Fishy Business

ASSESSING EGYPT'S GROWING AQUACULTURE SECTOR

Ammar Plumber

Ammar Plumber is an undergraduate and a Benjamin Franklin Scholar at the University of Pennsylvania. An economics major, he is spending his third year as a visiting student at the University of Oxford's Pembroke College, where he has taken an academic interest in Ancient Greek philosophy. He is also passionate about the issue of global food insecurity and its concomitant environmental challenges.

Based on hieroglyphic evidence, scholars say that fish farming in Egypt dates back over 4,000 years.[1] Despite its ancient history, Egyptian aquaculture was only recently scaled up to industrial levels. The past three decades have seen such a rapid expansion of Egyptian freshwater aquaculture that Egypt ranked eighth globally in total annual harvest weight of farmed fish in 2016.[2] However, technological advancement in the industry has remained slow, even during this period of growth. Egyptian fish farmers still chiefly use brackish water earthen ponds, which are confined to saline waste lands.[3] In particular, most fish farming takes place in the Nile Delta region, where land is becoming scarce as it is repurposed for agriculture.[4] Innovative strategies and technologies are needed to expand usable environments and to increase Egypt's productive potential. Egypt still lacks the technical knowledge needed to

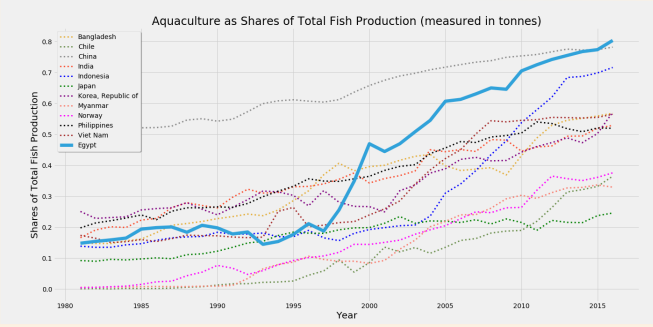

Figure 1

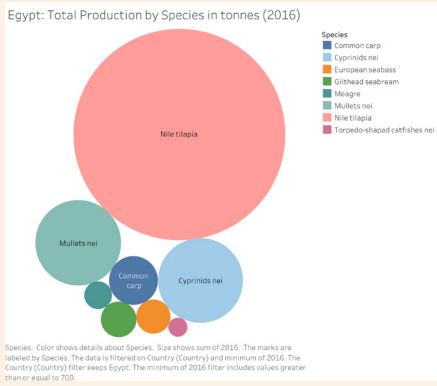

Figure 3

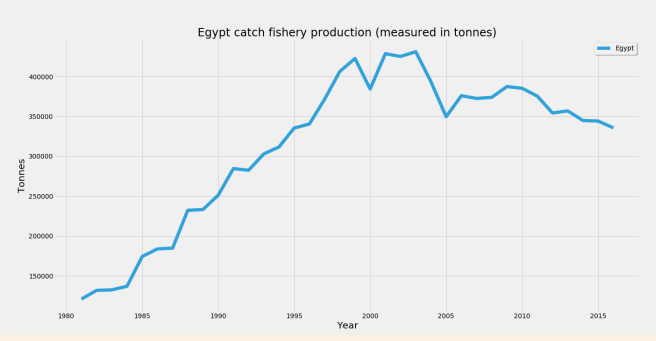

Figure 2

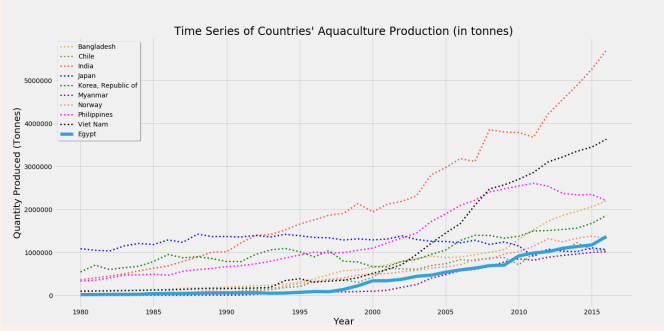

Figure 4

undertake large-scale mariculture—sea-based aquaculture—and accordingly produces mostly freshwater fish like tilapia, carp, and mullets.[5] Globally, countries have utilized many different systems, ranging from offshore cages to flooded rice fields.[6] While many of these possibilities have been explored in Egypt, brackish water earthen ponds remain the predominant mode of production.[7] And unlike other countries, Egyptian law additionally requires that fish farming only take place on land and water that is unsuitable for other purposes.[8] Given these constraints, improvements in productive potential are impossible unless Egypt learns how to farm in new ecosystems, such as the open ocean, deserts, and rice fields. In addition to its impact on the Egyptian population as a source of food, the future of the Egyptian fish-farming industry has far-reaching implications for the viability of aquaculture in other developing nations, especially those with similar ecosystems. Given the threats to marine life posed by ocean acidification, pollution, and overfishing, aquaculture has become an increasingly important source of food throughout the developing world. Its success and efficiency has the potential to ameliorate systemic crises of food insecurity and water scarcity.

In this paper, I hope to both quantitatively and qualitatively examine the historical development of Egyptian aquaculture over the past thirty-five years, and to determine what factors improve or inhibit Egypt's productive potential. To do this, I will graphically analyze time series production data retrieved from the United Nations Food and Agriculture Organization's database FishStatJ and tie observed trends to specific managerial, political, or technological changes in the industry. First, I will show that aquaculture is the dominant mode of fish production in Egypt and has far surpassed the output of wild caught fish. Then, I will provide a categorical breakdown of Egypt's aquaculture species and explain why certain fish are farmed more than others. Finally, I will use data visualizations to survey the international aquaculture landscape,

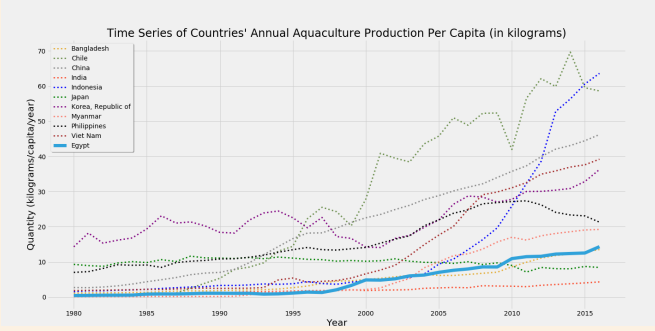

Figure 5

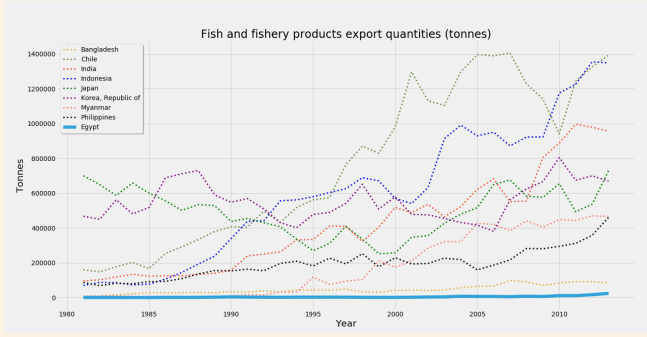

Figure 7

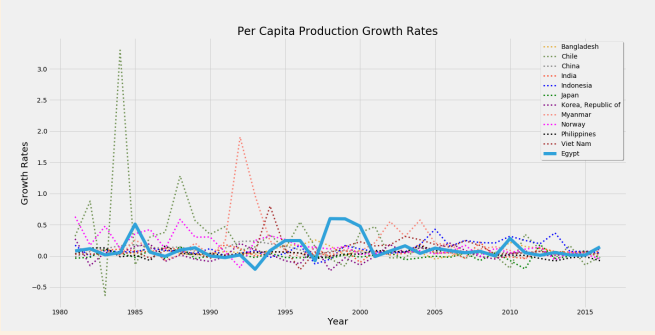

Figure 6

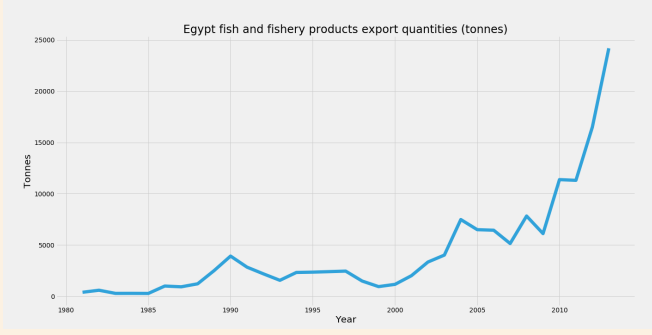

Figure 8

which may help to characterize and explain Egypt's development relative to other nations. Overall, I argue that Egypt's insufficient production in new inland and offshore environments has limited its fish farming industry's growth potential.

AQUACULTURE TERMINOLOGY

Before proceeding, it is necessary to define the technical terms that will be referenced throughout this paper. Aquaculture is generally divided into three categories based on the level of nutritional input: extensive, semi-intensive, and intensive. Extensive systems do not contain added nutritional inputs; fish subsist on food that is naturally present in the farming environment. Semi-intensive aquaculture systems use dietary supplementation, but natural food still comprises much of fish nutrition. Finally, intensive aquaculture involves adding nutritionally complete food to the ecosystem, often in the form of pellets.[9] The two most common types of feed are pelleted and extruded feed. Pelleting involves mildly heating, steaming, and pressurizing nutrients to produce a loosely-bound nodule of feed.[10] Extrusion, on the other hand, is a newer technology that allows more intense heat and pressure to be applied to the nutrients such that digestibility and feed cohesion are improved.[11] Another common practice is mono-sex fish production: by feeding hormones to fish fry, it is possible to reverse the sex of females and produce an all-male population.[12] This homogenization ensures that fish do not reproduce during pond cultivation and that they achieve greater mass than females can attain. Finally, integrated fish farming uses products of one farming environment as inputs for another to minimize waste.[13] Integrated systems are generally less environmentally costly and economically wasteful than non-integrated systems.

SHIFTING FROM CATCH FISHERIES TO AQUACULTURE

To demonstrate the increasing importance of aquaculture as a source of fish, Figure 1 plots aquaculture as shares of total national fish production from 1981 to 2016.[14]

Of the twelve largest aquaculture producers, Egypt had the highest proportion of aquaculture relative to total fishery product in 2016. Moreover, over the sample period, its share rose the most of any country displayed on the graph. In 1981, approximately 16% of fishery production was sourced from fish farms. Now, the proportion nears 80%—about a five-fold increase.[15] But, it would be erroneous to infer that catch fishery production has decreased. In fact, wild-fish production has nearly tripled since 1981, as shown in Figure 2.[16]

Rather, the Egyptian fish farming industry has so drastically outpaced growth in catch fisheries that wild-caught fish are now a minor fraction of total fish production. Plainly stated, Egypt has become heavily reliant on aquaculture as a food source.

SPECIES BREAKDOWN

Figure 3 is a packed bubble chart of Egyptian aquaculture output by species.[17] As a comparative benchmark, Nile tilapia in 2016 accounted for 940,309 tonnes of production.

Nile tilapia is far and away the most farmed fish species in Egypt, the second largest tilapia producer in the world.[18] Until 2005, tilapia constituted a much smaller percentage of total production.[19] The ensuing growth of Oreochromis nilotica can be attributed in part to the development of tilapia-specific sex homogenization technology. An all-male population produces a greater yield than a mixed sex one, a quality that appeals to profit-seeking fish farmers.[20] Mullets and carp are the next two most farmed fish species. Often, carp and tilapia are raised together in polyculture environments because of their complementary diets: the carp consume what the tilapia do not.[21] Tilapia, carp, and mullets are all raised in earthen pond environments, while European seabass, meagre, and gilthead seabream are mariculture.[22] The infancy of sea-based fish farming in Egypt explains why these saltwater species are such a small portion of total production.

AGGREGATE PRODUCTION

Now, I examine the basic question of how much aquaculture each country has produced in tonnes during each year startin in 1980 (Figure 4). To avoid distortion and more clearly illustrate Egypt's growth trajectory, it is necessary to exclude the two biggest producers, China and Indonesia, from the graph.[23]From this visualization, a few trends are apparent. First, Egyptian aquaculture began growing around 1984, and in 1997 industry growth accelerated considerably. Second, Egypt recently surpassed Japan and approximately matches Norway and Chile in total production. Third, based on the trend line, Egypt's growth appears to be one of the least volatile among the countries shown. More specifically, Egypt has enjoyed reliable growth in production whereas Japan's and the Philippines' outputs increased and then declined. This discrepancy in growth demands further explanation. Unlike Japan and the Philippines, Egypt is somewhat cushioned from the productive dominance of Chinese aquaculture because most Chinese fishery exports are destined for its neighbors and the United States.[24] Moreover, Egypt has the largest Middle Eastern aquaculture sector, and thus faces no competition from surrounding countries.[25] In possessing unthreatened regional market power, Egypt controls its own destiny. The longstanding success of the domestic industry depends primarily on Egypt's own policies and management practices and less on the market decisions of other countries.

PER CAPITA PRODUCTION

Despite the importance of these conclusions, total production provides an incomplete account of Egyptian aquaculture's ability to feed Egyptians, as population growth may outpace growth in output. For this reason, I also examine per capita aquaculture production, shown in Figure 5.[26]

Nearly quadrupling the second biggest per capita producer in 2016, Norway has consistently surpassed all other countries in this regard, which reflects the nation's specialization in aquaculture.[27] Despite having lower per capita production than most countries shown in the graph, Egypt has steadily increased its per capita output throughout the period shown. As in the aggregate production plot, Egypt overtook Japan in the past decade in per capita production. Furthermore, Egypt's per capita output growth path is strikingly like Bangladesh's. A remarkable number of similarities that influence both countries' aquaculture industries help explain this association. Both are developing coastal nations that only farm fish inland.[28] Like Egypt, Bangladesh's two predominant farmed fish species are common carp and a genetically improved species of Nile tilapia, which was brought in by the Bangladesh Fisheries

Research Institute in 1994.[29] Neither Egypt nor Bangladesh has fully implemented intensive farming systems, and both are researching new methods of integration, a development fundamental to each country's long-term success in the industry.

Figure 6, which shows growth rates of per capita production, reveals a few drastic fluctuations.[30]

Per capita growth rates reached extreme peaks in 1985 and 1998 and an extreme valley in 1993. This peak in 1998 is surpassed by only three countries during the examined period: Chile in 1984 and 1988, Myanmar in 1992, and Vietnam in 1994. According to the UN Food and Agriculture Organization, Egyptian aquaculture witnessed a period of significant technological reform starting in 1997.[31] Many farmers undertook intensive aquaculture operations in place of pre-existing semi-intensive systems and semi-intensive systems in place of extensive ones.[32] Land and water use restrictions drove this intensification, as fish farmers could not make use of new terrain.[33] Moreover, because of Egypt's steep population growth over the past few decades, demand for fish and other food sources has consistently risen.[34] Faced with limited options, businesses wishing to increase output must boost the yield of land already being used. As reflected in the data, Egyptian fish farmers in the past few decades have begun to use new management technologies such as extruded feed and sex homogenization to accommodate more fish and improve efficiency.[35]

While modernization is certainly good for the long-term health of the sector, production is ultimately capped by the amount of land available. Though fertile soils are unavailable for fish farming, there are other viable environments and farming strategies which would comply with regulations besides the highly prevalent earthen pond environments. Mariculture is the most obvious possibility, as seawater is neither needed for vegetative cultivation nor for most other industrial purposes. To this end, Egypt has taken steps to increase its mariculture knowledge base with the aim of augmenting its sea-based productive capacity. In 2010, Egypt's General Authority for Resources Development (GAFRD) signed an agreement with Vietnam to share aquaculture expertise, strategies, and technology.[36] This cooperative relationship is opportune, as both are developing economies with a historic bilateral relationship, and each has a comparative advantage in a different type of aquaculture: Egypt in freshwater and Vietnam in seawater.[37] While little information is available regarding the fruits of the original agreement, as recently as 2017, both countries signed memorandums of understanding (MOUs) expressing a commitment to invest in joint fish farming ventures.[38] Besides its international engagement, the Egyptian government has also initiated its own new mariculture projects in recent years in Port Said, northern Kafr El-Sheikh governorate, and around the Suez Canal.[39] The species being farmed include flat head grey mullet, gilthead sea bream, and European sea bass.[40] While these ventures are still in their infancy, Egyptian mariculture, if successfully undertaken, promises immense gains in farmed fish output.

Two other systems compliant with land- and water-use regulations are desert and rice-fields aquaculture. The former involves using underground water in desert environments to raise fish in tanks and then reusing effluent water from fish farming operations to irrigate crops.[41] This process serves to conserve freshwater, which could appeal to the relevant licensing agencies. Moreover, desert environments have few agricultural uses, so this form of aquaculture takes advantage of idle land. A second possibility entails stocking fish in submerged rice fields, a strategy long used in Vietnam, China, and Bangladesh. This method facilitates a symbiotic relationship between the two organisms that bolsters the yield of both; rice attracts pests and disease-carrying insects that fish can feed on.[42] Another advantage is the efficiency with which rice-field aquaculture uses water. The two products are cultivated together using half of the amount of water needed to raise them separately.[43] While many Egyptian farmers employ these two systems, more can be done. Less than 1% of Egyptian aquaculture production is farmed in the desert, and less than 5% is sourced from rice-fields, despite the fact that Egypt is the fourteenth largest paddy rice producer in the world.[44] Ultimately, integrated aquaculture offers the benefits of increased production without colossal environmental costs.

EXPORTS

In addition to studying production, it is also useful to inspect Egypt's fish farming export levels. Figure 7 plots a time series of fishery product export quantities measured in tonnes.[45] As extreme outliers relative to the other countries, China, Norway, and Vietnam are

omitted; excluding them makes the other countries' export trends more discernible.
From Figure 7, it is apparent that Egypt exports the least among the twelve largest aquaculture producers; its trend line remains relatively stagnant for the entire period shown. By showing only Egypt's aquaculture export levels, Figure 8 makes clear that Egypt's exports have indeed steadily increased since 2000, though more modestly than exports in the eleven other countries.[46]

But a categorized breakdown of fishery exports reveals that most are from capture fisheries rather than aquaculture farms.[47] Despite the abundance of aquaculture production in Egypt, the EU and United States reject Egyptian freshwater farmed fish, since Egyptian production methods do not meet their rigorous food safety requirements.[48] Safety concerns are related to drug residues and environmental contamination. An obvious possibility would be for Egyptian government to take regulatory action. Whether this type of solution would be advisable is beyond the scope of the argument advanced here. Regardless, other export growth avenues exist. There is substantial evidence that the development of Egypt's mariculture sector would serve this end. As of 2013, the only Egyptian aquaculture producers permitted to export to the EU were marine fish farmers.[49] Perhaps this is only a contingent feature of the fish farming market: if freshwater fish farmers were more attentive to matters of cleanliness, their products would also be approved. However, according to two researchers from the World Health Organization, freshwater ecosystems, by their very nature, are more susceptible to chemical and biological contamination than is open-sea farming.[50] This difficulty is compounded in Egypt, where freshwater farmers are statutorily barred from using high-quality water, as it is more urgently needed for other purposes. For these reasons, mariculture appears to be the most expedient opportunity to increase exports.

CONCLUSION

While much research is available about the state of Egyptian aquaculture in isolation, there is much more to be understood about how Egypt fares relative to other nations. To this end, relevant studies may offer profound insights regarding how Egypt can leverage its comparative advantage in aquaculture to bolster its position in the global economy. Analysis of production and export data revealed several noteworthy trends. First, Egypt seems to be economically insulated from the competition posed by Chinese aquaculture. Egyptian aquaculture is, therefore, secure in its short-term industrial autonomy. Second, Egyptian and Bangladeshi per capita production data and a litany of other factors suggest parallel developmental trajectories. Successes or failures in one country may offer insights about what may or may not work for the other. Evaluating Bangladeshi case studies may be a promising direction for future Egyptian aquaculture research. Finally, growth opportunities in mariculture and integrated land-based fish farming are possible avenues to boost exports and per capita production. While I do not offer specific policy recommendations here, the effectiveness of various policy measures in promoting mariculture and integrated aquaculture ought to be studied further. Should these growth opportunities be realized, fish farming holds great promise as a staple Egyptian food product.

ENDNOTES

1. Michael Zwirn, "Aquaculture in Egypt: Improving Food Security and Resolving Resource Allocation Conflicts," The Journal of Environment & Development 11, no. 2 (2002). 132.
2. FishStatJ, Fisheries and Aquaculture Department, FAO, http://www.fao.org/fishery/statistics/software/fishstatj/en (accessed March 15, 2018).
3. Mohamed Shaalan et al., "Aquaculture in Egypt: Insights on the Current Trends and Future Perspectives for Sustainable Development," Reviews in Fisheries Science & Aquaculture 26, no. 1 (2018): 102.
4. Shaalan et al., 100.
5. Zwirn, 133.
6. Elvira A. Baluyut, Aquaculture Systems and Practices: A Selected Review (Rome: UN Development Prog., 1989).
7. A. J. Rothuis et al., Aquaculture business opportunities in Egypt (Wageningen: Wageningen UR, 2013): 9.
8. Omar F. El-Gayar, "Aquaculture in Egypt and issues for sustainable development," Aquaculture Economics & Management 7, no. 1-2 (2003): 144.
9. Rothuis et al., 9-10.
10. Steven Craig and Louis Anthony Helfrich, "Understanding Fish Nutrition, Feeds, and Feeding," Virginia Cooperative Extension, Virginia Tech, 2009, https://vtechworks.lib.vt.edu/bitstream/handle/10919/48950/420-256_pdf.pdf?sequence=1 (accessed March 18, 2018).
11. Craig and Helfrich.
12. Shaalan et al., 101.
13. Thierry Chopin, "Integrated multi-trophic aquaculture," Northern Aquaculture 12, no. 4 (2006): 4.
14. FishStatJ.

15. Ibid.
16. Ibid.
17. Ibid.
18. The first is China; Khaw Hooi Ling, "Improved Tilapia Breeding Program in Egypt: A Year in Review," The Fish Tank, WorldFish, December 2, 2016, http://blog.worldfishcenter.org/2016/12/improved-tilapia-breeding-program-in-egypt-a-year-in-review/ (accessed March 20, 2018).
19. FishStatJ.
20. Shaalan et al., 101.
21. Ibid.
22. Shaalan et al., 102.
23. FishStatJ.
24. Nathanael Hishamunda and Rohana Subasinghe, Aquaculture Development in China: The Role of Public Sector Policies, FAO, 2003, http://www.fao.org/docrep/006/y4762e/y4762e05.htm (accessed March 24, 2018).
25. "Markets in the Middle East: Market, Trade and Consumption," GLOBEFISH, FAO, http://www.fao.org/in-action/globefish/fishery-information/resource-detail/en/c/338542/ (accessed March 20, 2018).
26. FishStatJ.
27. "Norway National Aquaculture Sector Overview," Fisheries and Aquaculture Department, FAO, http://www.fao.org/fishery/countrysector/naso_norway/en (accessed March 20, 2018).
28. "Bangladesh National Aquaculture Sector Overview," FAO Fisheries and Aquaculture Department, http://www.fao.org/fishery/countrysector/naso_bangladesh/en (accessed March 20, 2018).
29. M. A. Hossain, "Aquaculture in Bangladesh: Prospect of High Density Mixed Culture of Fish with Low Cost Diets," FAO, 2002, http://www.fao.org/tempref/docrep/fao/005/y3994e/Y3994E03.pdf (accessed March 23, 2018).
30. FishStatJ.
31. "Egypt National Aquaculture Sector Overview," Fisheries and Aquaculture Department, FAO, http://www.fao.org/fishery/countrysector/naso_egypt/en (accessed March 20, 2018).
32. "Egypt National Aquaculture Sector Overview."
33. El-Gayar, 144.
34. "Egypt National Aquaculture Sector Overview."
35. Ibid.
36. Cam McGrath, "Finding More Fish, between Egypt and Vietnam," Inter Press Service News Agency, October 28, 2010, http://www.ipsnews.net/2010/10/finding-more-fish-between-egypt-and-vietnam/ (accessed March 22, 2018).
37. Ibid.
38. "Egypt: 5 MOUs in the Fields of Investment, Stock Exchange and Ports to be Signed with Vietnam," TendersInfo News, August 26, 2017, http://proxy.library.upenn.edu:2395/global/article/GALE%7CA501881706?u=upenn_main (accessed March 22, 2018).
39. Shaalan et al., 105.
40. Ibid.
41. Shaalan et al., 104.
42. Ibid.
43. Ibid.
44. Shaalan et al., 104; FishStatJ; "Paddy rice production worldwide in 2017, by country (in million metric tons)," FAO, https://www.statista.com/statistics/255937/leading-rice-producers-worldwide/ (accessed March 24, 2018).
45. FishStatJ.
46. Ibid.
47. Ibid.
48. Rothuis et al., 16.
49. Rothuis et al., 15.
50. A. Reilly and F. Kaeferstein, "Food safety and products from aquaculture," Journal of Applied Microbiology 85, no. S1 (1998).

ADDITIONAL SOURCES

1. Algayd, Abdelhamid. "Analysis of the Development of Capture Fish and Aquaculture Production in Egypt (1996-2005)." Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis 56, no. 3 (2008): 13-20.
2. "Egypt." WorldFish. https://www.worldfishcenter.org/country-pages/egypt.
3. Eltholth, Mahmoud, Kimberly Fornace, Delia Grace, Jonathan Rushton, and Barbara Hasler. "Characterization of Production, Marketing and Consumption Patters of Farmed Tilapia in the Nile Delta of Egypt." Food Policy 51 (2015): 131-143.
4. Green, B W, Z. El Nagdy, and H. Hebicha. "Evaluation of Nile Tilapia Pond Management Strategies in Egypt." Aquaculture Research 33, no. 13 (2002): 1037-1048.
5. Macfadyen, Graeme, Ahmed Mohamed Nasr-Alla, Diaa Al-Kenawy, Mohamed Fathi, Hussein Hebicha, Ahmed Mohammed Diab, Samy Mohmed Hussein, Ramadan Mohamed Abou-Zeid, and Gamal El-Naggar. "Value-Chain Analysis." Aquaculture 362-363 (2012): 18-27.
6. Nasr-Allah, Ahmed Mohamed, Malcolm William Dickson, Diaa Abdel Reheem Al-Kenawy, Mohamed Fathi Mohamed Ahmed, and Gamal Othman El-Naggar. "Technical Characteristics and Economic Performance of Commercial Tilapia Hatcheries Applying Different Management Systems in Egypt." Aquaculture 426-427 (2014): 222-230.
7. "Study Data from University of Alexandria Update Knowledge of Aquaculture." Life Science Weekly. October 4, 2016.
8. Suloma, Ashraf and Hiroshi Y. Ogata. "Future of Rice-Fish Culture, Desert Aquaculture and Feed Development in Africa: The Case of Egypt as the Leading Country in Africa." Japan Agricultural Research Quarterly 40, no. 4 (2006): 351-360.
9. "Sustainable Transformation of Egypt's Aquaculture Market System." Mena Report. February 8, 2016.