Aquaculture site selection and carrying capacity estimates for inland and coastal aquaculture in the Arab Republic of Egypt

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Abstract

This paper reviews Egyptian aquaculture development and how carrying capacity management status can assist and protect the durability of this important industry. Rapid expansion of the Egyptian coastal aquaculture is identified as the major problem affecting the sustainable development of aquaculture, resulting in several important issues such as environmental pressure and pollution caused by agricultural and industrial development and the continuous increase of fertilization and fed fish in the north Nile delta zone. There are several laws and regulations dealing with the Egyptian fisheries, aquaculture sectors, but still lack of effective monitoring and legislation on the aquaculture site. The Nile Delta is the only delta in the Arab Republic of Egypt with a 230 km long, 360 km wide and triangular in shape. The Nile Valley and the Delta occupy about 33 000 km^2, which account for less than 4 percent of the total area. Egyptian fish farms produced over 705 490 tonnes of finfish in 2009, or about 65 percent of the country's total freshwater and marine fish production, providing a cheap source of protein for the country's 75.2 million people in 2008. In the last 10 years the aquaculture activity has been tremendously increased 3.3 times, where in 1999 aquaculture production was 214 thousand tonnes and becomes around 706 thousand tonnes in 2009. This paper provides some relevant recommendations on the effluent discharge of fish farms, as no concrete zoning scheme of land and water areas suitable for aquaculture is taking into the requirements, which can create problems on the water quality, environment and can influence on the community welfare. It is clear that the current bottlenecks limiting the reasonable aquaculture site selection and carrying capacity management. Different strategy proposals will be discussed to maintain a sustainable Egyptian aquaculture, from any retardation.

Introduction

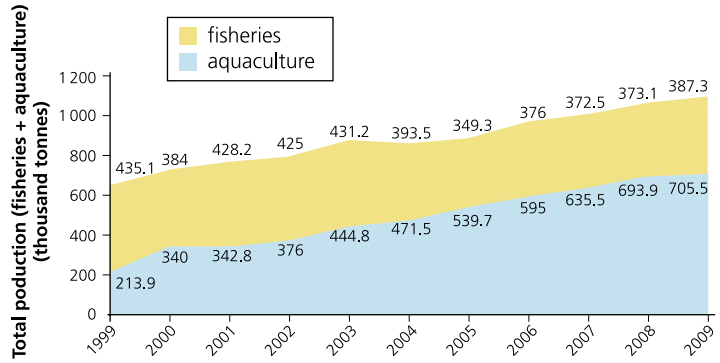
The Arab Republic of Egypt is located in the North-Eastern and South-Western corners of Africa and Asia respectively. The Nile Delta is the only delta in the Arab

Republic of Egypt with a 230 km long, 360 km wide and triangular in shape. The Nile Valley and the Delta occupy about 33 000 km^2, which account for less than 4 percent of the total area. The Arab Republic of Egypt is covered almost entirely by desert, 99 percent of the Arab Republic of Egypt's population living in just 5 percent of its land area, mainly concentrated along the Nile valley and the river's northern delta, which splinters out into the Mediterranean.

According to the General Authority for Fish Resources Development (GAFRD) statistics (GAFRD, 2010) and (Capmas, 2010a and b) the total fish production in the Arab Republic of Egypt was 1 092 888 tonnes where 705 490 tonnes were produced through aquaculture. The Arab Republic of Egypt has built the largest aquaculture industry in Africa, accounting for four out of every five fish farmed on the continent. Egyptian fish farms produced over 705 490 tonnes of finfish in 2009, or about 65 percent of the country's total freshwater and marine fish production, providing a cheap source of protein for the country's 75.2 million people in 2008. In the last 10 years the aquaculture activity has been tremendously increased 3.3 times, where in 1999 aquaculture production was 214 thousand tonnes and becomes around 706 thousand tonnes in 2009 (Figure 1).

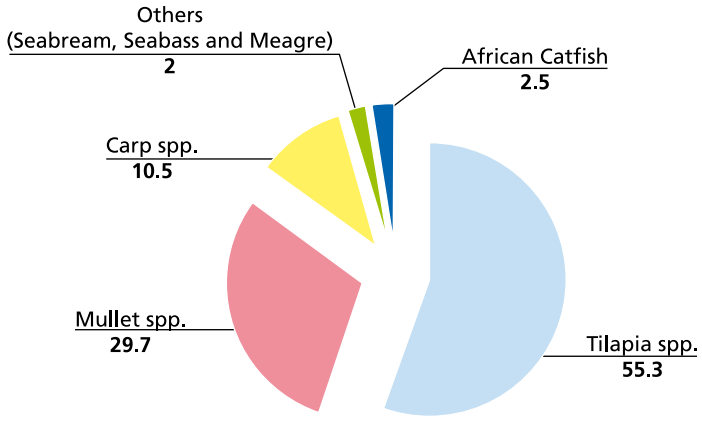
GAFRD plans to develop the country's aquaculture industry further, and has set a goal of 1.2 million tonnes of farmed fish, or about 75 percent of total fish production, by 2017. Its two-pronged strategy aims to increase the productivity of aquaculture operations using underground water, while encouraging investment in mariculture (Prof. Dr. Mohamed Fathy Osman, GAFRD's chairman – personal communication).

FIGURE 1
Fisheries and aquaculture production in Egypt for the period 1999-2009



Source: GAFRD (2010).

FIGURE 2
Egyptian aquaculture production ranking percent per fish species in 2009

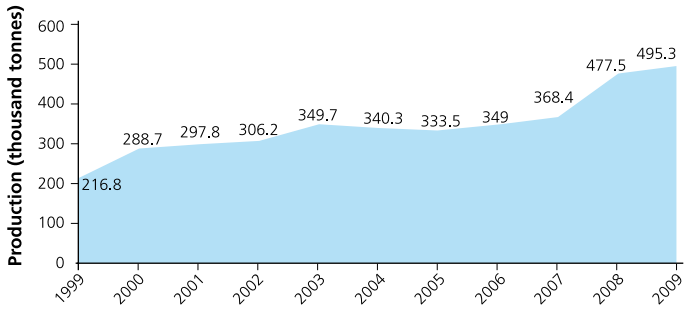


Source: GAFRD (2010).

Three decades ago tilapia and mullet were the main species reared in extensive earthen ponds. Today ten finfish (Tilapia, Mullet *spp*.; Grass Carp, Silver Carp; African Catfish; Bayad; Gilthead seabream; European sea bass; Meagre and Solia besidesfourcrustaceanspecies; *Macrobrachium rosenbergii*, *Penaeus semisulcatus*; *P. japonicus* and *P. indicus*), are playing an important role in the aquaculture production. During 2009 tilapia has chaired 55.3 percent of the total aquaculture production, followed by Mullet *spp*., Carp *spp*., African catfish and other species (Gilthead seabream, European seabass,etc.), 29.7 percent, 10.5 percent, 2.5 percent and 2 percent respectively (Figure 2).

During the period from the period from 1999 to 2009 the tilapia total production in the Arab Republic of Egypt has increased 2.3 times, where in 1999 tilapia culture was 216.8 thousand tonnes and becomes around 495.3 thousand tonnes in 2009 (Figure 3), due to a shift to intensive rearing methods and to faster growing species such as mono-sex tilapia (GAFRD, 2010).

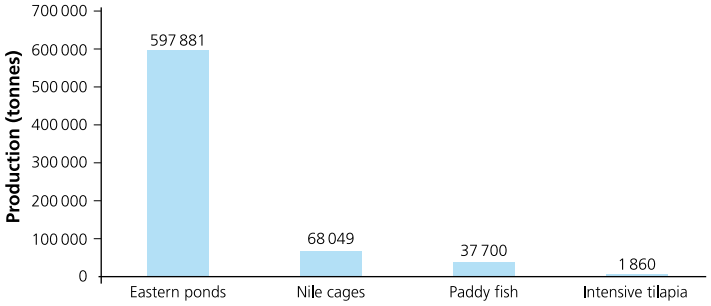
FIGURE 3
Total Tilapia production in Egypt for the period 1999-2009



Source: GAFRD (2010).

From the actual major culture system, earthen ponds production rank in the first with 84.8 percent of the total Egyptian aquaculture production, while cage culture follow by 9.7 percent, paddy filed come next with 5.3 percent of the total and at lastly 0.2 percent for tilapia intensive culture production in cement tanks mostly in the desert and arid zones and integrated with agriculture activities (Figure 4).

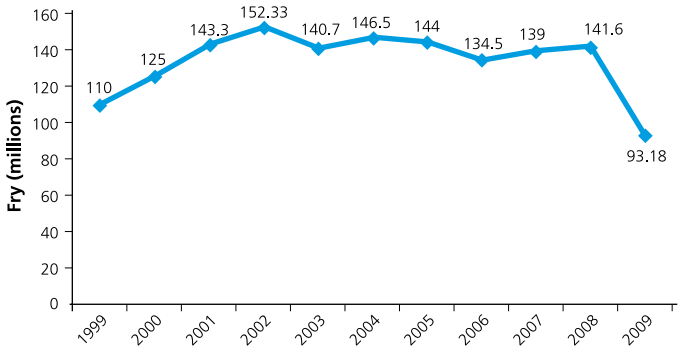
FIGURE 4
Egyptian aquaculture production system types in 2009



Source: GAFRD (2010).

Extensive and semi intensive earthen ponds for a total surface of around 151 818 hectares practiced in the Arab Republic of Egypt are characterized by medium stocking densities and limited water exchange rate. The public sector is charring only for less than 5 percent of the total surface and > 95 percent for the private sectors. The private sector is producing > 99.0 percent of the total aquaculture production, and the public sector contributes only with < 1.0 percent. The public sector is contributing more with the fry and fingerlings, extension support, artificial feeds and research support. The number of finfish fry currently produced from 113 authorized hatcheries has increased several folds compared to a few years ago, to reach 305 million seeds in year 2009. Figure (5) reports the tilapia fry production from authorized hatcheries for the period 1999–2009 (GAFRD, 2010). In addition more than 500 Nile tilapia not authorized hatcheries are charring with fry production for an estimated production of more than one billion fry. The public sector is charring for 71 percent of the total seed production and 29 percent for the private sectors. From the total fry produced 92 percent

FIGURE 5
Tilapia fry production from authorized hatcheries for the period 1999-2009



Source: GAFRD (2010).

are fresh water species mainly Nile tilapia; common carp; grass carp and silver carp. The 8 percent remain are marine aquatic finfish and crustacean species mainly Gilthead seabream; European sea bass; Solia and Green tiger shrimp.

Wild finfish fry, mainly mullet species, are collected from the wild, during the last 10 years (2000–2009), the maximum yield has reached 137.0 million in 2002 and the minimum capture was 41.0 million in 2006. In year 2009 the wild mullet fry cached was estimated to 57.4 million.

Water available for the Egyptian aquaculture industry

The Arab Republic of Egypt's main source of freshwater is the Nile River. The river supplies 56.8 billion m^3 of freshwater every year, which represents 97 percent of all renewable water resources in the Arab Republic of Egypt. Average rainfall in the Arab Republic of Egypt is estimated at 18 mm or 1.8 billion m^3 per year. Furthermore, the Arab Republic of Egypt has four different groundwater aquifers: the Nile Aquifer, the Nubian Sandstone Aquifer, the Moghra Aquifer and the Coastal Aquifer. The population has doubled in the last 40 years from 37 million in 1970 to 72 million in 2005 and is expected to reach 95 million in 2025, thus increasing the related water demands for public water supply and economic activities, in particular agriculture. The annual population growth rate decreased from 2.8 percent in the period 1976–86 to 2.1 percent in the period 1986–96, and has decreased further to 1.9 percent according to the 2004 estimate. These figures give an impression that the Arab Republic of Egypt is a water rich country but the growth in population makes it a water scarce country. Since 2005, the Arab Republic of Egypt is classified as a water scarce country as it has less than 1000 m^3 of fresh water per year and capita. Furthermore, it is forecasted that in 2025 the population will reach 95 million, which would mean a per capita share of only 600 m^3 per year. The prime water consumer in the Arab Republic of Egypt is the agricultural sector, with its share exceeding 82 percent of the total gross demand for water. Municipal and industrial uses account for 15 percent of the total water consumption in the country, while navigation and hydropower generation are considered as non-consumptive uses. Industry and mining account for nearly 18 percent of the GDP and almost 14 percent of total employment (Abdel-Gawad, Kandil and Sadek, 2004; Abdel-Gawad, 2008).

In the Arab Republic of Egypt the water resources both fresh and brackish water are the major constraints on further development, with use for potable water and land crop production having priority over aquaculture activities. The Arab Republic of Egypt has a rapidly expanding population and the government is concerned with future food security. The Nile is the nation's only renewable source of fresh water and this forms a bottle neck that sets limits to agriculture and its future expansion. Making use of this limited resource in the most efficient way is of great importance for the Arab Republic of Egypt (and for other countries with limited fresh water supplies).

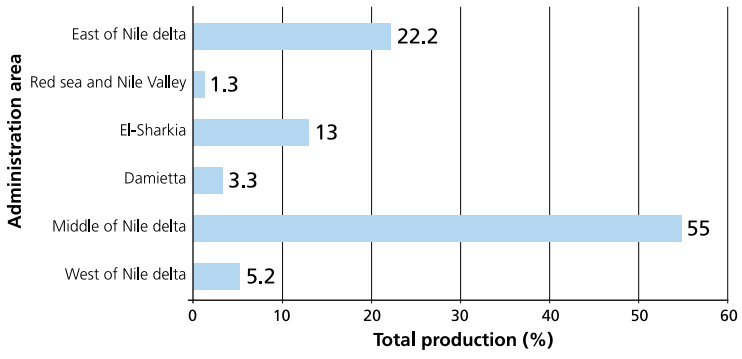
According to GAFRD's law No 124/1983 (GAAAP, 1993) only brackish and marine water, and infertile land that is not suitable for agriculture, can be used in aquaculture. Water supply should be restricted to water from lakes and agriculture drains. The use of fresh (i.e. irrigation) water is prohibited, although hatcheries established by the government are exempted from this rule. The use for potable water and land crop production has priority over aquaculture activities in the Arab Republic of Egypt. A key policy issue in the Arab Republic of Egypt is planning to increase the reused agriculture drainage water for the delta region in year 2014 to reach 1.4 times the actual quantity reuse in 2002 3 219 million m^3/year. In three Nile delta regions, the Integrated Irrigation Improvement and Management Project (IIIMP) is actually implementing an irrigation system improvement almost 235 thousand ha would be the focus for irrigation improvement of agriculture land in

four different governorates. It is perceived that drainage water quantity and salinity would negatively be impacted (-12 percent and 4 percent, respectively). Different environmental impacts will effect on the aquaculture ecosystem production in the Nile delta regions as water available for fish earthen ponds will be not adequate and the increase of salinity could effect on both production capacity and production composition. In addition, paddy field and spreading grass carps in drainage water channels could be negatively affected. This policy could retard the development of the aquaculture. The new policy of irrigation strategy could affect 60 percent of the actual aquaculture production (Anonymous, 2004).

Actual and future projection of the Egyptian aquaculture sites:

In the Arab Republic of Egypt, the most important inland aquaculture sites are primitive mouth of the Nile branch, paddy field, hosha, reservoirs in northern coastal lakes, inland lakes; land based earthen ponds, and cement and/or lining intensive tanks. From the actual major culture system, the extensive and semi-intensive sectors are paddy field ranks first with 575 210 ha (79.0 percent of the total Egyptian aquaculture land based), while brackish and marine water earthen ponds surface follow with 151 818 ha (21.0 percent). For the intensive culture the Nile cages in the mouth of Rashid branch ranks first with 5.2 million m^3 (95.0 percent of the total Egyptian intensive aquaculture), while cement and/or lining tanks in the desert follow with 300 400 m^3 (5.0 percent). From the actual major culture system, the extensive and semi-intensive sectors are paddy field ranks first with 575 210 ha (79.0 percent of the total Egyptian aquaculture land based), while brackish and marine water earthen ponds surface follow with 151 818 ha (21.0 percent).The Egyptian aquaculture map showed that fish farming activities are more concentrated in sub-regions of the Nile delta, where the water resources are available and non-agricultural lands. Other very few projects are located in Upper Egypt region, the Mediterranean Sea coast and the Red Sea coasts. GAFRD (2010) has estimated the total number of private brackish and marine earthen ponds farms in 2010, for 7 759 fish farms (69.0 percent under the leased license contract with GAFRD and 31.0 percent under the owned license in depended contract) distributed on 76 818 ha of land. The earthen ponds geographical distribution are mainly concentrated in the Nile delta, ranks first with 68.9 percent in the middle of delta, follow with 13.0 percent in north east of delta specially in Damietta governorate, contribute after that the west of delta with 11.6 percent. The remain of the earthen ponds area are located in the east of delta, associated with the Nile valley and red sea for only 6.5 percent (Figure 6). Other 75 thousands ha of earthen ponds are contracted for a short fish farm temporary contract period, for the need of cleaning the land from salt till they can shift to the plant production again.

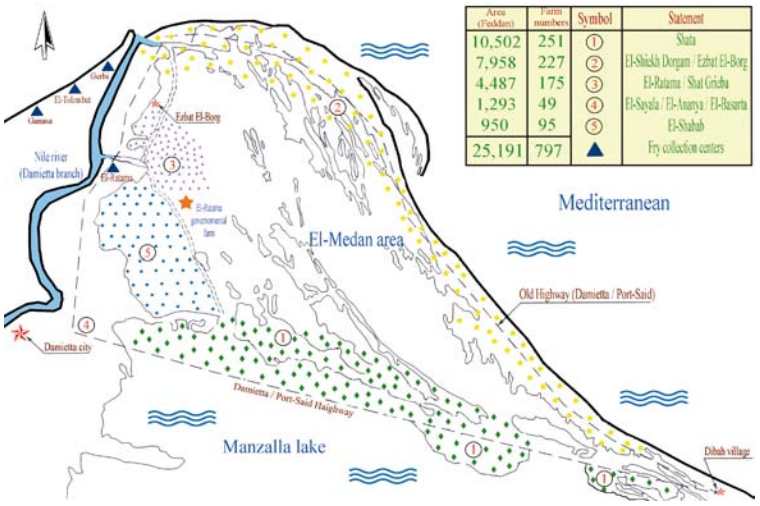
FIGURE 6
Geographical distribution of Egyptian private fish earthen ponds production in 2009



Source: GAFRD (2010).

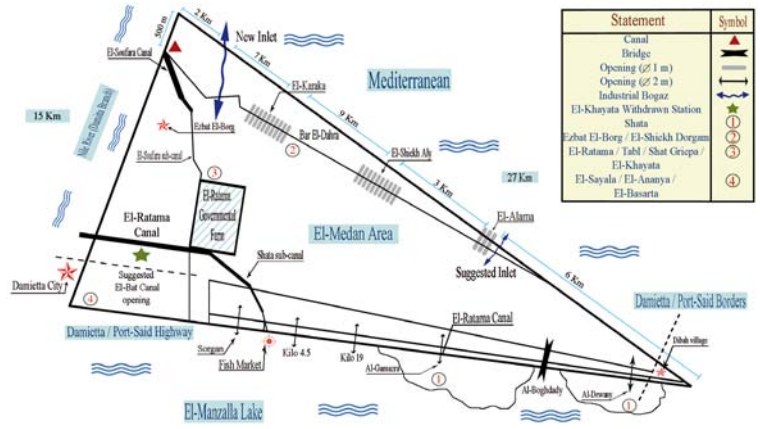
Sadek (2010a) has clarified two opposite examples of the waterbody change in Nile delta. The waterbody in lake Manzala has changed during 1973–2003, from 1 250 km^2 in 1973 to 850 km^2 in 2003, due for drying shallow the lake boarder for the need of reclamation lands. Ended the decrease of the waterbody lake has created a pressure

FIGURE 7
Distribution of aquaculture in Dibah Triangle Zone. Damietta – Port-Said, Egypt



Source: Aquaculture Consultant Office (ACO), Designer: Mahmoud Asfoor.

FIGURE 8
Distribution of different water resources in Dibah Triangle Zone. Damietta – Port-Said, Egypt



Source: Aquaculture Consultant Office (ACO), Designer: Mahmoud Asfoor.

environment on the fisheries of the lake. The second opposite example is located in the Dibah Triangle Zone – DTZ (Figure 7) in Damietta and Port-Said Governorates. DTZ is part of a wider ecosystem that includes the Manzalah lake and riparian areas of the whole Nile delta. The water area includes a long sand beach with exchanges with the Mediterranean Sea, Manzala lake and freshwater from the Nile (Damietta branch), with many fish and shrimp ponds (Figure 8). It has already been an important aquaculture production fish area (especially Sea bream; Sea bass; Mullet and Meagre) and in addition marine shrimps (*Penaeus semisulcatus*). The total surface of the DTZ is around 23 110 hectares, from which 46 percent for aquaculture and 54 percent for open fisheries. The TDA's waterbody complex has increased from 161 km^2 in 1987 to 168 km^2 in 2000, due the increase of mariculture farms. Ended this industry has increased an unstable environment for the area.

5. Environmental carrying capacity status and issues

5.1 Freshwater aquaculture

Rice-fish culture

The Arab Republic of Egypt is the largest rice producer in the Middle East and African countries. Egyptian rice yield is one of the highest in the world (9.1 tonne per ha. There is now considerable potential for rice-fish farming to further expand its contribution to improve the livelihoods and food security of the rural families (Suloma and Ogatai, 2006).

Field experiments of rice-fish culture using common carp in the early 1970s led to encouraging results. The rice-fish culture has contributed to the increase of total aquaculture production in the Arab Republic of Egypt. The improved rice-fish culture can effectively give a great contribution in a short time (Essawi and Ishak, 1975). In 2009, rice-fish culture was practiced in 575 210 ha and contributed for 37 700 tonnes about 5.5 percent of the total aquaculture production in the country, from which 44 percent tilapia; 31 percent common carp and 25 percent African catfish.

The stocking and growing of fish in an Egyptian rice field is basically an extensive aquaculture system that mainly relies on the natural food in the field. One constraint of the concurrent system is that the growing period of the fish is limited to that of rice, which is usually 100 to 150 days. The rice-fish project under the supervision of GAFRD is distributing free of charge the common seed carp fry to the farmers. The average production per ha was 50.0 kg for farmers within the rice-fish project, which 28 percent of the total area of rice-fish in the Arab Republic of Egypt, and decreasing to 19.0 kg/ha for the other farmers using agriculture land out side the project (GAFRD, 2010).

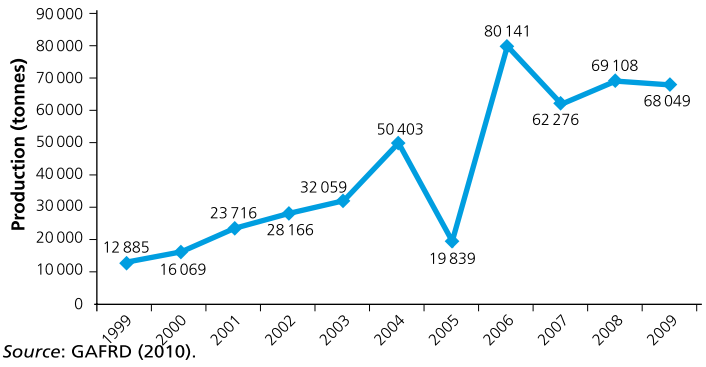
Nile cages

In the 1985 the first eight tilapia cages were established in Damietta Nile branch with a yearly production 1.92 tonnes, since this date there was a rapid increase in the cage numbers and cage production, reaching 24 718 cages and 68 049 tonnes (86 percent Silver carp and 14 percent tilapia) respectively in 2009 (Figure 9).

The environmental conditions in the Nile is no longer suitable for aquaculture, as the water environment in the areas were polluted in varying degrees by inorganic nitrogen, organic substances, phosphorus, and heavy metals. Sadek, Osman and Mezayen (2006) have reported that in the Arab Republic of Egypt the water resources both fresh and brackish water are the major constraints on further development, with use for potable water and land crop production having priority over aquaculture activities. Because of the legislation and environmental pressures of the cages, plus a conflict with other activities, the Egyptian authorities have removed all the Nile cages behind the two final fresh water control dams in the two Nile branches (Edfina and Faraskour).

Today most of the tilapia cage projects were located in two governorates Kafr-El-Sheik and Beheira near Rashid branch at the end of the Nile mouth with slightly brackish water. Few tilapia cages are located in El-Rayan inland lake in the governorate of Fayum.

FIGURE 9
Nile cages production in Egypt for the period 1999–2009



Source: GAFRD (2010).

5.2 Earthen ponds

Extensive

A famous regime for aquaculture called HOSHA system was commonly practiced during forties to seventies. The farmer build his muddy pond on the lake shore, allow water from the lake to come in, with no control for species or size of the fish, providing any agriculture products as food, maybe some organic fertilizers for 2–3 months duration, then pump the water out of the pond and harvest everything. In the extensive culture natural food, produced through pond fertilization, is considered an important element of fish growth during early growth stages. At later fattening stages supplemental feeds were applied. Sadek (2010a) has figured that the yearly production per hectare will fluctuate in the extensive culture ponds (polyculture Nile tilapia, carp *spp*. and mullet *spp*.) and/or (seabream, seabass and mullet *spp*.) from 500 kg to 1 tonne/ha. The extensive system is more popular, where, farmers stock ponds at low densities, and fish derive most of their nutrition from the natural food present in ponds. Also

fish farmers feed sea bream with wild collected fish (*Tilapia zillii*) and small size shrimp (*Palaemon spp*.) caught from northern delta lakes.

Semi-intensive

Modern aquaculture activities started at late seventies when the government established two big pilot projects in Kafer-El-Sheikh governorate seed production at Foua and the other for market size 500 h, fish farm at Zawia, at the same time, training for technicians had also been provided by the government in more advanced countries in aquaculture. During this time growing fish for market size was relatively successful. Production of mullet reached 1 tonne/ha using seed from wild catch and wheat meddling or rice brine as food.

Radwan (2008) has focused on the development of tilapia farming in a relatively short period (1990–2008) in the Nile delta with is low land, especially Kafr-El-Sheik governorate (Burullus Lake and surrounding area), which is today is a major economic aquaculture activity with more than 61 thousands hectares. GAFRD (2010) has reviewed that in 1990 tilapia aquaculture production was estimated to 20 thousand tonnes and reached 390.3 thousands in 2009 tonnes, which represent 55 percent of the total aquaculture production. The most important factors that resulted in such booming in production business described are:

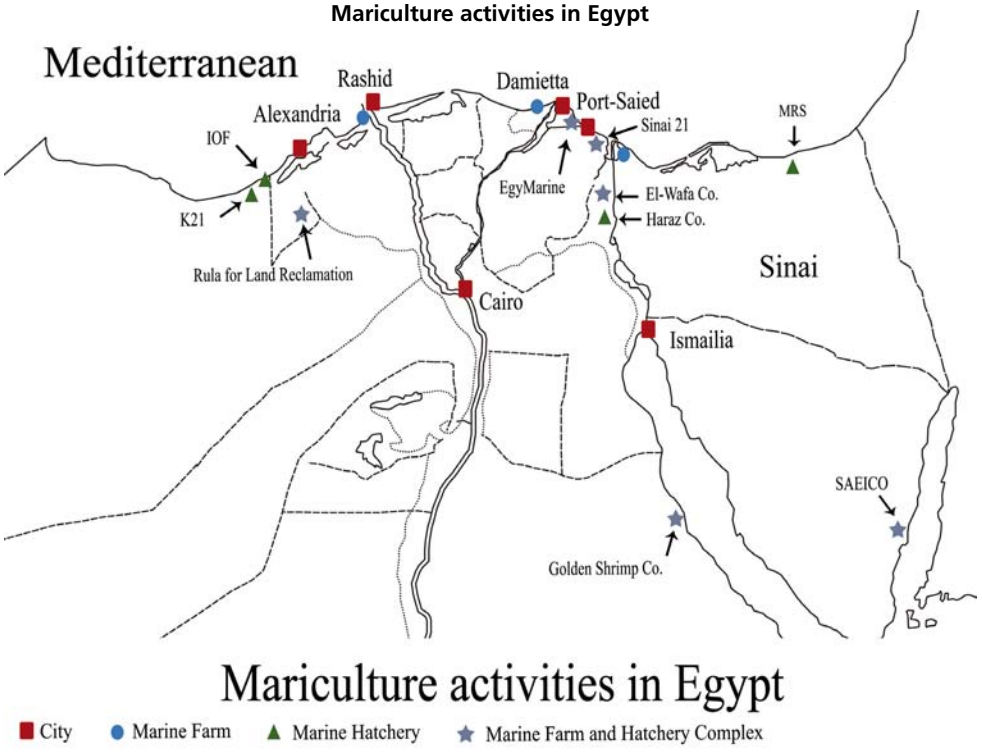
The Arab Republic of Egypt is a Mediterranean country characterized by cold winter as the air temperature could reach 5 degree Celsius or less at winter and water temperature could reach at that time 10 degree Celsius or less. Winter in the Arab Republic of Egypt is not suitable for Nile tilapia, in the nature this fish migrate to the south seeking warmer water in this winter time. This weather in the Arab Republic of Egypt limits the growth of Nile tilapia until the year 1991 when the commercial production of mono sex tilapia under green house in ponds proved it was an efficient and profitable technique (Radwan, 2008).

The yearly production per hectare will fluctuate in the semi-intensive culture earthen ponds from 4.5 to 20 tonnes/ha in monoculture system (tilapia or Meagre) and polyculture system (Nile tilapia associated with mullet *spp*.). During the last ten years, applied semi-intensive cultures indicates that fish farmers can grow more Nile tilapia or meagre and earn higher profits by using improved production methods (Sadek, 2010a).

Sadek (2010b) has reviewed the shrimp aquaculture development and describes the lessons learned to date in the Arab Republic of Egypt, as well as the problems and prospects for future development. During the last three decades, there has been increasing investment in shrimp farming in the Arab Republic of Egypt and there are clear indications for further investments, but still the production results are not commercially positive. The Arab Republic of Egypt is just beginning to develop its potential, and the government is encouraging shrimp farming. Three crustacean species are in the production *Penaeus semisulcatus*, *P. japonicus* and *P. indicus*. Today the Arab Republic of Egypt has two marine private hatcheries operate with a yearly production capacity of 400 million PL/year, and several farms in production with a total surface of around 1 000 ha. In addition two university research bodies operate marine finfish and shrimp hatcheries for research and training purposes at Alexandria and El-Arish. By the end of year 2009, the estimated annual heads-on production would have achieved 500 metric tonnes, which will represent only less than 2 percent of the Egyptian shrimp fisheries (Figure 10).

Shrimp farming in the Arab Republic of Egypt is characterized by extensive culture in Qarun inland lake and semi-intensive production systems using fertilizer and commercial feed. Most shrimp aquaculture is undertaken northeast and northwest of Nile delta near the Mediterranean Sea as well as along the Red Sea coast. Records of the production characteristics data for 24 artesian and commercial shrimp farms on different water salinity and soil types revealed difference in growth, survival and yields during the period 1993–2010. The management and production of these shrimp farms

FIGURE 10
Mariculture activities in Egypt



Source: Aquaculture Consultant Office (ACO), Designer: Mahmoud Asfoor.

during 90–150 days of grow-out are ranging for stocking densities (5 to 20 post larvae (PL)/m^2), survival rates (< 5 to 82 percent); average animal weight at final harvest (<10 to 32 gm) and shrimp yields average 26 to 864 kg/ha per year.

5.3 Egyptian desert intensive aquaculture

El-Guindy (2006), Sadek (2011) and Sadek *et al*. (2011) have reported that today the actual Egyptian commercial aquaculture desert farms are 20, with a total surface around 893 hectares and total yearly production around 13 000 tonnes, located in seven different provinces. These commercial farms are capable to produce (from < 5 to 6000 tonnes/year) different finfish species (Nile tilapia (*Oreochromis niloticus)*; Red tilapia; North African catfish *(Clarias gariepinus)*; Common Carp *(Cyprinus carpio);* Silver Carp *(Hypophthalmichthys molitrix);* Grass Carp *(Ctenopharyngodon idellus);* European seabass *(Dicentrarchus labrax);* Gilthead seabream *(Sparus aurata)* and exotic species mainly Koi; Fantail; Molly). The water source is the underground water and agricultural drainage water with different salinity ranging from < 0.5 to 26 gr/L and with an ambient water temperature ranging from 22 to 26 °C. Most of the commercial farms are using flow through system associated to the agriculture irrigation land, to give an opportunity to produce three different crops (fish/plant/sheep). Only two commercial farms are using both flow through and recycle systems, remain farms are using only flow through system integrated to the agriculture lands.

The tilapia (*Oreochromis niloticus* and *O. aureus*, or sex-reversed red tilapias) is one of the most promising species, among other edible and ornamental fish species. Due to suitable warm climate and plenty of warm constant underground water, the tilapia are continuously grown, round-year, to marketable size of 250–400 grams in 6–8 months, in biomass extending the densities of 20–30 kg/m^3.

Although the water contains variable high brackish salt concentrations (> 25 gr/L), was utilized for integrated agriculture, e.g. irrigation of Salicornia crops combined

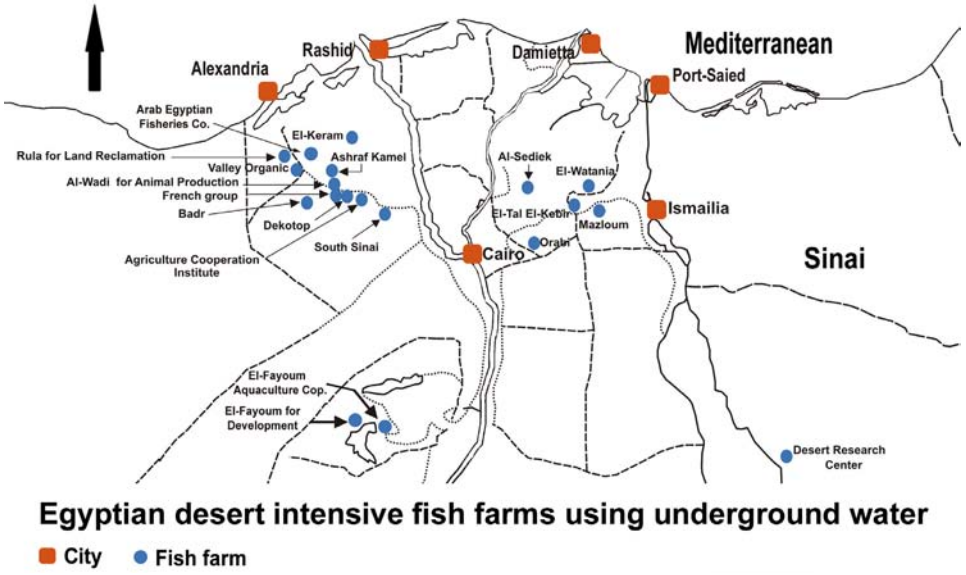
with intensive European seabass and Gilthead seabream aquaculture, with a yearly production 100 tonnes/year of both species.

Most of the commercial farms are purchasing their fish fry from the local market, and only five of these farms have their own hatchery. Different issues are effecting the developing of these commercial aquatic desert farms, mainly the water quantity/ quality; excess of effluent water; fingerlings supply; feed quality; feed prices; over head of the production cost; need for technical experiences; marine fish diseases and availability of credit

Egyptian desert aquaculture could be a durable industry as even lower economic returns of conventional crops are acceptable in locations where no other opportunities

exist for agricultural production. Facilitate aquaculture development by actively extending the FFF's messages: Fish does not consume, but only uses water; Fish farming is a clean production system and fish farming discharge water has added value for agriculture (Figure 11).

FIGURE 11
Egyptian desert intensive fish farms using underground water



Source: Aquaculture Consultant Office (ACO), Designer: Mahmoud Asfoor.

5. Economic analysis of fish farming

El-Naggar, Nasr-Alla and Kareem (2008) have examined factors influencing the fish farming enterprise in Behera with a view to finding out what are the socio-economic characteristics of the farmers, identify, and determine various performance indicators of economic viability or profitability, correlation between the production variables and the total revenue, factors influencing profitability, and identifying problems militating against 15 fish farmers in the Nile delta.

The data collected included: socio-economic characteristics (age, gender, marital status, educational level etc), production costs; cost of feed, cost of fish seed, other costs (maintenance, fertilizer, fuel, transport etc) and output data per the period under review.

Sadek, Sabry and Asfoor (2009) and Sadek (2010a) have examined the economic analysis of Egyptian fish farming in different Nile Delta areas: area A (Kafr El-Sheik) and area B1 and B2 (Damietta). Sample survey of 215 farmers representing the fish farming community in areas was used. The study was conducted from April 2006 to October 2008 covering one production season of 8 months for tilapia monoculture; 15 months for meagre monoculture and 24 months for seabream/seabass/mullet polyculture.

Different performance indicators of the selected Egyptian earthen fish farms management characteristics were considered (land ownership; age of respondents; farm Size-ha; job status; marital status; farm managers skill; fish stocking fry/ha in both monoculture and polyculture; fertilization; feed/feeding; fish yield Kg/ha; and source of finance).

In area (A) tilapia monoculture was dominated. The study result revealed that the average age of fish operators was (45 years), majority are married (71.5 percent), fairly level of education (67 percent) and majority with rented land ownership (69.9 percent) and tilapia represented over 91 percent of total fish harvested. The top ranking serious constraints facing fish farmers in that area were found high prices of fish feed; declining fish prices and lack of credit finance. Feed costs per kg of fish were LE 3.10, representing 63.3 percent of the production costs. The break-even analysis showed average production costs of LE 6.80/kg of fish while the sales price is LE 7.25/kg. Result figures showed that there is high positive relationship between cost of feed and extra labors to the level of farm income.

The study results in area (B-1) revealed that the meagre monoculture was applied. The performance indicator showed that the average age of fish operators was (49.5 years), majority are married (80.5 percent), highly level of education (59 percent) and majority with rented land ownership (77.3 percent). Two main serious constraints were found high prices of fish seed, availability of trash fish feed, low water quality source and lack of experience of fish diseases. The break-even analysis showed average production costs of LE 15.0/kg of fish while the sales price is LE 25.0/kg. Result figures showed that there is high positive relationship between high fish density, availability of trash fish feed and water exchange rate to the level of farm income

In area (B-2) the polyculture of seabream/seabass/mullet was widespread. The performance indicator showed that the average age of fish operators was (52.0 years), majority are married (86.3 percent), medium level of education (41 percent) and majority with rented land ownership (89.0 percent). Several serious constraints were found high prices and low quality of fish seed; availability of good and acceptable price of marine fish feed and poor to medium water quality source. The break-even analysis figured average production costs of LE 30.0, 35 and 8/kg of seabream; seabass and mullet respectively, while the sales price is LE 47.0, 58 and 16/kg respectively. Result figures showed that there is high positive relationship between increasing the water exchange rate, high fish density using fingerlings and not fry, availability of good and acceptable of marine fish feed to the level of farm income.

6. Aquaculture constraints

Egyptian aquaculture has a largest industry and most of the production comes from thousands of small-scale farms owned by individual farmers, which brings the difficulty in coordinating farm scales and distribution for the local fisheries administrative authorities. During the last three decades it was appear a development change of the Egyptian aquaculture structure. The ecosystem impacts of species and farming practices on ecosystem balance, water quality and environmental health.

Environmental Impacts of Aquaculture on the fisheries of the Egyptian northern costal lakes, due for the nutrient discharge and accumulation of waste in north Nile Delta:

- uneaten fish food, fish excretory products and organic matter (components of solid and dissolved waste are various forms of carbon, nitrogen and phosphorous);
- can alter the species composition and density of phytoplankton;
- increasing the risk of toxic algal blooms; and
- effects on the substrate ecosystem = accumulation of organic matter on the lake/seabed = can produce major changes in the sediment chemistry.

Although some internationally growing intensive farming technique such as tilapia cage farming and tilapia hatchery also have deficiencies, e.g. genetic pollution caused by fish escape, disease transmission, etc., and some may have caused serious environmental problems in somewhere, but could be evitable if all the needed measures are complete.

Tilapia hatcheries have deficiencies, e.g. genetic pollution caused by fish escape, disease transmission, and some may have caused serious environmental problems in somewhere, but could be evitable if all the needed measures are complete.

As the result of the increase in the tilapia production from 20 thousands in 1990 until it reached 390.3 thousand tonnes by 2009, tilapia price started to decline since 1998 to reach level of brake even at 2002. Because of the dramatic increase of the food cost, many producers witnessed great loss during the last few years some of them are already out of business while others are struggling hopping to balance between the cost and the selling price, moreover the economic effect of business in the golden period 1991 – 2000 is still in the background of the decision-makers which creates another financial load on the producer due to un realistic taxes. A drop in the production is expected and there is an urgent need for solving the export problems and to have an added – value technology in the Arab Republic of Egypt. The boom of production consequently accompanied by selling price decline to reach cost even by 2002 without any considerable increase while production coast increased 300 percent, however developing the production technology to be more efficient technically and economically is a major concern of Kafr-El-Sheikh aquaculture.

Sadek (2010a) has reported the changes in the prices of main raw materials used in fish feed industry during the period 1992–2009. During the same period, the price of tilapia feed (25 percent protein) has increased from US$165/ tonne in 1995 to US$217/tonne and in 2009 (US$550/tonne in 2009). The Arab Republic of Egypt has more than 20 facilities of aquatic feed (5 of them are extruder) capable to produce around 500 thousand tonnes/year. The development of the Egyptian aquaculture will need more importation of fish feed ingredients, but this will demand increase the supply of foreign currency.

Recommendations:

- Estimating the carrying capacity and production capacity culturing different aquatic ecosystems (rice field; Nile cages; brackish water earthen ponds and intensive desert aquaculture), with different aquatic finfish, fresh-water prawn and marine shrimp. The evaluation balance of the primary nutrients involved in the different aquaculture ecosystem activities, could be realized by estimating the environmental carrying capacity of areas and nutrients for maximizing the output performance;
- Evaluating the expected future water budget available for aquaculture, due to the future limitation of fresh and brackish water;
- Considering the assigned aquaculture zone and individual farm site selection, with development of current legislation, regulations and actual compliance;
- Adopting an effective program of fish farming among small-scale farmers:
  - comparing the actual stocking rate for the extensive culture (<1–2 fish/m^3) using different weight of wild fish or fish produced from hatchery (2 to 20 gm/fish) without aeration and with higher stocking associated with aeration;
  - applying different water exchange practices;
  - constructing different size of earthen ponds with different water depth, comparing the actual popular dimension (0.5 to 1 ha with 2 meter water depth) with larger earthen ponds;
  - comparing using trash fish/shrimp; artificial compressed pellet or extruded feed;
  - studying the economic aspects of small; medium and large fish farms.
  - evaluating the local and export marketing of fish to bring the maximum benefit to the farmers; and
  - supporting applied research on the different aspects of fish with governmental and private NG bodies.
- Covering gaps in information and data on carrying capacity and site selection issues;

- Improving and applying the ecosystem approach to aquaculture (EAA) for the actual and new aquaculture projects, in the different aquaculture geographical area effluent discharge and if fish farms should be equipped with effluent treatment facility;
- Mitigating shrimp farming technical and institutional constrains mainly (quality of seed production and their limited seasonality from April to August; competition and restrictions on coastal land; availability of specialized feeds; shortage of technical manpower; lack of information on the environmental impact and impact of disease stress). Shrimp culture can develop rapidly in the coming decade if the government and NGO bodies could Overall shrimp sustainable development production efficiency will be facilitated by evaluating the production parameters of the different shrimp species in the two different ecosystems in the Red Sea and the Mediterranean Sea coasts; decreasing the cost of PL and juvenile around the year; enhancing the availability of skilled capacity staff; achieving in applied scientific research; enhancing high quality formulated feed and understanding of shrimp pathogens and microbial ecology, by the use of environmentally friendly aquatic drugs);
- Estimating the water needs and salinity tolerance of common Egyptian crops (fish/crustacean/cloves/animal production) in the desert aquaculture to reach a durable development industry, with the encouraging using the RAS in the desert aquaculture feasible projects. In addition research effort would be needed to identify non-conventional crops using brackish aquifers in the application of *Salicornia* irrigation systems and animal production. Crops are adapted to brackish irrigation the economic returns are always rather low, even when more salt-resistant varieties are used;
- Evaluating the specific and applied research projects to the carrying capacity. Effort would be needed to establish pilot projects for the different Egyptian aquaculture ecosystems including: rice field; Nile cages; brackish/marine water earthen ponds and intensive desert aquaculture with an emphasis to the aquaponic opportunities;
- Supporting artesian and commercial financial credit for aquaculture projects, which could open new prospects for an EAA development taking into consideration the carrying capacity of the different geographical aquatic ecosystem; and
- Assisting the existing ten Egyptian aquaculture producer's associations and societies for assisting artesian fish farmers and commercial farms to pioneer the management culture techniques; increase the availability of commercial inputs, improved marketing distribution channels and facilitate credit.

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