Aquaculture 520 (2020) 734940

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aquaculture

Employment generation in the Egyptian aquaculture value chain: implications for meeting the Sustainable Development Goals (SDGs)☆

Ahmed Nasr-Allah[a,*], Alexandros Gasparatos[b], Alice Karanja[b], Eric Brako Dompreh[c], Seamus Murphy[a], Cristiano M. Rossignoli[d], Michael Phillips[d], Harrison Charo-Karisa[a]

[a] WorldFish, Cairo, Egypt
[b] Institute for Future Initiatives (IFI), University of Tokyo, Tokyo, Japan
[c] Graduate Program in Sustainability Science-Global Leadership Initiative (GPSS-GLI), University of Tokyo, Japan
[d] WorldFish, Penang, Malaysia

ARTICLE INFO

Keywords:
Aquaculture
Employment
Gender
Sustainable development

ABSTRACT

Egypt faces multiple interlinked challenges such as unemployment, poverty and gender inequality that pose tremendous barriers in the current efforts to achieve sustainable development. Aquaculture is a primary sector of the economy that has high potential to not only for provide nutritious food, but also to contribute to the national economy. The aquaculture value chain provides substantial employment generation opportunities, including for females and the youth. This paper assesses employment generation along the different stages of the aquaculture value chain in the main governorates that are responsible for about 80% of the Egyptian aquaculture production. In particular it analyses data from surveys in hatcheries (N = 40), feed mills (N = 14), fish farms (N = 234), and fish trading and retailing (N = 182) as a proxy of employment generation patterns for the entire sector. We estimated that aquaculture generates 19.56 Full Time Equivalent (FTE) jobs per 100t of produced fish along the entire value chain. However most of these jobs are generated for males over 30 years of age, with few jobs for females or younger people. Most jobs for female are currently generated at the retailing stage. Boosting employment generation across the entire value chain, especially for females and the youth, can contribute to the attainment of multiple Sustainable Development Goals (SDGs) such as SDG 8 and SDG 5.

1. Introduction

Global unemployment rates stand at an alarming 6%, with close to 200 million people being out of employment (World Bank, 2017a). Unemployment rates in Africa are even higher, officially standing at 7.9%, but possibly being much higher (World Bank, 2017a). However in some African countries such as Egypt, current unemployment rates can stand even higher, at 12.1%, despite recent reduction (World Bank, 2017a).

Aquaculture is a primary economic sector with significant potential for employment generation. Globally, aquaculture provides more than 23 million direct and indirect full time jobs, largely concentrated in developing countries (Ottinger et al., 2016; Valderrama et al., 2010). Employment generation from aquaculture has been significant in regions which have struggled to develop more viable long-term employment pathways (Grealis et al., 2017). Women play a major role in aquaculture value chains globally (FAO, 2016), but they often receive unequal benefits from their involvement (Kruijssen et al., 2018).

As global fish demand is expected to increase by about 47 million tonnes in the next few years (due to both growth in population and per capita consumption), global aquaculture output is also expected to increase by 19 million tonnes (FAO, 2017). However, this still leaves a demand-supply gap of more than 24 million tonnes. The expected expansion can offer substantial employment generation opportunities, especially for youth and females, as well as possibilities for creating and expanding small- and large-scale businesses in the sector (FAO, 2017; Shaalan et al., 2018).

Egypt is one of the countries where aquaculture can generate important socioeconomic benefits. Currently Egypt has the largest aquaculture production in Africa (Shaalan et al., 2018). Given its strong current growth (see next paragraph), aquaculture can contribute to curbing the country's persistently high unemployment rates, particularly for women and youth. Youth unemployment is high both for males

☆ All authors listed above were part of the study team which planned and executed the fieldwork which generated the data and information used and presented in this paper.

* Corresponding author at: WorldFish Center, 24 (B) Anwar El-Mofti St., 5th Floor, Apt. # 52, Nasr City 11759, Cairo, Egypt.
E-mail address: A.Allah@cgiar.org (A. Nasr-Allah).

https://doi.org/10.1016/j.aquaculture.2020.734940
Received 19 July 2018; Received in revised form 25 December 2019; Accepted 7 January 2020
Available online 10 January 2020

(29% in 2016) and females (45% in 2016) (World Bank, 2015), while women make up only 24% of the labour force (World Bank, 2016). At the same time aquaculture can have multiple other benefits for a country that faces various interlinked challenges related to population increase, urbanization, food security and unsustainable consumption and production (Galli et al., 2017; Osama et al., 2017)[1].

Currently fish demand and aquaculture output increase hand in hand. Per capita consumption of local fish has increased by 75% between 2007 and 2016; from 13.5kg/year to over 18 kg/year. Currently fish provide approximately 38% of the animal protein demand of the Egyptian population (CAPMAS, 2018), and is an affordable source of micronutrients essential for good health. Per capita fish consumption increase is currently higher than for beef and poultry meat, which further highlight the growing importance of fish in the local diets. At the same time, total fish production capacity has been increasing substantially (Table 1). In 2016, aquaculture contributed more than 80% of total national fish production, up from 47% in 2000 (Table 1). The increase in aquaculture output is mainly attributed to the significant promotion of new technologies such as the use of extruded fish feed, stocking mono-sex tilapia, and improved farm management practices (Hebisha and Fathi, 2014). Fish farming in Egypt is strongly concentrated in low-lying land around the northern lakes (Manzala, Burullus, Edko and Mariout) (Nasr-Alla et al., 2012).

The above trends create strong pre-conditions for further growth in the sector, and high potential to generate employment. In 2015, fish production contributed about USD 3.2 billion to the Egyptian national Gross Domestic Product (GDP) (GAFRD, 2017). The sector serves as a source of employment for over 580,000 individuals (Shaalan et al., 2018), but this figure might be an overestimate (FAO, 2018), as it might not capture properly seasonal or part-time employment in the sector. Apart from direct permanent jobs, other employment opportunities include seasonal workers during harvesting and other periods of intensive activity, as well as indirect employment in the fish processing, transport, retailing, and boat and net manufacturing sectors (FAO, 2009). The positive effects of aquaculture to the national economy have triggered both government agencies and non-governmental organizations to implement different interventions in the sector(Shaalan et al., 2018). Major projects include the National Project for Marine Aquaculture in the Suez Canal, Ghalioun Lake Project in Kafr El Sheikh and the National Project for Developing East Port Said (USDA, 2016). These projects, have contributed to the rapid expansion of support activities such as local feed mills and hatcheries, which have further made the sector more sophisticated and diverse.

The above trends suggest that aquaculture provides a nutritious and dependable source of food that can enhance national food security, but at the same time it is an agent of economic growth. Aquaculture expansion in Egypt generates employment opportunities across the entire value chain (Section 2.1), including jobs for women and the youth. Thus it can be argued that the Egyptian aquaculture sector sits at the interface of multiple sustainable development goals (SDGs). Aquaculture can contribute to SDG2 (Zero Hunger), but also to SDG1 (No Poverty), SDG8 (Decent Work and Economic Growth), and SDG5 (Gender Equality). Meeting the SDGs has become an integral element of Egyptian policy, especially through the Sustainable Development Strategy Vision 2030, which outlines programs, policies and measurable indicators for sustainable development (Sharm El-Sheikh, 2015). Thus aquaculture can play a significant role in the current efforts to catalyse sustainable development in the country (Shaalan et al., 2018).

The aim of this paper is to discuss the potential contribution of Egyptian aquaculture to meet SDGs related to employment generation and gender equality. In particular, we assess employment generation by age and gender across the different stages of the aquaculture value chain, including feed mills, hatcheries, fish farms and traders/retailers. We focus on the main fish production governorates of Kafr El-Sheikh, Sharkia, Behera, Damietta and Fayoum that are responsible for more than 80% of the Egyptian aquaculture output (GAFRD, 2018). Section 2 outlines the aquaculture value chain in Egypt and the methodology used to quantify employment generation. Section 3 quantifies employment generation across the value chain in the different governorates. Section 4 synthesizes the main findings and identifies the implications of the current employment generation trends for meeting key SDGs in Egypt.

2. Methodology

2.1. Study context

Figure 1 outlines the aquaculture value chain in Egypt as considered in this paper. The value chain mainly comprises feed mills, hatcheries, fish farms, and traders/retailers. These stages reflect radically different roles within the value chain[2], as discussed below.

There are about 440 hatcheries (Nasr-Allah et al., 2014) and 60 feed mills (El-Sayed, 2014) in Egypt. Hatcheries are typically privately owned, and produce all male tilapia fry and fingerling [3], which is then mostly sold to fish farms at an average weight 0.2-0.5 g for fry and 1-5 g for fingerlings. On average hatcheries have a size of 1.7 ha and around 10,700 of brooders per hatchery (Nasr-Allah et al., 2014). Feed mills mainly produce floating, extruded or sinking pellets (mainly for tilapia), with crude protein levels ranging between 25 and 45% (El-Sayed, 2014).

Freshwater fish farms produce the bulk of the fresh fish in the country. In terms of produced species, tilapia is the dominant species. In 2016 it accounted for more than two thirds of all fish produced through aquaculture in the country (Figure 2). Other important species/groups include carps (*Cyprinids,* mainly common carp and grass carp, 15%), mullet (*Mugilidae spp*, 11%) and catfish (*Clarias spp*, 2.5%). Egypt is the third largest tilapia producer in aquaculture globally (after China and Indonesia), and the largest producer of mullet (FAO, 2018). Earth ponds is the dominant production system (accounting for 86% of total production in 2016), followed by cages (12.8%) (GAFRD, 2018).

Fish farms distribute fish to traders and wholesalers. These larger traders distribute fish to retailers and food service (e.g. restaurants) usually within 1 day from purchase. On average these traders sell 99% of the fish bought, amounting to an average sales volume of 1,112 t/year and EGP 11.9 million (Lentisco and Alonso, 2012). Retailers sell directly to domestic consumers live or fresh fish (with or without ice), and also are typically in possession of the fish for a day. On average retailers have an average sales volume of 65 t and EGP 940,000 (Nasr-Alla et al., 2012).

Our study focused on the governorates of Kafr El-Sheikh, Sharkia,

[1] The current population is close to 100 million (World Bank, 2017b), and is projected to increase to over 150 million by 2050 (World Bank, 2017b). Approximately 60% of the national population is under the age of 30, and an estimated 20% of the population lives on less than USD 1 per day. Egypt ranks 135th out of 144 countries for gender inequality in economic participation and opportunity (World Economic Forum, n.d.). Such strong gender disparities are due to a series of factors such as social norms and attitudes, economic pressures, religious beliefs, access to finance and markets, and structural forces (Assaad and Krafft, 2013; Biltagy, 2014; Nassar and Biltagy, 2017).

[2] The overwhelming majority of the persons involved in the Egyptian aquaculture chain are engaged in these four stages. Other types of engagement include equipment dealers (e.g. for aeration and oxygenation systems) and fish processors. However, the actual number of people involved in these stages tends to be low in Egypt, while they are not necessarily located in the same governorates where fish is produced and sold. For these reasons we did not consider employment generation in fish processing and aquaculture equipment trading in our analysis.

[3] There are also eight medium and small size hatcheries dedicated for other species such as sea bass and sea bream (GAFRD, 2018). However, these are not located in the study governorates. For this reason, we did not consider these hatcheries in this study.

Table 1
Key statistics for fisheries and aquaculture in Egypt.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Fisheries (1000t)	372	374	387	385	375	354	357	345	344	336
Aquaculture (1000t)	636	694	705	922	987	1,018	1,098	1,137	1,175	1,371
Total fisheries production (1000t)	1,008	1,068	1,093	1,307	1,362	1,372	1,454	1,482	1,519	1,706
Farmed fish (% of total)	62.9	64.8	64.4	70.3	72.4	74.2	75.5	76.7	77.3	80.3
Fish imports (1000 t)	258.9	136.8	135.5	256.8	182.2	335	236	354.6	296.1	311.1
Fish exports (1000 t)	4.4	6.7	7.6	10.6	9.5	16	20	28.0	19.7	47.8
Fish farming (% of total consumption)	50.2	57.8	57.6	59.2	64.2	60.0	65.7	62.9	65.4	69.6
Local Fisheries Supply (Kg/cap/yr)	13.50	14.13	14.13	16.44	16.82	16.48	16.94	16.75	16.85	18.22
Local and Imported Fisheries Supply (Kg/cap/yr)	16.98	15.95	15.89	19.7	19.09	20.55	19.73	23.47	20.83	21.64

Source: (GAFRD, 2018)

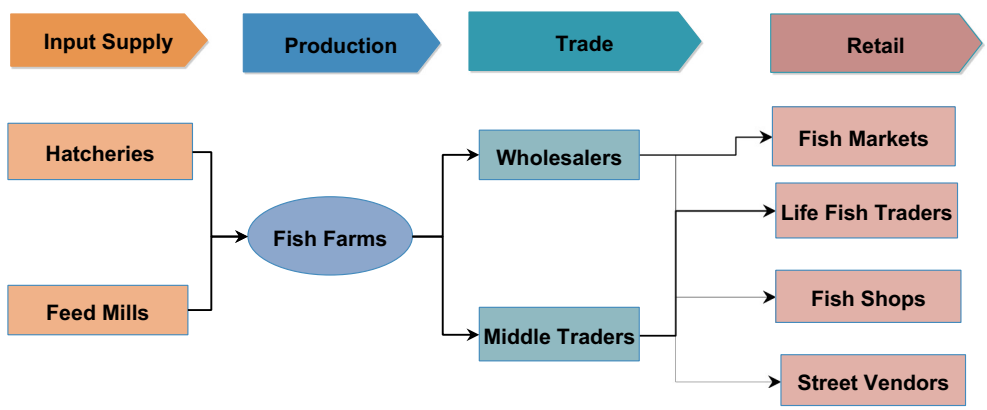

Fig. 1. Aquaculture value chain in Egypt and linkages among the main actors. Source: (Macfadyen et al., 2011; Macfadyen et al., 2012b)

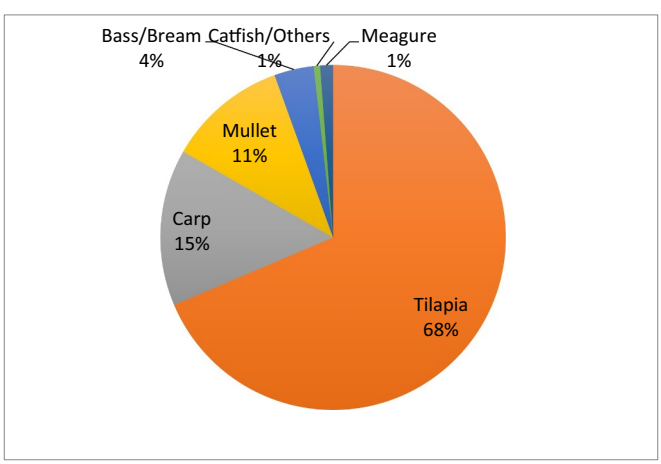

Fig. 2. Fish species produced through Aquaculture in 2016.

Behera, Damietta and Fayoum (Fig. 3). The selection was based on the fact that these areas collectively account for more than 80% of the Egyptian aquaculture production in 2016 (CAPMAS, 2018; GAFRD, 2018), hence they could be seen as a good proxy of the employment generation patterns for the entire aquaculture sector.

WorldFish targeted several of the fish farms in the study governorates with interventions that could enhance fish productivity, and have a positive impact on local communities. The specific interventions include: (a) introduction of improved tilapia strains with higher growth rates and yields, (b) training on best management practices, and (c) improvement of conditions for women fish retailers (Ibrahim et al., 2019; El Azzazy et al., 2018; Dickson et al., 2016; Macfadyen et al., 2012a,b; Haque and Dey, 2017; Panda et al., 2012). These interventions targeted key aspects of fish production and retailing, with the aim of boosting employment at various nodes of the value chain, especially for women (Haque and Dey, 2017).

2.2. Data collection

Data were collected through questionnaires that targeted the different groups within the aquaculture value chain, namely hatcheries, feed mills, fish farms, and the post-harvest sub-sector including traders, wholesalers and retailers (Fig. 1). The questionnaires varied between actors in order to reflect their different operations and roles within the value chain. However all questionnaires included questions about the output and employment (e.g. number of permanent/temporary employees, employment type for each gender). The questionnaire were drafted in English and then translated into Arabic. The different questionnaires were piloted at the WorldFish Centre in Abbassa, and were revised following the insights gained during piloting. Subsequently we trained enumerators that undertook the data collection.

We select the study areas and sample size through a purposive expert sampling approach (Daniel, 2012; UN, 2005). There were three different reasons that prohibited us to adopt a probability sampling approach namely: (a) the concentration of aquaculture activities in some specific governorates; (b) the lack of complete information for two of the four stages of the value chain namely fish farming and fish trading (and thus the inability to create comprehensive respondent lists to allow the use of statistical techniques to estimate sampling size), and (c) logistical constraints. The decision over the geographical coverage and number of samples for each stage of the value chain is based on insights from the academic literature, assumptions based on secondary data, and logistical constraints, and is informed through our experience conducting similar surveys in Egyptian aquaculture systems (and elsewhere) (e.g. Macfadyen et al., 2012b).

Even though the expert approach to sample size selection is influenced by the lack of comprehensive information, the actual selection of the respondents follows a much more rigorous approach to ensure the

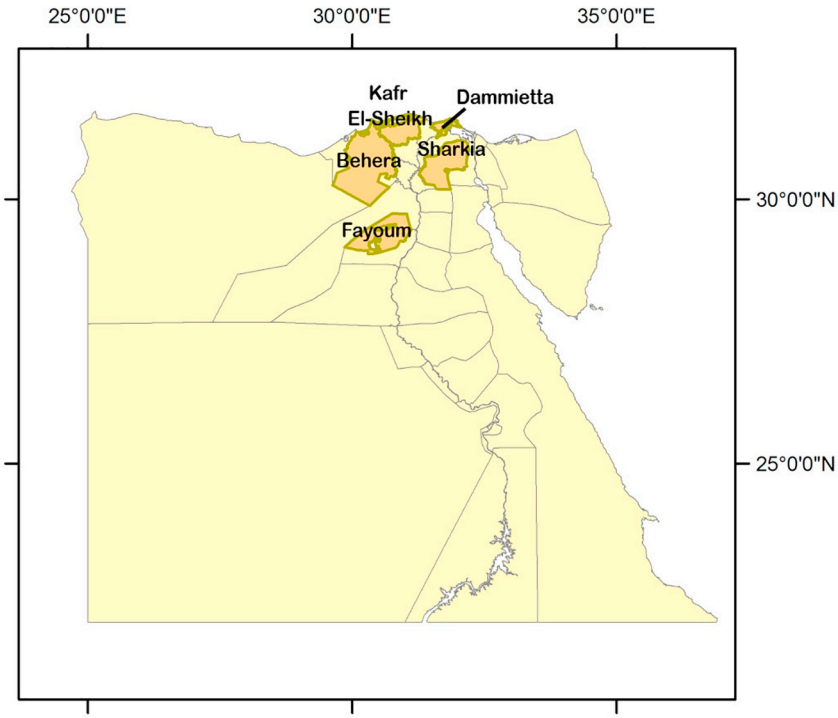

Fig. 3. Map of Egypt with location of study governorates.

Table 2
Number of interviews for each value chain actor, by governorate.

	Hatcheries	Feed mills	Fish farms	Fish Traders	Total
Behera	5	2	36	33	76
Fayoum	-	-	38	28	56
Kafr El-Sheikh	30	9	110	88	235
Sharkia	5	3	29	33	70
Damietta	-	-	21	-	21
Total	40	14	234	182	458

Table 3
Number of interviews for different types of fish traders and retailers, by governorate.

	Wholesalers	Middle traders	Retailers			Live fish sales and transport
			Fish shops	Fish markets	Street vendors	
Behera	4	4	7	7	7	4
Fayoum	4	4	6	6	6	4
Kafr El-Sheikh	9	10	21	21	20	7
Sharkia	8	0	7	7	6	5
Total	25	18	41	41	39	20

effective randomization of the sample, and includes techniques such as selection from lists, transect walks and snowballing (Daniel, 2012). Such purposive expert approaches to select sample size and study location are often employed in value chain analyses of aquaculture and fisheries due to the absence of key information (e.g. Bevilacqua et al., 2019; El-Sayed et al., 2015; Kaminski et al., 2018).

In total the selected sample consists of 14 feed mills, 40 hatcheries, 234 fish farms and 182 fish traders across the different governorates (Tables 2–3). Information availability dictated the adoption of the different sampling procedures, as a means of ensuring the effective randomization of samples (see below). Mixed sampling methods to identify respondents due to information availability is common in studies that contain multiple study groups (Gasparatos et al., 2018). The specific constraints and decisions for each stage of the value chain are explained in more detail below.

We sought to survey about 10% of feed mills and hatcheries, as based on previous experience we judge this to allow for a good representative sample for each group. However, due to the small number of feed mills (N = 60) we eventually increased the sample size to 14 feed mills (approximately 23%) to reduce any possible analytical errors due to small sample size. We then randomly sample hatcheries and feed mills from comprehensive databases updated by WorldFish (Nasr-Allah et al., 2014; El-Sayed, 2014).

As there is no comprehensive database of fish farms in Egypt, we rely on judgment and secondary data on fish production at the governorate level to select (a) the overall sample size and (b) the sample breakdown between governorates. First, we select the total number of fish farms (N = 234) through expert judgment due to the inability to use statistical techniques to accurately estimate sample number. The sample size is based on previous experience conducting baseline studies of the Egyptian aquaculture value chain (Macfadyen et al., 2012b). Second, we estimate the actual sample size at the governorate level based on the fish production output of each governorate compared to the total national fish production. This proportionate sampling approach is used to avoid oversampling fish farms from any given governorate. Third, we adopt a systematic sampling approach to select the respondents across the different governorates. In particular through WorldFish Centre contacts in each of the governorates we identify the

districts (and the specific areas within districts) that have high aquaculture activity that could be considered typical of the specific governorate. Fourth, we identified sample sizes in each district based on a rough proportional distribution according to information provided from the local contacts (e.g. higher numbers in districts believed to have a larger number of fish farms)[4]. Fifth, we arranged visits to the different fish farming communities, and we selected fish farms randomly through transect walks, again due to the lack of comprehensive list of farms. In particular, starting from a fixed point, enumerators walked in each direction visiting the first farm on right hand side, followed by the third farm on the left hand side, and then again the third farm on the right hand side. The adopted transect walk approach allowed for a high degree of randomization, but at the same time raises some issues about representativeness (Section 4.3).

Similar to fish farms sampling size is selected based on estimates about study needs and is based on previous experience conducting baseline studies of the Egyptian aquaculture value chain (Macfadyen et al., 2012b). Actual respondents were selected through a snow-ball sampling approach as explained below. At the beginning of the survey, the enumerators visited the wholesale fish market in the capital city of each governorate. Through this initial visit we developed a list of wholesalers, middle traders and other retailers. The wholesalers who were interviewed identified traders in other districts within the governorate. After finishing the interviews in the capital of each governorate, the enumerators moved to different districts until the desired sample was achieved. Through this process a total of 11 districts were visited as below:

- Kafr El-Sheikh governorate: Kafr El-Sheikh, Desouk, El-Hamoul, and Balteem districts;
- Beheira governorate: Rashid, Badr, and Edko districts;
- Fayoum governorate: Fayoum, Ibshwai districts;
- Sharkia governorate: Bilbeis, and Abou Hamad districts.

We ensured that each respondent was highly knowledgeable about the operations of each respective entity. In all cases the respondent was either the owner or the manager of the operations (and in some cases the respondent was both the manager and the owner of the operations).

2.3. Data analysis

Data from the hard-copy questionnaires were entered into excel spreadsheets, and checked for validity and correctness by the enumerators responsible for completing the individual interviews.

To calculate employment generation, we converted part time jobs to full time equivalents (FTE), and aggregated them with the full time jobs. We calculated for each stage of the value chain employment generation indices as below:

- Hatcheries: FTE jobs generated per 0.66 million tilapia seed, which is necessary for producing 100t of fish (FTE per 100t of fish) (Section 3.2). This is based on the survival rate for tilapia fry to market size in growing ponds (57.2%) (Bolivar et al., 2004), and an average tilapia harvest weight of 265g (Macfadyen et al., 2012b). Based on these assumptions 0.66 million tilapia fry is necessary to produce 100t fish.
- Feed mills: FTE jobs generated per 150t of produced fish feed, which is necessary for producing 100t of fish (FTE per 100t of fish) (Section 3.3). We use a Food Conversion Ratio (FCR) to assume the quantity of fish feed needed to produce 1 kg fish. Studies have reported FCR values of 1.5-1.8 in different aquaculture farms in Egypt depending on the type of intervention (Dickson et al., 2016) (see Section 2.1). For this study, we assume a FCR of 1.5, which implies that 150t of fish feed would be necessary to produce 100t of fish.
- Fish farms: FTE jobs generated per 100t of produced fish (FTE per 100t of fish) (Section 3.4);
- Traders/retailers: FTE jobs generated per 100t of sold fish (FTE per 100t of fish) (Section 3.5).

To assess job creation by age and gender we also calculated FTE job generation per 100t of produced fish, for both males and females above 30 years of age (FTE > 30 per 100t) and below 30 years of age (FTE < 30 per 100t).

We also calculate employment generation for ancillary transport services for each stage of the value chain. However due to the nature of transport activities and the fact that service providers can change from time to time, it is not possible to calculate accurately employment generation by gender and age. For this reason, we calculated only the overall transport-related employment generation (in FTE jobs per 100t of produced fish), not differentiating by age group and gender.

We then aggregate the estimated values for each stage of the value chain to derive the employment generation for the entire value chain (Section 3.6). However, considering the different sampling approaches and the calculation procedure for transport, caution is needed when interpreting the overall employment results.

3. Results

3.1. Characteristics of the value chain

On average each hatchery produced 8.0 million seeds. The highest average production was in Sharkia (10.5 million seed per hatchery) followed by Behera (8.0 million seed per hatchery) and Kafr El Sheikh (7.6 million seed per hatchery) (Table S1, Supplementary Electronic Material). Seed comes overwhelmingly in the form of fry (93%) rather than fingerlings (7%). The average hatchery size is 1.33 ha, with hatcheries in Sharkia being on average the largest (1.64 ha). However, hatcheries in Kafr El Sheikh have the highest seed production per unit area (9.45 million seed per ha), which makes them more intensive and high yielding compared to hatcheries in Behera and Sharkia (Table S1, Supplementary Electronic Material).

The production capacity of feed mills varies, being on average 8,500 t/yr, 12,167 t/yr and 2,667 t/yr in Behera, Kafr El-Sheikh and Sharkia respectively. Feed mills in Behera and Sharkia produce only pelleted feed, while mills in Kafr El-Sheikh produce both pelleted (29%) and extruded feed (71%) (Table S2, Supplementary Electronic Material). Most of the surveyed feed mills normally run a single work shift, but some feed mills in Kafr El-Sheikh run two or three shifts. This is reflected in their higher (on average) production capacity.

Overall average farm size is 21.4 feddan (one feddan = 0.42 hectare). Total area of fish farm surveyed in this study is 5150 feddan (2163 hectare) and distributed are as follow: 1015, 827, 1561, 1020 and 727 feddan in governorates of Behera, Fayoum, Kafr El Sheikh, Sharkia and Damietta, respectively (Table S3, Supplementary Electronic Material). Average annual fish production per fish farm was 93.5 t (range: 63.9-144.5 t) or 10.3 t/ha (range 9.4-12.2 t/ha) (Table S3, Supplementary Electronic Material). Figure 4 outlines fish productivity per unit area for different species, highlighting the much higher productivity of tilapia per unit area (see also Table S3,

[4] The specific study districts and sample sizes are as follow. Kafr El Sheikh governorate: Al Reyad (N = 46), Brulus (N = 34), Motubas (N = 30); Behera governorate: Abohoms (N = 5), Edko (N = 22), Kafr el Dawar (N = 9); El Sharkia governorate: Hessinia (N = 29); Fayoum governorate: El Sedeek (N = 29), Ibshewai (N = 5), Snoras (N-4). Due to the characteristics of Egyptian fish farming many of the fish farms are concentrated in relatively uninhabited areas. For this reasons instead of identifying specific villages in each of these districts we identified areas of high aquaculture activity that were considered typical of the specific district and governorate. This was based on insights of local contacts and experts. Due to the rather large distance between farms (average farm size is 21.4 feddan or 9ha) it limited the number of interviews to two to three per day per data collectors

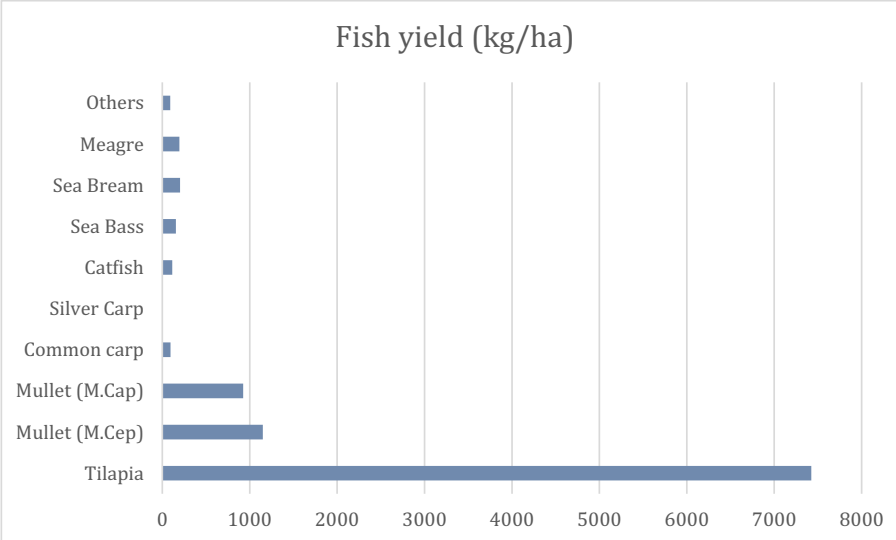

Fig. 4. Average productivity for different fish species (in kg/ha).

Table 4
Sales volumes for fish traders and retailers across governorates (in t/yr).

	Behera	Fayoum	Kafr El-Sheikh	Sharkia	Average
Middle traders	5,355	468	459	-	1,549
Wholesalers	1,275	400	442	901	715
Fish shops	50	26	70	20	52
Fish markets	16	16	56	21	37
Street vendors	12	13	30	20	23
Live fish traders/transporters	9	18	32	16	22

Supplementary Electronic Material).

On average, respondents in trading and retailing have been operating for 9.8 years. Respondents in Fayoum governorate have the highest average experience (16.0 years), followed respondents in Behera (9.3 years), Sharkia (8.4 years) and Kafr El-Sheikh (8.4 years). From a gender perspective, 72% of respondents in trading and retailing are males and 28% female, with male respondents dominating all governorates apart from Fayoum (Table S4, Supplementary Electronic Material). Sales volume varied substantially between the different types of fish traders and retailers (Table 4).

3.2. Employment generation in hatcheries

On average, hatchery-related job creation across the study governorates amounts to 3.55 FTE jobs per hatchery and 0.41 FTE jobs per 0.66 million fry (equivalent to 100t of produced fish), including contribution from ancillary transport services (Table 5). In particular, hatcheries in Behera governorate generate the most jobs (0.54 FTE jobs per 0.66 million fry, and 5.08 FTE jobs per hatchery), followed by hatcheries in Sharkia (0.27 FTE jobs per 0.66 million fry, and 3.90 FTE jobs per hatchery) and Kafr El-Sheikh (0.41 FTE jobs per 0.66 million fry and 3.23 FTE jobs per hatchery).

There is almost equal employment generation across age groups in terms of FTE jobs per hatchery, with hatcheries in Behera and Sharkia generating on average more jobs for people below 30 years of age for both major employment indicators (Table 5, Figure 5). We did not identify any employment generation for females in any governorate.

3.3. Employment generation in feed mills

On average, feed mill-related job creation amounted to 13.81 FTE jobs per feed mill or 0.39 FTE jobs per 150 t of produced feed (equivalent to 100t of produced fish), including from ancillary transport services (Table 6). Overall job creation ranged between 0.74 FTE jobs per 150t feed in Sharkia, to 0.35 FTE jobs per 150t feed in Behera and 0.29 FTE jobs per 150t feed in Kafr El-Sheikh, all including employment contribution from transport (Table 6).

Employment generation is relatively well-balanced between employees under 30 years of age (0.12 FTE jobs <**30** per 150t feed), and over 30 years of age (0.18 FTE jobs >**30** per 150t feed). Employment generation in feed mills in Sharkia is almost the same between age groups, while in Behera job generation is higher for those below 30 years (Table 6, Figure 6). As in the hatcheries, jobs in feed mills were occupied only by males.

Table 5
Employment generation indicators for hatcheries.

	Behera	Kafr El-Sheikh	Sharkia	Average
FTE jobs per hatchery	5.08	3.23	3.90	3.55
FTE jobs >30 per hatchery	1.94	1.92	0.70	1.77
FTE jobs <30 per hatchery	3.14	1.31	3.20	1.78
Transport FTE jobs per hatchery	0.13	0.23	0.11	0.21
FTE jobs per hatchery incl. transport	5.21	3.46	4.01	3.76
FTE jobs per 0.66 million fry (or 100t fish)	0.53	0.38	0.26	0.39
FTE jobs >30 per 0.66 million fry (or 100t fish)	0.23	0.24	0.06	0.22
FTE jobs <30 per 0.66 million fry (or 100t fish)	0.31	0.14	0.20	0.17
Transport FTE jobs per 0.66 million fry (or 100t fish)	0.01	0.03	0.01	0.02
FTE jobs per 0.66 million fry (or 100t fish) incl. transport	0.54	0.41	0.27	0.41

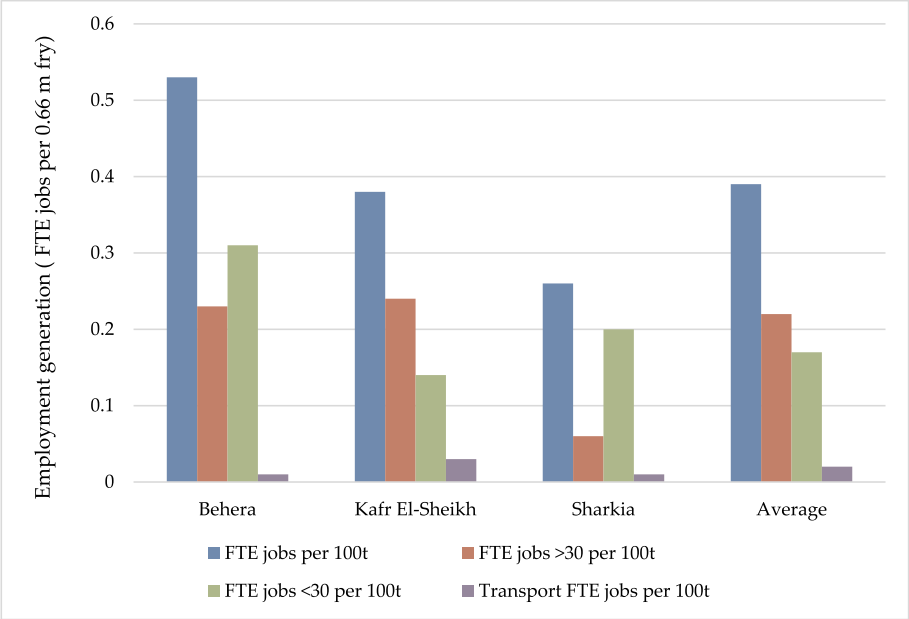

Fig. 5. Hatcheries' FTE jobs generation per 0.66 million fry (equivalent to 100t fish)

Table 6
Employment generation indicators for feed mills.

	Behera	Kafr El-Sheikh	Sharkia	Average
FTE jobs per feed mill	18.40	14.82	7.72	13.81
FTE jobs >30 per feed mill	7.00	10.21	3.82	8.38
FTE jobs <30 per feed mill	11.40	4.62	3.90	5.43
Transport FTE jobs per feed mill	2.73	4.32	3.18	3.85
FTE jobs per feed mill incl. transport	21.13	19.14	10.90	17.66
FTE jobs per 150t feed (or 100t fish)	0.30	0.22	0.54	0.30
FTE jobs >30 per 150t feed (or 100t fish)	0.13	0.16	0.27	0.18
FTE jobs <30 per 150t feed (or 100t fish)	0.17	0.07	0.27	0.12
Transport FTE jobs per 150t feed (or 100t fish)	0.05	0.07	0.20	0.09
FTE jobs per 150t (or 100t fish) incl. transport	0.35	0.29	0.74	0.39

3.4. Employment generation in fish farms

On average, fish farm-related jobs amounted to 7.03 FTE jobs per 100t of produced fish, including from ancillary transport services. The overall job generation ranges between governorates as follows: Fayoum (7.85 FTE jobs per 100t), Behera (7.34 FTE jobs per 100t), Kafr El-Sheikh (6.74 FTE jobs per 100t), Damietta (6.76 FTE jobs per 100t), and Sharkia (5.63 FTE jobs per 100t), all including employment generation from ancillary transport services (Table 7). There is no job generation for females in the surveyed fish farms.

On average twice as many jobs are generated for individuals above 30 years of age (4.24 FTE jobs > 30 per 100t, compared to 2.08 FTE jobs < 30 per 100t). This substantially higher job generation for older people is evident across all five study governorates. In some extreme cases, job generation is 3 times lower for younger people than for older people, e.g. Fayoum (5.03 FTE jobs > 30 per 100t vs. 1.75 FTE jobs < 30 per 100t) and Damietta (4.44 FTE jobs > 30 per 100t vs. 1.49 FTE jobs < 30 per 100t) (Table 7, Fig. 7).

As mentioned in Section 2.1 several fish farms in the study governorates received intervention from WorldFish such as improved fish strains and training. Some farms received both interventions (N = 26), some only training (N = 96), some only the improved fish strain (N = 6), and others no intervention at all (control) (N = 106). Table 8 shows that employment generation was consistently lower for the fish farms that received interventions compared to the control, though the differences are not statistically significant at this stage. The fish farms that received interventions showed a consistent decrease in employment generation between 2015 and 2017, but the differences are not also statistically significant.

3.5. Employment generation is fish marketing

The overall number of FTE jobs created per 100t of sales volume varied among different players, but is much lower for middle traders and wholesalers (Table 9) than retailers (Table 10). In particular, when taking into account transport, jobs generation is 1.59 FTE jobs per 100t of sold fish (Table 9). Disaggregated data estimate employment generation of 1.63 FTE jobs per 100t for middle traders (Table S5, Supplementary electronic Material) and 1.56 FTE jobs per 100t for wholesalers and middle traders (Table S6, Supplementary Electronic Material). Most jobs were created for males over 30 years with very limited generation of jobs for females (only observed for wholesalers in Fayoum) (Table 9).

More substantial job generation is observed in fish retailing across all governorates (Table 10). In particular, when taking into consideration job generation from ancillary transport services, job creation amounted to 10.13 FTE jobs per 100t of sold fish. Disaggregated data suggest the generation of 11.87 FTE jobs per 100t for fish shop retailers, 7.29 FTE jobs per 100t for fish market retailers, 9.68 FTE jobs per 100t for street vendors, 13.59 FTE jobs per 100t for live fish sellers and

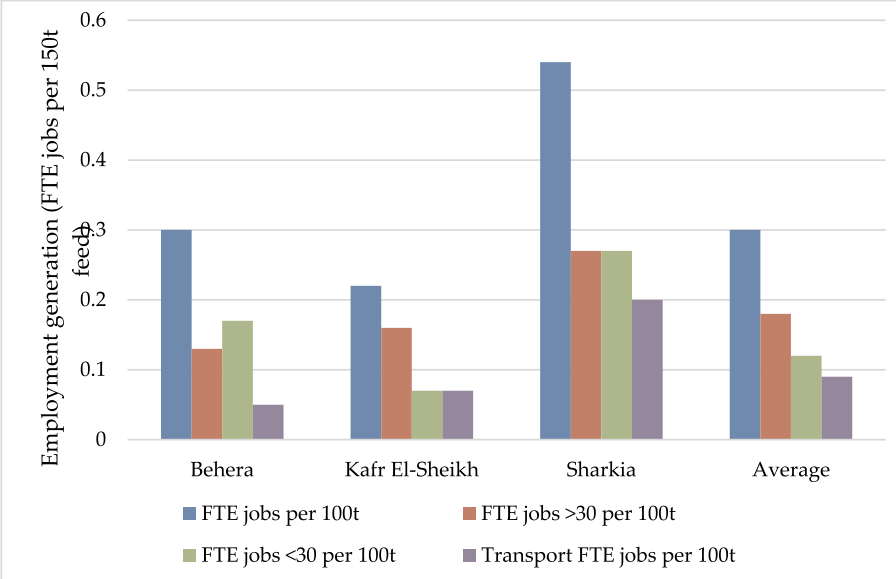

Fig. 6. Feed mills' FTE jobs generation per 150t feed (equivalent to 100t fish)

transporters (Tables S7-S10, Supplementary Electronic Material). In contrast to other stages of the value chain, retailing offered substantial employment opportunities for youth and females. Actually street vending and live fish sales/transport were the only stages of the value chain with parity between the jobs generated for males and females (Fig. 8).

3.6. Employment generation across the value chain

The value chain analysis indicates the creation of about 19.56 FTE jobs per 100t of produced fish, including employment generation from ancillary transport services (Table 11–12). The trading and retailing segment of the value chain generated the highest number of jobs at an average of 8.96 FTE jobs per 100t of produced fish, with an added 3.58 FTE jobs per 100t of produced fish from ancillary transport activities (Table 11–12). In the trading and retailing stages the generated jobs were overwhelmingly permanent (96% and 99% respectively) (Table 13). However permanent employment generation was much lower in fish farms, standing only at 65% (Table 13).

A large proportion of jobs were generated for youth, especially in hatcheries (48% of total), feed mills (41%), and middle traders/wholesalers (40%) (Table 14). Overall, males dominated employment generation across all stages of the value chain (Table 15). Practically there were no females occupied in the surveyed hatcheries, feed mills and fish farms, but there was a much more significant job creation for females in the fish retailing stage, amounting to 32% of total job generation (Table 15).

4. Discussion

4.1. Employment generational patterns and co-benefits

The present study estimates substantial employment generation across the aquaculture value chain in Egypt, in the order of 19.56 FTE jobs per 100t of produced fish (including the employment contribution from ancillary transport services). Very few studies have attempted to estimate employment generation across the aquaculture value chain, so it is difficult to put these findings into perspective. Previous studies in Egypt have estimated that aquaculture generates 14 FTE per 100t of produced fish (Macfadyen et al., 2011; Macfadyen et al., 2012b). However these studies did not consider employment generation in hatcheries and feed mills, and had small samples from fish traders, so they have likely underestimated the total employment generation from the sector. Our estimates of employment generation from feed mills is comparable with other studies in Egypt (El-Sayed, 2014; El-Sayed et al., 2015)

Regarding employment generation for females, our study reflects the findings of recent reviews and meta-analyses, which have identified that women receive lower benefits from involvement in aquaculture value chains, especially during the production stages (Mula and Sarker, 2013; Sharm El-Sheikh, 2015). Nonetheless, the participation of women in fish retailing is substantial, and as high as 40% in some governorates such as Fayoum (Section 3.5). This is a very promising pattern towards addressing the gender gap in the Egyptian aquaculture value chain (D'Allessandro Y., 2014). Indeed, reports suggest a high proportion (40-

Table 7
Employment generation indicators for fish farms.

	Behera	Fayoum	Kafr El-Sheikh	Sharkia	Damietta	Average
FTE jobs per farm	6.03	3.23	3.08	5.89	6.90	5.91
FTE jobs >30 per farm	3.80	2.40	1.97	3.94	5.17	3.94
FTE jobs <30 per farm	2.23	0.83	1.11	1.95	1.73	1.98
Transport FTE jobs per farm	0.61	0.54	0.21	0.66	0.90	0.45
FTE jobs per farm incl. transport	6.64	3.77	3.29	6.55	7.80	6.36
FTE jobs per 100t fish	6.56	6.77	6.19	5.13	5.93	6.33
FTE jobs >30 per 100t fish	4.13	5.03	3.97	3.43	4.44	4.24
FTE jobs <30 per 100t fish	2.42	1.75	2.23	1.70	1.49	2.08
Transport FTE jobs per 100t fish	0.78	1.08	0.55	0.50	0.83	0.70
FTE jobs per 100t fish incl. transport	7.34	7.85	6.74	5.63	6.76	7.03

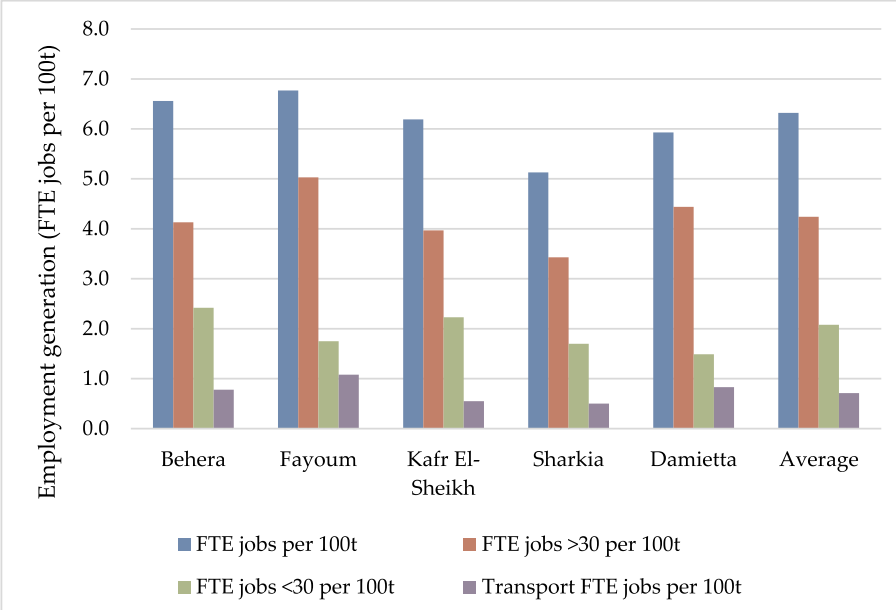

Fig. 7. Feed farms' FTE job generation per 100t fish

80%) of post-harvest and marketing activities are performed by women (Lentisco and Lee, 2015; Harper et al., 2013; Lentisco and Alonso, 2012; Weeratunge et al., 2010), suggesting a potential for improvement. It is thus highly likely that the post-harvest segment of the aquaculture value chain can offer the highest opportunities for achieving positive impact for women.

An interesting finding of this study is the lower employment generation in farms that have received interventions aiming to increase fish productivity, such as training and improved fish strains (Section 3.4). While our study was cursory in this respect, it is highly possible that such interventions might result in intensification of fish production. Other studies in Egypt support this conclusion as they have reported that the training of fish farmers best management practice has resulted in improved efficiency, reducing feed costs rather than increasing production (Haque and Dey, 2017). Several studies have identified that exogenous interventions in aquaculture value chains offer benefits beyond employment generation (Table 16). When implementing such interventions co-benefits need to be maximized to the extent possible, to ensure that any potential job loss due to intensification can be offset by other benefits when scaling up such interventions.

4.2. Implications for meetings SDGs

As discussed above, aquaculture can catalyze employment generation across its entire value chain in Egypt. However, most of these jobs are held by people over 30 years of age. In particular FTE job generation for this age group (FTE > 30) is substantially higher across all stages of the value chain (Section 3.6).

More importantly these jobs are occupied predominately by males (Section 3.6). Retailing is the only stage of the value chain with high employment generation for females, albeit still significantly lower than males in most governorates (Section 3.6)). More crucially, we did not identify any employment generation for females in the production stages of the value chain, as practically there were no female jobs reported in the surveyed hatcheries, feed mills and fish farms. To some extent, the low employment generation for females is to be expected in fish farms, considering the manual nature of the job, and the need to stay on site (and away from family) for extended periods of time. Furthermore, a significant portion of jobs in fish farms is temporary (Section 3.6), and is usually on offer during periods of high labour demand such as harvesting. However, it is troubling to see the lack of female representation in hatcheries and feed mills, as some of these jobs are high-skill and better paying (e.g. technical managers, feed formulation specialists, supervising engineers, quality control specialists). The lack of representation of females in these stages suggests the difficulty, for women, of obtaining higher-skilled jobs in the production stages of the value chain.

Barriers to female engagement and training in the past, and the remoteness of fish farm and hatcheries might have contributed to the current lack of female representation in skilled jobs in the aquaculture production stages in Egypt (Macfadyen et al., 2012b; Nasr-Allah et al., 2014). However these barriers are gradually overcome considering the greater gender balance in the new graduate courses on fisheries and aquaculture in the major Egyptian universities. Indeed in the past 4

Table 8
Employment generation according to type of intervention.

Groups (First group vs. Second group)	Mean FTE jobs per 100 t (First group)	Mean FTE jobs per 100t (Second group)	P-value
Abbassa strain (2017) vs. Control (2017)	5.59	6.67	0.1135
Both interventions (2017) vs. Control (2017)	6.06	6.67	0.1837
Training (2017) vs. Control (2017)	5.72	6.67	0.0414
Training (2017) vs. Abbassa strain (2017)	5.72	5.59	0.4362
Abbassa strain (2017) vs. Both interventions (2017)	5.59	6.06	0.3025
Training (2017) vs. Both interventions (2017)	5.72	6.06	0.2992
Training (2017) vs. Training (2015)	5.72	6.47	0.0826
Abbassa strain (2017) vs. Abbassa strain (2015)	5.59	5.94	0.3666
Both interventions (2017) vs. Both interventions (2015)	6.06	6.96	0.1235

Table 9
Employment generation indicators for fish wholesalers and middle traders.

	Behera	Fayoum	Kafr El-Sheikh	Sharkia	Average
FTE jobs per 100t fish	0.30	2.30	1.60	1.00	1.40
FTE jobs men >30 per 100t fish	0.20	1.70	0.70	0.86	0.82
FTE jobs men<30 per 100t fish	0.14	0.44	0.94	0.16	0.55
FTE jobs women>30 per100t fish	0.00	0.07	0.00	0.00	0.01
FTE jobs women<30 per 100t fish	0.00	0.07	0.00	0.00	0.01
Transport FTE jobs per 100t fish	0.05	0.24	0.31	0.02	0.19
FTE jobs per 100t fish incl. transport	0.35	2.54	1.91	1.02	1.59

Table 10
Employment generation indicators for fish retailers.

	Behera	Fayoum	Kafr El-Sheikh	Sharkia	Average
FTE jobs per 100t fish	10.07	12.67	5.41	6.5	7.56
FTE jobs men >30 per 100t fish	7.96	3.00	2.17	3.49	3.56
FTE jobs men<30 per 100t fish	1.00	4.61	1.09	0.78	1.57
FTE jobs women>30 per100t fish	1.11	5.06	1.98	2.05	2.32
FTE jobs women<30 per 100t fish	0.00	0.00	0.17	0.19	0.12
Transport FTE jobs per 100t fish	0.87	5.85	2.56	0.40	2.57
FTE jobs per 100t fish incl. transport	10.94	18.52	7.97	6.90	10.13

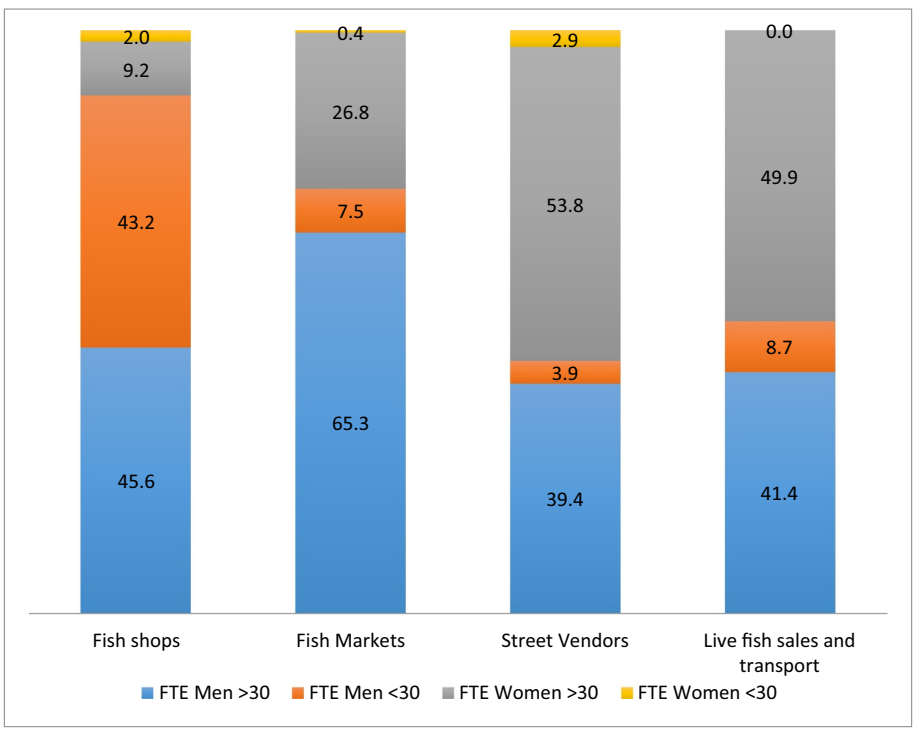

Fig. 8. Proportion of FTE job generation by age and gender among retailers (in %)

years the number of female graduates from such courses is almost on par with that of male students, suggesting that the barriers to training are gradually, if completely, disappearing (Said, personnel communication 2019). It is also worth pointing that females currently occupy 34% of the researcher positions at the Central Laboratory for Aquaculture Research (CLAR), which is part of the Agriculture Research

Table 11
Employment generation across the aquaculture value chain (in FTE jobs per 100t of produced fish).

	Behera	Fayoum	Kafr el Sheikh	Sharkia	Damietta	Average
Hatcheries	0.53	n/a	0.38	0.26	n/a	0.39
Feed mills	0.30	n/a	0.22	0.54	n/a	0.30
Fish farms	6.56	6.77	6.19	5.13	5.93	6.33
Middle trader/ wholesalers	0.34	2.29	1.64	1.02	n/a	1.40
Retailers	10.07	12.67	5.41	6.50	n/a	7.56
Total	17.80	21.73	13.85	13.45	5.93	15.98

Table 12
Employment generation from transport activities across the aquaculture value chain (in FTE jobs per 100t of produced fish).

	Behera	Fayoum	Kafr el Sheikh	Sharkia	Damietta	Average
Hatcheries	0.01	n/a	0.03	0.01	n/a	0.02
Feed mills	0.05	n/a	0.07	0.20	n/a	0.09
Fish farms	0.78	1.08	0.55	0.50	0.83	0.70
Middle trader/wholesalers	0.05	0.24	0.31	0.02	n/a	0.19
Retailers	0.87	5.85	2.56	0.40	n/a	2.57
Total	1.76	7.16	3.52	1.13	0.83	3.58

Table 13
Permanent jobs as a fraction of total employment generation (in percent).

	Behera	Fayoum	Kafr el Sheikh	Sharkia	Damietta	Average
Hatcheries	67%	NA	77%	70%	NA	75%
Feed mills	85%	NA	61%	92%	NA	71%
Fish farms	67%	55%	68%	62%	67%	65%
Middle trader/ wholesalers	100%	82%	99%	100%	NA	96%
Retailers	100%	96.5%	100.0%	100.0-%	NA	99%

Table 14
Fraction of employment generation for youth (in percent).

	Behera	Fayoum	Kafr el Sheikh	Sharkia	Damietta	Average
Hatcheries	63%	NA	40%	86%	NA	48%
Feed mills	56%	NA	29%	51%	NA	41%
Fish farms	37%	26%	36%	33%	25%	33%
Middle trader/wholesalers	41%	22%	57%	16%	NA	40%
Retailers	9.9%	36.4%	23.3%	14.8%	NA	22%

Table 15
Male employment generation as a fraction of total employment generation (in percent).

	Behera	Fayoum	Kafr el Sheikh	Sharkia	Damietta	Average
Hatcheries	100%	100%	100%	100%	NA	100%
Feed mills	100%	100%	100%	100%	NA	100%
Fish farms	100%	100%	100%	100%	100%	100%
Middle trader/ wholesalers	100%	93.6%	100%	100%	100%	98%
Retailers	89%	60.1%	60.2%	65.7%	89.0%	68%

Center (ARC), Ministry of Agriculture. While there is room for improvement this is a very promising trend, as these are very high skilled jobs.

It can be argued that this substantial employment generation (especially for the youth and females) can play an important role to ongoing efforts to meet SDG8 and SDG5 in Egypt. However, the lower employment generation for youth and females curbs to some extent the contribution of the sector for sustainable development in Egypt. It is absolutely crucial to boost the creation employment for youth and females along the value chain in order to maximize the potential of the sector to become an agent of sustainable development.

In the short term, the fish trading and retailing stage offers the best opportunity for job creation for females. In the medium- and long-term the gradual growth of the aquaculture sector due to increased fish production following the adoption of relevant interventions (e.g. improved fish strains, good production practices, see Section 2.1) can possibly boost the generation of high-skilled jobs for females and the youth in hatcheries and feed mills. Fish processing offers another opportunity for the long-term generation of skilled jobs, as the Egyptian aquaculture value chain has currently minimal value addition in terms of fish processing (Macfadyen et al., 2012b). For example, it has been suggested that increasing fish fillet sales can help generate female employment from fish processing in Egypt (Macfadyen et al., 2012a). Other fish processing-related activities such as gutting and scaling could also possibly boost unskilled female employment to an appreciable extent, but further research would be needed to understand the actual potential.

It is worth noting that employment generation is lower in fish farms that have received interventions aiming to boost fish yields, such as improved strains and training for best management practices. Although these differences are not statistically significant at this point in time, they suggest that interventions aiming to enhance fish yields and overall fish production in the long-term may curb employment generation at the fish farm stage of the value chain. Even though such interventions may catalyze broader employment generation in other stages of the value chain, it is important to keep in mind that some

Table 16
Examples of employment benefits and other co-benefits from aquaculture interventions.

Stage	Intervention	Employment generation	Co-benefits	Country	Citation
Farm	- Technological intervention	2495 jobs created - Fencing: 266 jobs - Guarding: 580 jobs - Harvesting: 1648 jobs	- Increased income - Food security	Bangladesh	(Haque and Dey, 2017)
Farm	- Knowledge - Financing - Marketing	Employment generation: - 387 man-days (277 man-days) higher than the control	- Higher financial contribution to families compared to the control (Rs. 3,265/- vs. Rs. 2,490/-)	India	(Panda et al., 2012)
Farm	- Knowledge	- Employment generation from 6.3 to 9.7 human-days/household	- Increased income	India	(Mula and Sarker, 2013)
Farm	- Mud crab farming - Milkfish farming - Mangrove nursery	- Increased employment	- Improved food supply - Increased income - Improved food security	Kenya	(Mirera et al., 2014)
Farm	- Fish culture - Fish-cum-duck culture - Hatchery	- Increased employment	- Fish yield increases to 4-6 t/ha/yr (from a benchmark of around 1 t/ha/yr) - Reduced vulnerability - Wealth generation	India	(Chakrabarti et al., 2017)
Farm Hatchery Other stages	Bangladesh Country-level data	Employment generation - 3.15 million FTE jobs (at farm level) - 642,000 FTE jobs (at other stages)	- Reduced vulnerability - Reduced poverty - Improved food security	Bangladesh	(Phillips et al., 2016)

employment trade-offs might emerge. Hence, when implementing such interventions, it is necessary to implement measure to absorb these lost jobs in other parts of the value chain and/or enhance the co-benefits of the intervention (Table 16). Fish processing could be a priority stage for such efforts, as it remains a rather underdeveloped stage of the aquaculture value chain in Egypt.

4.3. Limitations and future research

The information initially available to the research team was not consistent among the different stages of the aquaculture value chain. This discrepancy in available information, combined with the geographic distribution of the study areas, posed some limitations for data collection that should be taken into consideration when using the outcomes of this study.

First, sample size and study locations were selected though expert judgment from past experience conducting value chain analysis in Egypt (Macfadyen et al., 2012b) and logicstical constraints. Furthermore, study locations were a sub-set of the Egyptian governorates that host aquaculture activities. Even though the selected governorates are responsible for the bulk of aquaculture output in Egypt (about 80% of total output, see Section 1 and 2.1), they do not perfectly reflect the production practices and patterns in other parts of the country. Thus, even though the selected governorates (and the specific study districts and areas within them) provide a good proxy for employment generation patterns within the Egyptian aquaculture sector, it can be argued that they are not perfectly representative of the entire sector. This inability to adopt a probability sampling approach might have inserted biases in our employment generation estimates (Daniel, 2012; UN, 2005). Thus they should be viewed and interpreted as proxies, rather than perfectly representative estimates of employment generation across the Egyptian aquaculture value chain. Future studies should seek to expand the scope of this study by including more governorates in order to obtain a more comprehensive picture of employment generation patters across the country.

Second, contrary to hatcheries and feed mills, there is no comprehensive database of fish farms and fish traders/retailers operating in the different governorates (Section 2.2). Thus we could not select randomly fish farms and fish traders/retailers from list, as for hatcheries and feed mills. To ensure the effective randomization of the sample, the selection of fish farmers was performed though transect walks, and the selection of fish traders/retailers through snowballing. Although the randomization process has been robust, there should be caution when comparing the levels of employment generation between the different stages of the value chain.

Third, it is difficult to accurately estimate employment generation for transport-related activities, especially disaggregated by age and gender. Transport services are often outsourced, and the transport service vendors can change over time, even within the same year. The respondents were unable to report accurately the age and gender of the actual transport service providers, so we opted to report aggregate employment generation estimates not differentiating by gender and age. While it is highly possible that males will dominate the employment profile of transport services, it is not possible to infer with a high degree of accuracy employment generation by age.

Fourth, the aim of this survey was to assess overall employment generation across the different stages of the aquaculture value chain. However, due to the data collection and analysis methods it has not been possible to explain some interesting outliers, such as the high fraction of youth employment in Sharkia hatcheries (Table 5, 14) and Behera feed mills (Table 6, 14), and female employment in Fayoum sales (Table 10, 15). Understanding the reasons behind these outliers can possibly create more nuanced insights about job generation patterns in the sector that can be used to boost youth and female employment in other governorates. Furthermore, our survey did not attempt to elicit information about skill-level, wages, job quality, and satisfaction with employment. To elicit such variables with a high degree of accuracy it would have been necessary to interview every single employee, which was not logistically possible under the focus and constraints of the current research. However, such variables must be captured when seeking to investigate whether the generated jobs are decent. Furthermore, this type of information is necessary for understanding better the gender-differentiated outcomes in fish retail (e.g. whether there is income parity between female and male traders, retailers, and related employees). This type of information can provide a better lens to establish the actual contribution and potential of aquaculture for the meeting the SDGs in Egypt, and should be prioritized for future work. Such knowledge can possibly be invaluable for designing better interventions to curb the gender-differentiated outcomes and constraints that limit female participation in the aquaculture value chain.

Fifth, our study identified some differences in employment generation between fish farms that have received improved fish strains, training, or both, compared to farms that have not received such interventions. Even though the employment differences are not statistically significant at this point in time, farms that received intervention

can have a significantly lower employment generation potential in the longer-term as they further intensify production (see Section 4.2). Thus while such interventions could increase fish output (and thus overall employment generation across the entire value chain), it is highly possible that this will come at the expense of jobs at the fish farming stage. Our study was not designed to explain this phenomenon, so our results should be considered cursory in this respect. However, such employment trade-offs need to be assessed in future studies to understand better how interventions in aquaculture can affect progress in meeting SDG 5 and 8.

Finally, our study focused at the interface of SDG 5 and 8. However aquaculture can have important interactions with various other SDGs, such as SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water), to name just a few. Future studies should explore more extensively the interface between these SDGs (and the underlying targets) to clarify whether, how, and to what extent aquaculture can catalyse sustainable development in Egypt.

5. Conclusions

The present study assesses employment generation across the different stages of the aquaculture value chain in Egypt. The study focused on the five governorates that are responsible for approximately 80% of aquaculture production in Egypt, as a good proxy of employment generation patterns in the sector, rather than a representative estimate.

Overall, the results suggest that aquaculture can generate significant levels of employment, amounting to 19.56 FTE jobs per 100t of produced fish. This, combined with the ongoing growth of the sectors, means that aquaculture can contribute substantially to efforts to meet SDG 8 in Egypt. However, females and the youth currently hold a relatively small fraction of these jobs. With the exception of fish retailing, jobs for females are practically non-existent in the other stages of the aquaculture value chain. It is crucial to generate more jobs for females if the aquaculture sector is to become an even more important agent of sustainable development in Egypt. In the short-term the retailing sector can offer the greatest opportunities for female job generation. However, the gradual growth of the sector needs to include plans and strategies for boosting female employment in the other stages of the value chains, and especially at the production stages such as hatcheries and feed mills.

Declaration of Competing Interest

All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.

Acknowledgments

This publication was undertaken in the framework of Sustainable Transformation of Egypt's Aquaculture Market System (STREAMS) project, funded by the Swiss Agency for Development and Cooperation. The current research is a contribution to the CGIAR Research Program on Fish Agri-Food Systems (FISH). AK and ED acknowledge the support of a Monbukagakusho scholarship offered by the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT) through the Graduate Program in Sustainability Science - Global Leadership Initiative (GPSS-GLI), at the University of Tokyo. We acknowledge the support of Diaa Al-Kenawy, Mohamed Tharwat and Ashraf Shabaan for their effort in data collection, and Marcin Jarzebski for developing Fig. 3.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aquaculture.2020.734940.

References

Assaad, R., Krafft, C., 2013. The Egypt labor market panel survey: introducing the 2012 round. IZA Journal of Labor & Development 2 (1), 8. https://doi.org/10.1186/2193-9020-2-8.

Bevilacqua, A.H.V., Angelini, R., Steenbeek, J., Christensen, V., Carvalho, A.R., 2019. Following the Fish: The Role of Subsistence in a Fish-based Value Chain. Ecological Economics 159, 326–334. https://doi.org/10.1016/j.ecolecon.2019.02.004.

Biltagy, M., 2014. Estimation of Gender Wage Differentials in Egypt Using Oaxaca Decomposition Technique. Topics in Middle Eastern and African Economies 16 (1), 17–42. http://meea.sites.luc.edu/volume16/pdfs/Biltagy.pdf.

Bolivar, R.B., Boy, E., Jimenez, T., Rey, J., Sugue, A., Brown, C.L., 2004. Effect of stocking size on the yield and survival of Nile Tilapia (Oreochromis niloticus L.) on-grown in ponds. In: New Dimensions in Farmed Tilapia. Proceedings from the 6th International Symposium on Tilapia in Aquaculture. Manila, Philippines, p. 805. https://cals.arizona.edu/azaqua/ista/ista6/ista6web/pdf/574.pdf.

Chakrabarti, P.P., Ghosh, A., Mohapatra, B.C., Barik, N.K., Das, A., Kumar, K., Mondal, S.C., Majhi, D., Mistry, A., Jayasankar, P., 2017. Alternate livelihood development for 'Aila' affected tribal people through aquaculture in Bali Island of the Sunderban, West Bengal, India. Indian Journal Of Fisheries. 64, 14–21.

CAPMAS, 2018. Egypt in figures. Central Agency for Public Mobilization And Statistics, Cairo. Retrieved from http://www.capmas.gov.eg/HomePage.aspx (accessed 7.07.18).

D'Allessandro, Y., 2014. Documentation Report-Livelihoods and Working Conditions of Women Fish Retailers Improved Improving Employment and Income through the Development of Egypt's Aquaculture Sector (IEIDEAS) project. Project report: http://www.careevaluations.org/wp-content/uploads/evaluations/ieideas-final-evalution-report.pdf.

Daniel, J., 2012. Sampling Essentials: Practical Guidelines for Making Sampling Choices. Sage, New York.

Dickson, M., Nasr-Allah, A.M., Kenawy, D., Fathi, M., El-Naggar, G., Ibrahim, N., 2016. Improving employment and income through development of Egypt's Aquaculture sector (IEIDEAS) Project. WorldFish, Penang, Malaysia. Program Report: 2016-14. http://pubs.iclarm.net/resource_centre/2016-14.pdf.

El-Sayed, A.-F., 2014. Value chain analysis of the Egyptian aquaculture feed industry. WorldFish, Penang, Malaysia. 2014-22. Project Report: http://pubs.iclarm.net/resource_centre/2014-22.pdf.

El-Sayed, A.-F.M., Dickson, M.W., El-Naggar, G.O., 2015. Value chain analysis of the aquaculture feed sector in Egypt. Aquaculture 437, 92–101. https://doi.org/10.1016/J.AQUACULTURE.2014.11.033.

FAO, 2009. Part I Statistics and main indicators FAO Fisheries statistics. FAO. http://www.fao.org/docrep/016/aq187t/aq187t.pdf.

FAO, 2016. Promoting gender equality and women's empowerment in fisheries and aquaculture. http://www.fao.org/3/a-i6623e.pdf.

FAO, 2017. FAO Aquaculture Newsletter. No. 57 (September). Rome. https://doi.org/10.1371/journal.pone.0175098.

FAO, 2018. State of Fisheries and Aquaculture in the world 2018. WWW Document. http://www.fao.org/state-of-fisheries-aquaculture/en/.

GAFRD, 2017. Fishery statistics year book 2015. Ministry of Agriculture and Land Reclamation, Cairo, Egypt.

GAFRD, 2018. Fishery statistics year book 2016. General Authority for Fish Resources Development. Ministery of Agriculture and Land Reclamation, Cairo, Egypt.

Galli, A., Iha, K., Halle, M., El Bilali, H., Grunewald, N., Eaton, D., Capone, R., Debs, P., Bottalico, F., 2017. Mediterranean countries' food consumption and sourcing patterns:An Ecological Footprint viewpoint. Science of the Total Environment 578, 383–391. https://doi.org/10.1016/j.scitotenv.2016.10.191.

Haque, A.B.M.M., Dey, M.M., 2017. Impacts of community-based fish culture in seasonal floodplains on income, food security and employment in Bangladesh. Food Security 9, 25–38. https://doi.org/10.1007/s12571-016-0629-z.

Harper, S., Zeller, D., Hauzer, M., Pauly, D., Sumaila, U.R., 2013. Women and fisheries: Contribution to food security and local economies. Marine Policy 39, 56–63. https://doi.org/10.1016/J.MARPOL.2012.10.018.

Hebisha, H., Fathi, M., 2014. Small and medium scale aquaculture value chain development in Egypt: Situation analysis and trends. In: WorldFish/ILRI Project Report. ILRI, Nairobi, Kenya. http://hdl.handle.net/10568/41882.

Ibrahim, N.A., Nasr-Allah, A., Charo-Karisa, H., 2019. Assessment of the impact of dissemination of genetically improved Abbassa Nile tilapia strain (GIANT-G9) versus commercial strains in some Egyptian governorates. Aquaculture Research 50, 2951–2959. https://doi.org/10.1111/are.14249.

Kaminski, A.M., Genschick, S., Kefi, A.S., Kruijssen, F., 2018. Commercialization and upgrading in the aquaculture value chain in Zambia. Aquaculture 493, 355–364. https://doi.org/10.1016/j.aquaculture.2017.12.010.

Kruijssen, F., McDougall, C.L., van Asseldonk, I.J.M., 2018. Gender and aquaculture value chains: A review of key issues and implications for research. Aquaculture 493, 328–337. https://doi.org/10.1016/J.AQUACULTURE.2017.12.038.

Lentisco, A., Alonso, E., 2012. On Gender Mainstreaming Strategies and Tools in Fisheries Development Projects: RFLP Gender Strategy and Lessons from the Asia-Pacific Region. Asian Fisheries Sciences 25S, 105–117. https://doi.org/10.1016/j.worlddev.2015.11.007.

Lentisco, A., Lee, R.U., 2015. A Review Of Women's Access To Fish In Small-Scale Fisheries. In: FAO Fisheries and Aquaculture Circular, (C1098), I, . http://www.fao.org/3/a-i4884e.pdf.

Macfadyen, G., Nasr Allah, A.M., Kenawy, D.A.R., Ahmed, M.F.M., Hebicha, H., Diab, A., Hussein, S.M., Abouzied, R.M., Naggar, G., 2011. Value-chain analysis of Egyptian aquaculture. WorldFish Center, Penang.

Macfadyen, G., Mohamed Nasr-Allah, A., Dickson, M., 2012a. The market for Egyptian farmed fish. WorldFish Center, Egypt. https://doi.org/10.13140/2.1.2060.6409. 43 pp.

Macfadyen, G., Nasr-Alla, A.M., Al-Kenawy, D., Fathi, M., Hebicha, H., Diab, A.M., Hussein, S.M., Abou-Zeid, R.M., El-Naggar, G., 2012b. Value-chain analysis — An assessment methodology to estimate Egyptian aquaculture sector performance. Aquaculture 362–363, 18–27. https://doi.org/10.1016/J.AQUACULTURE.2012.05.042.

Mirera, D.O., Ochiewo, J., Munyi, F., 2014. Social and economic implications of small-scale mud crab (Scylla serrata) aquaculture: the case of organised community groups. Aquaculture International 22 (4), 1499–1514.

Mula, G., Sarker, S.C., 2013. Impact of Improved Agro-techniques on Sustainable Livelihood Empowerment: An Economic Study from West Bengal. Agriculture Econnomic Research Review 26, 2013–2129. https://ageconsearch.umn.edu/bitstream/158506/2/13-G-Mula.pdf.

Nasr-Alla, A., Macfadyen, G., Dickson, M., Al-Kenawy, D., Fathi, M., El-Naggar, G., 2012. Value chain analysis of the Egyptian aquaculture sector. In: Proceedings of IIFET Conference in Dar El Salam, Tanzania from 16 to 20 July 2012, https://doi.org/10.13140/2.1.3709.2808.

Nasr-Allah, A.M., Dickson, M.W., Al-Kenawy, D.A., Fathi, M., El-Naggar, G.O., Azazy, G.E., Grana, S.H., Diab, A.M., 2014. Value chain analysis of egyptian fish seed production. In: 4th Conference of Central Laboratory for Aquaculture Research, Egypt. 2014. pp. 351–372. https://doi.org/10.13140/2.1.2267.4880.

Nassar, H., Biltagy, M., 2017. Poverty, Employment, Investment, and Education Relationships: The Case of Egypt. SAGE Open 7, 215824401769715. https://doi.org/10.1177/2158244017697156.

Osama, S., Elkholy, M., Kansoh, R.M., 2017. Optimization of the cropping pattern in Egypt. Alexandria Engering Journal 56 (2), 557–566. https://doi.org/10.1016/J.AEJ.2017.04.015.

Ottinger, M., Clauss, K., Kuenzer, C., 2016. Aquaculture: Relevance, distribution, impacts and spatial assessments – A review. Ocean & Coastal Management 119, 244–266. https://doi.org/10.1016/J.OCECOAMAN.2015.10.015.

Panda, N., Mahapatra, A.S., Samal, R., Panda, N., Mahapatra, A.S., Samal, Á., 2012. Impact evaluation of SGSY on socio-economic development of women in aquaculture in Eastern Hills of Orissa. Aquaculture International 20 (2), 233–247. https://doi.org/10.1007/s10499-011-9452-x.

Phillips, M., Subasinghe, R.P., Tran, N., Kassam, L., Chan, C.Y., 2016. Aquaculture Big Numbers. Food and Agriculture Organisation (FAO), Rome.

Shaalan, M., El-Mahdy, M., Saleh, M., El-Matbouli, M., 2018. Aquaculture in Egypt: Insights on the Current Trends and Future Perspectives for Sustainable Development. Reviews in Fisheries Science & Aquaculture 26 (1), 99–110. https://doi.org/10.1080/23308249.2017.1358696.

Sharm El-Sheikh, 2015. Egypt's Sustainable Development Strategy: 2030 Vision. http://www.arabdevelopmentportal.com/sites/default/files/publication/sds_egypt_vi sion_2030.pdf.

UN, 2005. Designing Household Survey Samples: Practical Guidelines. United Nations, New York.

USDA, 2016. The State and Development of Aquaculture in Egypt. USDA, Foreign Agricultural Service. https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=The%20State%20and%20Development%20of%20Aquaculture%20in%20Egypt%20_Cairo_Egypt_11-6-2016.pdf (accessed on 2 June, 2018).

Valderrama, D., Hishamunda, N., & Zhou, X. (2010). Estimating employment in world aquaculture. *FAO Aquaculture Newsletter*, (45), 24. http://www.fao.org/3/al363e/al363e12.pdf

Weeratunge, N., Snyder, K.A., Sze, C.P., 2010. Gleaner, fisher, trader, processor: understanding gendered employment in fisheries and aquaculture. Fish and Fisheries 11 (4), 405–420. https://doi.org/10.1111/j.1467-2979.2010.00368.x.

World Bank, 2015. World Development Indicators | The World Bank. [WWW Document]. URL. http://wdi.worldbank.org/table/2.5 (accessed 10 July 2018).

World Bank, 2016. Labor Force Participation Rate, Female (% of Female Population Ages 15+), Modeled ILO Estimate. [WWW Document]. URL. http://databank.worldbank.org/data/reports.aspx?source=2&series=SL.TLF.CACT.FE.ZS&country= (accessed 10 July 18).

World Bank, 2017a. Unemployment, total (% of total labor force) (modeled ILO estimate) | Data. [WWW Document]. URL. https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?locations=EG, Accessed date: 10 July 2018.

World Bank, 2017b. Egypt, Arab Republic Population, total | Data. [WWW Document]. URL. https://data.worldbank.org/indicator/SP.POP.TOTL?locations=EG (accessed 10 July 2018).

World Economic Forum, 2017. The Global Gender Gap Report 2017 Insight Report. http://www3.weforum.org/docs/WEF_GGGR_2017.pdf (accessed on 8 May. 2018).