent years, owing to increasing demand for FDI, the growing FBF industry has turned to fishery resources that are key for direct human consumption (Cashion, 2016; FAO, 2020b). For instance, in the Gambia, Mauritania and Senegal, fishmeal is now mainly produced from small pelagic fish species, such as bonga (*Ethmalosa fimbriata*), flat sardinella (*Sardinella maderensis*) and round sardinella (*S. aurita*) (Corten *et al.*, 2017). One of the concerns gaining attention is that these species constitute the main source of animal protein, essential micronutrients and fatty acids for millions of people in the region, particularly for people with lower incomes or low purchasing power (Thiao *et al.*, 2018). Therefore, it is important to understand the context and degree to which there are nutritional and societal benefits, opportunities, costs and trade-offs. This study also supports the implementation of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication – or “SSF Guidelines” (FAO, 2015).

1.2 OBJECTIVE

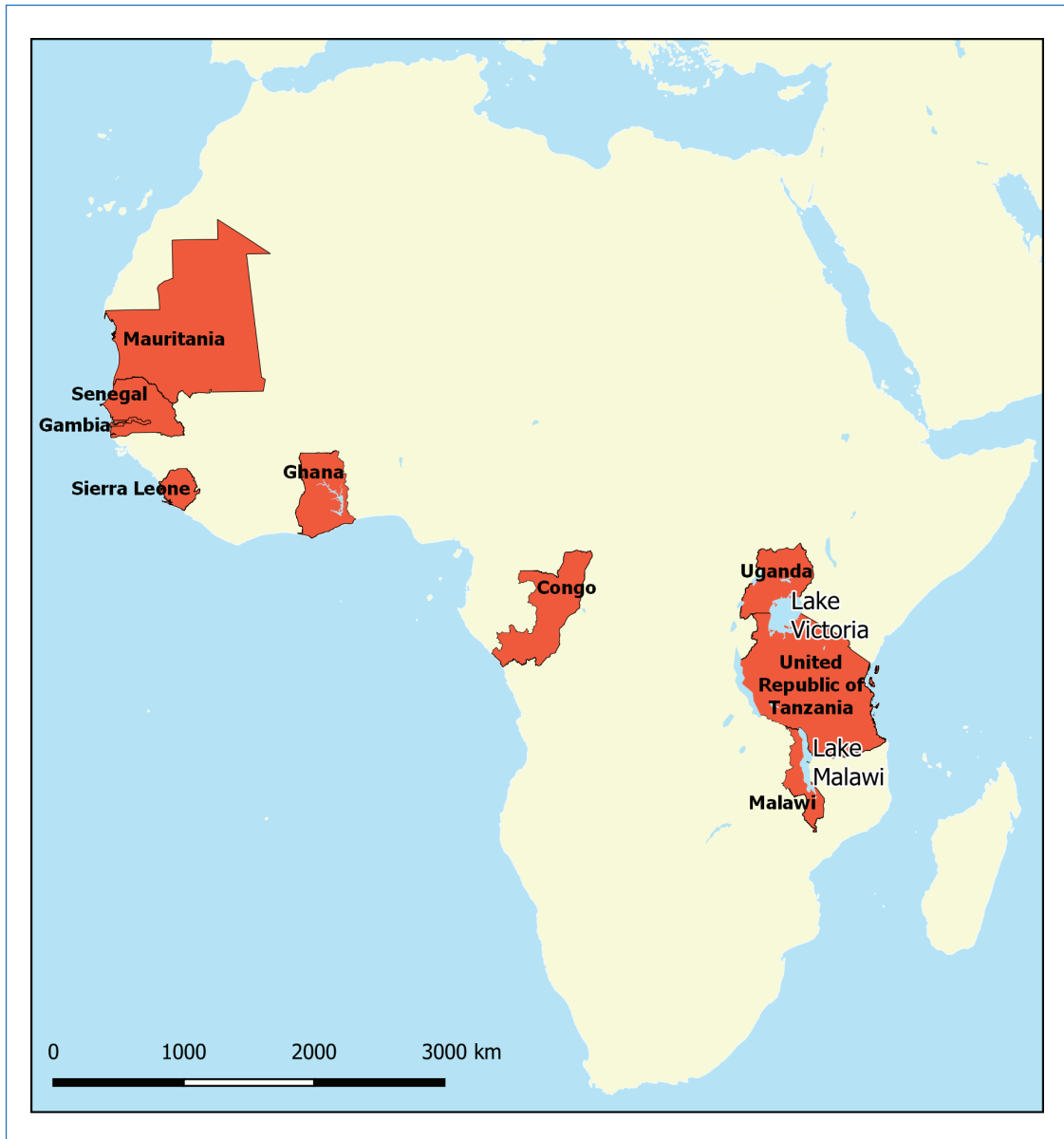
The overall objective of the study was to undertake a preliminary assessment of the observed and potential socio-economic and biological costs, benefits, opportunities and trade-offs of the FBF industry. This study aims to generate evidence to better guide policy- and decision-making, as well as future research, regarding the use of fishery resources as animal feed ingredients, where those resources are sourced from selected coastal and riparian countries in sub-Saharan Africa. The study specifically sought to:

- Provide a global and regional overview of spatio-temporal trends of FDI production;
- Examine the observed and potential impacts of the FBF industry on food and nutrition security and livelihoods;
- Examine the observed and potential impacts of the FBF industry on the status and exploitation of fish stocks, mainly small pelagic species;
- Formulate conclusions and propose recommendations for decision-making and future research concerning the environmental, economic and social sustainability of the FBF industry.

1.3 SCOPE OF THE STUDY

The study included nine countries in sub-Saharan Africa. These countries represented CECAF member states as well as countries participating in the FAO EAF-Nansen Programme and FAO-Norad project “Empowering women in small-scale fisheries for sustainable food systems”. The countries in the study are the Congo, the Gambia, Ghana, Malawi, Mauritania, Senegal, Sierra Leone, Uganda and the United Republic of Tanzania (Figure 1). In the United Republic of Tanzania, part of Lake Victoria and marine waters were included in this study. Whilst this study sought to understand which species were involved in FDI production, the study did set out with a focus on small pelagic species (known to be a focus of the industry), such as bonga (*Ethmalosa fimbriata*) and sardinellas (*Sardinella* spp.) in West and Central Africa, and two small indigenous cyprinid species – dagaa/mukene (*Rastrineobola argentea*) and usipa (*Engraulicypris sardella*) – from the Great Lakes in East Africa (Lake Victoria and Lake Malawi).

FIGURE 1. Map of case study countries, including Lake Victoria and Lake Malawi



Source: UN Geospatial. 2020. BND_A_CTY [Shapefile]. New York, US, United Nations.

Note: The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any Pays, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

2. Methodology

2.1 OVERVIEW OF THE METHODOLOGY

The methodology was based on six main tasks for gathering the documentation, collecting and analysing the data, and formulating recommendations for decision-making and future research (Figure 2).

2.2 DESK REVIEW

We identified peer reviewed journal articles, reports, and grey literature through online search platforms such as Google Search, AGORA (Access to Global Online Research in Agriculture) and ProQuest. Experts from the Food and Agriculture Organization of the United Nations (FAO), WorldFish and other partners identified and provided further published papers, technical reports, as well as administrative and regulatory documents. Relevant national and international on-site and online sources were explored to collect further background data including information held by fisheries administrations, customs authorities, FAO (www.fao.org/figis) and the International Trade Centre (<https://www.trademap.org>).

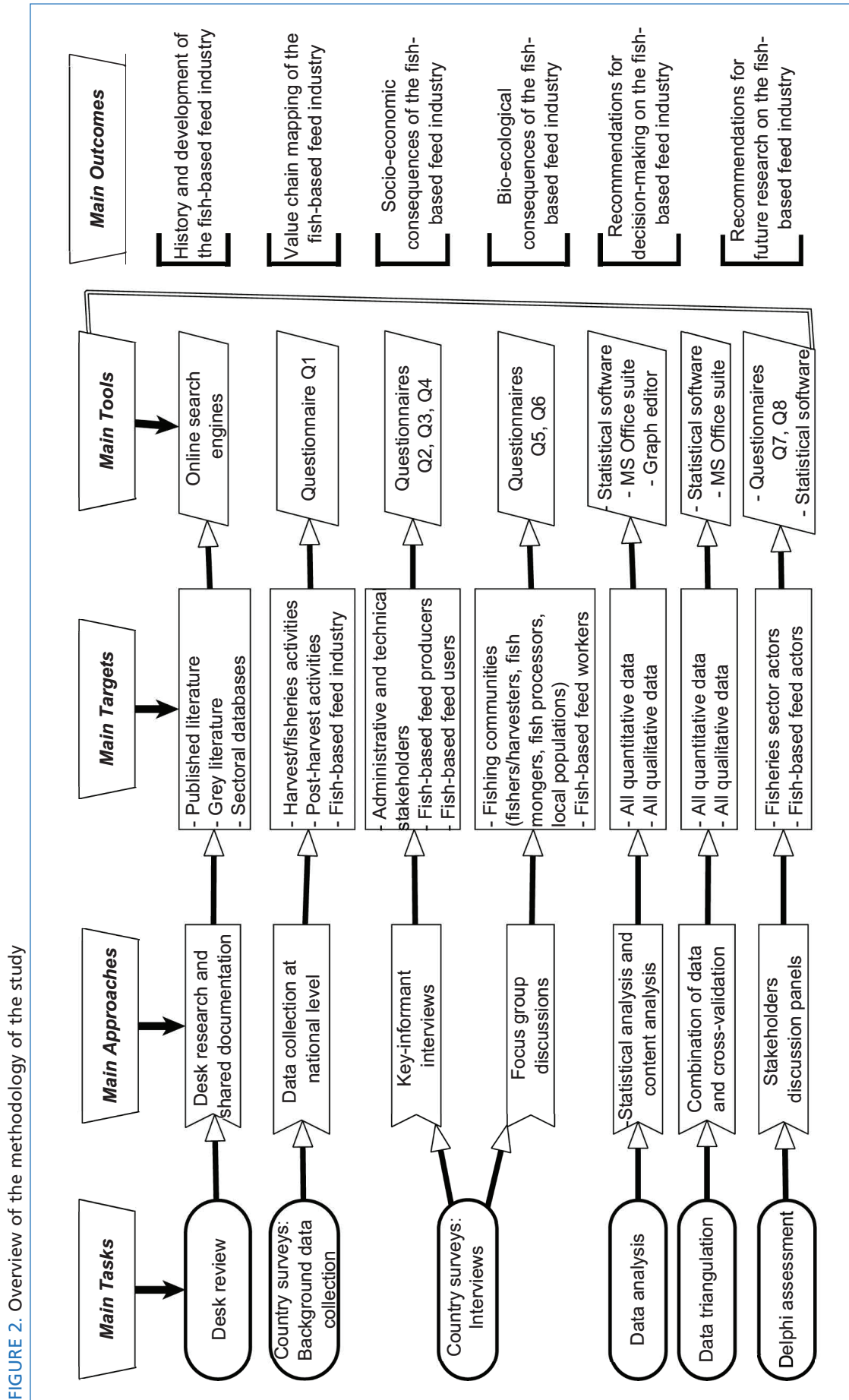
2.3 COUNTRY SURVEYS

In the nine countries national consultants used a standard questionnaire, and entered response data in Google Forms. The work included two parts:

- Collection of background quantitative data on fishing, post-harvest activities and the production and use of FDI and FBF products;
- Collection of qualitative information through stakeholder interviews regarding their perceptions and views on different dimensions of FDI production and the FBF industry in their countries, as well as their suggestions for policy recommendations and future research.

The national background quantitative data collection was focussed on understanding the period 2015–2019. A questionnaire Q1 (see Annex 1) was used to guide data gathering and included information on the following:

- Capacity – corresponding to major infrastructure in place and including characteristics, number and trends that provide an idea about the production potential. The focus was on understanding capacity of factories producing fishmeal and fish oil as FDI. However, where information was available, local milling companies and artisanal workshops involved in the manufacture of FBF (e.g. by mixing FDI with other ingredients) were also included. In addition, in cases where there were industrial and/or artisanal fishing fleets dedicated to the supply of catches as raw material, the fleet size was indicated;
- Production – focusing on the production volumes of FDI, mainly fishmeal and fish oil, as quantitative data on manufactured FBF by milling companies and local farmers are not generally available to the public;
- Destination of exports – assessing the relative importance (based on volumes and values of exports) of countries importing fishmeal in terms of market shares;
- Other value chain information like the types and characteristics of the stakeholders – contributing to the mapping of the FBF industry.



A wide range of stakeholders took part in the interviews (women: n = 234; men: n = 530). Respondents either worked in fisheries administrations, research institutions and fishing communities or as FDI and FBF producers and users. Stakeholders outside the fisheries and FBF sectors who were concerned with livelihoods, food and nutrition security, health, and the environment were also interviewed. Depending on the type of stakeholder and issues addressed, two types of interviews were carried out: key informant interviews (KIIs) and focus group discussions (FGDs) (Table 1). Participants for KIIs and FGDs were purposively identified and selected by national consultants based on their interest and/or apparent knowledge of the FBF industry. Hence, stakeholders had a vested interest in the current and future utilization of small pelagic fish species (e.g. fishers, processors, formal or informal fish traders, industry representatives, community-based groups, consumers, decision-makers, policy-makers, researchers and non-governmental organizations and nonstate actors).

- Key informant interviews covered stakeholders working in administration and in technical institutions (n = 45), as well as FDI and FBF producers (n = 39) and users (n = 38). Three customized questionnaires were designed: Q2 for administrative and technical stakeholders (Annex 2); Q3 for FDI and FBF producers (Annex 3); and Q4 for FDI and FBF users (Annex 4). Interviews were conducted through face-to-face interviews, phone calls and/or emails depending on the prevailing circumstances during the COVID-19 pandemic when restrictions for in-person meetings were commonly in place;
- Focus group discussions were conducted with 193 women and 362 men from fishing communities, including fishers/harvesters, fishmongers and fish processors, using questionnaire Q5 (Annex 5); and permanent and temporary employees (23 women and 64 men) working in the FBF industry applied questionnaire Q6 (Annex 6). Each focus group discussion included up to ten people and was facilitated by national consultants.

TABLE 1. Sample size for interviews by country and gender

Country	Sample size for KII			Sample size for FGD			Total sample size for KII and FGD		
	Women	Men	Total	Women	Men	Total	Women	Men	Total
Congo	1	7	8	12	23	35	13	30	43
Gambia	2	15	17	33	20	53	35	35	70
Ghana	1	15	16	21	19	40	22	34	56
Uganda	5	18	23	16	42	58	21	60	81
Malawi	3	9	12	27	38	65	30	47	77
Mauritania	1	22	23	1	57	58	2	79	81
Senegal	3	13	16	57	137	194	60	150	210
Sierra Leone	2	5	7	36	45	81	38	50	88
United Republic of Tanzania	0	0	0	13	45	58	13	45	58
Total	18	104	122	216	426	642	234	530	764

Notes: FGD = focus group discussion; KII = key informant interview.

2.4 ANALYSIS OF DESK REVIEW AND COUNTRY SURVEY DATA

The quantitative data from the desk review and the country surveys were analysed and plotted to understand spatio-temporal trends in FDI production and the FBF industry. Combined with qualitative information from stakeholder interviews, value chain mapping, inspired by the FISH4ACP method (FAO, 2020d), was used to develop flowcharts that depict value chain functions and the actors and linkages between them, from the supply of raw materials to the final use of FBF products.¹ The results of this analysis are presented in

¹ Value chain mapping is a good first step but detailed and systematic value chain analysis could usefully be undertaken to better understand the configuration of the complex arrangements in specific countries and to analyse who gains the most and where they are located, opportunities to maximise economic returns and animal and human nutritional outcomes and promote feed and food safety and resilience to external shocks.

Section 3 (Overview of the global FDI production sector) and Section 4 (Development and status of the FBF industry in sub-Saharan Africa). More detailed information on each country is provided in Section 9 (Detailed analyses by selected country).

The desk reviews and country survey data were also analysed to describe the likely socio-economic and biological impacts of FDI production and the FBF industry in sub-Saharan Africa. To compare the qualitative responses provided in the key informant interviews and focus group discussions, results were triangulated to look for similarities and coherence amongst different perspective and data types. These results are provided in Section 5 (Socio-economic impacts of the FBF industry in sub-Saharan Africa) and Section 6 (Biological impacts of the FBF industry on fishery resources). See Section 9 (Detailed analyses by selected country) for more information on each country.

Together with the suggestions provided by stakeholders in the country surveys, the above analyses also provided the preliminary recommendations that formed the basis for the stakeholder Delphi assessment (presented in the subsequent section).

2.5 STAKEHOLDER DELPHI ASSESSMENT THROUGH REPRESENTATIVE PANELS

A Delphi assessment is a technique used to generate opinion and/or consensus about a particular topic or policy issue over a series of iterative rounds of rating statements (which were determined from country surveys). The participants (panel members) in the stakeholder Delphi assessment (see Box 1) were those individuals that national consultants had identified to participate in country surveys which ensured representation across a range of roles and interests associated with the FBF sector (the United Republic of Tanzania was excluded due to logistical issues). Contrary to the “classical Delphi” approach where only subject-matter experts are involved as panel members, a “stakeholder Delphi” assessment strategy was adopted to include a broader range of perspectives including technical officers, women and men from fishing communities, and FDI and FBF producers and users. In this way, the stakeholder Delphi assessment facilitated the interactive participation of different groups of actors whose knowledge and opinions are critical to understanding and contextualizing the recommendations.²

Two rounds were conducted using questionnaires Q7 and Q8 (see Annexes 7 and 8). The number of rounds was limited to two due to practical considerations. The desk review and country surveys had facilitated the identification of preliminary recommendations that were used as a starting point. Between 11 to 36 participants from each country contributed to Round 1 (Table 2) and the total number of participants across all countries reached 150 individuals, which fulfilled the requirement for general statistical significance (Bunting, 2008). Of the 150 original panel members in Round 1, 106 went on to respond in Round 2, equating to a retention rate of 71 percent and indicating that participants were engaged with, and committed to, the process and its anticipated outcomes. To maintain good levels of representation in Round 2, it was decided to permit the inclusion of nine replacement stakeholders who had been invited to participate in Round 1 but could not do so then owing to various circumstances. Therefore, a total of 115 responses were received during Round 2 (Table 2).

Fifteen recommendations for decision-makers and six for future research had been derived from the desk review and country surveys. These were used for the rating exercise in the Round 1.

² To ensure the study adopted an ethical approach to engaging with participants and managing their data, approval (UREC application 19.5.5.9) was granted for the study protocol from the University Research Ethics Committee of the University of Greenwich.

Box 1. Stakeholder Delphi assessment

A Delphi assessment is a process of engaging a “panel” of participants in an anonymous process to express their views without knowing the replies of the other panelists. The technique is used to generate opinion and/or consensus about a particular topic or policy issue over a series of iterative rounds, usually two to three. The assessment strives to assign equal weight to all points of view and is particularly appropriate when decision-making is required in a politically sensitive environment, and when the decisions can affect strong factions with opposing agendas and objectives (Bunting, 2008; Bunting, 2010; Lund *et al.*, 2014). Such a context characterizes the fish-derived ingredient production and fish-based feed industry, which is a politically and socio-economically sensitive issue in sub-Saharan Africa.

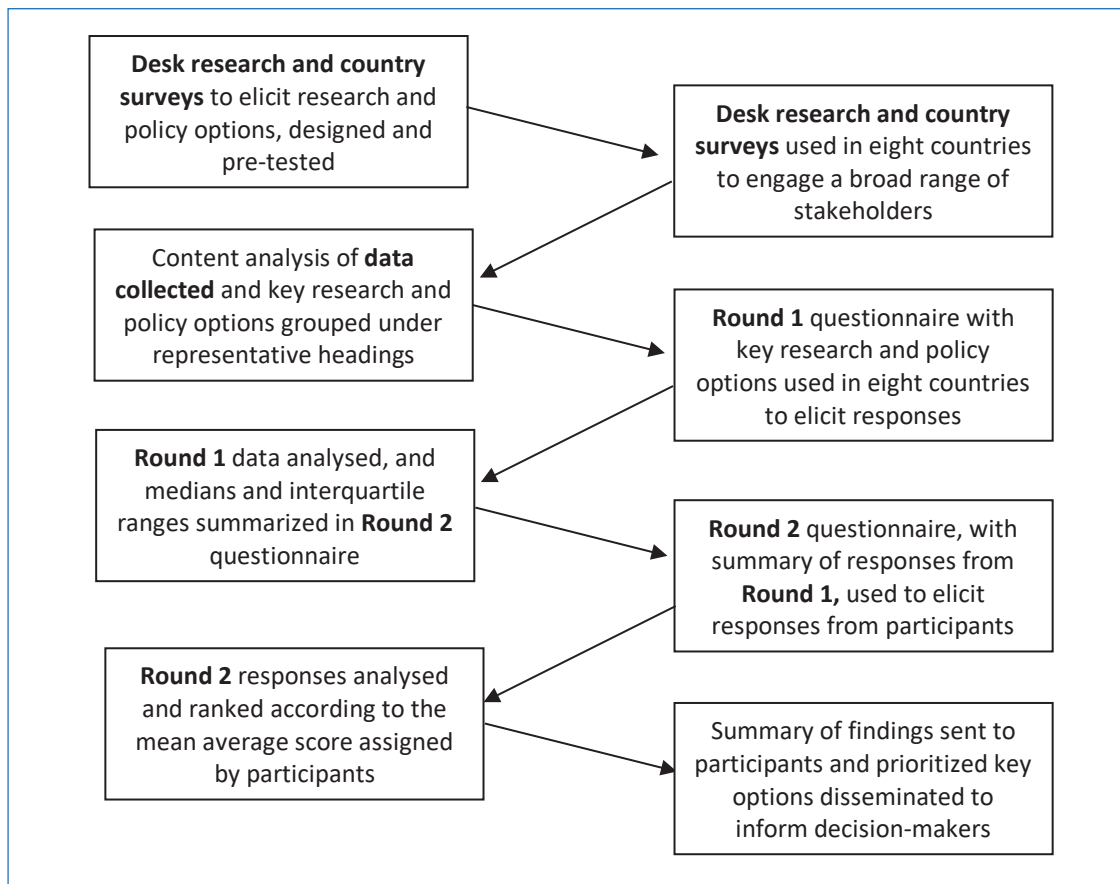
TABLE 2. Number of participants in the stakeholder Delphi assessment

Country	Round 1	Round 2
Mauritania	36	15
Senegal	15	15
Gambia	11	13
Sierra Leone	12	12
Ghana	17	17
Congo	25	25
Malawi	16	10
Uganda	16	6
Regional organizations	2	2
Total	150	115

Accordingly, stakeholders participating in the Delphi assessment ($n = 150$) were asked to rate the importance of each of the recommendations on a scale of 1 to 10, where 1 referred to a low level of importance and 10 corresponded to a high level of importance. The median (middle ratings) and interquartile range (25 percent and 75 percent) from the responses received were calculated and used to prepare the Round 2 questionnaire. In Round 2, participants ($n = 115$) were requested to either agree with the median value for each recommendation calculated from Round 1 or suggest an alternative rating. When this lay outside the interquartile range, participants were asked to provide a brief explanation to contextualize their response. Based on responses from Round 1 and Round 2, qualitative statistical analysis tested the strength of agreement among participants (Caffey, 1998). Patterns in ratings assigned by participants were assessed using Friedman’s test, and the strength of agreement was evaluated using Kendall’s coefficient of concordance (W) (Friedman, 1937; Schmidt, 1997).

The stakeholder Delphi assessment process is depicted in Figure 3. The assessment results are provided with the recommendations in Section 8. These include ten policy recommendations and five research recommendations, including those receiving a mean rating of at least 8 out of 10 at the end of Round 2.

FIGURE 3. Schematic for steps in the stakeholder Delphi assessment



3. Overview of the global fish-derived ingredient production sector

3.1 DEVELOPMENT OF THE GLOBAL FISH-DERIVED INGREDIENT MARKET

Recognition of the potential of FBF for animal protein and lipid sources (particularly essential fatty acids) as key advantages in both swine and poultry feeding has a long history. At the beginning of the 1880s, farmers became aware of these nutritional qualities of FBF as infrastructure, logistics and technology developed for the swine and poultry industries (Denton *et al.*, 2005). The use of fishmeal and fish oil as FDI in swine and poultry feeds was recorded a century ago (Ashbrook, 1917). Based on the International Fishmeal and Fish oil Organisation data (Auchterlonie, 2017), at least 98 percent of fishmeal and fish oil produced was directed to pig and poultry feeding before the 1980s. Rapid growth of the aquaculture sector has resulted in it being the top consumer of FBF. Therefore, in recent years, about 75 percent of global fishmeal and fish oil production has been used for aquaculture (Auchterlonie, 2017).

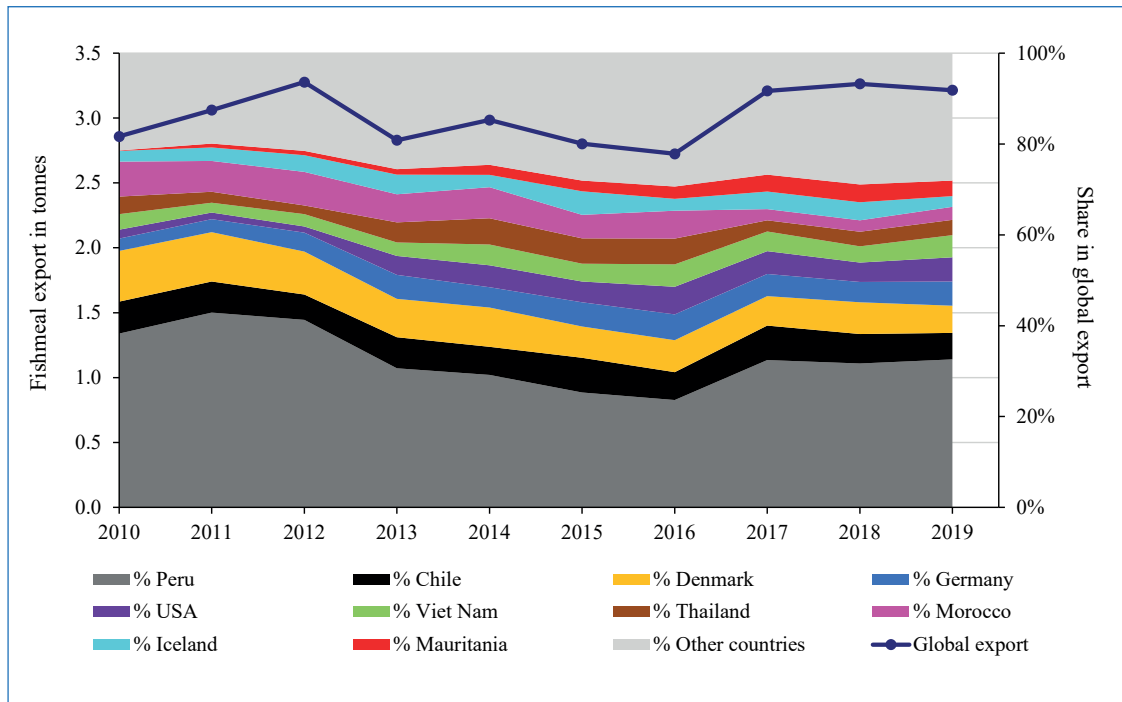
This important change in market demand has had considerable impacts on recent trends in FDI production, with potential to extend into the future. While the annual production of FDI has generally decreased since the 1990s, recently stabilizing around 5 million tonnes for fishmeal and 1 million tonnes for fish oil (Auchterlonie, 2017), demand is projected to increase in the coming decade. In 1995 over 30 million tonnes of fish catch was directed into FDI production, whereas this had declined to less than 14 million tonnes in 2014 owing to the decreased catch in Peru. Recently, 12 percent of global fish production (i.e. 22 million tonnes of catch) was used for non-food purposes, of which 82 percent was processed into fishmeal and fish oil (FAO, 2020a). According to FAO, to sustain the future demand, the production of FDI will mainly be dependent upon whole fish, while the use of fish by-products will hardly exceed 1 million tonnes per year despite its increasing share in total raw materials used for fishmeal and fish oil production.

3.2 TRADE IN FISH-DERIVED INGREDIENTS

According to the ITC trade statistics for international business development (<https://www.trademap.org>), global fishmeal exports averaged 3 million tonnes per year between 2010 and 2019 (Figure 4). During this period, the top ten countries that largely dominated the fishmeal export market accounted for an average of 75 percent of the total exported quantities. Peru has always been the leading exporter with an average of 33 percent of global exports, corresponding to almost 1 million tonnes per year. Ranked seventh and tenth, Morocco and Mauritania were the only two African countries among the top ten world fishmeal exporters, with about 113 000 and 66 100 tonnes per year, respectively, during the period 2010–2019.

Based on ITC data (<https://www.trademap.org>) in addition to fishmeal, fish oil is another major FDI marketed worldwide, with total exports ranging from a minimum of 0.7 million in 2013 to a peak of 1 million tonnes in 2019. The export market has also been dominated by Peru during the past decade with, on average, 18 percent of global exports. Mauritania, which has consistently been the tenth highest fish oil exporter, has had a considerable change over the decade with its exports increasing by a scale factor of 23 over a ten-year period to more than 15 000 tonnes in 2019.

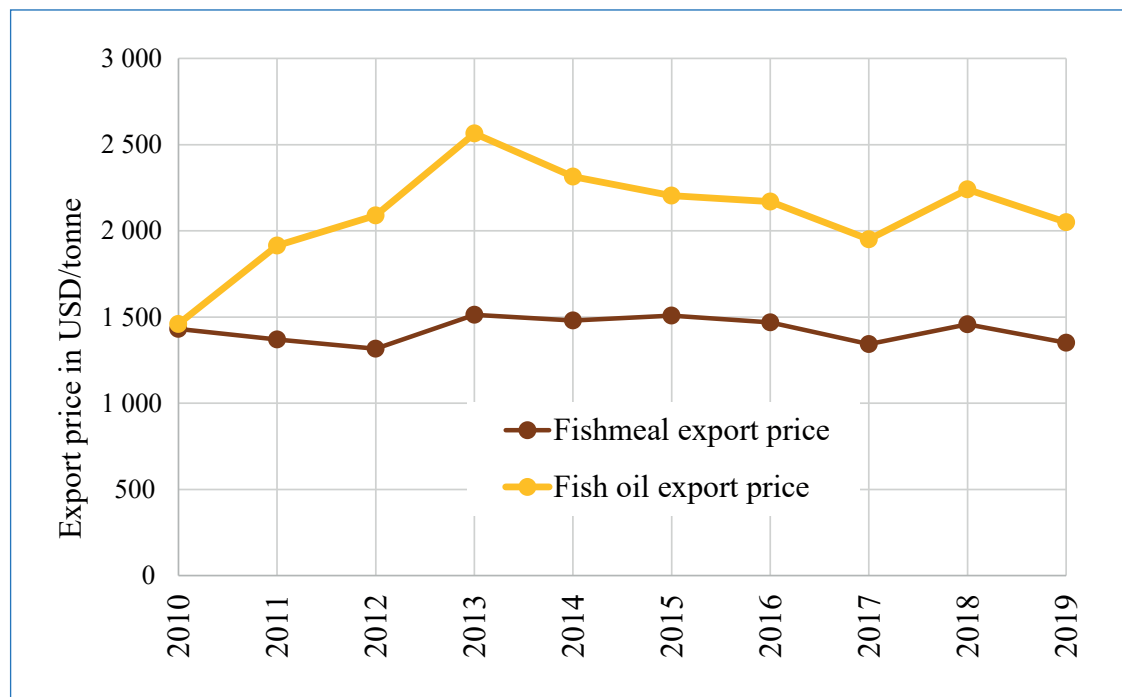
FIGURE 4. Total annual global fishmeal export and market share of the top ten exporters



Source: Data are extracted from <https://www.trademap.org>

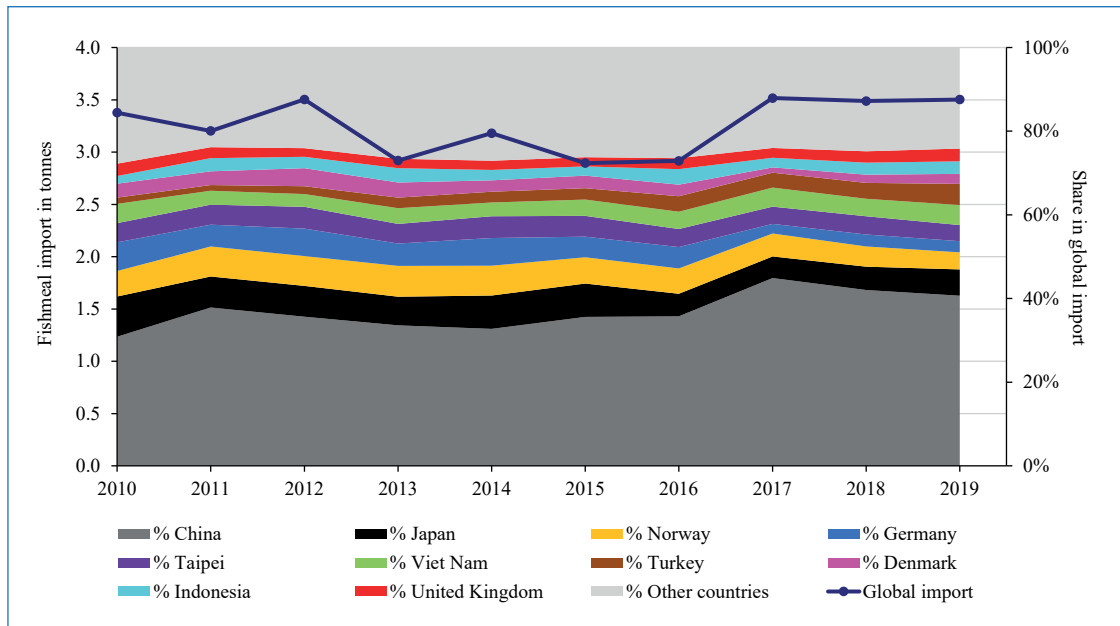
During the decade 2010–2019, the average fishmeal export price per tonne was relatively stable, at around USD 1 400 (Figure 5). This level is high compared to the price in 2001, which was only USD 480 (ITC data, <https://www.trademap.org>). Regarding fish oil, the export price increased from USD 1 460 per tonne in 2010 to just over USD 2 000 in 2019 but with some fluctuations along the way.

FIGURE 5. Average fishmeal and fish oil global export prices in the past decade



Source: Data are extracted from <https://www.trademap.org>

FIGURE 6. Total annual global fishmeal import and market share of the top ten importers



Source: Data are extracted from <https://www.trademap.org>

China has dominated global fishmeal imports in recent decades (Figure 6). During the period 2010–2019, Chinese imports reached an average of 37 percent of global imports (1.2 million tonnes per year) which peaked in 2017 at 1.6 million tonnes which at that time constituted almost 45 percent of the global market. None of the other top importing countries such as Japan, Norway and Germany imported more than 7 percent of the total global imports. No African countries were among the top ten fishmeal importers.

According to the ITC data (<https://www.trademap.org>), with about 20 percent of global imports, Norway has been the leading fish oil importer on the global market. Over the period 2010–2019, Norway imported about 200 000 tonnes of fish oil per year. This was followed by Denmark, whose total imports of fish oil hovered around 100 000 tonnes per year, corresponding to 11 percent of global fish oil imports. In recent years, these two countries have had relatively stable market shares. Among the top ten importers, Turkey and Singapore recorded more dynamic trade, with market shares that were negligible in the early 2010s but reaching at least 6 percent in 2019.

3.3 PROGRESS AND CHALLENGES FOR ALTERNATIVES TO FISH-DERIVED INGREDIENT

In general, the search for alternative raw materials for feed ingredients to replace fish is focussed on other aquatic and terrestrial fauna and flora. Under consideration, for example, are the underutilized stocks of marine zooplankton, such as Antarctic krill and copepods and freshwater shrimp (Kubiriza *et al.*, 2018; FAO, 2020a), as well as abundant small wild animals like earthworms, insects, maggots and snails (Tacon and Metian, 2008). Insect meals from farmed insects hold a great deal of promise (Hua *et al.*, 2019). Research since the early 1980s has demonstrated the potential of by-product proteins made from poultry byproducts, such as feathers, blood, meat and bones (Tacon *et al.*, 1983; New, Tacon and Csavas, 1994; Ogello *et al.*, 2014). Regarding plant alternatives, agro-processing waste, *Azolla pinnata*, duckweed, microalgae, microbial biomass, soybean and spirulina have been tested as fishmeal alternatives (El-Sayed, 1999; El-Sayed, Moyano and Martinez, 2000; Takeuchi *et al.*, 2002; Hua *et al.*, 2019; Atkins *et al.*, 2020).

Most of the alternative ingredients have been tested in aquafeeds, for example in the feeding of farmed tilapia and shrimp (Dominy and Ako, 1988; Kellems and Church, 1998; El-Sayed and Tacon, 1997; Ogello *et al.*, 2014). These ingredients have demonstrated significant economic advantages in terms of affordability (Poppi *et al.*, 2011; Dominy and Ako, 1988). However, there are challenges and technical constraints in production processes and in relation to bioavailability of nutrients in feeds, which, for example, mean that there is still low performance when dependent solely on nutrients from plant-source ingredients (Tacon and Jackson, 1985; Hardy, 1996; El-Sayed, 1999; Francis, Makkar and Becker, 2001; Munguti *et al.*, 2014). Alternative animal-source ingredients, such as meat and bones, have been restricted in aquaculture and animal feeds due to a fear of interspecific disease transfer (EU, 2009) and because of potential competition with human meat consumption (Ogello *et al.*, 2014).

In sub-Saharan Africa, locally made alternatives that could be used instead of FBF products are not always available or are too costly (see the discussion below in sub-Section 4.2). Some of the ingredients used are ants, cassava flour, cottonseed, groundnut cakes, maize, rice, soybean, termites and wheat brans, but in Africa many of these are exported. Hence, the search for alternative ingredients by farmers in sub-Saharan Africa is motivated more by high costs and low availability of FBF products, rather than (at this stage) a want to reduce or eradicate FDI production.

4. Development and status of the fish-based feed industry in sub-Saharan Africa

4.1 FISH-DERIVED INGREDIENT AND FISH-BASED FEED CAPACITY AND PRODUCTION

Substantial variation is apparent in FBF and FDI capacity and production across the nine sub-Saharan African countries (see Table 3 for details)³:

- Mauritania has, by far, the largest production capacity, and, as noted above, is among the top ten exporting countries globally (Figure 6). The FDI factories, which are mostly located in the northern coastal city of Nouadhibou, increased from five in 2010 to 35 in 2019. Based on visits to 13 factories, the average daily processing capacity was estimated at 611.5 tonnes per facility in 2019. Fishmeal production increased from 23 131 tonnes in 2010 to 99 491 tonnes in 2019. Fish oil production amounted to 32 019 tonnes in 2019. Sardinellas and bonga are used as raw materials and there are dedicated fishing fleets supplying factories;
- Senegal has a large production capacity, with FDI factories increasing from five in 2015 to eight in 2019. The maximum processing capacity varies from 150 to 300 tonnes per factory per day. In addition, some small artisanal fishmeal workshops were identified during field visits. There are also some feed mills that manufacture FBF by mixing locally produced FDI with other ingredients. The total fishmeal production is estimated to be around 12 000 tonnes per year. Regarding fish oil, production did not start significantly until 2013 and reached around 2 502 tonnes in 2015. Then it strongly fluctuated in recent years and peaked at 3 468 tonnes in 2019. In addition to sardinella and bonga, by-products from local canneries are used as raw materials;
- In the United Republic of Tanzania, ten fishmeal and fish oil factories and/or milling companies producing FBF were identified. The total cumulative capacity was estimated at about 4 635 tonnes of FDI and FBF per year. However, in 2019, only 323 tonnes were produced by these ten registered companies. In addition, there are some small-scale fish farmers who produce their own FBF using small machines with production capacity ranging between 400 and 1 000 kg per day. The FDI raw material consists mainly of catches of silver cyprinid (mukene/dagaa), but processing by-products of Lake Victoria Nile perch are also used;
- Uganda had only two feed mills in 2015, with the number increasing to 12 in 2019. The average capacity of each of these milling companies is estimated at about 5 tonnes per week. There are also tens of artisanal fishmeal producers supplying small artisanal millers that produce for local fish and livestock farmers. Silver cyprinid (mukene/dagaa) are mainly used as raw material, but quantitative data on FDI production are not available.

Among the other countries in the study, the Congo, the Gambia and Ghana have more limited production capacity, including some FDI factories as well as feed mills, but production data are scarce. The Congo has dedicated fishing fleets to capture essentially small pelagic fish for fishmeal and fish oil production. Currently, Malawi and Sierra Leone do not host any established fishmeal and fish oil factories apart from two medium-scale milling companies that are locally producing feed for poultry farmers. However, it is noteworthy that likely considerable, but unassessed, quantities of small pelagic species are fished in Sierra Leone and transported to neighbouring Guinea⁴ to sell mainly to small and medium-sized poultry feed producers.

³ Production volumes of manufactured FBF were not available. So we focussed on FDI.

⁴ Guinea was not included in the study. Therefore, the characteristics of the FDI industry in this country have not been analysed.

TABLE 3. Key characteristics of the fish-based feed industry

Country	Capacity	Production
Mauritania	<p>Number of fishmeal and fish oil factories increased from 5 factories in 2010 to 37 in 2017 before slightly decreasing to 35 in 2019.</p> <p>Average daily processing capacity estimated at 611.5 tonnes per factory in 2019.</p> <p>Dedicated fishing fleet: from 300 artisanal canoes in 2016 to 204 in 2019; and 77 industrial fishing vessels in 2019 after a peak of 87 vessels in 2017.</p>	<p>Fishmeal: from 23 131 tonnes in 2010 to a peak of 127 940 tonnes in 2018 following a strong increasing trend.</p> <p>Fish oil: from 2 937 tonnes in 2010 to a peak of 40 045 tonnes in 2018 following a strong increasing trend.</p> <p>Raw material: essentially catches of round and flat sardinellas and bonga.</p>
Senegal	<p>Number of fishmeal and fish oil factories increased from five in 2015 to eight in 2019.</p> <p>Maximum daily processing capacity varying from 150 to 300 tonnes per factory.</p> <p>Five artisanal fishmeal production units and some small workshops, as well as some feed mills of different sizes.</p>	<p>Fishmeal: from about 4 000 tonnes/year in the early 2000s to a peak of about 18 000 tonnes in 2014, and then stabilizing at around 12 000 tonnes/year in recent years.</p> <p>Fish oil: from about 400 tonnes in 2007 to a peak of 3 468 tonnes in 2019 with strong fluctuations in recent years.</p> <p>Raw material: mainly catches of round and flat sardinellas and bonga but also including a few byproducts from local canneries.</p>
Gambia	<p>Three fishmeal and fish oil factories of medium capacity are operating.</p>	<p>Fishmeal: from 1 555 tonnes in 2017 to 1 969 tonnes in 2018, then a strong decrease in 2019.</p> <p>Fish oil: a decrease from 1 378 tonnes in 2017 to 823 tonnes in 2018.</p> <p>Raw material: essentially catches of round and flat sardinellas and bonga.</p>
Sierra Leone	<p>Two medium-scale feed milling companies.</p>	<p>No significant production apart from two milling companies that are using wastes of fish, oyster and shells to produce feed for poultry farmers.</p> <p>However, considerable unassessed quantities of small pelagic fish species are fished and sold to poultry feed producers in neighbouring Guinea.</p>
Ghana	<p>Two fishmeal and fish oil factories, and several artisanal fishmeal producers.</p> <p>Fourteen feed milling companies.</p>	<p>No quantitative data exist on FDI and FBF production.</p> <p>However, most of the factories produce FDI from processing wastes and by-products from tuna, herring, anchovy and mackerel.</p>
Congo	<p>One fishmeal and fish oil factory established in 2017, with eight production lines, each equipped with a tank of 30 tonnes for fresh fish.</p> <p>Dedicated fishing fleet: from 10 in 2017 to 37 industrial vessels in 2019.</p>	<p>From 25 December 2017 to 20 November 2018: 7 409 tonnes of fishmeal and 1 796 tonnes fish oil.</p> <p>In 2019, the production (likely underestimated) was 4 746 tonnes of fishmeal and 500 tonnes of fish oil.</p> <p>Raw material: essentially catches of sardinellas.</p>
Malawi	<p>Two minor feed milling companies with a processing capacity of 2 tonnes per day.</p>	<p>No significant production apart from two milling companies that are using wastes of usipa (<i>Engraulicypris sardella</i>) to produce feed for local farmers.</p> <p>In addition, the National Aquaculture Centre was able to produce 61.9 tonnes of FBF in 2019.</p>
United Republic of Tanzania	<p>Ten fishmeal and fish oil factories and/or milling companies with a cumulative capacity of about 4 635 tonnes per year.</p> <p>Some small-scale fishmeal producers using small machines whose production capacity varies between 400 and 1 000 kg per day.</p>	<p>In 2019, officially registered milling companies produced 323 tonnes of FBF.</p> <p>Raw material: mainly catches of silver cyprinid (mukene/dagaa) but also by-products of Lake Victoria Nile perch.</p>
Uganda	<p>Tens of artisanal fishmeal producers as well as several artisanal millers.</p> <p>From 2 in 2015 to 12 milling companies in 2019, with processing capacity of about 5 tonnes/week.</p>	<p>No quantitative data exist on FDI and FBF production.</p> <p>Raw material: essentially catches of silver cyprinid (mukene/dagaa).</p>

Source: Study desk review and country surveys.

4.2 DESTINATION OF FISH-DERIVED INGREDIENT EXPORTED FROM SUB-SAHARAN AFRICA

Considering fishmeal which is by far the main FDI exported from sub-Saharan Africa, the countries of China, Turkey and Viet Nam are currently key markets for production deriving from Mauritania, Senegal, the Congo and the Gambia (Table 4). The Russian Federation used to be an important fishmeal destination for Mauritanian production, but exports to the country have declined during the past decade. The United Republic of Tanzania exports FDI to Kenya.

Regarding fish oil exported from sub-Saharan Africa, according to the ITC data (<https://www.trademap.org>), there is a variety of destinations (Table 4). However, European countries such as France, Denmark, Norway, Spain and Turkey are generally the major markets, more especially for Mauritania, Senegal and Ghana. Depending on the country, there are also some particular clients such as Chile, Australia and China that are respectively the main fish oil buyers for Gambia, Ghana and Congo. For Sierra Leone, Malawi, the United Republic of Tanzania and Uganda, no fish oil export was reported in recent years.

TABLE 4. Destination of fishmeal and fish oil exported from sub-Saharan Africa

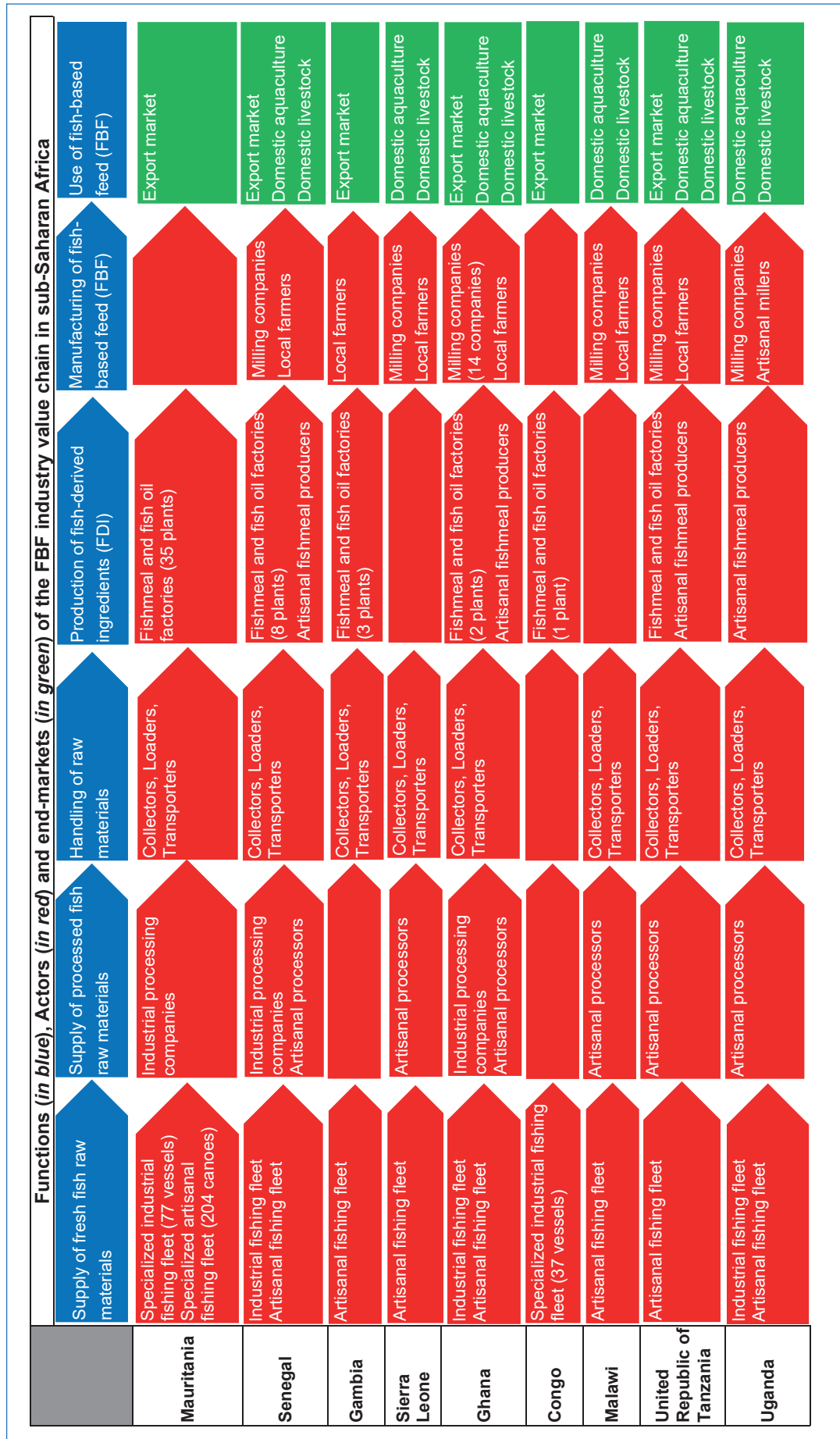
Country	Destination of fishmeal	Destination of fish oil
Mauritania	The Russian Federation was the major importer in the early 2010s with up to 61 percent of market share in 2011. China and Turkey are the major importers in recent years with, respectively, 46 percent and 21 percent of market share in 2019.	Mauritania has various fish oil importers but France was the major destination in 2019 with 15 101 tonnes (44 percent of total export). The other major clients were Denmark (17 percent), Norway (11 percent) and Turkey (11 percent).
Senegal	Cameroon was a major importer in the early 2010s with up to 57 percent of market share in 2012. Viet Nam and Turkey were major importers in recent years with respective market shares reaching 36 percent in 2019 and 26 percent in 2018.	In 2019, Denmark imported 528 tonnes from Senegal (60 percent of total fish oil export). It was followed by Spain with 216 tonnes (25 percent of total fish oil export).
Gambia	China has always been the only importer of the entire production.	In 2019, 4 909 tonnes were destined to Chile, corresponding to 83 percent of the total Gambian fish oil export.
Sierra Leone	No substantial production that may be exported.	No reported fish oil export.
Ghana	Very few fishmeal exports recorded in the early 2010s, but most of the production is now sold in the domestic market.	In 2019, Australia was the main client with 203 tonnes corresponding to 61 percent of total export. It was followed by France (39 percent).
Congo	China has always been the only importer of the entire production.	In 2019, China alone was the destination of all the reported fish oil export (500 tonnes).
Malawi	No substantial production that may be exported.	No reported fish oil export.
United Republic of Tanzania	Kenya has always been the major importer over the past decade. Since 2016, all fishmeal exports are destined to Kenya.	No reported fish oil export in recent years. But among the 18 exported in 2014, 15 were destined to the Democratic Republic of Congo.
Uganda	All the production is sold in the domestic market.	No reported fish oil export.

Source: Desk review, ITC data and country surveys.

4.3 VALUE CHAIN MAPPING OF THE FISH-BASED FEED INDUSTRY

The number and types of functions and actors occurring and interacting along the FBF value chain vary from one country to another (Figure 7). In general, six functions have been identified in all the value chains: supply of fresh fish as raw material; supply of processed fish (wastes/remnants or byproducts) as raw material; handling of raw material; production of FDI (fishmeal and fish oil); manufacturing of FBF (mixing of FDI with other ingredients); and use of FBF corresponding to the final markets. However, in some countries, such as the Congo, some functions do not exist. In countries such as Senegal and Uganda, there are more functions and actors involved, making their value chains relatively complex. For the most part, while the FDI produced are mainly and sometimes entirely devoted to the export market, in other countries such as Malawi and Sierra Leone, the domestic aquaculture and livestock sectors are the end markets of the value chain.

FIGURE 7. Value chain map of the fish-based feed industry in sub-Saharan Africa



5. Socio-economic impacts of the fish-based feed industry in sub-Saharan Africa

5.1 IMPACTS ON EMPLOYMENT AND LIVELIHOODS OF LOCAL COMMUNITIES

The FBF industry creates jobs in factories and milling companies in most of the countries in this study (Table 5). For instance, in Mauritania, in 2019, there were 1 972 FBF factory workers, and in Senegal, in 2018, there were 129 permanent factory workers and 264 temporary factory workers. It has been estimated that there are also thousands of indirect jobs, such as selling or repairing canoes, nets and other materials, as well as processing activities (drying fish) and supplying raw materials (including processing by-products) to the FBF industry. Moreover, the country surveys indicated that fishers are generally able to sell an increased volume of catch at higher prices to the industry than their more traditional buyers (local fishmongers and consumers), thus increasing their income.

However, many of the jobs created are uncertain or temporary and do not always provide employment to people in the local area. For example, respondents explained that while there are workers in the FBF industry in Senegal from the local population, employees in this industry in Mauritania are mainly foreigners from China and Senegal. In Mauritania, 74 percent of the positions are permanent. In the Gambia, local workers are employed in lower grade jobs, whereas higher grade or qualified positions are generally held by foreigners. In the Congo, only 30 percent of the workers come from local communities and 82 percent of them are temporarily employed.

Respondents reported that the FBF industry seemed to be in competition for fish and raw materials with the artisanal fishing and post-harvest sectors. Not enough data exist to quantitatively evaluate the net effect on local employment. However, country surveys indicated that jobs and livelihoods of post-harvest workers, who are often women, are threatened by the reduced availability and higher prices of fish and raw materials driven by competition with the FBF industry. For example, in Sierra Leone, it was reported that the supply of small pelagic species to the growing FBF industry in Guinea is having a negative impact on the livelihoods of hundreds of Sierra Leonean fishers and post-harvest workers. In the Congo, the fish meal and fish oil factory now has its own industrial fishing fleet, and this has led to the loss of jobs in artisanal fisheries.

TABLE 5. Summary of observed and perceived impacts on livelihoods in communities

Country	Observed/perceived positive impacts	Observed/perceived negative impacts
Mauritania	In 2019, there were 1 972 direct workers in the factories, 74 percent of whom were permanent workers. Hundreds of other indirect jobs created (fishers, loaders, transporters, etc.). More income for fishers due to the increase in volume of catch sold and higher fish prices.	Most of the direct and indirect jobs are largely held by foreigners. Competition with mostly women processors and fish traders that threatens their livelihoods.
Senegal	In 2018, there were 129 permanent and 264 temporary workers in the factories, generally recruited from the local population. Tens of collectors supplying the factories with raw material. More income for fishers due to increase in volume of catch sold and higher fish prices.	Competition for fish and raw material with thousands of workers operating in artisanal postharvest activities, which threatens their livelihoods.
Gambia	Some unknown number of direct jobs in the factories. Some collectors supplying factories with raw material. More income for fishers due to increase in volume of catch sold and higher fish prices.	Local workers are employed in lower grade jobs, while foreigners generally hold qualified ones. Fishers supplying raw material are mostly foreigners. Competition with hundreds of workers operating in artisanal post-harvest activities, which threatens their livelihoods.
Sierra Leone	In 2019, there were 18 direct jobs in milling companies and several unassessed on-farm producers. More income for fishers supplying the fishbased feed industry in Guinea.	Irregular and precarious jobs. The targeting of small pelagic species to supply the fish-based feed industry in Guinea has been threatening the source of livelihoods of hundreds of fishers and postharvest workers.
Ghana	Fishmeal factories and feed milling companies provide some job opportunities for local communities. More income for processors supplying raw material (by-products).	No significant impacts reported.
Congo	Few direct jobs in the existing factory (55 workers in 2019).	As the factory has its own industrial fishing fleet, it has been developing to the detriment of jobs in artisanal fisheries. Only 30 percent of jobs for local communities; 82 percent of jobs were temporary in 2019.
Malawi	No significant impacts reported.	No significant impacts reported.
United Republic of Tanzania	Over 20 000 direct and indirect jobs created. More income for fishers supplying raw material.	Most of the workers are poorly paid.
Uganda	Many direct jobs in the existing factories and milling companies in Uganda. Many indirect jobs in harvest and post-harvest activities that supply the industry.	Most of the workers are generally in a precarious situation because of very low earnings.

Source: Study country surveys.

5.2 IMPACTS ON FOOD SECURITY AND NUTRITION

Food and nutrition security can be impacted by the FBF industry in two main ways; changing accessibility and availability of quality foods (fish used for ingredients, or the products reliant on FBF), or impacting upon incomes that women, men and their households have to purchase quality foods to meet nutritional needs. Assessing what the impact of the FBF industry is on food and nutrition security is difficult to judge because insufficient information is available and food and nutrition security is a complex issue, which refers not only to the availability of food but also to the availability of good quality food that meets nutrient needs; additionally, the issue also involves individuals having access to food, through resources such as income to buy food that meets their needs, and agency to choose the foods which they desire. Information collected in the country surveys provides some examples and indications of how food and nutrition security are being affected in the countries (Table 6). In Ghana, Malawi, Senegal, Sierra Leone, Uganda and

TABLE 6. Summary of observed and perceived impacts on national food security and nutrition

Country	Observed/perceived positive impacts	Observed/perceived negative impacts
Mauritania		Limited disadvantages, as the dependency of the country on fish in general and on small pelagic species in particular is relatively low. However, poorer households that do consume fish may be negatively affected because of increasing fish prices (from less than USD 95 per tonne in the early 2010s to over USD 400 currently).
Senegal	A small part of the artisanally produced FBF contributes to livestock production and aquaculture	Considerable negative impact because the country is strongly dependent on fish consumption and may have a projected gap of fish demand of about 150 000 tonnes every year during the 2020s. In Senegal, but also in neighbouring countries, increase in FDI production that may depend on edible fish will worsen the already critical situation of fish availability and affordability.
Gambia		Considerable negative impact, as bonga, which is key to most consumers, is already overexploited and still heavily targeted by the existing FDI factories. During the 2020s, the country will have an average of about 15 000 tonnes of extra fish demand to be satisfied every year.
Sierra Leone	On-farm FBF locally produced contributes to improve food security by sourcing poultry and fish farms	No significant negative impacts so far, but there is an increasing scarcity of fish in recent years that may be worsened by the supply of raw material to the FBF industry supplying local poultry farmers in neighbouring Guinea.
Ghana	Part of FBF produced contributes to improving food security by sourcing livestock and fish farms	Moderate negative impact, as the industry mainly processes offal and by-products. However, an increase in the production of FDI that may depend on edible fish will probably worsen the situation of fish availability and affordability which is already critical.
Congo		The country imports about 40 percent of fish consumed, and thus the establishment of the first but large FDI factory may aggravate the deficit of fish for consumption.
Malawi	On-farm FBF locally produced contributes to improving food security by sourcing poultry and fish farms	No significant negative impacts so far, as the industry is still very rudimentary.
United Republic of Tanzania	Part of FBF produced contributes to improving food security by sourcing livestock and fish farms	Limited disadvantages in general, as most fishmeal produced is from fish that are considered to be non-edible mainly because of post-harvest issues. The use of freshwater and marine shrimps as raw material could potentially be promoted but further assessment is needed first to understand the likely biological, ecological and socio-economic implications of this in different ecosystems and communities.
Uganda	Part of FBF produced contributes to improving food security by sourcing livestock and fish farms	Fishmeal production that mainly relies on mukene/dagaa for raw material competes directly with the poorest consumers who strongly depend on this species. Fishmeal production has contributed to increase fish prices beyond what many consumers could afford.

Source: Study country surveys.

Notes: FBF = fish-based feed; FDI = fish-derived ingredient.

the United Republic of Tanzania, the country surveys showed some of the feed produced by smaller millers/workshops or on-farms is used for livestock and farmed fish that supply local markets. If the FBF production is based on processing wastes and byproducts, the result of non-edible fish or fish that otherwise would have been wasted because of excessive catches and market surpluses, the net effect would be to increase food supply to local consumers which respondents felt was the case in Ghana.

However, if fish that is fit for human consumption is redirected from direct human consumption to FDI production, the availability of fish in local markets is reduced, decreasing physical or economic access to fish. Increased demand for fish from the FBF industry may also affect prices and thus impact the affordability of fish for local consumers with low purchasing power. Some examples from the country surveys include the following:

- In Mauritania, the dependency of the country on fish for food (especially on small pelagic fish) is relatively low (influenced by cultural preferences for meat). However, poor households that do depend on small pelagic fish for their diets may be negatively affected because of increasing fish prices. Based on data provided by the Mauritanian Institute for Oceanographic and Fisheries Research, the average fish price increased from less than USD 95 per tonne in the early 2010s to over USD 400 at present;
- In Senegal, an increase in FDI production based on edible fish is likely to impact negatively on local fish availability and affordability. According to global fish consumption projections (Cai and Leung, 2017), the gap in fish supply to satisfy demand in Senegal in the 2020s is estimated at about 150 000 tonnes per year. This gap was calculated by comparing the trend of fish demand driven by population growth and income elasticity to the potential future fish supply taking into account the national production of the fisheries and aquaculture sectors;
- The Congo has a large deficit in fish supply to satisfy consumption needs of its population; about 40 percent of the fish consumed in the country is imported. The establishment in 2017 of a large FDI factory may be aggravating this deficit in fish supply for local consumption;
- In Uganda, as the fishmeal industry mainly relies on mukene/dagaa, it competes directly with the poorest consumers who strongly depend on this species for food. In combination with the huge regional market for mukene/dagaa for human consumption, the fishmeal industry has contributed to increasing fish prices beyond what most consumers may be able to afford.

Income earned by farmers and other workers of the FBF industry, increasing their purchasing power, may impact food and nutrition security positively by enabling them to buy more food for their families and diversify their diets. This was noted as an observed or perceived positive impact across all study countries, with additional observed or perceived positive impacts noted in Table 6. The analysis, however, is complicated, as it depends on availability and accessibility of nutritious foods and varies based on consumer choice, and thus it was not possible to cover this aspect in the country surveys.

5.3 IMPACTS FOR PUBLIC HEALTH AND WELL-BEING

In Senegal, Uganda and the United Republic of Tanzania, many local communities have noticed significant improvements in terms of reduced pollution in the environment. Owing to a lack of storage/freezing infrastructure, tonnes of unsold fish used to be left rotting on the beach and near houses when catches exceeded what could be absorbed by supply chains and markets, which generated bad odours and carried a high risk of microbiological contamination. The same situation was also frequently observed in artisanal processing sites where fish by-products and wastes were left directly on the ground. However, in areas where factories are located, local populations argue that these factories have been helping to remove these fish wastes, therefore making the local environment much cleaner.

A variety of negative impacts generated by the FBF industry were identified in all nine countries. In addition to smoke and bad odours, communities observed that wastewater discharged from factories was negatively impacting the environment. Based on the opinions of some technical stakeholders and local communities interviewed, this may lead to increased respiratory and skin diseases, particularly for vulnerable children and the elderly. Incidents of various diseases, such as rhinitis, cough, asthma, diarrhoea and nausea, have increased, as reported by local populations and technical staff. Additionally, poorly equipped factory workers and most artisanal processors who provide processing wastes for raw materials experience high exposure to such diseases and also suffer from frequent injuries. This is the perceived situation in Nouadhibou, the second-largest city in Mauritania, whereas in

Nouakchott, the capital, the situation is less worrisome because factories are located 28 km south of the city and therefore far from densely populated areas. In Ghana, the disadvantages are limited because of protective regulations, which are regularly enforced and monitored by the Environment Protection Agency.

5.4 IMPACTS FOR NATIONAL AND LOCAL ECONOMIES

As FDI are generally exported, foreign exchange earnings and related government revenues are important in many of the countries. The data identified by the study are summarized in Table 7.

TABLE 7. Summary of observed and perceived impacts for national and local economies

Country	FDI (fishmeal and fish oil) export value (USD)	Year	Percent of total fishery commodity exports	Estimated annual government revenues
Mauritania	200 000 000	2018	15	5 percent of value added tax; fishing licence fees
Senegal	7 162 000	2018	2	
Gambia	281 000	2018	< 0.1	
Sierra Leone	Negligible			
Ghana	226 858 000	2019		
Congo	2 478 000	2019	42	
Malawi	Negligible			
United Republic of Tanzania	63 000	2019	< 0.1	USD 2 million of taxes and royalties
Uganda	N/A			USD 80/producer as local tax

Source: Study country surveys and FAO databases (www.fao.org/figis). ITC trade date. Mauritania: Tarbiya and Mouhamédou (2011).

In all countries, the surveys also indicated that there are important unassessed amounts of salaries/revenues earned by workers along the value chain of the FBF industry. Additionally, it can be assumed that taxes are being paid, although no quantification of these government revenues was possible. An estimate of earnings is available only for the United Republic of Tanzania: a collective USD 600 000 000 of revenue is earned annually by all workers along the value chain.

5.5 IMPACTS ON NATIONAL AQUACULTURE AND LIVESTOCK SECTORS

As most of the FDI and FBF produced in the study countries are exported, the industry does not generally appear to have any particular impact on local aquaculture and livestock development. Still, in Ghana, Senegal, Uganda and the United Republic of Tanzania, the use of locally made FBF is deemed to slightly contribute to the improvement of productivity in the emerging aquaculture and/or growing intensive livestock sector. A lack of availability and affordability of manufactured FBF is seen by fish and/or livestock farmers as a major constraint for their activities, and the existing locally made or imported FBF is generally neither sufficient nor efficient to use.

6. Biological impacts of the fish-based feed industry on fishery resources

In Northwest Africa (including the Gambia, Mauritania and Senegal), FDI, essentially fishmeal and fish oil, are mainly made of small pelagic fish, in particular bonga (*Ethmalosa fimbriata*), sardine (*Sardina pilchardus*) and sardinellas (*Sardinella aurita* and *S. maderensis*). Given the transboundary nature of these resources, stock assessments are conducted at the subregional scale through CECAF, specifically through the Working Group on the Assessment of Small Pelagic Fish Off Northwest Africa. According to the most recent stock assessment results (FAO, 2020b), sardinella and bonga are overexploited, whereas the two stocks of sardine are considered not fully exploited (Table 8). For sardine, while the stock is now considered sustainably exploited, a precautionary approach is required due to the high sensitivity of its abundance in relation to hydroclimatic factors.

TABLE 8. State of the main small pelagic stocks in CECAF-North in 2019

Stock	State	Recommendations
Sardinellas (<i>Sardinella aurita</i> , <i>S. maderensis</i>)	Overexploited	Immediately and substantially reduce the fishing effort and catch in all the countries within the region (50 percent reduction is required).
Bonga (<i>Ethmalosa fimbriata</i>)	Overexploited	Effort and catch have to be reduced to below their 2017 levels to allow a level of biomass that can ensure sustainability.
Sardine (<i>Sardina pilchardus</i>)	Not fully exploited	The instability of this species vis-à-vis hydroclimatic changes requires a precautionary approach and a catch limit with close monitoring.

Source: Report of the CECAF Working Group on the Assessment of Small Pelagic Fish Off Northwest Africa, Casablanca, Morocco, 8–13 July 2019 (FAO, 2020b).

Note: For further information on the assessment of fish stocks see Lakhnigie *et al.* (2019).

In a context of overexploitation of some of the main small pelagic stocks in Northwest Africa, CECAF has expressed concern that the advent and expansion of the FBF industry may be worsening the situation in the whole subregion by fostering the increase of fishing intensity and a change in fishing pattern (FAO, 2020b). For instance, in Mauritania, 340 000 tonnes of sardinellas were processed into fishmeal and fish oil in 2018 (Corten *et al.*, 2017), representing 87 percent of the total catch (total estimated catch 390 000 tonnes) (FAO, 2020b). Moreover, in addition to bonga that had never been exploited commercially in this country before the development of the FDI factories (Corten *et al.*, 2017), it was reported that, for the first time, in 2018, the sardine had begun to be used, which was one of the reasons for the growth of fishmeal and fish oil production during that year (FAO, 2020b). According to information shared during the country survey interviews, with the establishment of the industry, fishers in the subregion now have more opportunities to sell their catches and therefore are encouraged to intensify the fishing effort.

The Southern CECAF area, from the northern border of Guinea-Bissau to the southern border of Angola, covers heterogeneous ecosystems and a range of fishery resources, including stocks of small pelagic fish shared between different countries. Three of the case study countries – the Congo, Ghana and Sierra Leone – all have fisheries for small pelagic resources, including sardinellas and bonga, that are caught and even targeted for fishmeal and oil production. The last meeting of the CECAF stock assessment working group on small pelagic species (subgroup South) was held in September 2018, and important key results on the state of resources were generated (FAO, 2019). The two species of sardinella and bonga are spread along the whole area; however, for each of them different sub-stocks were considered for the purpose of the assessment and recommendations (Table 9). The state of the different stocks of these species and the related management recommendations of the

TABLE 9. State of the main small pelagic stocks in CECAF-South in 2018

Stock	State	Recommendations
<i>Sardinella aurita</i> : West (Côte d'Ivoire, Ghana , Togo and Benin)	Overexploited	Current catch is not sustainable. Catch will have to be reduced to avoid future depletion of the stock. The fishery should be closed.
<i>S. maderensis</i> : West (Côte d'Ivoire, Ghana , Togo and Benin)	Overexploited	The stock is in very bad condition, near collapse. The fishery should be closed.
<i>Sardinella</i> spp.: North (Guinea Bissau, Guinea, Sierra Leone and Liberia)	Not fully exploited	As a precautionary measure and due to uncertainty in the data, do not exceed current fishing level for 2017 (60 000 tonnes).
<i>Sardinella</i> spp.: South (Gabon, Congo, Democratic Republic of the Congo and Angola)	Fully exploited	As a precautionary approach, it is recommended not to exceed catch level of the average of the past five years (122 000 tonnes).
<i>Ethmalosa fimbriata</i> : North (Guinea Bissau, Guinea, Sierra Leone and Liberia)	Assessment results not conclusive	As a precautionary measure, do not increase catches from the average of the past five years (46 000 tonnes).
<i>E. fimbriata</i> : West (Côte d'Ivoire, Ghana , Togo and Benin)	Assessment results not conclusive	As a precautionary measure, the catch limit should not exceed the average of the past five years (7 003 tonnes).
<i>E. fimbriata</i> : South (Gabon, Congo and Democratic Republic of the Congo)	Not fully exploited	As a precautionary measure and due to uncertainty in the data, do not increase catches of this species from the average of the past five years (5 000 tonnes).

Source: Report of the FAO/CECAF Working Group on the Assessment of Small Pelagic Fish – Subgroup South, Elmina, Ghana, 12–20 September 2018 (FAO, 2019).

working group is provided in Table 9. The selected countries of this study are highlighted in bold. For species that are essentially caught and even targeted for fishmeal and fish oil production (such as bonga and sardinellas), the state of exploitation is variable from one sub-stock area to another (FAO, 2019).

Off the coast of Ghana and its neighbouring countries (Western sub-stock), both sardinella species are considered seriously overexploited and a reduction, or even a closure of the fishery targeting these stocks, was recommended to allow recovery (FAO, 2019). In the case of bonga, no conclusions could be reached based on the assessments, but a reduction of catch was recommended. For these species for which overexploitation has been noted, any extra fishing pressure intended for FBF production may likely worsen the situation and potentially lead to stock depletion.

Regarding the Northern and Southern sub-stocks off the coasts of the Congo and Sierra Leone, the exploitation level for both sardinellas is still sustainable. Nevertheless, because of the uncertainty in the data, a limitation of catch level has been recommended as a precautionary measure. While the maximum recommended catch for sardinellas is 122 000 tonnes for the whole Southern stock area, in the Congo, respectively, 21 555 and 23 730 tonnes (of essentially sardinellas) were fished in 2018 and 2019 for fishmeal and fish oil production in the newly established factory. In terms of comparison, it should be noted that the Congo's total sardinella catch in 2018 was 26 732 tonnes (www.fao.org/figis). For bonga, the state of exploitation is uncertain due to a lack of enough accurate data (FAO, 2019). The fishery generally occurs in estuaries where the data collection coverage is poor in all CECAF countries. Because of this gap, a precautionary approach with catch limitation is necessary, even for the Southern sub-stock where the situation seems to be better. In the Northern distribution area where the recommended sustainable catch level is only 46 000 tonnes (FAO, 2020b), the Sierra Leone country survey indicated that the growing FBF production for poultry farmers in Guinea has been encouraging more fishing pressure in their national waters. In such a context, the targeted catch from Sierra Leone as well as the establishment in 2016 of a fishmeal and fish oil factory in the Congo may lead to overexploitation of small pelagic fish species if not managed in an appropriate way.

In the East African inland waterbodies included in the study, the fishmeal industry relies substantially on silver cyprinid (*Rastrineobola argentea*), locally called mukene or dagaa. This species is found in Lake Victoria, which is a large waterbody shared between the United Republic of Tanzania (49 percent of total surface of the lake), Uganda (45 percent) and Kenya (6 percent). Based on the most recent hydroacoustic survey in 2019 (LVFO, 2019), dagaa/mukene was the most abundant species with 34 percent of the total standing stock in Lake Victoria. Although it has become the largest fishing focus in the lake by weight since 2005, no signs of overexploitation have been noticed (Isaacs, 2016). It even resulted from the hydroacoustic survey that the biomass stock increased from 792 848 tonnes in 2016 to 936 247 tonnes in 2019 (LVFO, 2019). It has been reported that mukene/dagaa is a short-lived species that is resistant to overexploitation because of its very high turnover. It reproduces its own biomass four to five times per year, while only 10 percent of annual production is harvested (Kolding *et al.*, 2019).

Regarding the United Republic of Tanzania, in addition to mukene/dagaa, a part of the fishmeal is produced from by-products of Nile perch (*Lates niloticus*), as well as freshwater shrimp (*Caridina nilotica*), sergestid shrimp (*Acetes* spp.) and other species, especially of families Engraulidae (*Stolephorus commersonnii* and *Stolephorus indicus*) and Clupeidae (*Spratelloides gracilis* and *Sardinella albella*). In general, most of the stakeholders interviewed had no concerns regarding the state of exploitation of these species. According to the technical staff of the Ministry of Fisheries, interviewed during the country survey, the potential yield in inshore waters is estimated at 100 000 tonnes per year for the four Engraulidae and Clupeidae species mentioned above, while the annual catch is limited to around 56 000 tonnes. However, no information is available about the current status of the stock. Regarding freshwater shrimp (*C. nilotica*), hydroacoustic surveys done in 2019 indicated that the estimated lake-wide mean biomass was 565 348 tons, representing about 21 percent of the total biomass in Lake Victoria (LVFO, 2019). Only a tiny fraction is harvested but former research indicated that the sustainability of the fisheries of Lake Victoria depends among other things on the abundance and availability of *C. nilotica* because it is an important food source for the fish stocks (Budeba and Cowx, 2007). Regarding marine sergestid shrimp (*Acetes* spp.), there is no available relevant data that inform about the risk of the FBF on the status of the stock.

In Malawi, fish-based raw materials used by local milling companies are sourced from the cyprinid (*Engraulicypris sardella*), known as usipa, which is fished from Lake Malawi. Results from a study show that the total catch from the lake varied between 60 000 and 90 000 tonnes per year, with a rapidly increasing contribution of usipa in recent years comprising around 60–70 percent of the total catch (Kolding *et al.*, 2019). As the FBF industry is still rudimentary, respondents noted that overfishing is not currently considered a threat for this species.

7. Conclusions

The growth of the aquaculture and livestock sectors has driven increased global demand for FBF which are reliant on FDI, principally fishmeal and fish oil. In sub-Saharan Africa, the FBF sector has expanded in some countries and regions, representing a series of new and emerging challenges and opportunities. Policy and economic reforms and adjustments to improve the governance of the FBF industry in sub-Saharan Africa must take account of the broad range of historical experiences of the different countries, as well as the heterogeneity of the production capacities and volumes, the types and magnitude of raw materials used to produce FDI, and the destination of the products. To this end, the accounts of nine countries provided in this report can be a useful starting point. Nonetheless, further research is required into the drivers for use of fish in FDI and FBF to explore if, and the degree to which, raw materials are in fact unfit for human consumption⁵ or otherwise being directed away from potential human consumption. Research here needs to understand on-board handling of fish and the impact on quality, as well as market and others institutional incentives for landing fish for FBF rather than markets that directly supply human consumption.

In the Congo, the Gambia, Mauritania and Senegal, there are intensive FBF production models with large infrastructure and processing capacity. In these countries, the raw materials consist of large quantities of small pelagic fish (essentially round and flat sardinellas, bonga and sardine) caught from marine and estuarine waters which are processed into FDI. Almost all of the FDI produced in these countries is exported to China and Turkey, whose nationals are generally owners and capital investors in the sub-Saharan Africa-based factories and industrial fishing fleets serving the sector. In Ghana, factories and artisanal workshops that produce FDI source the raw materials from industrial cannery byproducts and artisanal processing wastes. In Sierra Leone, the FBF industry is either very small or non-existent, but there is ongoing exploitation of small pelagic fish to supply the growing FBF industry in neighbouring Guinea, whose main customers are local poultry farmers.

In East Africa (Malawi, Uganda and the United Republic of Tanzania), there are small and medium-sized factories and artisanal workshops that source raw materials for fishmeal production from artisanal fisheries. In these countries, two cyprinid species, locally known as dagaa/mukene and usipa, are harvested from Lake Victoria and Lake Malawi and processed into fishmeal after being dried.

There are a range of actors working along the value chain, which differs according to the model of production and use of FDI and FBF in each country. It is important to note that in most cases, with or without industrial fisheries, the artisanal fleet plays a major role in the supply of raw materials to FDI producers and FBF manufacturers either directly through fresh fish or indirectly through artisanal and/or industrial processing wastes and by-products. Several intermediary players (collectors, loaders, transporters) maintain the link between the raw material suppliers and the FDI producers and FBF manufacturers. Although in a few countries a portion of FDI, especially fishmeal, is used locally by milling companies and farmers for feed manufacturing, most (if not all) of the national production of Mauritania, Senegal, the Gambia, Congo and the United Republic of Tanzania is exported.

⁵ It is worth challenging this notion when it arises, as in theory all fish should be fit for human consumption if handled properly to ensure food safety. There is an urgent need for further research into the underlying causes or drivers for why fish is considered unfit for human consumption, to better understand if it is in fact consumer choice and preference that deem these fish unfit or if there is a need for improvement in harvesting, handling, marketing, or policies to incentivize fish for direct human consumption rather than for the FDI industry.

In general, the FBF industry offers some economic opportunities through employment. This is particularly the case for income generated for many direct and indirect workers along the value chain, for example in the case of the United Republic of Tanzania, the inflow of foreign currency through exports, and the taxes, royalties and fishing licences paid to governments. On the other hand, the industry's social benefits remain limited, perhaps benefiting relatively few entities, and are accompanied by threats to livelihoods, employment, food security and nutrition, and the health and well-being of local communities. Despite its importance in terms of the volumes of production, the use of FBF to develop the aquaculture and livestock sectors remains very low in the countries considered in this study. In fact, farmers who have been facing the unavailability and high cost of manufactured feed resort mainly to local alternatives, for which productivity performance is often low.

Regarding the biological dimension, the main concern about the FBF industry is whether it is driving overexploitation of small pelagic fish in West and Central Africa coastal countries, especially round sardinella, flat sardinella and bonga. However, in Malawi, Uganda and the United Republic of Tanzania, this threat is low, as stocks of indigenous cyprinid species (e.g. *mukene/dagaa* fish) targeted for fishmeal remain in a good state of exploitation (Kolding *et al.*, 2019). The relatively lower risk to such species is due to their high turnover.

The findings that resulted from this study represent a resource for better understanding of the development and challenges of the FBF industry in sub-Saharan Africa. The recommendations highlighted should allow for progress towards a sustainable management of this industry by combining evidence-based decision-making and priority-oriented future research. A holistic approach is required when assessing opportunities to enhance, optimise or reduce the use of fishmeal and fish oil for FBF production. The complexity of the situation must be comprehensively understood, especially in underdeveloped regions, and locally appropriate solutions will need to be developed in partnership with the relevant stakeholders.

8. Recommendations – prospects for decision-making and future research

As described in the Methodology section (Section 2), preliminary recommendations were defined based on the desk review and country surveys. Accordingly, fifteen recommendations for decision-makers and six for future research were identified. Subsequently, a prioritization process was undertaken through a two-round Delphi assessment allowing stakeholders to rate all recommendations from 1 to 10 based on the level of importance to participants. The list was narrowed down to ten policy recommendations and five research recommendations. This list of 15 are those recommendations that received a mean rating of over 8 out of 10. The other recommendations were not considered further here as they were rated less highly by respondents in Round 2. To facilitate their implementation, these fifteen key priority recommendations were contextualized drawing on insights derived from the desk review and country surveys. Therefore, for each recommendation summarized below, the rationale in relation to the findings of the study as well as the major implementation challenges are described.

8.1 RECOMMENDATIONS FOR DECISION-MAKING

RDM1 – Regulate and limit the number, capacity and production of the FBF industry based on the status of fish stocks and need for fish for human consumption.

The FBF industry has been rapidly expanding. This has led to concerns about exploitation of the major fish stocks of small pelagic species and increasing scarcity and unaffordability of fish for consumption. These risks and trade-offs have to date been ungoverned. Therefore, effective regulation of the FBF in sub-Saharan Africa is necessary to ensure the sustainable exploitation of small pelagic fish species while privileging food security and better nutrition. In terms of challenges, regulating the FBF industry according to the status of the major fish stocks and the demands of fish consumption may be challenged by the lack of political will and reluctance of lobbies involved in this industry. This strategy may also require consistent and durable funding and human resources for regular and accurate stock assessments, consumption studies and strict monitoring of the FBF industry itself.

RDM2 – Promote effective fish harvesting and post-harvesting practices to reduce bycatches and losses being directed to fish FDI production.

In addition to the targeted catches, part of fish devoted to FDI production results from bycatches and avoidable fish processing wastes/remnants that could be vital for human consumption. Therefore, promotion of better harvesting and post-harvesting methods are necessary to improve fish availability for human consumption instead of FDI production. Reducing bycatches may require an effective monitoring and surveillance system to ensure compliance with local, national and regional fisheries regulations. On the other hand, to reduce post-harvest losses, it may be necessary to promote capacity-building and innovation while investing in adequate fish storage and transport infrastructure as well as in processing technologies.

RDM3 – Purposively regulate the price for edible fish by setting it to a high level for FDI producers to maintain more incomes for fishers supplying the FBF industry and to a low affordable level for local processors and consumers.

To guarantee its supply of fish (generally edible) as raw materials, the FBF industry often offers higher prices that are profitable for fishers but hamper the possibility of local processors and consumers buying enough fish for their needs to fulfil demand for direct human consumption of fish. Consequently, direct political intervention is needed to

purposely regulate the fish price to reduce the harmful competition between the FBF industry and other fish users. However, measures regarding the fish price may be challenged by the lack of political will and reluctance of lobbies involved in the FBF industry. Such a policy may also go against existing national and international regulations on fair trade. This strategy may require overcoming the technical difficulty of defining such an optimal price and its regular adjustment considering the very dynamic and fluctuating context of the fisheries sector. In addition, monitoring the optimal price and controlling its enforcement may require consistent funds, technical staff and logistics.

RDM4 – Implement an environmental audit of existing FBF producers to check and monitor their level of enforcement of national norms/standards.

Most of the existing fishmeal and fish oil factories, FBF milling companies as well as artisanal FBF producers have negative impacts on the health of workers and local communities while also degrading the aquatic ecosystems near their locations. Considering this situation, an environmental audit of existing FBF producers will help to measure and monitor enforcement of national safeguard norms/standards in place with the objective of reducing the ecological impact of the industry. However, in countries where specific norms/standards do not exist, it may be necessary to establish them and define new appropriate regulations. In addition, there is a need to ensure that there are sufficient competent technical staff, resources and equipment to carry out comprehensive and rigorous environmental audits. To ensure enforcement of national norms/standards, it may be necessary to impose penalties on non-compliant FBF producers.

RDM5 – Promote environmentally friendly and healthy/safe FBF production technologies.

Whether appropriate national regulations are in place or not, the existing FDI factories, FBD milling companies and artisanal FBF producers generally lack adequate technologies for mitigating negative impacts on the local environment and human health and well-being. Therefore, wherever necessary, environmentally friendly and healthy/safe technologies must be promoted to reduce risks associated with, for example, liquid and solid wastes, smoke, dust, toxins and injuries. In terms of challenges, such a policy may require effective risk assessments to identify, analyse and fix all sources of hazards along the value chain of the FBF industry. Promoting healthier and safer technologies may require substantial investment and allocation of appropriate funding. In addition, workers may need to undergo capacity-building training to ensure adequate use and management of the new technologies that will be put in place.

RDM6 – Prohibit fishmeal and fish oil factories and feed mills from dumping toxic wastes into the sea and inland waters.

One of the major ecological problems of the FBF industry is the dumping of toxic wastes in aquatic ecosystems. Consequently, all countries in sub-Saharan Africa must pursue any possible measure and take action for the complete prohibition of such practices. However, prior to the implementation of this policy, it may be necessary to chemically analyse all types of wastes generated by the industry to assess the magnitude and level of toxicity of each one of them. Depending on the composition of the wastes produced it may be possible to use them productively (e.g. biogas or fertiliser). On the other hand, effective monitoring of compliance with the prohibition measures may require the availability of more competent technical staff, consistent funds and equipment/logistics. Also, for the prohibition policy to succeed, it may be necessary to impose penalties on non-compliant producers.

RDM7 – Make sure fishmeal and fish oil factories and feed milling companies are constructed far away from residential areas to avoid adverse impacts on residents.

The exposure of local communities to the harmful effects of the FBF industry is generally due to the establishment of most of the factories and feed mills in or close to residential areas. In

this context, FDI factories and FBF milling companies should be located at a safe distance away from inhabited areas. While this measure is possible if new FDI factories and milling companies have to be constructed, one of the major challenges may be the relocation of existing ones. However, the establishment of factories and feed mills further from residential areas may require investment in infrastructure and support services to ensure the effectiveness of the supply chain by allowing easy delivery of necessary raw materials to the producers and transport of outputs to the end markets. If not managed appropriately, this option may result in negative impacts on virgin natural landscapes and wildlife habitats while increasing greenhouse gas emissions from the transport of workers, raw materials and products. Production costs may also increase, hence making the manufactured FBF less affordable to local farmers.

RDM8 – Promote the use of plant-based and/or insect-based protein as feed alternatives in national aquaculture and livestock sectors.

The intensifying use of small pelagic species in sub-Saharan Africa as raw materials to respond to the increasing global and national FBF demand has likely contributed towards the overexploitation of selected marine fish stocks while undermining the livelihoods of local communities and fish availability for consumption. Thus, to develop the growing or emerging national aquaculture and intensive livestock sectors that need manufactured protein feed, it is necessary to promote alternative ingredients that could efficiently replace FDI. One of the major challenges of this recommendation is its requirements for investment in technologies capable of producing such alternative plant- and insect-based ingredients and capacity-building training for workers in the industry. Production of plant-based ingredients may require more arable land incurring the risk of land disputes/conflicts in local communities and competition with local food production. The use of insect-based ingredients may face cultural barriers and reluctance in some countries while also threatening the local biodiversity.

RDM9 – Assist and train local fish and livestock farmers so that they can formulate and produce efficient alternative feeds.

In sub-Saharan African countries, there are many artisanal and on-farm FBF producers whose outputs are made in such a rudimentary way that they do not generally meet the required quality that can guarantee better yields in national aquaculture and livestock sectors. Combining this weakness with the lack of enough available and affordable fish raw materials for FDI production, there is a real necessity to help local fish and livestock farmers move towards the manufacturing of efficient to use alternative feeds, based on locally available ingredients of aquatic and terrestrial origin. However, to shift towards such alternative feeds, prior trials may be necessary to identify which locally accessible ingredients best meet the nutritional needs of farmed fish and animals. Moreover, assisting local farmers may require the availability of enough competent technical staff, consistent funds and logistics. In addition, training local farmers may involve developing appropriate capacity-building tools, methods and strategies in a context where the level of illiteracy is high. Also, new safeguard measures may be required to ensure that the promotion of novel feed ingredients and products will not have negative impacts on human nutrition and does not threaten the local environment and biodiversity.

RDM10 – Implement and effectively enforce specific policies to the FBF industry.

The FBF industry has been rapidly developing in sub-Saharan African countries without enough specific national policies capable of ensuring its sustainability while mitigating its negative socio-economic and biological impacts. Therefore, implementing and enforcing such policies that will cover all measures recommended above should be a priority for all governments concerned by this issue. But the establishment of specific policies may face the lack of political will and reluctance of lobbies involved in the FBF industry. Also, their effective implementation and enforcement may necessitate the provision of more competent

technical staff, substantial funds and equipment/logistics. Capacity-building may also be needed to ensure that all stakeholders (administrations, communities, FBF producers and users, etc.) fully understand the new policies.

8.2 RECOMMENDATIONS FOR FUTURE RESEARCH

RFR1 – Ensure regular assessment of key small pelagic fish stocks based on improved data resolution/quality as well as effective monitoring of harvest and post-harvest activities.

Supply of raw materials for FDI production relies essentially on small pelagic species that have generally experienced heavy fishing pressure leading to overexploitation of selected marine stocks. As sustainable exploitation of these species is essential to satisfy multiple socio-economic needs, regular accurate stock assessment and effective monitoring of harvest and post-harvest operations are necessary for sustainable management of small pelagic fish species in sub-Saharan Africa. However, one of the main challenges is that such research activities may encounter the lack of funds, effective equipment and technical staff to collect and analyse the relevant data needed at the national and regional levels. On the other hand, recommendations resulting from the stock assessment and fisheries monitoring may not be implemented by countries due to weaknesses in the existing governance systems.

RFR2 – Assess and monitor fish consumption, including its affordability and importance for food security and better nutrition.

The FBF is rapidly developing in a context of fish scarcity in many sub-Saharan African countries. Consequently, particular attention has to be placed on the major drivers, patterns and trends of fish consumption to guarantee and reinforce its vital role for food security and better nutrition in these countries. However, although the establishment of national assessment and monitoring programmes on fish consumption is important, it may be endangered by insufficient funds and technical staff for its effective and durable implementation. In addition, it may necessitate consistent investment in capacity-building, equipment and logistics. Further research may be required in terms of maximizing the nutritional and economic benefits of wild stocks for the local communities.

RFR3 – Assess the national/regional demand/need and affordability of FBF for the aquaculture and livestock sectors.

Although FDI are produced in sub-Saharan Africa, almost all the production is exported and is not significantly used to leverage the yields of the aquaculture and livestock sectors. Because enough efficient alternatives are not available yet, FBF could play a major role if adequately used for that purpose. From that perspective, it is necessary to understand the magnitude of national/regional demand/need for FBF as well as its affordability for local farmers. However, assessing these key indicators will bring into sharp relief the lack of substantial funds, competent technical staff and equipment/logistics. On the other hand, findings that could result from this research may not be applied at large scale due to the lack of political will and reluctance of lobbies involved in the FBF industry.

RFR4 – Assess the chemical characteristics of all types of wastes generated by the FDI factories and their environmental and health impacts.

The fishmeal and fish oil factories generate wastes that are deemed to be toxic. However, the chemical characteristics of such wastes and their impacts on the environment and health are not well known in sub-Saharan African countries. Therefore, assessment activities are necessary to establish and implement appropriate safeguard measures and potential means of productive reuse. Among the major challenges, it should be noted that research on this issue may be hindered by reluctance and lack of cooperation of managers and workers from the FDI factories. It may also require consistent funding, effective equipment/logistics and technical staff to collect and analyse the relevant needed data.

RFR5 – Promote research programmes to identify alternatives to FBF and assess their feasibility, viability, efficiency and profitability.

To develop the aquaculture and livestock sectors in sub-Saharan African countries, governments and industries must promote a necessary shift towards alternative protein feeds that do not rely on food fish and seek accurate knowledge to guide decision-makers and local farmers in this perspective. Therefore, supporting research programmes and promoting knowledge sharing and networking internationally on this issue should be a priority to identify alternative protein feeds that are adapted to national and local needs and standards and to assess key drivers related to their feasibility, viability, efficiency and profitability at small and large scales. The major challenge is that research on this issue may be constrained by lack of sufficient funds, effective equipment and technical staff to collect and analyse the relevant data. In addition, findings that would result from this research may not be applied at large scale owing to the lack of political will and cultural barriers about the use of insects as alternative ingredients for feed production.

9. Detailed analyses by selected country

9.1 DETAILED ANALYSIS FOR MAURITANIA

9.1.1 Development and status of the fish-based feed industry

9.1.1.1 History and development of the industry

The history and development of the fishmeal and fish oil industry in Mauritania is widely documented (Ould Mohamed, 2010; Tarbiya and Mouhamédou, 2011; Corten, Braham and Sadegh, 2017). The first appearance of this industry dates back to 1965 with the creation of SOMIP (Société Mauritanienne d'Investissement et de Pêche) whose processing capacity was up to 600 tonnes per day. Because of the fishmeal market recession and very high production costs, the company closed in 1974, but two years later, in 1976, it reopened under the new name of COMAPOPE (Compagnie Mauritano-Portugaise de Pêche). The strong development of the fishmeal industry, however, started in 2011 when the city council of Nouadhibou, the main fishing site located in northern Mauritania, allocated a new area ("El Bountiya") for industrial development (Corten, Braham and Sadegh, 2017). As a result of high fishmeal and fish oil prices, the interest of investors became extremely important; soon 20 authorizations were issued for the construction of new factories. Because the offal from local processing activities was no longer sufficient as raw material for all existing factories, artisanal purse seine canoes from Senegal as well as Chinese and Turkish industrial vessels were chartered to exclusively fish on behalf of fishmeal and fish oil factories.

9.1.1.2 Capacity of the industry

In 2010, only five fishmeal and fish oil factories operated in Mauritania. In a very short period of time, however, the number of factories significantly increased (Corten, Braham and Sadegh, 2017). Based on updated data that were collected in the field, the number of factories amounted to 37 in 2017 before slightly decreasing to 35 in 2019 (Figure 8). Considering 13 factories that were visited in 2019, the average daily processing capacity was estimated at 611.5 tonnes per factory. All factories have their own storage sheds, with capacity ranging from 1 000 to 5 000 tonnes. The total number of canoes chartered to specially fish for factories peaked at 300 in 2016 before decreasing to 204 in 2019. During this same period, the number of industrial fishing vessels increased sharply, from only 14 in 2015 to 77 in 2019, after reaching a high of 87 vessels in 2017.

FIGURE 8. Number of fishmeal and fish oil factories in Mauritania

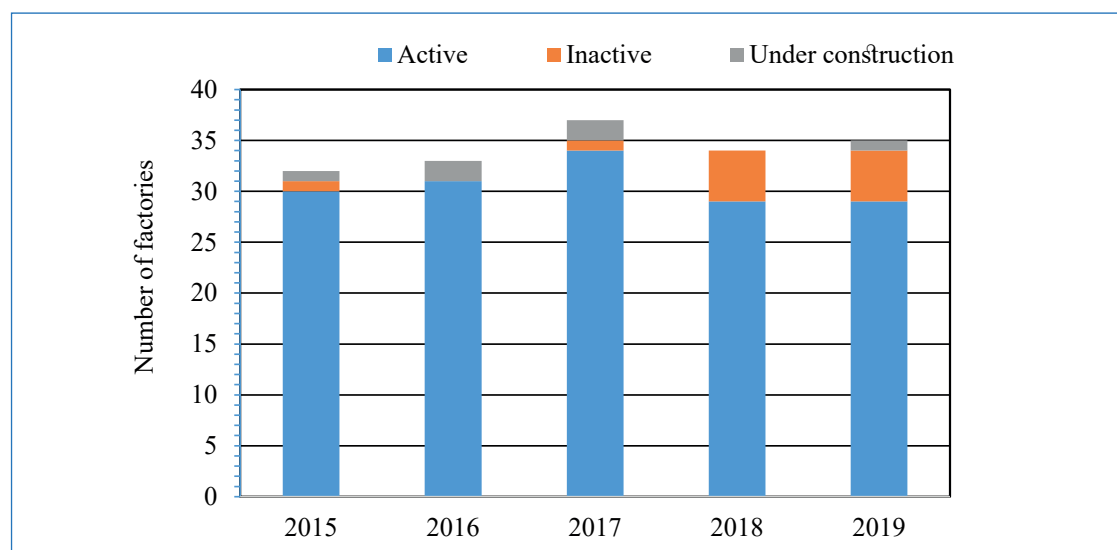
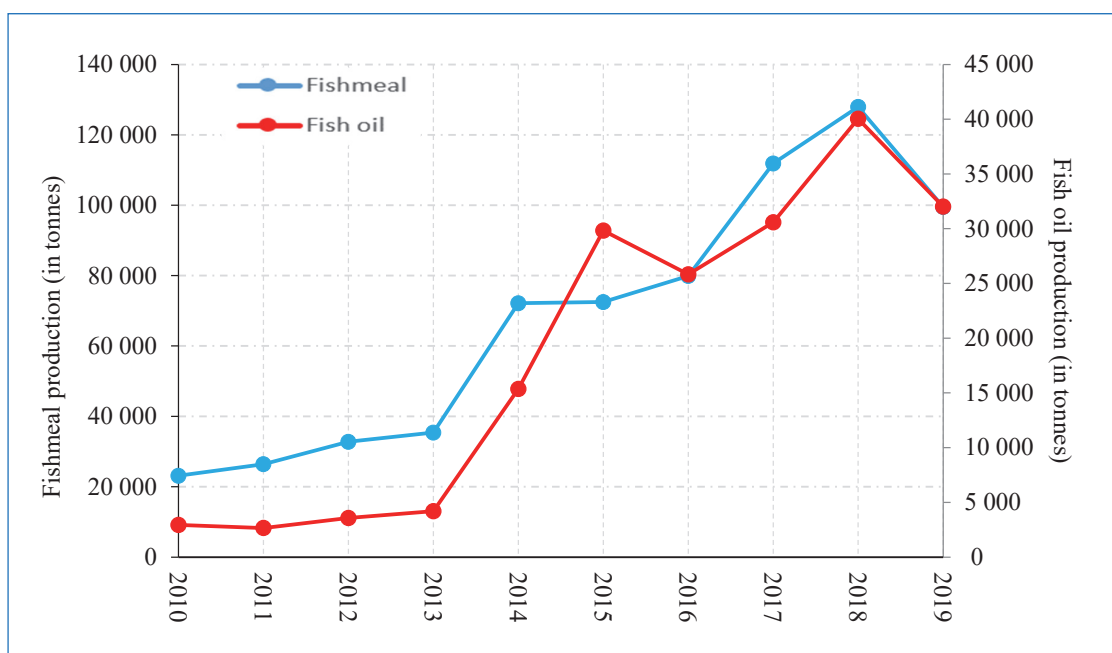


FIGURE 9. Volume of fishmeal and fish oil production in Mauritania



9.1.1.3 Production of the industry

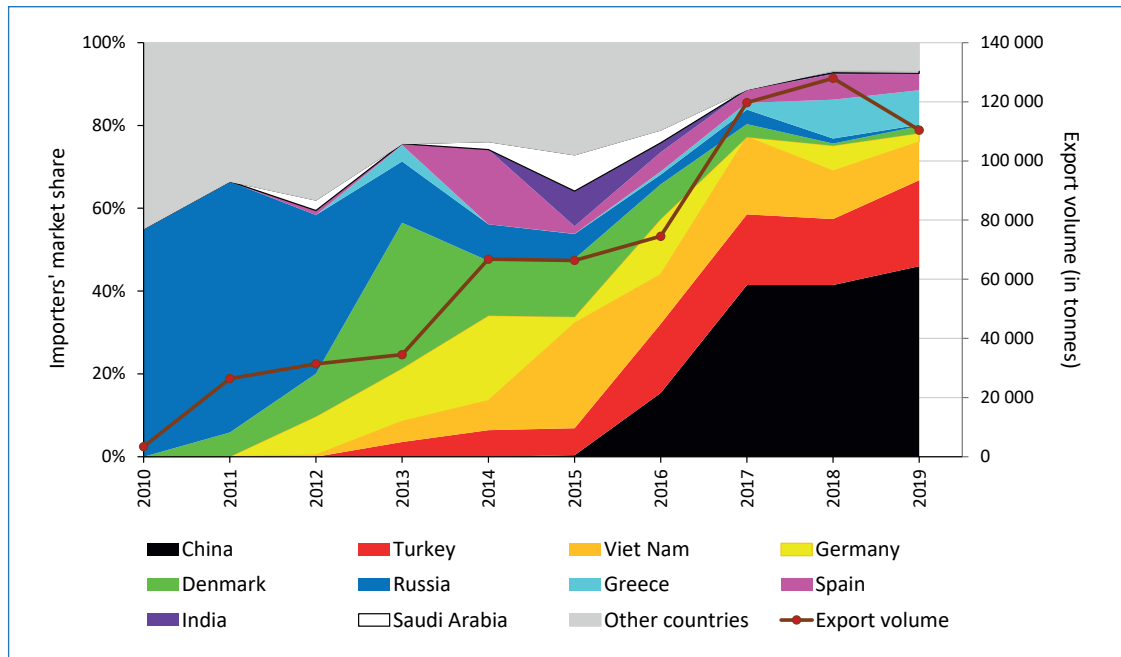
According to data collected in the national customs, fishmeal production tripled in four years, from 23 131 tonnes in 2010 to 72 149 tonnes in 2014 (Figure 9). During this same period, the volume of fish oil produced increased fivefold, from 2 937 to 15 366 tonnes. In the period 2015–2018, fishmeal production doubled and reached a historic high of 127 940 tonnes. Also, in 2018, a peak of 40 045 tonnes was noted for fish oil. Since 2009, when the volume of fish processed started to be split in species composition, the bulk of the raw material used for fishmeal and fish oil production was composed of fresh fish landings, in particular sardinellas (*Sardinella aurita* and *S. maderensis*) and bonga (*Ethmalosa fimbriata*), while the amount of offal was relatively small (Corten, Braham and Sadegh, 2017). According to the usual conversion ratio indicating that 4 to 5 kg of fresh fish are necessary to produce 1 kg of fishmeal (Péron, Mittaine and Le Gallic, 2010), the level of production in 2018 might correspond to a catch volume of about 575 700 tonnes.

9.1.1.4 Destination of fish-derived ingredient produced

All fishmeal and fish oil produced in Mauritania is exported. According to ITC data, over the past decade this country has very quickly become one of the biggest fishmeal exporters in Africa, and even in the world. From 3 385 tonnes in 2010, the volume of fishmeal exports increased by a factor of 38, reaching 127 940 tonnes in 2018 (Figure 10). This increase was also characterized by considerable changes in terms of destination. In the early 2010s, the Russian Federation was largely the main importer, with up to 61 percent of market share in 2011. To a lesser extent, Denmark and Germany were also relatively important destinations with, respectively, 35 percent and 20 percent of the market in 2013–2014. New importers emerged in the mid-2010s and became Mauritania's main customers. This is especially the case for China, whose fishmeal import started low in 2015 and then increased sharply to 46 percent of the Mauritanian market in 2019. Turkey also became a major destination in recent years. Its market share, which was only 4 percent in 2013, rose to 21 percent in 2019.

Regarding fish oil, Mauritania has various fish oil importers. However, France was the major destination in 2019 with 15 101 tonnes (44 percent of total export). The other major clients were Denmark (17 percent), Norway (11 percent) and Turkey (11 percent).

FIGURE 10. Volume of fishmeal export of Mauritania and importers' market shares

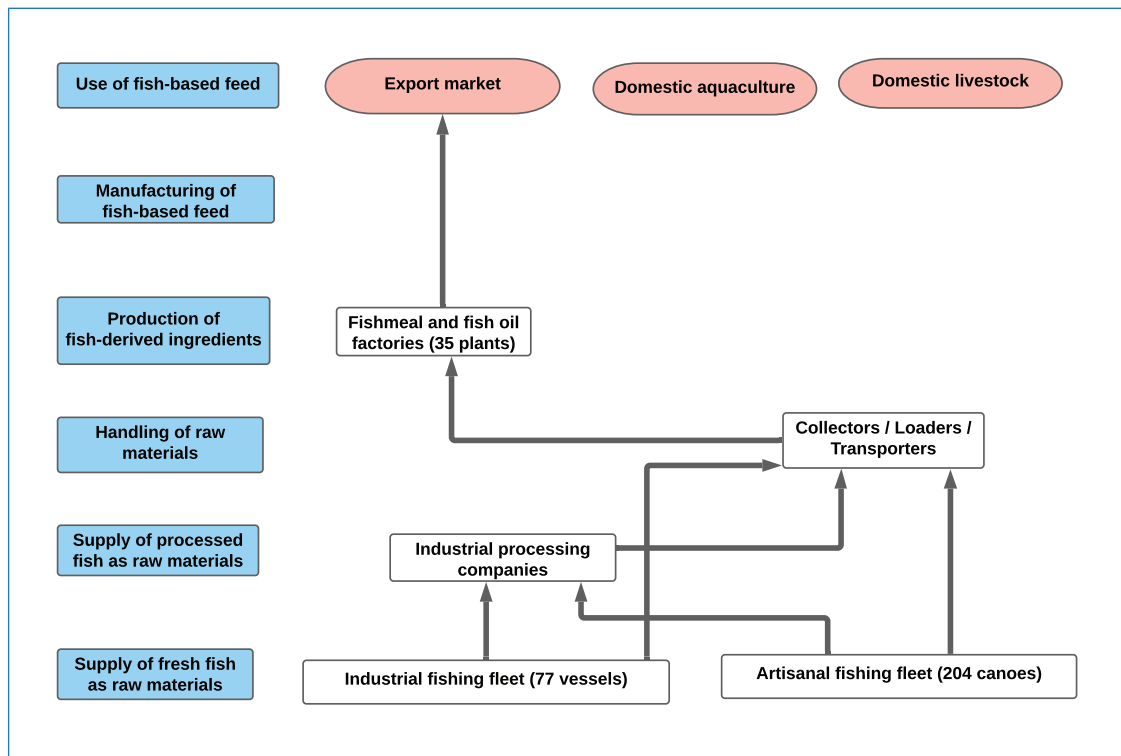


Source: Data extracted from the ITC exports online database.

9.1.1.5 Value chain mapping of the industry

The value chain map of the FBF industry in Mauritania is presented below (Figure 11). Five types of actors are the players along the value chain. Both industrial and artisanal fishing fleets supply the factories with fresh fish, which is combined with small industrial processing offal to form raw materials used for producing FDI (fishmeal and fish oil). In charge of handling these raw materials are the collectors, loaders and transporters, who serve as intermediaries between suppliers and producers. Because the entire gross production is directly sold abroad, export is the only end market without any FBF manufacturing activity.

FIGURE 11. Value chain mapping of the fish-based feed industry in Mauritania



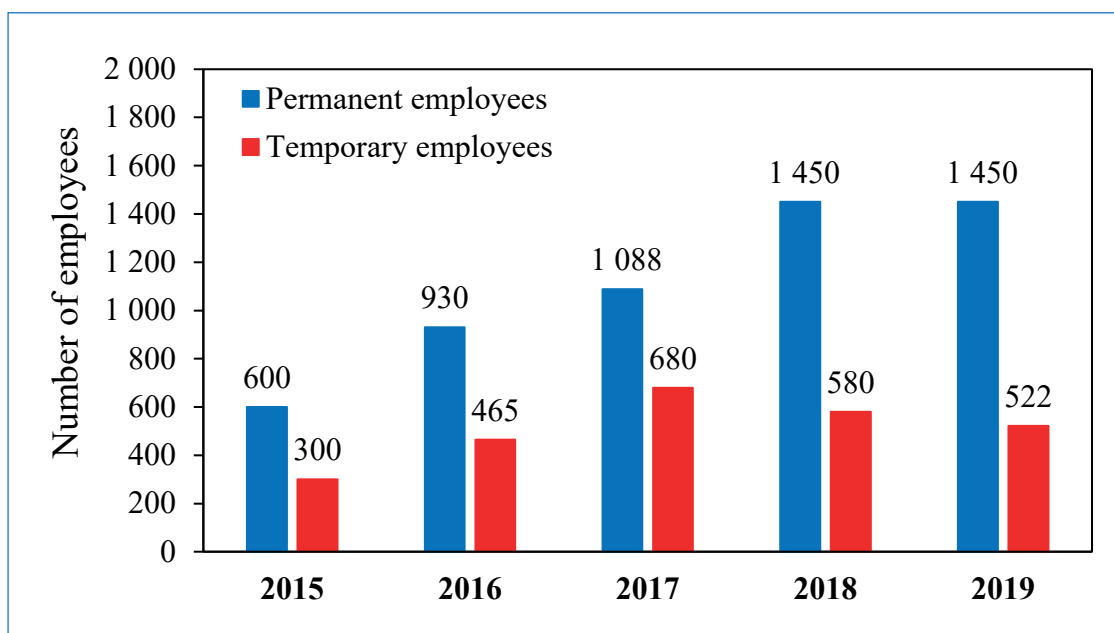
9.1.2 Socio-economic impacts of the fish-based feed industry

9.1.2.1 Impacts for livelihoods in communities

The major positive impact is the contribution of the industry in reducing unemployment. The number of direct jobs created by operating factories steadily increased from 900 in 2015 to 1 972 in 2019 (Figure 12). There is also a strong predominance of permanent jobs, which increased from 67 percent to 74 percent over the past five years. In addition to direct jobs, there are a number of other workers whose livelihoods depend on the industry. This is, for example, the case of fishers operating in fishing canoes and vessels chartered or owned by existing factories. Moreover, many people, such as collectors, loaders and transporters, are involved in the handling of landed fish and processing offal, which are raw material for FDI production. Some stakeholders encountered in the field believe that this industry improves their incomes through its ability to ease the sale of fishery products, particularly in the event of excess and/or deteriorated fish catches.

In terms of negative impacts, local stakeholders mentioned that the number of jobs created by the FBF industry is very low compared to its capacity for large-scale employment. Some technicians from the Ministry of Fisheries explained that when factories become operational they generally do not comply with the number of jobs to which they officially committed during the authorization process for their creation. In addition, contrary to what factory managers often state, an important part of existing jobs are, in fact, temporary and also largely held by foreigners (Tarbiya and Mouhamédou, 2011). Generally, workers are Senegalese, Chinese and Turkish nationals working not only in chartered fishing canoes and vessels but also in the factories. Moreover, the industry has been competing with women processors working on salt-dried fish and whose livelihoods are now seriously threatened. This same threat has also been noted by many fishmongers who supply the local market.

FIGURE 12. Number of employees in the fish-based feed industry in Mauritania



9.1.2.2 *Impacts for national food security*

In Mauritania, despite the relatively low volume of fish sold in the national market owing to a lack of demand and suitable facilities, small pelagics constitute an important cheap source of animal protein and may therefore help to guarantee food security for people (Tarbiya and Mouhamédou, 2011). Currently, most landed catches of small pelagics are processed into fishmeal and fish oil, while national per capita fish consumption remains low at around 8–10 kg, far from the global average of 20.5 kg in 2018 (FAO, 2020a). Members of the National Fishers Federation stated that the FBF industry has been reducing the availability of fish in local markets. The fishers argued that selling their catches to factories is much easier and more profitable than selling at the local market. As a result, fish has become more expensive. For example, the price of sardinella was less than USD 100/tonne in the early 2010s but is currently over USD 400/tonne. In this context, the objective of the Government in promoting more fish consumption in rural areas through the creation of the National Fish Distribution Company (SNDP) may be in vain.

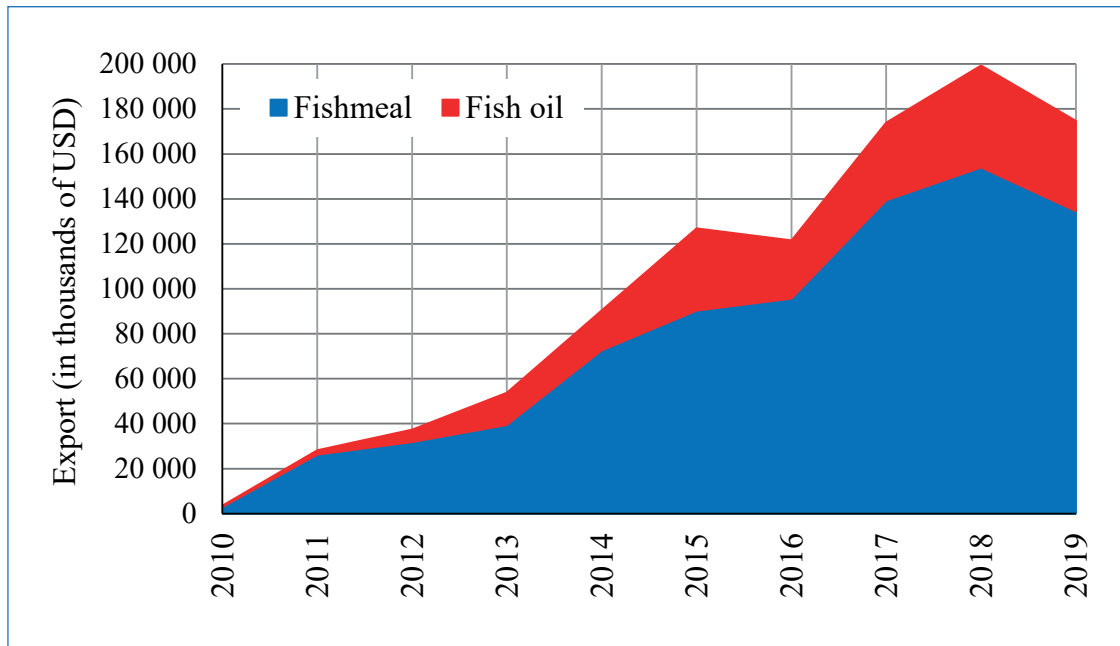
9.1.2.3 *Impacts for public health and well-being*

The rapid development of the FBF industry in Mauritania was not accompanied by strict measures for controlling and monitoring associated risks for public health and well-being. When requesting authorization to build a factory, investors usually agree to install adequate technical systems to mitigate harmful impacts. However, the commitments are almost never respected once the factory is operational. Consequently, in areas where fishmeal and fish oil factories are located, in addition to smoke and foul smells, the discharge of wastewaters are thought to be causing respiratory and skin diseases in the local population. Through interviews with the local communities in Nouadhibou, where most of factories are located, serious concerns were raised regarding increasing cases of asthma in children and the elderly. However, at the moment, the situation is less worrying in the city of Nouakchott because the factories are located 28 km away south of the city and therefore far from the great densities of human populations. Regarding the workers in the factories, the lack of adequate protective equipment for preventing health risks is often mentioned. Observed and potential impacts on public health and well-being have recently prompted the Mauritanian authorities to pursue important initiatives. In 2019, an inter-institutional commission was created to ensure compliance with the commitments that investors made to obtain authorization to set up FDI factories. These include the mandatory installation of odour filters and a smoke evacuation system.

9.1.2.4 *Impacts for national and local economies*

The FBF industry in Mauritania has various potential and/or observed direct impacts on the national and local economies. For instance, at the national level, foreign currency inflows from fishmeal and fish oil exports are a considerable direct contribution to the economy. According to ITC data, from only USD 2 936 000 in 2010, fishmeal brought a peak of USD 153 891 000 in 2018 (Figure 13). Over the same period, fish oil exports increased from USD 649 000 to USD 45 503 000. Therefore, in 2018, the cumulative exports of these two FDI generated about USD 200 million to the Mauritanian economy. In terms of comparison, the amount of FDI exports corresponded to 15 percent of total exports of fish commodities, which was USD 1.3 billion in 2018 (www.fao.org/figis). In addition to exports, added taxes paid to the public treasury are also a consistent direct contribution to the economy. According to Tarbiya and Mouhamédou (2011), this kind of tax represented 5 percent of the total value added of the industry in 2010, corresponding to MRU 16 million (about USD 432 000). However, interviews with officers from the fisheries administration revealed that due to lack of effective control, factory managers constantly attempt to evade and minimize the amount of taxes to pay. Fishing boats chartered by the factories also pay for fishing licences, fees collected by the Government. At the local scale, salaries and other revenues earned by workers represent the bulk of economic benefits generated by the FBF industry.

FIGURE 13. Value of fishmeal and fish oil exports in Mauritania during the past decade



Source: Data extracted from the ITC exports online database.

9.1.2.5 Impacts for national aquaculture and livestock sectors

In Mauritania, aquaculture is an embryonic activity whose production is practically non-existent. On the other hand, according to the Ministry of Livestock, livestock rearing is the pillar of the rural sector, with more than 20 million heads of cattle, for a population of less than 5 million inhabitants. Livestock plays a major economic and social role and represents around 12 percent of the gross domestic product. However, livestock rearing continues to be practised in a traditional and extensive manner in large semi-desert spaces or within the Senegal River delta in the southern border of the country. The use of FBF is practically unknown in the aquaculture and livestock sectors. Thus, the large production of fishmeal and fish oil in Mauritania does not make any contribution to the development of these two sectors. Most of the local communities interviewed acknowledged ignoring the potential for FBF to help improve their livestock productivity.

9.1.3 Biological impacts of the fish-based feed industry

9.1.3.1 Impacts on fishery resources

In Mauritania, the artisanal and coastal fishing effort as well as the small pelagics catches began increasing drastically in response to the rapid development of fishmeal and fish oil factories in the early 2010s, (Tarbiya and Mouhamédou, 2011). According to FAO (2020b), the small pelagics fisheries in the country continue to expand, in particular with a considerable part of coastal purse seiners and artisanal canoes operating to supply the fishmeal and fish oil factories. However, the fishing pressure occasioned by this industry and its impacts on the state of exploitation may vary from one species to another. For instance, round sardinella is more targeted than flat sardinella (Corten, Braham and Sadegh, 2017). On the other hand, although bonga was known to inhabit Mauritanian waters, it had never been exploited commercially before the advent of the FBF industry. In 2018, 340 000 tonnes of bonga were processed into fishmeal and fish oil (Corten, Braham and Sadegh, 2017), representing 87 percent of the total catch that was estimated at about 390 000 tonnes (FAO, 2020b). In addition to bonga, the FBF industry also recently started using sardine in 2018, which was one of the reasons for the growth of fishmeal and fish oil production during that year (FAO, 2020b). As small pelagics exploited in Mauritania are part of larger regional

stocks, the expansion of the FBF industry in the country may increase fishing pressure and worsen the overexploitation of these stocks at regional scale.

9.1.3.2 Impacts of fish-based feed on ecosystems

Most of the fishmeal and fish oil factories in Mauritania are based in Nouadhibou alongside a bay named Baie du Lévrier. The presence of this highly polluting industry in the immediate vicinity of this biologically sensitive bay is a real threat to its biotope and the biocenosis. When the first factories in Mauritania were established, attention was drawn to the fact that this bay is a reservoir for many species, including bonga and flat sardinella, which may be threatened (Sidi, 2010). Nowadays, liquid wastes from the factories are considered by the local communities to be harmful to aquatic fauna. These communities have observed more frequent unexpected mortality of small specimens of several species in the bay. In the particular case of lobster, local fishers argued that the installation of the factories resulted in high mortality, which led to the scarcity of this species in the area. However, some factory managers affirmed that they are setting up treatment systems capable of cleaning wastewaters before their discharge into the bay. In addition to aquatic pollution, the FBF industry in Mauritania has chartered a semi-industrial fleet with very sophisticated but not selective fishing gear that may be responsible for considerable quantities of bycatches.

9.2 DETAILED ANALYSIS FOR SENEGAL

9.2.1 Development and status of the fish-based feed industry

9.2.1.1 History and development of the industry

The first two fishmeal factories, Afric Azote and Sénégal Protéines, were respectively established in 1967 and 1976 (MPPEM, 2019). The objective was to generate value added from the extra unsold fish catch and fish processing wastes. However, industry development was not significant until the 2000s, when more investments were made to create new factories. Based on field surveys, three new factories were built between 2011 and 2014. Subsequently, in 2017–2018, four new factories were established. Interviews also revealed that two factories are currently under construction. Besides industrial factories, five artisanal fishmeal workshops were identified.

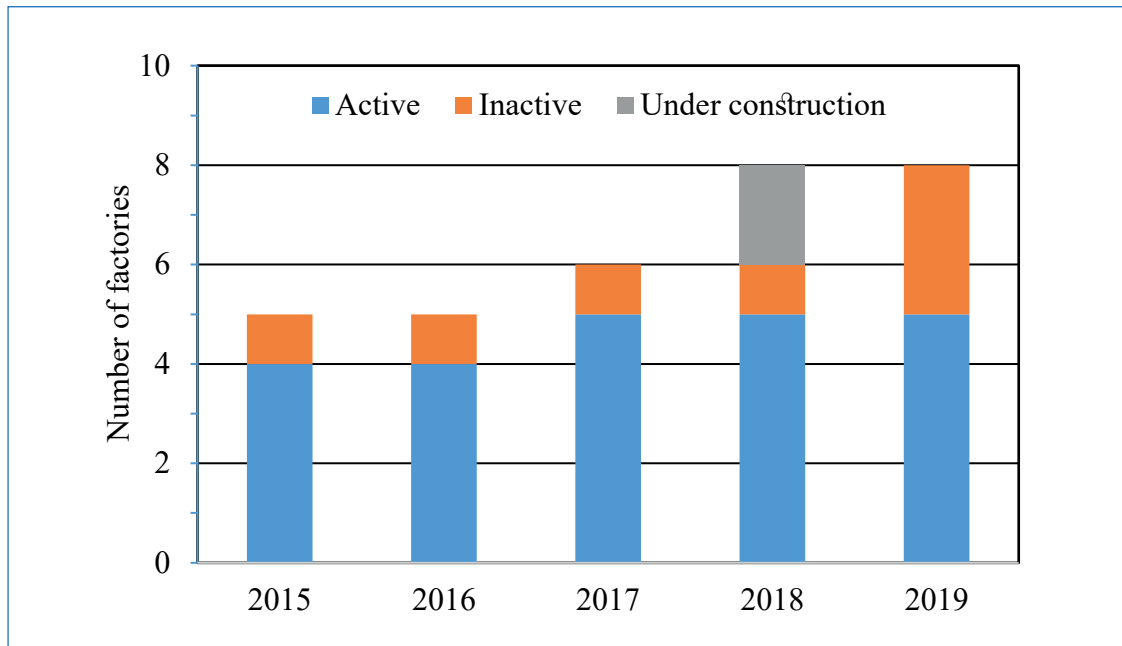
9.2.1.2 Capacity of the industry

From five in 2015, the number of fishmeal and fish oil factories slightly increased to six in 2017 (Figure 14). Two new factories were built during the following year. However, among the eight existing factories in 2019, three were not operational. In addition to these industrial factories, five artisanal fishmeal workshops were identified. Based on the data collected from the visited factories, the maximum daily processing capacity varies from 150 to 300 tonnes per factory. However, according to FDI producers interviewed, this capacity is far from being fully operational. In fact, the activity is just limited to only about four months per year due to a lack of fish for raw material. Unlike in Mauritania, the factories in Senegal do not specifically charter industrial vessels or artisanal canoes for their supply. They only work with individual suppliers who provide processing wastes and fresh fish collected in the major landing sites of the country.

9.2.1.3 Production of the industry

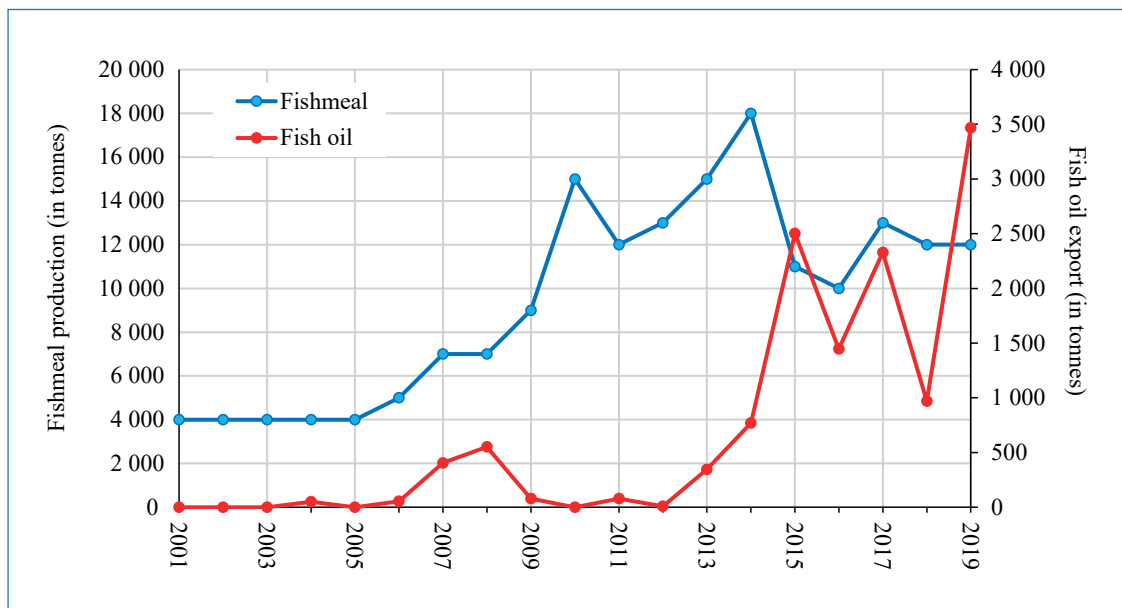
In Senegal, the official data collected from the Directorate of the Fish Processing Industries regarding the volume of FDI production are probably underestimated compared to the statistics recorded in international databases. Therefore, regarding the fishmeal production, we opted for data compiled by the United States Department of Agriculture and stored

FIGURE 14. Number of fishmeal and fish oil factories in Senegal in recent years



in the Index Mundi [Website](#). In terms of the volume of fish oil produced, the export data were analysed as a proxy considering the fact that almost the entire production, if not all, is sold abroad. After being stable at around 4 000 tonnes per year at the beginning of the 2000s, fishmeal production took off in 2006 and underwent a strong upward trend until 2014 (Figure 15). Within this period, it quadrupled, reaching a peak of 18 000 tonnes. Subsequently, production recorded a drastic drop before stabilizing at around 12 000 tonnes per year in recent years. Regarding fish oil, with the exception of around 400 tonnes in 2007–2008, the production did not significantly start until 2013. Then, in the following three years, it was multiplied by seven, reaching a maximum of 2 502 tonnes in 2015. More recently, the trend was marked by strong fluctuations with, in particular, a historical record of 3 468 tonnes in 2019.

FIGURE 15. Volume of fishmeal production and fish oil export in Senegal



9.2.1.4 Destination of fish-derived ingredient produced

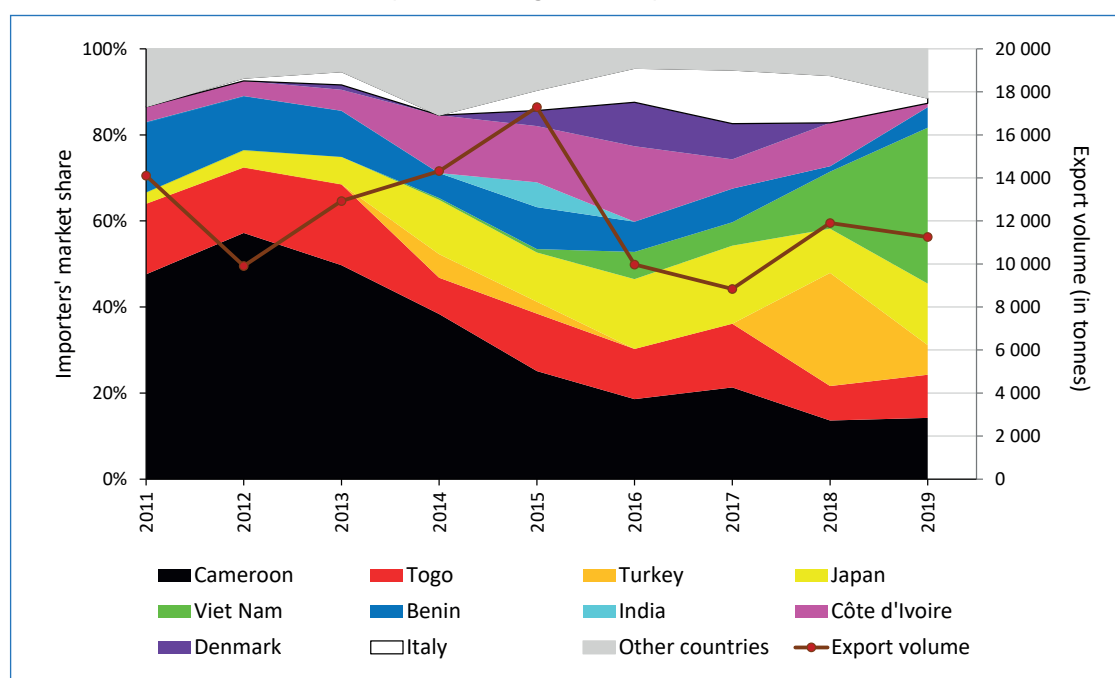
Fishmeal produced in Senegal is essentially destined to export. Based on the ITC data, the volume of fishmeal exported increased from 9 906 tonnes in 2012 to a peak of 17 289 tonnes in 2015 (Figure 16). Then, following a significant drop in 2016, it has been recently fluctuating around 10 000 tonnes per year. Regarding the destinations, considerable changes occurred during the past decade. In the early 2010s, three African countries bought most of the fishmeal exported by Senegal. This is especially the case of Cameroon, whose market share reached 57 percent in 2012, as well as Togo and Benin, to a lesser extent. However, as the market shares of these three African countries declined gradually, new customers emerged and became major destinations in recent years. This is notably the case for Turkey, which had 26 percent of market share in 2018, and Viet Nam, which became the biggest importer with 36 percent of total fishmeal exported by Senegal.

Apart from fishmeal, fish oil is the FDI produced in Senegal. In 2019, Denmark imported 528 tonnes from Senegal, corresponding to 60% of total fish oil export. It was followed by Spain with 216 tonnes (25% of total fish oil export).

9.2.1.5 Value chain mapping of the industry

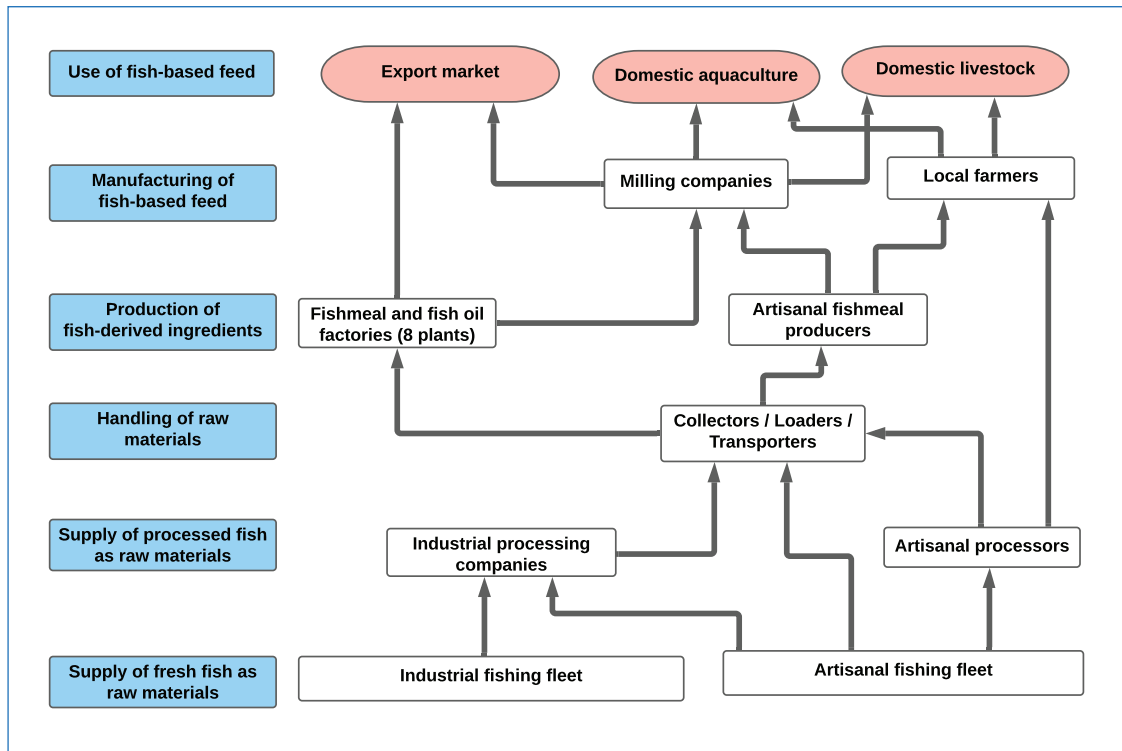
With nine types of actors intervening in all the six functions, the value chain of the FBF industry in Senegal is relatively complex (Figure 17). The artisanal fishing fleet plays a key role in the supply of raw material, as it provides fresh fish to the factories. In addition, both industrial and artisanal fisheries supply fish to processors whose wastes and by-products are also part of the raw materials. Their handling is under the responsibility of collectors, loaders and transporters. However, some local farmers get their raw materials directly from artisanal processors. Both factories and artisanal producers are involved in FDI production. Even if most of the fishmeal and fish oil produced is exported, the domestic aquaculture and livestock sectors are also minor end markets. They are supplied in manufactured FBF by local farmers as well as milling companies that also export part of their output in neighbouring countries such as the Gambia and Mali.

FIGURE 16. Volume of fishmeal export of Senegal and importers' market shares



Source: Data extracted from the ITC exports online database.

FIGURE 17. Value chain mapping of the fish-based feed industry in Senegal



9.2.2 Socio-economic impacts of the fish-based feed industry

9.2.2.1 Impacts for livelihoods in communities

With around three quarters of the landings in Senegal, small pelagic species (mainly sardinellas and bonga) are the most important source of livelihoods for thousands of actors along the fisheries value chain. This is especially the case for harvesters, fishmongers and fish processors. In terms of positive impacts, the FBF industry creates jobs, some of which are salaried. From the field surveys, a total of 129 permanent and 264 temporary workers were identified in 2018. In addition to these direct jobs, there are also tens of collectors, loaders and transporters who earn money by supplying the factories in fresh fish and processing wastes and by-products. In general, unqualified employees are recruited from the local communities. The FDI factories allow fishers targeting small pelagic species to easily sell their catch while offering better prices that contribute to increase their incomes. Regarding the negative impacts, the competition against post-harvest activities (processing and trading) is mostly pointed out. More specific, the FBF industry has been hampering the supply of raw materials for artisanal processors. It also reduces the marketing opportunities of fishmongers, both wholesalers and retailers (APRAPAM, 2017). Therefore, all these actors who generally lack alternative opportunities may become poorer.

9.2.2.2 Impacts for national food security

As a significant part of many national dishes, fish plays a major role in food security in Senegal where the per capita consumption is estimated at 25–26 kg (Thiao *et al.*, 2018), while the global average was 20.5 kg in 2018 (FAO, 2020a). Because of their higher level of abundance and lower price, fish consumption is widely dominated by small pelagic species, particularly sardinella species and bonga, which account for about 70 percent of total landings. According to world projections on fish consumption, the gap in fish demand to be satisfied in Senegal during the 2020s is estimated at about 150 000 tonnes per year (Cai and Leung, 2017). Therefore, an increase in FDI production relying on edible fish may likely worsen the situation of fish unavailability and unaffordability which is already critical (Thiao *et al.*, 2018). Nevertheless, a small part of FBF locally produced is deemed

to contribute to improve food security by sourcing the livestock and fish sectors whose production is generally sold inside the country.

9.2.2.3 Impacts for public health and well-being

In Senegal, the potential and/or observed negative impacts of the FBF industry on public health and human well-being are related to its air, water and soil pollution. People living near the fishmeal and fish oil factories frequently complain about the smoke and very bad odours they generate. According to local communities living near factories, the air breathed is sometimes pungent and entails sensations of suffocation. The increase in respiratory illnesses, such as rhinitis and cough that more particularly affect children and the elderly as well as adults with chronic diseases, is deemed to be caused by these nuisances. On the other hand, cases of diarrhoea, vomiting and nausea that may be linked to the wastewaters are sometimes reported not only by factory workers, who are generally not equipped with suitable protective means, but also by people living near FDI production areas. However, despite the negative impacts of the FBF industry, many people stated that it also has had considerable positive impacts on health and well-being. In many coastal landing sites, in times of high abundance of small pelagics, tonnes of fish used to be left rotting on the beach and near houses. The industry has contributed to reducing this pollution in cities and villages where factories are established.

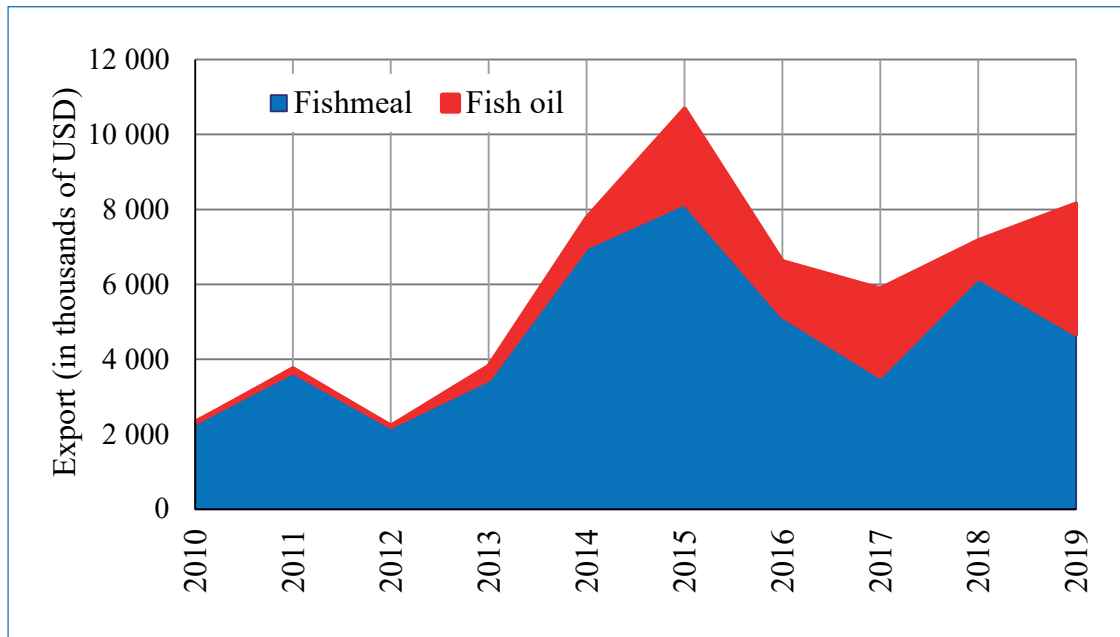
9.2.2.4 Impacts for national and local economies

In Senegal, the direct impacts of the FBF industry on the national and local economies are mainly related to exports and taxes. Over the past decade, based on the ITC export data, the cumulated value of fishmeal and fish oil exports has fluctuated between about USD 2 million and USD 11 million (Figure 18). In recent years, fishmeal exports decreased drastically, whereas the value of exported fish oil was relatively stable at around USD 3 million per year. However, in terms of comparison, the amount of USD 7 162 000 generated by the FDI exports in 2018 represents only 2 percent of total exports of fish commodities (www.fao.org/figis). In addition to exports, five officers who were interviewed at the Ministry of Fisheries and Maritime Economy and the Ministry of Environment and Sustainable Development indicated that though the industry also pays taxes to the Government, there is likely to be tax evasion because of the lack of close monitoring. At the local scale, the main economical contribution corresponds to the incomes earned by workers along the value chain, but also the taxes paid to the municipalities where the factories are located.

9.2.2.5 Impacts for national aquaculture and livestock sectors

In view of the main objective for generating income and increasing the supply of fish for consumption, consistent public investments have been made by the Government in recent years to foster intensive and sustained aquaculture production. In addition, several initiatives have been taken to encourage and support private operators who would like to operate in the sector. However, despite the fairly significant production of fishmeal and fish oil in the country, the lack of availability and affordability of manufactured fish feed remains a major constraint. Regarding the livestock sector which is also very important in the country, the use of manufactured FBF has contributed to its development over the past few years and, more specifically, for use in poultry farming. This type of feed, which had been used for a long time in artisanal form, has now become widespread with the establishment of milling companies. Apart from chicken, to a much lesser extent, other animals such as ruminants have also been more and more fed with manufactured feed that may include a small proportion of FDI. Nevertheless, despite the great potential for using FBF to develop the aquaculture and livestock sectors, most of the FDI production is actually exported. The farmers interviewed stated that FDI are mostly sourced from artisanal fishmeal producers. However, they occasionally solicit some factories in place but their prices are generally high.

FIGURE 18. Value of fishmeal and fish oil export in Senegal during the past decade



Source: Data extracted from the ITC exports online database.

9.2.3 Biological impacts of the fish-based feed industry

9.2.3.1 Impacts of fish-based feed on fishery resources

In Senegal, small pelagics represent the major component of total catches, with at least 70 percent of landings from artisanal fisheries, which are the main suppliers of raw material for FDI production. However, in a context of free access, the artisanal fishing fleet has considerably increased its capacity and effort over the past two decades. Many purse seine canoes operate not only along the entire coastal waters of Senegal but also in neighbouring countries such as the Gambia and Mauritania. In such a context, the establishment of fishmeal and fish oil factories is likely increasing the risk of overexploitation of sardinellas and bonga throughout their distribution area.

9.2.3.2 Impacts of fish-based feed on ecosystems

According to most of the stakeholders who were interviewed, the ecological risks of the FBF industry is related to the pollution of the coastal waters. Because of their liquid wastes produced, the factories are degrading water quality. The officers of the Ministry and Maritime Economy of Fisheries are concerned that the industry has likely been encouraging more bycatch, which can be easily processed into fishmeal and fish oil.

9.3 DETAILED ANALYSIS FOR THE GAMBIA

9.3.1 Development and status of the fish-based feed industry

9.3.1.1 History and development of the industry

Based on interviews in the field, the FBF industry started in the early 2000s in an artisanal form. At that time, raw material was mainly processing wastes such as scales and heads that were then pounded and mixed with other local ingredients. However, more recently, an industrial form emerged with the establishment, in 2016, of modern factories (Avadí *et al.*, 2020). Currently, three factories owned by Chinese investors are operating in the country.

9.3.1.2 Capacity of the industry

Currently, there are three Chinese medium-sized fishmeal and fish oil factories that are located along the Atlantic coast, namely, Golden Lead Import and Export Trade Company based in Gunjur; JXYG Aquatic Products Limited in Kartong; and Nessim Imports and Exports in Sanyang. Any information about the processing and storage capacity of these factories is available. In order to guarantee their supply of raw material, these factories mainly rely on Senegalese purse seiners specifically chartered to fish small pelagic species, but they also benefit from the landings provided by Gambian artisanal fishers, who use encircling gillnets. In addition, a few local farmers have also been using artisanal processing wastes to rudimentarily produce on-farm FBF.

9.3.1.3 Production of the industry

Because official statistics are lacking on the production of FDI and FBF in the Gambia, since almost all fishmeal and fish oil produced are exported, ITC export data were used as a proxy. Based on that information, production of fishmeal increased from 1 555 tonnes in 2017 to 1 969 tonnes in the following year. However, in 2019, production drastically dropped to only about a quarter of its level of 2018. For fish oil, production decreased from 1 378 tonnes in 2017 to 823 tonnes in 2018. In terms of destination, the existing factories are owned by Chinese nationals who produce and export to their home country. However, some local farmers in Tanjeh village, on the west coast of the Gambia, have been recently using fish processing remnants that they mix with other ingredients for poultry feed.

9.3.1.4 Value chain mapping of the industry

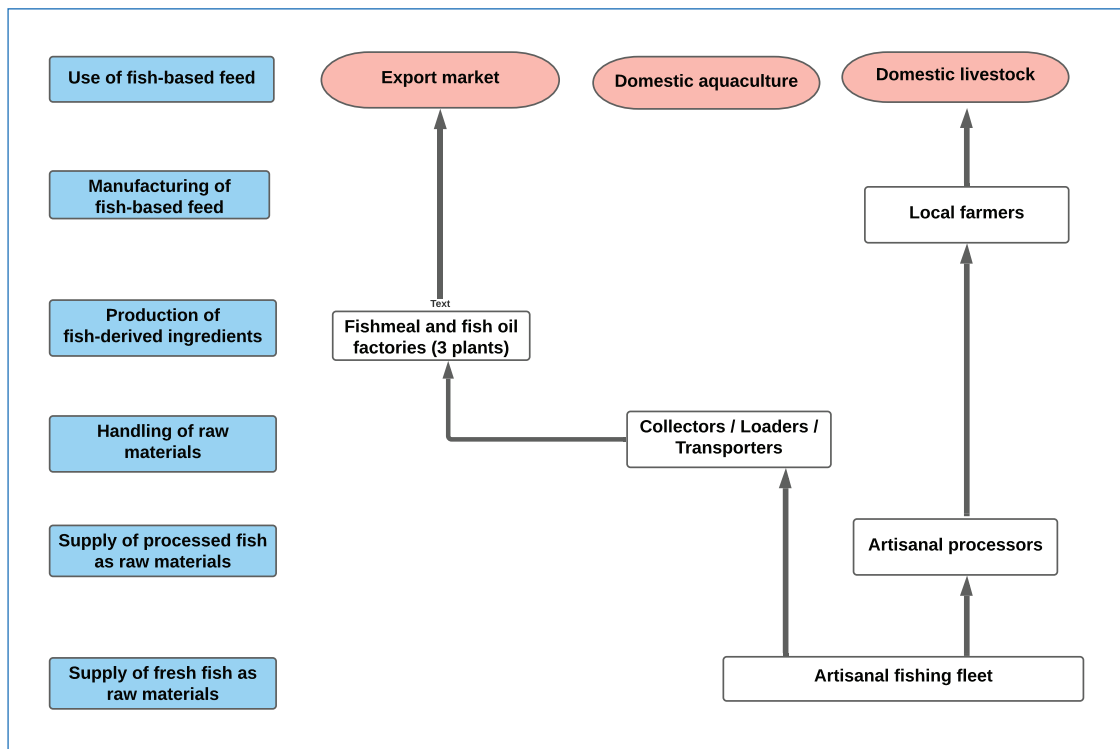
The value chain of the FBF industry in the Gambia is presented in Figure 19. As raw materials, fresh fish used by the fishmeal and fish oil factories is supplied by the artisanal fishing fleet. In charge of handling this raw material, the collectors, loaders and transporters are important intermediaries between the fishers and the FDI producers. Nearly the entire gross production of fishmeal and fish oil is directly sold abroad. Therefore, export is the major end market of these FDI without any feed manufacturing activities. However, there are a few local farmers who obtain fish wastes from artisanal processors, which they mix with other ingredients for poultry feed.

9.3.2 Socio-economic impacts of the fish-based feed industry

9.3.2.1 Impacts for livelihoods in communities

While the expectations in terms of job creation for young people have not yet been met, the existing fishmeal factories are in competition with the other sources of livelihoods (Avadí *et al.*, 2020). On the basis of interviews, interviewees revealed that while factories employ local workers in lower grades, qualified employees along the value chain are generally foreigners. For instance, fresh fish as a raw material is mainly provided by locally based Senegalese fishers, while the technical staff in the factories are usually Chinese nationals. The industry has been significantly undermining post-harvest activities, in particular by depriving women fish processors of raw materials. For example, bonga fish, which is mainly used by fish smokers has considerably become expensive with its price increasing from about GMD 500 (USD 10) for a pan of 30 kg to around GMD 2 000 (USD 40) since commencement of the industry in 2017. Negative impacts on livelihoods also exist for people working in post-harvest activities, such as fish traders and drivers of refrigerated trucks. Despite serious constraints on livelihoods, some local communities reported a few positive impacts. For instance, in the landing site of Kartong, the people who are directly involved in the supply and handling of fish raw material to the local fishmeal factory have stated they earn more income. In addition, workers at the JXYG factory have said they are able to build

FIGURE 19. Value chain mapping of the fish-based feed industry in the Gambia



new and more comfortable houses because of the salaries they obtain from the FBF industry. Some workers have even invested in other activities such as poultry farming.

9.3.2.2 Impacts for national food security

The proportion of people considered to be food insecure in the Gambia has increased from 5 to 8 percent over the past five years, which is partly due to the fluctuating abundance of bonga fish that is heavily targeted by the operating FBF factories (Avadí *et al.*, 2020). Additionally, it has been estimated that in the 2020s, the country will have an average gap of about 15 000 tonnes of extra fish demand to be satisfied every year (Cai and Leung, 2017). Relative to the low size of the national population that is, however, very dependent on fish consumption (24–25 kg/person/year), such a gap in fish demand is considerable. Hence, the establishment of the FBF industry is seen by many local stakeholders to be one of the major causes of the lack of fish in the country. Local communities stated that because fish has become extremely rare and expensive in local markets, obtaining enough to satisfy household need is now almost impossible.

9.3.2.3 Impacts for public health and well-being

Almost all the people interviewed in the Gambia argued that the FBF industry is a major threat to public health and human well-being because of the pollution it causes. In areas where factories are located, local communities have been regularly complaining to authorities, occasionally holding public demonstrations to show their concern and anger. A senior officer at the Ministry of Fisheries and Water Resources explained that the factories generate a thick smoke that makes it difficult to breathe; therefore, there are more frequent respiratory diseases such as asthma that are deemed to be linked to the industry. In addition, because the factories generate bad odours, people are often seen covering their noses when the factories are in operation.

9.3.2.4 Impacts for national and local economies

In 2019, the net operating profit of the FBF industry was estimated at about USD 230 900 with a value added of USD 431 360 (Avadí *et al.*, 2020). Based on ITC data, fishmeal and fish oil exports decreased from USD 332 000 in 2017 to USD 281 000 in 2018, representing less than 0.1 percent of the total value of fish commodities exports (www.fao.org/figis). In the cumulative export values of these two FDI products, fishmeal contributed, respectively, for 57 percent in 2017 and 71 percent in 2018. More recently, in 2019, the estimated export value for fishmeal reached USD 687 000. According to technical officers of the fisheries administration, the FBF factories pay taxes to the Government, but the amount is unknown. Potential tax evasion, however, has been addressed. For instance, in April 2020, the Fisheries Department requested one of the factories to pay GMD 500 000 (USD 9 500) as an annual operational fee. Also, by contributing to reduce post-harvest losses, the FBF industry provides more value added to the economy. At the local level, communities occasionally receive support as part of corporate social responsibility, which includes funding local social and cultural events.

9.3.2.5 Impacts for national aquaculture and livestock sectors

Although aquaculture started in the Gambia in 1979, it has not yet achieved expected results. Despite the establishment of fishmeal and fish oil factories in the country, one of the key constraints is the lack of quality manufactured feed. In fact, the very few fish farmers who use FBF are importing the feeds. Therefore, the existence of the FBF industry in the Gambia does not really benefit aquaculture development. In terms of the livestock sector, significant progress has been made in the Gambia in recent years. However, the farmers who were interviewed said they do not use any products from locally operating FBF factories. Some local farmers, though, are using fish remnants for poultry feed.

9.3.3 Biological impacts of the fish-based feed industry

9.3.3.1 Impacts of fish-based feed on fishery resources

In the Gambia, small pelagic species, particularly sardinellas (*Sardinella aurita* and *S. maderensis*) and bonga (*Ethmalosa fimbriata*) are the most landed fish. These species accounted for 81 percent of total fish landings in 2018 (FAO, 2020b). Before the start of the FBF industry, the volume of catch was limited because of the small size of the local fish market. Since 2017, with the establishment of the factories, the fishers now have fewer constraints to sell their catches and therefore are encouraged to intensify their fishing effort. As a result, the highest level of small pelagic catch (42 662 tonnes) was recorded in 2017 when the three fishmeal factories were fully operational. The last stock assessment by the Working Group of the Fishery Committee for the Eastern Central Atlantic (CECAF) confirmed that the feed industry has been stimulating an increase in fishing effort (FAO, 2020b). This intense fishing pressure has likely been contributing to the exploitation of small pelagics, whose total catch was at a very low level in 2019, at 26 213 tonnes only.

9.3.3.2 Impacts of fish-based feed on ecosystems

According to fishing communities and local populations, fishmeal and fish oil factories directly discharge wastewaters into the sea. Communities and people think this practice of dumping toxic wastes is harmful to the coastal environment and the local aquatic fauna. In addition to the pollution, many stakeholders stated that illegal fishing nets with small mesh sizes used in estuarine areas have been causing more bycatch destined to FDI production.

9.4 DETAILED ANALYSIS FOR SIERRA LEONE

9.4.1 Development and status of the fish-based feed industry

9.4.1.1 History and development of the industry

In Sierra Leone, the Ministry of Fisheries and Marine Resources has never provided a licence for the establishment of a modern FBF industry. Although Asian investors have requested several authorizations in the past, their demands have always been rejected because the ongoing 2018 Fisheries and Aquaculture Act does not make provisions for such investment. Therefore, there is no consistent history of FBF industry in the country. However, according to information collected from the Institute of Marine Biology and Oceanography, there used to be an informal production of fishmeal. This activity was sourced by the catches of Russian fishing fleets that operated in Sierra Leone from 1975 to the late 1980s.

9.4.1.2 Capacity of the industry

Currently, Sierra Leone does not have any physically established fishmeal and fish oil factories. However, it resulted from interviews that there are ongoing destructive fishing practices in artisanal fisheries that are targeting small pelagics during breeding seasons to supply the FBF industry in neighbouring Guinea. A considerable part of artisanal fishers have been engaged in this illegal fishing practice, using small mesh-sized “mosquito nets” to target juvenile fish, which they sun dry and sell to Guinea for poultry feed production. A part of fish directed to this country also includes bycatches that are discarded by industrial trawlers. It is important to mention that two medium-scale milling companies and a few local farmers are rudimentarily manufacturing FBF using artisanal processing wastes and remnants.

9.4.1.3 Production of the industry

Sierra Leone does not have consistent FBF production and no quantitative data about the production. The survey revealed that the two recently established medium-sized feed milling companies have been manufacturing FBF by mixing artisanal dried and pounded fish with other local ingredients such as cereal bran. This product is sold to local poultry and fish farmers. As raw materials, the companies use fish scales, bones and broken pieces collected essentially from artisanal fish processors. Some local farmers also have a rudimentary way of producing on-farm FBF.

9.4.1.4 Value chain mapping of the industry

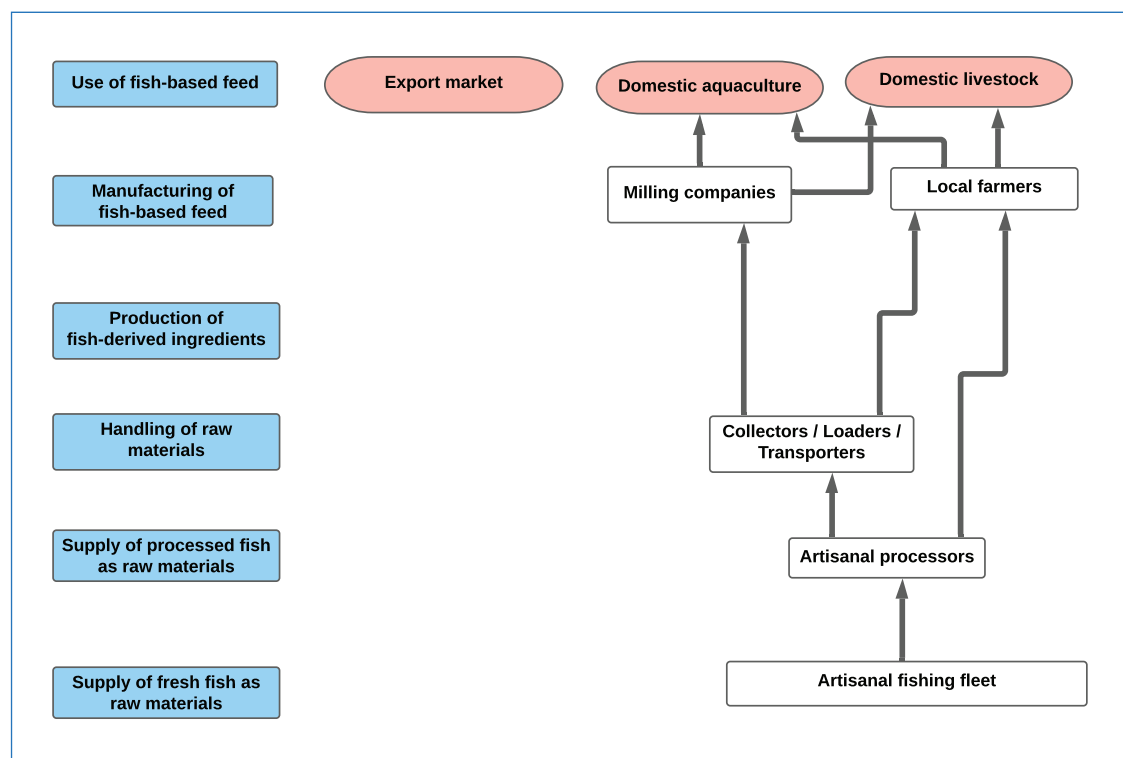
As the FBF industry in Sierra Leone is rudimentary, actors in the artisanal sectors are the key players of the value chain (Figure 20). From the fresh fish provided by the artisanal fishing fleet, artisanal processors generate wastes/remnants that form the bulk of raw materials. After being dried and pounded, the raw materials are used by milling companies and local farmers that produce manufactured FBF mixed with other local ingredients such as cereal bran. In charge of handling these raw materials, the collectors, loaders and transporters are important stakeholders. Some farmers, however, obtain their raw materials directly from artisanal fish processors. All the production is used in the local aquaculture and livestock sectors.

9.4.2 Socio-economic impacts of the fish-based feed industry

9.4.2.1 Impacts for livelihoods in communities

Because a consistent FBF industry in Sierra Leone does not exist, the direct contribution to livelihoods is not significant. The two operating milling companies and on-farm producers have a very limited capacity to create a considerable number of jobs. On the other hand, the destructive fishing practices targeting small pelagics to supply the FBF industry in Guinea have been threatening the source of livelihoods for many people working in the artisanal

FIGURE 20. Value chain mapping of the fish-based feed industry in Sierra Leone



fisheries value chain. Although fishers involved in these practices are earning greater incomes, they are undermining fish availability for hundreds of harvesters and post-harvesters. As a result, they also have been generating more conflicts among local fishing communities.

9.4.2.2 Impacts for national food security

As the FBF industry in Sierra Leone is minor in size, many of the local stakeholders argued that it does not have a significant impact on national food security. However, there is a relatively common consensus on the increasing scarcity of fish in recent years alongside the observation that fish size is becoming smaller. High fishing pressure and multiple illegal bad fishing practices have been indicated as the major causes of this situation. Therefore, all fishing activities consisting in targeting small pelagics to supply the FBF industry in Guinea are strongly blamed by many stakeholders. On the contrary, local FBF producers are deemed to be positively contributing to improving food security. By sourcing the poultry and fish farms, producers have been helping to improve the availability and affordability of animal protein in the country.

9.4.2.3 Impacts for public health and well-being

As the FBF industry is so far very rudimentary in Sierra Leone, there is no significant threat to public health and human well-being. However, concerns have been raised about artisanal processing activities that somehow supply raw material to local milling companies and artisanal producers. Because of the lack of appropriate facilities, the processing activities may likely be harmful for processors, particularly to the health and well-being of women.

9.4.2.4 Impacts for national and local economies

The direct contribution of the FBF industry to the national economy and local economies is negligible. However, as the raw materials are sourced from post-harvest wastes, it helps

to add more value to the fisheries products. In addition, because the industry has been more or less contributing to improve the availability of animal feed, it also indirectly supports the economy by assisting fish and poultry farmers to develop their activities. In contrast, the supply of fish-based raw material to poultry feed producers based in Guinea have negative economic impacts. Fishers engaged in this practice do not generally pay fishing licences and taxes while undermining the sources of incomes for local communities.

9.4.2.5 Impacts for national aquaculture and livestock sectors

The development of the aquaculture and livestock sectors has been very slow in recent years. Pond-based aquaculture was introduced in Sierra Leone in 1976 with the establishment of a government fish breeding station at Makali in Tonkolili District (Kassam *et al.*, 2017). Following this initiative, there were innovations and technical support, including for pond construction and fish farm management. Despite the breakthroughs recorded at that time, the civil war destroyed all infrastructure. Similarly, the livestock sector was also dramatically impacted by this war and despite political will, significant progress has not yet been achieved. In such a context, the availability and affordability of manufactured FBF may inspire these two sectors to take action. Nevertheless, the industry, which is in a rudimentary stage, is not capable of helping to achieve this objective. In a survey carried out in 2017 (Kassam *et al.*, 2017), fish-farmers mainly feed their fish with rice bran (100 percent), termites (95 percent), cassava flour (75 percent), leaves of cassava, sweet potato and other leaves (55 percent), palm kernels (35 percent), meal (20 percent) and on-farm formulated feed (15 percent).

9.4.3 Biological impacts of the fish-based feed industry

9.4.3.1 Impacts of fish-based feed on fishery resources

In Sierra Leone, the total catch of *Sardinella aurita* almost quadrupled between 2016 and 2017, from 16 to 43 tonnes (FAO, 2019). Therefore, in recent years, the fishing mortality of this species has considerably increased. As a targeted species to source the developing FBF industry in neighbouring Guinea, there is an increasing risk of overexploitation for *S. aurita*. In addition to this species, *Ethmalosa fimbriata* and *Ilishia africana* are also targeted and, therefore, may also be threatened.

9.4.3.2 Impacts of fish-based feed on ecosystems

As there is no significant FBF production in Sierra Leone, the impacts on the aquatic ecosystem are deemed to be very minor. So far, marine and estuarine water pollution is not seen as a major problem. However, illegal fishing practices may undermine local biodiversity.

9.5 DETAILED ANALYSIS FOR GHANA

9.5.1 Development and status of the fish-based feed industry

9.5.1.1 History and development of the industry

In Ghana, the booming poultry enterprises from the 1960s to the mid-1980s involved an increasing demand for animal feed, which facilitated the establishment of about 30 milling companies. However, following this favourable period, the number of companies reduced to about 14 in 2010 (FAO, 2014). The availability of quality feed was a major challenge in the fish farming sector until 2011, when the first commercial FBF factory called Raanan Fish Feed West Africa was established. New companies have since emerged, such as Beacon Hill Fish Feed, Ghana Agro Food Company Ltd, AgriCare Ltd and West Africa Limited, whose main products are for poultry and livestock (Rurangwa *et al.*, 2015).

9.5.1.2 Capacity of the industry

Currently two FDI factories are operating in Ghana. They are tuna canneries that have been processing their own by-products into fishmeal and fish oil. Moreover, there are nine large-scale commercial feed milling companies comprising two fish feed and seven poultry and livestock feed factories. In addition, five medium to small-scale mills are producing feed according to customer demand. There are also several artisanal fishmeal producers and local on-farm feed manufacturers.

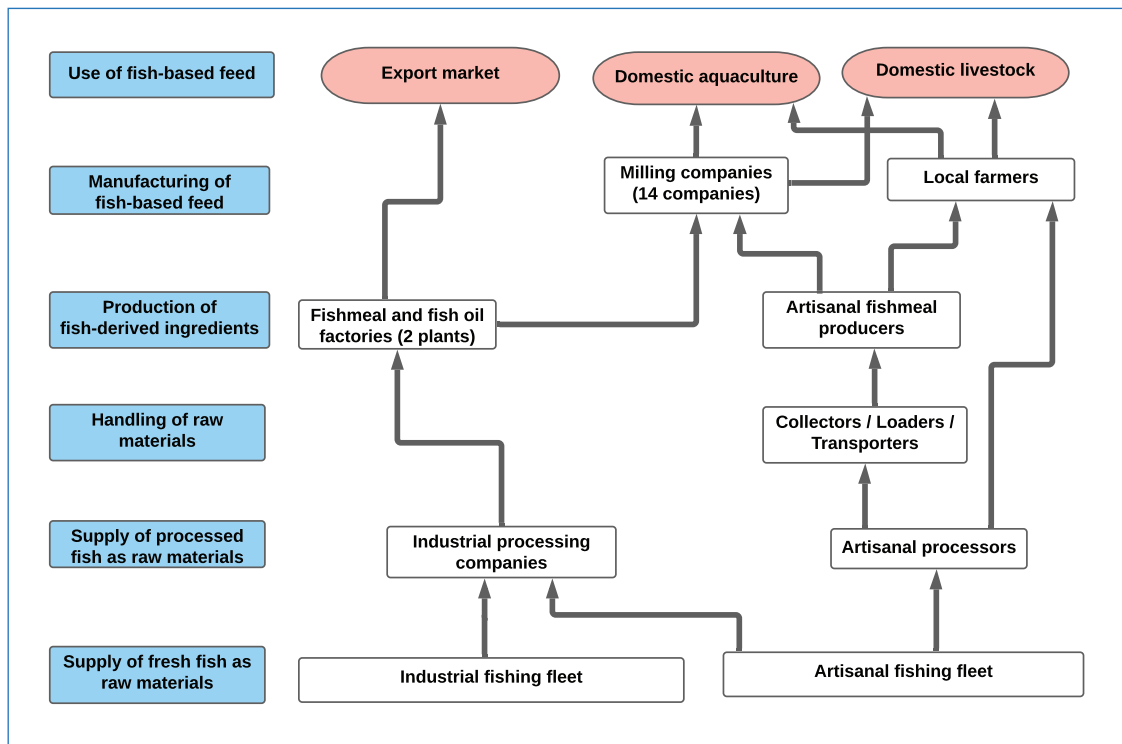
9.5.1.3 Production of the industry

Given an absence of quantitative data on the FBF production, the interviews with five producers allow to better understand some qualitative key aspects. For instance, the existing fishmeal and fish oil factories and artisanal producers are sourced from both industrial and artisanal processors. Their raw materials are wastes and by-products of tuna, herring, anchovy and mackerel as well as cuttlefish and octopus. Also, the use of freshwater silver cyprinid (*Rastrineobola argentea*) has also been reported in the literature (Hecht and Jones, 2009).

9.5.1.4 Value chain mapping of the industry

With nine types of actors acting in the different functions, the FBF value chain in Ghana is relatively complex (Figure 21). Raw materials are generated by the industrial and artisanal processors that are supplied by both fishing fleets. Collectors, loaders and transporters have the responsibility for handling these raw materials to supply the fishmeal factories and artisanal producers. However, some farmers directly obtain processing wastes from artisanal processors. Even if part of the FBF produced is exported, the domestic aquaculture and livestock sectors are also end markets. They are supplied in manufactured FBF by the milling companies and local farmers.

FIGURE 21. Value chain mapping of the fish-based feed industry in Ghana



9.5.2 Socio-economic impacts of the fish-based feed industry

9.5.2.1 Impacts for livelihoods in communities

The FDI factories as well as most of the feed milling companies recruit their workers from the immediate or neighbouring communities where they are located; therefore, they provide opportunities for employment and contribute to generate income and enhance social stability. The type of employment and number of jobs created vary with the size of the company. The number of staff is relatively low in small companies, such as Akwaaba Feed, which has only 17 permanent employees (15 men and 2 women). Companies may have more than 100 employees in medium- and large-sized producers such as Raanan Fish Feed West Africa (100 men and 30 women). Regarding the fishing communities, the industry provides incomes to fishers, processors and other workers in the value chain.

9.5.2.2 Impacts for national food security

In Ghana, fish is the preferred and cheapest source of animal protein, both for poor and rich people in rural and urban areas. It makes up 22.4 percent of household food expenditure and 60 percent of the population's protein diet (MoFAD, 2018). Per capita fish consumption is estimated at 20–25 kg, higher than the West African average (MoFAD, 2018). In such a context, most of the local stakeholders stated that an increase in FDI production using edible fish may aggravate the problem of its availability and affordability in the country. However, the contribution of the FBF industry for the development of the livestock and aquaculture sector is seen to be an important opportunity to improve food security and nutrition. It can help to improve the availability of cheaper meat and farmed fish. On the other hand, a considerable part of money earned by direct and indirect workers along the value chain may be a good contribution for food security and nutrition, but this is not guaranteed as the extra income earned may also be used for other needs.

9.5.2.3 Impacts for public health and well-being

The risks on public health and well-being are deemed to be very limited both for local communities and workers. In all factories and milling companies visited, the workers were equipped with protective means such as head gear, face masks and earplugs, which are provided by their employers. The major problem pointed out by some local populations was the noise generated from operating milling companies. Because of routine inspections by the Environment Protection Agency, discharge of wastes is generally well monitored and regulated.

9.5.2.4 Impacts for national and local economies

Although Ghana is not a big FBF producer, this industry manages to contribute to improving the trade balance. Based on ITC data, in 2019, the total value of fishmeal and fish oil exports was, respectively, USD 2 312 000 and USD 1 731 000. However, this cumulated amount represented only 2 percent of the total value of fish commodities exports estimated at USD 226 858 000 in 2019 (www.fao.org/figis). In terms of taxes, the contribution to the national and local economies is relatively low due to the very attractive investment policy in place in the country. The Government offers agribusiness companies a five-year tax exoneration. In addition, companies registered under the Ghana Free Zones Authority, such as the two fishmeal factories, are taxed at a rate of 1 percent of their net profit for the first ten years of operation, and thereafter at a rate of 15 percent. There are also location-based tax rebates for manufacturing agribusinesses, such as the milling company Akwaaba Feed, that are located in a remote district out of a regional capital. However, income generated by the FBF industry for its workers and local communities has to be considered as a positive impact.

9.5.2.5 Impacts for national aquaculture and livestock sectors

Although important efforts have been made in recent years, the development of the aquaculture and livestock sectors in Ghana has been mainly hampered by the high cost of efficient manufactured feed. As a result of the increasing demand, most of the feed sold by local vendors are below the recommended standards. For example, while commercial fish feed for tilapia usually contains 24 percent to 28 percent crude protein, most of the local farmers hardly can afford to buy it and instead use feed with lower protein levels, such as rice bran, brewer's waste, groundnut bran and maize bran (Amenyogbe *et al.*, 2018). On the other hand, considering the livestock sector, manufactured feed in general and FBF in particular are expensive and not available enough on a regular basis. Because of this gap, poultry farms and piggeries usually have to resort to other local ingredients to produce feed.

9.5.3 Biological impacts of the fish-based feed industry

9.5.3.1 Impacts of fish-based feed on fishery resources

There are two types of artisanal purse seines (25 mm and 10 mm mesh size) and beach seines (10 mm mesh size) targeting small pelagic species in Ghana. In 2016, 3 346 purse seine and 1 084 beach seine canoes, all powered by outboard motors of 40 hp, were operating along the entire coast. This very heavy fishing pressure is certainly the major factor that led to the potential depletion of sardinellas off Ghana and neighbouring countries (FAO, 2019). Considering all major small pelagics, total catch of these species strongly decreased from 134 000 tonnes in 2012 to 119 000 tonnes in 2017, with in general, relatively low total catches during the past five years (FAO, 2019). In such a context, any attempt to target these species for FBF production may likely worsen the situation.

9.5.3.2 Impacts of fish-based feed on ecosystems

Because of regular inspections made by the Environment Protection Agency, most managers of FBF factories and milling companies declared having taken appropriate measures to limit their wastes discharges in the open environment. Therefore, pollution of the aquatic ecosystems is not seen as a major ecological threat. This statement was confirmed by local communities, who think that the risk is minor.

9.6 DETAILED ANALYSIS FOR THE CONGO

9.6.1 Development and status of the fish-based feed industry

9.6.1.1 History and development of the industry

The FBF industry is quite recent in the Congo. Based on the political will of the Government for promoting private investments in the fisheries sector, the Ministry of Fisheries allowed the establishment of the first fishmeal and fish oil factory in the country. Therefore, in 2015–2016, the Chinese company Rong Chang Long Distance Fishing was built near the major coastal city of Pointe Noire in Southern Congo. In fact, it is an industrial complex that sits on 15 hectares.

9.6.1.2 Capacity of the industry

Currently, the Congo has one fishmeal and fish oil factory that is fully operational since 2017. It has eight production lines, each equipped with a tank whose capacity is 30 tonnes of fresh fish corresponding to a potential production of 7 tonnes of fishmeal and 2.5 tonnes of fish oil. The factory has its own fishing fleet, which markedly increased from 10 vessels in 2017 to 37 in 2019. A landing dock of about 200 metres was specifically built and directly connected to the factory, allowing to transport the landed fish immediately from the vessels to the production lines by mechanical trolleys. There is a storage shed of 5 000 to 6 000 square metres to protect the products from any source of deterioration.

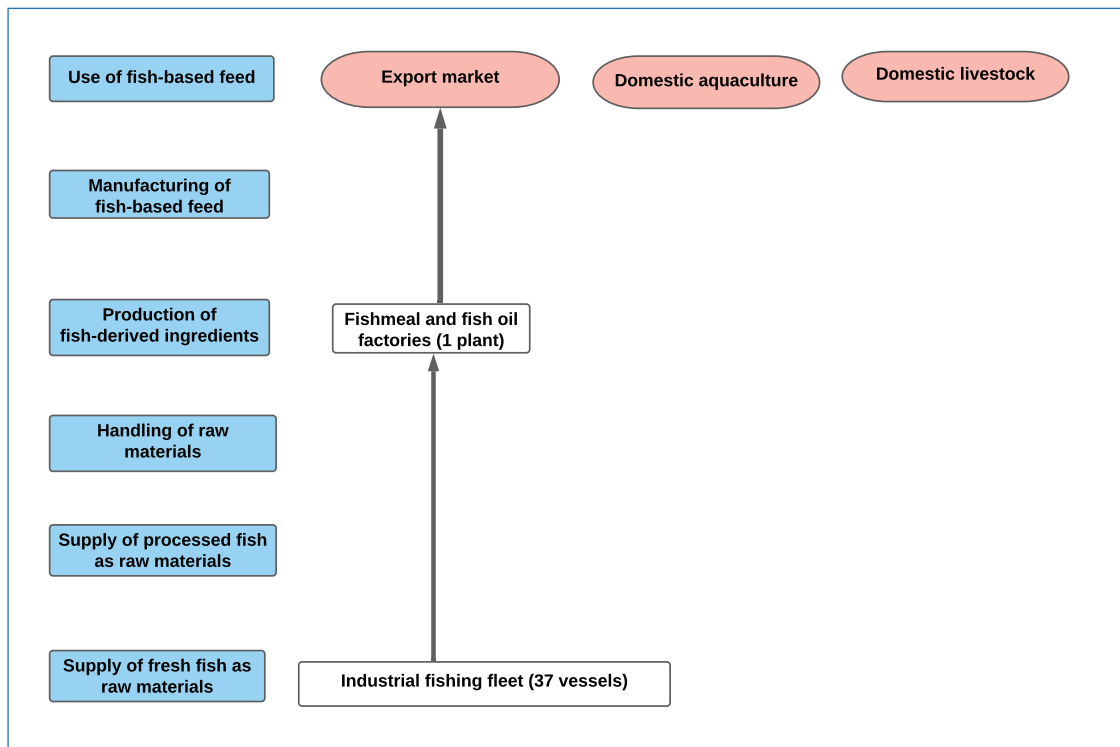
9.6.1.3 Production of the industry

Based on data provided by the Directorate of Fisheries and Aquaculture, over the period from 25 December 2017 to 20 November 2018, the factory processed 21 555 tonnes of fresh fish. This fish processing allowed for production of 7 409 tonnes of fishmeal and 1 796 tonnes of fish oil. In 2019, the volume of fresh fish processed was 23 730 tonnes with a declared production of 4 746 tonnes of fishmeal and 500 tonnes of fish oil. However, considering the quantities of fish processed in this year and the corresponding yields in 2018, the production declared in 2019 was largely underestimated. Based on the average conversion ratio of 4.5 (Péron, Mittaine and Le Gallic, 2010), production might logically be at least around 8 000 tonnes of fishmeal and 2 000 tonnes of fish oil. Small pelagics, and more specifically the sardinellas, constitute the bulk of the raw materials. All the production of fish meal and fish oil is sold abroad, particularly to China.

9.6.1.4 Value chain mapping of the industry

The FBF value chain in the Congo has two types of actors (Figure 22). The industrial fishing fleet supplies the factory with fresh fish raw material for fishmeal and fish oil production. Because of the landing dock that is directly linked to the factory, there is no intermediary actor in the handling function. The entire gross production is directly sold abroad to China. Export is the only end market of FDI produced without any FBF manufacturing activities.

FIGURE 22. Value chain mapping of the fish-based feed industry in the Congo



9.6.2 Socio-economic impacts of the fish-based feed industry

9.6.2.1 Impacts for livelihoods in communities

In 2017, when the fishmeal and fish oil factory opened, it employed 330 workers, 39 percent of whom were permanent workers (Figure 23). However, only 30 percent of these workers came from local communities. During the next two years, the total number of jobs dropped significantly, numbering 100 workers in 2018 and only 55 in 2019. At the same time, jobs became even more precarious, as employees largely became temporary workers (90 percent in 2018 and 82 percent in 2019). The employees who were interviewed stated that the money they receive from the industry allows them to meet the basic needs of their families. Although the FBF industry has been contributing to job creation, it has also been undermining other livelihood opportunities. Local communities have argued that the industry has been operating to the detriment of jobs in artisanal fisheries and the associated post-harvest activities, such as fish trading and processing, where many women work.

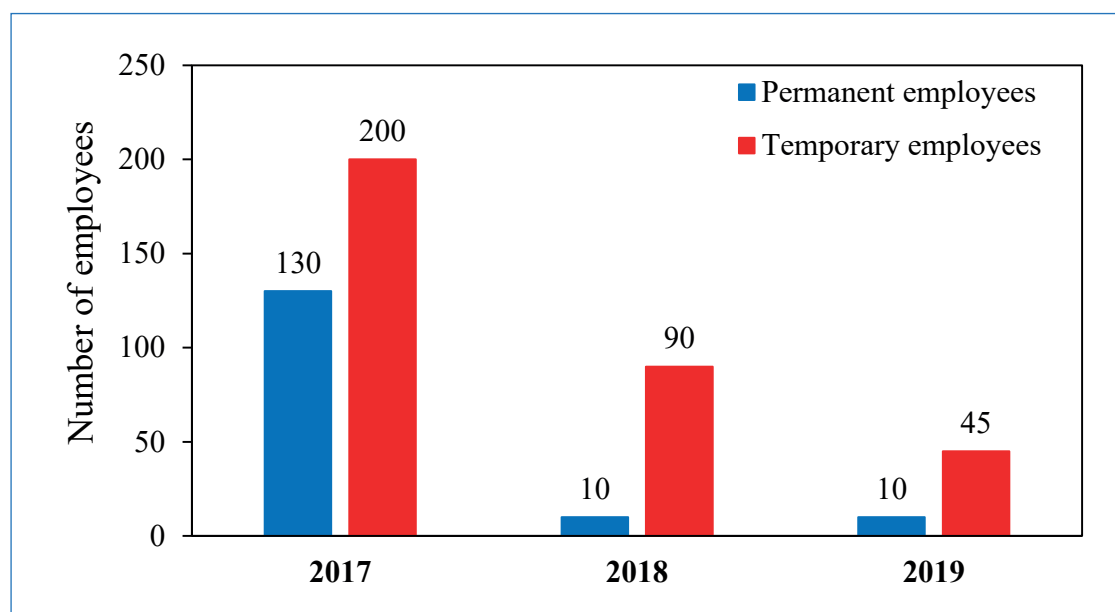
9.6.2.2 Impacts for national food security

Given the high cost of meat, the Congolese people resort to eating fish, which used to be relatively inexpensive to buy. Currently, national production is unable to satisfy the domestic growing demand for fish. According to the Ministry of Fisheries, the country imports about 40 percent of fish consumed. In such a context, the establishment of the first but huge FDI factory is seen as a competitor that may worsen the lack of fish for consumption. This risk is even greater, as small pelagics that are targeted for raw material are the most consumed species in the country. For consumers, severe fish scarcity resulted in soaring prices for sardinellas at local landing sites and markets.

9.6.2.3 Impacts for public health and well-being

In the Congo, the operating FDI factory which is located in the coastal area, dumps its wastes in the sea without prior treatment. Many people think the harmful substances in the wastes will lead to food poisoning through the fish caught in the area and consumed locally. In addition, the bad odours and thick smoke have been polluting the air, making it difficult to breathe. After the three years in which the factory has operated, people living close to the structure have started raising serious concerns about the effects of the factory on the environment. Respiratory diseases are the most frequently mentioned public health and well-being issue.

FIGURE 23. Number of employees in the fish-based feed industry in the Congo



9.6.2.4 Impacts for national and local economies

In the Congo, the FBF industry has recently emerged. Therefore, its impacts on the national economy and local economies are thus far considered to be relatively low. However, based on ITC exports data, the contribution to the trade balance was cumulatively estimated at USD 2 478 000 in 2019, corresponding to 42 percent of the total value of fish commodities exports (www.fao.org/figis). Fishmeal accounted for USD 2 300 000 while fish oil provided USD 178 000. The industry pays taxes, which are, however, deemed to be negligible compared to the capacity of the factory.

9.6.2.5 Impacts for national aquaculture and livestock sectors

The aquaculture sector in the Congo is in its initial stages. Its production system is essentially based on subsistence farms with low yields of between 500 kilograms and 1 tonne/hectare per year against a potential of 20 tonnes in an intensive system. In addition, the Congo has always based most of its economic and social development on oil exploitation, weakening the livestock sector. Efforts, however, are being made to change both sectors, especially in poultry farming. Despite the opportunities the FDI factory may offer, it makes no significant contribution to the development of the aquaculture and livestock sectors. All fishmeal and fish oil produced are exported, while local farmers overwhelmingly use local feed ingredients.

9.6.3 Biological impacts of the fish-based feed industry

9.6.3.1 Impacts of fish-based feed on fishery resources

In the Congo, the fishing pressure is thus far relatively low with, for instance, 685 canoes recorded in 2017 (FAO, 2019). On the other hand, after reaching seven vessels in 2000, the number of sardine boats has never exceeded five units since 2001. In terms of catch, 20 000 tonnes of *Sardinella aurita* and 23 000 tonnes of other sardinellas (*Sardinella* spp.) were recorded in 2017. This level of total catch for all sardinellas corresponds to about 35 percent of the maximum recommended in the entire distribution area (FAO, 2019). However, although fishing pressure remains relatively low, the sardinella stock is fully exploited and therefore may be very vulnerable to the emerging FBF industry in the Congo.

9.6.3.2 Impacts of fish-based feed on ecosystems

Because the factory was established three years ago, its ecological impacts on the local aquatic ecosystems are still not well known. However, some people interviewed fear the potential impacts of the liquid wastes discharged directly into the sea.

9.7 DETAILED ANALYSIS FOR MALAWI

9.7.1 Development and status of the fish-based feed industry

9.7.1.1 History and development of the industry

The production of FBF in Malawi dates back to the 1960s when the Government decided to promote intensive livestock farming that required the availability of protein feed ingredients (Safalaoh, 2002; Kang'ombe, Kapute and Ntenjera, 2009). However, the industry, which has never been competitive, has been rather dormant in recent years. Apart from a rudimentary artisanal production system, farmers have always relied on imports mainly from the United Republic of Tanzania. Currently, there are some uncounted small milling companies manufacturing FBF on customer demand. However, their outputs are generally below recommended standards and not suitable for the poultry and fish species farmed in the country.

9.7.1.2 Capacity of the industry in Malawi

Malawi does not have an FDI factory. Although there are some small milling companies that are manufacturing FBF by mixing fish remnants with other local ingredients, they are mainly operating on customer demand. The daily capacity of these milling companies is about 2 tonnes, but they do not operate regularly. Some local fish and livestock farmers also rudimentarily produce FBF for themselves.

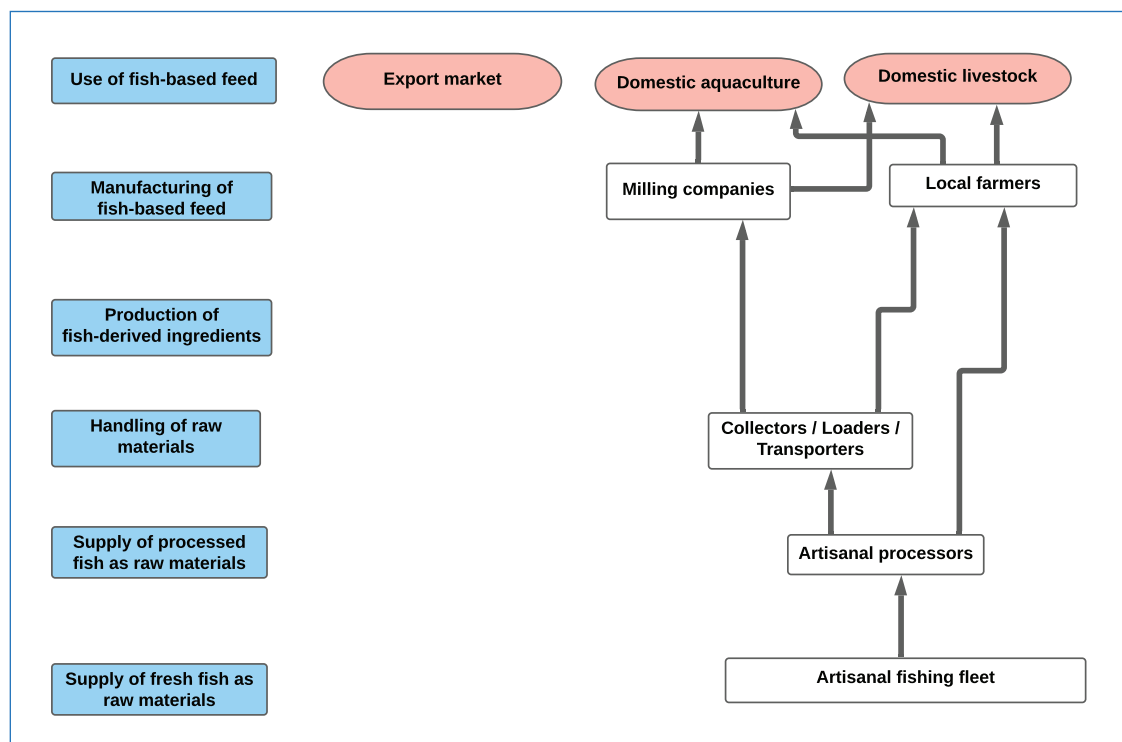
9.7.1.3 Production in Malawi

The FBF industry is based on an artisanal production system. There are no quantitative data regarding the level and trend of the production. Raw materials are composed of artisanally processed Lake Malawi sardine (*Engraulicypris sardella*), a cyprinidae locally known as usipa. The storage duration of the production does not generally exceed three months before being supplied to local customers.

9.7.1.4 Value chain mapping of the industry

Because the FBF industry is rudimentary, artisanal actors are key players of the value chain (Figure 24). From the fresh fish provided by the artisanal fishing fleet, artisanal processors sun dry the fish that is supplied to artisanal fishmeal producers. The collectors, loaders and transporters are also important actors due to being in charge of the handling of this raw material, although some local farmers deal directly with artisanal processors. The local milling companies and local farmers manufacture FBF by mixing the artisanally made fishmeal with other local ingredients such as cereal bran. The whole production is used in the domestic aquaculture and livestock sectors.

FIGURE 24. Value chain mapping of the fish-based feed industry in Malawi



9.7.2 Socio-economic impacts of the fish-based feed industry

9.7.2.1 Impacts for livelihoods in communities

In Malawi, the FBF industry is not substantially developed. Therefore, its impacts on livelihoods for local communities is very limited. However, the growing use of FBF has the potential to create more jobs and increase incomes for workers along the value chain.

9.7.2.2 Impacts for national food security

Impacts of the FBF industry on national food security and nutrition are not very significant. However, it has been contributing in various degrees to the availability of meat and fish through the use of manufactured feed in the livestock and aquaculture sectors. In addition, part of the money earned by workers along the value chain may help to purchase food for their households.

9.7.2.3 Impacts for public health and well-being

Although the FBF industry in Malawi is still rudimentary, some concerns have been raised about its potential negativity on public health and well-being. The most important complaint from workers along the value chain is the lack of protective equipment. In the artisanal fishmeal workshops and milling companies, the inadequacy of technical equipment in the production process as well as the lack of skills in the maintenance of machinery is considered to be a major risk. Because of this situation, there are frequent injuries among workers.

9.7.2.4 Impacts for national and local economies

The direct contribution of the FBF industry to the national economy and local economies is limited in Malawi. Although, the industry provides income to many workers along the value chain, its inability to export does not help to improve trade balance in the country.

9.7.2.5 Impacts on aquaculture and livestock development

The level of FBF production is so low that the contribution of this industry on the aquaculture and livestock sectors is not very significant. Although there are some local FBF milling companies, their products lack quality and remain expensive for local farmers. Most of the available FBF products of better quality are imported.

9.7.3 Biological impacts of the fish-based feed industry

9.7.3.1 Impacts of fish-based feed on fishery resources

The FBF industry is sourced from the cyprinidae *Engraulicypris sardella*, locally known as usipa. Despite the lack of consistent data, local stakeholders stated that the fish stock is still in a good situation. The total catch from Lake Malawi varies between 60 000 and 90 000 tonnes per year with a rapidly increasing contribution of usipa, representing around 60 to 70 percent in recent years (Kolding *et al.*, 2019). These results may indicate that this species has not yet been threatened by the operating FBF industry.

9.7.3.2 Impacts of fish-based feed on ecosystems

Considerable impacts on the aquatic ecosystems have not been noted by local stakeholders. Despite the use of usipa by local feed producers, the risk for the lake ecosystem remains very low.

9.8 DETAILED ANALYSIS FOR THE UNITED REPUBLIC OF TANZANIA

9.8.1 Development and status of the fish-based feed industry

9.8.1.1 History and development of the industry

Starting from a rudimentary form, the FBF industry has existed in the United Republic of Tanzania for a long time, as some people used to mix fish processing wastes with cereal bran to feed their domestic animals. An industrial production system, however, emerged during the post-independence period of the 1960s and the 1970s. In this regard, feed availability was considered a priority by the Government in order to foster the development of the livestock sector as a means for achieving rural socio-economic transformation. The first company was established in 1973 with a fleet of four fishing boats, which were able to produce 60 tonnes of fishmeal per day. Similarly, the Government established allied companies, including the United Republic of Tanzania Animal Feed Company (TAFCO), the National Poultry Company (NAPOCO) and the National Milling Corporation (NMC). These companies used to purchase fishmeal as an important ingredient in animal feed production. The setup lasted for about 10–15 years before almost everything collapsed, as the public-led economic model failed to deliver return on investment. Following the recent relaunch of the industry, some medium- sized FBF factories and milling companies are currently in place.

9.8.1.2 Capacity of the industry

Based on field visits, 11 industrial fishmeal and fish oil factories and milling companies are operating in the United Republic of Tanzania. Their capacity varies strongly according to the type of activity (FDI production and FBF manufacturing). The total cumulated production capacity of the industry is about 4 635 tonnes of FBF per year. In addition to the industrial factories, small artisanal fishmeal producers are also identified. FBF is manufactured by milling companies as well as by local farmers who mix fishmeal with other ingredients to sell in local markets.

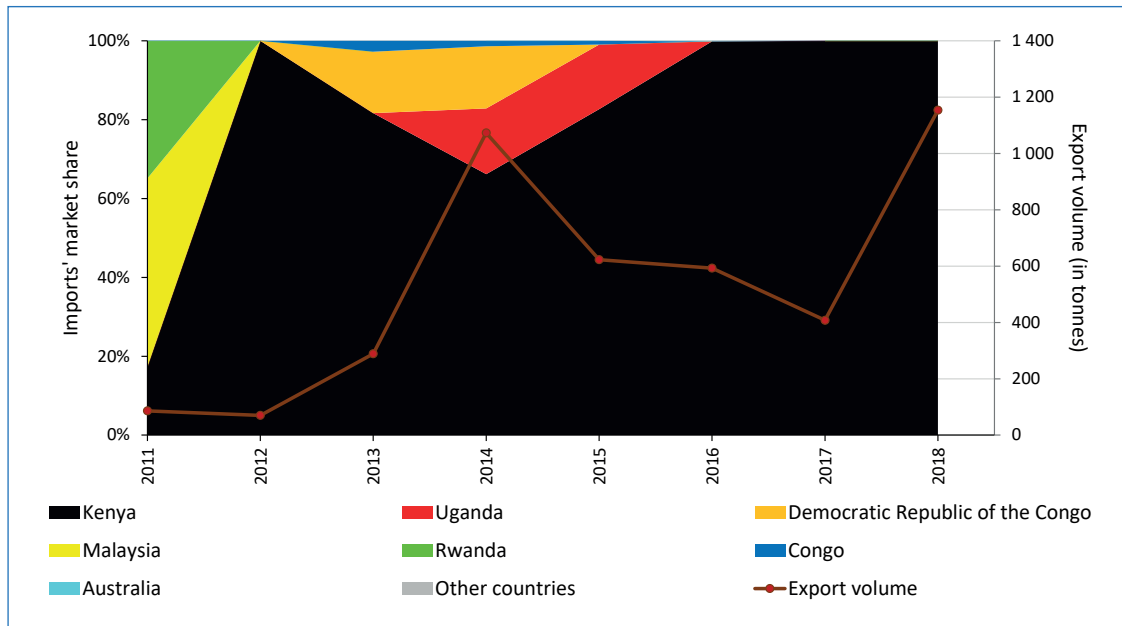
9.8.1.3 Production of the industry

Official data about the production of FDI and FBF are lacking in the United Republic of Tanzania. However, most of the stakeholders argued that production is largely constrained by an inadequate supply of fish for raw materials. In years past, fishmeal was produced from the huge stock of haplochromine in Lake Victoria. During recent years, however, there is a strong decrease in the abundance of haplochromine because of overfishing and the expansion of predators, mainly Nile perch; therefore, now the production relies essentially on alternatives species. According to data provided by the Ministry of Livestock and Fisheries, with around 25 000 tonnes per year, silver cyprinid (*Rastrineobola argentea*), known as dagaa, accounted for about 60 percent of fish dried and processed into fishmeal. The second source in terms of volume is related to processing by-products of Lake Victoria Nile perch that represent about 21 percent.

9.8.1.4 Destination of fish-derived ingredient produced

In addition to a proportion used in the country, a part of fishmeal produced in the United Republic of Tanzania is sold abroad, mainly to East African countries (Isaacs, 2016). However, according to ITC data, exports have strongly fluctuated over the past decade (Figure 25). Between 2011 and 2014, exports increased sharply from 86 tonnes to a peak of 1 073 tonnes. In the following years, the variability of exports has been very important. Kenya has always been the major destination over the decade. However, the United Republic of Tanzania's fishmeal buyers include Malaysia and Rwanda with, respectively, 47.7 percent and 34.9 percent of market share in 2011, as well as the Congo, the Democratic Republic of the Congo and Uganda. Regarding fish oil, no export has been reported in recent years. However, among the 18 exported in 2014, 15 were destined to the Democratic Republic of Congo.

FIGURE 25. Volume of fishmeal export of the United Republic of Tanzania and importers' market shares

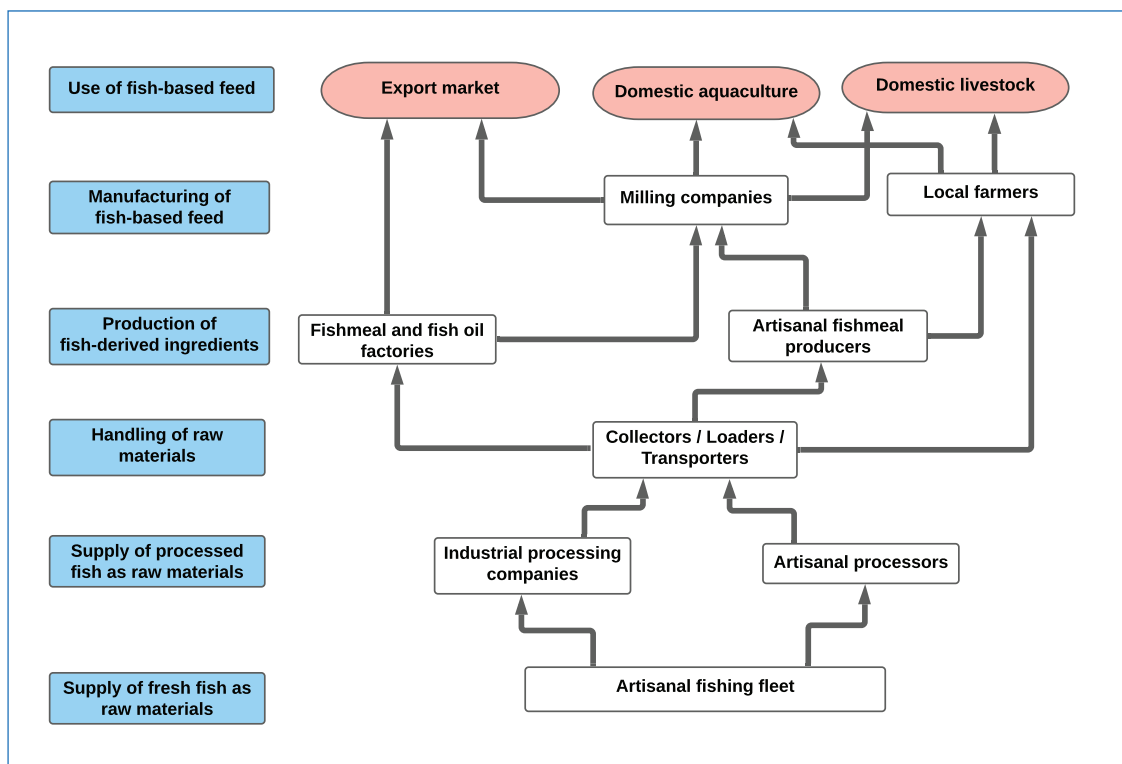


Source: Data extracted from the ITC exports online database.

9.8.1.5 Value chain mapping of the industry

Various types of actors are active in the different functions of the value chain in the United Republic of Tanzania. (Figure 26). The artisanal fishing fleet provides fresh fish, which is then artisanally processed and used for FDI production (essentially fishmeal). Collectors, loaders and transporters are in charge of handling the raw materials. Both exports and the domestic aquaculture and livestock sectors are the end markets of the FDI and manufactured FBF.

FIGURE 26. Value chain mapping of the fish-based feed industry in the United Republic of Tanzania



9.8.2 Socio-economic impacts of the fish-based feed industry

9.8.2.1 Impacts for livelihoods in communities

The FBF industry in the United Republic of Tanzania is labour intensive and thus is a pro-employment production system. Currently, according to the Ministry of Fisheries, the industry has been employing over 20 000 workers in the value chain; this number includes direct and, especially, indirect jobs. Workers include fishers, collectors, loaders, transporters and fish driers, as well as workers in factories and milling companies.

9.8.2.2 Impacts for national food security

The industry is not a significant threat to national food security in the United Republic of Tanzania, according to local stakeholders. The bulk of FDI and FBF being produced originates from low-grade marine and freshwater sardines, mainly dagaa. The real but limited concern in terms of food security is related to the increasing volumes of freshwater shrimp from Lake Victoria and shrimp from marine waters that are being used for fishmeal production. Although small shrimps are not popular for urban consumers, they are important food items for rural coastal communities. On the other hand, a part of FBF produced is deemed to be contributing to improve the availability of meat from farmed livestock and fish.

9.8.2.3 Impacts for public health and well-being

Before the advent of the FBF industry in the United Republic of Tanzania, fish processors in Lake Victoria were facing a real problem regarding the careless disposal of tonnes of wastes, which were being dumped directly on the ground. In addition to the mountains of non-edible low-quality fish left on the ground, the wastes were causing pollution, which was harmful to community health and well-being. In such a context, the FBF industry is seen as a blessing contributing to a cleaner and more pleasant living environment. On the other hand, workers in the fishmeal value chain, particularly the processors and loaders supplying raw materials to the industry, have been facing health risks. Because of a lack of adequate protective equipment and measures, workers are usually wounded by fish bones while regularly suffering from respiratory diseases because of the processing smoke and dust they permanently breathe. However, there are a number of ongoing and/or envisaged efforts at the national and local levels to improve health conditions and the work environment. These efforts include promotion of hygiene and safety practices as well as environmental and social impact assessments for processing factories.

9.8.2.4 Impacts for national and local economies

Part of the fishmeal produced in the United Republic of Tanzania is exported and therefore contributes towards improving trade balance. Based on ITC data, the value of fishmeal exports has increased strongly in recent years. From USD 12 000 in 2016, the amount almost doubled the following year. In 2019, the amount reached USD 63 000, which, however corresponded to only less than 0.1 percent of total exported fish commodities (www.fao.org/figis). On the other hand, based on information provided by the Ministry of Fisheries, the FBF industry generates over TZS 1.4 trillion per year (USD 600 million) of total revenue earned by workers. It has been estimated that this industry annually pays over TZS 5 billion (USD 2 million) to the Government as taxes and royalties.

9.8.2.5 Impacts for national aquaculture and livestock sectors

Demand for manufactured feed has strongly increased in recent years to support the rapid development of the aquaculture and livestock sectors. As a result, FBF have become less available and barely affordable to many local small-scale farmers (Rukanda, 2018). Farmers

mainly rely on low-quality FDI produced locally, which they combine with other ingredients such as cassava flour, rice bran, sunflower oil, soya bean meal and seed cake. As for commercial farmers, they prefer buying imported feed to guarantee more quality and safety.

9.8.3 Biological impacts of the fish-based feed industry

9.8.3.1 Impacts of fish-based feed on fishery resources

In addition to dagaa (*Rasteneobola argentea*), which is the major source of raw materials for fishmeal, other species used by the FBF industry are Nile perch (*Lates niloticus*), freshwater sardine (*Caridina nilotica*), sergestid shrimp (*Acetes* spp.) and other species, especially of the families Engraulidae (*Stolephorous commersonnii* and *Stolephorus indicus*) and Clupeidae (*Spratelloides gracilis* and *Sardinella albella*). The risk of overexploitation is very low, particularly for species fished in the Tanzanian part of Lake Victoria, where the cumulative maximum sustainable yield stands at about 2 210 000 tonnes, while the current total catch is only around 248 600 tonnes per year (LVFO, 2017). In the case of dagaa in Lake Victoria, its biomass stands at over 1.3 million tonnes, while the total annual catch is around 130 000 tonnes. Because of dagaa's rapid growth rate and short life cycle, local scientists have argued that its exploitation at a yearly level of 70 percent of its biomass is possible without threatening the stock. A similar situation has been discussed for the four Engraulidae and Clupeidae species mentioned above, whose potential yield in inshore waters is estimated at about 100 000 tonnes per year, while annual catch is still limited to around 56 000 tonnes. Regarding freshwater shrimp (*C. nilotica*), hydroacoustic surveys done in 2019 indicated that the estimated lake-wide mean biomass was 565 348 tons, representing about 21 percent of the total biomass in Lake Victoria (LVFO, 2019). Only a tiny fraction is harvested but former research indicated that the sustainability of the fisheries of Lake Victoria depends among other things on the abundance and availability of *C. nilotica* because it is an important food source for the fish stocks (Budeba and Cowx, 2007). Regarding marine sergestid shrimp (*Acetes* spp.), there is no available relevant data that inform about the risk of the FBF on the status of the stock.

9.8.3.2 Impacts of fish-based feed on ecosystems

In terms of impacts, the main reproach against the FBF industry is its liquid wastes that have been causing water pollution in Lake Victoria. On the other hand, it has also been contributing to reducing the discharges of processing solid wastes that may be harmful to the ecosystem.

9.9 DETAILED ANALYSIS FOR UGANDA

9.9.1 Development and status of the fish-based feed industry

9.9.1.1 History and development of the industry

An important step in the development of the FBF industry has been the promulgation of the Uganda National Feed Policy aiming to improve animal productivity. Hence, there has been a need to supplement the conventional feed resources with compounded feed (MAAIF, 2005). Then, due to many other policies and plans, there has been a rise in the manufacture and use of FBF when considerable volumes of mukene/dagaa (*Rastrineobola argentea*) started being processed into fishmeal for animal manufactured feed. Considering the growing demand, many traders who used to deal in human consumption shifted to FBF activities that were largely more profitable. Until end of the 2000s, the bulk of fishmeal used in the aquaculture sector was made in the country (Rutaisire, 2007).

9.9.1.2 Capacity of the industry

In recent years, the number of milling companies involved in FBF production has continued increasing (Figure 27). From only two companies in 2015, the number became ten two years later, peaking at 12 in 2019; however three companies were not operational and one was under construction. Based on discussions with producers, the average installed capacity of these companies is about 500 tonnes per week. On the other hand, there are tens of small-scale milling companies that have never been enumerated. From interviews, their average production capacity is around 5 tonnes per week. On the other hand, there are several artisanal producers that also supply local fish and livestock to farmers.

9.9.1.3 Production of the industry

Owing to lack of quantitative data, it was not possible to analyse the recent trend of FBF production in Uganda. Although standards have been defined by East African countries to harmonize requirements governing the quality of fishmeal within the region (EAC, 1999), most of the producers do not fulfil them as their production is essentially destined for local fish and livestock farmers. Two peaks of production are recorded every year in relation with the major annual festive periods. The first is from October to early December, preceding Christmas. The second is April, just before Easter. During these periods, demand for chicken is high, hence demand for manufactured FBF.

9.9.1.4 Value chain mapping of the industry

Several types of actors intervene in the different functions of the value chain (Figure 28). Supplied with fresh fish by both industrial and artisanal fishing fleets, the artisanal processors play a key role. They are in charge of drying mukene before delivering it to artisanal fishmeal producers and millers. Although some processors directly supply the milling companies and artisanal millers, there are also collectors, loaders and transporters who intervene in the handling of the dried mukene used as raw materials. All national production of manufactured FBF is entirely sold to the domestic aquaculture and livestock sectors.

FIGURE 27. Number and status of feed factories in Uganda in recent years

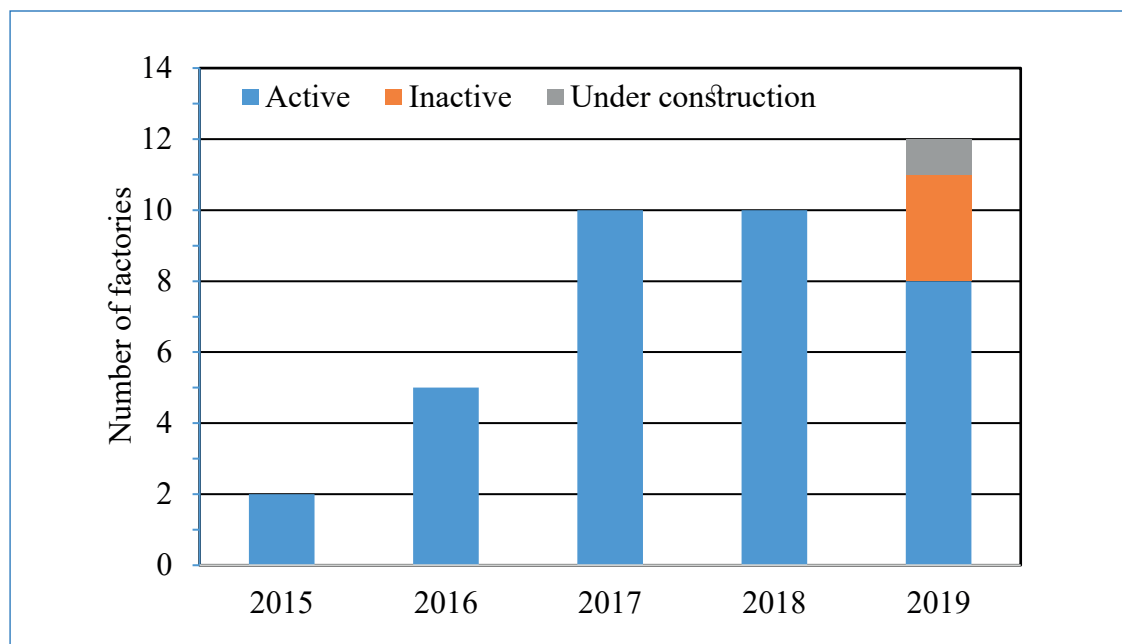
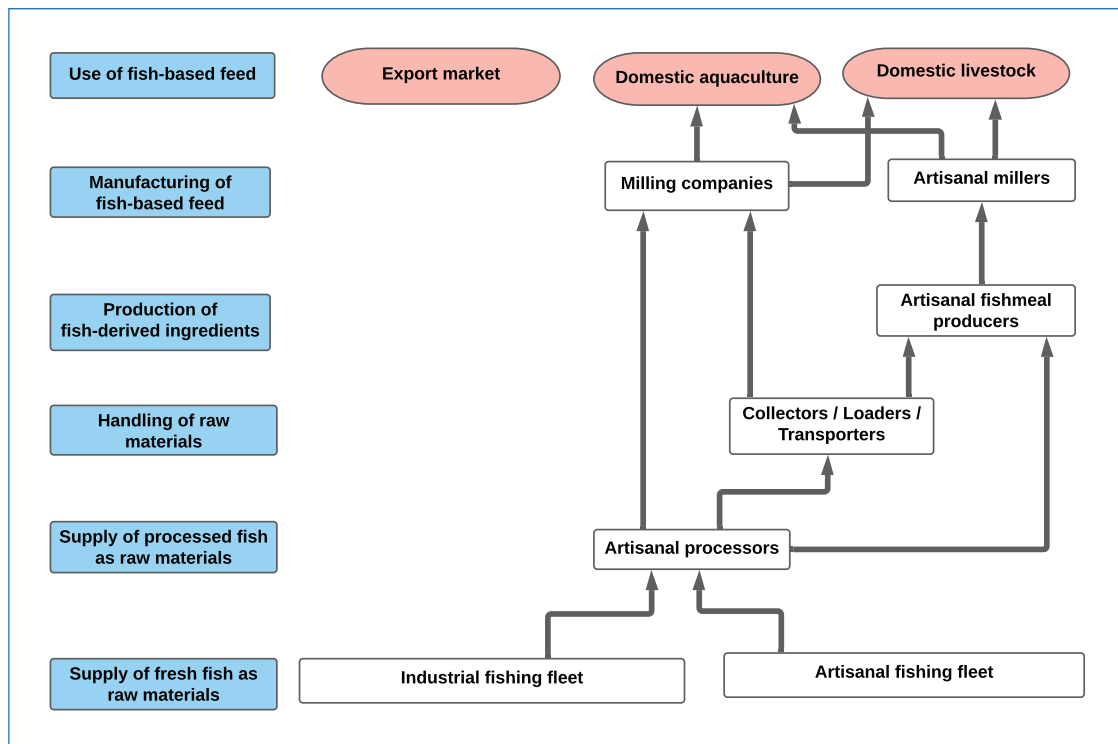


FIGURE 28. Value chain mapping of the fish-based feed industry in Uganda



9.9.2 Socio-economic impacts of the fish-based feed industry

9.9.2.1 Impacts for livelihoods in communities

The FBF industry offers important livelihoods opportunities along the entire value chain. At fish harvest level, increased demand of mukene for fishmeal creates jobs, mainly for fishers but also for boat and gear makers and repairers. In post-harvest activities, there are many workers, including artisanal processors that notably include women working in the sun drying of mukene devoted to fishmeal production. On the other hand, some workers such as collectors, loaders and transporters have taken advantage of the development of the industry. Opportunities inside fishmeal factories and milling companies comprise employment for skilled permanent and unskilled temporary workers.

9.9.2.2 Impacts for national food security

In Uganda, some households do not eat mukene because of perceived health issues that may be linked to the inappropriate handling and processing system, while others relegate it as food for poor people (Bwambale *et al.*, 2017). Many communities, however, generally consume it as a sauce prepared mainly from dried fish. Therefore, the FBF industry that relies on this species has a potential to compete directly with poor rural and urban consumers around Lake Victoria for which mukene plays a vital role (Isaacs, 2016). Instead of representing direct competition, the major problem is related to the handling and artisanal fish processing system that generates considerable post-harvest losses and makes most of the catch generally unfit for human consumption (LVFO, 2016). On the other hand, the industry has also been contributing to improving fish and meat by sourcing feed to the aquaculture and domestic sectors.

9.9.2.3 Impacts for public health and well-being

In Uganda, several potential risks on communities' health and well-being have been identified in the FBF value chain. Fishers targeting mukene for raw materials have been facing the

risk of drowning because of frequent stormy weather. At landing sites, fish loaders report having developed chest and back pains. In addition to bad odours, processors have been breathing harmful dust that is believed to cause chest infection, while the fluid from fresh mukene causes skin rash. Additionally, processors interviewed stated that fish bones usually pierce their hands and the small scales affect their eyes, which occasionally result in serious injuries. Workers in fishmeal factories and milling companies have been complaining about the dust they breathe in without personal protective wear and equipment. As most of the milling companies are located in close proximity to communities, the air pollution and noise the companies generate also affect the public health and well-being of local communities. To mitigate these harmful impacts, local and central authorities have imposed various measures, including regular inspections, sensitization of the communities, processors and feed manufacturers, as well as training on proper mukene handling and processing methods.

9.9.2.4 Impacts for national and local economies

Incomes generated for thousands of direct and indirect workers are the main economic contributions of the industry, which contributes towards increasing the productivity of the aquaculture and livestock sectors that provide revenues to farmers. Moreover, in districts where milling companies are located, the local governments earn tax revenues. According to the Ministry of Fisheries, the industry pays about UGX 300 000 (about USD 80) annually per factory as a local administration tax.

9.9.2.5 Impacts for national aquaculture and livestock sectors

The FBF industry has led to growth and improvement of the aquaculture and livestock sectors in recent years, due to providing compounded protein feed. Because in the past quality fish feed has been the biggest challenge for farming fish, poultry and other animals, the establishment of milling companies has been vital to improving the productivity of these two sectors. Some farmers rely on imports, however, because the quality of locally made FBF is not guaranteed.

9.9.3 Biological impacts of the fish-based feed industry

9.9.3.1 Impacts of fish-based feed on fishery resources

The FBF industry in Uganda relies essentially on silver cyprinid (*Rastrineobola argentea*), locally known as mukene. Based on the most recent hydroacoustic survey (LVFO, 2019), this species was the most abundant in Lake Victoria with 34 percent of the total standing stock. Since 2005, it has become the largest fishing focus in the lake by weight, with no sign of overexploitation noted in recent years (Isaacs, 2016). The 2019 hydroacoustic survey revealed that the biomass of the stock increased from 792 848 tonnes in 2016 to 936 247 tonnes in 2019 (LVFO, 2019); therefore, despite the presence of the FBF industry, mukene remains in a good situation.

9.9.3.2 Impacts of fish-based feed on ecosystems

The FBF industry in Uganda depends on fish sun dried on racks, bare ground or nets and thus processors usually remove the nearby vegetation to establish sufficient drying areas and other facilities. The cleared areas, however, create soil erosion and when it rains the processing wastes on the ground stream into the lake. Therefore, in addition to the deforestation occurring nearby, pollution of organic wastes is the major negative impact on the aquatic ecosystems of Lake Victoria.

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Glossary

Fish-derived ingredient (FDI) refers to all types of animal feed components made of fish and/or other aquatic animals such as crustaceans and molluscs. Fishmeal and fish oil are the two most common types of FDIs that are usually mixed with other ingredients, such as cereal grains and additives, in fish-based feed.

Fish-based feed (FBF) is a generic term that encompasses all animal feed products in which at least one of the components is a fish-derived ingredient.

Fishmeal is the clean, dried, ground tissue of undecomposed whole fish or fish cuttings/trimmings, either or both, with or without the extraction of part of the oil (FAO, 2001). Fishmeal (International Trade Centre – ITC – item code 230120) can take the form of powder/flours, pellets or granules and is considered unfit for human consumption. The International Fishmeal and Fish oil Organisation (IFFO) recommends that 75 percent of fishmeal should comprise whole fish, and the remaining 25 percent may be trimmings. On average, 4.5 kg of fish are necessary to produce 1 kg of fishmeal, corresponding to a conversion factor of 22 percent (Tacon and Metain, 2008; Péron, Mittaine and Le Gallic, 2010).

Fish oil is usually a clear brown/yellow liquid obtained through the pressing of cooked fish and subsequent centrifugation of the liquid obtained (Green, 2016; FAO, 2020a). Fish oil (ITC item code 1504) corresponds to fats and oils and their fractions of fish or marine mammals, whether or not refined (excluding chemically modified). As for fishmeal, many different species are used for fish oil production, with oily fish, especially anchoveta and other small pelagic fish, being the main species (Green, 2016). The conversion factor is only 5 percent on average, meaning that for 1 kg of fish oil, about 20 kg of fish are required (Tacon and Metain, 2008). Fish oil can be used as a human dietary supplement; however, this is not explored in this report.

A **fishmeal factory** produces fishmeal and fish oil. A **feed mill, or milling company**, manufactures feed – FBF – by powered machinery (Ricke *et al.*, 2018).

Annex 1. Questionnaire 1: Background data to be collected at the national level

Note: Based on existing databases, grey and published literature and expert estimates, for each of the variables below, indicate the value from 2015 to 2019. In the column “**Data source**”, provide all details (e.g. references) related to the source of the recorded values. In column “**Comments**”, mention any useful information (e.g. spatial coverage, data collection methodology).

1. Fisheries sector

Level	Variable	2015	2016	2017	2018	2019	Data source	Comments
Harvest	Number of fishers/harvesters (all fisheries and all species)							
	Number of fishers/harvesters in artisanal fisheries (targeting small pelagics)							
	Number of fishers/harvesters in industrial fisheries (targeting small pelagics)							
	Catch volume (in tonnes) for all fisheries and all species							
	Catch value (in national currency) for all fisheries and all species							
	Catch volume (in tonnes) of small pelagics for artisanal fisheries							
	Catch value (in national currency) of small pelagics for artisanal fisheries							
Post-harvest	Number of women fish wholesalers (all species)							
	Number of men fish wholesalers (all species)							
	Number of women fish wholesalers (small pelagics)							
	Number of men fish wholesalers (small pelagics)							
	Number of women fish retailers (all species)							
	Number of men fish retailers (all species)							
	Number of women fish retailers (small pelagics)							
	number of men fish retailers (small pelagics)							
	Number of women fish processors (all species)							
	number of men fish processors (all species)							
	Number of women fish processors (small pelagics)							
	Number of men fish processors (small pelagics)							
	Total volume (in tonnes) of processed fish (all species)							
	Total value (in national currency) of processed fish (all species)							
	Total volume (in tonnes) of processed fish (small pelagics)							
	Total value (in national currency) of processed fish (small pelagics)							
	Total volume (in tonnes) of exported fish (all species)							
	Total value (in national currency) of exported fish (all species)							
	Total volume (in tonnes) of exported fish (small pelagics)							
	Total value (in national currency) of exported fish (small pelagics)							
Country per capita fish consumption (all species)								
Total quantity of fish consumption (all species) in the country								
Total quantity of fish consumption (small pelagics) in the country								

2. Aquaculture sector

Variable	2015	2016	2017	2018	2019	Data source	Comments
Total number of fish farms							
Direct employment in fish farms							
Total production (in tonnes)							
Total production (in national currency)							
Production exported (in tonnes)							
Production exported (in national currency)							
Production consumed in the country (in tonnes)							
Describe the main species farmed							

3. Fish-based feed industry

Variable	2015	2016	2017	2018	2019	Data source	Comments
Number of FDI factories and FBF companies currently operational							
Number of FDI factories and FBF companies currently not operational							
Number of FDI factories and FBF companies currently under construction							
Number of artisanal vessels fishing only for the FDI factories							
Number of industrial vessels fishing only for the FDI factories							
Quantity of edible fish (all species) destined to FDI production							
Quantity of edible fish (small pelagics) destined to FDI production							
Quantity of non-edible fish (all species) destined to FDI production							
Number of permanent employees working in FDI factories and FBF companies							
Number of temporary employees working in FDI factories and FBF companies							
Volume of FDI and FBF production (in tonnes)							
Value of FDI and FBF production (in local currency)							
Volume of FDI and FBF exported (in tonnes)							
Value of FDI exported (in local currency)							
Volume of FDI and FBF produced and sold in the country (in tonnes)							
Value of FDI and FBF produced and sold in the country (in local currency)							
Volume of FDI and FBF imported in the country (in tonnes)							
Total amount of tax paid by the FDI factories and FBF companies							
Total amount of salary paid by the FDI factories and FBF companies							

Note: FDI = fish-derived ingredient; FBF = fish-based feed.

Annex 2. Questionnaire 2: Key informant interviews with administrative and technical stakeholders

Main targets: national and local officers from fisheries, aquaculture, livestock, environment, public health and public finance administrations, and research institutions

1. Identification information

Questionnaire number:
Country: Mauritania <input type="checkbox"/> Senegal <input type="checkbox"/> Gambia <input type="checkbox"/> Sierra Leone <input type="checkbox"/> Ghana <input type="checkbox"/> Congo <input type="checkbox"/> Malawi <input type="checkbox"/> United Republic of Tanzania <input type="checkbox"/> Uganda <input type="checkbox"/>
Date of interview (format DD/MM/YYYY): /...../...../...../
Respondent's name (optional):
Respondent's phone and e-mail (optional):
Respondent's gender: Man <input type="checkbox"/> Woman <input type="checkbox"/>
Respondent's occupation:
Name of the institution:
Sector: Fisheries <input type="checkbox"/> Aquaculture <input type="checkbox"/> Environment <input type="checkbox"/> Public finance <input type="checkbox"/> Public health <input type="checkbox"/> Other sector <input type="checkbox"/> Specify

2. Describe the history and recent development of the fish-based feed industry in the country during the past five years

3. Describe both the positive and negative impacts of the fish-based feed industry on the following aspects of the national/local economy during the past five years

- a. Job creation
- b. Income generation
- c. Tax payment
- d. Promotion of exports
- e. Other aspects

4. Describe both the positive and negative impacts of the fish-based feed industry on the harvest activities of the fisheries sector during the past five years

5. Describe both the positive and negative impacts of the fish-based feed industry on the post-harvest activities of the fisheries sector during the past five years

6. Describe both the positive and negative impacts of the fish-based feed industry on the development of the aquaculture and livestock sectors during the past five years

7. Describe the fishing gear used and the main species targeted to serve as raw materials for fish-derived ingredients and how they are impacted by the industry during the past five years

8. Describe the impacts of the fish-based feed industry on the following aspects of the local environment during the past five years

- a. Air pollution
- b. Water pollution
- c. Soil pollution
- d. Other aspects

9. Describe the impacts of the fish-based feed industry on the following aspects of local public health during the past five years.

- a. Respiratory diseases
- b. Skin diseases
- c. Digestive diseases
- d. Other aspects

10. Describe the impacts of the fish-based feed industry on the availability and affordability of fish for direct consumption at the local/national level during the past five years

11. What measures have been taken by the local and central authorities in order to eradicate or limit the harmful impacts of the fish-based feed industry?

12. Provide recommendations for decision-making about the fish-based feed industry

13. Provide recommendations for future research about the fish-based feed industry

Annex 3. Questionnaire 3: Key informant interviews with fish-derived ingredients and fishbased feed producers

Main targets: top managers of fish-derived ingredients factories and fish-based feed companies

1. Identification information

Questionnaire number:
Country: Mauritania <input type="checkbox"/> Senegal <input type="checkbox"/> Gambia <input type="checkbox"/> Sierra Leone <input type="checkbox"/> Ghana <input type="checkbox"/> Congo <input type="checkbox"/> Malawi <input type="checkbox"/> United Republic of Tanzania <input type="checkbox"/> Uganda <input type="checkbox"/>
Name of city/village:
Date of interview (format DD/MM/YY): /...../...../...../
Respondent's name (optional):
Respondent's phone and e-mail (optional):
Respondent's gender: Man <input type="checkbox"/> Woman <input type="checkbox"/>
Respondent's nationality:
Respondent's occupation:
Name of the factory:
Year of establishment of the factory:
Production of FDI and FBF: Only <input type="checkbox"/> Mainly <input type="checkbox"/> Accessorily <input type="checkbox"/>
Specify other products, if any:
Maximum daily production capacity of FDI and FBF (in kg):

2. Employment information

Indicators	2015	2016	2017	2018	2019
Number of employees from the local city/village					
Number of employees from other cities/villages					
Number of employees coming from foreign countries					
Number of permanent men employees					
Number of permanent women employees					
Number of temporary men employees					
Number of temporary women employees					
Remuneration for permanent employees (in local currency)					
Remuneration for temporary employees (in local currency)					

3. Fish-based raw material supply

Describe the types and importance of fish-related raw materials used in your factory/ company.

.....

.....

.....

Describe your suppliers as well as changes in fish-related raw material sourcing over time.

.....

How and who transports fish-related raw materials from their origin to the factory/ company?

.....

Describe types and importance of species used as fish-related raw materials and why.

.....

Key quantitative indicators on fish-related raw materials

Indicators	2015	2016	2017	2018	2019
Number of artisanal vessels chartered to fish for the factory					
Number of industrial vessels chartered to fish for the factory					
Volume of fresh fish supplied by the above artisanal vessels (kg)					
Volume of fresh fish supplied by the above industrial vessels (kg)					
Volume of fresh fish supplied by other artisanal vessels (in kg)					
Volume of fresh fish supplied by other industrial vessels (in kg)					
Volume of fish wastes/by-products bought from landing sites (in kg)					
Volume of fish wastes/by-products bought from artisanal processors (in kg)					
Volume of fish wastes/by-products bought from industrial processors (in kg)					
Volume of fish wastes/by-products bought from fish farmers (in kg)					
Volume of fish wastes/by-products bought from other sources (in kg)					
Specify other sources:					

4. Production activities

Describe the major steps of the production process

.....
.....
.....

What are the periods of highest production during the year and why?

.....
.....
.....

What are the type of fish-derived ingredients and fish-based feed products produced in the factory/company?

- | | | | | |
|------------------------|-------------------------------|---------------------------------|--------------------------------------|--------------------------------|
| Fishmeal/powder: | Only <input type="checkbox"/> | Mainly <input type="checkbox"/> | Accessorily <input type="checkbox"/> | Never <input type="checkbox"/> |
| Fish pellets/granules: | Only <input type="checkbox"/> | Mainly <input type="checkbox"/> | Accessorily <input type="checkbox"/> | Never <input type="checkbox"/> |
| Fish cuttings: | Only <input type="checkbox"/> | Mainly <input type="checkbox"/> | Accessorily <input type="checkbox"/> | Never <input type="checkbox"/> |
| Whole fish: | Only <input type="checkbox"/> | Mainly <input type="checkbox"/> | Accessorily <input type="checkbox"/> | Never <input type="checkbox"/> |
| Fish oil: | Only <input type="checkbox"/> | Mainly <input type="checkbox"/> | Accessorily <input type="checkbox"/> | Never <input type="checkbox"/> |
| Other products: | Only <input type="checkbox"/> | Mainly <input type="checkbox"/> | Accessorily <input type="checkbox"/> | Never <input type="checkbox"/> |

Specify the other fish-based feed products:

Specify the technical and economic reasons why the factory/company is oriented in the above products:

.....

What are the types and magnitude of wastes that are generated from the production process and how they are managed?

.....
.....
.....

Key quantitative indicators related to production

Indicators	2015	2016	2017	2018	2019
Volume of fishmeal/powder produced (in kg)					
Value of fishmeal/powder produced (local currency)					
Volume of fish pellets/granules produced (in kg)					
Value of fish pellets/granules produced (local currency)					
Volume of fish cuttings produced (in kg)					
Value of fish cuttings produced (local currency)					
Volume of whole fish produced (in kg)					
Value of whole fish produced (local currency)					
Volume of fish oil produced (in kg)					
Value of fish oil produced (local currency)					
Volume of other fish-based outputs (in kg)					
Value of other fish-based outputs (local currency)					
Total volume of all fish-based outputs (in kg)					
Total value of all fish-based outputs (local currency)					

5. Storage activities

What are the usual storage durations of the products before selling?

.....

Describe the types and capacities of the storage infrastructure/facilities of the factory/company.

.....

Describe any storage support provided to you by other actors outside the factory/company.

.....

6. Selling activities

Describe the key markets and buyers/users by type of product.

.....

How and who transports the products from the factory/company to the buyers/users?

.....

Describe any selling support provided to you by other actors outside the factory/company.

.....

Key quantitative indicators related to the selling of products

Indicators	2015	2016	2017	2018	2019
Volume of products sold to national fish farmers (in kg)					
Volume of products sold to national poultry farmers (in kg)					
Volume of products sold to national pig farmers (in kg)					
Volume of products sold to other national animal farmers (in kg)					
Volume of products sold to other national buyers/users					
Specify the other national buyers/users:					
Volume of products sold outside the country (in kg)					
Total turnover generated (local currency)					
Total production cost (local currency)					
Tax paid to the central government (local currency)					
Tax paid to the local administration (local currency)					
Total net profit generated (local currency)					

7. Awareness and management of risks

What is your opinion on the types and magnitude of the following proven/potential risks that may be associated with your activities?

- Incitement to overfishing: Major risk Minor risk Any risk
- Incitement to juveniles fishing: Major risk Minor risk Any risk
- Harmful air pollution: Major risk Minor risk Any risk
- Harmful water pollution: Major risk Minor risk Any risk
- Harmful soil pollution: Major risk Minor risk Any risk
- Lack of fish for local/national processors: Major risk Minor risk Any risk
- Lack of fish for local/national consumers: Major risk Minor risk Any risk
- Loss of livelihoods for fishing communities: Major risk Minor risk Any risk
- Conflict with/between fishing communities: Major risk Minor risk Any risk
- Conflict with/between local populations: Major risk Minor risk Any risk
- Threat to local public health: Major risk Minor risk Any risk

Specify any other proven/potential risk that may raise attention:

.....

What practical measures have you been taking in your factory/company to address the above risks?

.....

.....

8. Possible alternatives

Apart from fish-derived ingredients, what are the other alternatives you have for producing protein feed?

.....

.....

.....

Why are fish-derived ingredients preferred instead of alternatives?

.....

.....

.....

9. Recommendations

What would you recommend to decision-makers in order to ensure socio-economic and biological sustainability for the fish-based feed industry?

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.....
.....

What future research would you recommend in order to better understand and sustainably manage the fish-based feed industry?

.....
.....
.....

Annex 4. Questionnaire 4: Key informant interviews with local fish-based feed users

Main targets: fish farmers, poultry farmers, pig farmers and other users

1. Identification information

Questionnaire number:
Country: Mauritania <input type="checkbox"/> Senegal <input type="checkbox"/> Gambia <input type="checkbox"/> Sierra Leone <input type="checkbox"/> Ghana <input type="checkbox"/> Congo <input type="checkbox"/> Malawi <input type="checkbox"/> United Republic of Tanzania <input type="checkbox"/> Uganda <input type="checkbox"/>
Name of city/village:
Date of interview (format DD/MM/YYYY): /...../...../...../
Respondent's name (optional):
Respondent's phone and e-mail (optional):
Respondent's gender: Man <input type="checkbox"/> Woman <input type="checkbox"/>
Respondent's nationality:
Type of user: Fish farmer <input type="checkbox"/> Poultry farmer <input type="checkbox"/> Pig farmer <input type="checkbox"/> Other user <input type="checkbox"/>
Specify other user:

2. Employment information

Indicators	2015	2016	2017	2018	2019
Number of permanent men employees					
Number of permanent women employees					
Number of temporary men employees					
Number of temporary women employees					
Remuneration for permanent employees (in local currency)					
Remuneration for temporary employees (in local currency)					

3. Fish-based feed use

What types of fish-based feeds do you use in your activities?

- Fishmeal/powder: Only Mainly Accessorily Never
- Fish pellets/granules: Only Mainly Accessorily Never
- Fish cuttings: Only Mainly Accessorily Never
- Whole fish: Only Mainly Accessorily Never
- Fish oil: Only Mainly Accessorily Never
- Other fish-based feeds: Only Mainly Accessorily Never

Specify the other fish-based feeds:

Specify the main reasons why you use the above types of fish-based feeds.

.....

.....

.....

Describe the characteristics and location of your suppliers.

.....

.....

.....

In terms of availability and affordability, how easy is it to get enough fish-based feeds?

.....

.....

.....

Apart from fish-based feeds, what alternative protein feeds do you use?

.....

.....

.....

Why are fish-based feeds preferred instead of alternative protein feeds?

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.....

.....

Key quantitative indicators related to your fish-based feed use

Indicators	2015	2016	2017	2018	2019
Volume of fishmeal/powder used (in kg)					
Value of fishmeal/powder used (local currency)					
Volume of fish pellets/granules used (in kg)					
Value of fish pellets/granules used (local currency)					
Volume of fish cuttings used (in kg)					
Value of fish cuttings used (local currency)					
Volume of whole fish used (in kg)					
Value of whole fish used (local currency)					
Volume of fish oil used (in kg)					
Value of fish oil used (local currency)					
Volume of other fish-based feeds (in kg)					
Value of other fish-based feeds (local currency)					
Total volume of all fish-based feeds (in kg)					
Total value of all fish-based feeds (local currency)					

4. Awareness of risks

What is your opinion on the types and magnitude of the following proven/potential risks that may be associated with the fish-based feed industry?

- Incitement to overfishing: Major risk Minor risk No risk
- Incitement to juvenile fishing: Major risk Minor risk No risk
- Harmful air pollution: Major risk Minor risk No risk
- Harmful water pollution: Major risk Minor risk No risk
- Harmful soil pollution: Major risk Minor risk No risk
- Lack of fish for local/national processors: Major risk Minor risk No risk
- Lack of fish for local/national consumers: Major risk Minor risk No risk
- Loss of livelihoods for fishing communities: Major risk Minor risk No risk
- Conflict with/between fishing communities: Major risk Minor risk No risk
- Conflict with/between local populations: Major risk Minor risk No risk
- Threat to local public health: Major risk Minor risk No risk

Specify any other proven/potential risk that may raise attention:.....
.....

5. Recommendations

What would you recommend to decision-makers in order to ensure socio-economic and biological sustainability for the fish-based feed industry?

.....
.....
.....

What future research would you recommend in order to better understand and sustainably manage the fishbased feed industry?

.....
.....
.....

Annex 5. Questionnaire 5: Focus group discussion with fishing communities

Main targets: fishers, fish processors, fishmongers and local populations

1. Identification information

Country:
Mauritania <input type="checkbox"/> Senegal <input type="checkbox"/> Gambia <input type="checkbox"/> Sierra Leone <input type="checkbox"/> Ghana <input type="checkbox"/> Congo <input type="checkbox"/> Malawi <input type="checkbox"/> United Republic of Tanzania <input type="checkbox"/> Uganda <input type="checkbox"/>
Name of community/site:
Date of discussion (format DD/MM/YY): /...../...../...../
Number of participants: Man..... Woman.....
Composition of the group: Fishers <input type="checkbox"/> Processors <input type="checkbox"/> Fishmongers <input type="checkbox"/> Local populations <input type="checkbox"/> Mixed group <input type="checkbox"/> Specify

2. What are both the positive and negative impacts of the fish-based feed industry on your livelihood activities during these past five years?

3. What are both the positive and negative impacts of the fish-based feed industry on the availability and affordability of fish for consumption during these past five years?

4. What are both the positive and negative impacts of the fish-based feed industry on the overall social and economic local life (job, income, infrastructure, conflicts, etc.)?

5. What are both the positive and negative impacts of the fish-based feed industry on the local environment, public health and well-being during these past five years?

6. What are both the most impacted fish species by the fish-based feed industry, the fishing gear used, and the types and magnitude of impacts during these past five years?

7. What recommendations would you like to propose to decision-makers and researchers about the fish-based feed industry?

Annex 6. Questionnaire 6: Focus group discussion with workers of the fish-based feed industry

Main targets: permanent and temporary employees of the industry

1. Identification information

Country: Mauritania <input type="checkbox"/> Senegal <input type="checkbox"/> Gambia <input type="checkbox"/> Sierra Leone <input type="checkbox"/> Ghana <input type="checkbox"/> Congo <input type="checkbox"/> Malawi <input type="checkbox"/> United Republic of Tanzania <input type="checkbox"/> Uganda <input type="checkbox"/>
Name of city/village:
Name of the factory:
Date of discussion (format DD/MM/YYYY): /...../...../...../
Number of participants: Man..... Woman.....
Composition of the group: Permanent workers <input type="checkbox"/> Temporary workers <input type="checkbox"/> Mixed group <input type="checkbox"/>

2. What are the advantages of the fish-based feed industry for your livelihoods?

3. What are the major constraints and risks related to your working conditions in the fish-based feed industry?

4. How would you describe the impacts of the fish-based feed industry on fisheries resources and on the local environment?

5. What recommendations would you like to propose to decision-makers about the fish-based feed industry?

6. What recommendations would you like to propose to researchers about the fish-based feed industry?

Annex 7. Questionnaire 7: Round 1 Delphi stakeholder panel

Thank you for taking time to contribute to our study; we hope that you find it interesting being involved in this process.

Please complete the following information to permit us to characterize your stake or role related to small pelagic fish in West Africa and the Great Lakes Region of eastern Africa.

1. Please indicate with a tick mark the geographic location where you feel you have your main interest in small pelagic fish:

- (a) Great Lakes Region [] (b) West Africa [] (c) Sub-Saharan Africa []
 (d) African continent [] (e) Global []
 (f) Or please specify country(ies) or waterbody(ies) or other locations:
-

2. Please indicate by ticking **one box** where you feel your main interest lies regarding small pelagic fish:

- (a) Community-based group [] (b) Consumer [] (c) Decision-maker []
 (d) Fisher [] (e) Formal fish trader [] (f) Informal fish trader []
 (g) Industry representative [] (h) NGO [] (i) Non-state actor []
 (j) Policy-maker [] (k) Processor [] (l) Researcher []
 (m) Or other (please specify):
-

3. Please indicate by ticking **no more than 2 boxes** the fish species or products where your main interest lies with regard to small pelagic fish:

- (a) Animal feeds [] (b) Complementary foods for children []
 (c) Dietary fortification for humans [] (d) Freshwater species []
 (e) Fishmeal [] (f) Fish oil []
 (g) Fresh fish [] (h) Marine species []
 (i) Pelagic species [] (j) Small, salted fish []
 (k) Small, dried fish [] (l) Small, smoked fish []
 (m) Value-added products []
 (n) Or others (please specify):
-

Rating Recommendations for Decision-Making and Future Research

Please take the time to consider the key options for recommendations for decision-making and future research presented below. These have been identified through a regional consultation process conducted by the Food and Agriculture Organization of the United Nations (FAO) with a focus on the Gambia, Ghana, Mauritania, Senegal and Sierra Leone in West Africa and Lake Albert (Democratic Republic of the Congo and Uganda) and Lake Victoria (Kenya, Uganda and the United Republic of Tanzania) in the African Great Lakes Region.

Q6. Recommendation 6. Establish regulations and guidelines for fishers catching shrimp in Sierra Leone so that their bycatches can be used for fish-based feed instead of being discarded.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q7. Recommendation 7. Ensure regular assessment of key stocks of fish and effective monitoring of harvest and postharvest activities/operations of the fisheries sector at a national level.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q8. Recommendation 8. Ensure regular assessment of key stocks of fish and effective monitoring of harvest and postharvest activities/operations of the fisheries sector at a regional level (African Great Lakes Region or West Africa coastal zone).

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Ensuring ecosystems, individuals and communities are healthy

Q9. Recommendation 9. Allow the production of fish-derived ingredients and fish-based feed only from the wastes and by-products generated by fish processing industries.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q10. Recommendation 10. Make sure that fish-derived ingredients factories and fish-based feed companies are constructed far away from towns and villages to avoid adverse impacts on residents.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q11. Recommendation 11. Prohibit fish-derived ingredients factories and fish-based feed companies from dumping toxic wastes into the sea and inland waterbodies (e.g. lakes, rivers and wetlands).

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q12. Recommendation 12. Promote environmentally friendly and healthy/safe (for workers) fish-derived ingredients and fish-based feed production technologies.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q13. Recommendation 13. Implement an environmental audit for existing fish-derived ingredients factories and fishbased feed companies to check and monitor their capacity and level of enforcement of national norms/standards.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q14. Recommendation 14. Promote the use of plant-based and/or insect-based protein as feed alternatives in national aquaculture and livestock sectors.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q15. Recommendation 15. Conduct research to assess the chemical properties of all types of wastes from fish-derived ingredients factories and fish-based feed companies and their environmental and health effects.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Promoting equitable and nutrition-sensitive food and feed systems

Q16. Recommendation 16. Define and introduce minimum price controls for fish that can be purchased by fishderived ingredients and fish-based feed producers to ensure more income for fishers and encourage fish availability for local consumers and processors.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q17. Recommendation 17. Assist and train local fish and livestock farmers so that they can formulate and produce alternative and efficient feeds.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Q18. Recommendation 18. Promote national research programmes to identify alternatives to fish-based feed and assess their feasibility, viability, efficiency and profitability.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Annex 8. Questionnaire 8: Round 2 Delphi stakeholders panels

Thank you for your contribution to the study in Round 1 and for continuing to be involved in the process. Based on the feedback of the other participants, which consisted of 150 members in Round 1, we have calculated the median or middle rating assigned to the importance of each item. We have also calculated the interquartile range, i.e. the range of values that cover the middle 50 percent of participant responses (shaded in grey in the questions below).

We would now like to ask you to reconsider each item and the responses received from the participants during Round 1. We kindly ask that you either agree with the median rating of the group or suggest an alternative rating, based on your personal perspective and your own knowledge and expertise. Please rate the importance that you attach to each item on a scale of 1 to 10, where 1 is low importance and 10 is high importance. Please circle or place a cross on/next to your preferred rating.

If your preferred rating lies outside the interquartile range (shaded area), we ask that you include a brief written explanation, which will help us understand your opinion.

Key Options for Recommendations

Enhancing the contribution of healthy fish stocks to nutrition

Q1. Recommendation 1. Promote better fish harvesting and post-harvesting methods to reduce bycatches being directed away from human consumption and used instead for fish-derived ingredients and fish-based feed production (median rating was 9 and interquartile range was 7–9).

If you agree with the median rating of 9, please tick here and move to Q2. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Brief explanation:

.....

Q2. Recommendation 2. Regulate and limit the number, capacity and production of fish-derived ingredients based on the status of fish stocks and need for fish for human consumption (median rating was 9 and interquartile range was 7–10).

If you agree with the median rating of 9, please tick here and move to Q3. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Brief explanation:

.....

Q3. Recommendation 3. Authorize fish-derived ingredients and fish-based feed production only from fish species that are not consumed by the local/national population (median rating was 9 and interquartile range was 6–10).

If you agree with the median rating of 9, please tick here and move to Q4. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Brief explanation:

.....

Q4. Recommendation 4. Conduct research to assess the stock of silver cyprinid (*Rastrineobola argentea*), locally called “*dagaa* or *mukene*”, and find appropriate and efficient solutions to develop its value chain in Malawi, thus making more of this fish available for direct human consumption (median rating was 7 and interquartile range was 5–10).

If you agree with the median rating of 7, please tick here and move to Q5. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Brief explanation:

.....

Q5. Recommendation 5. Assess and monitor fish (categorized by, for example, size, species, source of production and means of processing/preservation) consumption, affordability and importance for food security and nutrition (median rating was 9 and interquartile range was 7–10).

If you agree with the median rating of 9, please tick here and move to Q6. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	10
Low importance									High importance

Brief explanation:

.....

Q6. Recommendation 6. Establish regulations and guidelines for fishers catching shrimp in Sierra Leone so that their bycatches can be used for fish-derived ingredients and fish-based feed instead of being discarded (median rating was 7 and interquartile range was 5–9).

If you agree with the median rating of 7, please tick here and move to Q7. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.



Brief explanation:

.....

Q7. Recommendation 7. Ensure regular assessment of key stocks of fish and effective monitoring of harvest and postharvest activities/operations of the fisheries sector at a national level (median rating was 10 and interquartile range was 8–10).

If you agree with the median rating of 10, please tick here and move to Q8. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.



Brief explanation:

.....

Q8. Recommendation 8. Ensure regular assessment of key stocks of fish and effective monitoring of harvest and postharvest activities/operations of the fisheries sector at a regional level (African Great Lakes Region or West Africa coastal zone) (median rating was 9 and interquartile range was 8–10).

If you agree with the median rating of 9, please tick here and move to Q9. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.



Brief explanation:

.....

Ensuring ecosystems, individuals and communities are healthy

Q9. Recommendation 9. Allow the production of fish-derived ingredients and fish-based feed only from the wastes and by-products generated by the fish processing industries (median rating was 7 and interquartile range was 6–9).

If you agree with the median rating of 7, please tick here and move to Q10. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.



Brief explanation:

.....

Q10. Recommendation 10. Make sure that fish-derived ingredients factories and fish-based feed companies are constructed far away from towns and villages to avoid adverse impacts on residents (median rating was 10 and interquartile range was 7–10).

If you agree with the median rating of 10, please tick here and move to Q11. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.



Brief explanation:

.....

Q11. Recommendation 11. Prohibit fish-derived ingredients factories and fish-based feed companies from dumping toxic wastes into the sea and inland waterbodies (e.g. lakes, rivers and wetlands) (median rating was 10 and interquartile range was 9–10).

If you agree with the median rating of 10, please tick here and move to Q12. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.



Brief explanation:

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Q12. Recommendation 12. Promote environmentally friendly and healthy/safe (for workers) fish-derived ingredients and fish-based feed production technologies (median rating was 10 and interquartile range was 9–10).

If you agree with the median rating of 10, please tick here and move to Q13. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	10
Low importance								High importance	

Brief explanation:

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Q13. Recommendation 13. Implement an environmental audit for existing fish-derived ingredients factories and fishbased feed companies to check and monitor their capacity and level of enforcement of national norms/standards (median rating was 10 and interquartile range was 9–10).

If you agree with the median rating of 10, please tick here and move to Q14. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	10
Low importance								High importance	

Brief explanation:

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Q14. Recommendation 14. Promote the use of plant-based and/or insect-based protein as feed alternatives in national aquaculture and livestock sectors (median rating was 9 and interquartile range was 7–10).

If you agree with the median rating of 9, please tick here and move to Q15. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	10
Low importance						High importance			

Brief explanation:

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Q15. Recommendation 15. Conduct research to assess the chemical properties of all types of wastes from fish-derived ingredients factories and fish-based feed companies and their environmental and health effects (median rating was 10 and interquartile range was 7.5–10).

If you agree with the median rating of 10, please tick here and move to Q16. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	<u>10</u>
Low importance									High importance

Brief explanation:

Promoting equitable and nutrition-sensitive food and feed systems

Q16. Recommendation 16. Define and introduce minimum price controls for fish that can be purchased by fish-derived ingredients and fish-based feed producers to ensure more income for fishers and encourage fish availability for local consumers and processors (median rating was 8 and interquartile range was 7–10).

If you agree with the median rating of 8, please tick here and move to Q17. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	<u>8</u>	9	10
Low importance									High importance

Brief explanation:

Q17. Recommendation 17. Assist and train local fish and livestock farmers so that they can formulate and produce alternative and efficient feeds (median rating was 10 and interquartile range was 9–10).

If you agree with the median rating of 10, please tick here and move to Q18. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	9	<u>10</u>
Low importance									High importance

Brief explanation:

Q18. Recommendation 18. Promote national research programmes to identify alternatives to fish-based feed and assess their feasibility, viability, efficiency and profitability (median rating was 9 and interquartile range was 7–10).

If you agree with the median rating of 9, please tick here and move to Q19. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

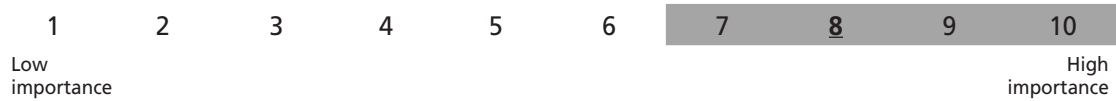


Brief explanation:

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Q19. Recommendation 19. Promote regional (African Great Lakes Region or West Africa coastal zone) research programmes to identify alternatives to fish-based feed and assess their feasibility, viability, efficiency and profitability (median rating was 8 and interquartile range was 7–10).

If you agree with the median rating of 8, please tick here and move to Q20. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.



Brief explanation:

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Q20. Recommendation 20. Allow only the national professionals of the fisheries sector to invest in the fish-based feed industry (median rating was 5 and interquartile range was 2–6).

If you agree with the median rating of 5, please tick here and move to Q21. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.



Brief explanation:

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Q21. Recommendation 21. Promote the establishment of fish-based feed industry in Malawi to support the development of the national aquaculture sector (median rating was 7 and interquartile range was 5–10).

If you agree with the median rating of 7, please tick here and move to Q22. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	<u>7</u>	8	9	10
Low importance									High importance

Brief explanation:

Q22. Recommendation 22. Implement and effectively enforce the policies and norms/standards specific to the fishbased feed industry (median rating was 9 and interquartile range was 7–10).

If you agree with the median rating of 9, please tick here and move to Q23. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	8	<u>9</u>	10
Low importance									High importance

Brief explanation:

Q23. Recommendation 23. Assess the national/regional demand/need and affordability of fish-based feed for the aquaculture and livestock sectors (median rating was 8 and interquartile range was 7–10).

If you agree with the median rating of 8, please tick here and move to **Section A** below. If not, please indicate an alternative rating on the scale below and, if this lies outside the interquartile range (shaded area), please provide a brief explanation in the space below.

1	2	3	4	5	6	7	<u>8</u>	9	10
Low importance									High importance

Brief explanation:

Section A. Please include any comments or feedback that you may have here:

Thank you for taking the time to complete this study. We ask that you please return your completed form to the local FAO consultant as arranged, and the consultant will feed the information you have provided here into the stakeholder Delphi process. As agreed previously, we will provide all participants with a summary of the study findings as soon as possible.

Thank You.

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