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Status of fisheries in Egypt: reflections on past trends and management challenges

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Abstract This paper provides a summary from primary and grey literature on the current status of fisheries in Egypt. It also discusses gaps which may impede effective management, and highlights future challenges. Total national seafood production has grown steadily overall in the last 15 years due to the rapid growth of aquaculture, despite a decline in fisheries production (about 23 %) from 1997 to 2012. The total production in 2012 was approximately 1,371,975 tonnes, tripling the 457,036 tonnes obtained in 1997. Fisheries production amounted to 354,237 tonnes (25 %) whilst aquaculture produced 1,017,738 (75 %) tonnes in 2012. Fisheries in Egypt's northern lakes were the most important (36 %) followed by marine fisheries in the Mediterranean and Red Seas (32 %), which had the greatest variations in catch. The main decline in wild fisheries was due to the reduced landings from both marine and northern lake fisheries. Egypt has a wide variety of marine and freshwater species, comprising *Sardina pilchardus*, *Penaeus japonicus*, *Mugil cephalus*, and

Saurida undosquamis, etc.; while *Oreochromis niloticus*, *Clarias gariepinus* are the main cultured species. The Egyptian fishing fleet increased by over 40 % from 3415 motorised vessels in 1997–4909 vessels in 2012. Most of these (3046 vessels, 62 %) fish in the Mediterranean, while the rest (1863 vessels, 38 %) fish in the Red Sea. Longlines were the fishing gear most used by the motorised vessels (45 %), followed by trawlers (26 %). Policy during the past few decades has been development-oriented, encouraging investment in aquaculture to ensure sustainable fish production, rather than managing wild fisheries in a sustainable way. Despite vigorous efforts through national legislation to address fishery management issues, the weak enforcement, low compliance and unregulated fishing suggest the need to restructure the fisheries management system. The main fisheries stakeholders (policy makers, scientists and fishery managers) should consider the different scales of these fisheries and the context in which they operate, in order to develop suitable management strategies.

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Introduction

Most of the world fish production comes from developing countries (e.g. tropical fisheries) (FAO

2014). In many of these countries policy makers do not appear to consider management approaches that do not rely on the formal stock assessment process (Mahon 1997). They try to adopt the same fisheries management strategies used in developed countries, which can lead to mismanagement of some of the associated fisheries (Ruddle and Hickey 2008). For instance, the western ideal marine protected area (MPA) model is increasingly seen as culturally and socially flawed and inappropriate in some developing countries (Ruddle and Hickey 2008). The intrinsic idea is common sense to indigenous peoples, who in many cases have already provided environmental stewardship and protection of these areas for centuries. In addition, some of these countries have limited resources for enforcing regulations inside the MPA, which then end up with weak compliance (Samy et al. 2011). Consequently, many MPAs in these countries have little effect on fishing pressure and are now functioning as 'paper parks' (Advani et al. 2015).

Egypt is located in the northeast corner of the African continent, it borders the Mediterranean Sea, between Libya and the Gaza Strip, and the Red Sea, north of Sudan. Being surrounded by two seas and having more freshwater than any other country in the region, it is not surprising that fisheries in Egypt are an important part of its culture and society. Fishing has been conducted there since the dawn of humanity and still continues to be an important activity. It has a total area of 1,001,450 km² of which 6000 km² are water. The country has a lengthy coastline of about 2450 km along both the Mediterranean and Red Seas. The Mediterranean coast of Egypt extends for about 950 km from Rafah at the east of Sinai to Sallum west of the Egyptian–Libyan border (Bird 2010). It is one of the longest Mediterranean coastlines in North Africa. The Red Sea coast of Egypt, which includes the Gulfs of Suez and Aqaba and the intervening Sinai Peninsula, is about 1500 km in length (Bird 2010). The Red Sea has long been recognised as a region of high biodiversity (Samy et al. 2011) and home to well over than 1000 species, many of them with commercial value.

The Nile, the world's longest river, flows northward through Egypt for over 1532 km (Shawki et al. 2005) before it empties into the Mediterranean Sea. Just below Cairo the river splits into two major branches, the Rosetta and the Damietta. This area is known as the Nile Delta, or Lower Egypt, which has rich inland

waters and coastal lakes (Table 1) with significant capture fishery and aquaculture potential. Via its many irrigation canals, the Nile feeds the northern lakes of Mariut, Edku, Burullus and Manzala. Also fed are the coastal lagoons of Port Fouad and Bardawil, as well as the inland Timsah and Bitter lakes and the closed lakes of Qarun and Wadi Al Raiyan, not to forget the great reservoir behind the Aswan high dam (Lake Nasser) in Upper Egypt. Some small water bodies in the western desert also have been re-developed for fish production (Toshka and New Valley water bodies) (Table 1).

The first reports on the fisheries of Egypt date back to the beginning of the twentieth century (Fouad 1926; Wimpenny 1934; El-Saby 1951). Recently there have been no attempts to describe the status of Egyptian fisheries on a national level. The overall goal of this paper is to summarise the large body of data on Egyptian fisheries, as well as to explore the main issues and challenges raised, highlighting any gaps relevant to fisheries management. This paper is divided into three sections: (i) the first addresses the main characteristics of fisheries in comparison to

Table 1 Marine and freshwater bodies in Egypt, and their coastline length (km) or average surface area (km²)

| Fisheries | Coastline length (km) or surface area (km ²) |
|--------------------------------|--------------------------------------------------------------------------------------|
| Seas | |
| Mediterranean Sea | 950 km (Bird 2010) |
| Red Sea | 1500 km (Bird 2010) |
| Northern lakes | |
| Mariout | 250 km ² (Ahmed and Häder 2011) |
| Edku | 70 km ² (Magdy et al. 2008) |
| Burullus | 410 km ² (Shaltout and Al-Sodany 2008) |
| Manzala | 700 km ² (Ramdani et al. 2009) |
| Coastal lagoons | |
| Port Fuad | 60 km ² (Rahman 2011) |
| Bardawil | 650 km ² (Mehanna 2007a) |
| Inland lakes | |
| Bitter and Timsah (Suez Canal) | 250 and 15 km ² (Hamed et al. 2012) |
| Qarun | 235 km ² (El-Shabrawy and Dumont 2009) |
| Rayan | 703 km ² (Sayed and Abdel-Satar 2009) |
| Nasser | 5238 km ² (El-Shabrawy 2009) 6000 km ² (Shawki et al. 2005) |
| Nile river | 1532 km (Shawki et al. 2005) |

aquaculture, including: trends in landings, catch composition, fishing effort, and socio-economic aspects. (ii) The second provides an overview of the management regulations and the weaknesses of these tools in promoting effective management. (iii) The main findings and implications for the management of the Egyptian fisheries are discussed in the third section.

General methodology

A systematic search was conducted to obtain relevant literature pertaining to fisheries in Egypt. Some of the data was acquired through a predefined search in *Google Scholar*. Some of the terms used in the search were: fisheries in Egypt, Red Sea fisheries, eastern Mediterranean fisheries, etc. The name of all fisheries and lakes in Egypt combined with the main issues discussed in the paper were also used to widen the search. Results were not limited to texts available only in English or to peer-reviewed journals; it was extended to Arabic reports and un-indexed journals.

The General Authority for Fisheries Resources and Development (GAFRD) is the organisation responsible for managing Egyptian fisheries. Consequently, this paper primarily focuses on fisheries landings and fishing effort characteristics found in the GAFRD database spanning from 1997 to 2012. However, not all data were obtained directly from this organisation, other sources such as FAO statistics were used to perform a well-rounded analysis. According to GAFRD, fisheries in Egypt are divided into five main areas: the Seas, the northern lakes, coastal lagoons, inland lakes, and the River Nile (Table 1) (GAFRD 1997–2012).

In addition, non-parametric analyses were performed on landings data from 2012, by combining Non-metric Multidimensional Scaling (nMDS) and Similarity Percentage Analysis (SIMPER) (Clarke and Warwick 2001; Clarke and Gorley 2006) to determine whether there are temporal (seasonal) or spatial (between landing-sites) differences in the catch composition. SIMPER, was applied to identify the species that contributed to differences (when present) between groups. For the multivariate techniques, similarities among samples were calculated using the Bray–Curtis similarity index (Bray and Curtis 1957) on the monthly landings biomass (tonnes month⁻¹) by

species and annual landings biomass by species and landing site (tonnes landings site⁻¹ year⁻¹).

Finally, the fishing effort distribution between different fisheries regions is also presented. A map of Egypt was geo-referenced in a geographical information system (QGIS Development Team 2015). Additionally, the fishing effort of both motorised and sailing boats was allocated for each port and province.

Status of fisheries in Egypt

Total production trends

The building of the Aswan dam in the sixties led to the cessation of the fertile Nile floodwaters. This led to an unintended and widely-reported dramatic decline in coastal fish landings on the Egyptian Mediterranean coast (Halim 1960; Milliman 1997; Nixon 2003). However in the late 1980s, the coastal fishery began to show a surprising recovery. Today, landings are more than 3 times the pre-dam levels (Oczkowski et al. 2009).

Up to the late nineties, wild fisheries (including marine, brackish and fresh water) were the main sources (about 70 %) of national production in Egypt, around 550,500 tonnes annually. However, during the last two decades aquaculture production has grown rapidly, reflected in the annual national production growth rate (GAFRD 1997–2012). The total national production has increased steadily in the last 15 years (Fig. 1) (GAFRD 1997–2012). The only exception was in 2004 when production decreased (1.25 %). The total production in 2012 was 1,371,975 tonnes, tripling the 457,036 tonnes obtained in 1997. There was an increase of 19 % in the total national production in 1998 and 1999 in comparison to that in the former year. This growth was clearly due to aquaculture development. In 2003, aquaculture surpassed capture fishery in terms of volume for the first time, with 50.70 % of the total production (Fig. 1). Since then, aquaculture has become the main source of fish production in Egypt, reaching 74 % (1,017,738 tonnes) of the total national production in 2012 (El-Sayed et al. 2015). In turn, wild fisheries only provided a production of 26 % (354,237 tonnes). This amount has never been obtained in the history of the country, which puts Egypt in the top ten aquaculture producers in the world, as well as the highest producer in Africa

(FAO 2013; Hagar Dighiesh 2014). In 2011, Egypt was the eighth largest aquaculture producer in the world by quantity (986,820 tonnes) accounting for 1.57 % of world aquaculture production (FAO 2013; Macfadyen et al. 2011). Also, it is by far the largest in Africa, accounting for 70.5 % of aquaculture by volume and 65 % by value (FAO 2013).

It is important to note that beside the rapid growth of aquaculture, there was a decline in wild fisheries production of about 22.8 %, comparing 1997–2012. Figure 1 shows trends for total national, aquaculture and wild fisheries production (tonnes year⁻¹) obtained in Egypt between 1997 and 2012 (GAFRD 1997–2012). As a result of this growth, total production has greatly increased from an estimated value of 1.24 billion USD in 1999 to 2.94 billion USD in 2012 (Fig. 1) (GAFRD 1997–2012).

Trends in landings from the main areas

Most of the production in 2012 was obtained from aquaculture (74 %), while wild fisheries provided 26 %. The northern lakes were the most important source (36 %) within the wild fisheries, where Manzala Lake (18 %) provided the highest production, followed by Burullus (14.7 %), Mariout (2.09 %), and Edko (1.86 %). The landings from the northern lakes (Fig. 2a) declined in total catch between 2005 and 2009; however, between 2010 and 2012 production slightly increased. A similar trend was documented for

Fig. 2 Temporal evolution of total annual landings (tonnes) for each fishery: **a** total northern lakes, **b** detailed northern lakes, **c** marine fisheries, **d** detailed marine fisheries, **e** Nile river fishery, **f** inland fishery, **g** coastal lagoons, and **h** detailed coastal lagoons, for the period 1999–2012 (GAFRD 1999–2012)

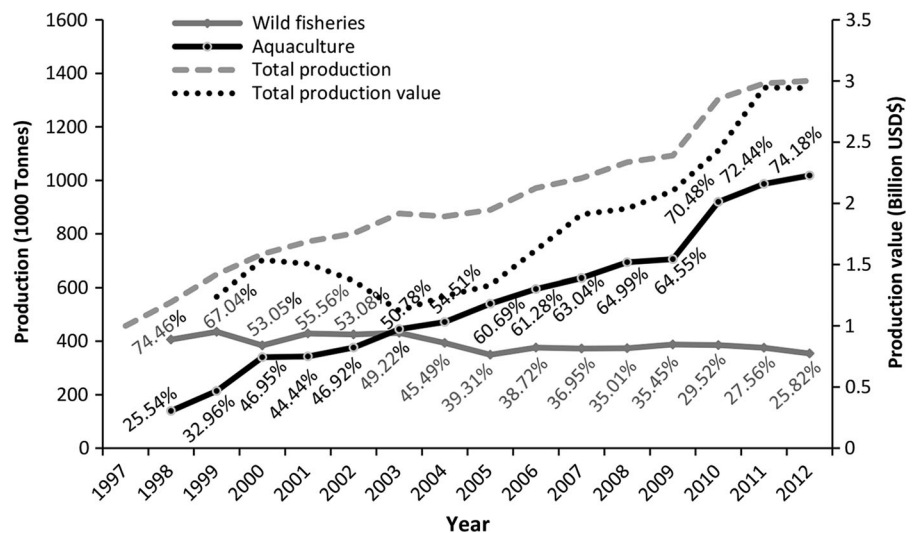
the same years in Manzala Lake, while other lakes have undergone a slight steady decrease (Fig. 2b).

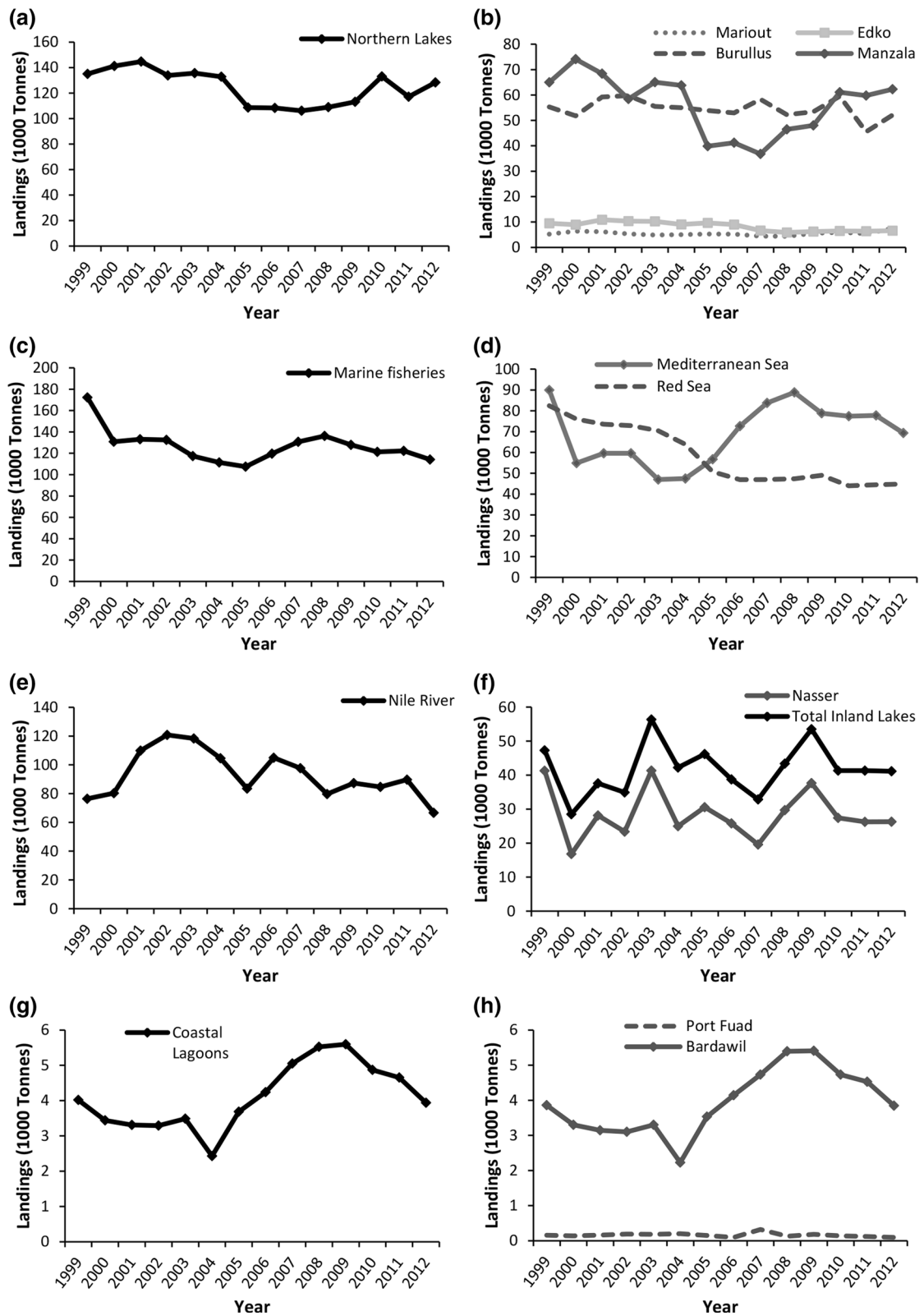
The marine fisheries, including both the Mediterranean and Red Seas were the second most important contributor (32 %) to the total fisheries production in 2012. The Mediterranean fisheries provided 19.6 %, and the Red Sea 12.66 %. A clear decline in total catches was observed between 1999 and 2012 (Fig. 2c). The same trend was observed in the Red Sea, while the Mediterranean showed a severe decline between 2000 and 2005, then a later recovery to catch levels similar to 1999 (Fig. 2d).

Freshwater fisheries have always had a large production potential due to the large river systems consisting of approximately 1532 km of river (Shawki et al. 2005). The Nile river fisheries contributed 18.8 % to the total production. Fluctuations in landings directly from the Nile were noted between 1999 and 2009, reaching a peak in 2002 and 2003. However, landings returned to the same rates in 2009, 2010 and 2011 and were followed by a drastic decrease in 2012 (Fig. 2e).

Inland fishing accounted for an 11.6 % share of the total fish production in 2012 (just over 41,000 tonnes—GAFRD 2012), to which Lake Nasser alone contributed the highest share of 7.5 % (Fig. 2f).

Fig. 1 Total national production in Egypt for the period 1997–2012, including wild fisheries and aquaculture (tonnes year⁻¹) and their percentage (GAFRD 1997–2012), and annual total production value (in US dollars) for the period 1999–2012 (GAFRD 1999–2012)





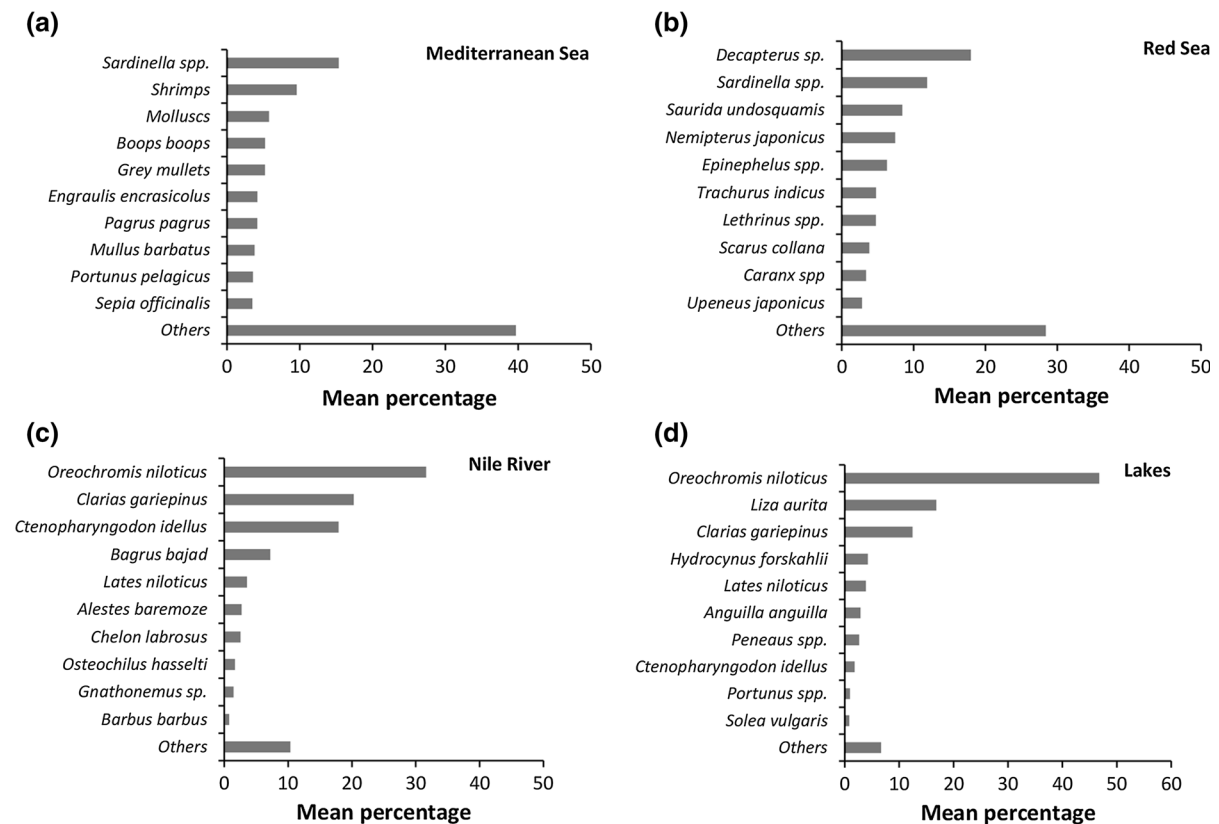


Fig. 3 Mean catch composition for each fishery: **a** Mediterranean Sea, **b** Red Sea, **c** Nile river and **d** Lakes, showing the mean proportion (in biomass) of the 10 most important species in the total catch of 2012. Common names refer to a group of

species in the original data, Shrimps (*P. japonicus*, *M. stebingi*, *P. semisulcatus* and *T. curvirostris*), Grey mullets (*M. cephalus*, *L. aurata* and *L. ramada*) and Molluscs (species not defined in the data)

Although there have been some peaks recorded in recent decades in inland fisheries production, e.g. 2003 (56,350 tonnes) and 2009 (53,500 tonnes), it has been considerably less (41,126 tonnes) recently (2012) compared to the inland water potential.

Finally, two coastal lagoons, Bardawil and Port Fuad, provided a minimal 1.11 % share of fisheries production. The bulk of coastal lagoon production comes from Bardawil (Fig. 2h), which has steadily increased since 2004 to reach its maximum (5550 tonnes) in 2008 and 2009. However, a decline was recorded over a 3-year period (4730 tonnes in 2010, 4530 tonnes in 2011 and 3850 tonnes in 2012), but it is still slightly lower than 1999 (about 3860 tonnes) (GAFRD 1999–2012).

Catch composition

Marine fisheries capture a variety of species. The most landed species in both the Mediterranean Sea and the

Red Sea in 2012 are presented (Fig. 3a, b) (GAFRD 2012). Sardines *Sardinella aurata* and *Sardina pilchardus* were the most landed species (15.34 %) in the Mediterranean, followed by the shrimps *Penaeus japonicus*, *Metapenaeus stebingi*, *Penaeus semisulcatus* and *Trachypenaeus curvirostris* (9.57 %), molluscs (5.78 %), bogue *Boops boops* (5.23 %), grey mullets *Mugil cephalus*, *Liza aurata* and *Liza ramada* (5.22 %) and anchovy *Engraulis encrasicolus* (4.19 %). The most targeted species in the Red Sea were: round scad *Decapterus* sp. (17.96 %), sardines (11.88 %), lizardfish *Saurida undosquamis* (8.43 %), threadfin bream *Nemipterus japonicus* (7.43 %), groupers (6.3 %) and mackerel or Arabian scad *Trachurus indicus* (4.78 %). The four most important species represent approximately two-thirds of the total landings from the Nile fisheries (Fig. 3c). Dominant species in the Nile were: tilapias *Oreochromis niloticus*, *Oreochromis aureus*, *Tilapia*

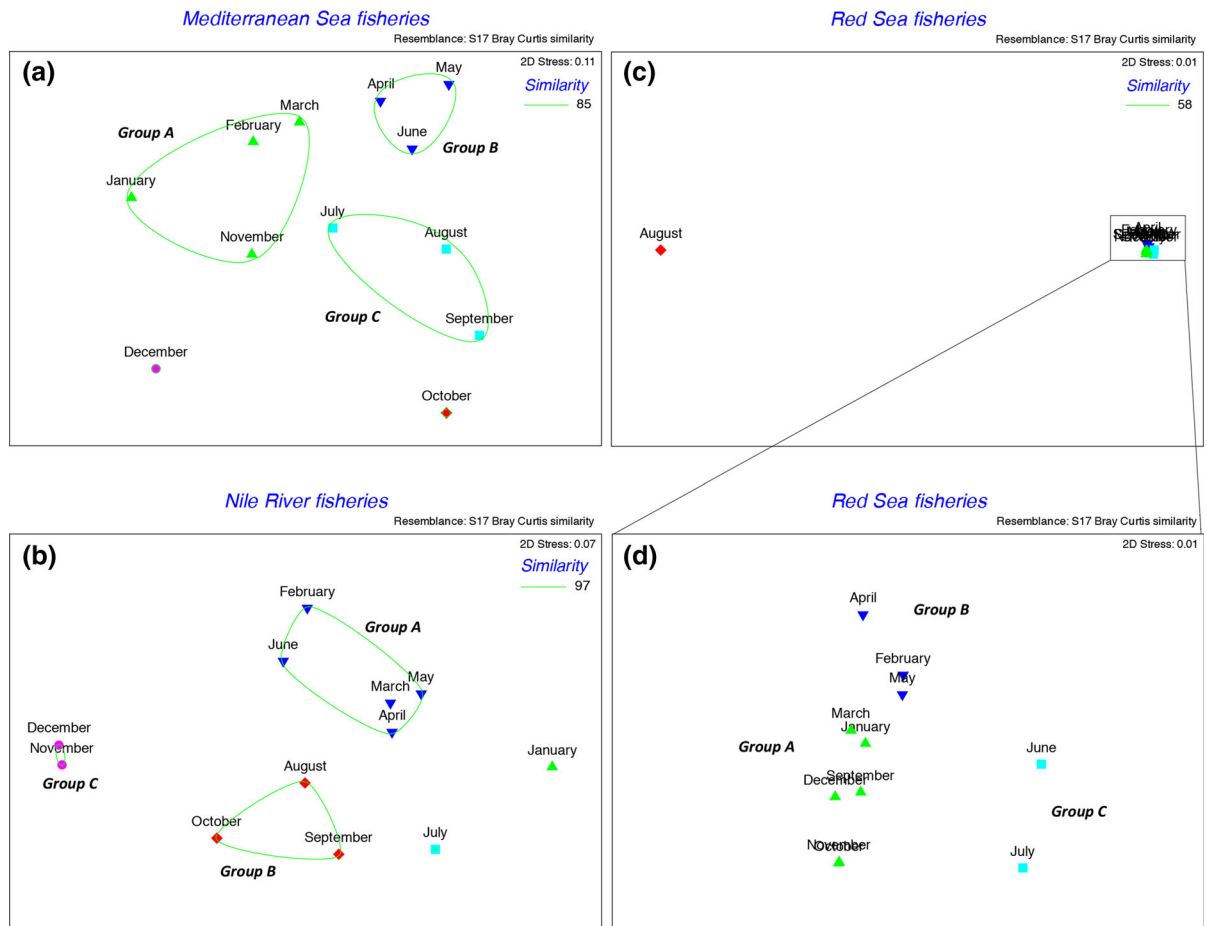


Fig. 4 Two dimensional nMDS ordination of samples (tonnes month⁻¹) used to analyse temporal (seasonal) differences in the structure of catch composition. Fisheries regions:

zilli and *Sarotherodon galilaeus* (31.6 %), catfish *Clarias gariepinus* (20.27 %), grass carp *Ctenopharyngodon idellus* (17.9 %) and bagrus *Bagrus bajad* (7.2 %). While 80 % for the lakes were represented by: tilapias (46.78 %), grey mullets (16.83 %), catfish (12.47 %), and elongate tigerfish *Hydrocynus forskahlii* (4.24 %) (Fig. 3d).

Assessing whether there is any temporal (seasonal) differences in the structure of catch composition, the nMDS showed a similarity level of 85 % in the Mediterranean Sea, 97 % in the Nile River and 58 % in the Red Sea between all samples, considering monthly landings by region (Fig. 4). However some differences were detected between groups of samples at a very low level of dissimilarity. Accordingly, three groups of samples were identified in both the

a Mediterranean fisheries, **b** Nile river fisheries, **c** and **d** Red Sea fisheries. Groups A, B and C are separated according to the similarity percentage outlined in the figure legend

Mediterranean (Fig. 4a) and the Nile river (Fig. 4b). In general, the catch composition was similar for successive months. For instance, in November, January, February and March: Group A shows an 88.47 % similarity (Fig. 4a). In April, May and June: Group B indicates a 93.31 % similarity level (Fig. 4a). Finally in July, August and September: Group C shows an 87.76 % similarity level (Fig. 4a). In the Red Sea, the catch composition for August was clearly different from the rest of the samples (Fig. 4c). Nevertheless, the other months showed the same trend as the Mediterranean and Nile (Fig. 4d). Table 2 shows the species that contributed to these differences and their average abundance in each group by region.

In the same way, spatial differences (between landing sites) were observed in the structure of catch

Table 2 Mean biomass (tonnes month⁻¹) and contribution percentage of the species that contributed more than 5 % to the similarity according to SIMPER analysis

| Group A | | | Group B | | | Group C | | |
|---------------------------------|-----------|-----------|---------------------------------|-----------|-----------|---------------------------------|-----------|-----------|
| Average similarity: 88.47 | | | Average similarity: 93.31 | | | Average similarity: 87.76 | | |
| Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % |
| Mediterranean sea fisheries | | | | | | | | |
| <i>Sardinella</i> spp. | 631.50 | 14.05 | <i>Sardinella</i> spp. | 846.00 | 14.68 | <i>Sardinella</i> spp. | 1022.00 | 15.56 |
| Shrimps ^a | 406.25 | 9.98 | Shrimps ^a | 543.00 | 9.40 | Shrimps ^a | 775.00 | 14.26 |
| Molluscs ^a | 338.50 | 8.71 | <i>Boops boops</i> | 404.33 | 6.98 | Molluscs ^a | 317.33 | 6.47 |
| Grey mullets ^a | 293.50 | 7.38 | Molluscs ^a | 351.67 | 6.38 | Grey mullets ^a | 333.00 | 6.29 |
| <i>Boops boops</i> | 320.50 | 7.34 | <i>Engraulis encrasicolus</i> | 361.67 | 6.03 | <i>Portunus pelagicus</i> | 298.00 | 6.01 |
| | | | <i>Pagrus pagrus</i> | 349.67 | 6.00 | <i>Argyrosomus regius</i> | 254.33 | 5.07 |
| | | | Grey mullets ^a | 295.67 | 5.15 | | | |
| | | | <i>Mullus barbatus</i> | 315.00 | 5.04 | | | |
| Group A | | | Group B | | | Group C | | |
| Average similarity: 71.81 | | | Average similarity: 62.50 | | | Average similarity: 63.38 | | |
| Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % |
| Red sea fisheries | | | | | | | | |
| <i>Decapterus</i> sp. | 1253.67 | 18.97 | <i>Saurida undosquamis</i> | 427.67 | 21.38 | <i>Epinephelus</i> spp. | 322.00 | 25.35 |
| <i>Sardinella</i> spp. | 826.17 | 16.91 | <i>Nemipterus japonicus</i> | 397.33 | 17.19 | <i>Lethrinus</i> spp. | 228.50 | 20.13 |
| <i>Saurida undosquamis</i> | 413.17 | 10.23 | <i>Scarus collana</i> | 224.33 | 8.03 | <i>Upeneus japonicus</i> | 203.00 | 10.44 |
| <i>Nemipterus japonicus</i> | 343.33 | 7.92 | <i>Decapterus</i> sp. | 175.00 | 7.06 | <i>Scarus collana</i> | 117.50 | 8.01 |
| <i>Rastrelliger kanagurta</i> | 331.67 | 7.59 | <i>Lethrinus</i> spp. | 211.67 | 5.37 | <i>Caranx</i> spp. | 128.00 | 6.24 |
| <i>Epinephelus</i> spp. | 273.33 | 6.81 | | | | <i>Vabiola louti</i> | 156.50 | 5.78 |
| Group A | | | Group B | | | Group C | | |
| Average similarity: 97.56 | | | Average similarity: 98.04 | | | Average similarity: 98.44 | | |
| Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % |
| Nile river fisheries | | | | | | | | |
| <i>Oreochromis niloticus</i> | 1739.60 | 35.22 | <i>Oreochromis niloticus</i> | 1765.33 | 35.05 | <i>Oreochromis niloticus</i> | 1659.00 | 35.02 |
| <i>Clarias gariepinus</i> | 1111.20 | 22.23 | <i>Clarias gariepinus</i> | 1161.00 | 23.33 | <i>Clarias gariepinus</i> | 1071.50 | 22.84 |
| <i>Ctenopharyngodon idellus</i> | 1019.60 | 20.41 | <i>Ctenopharyngodon idellus</i> | 955.00 | 18.95 | <i>Ctenopharyngodon idellus</i> | 922.50 | 19.26 |
| <i>Bagrus bajad</i> | 411.80 | 8.22 | <i>Bagrus bajad</i> | 402.00 | 7.97 | <i>Bagrus bajad</i> | 353.00 | 7.19 |

The identified groups are based on nMDS of temporal changes in the structure of catch composition between the main landing sites in Mediterranean, Red sea and Nile fisheries

^a Refers to a group of species, defined in the main text

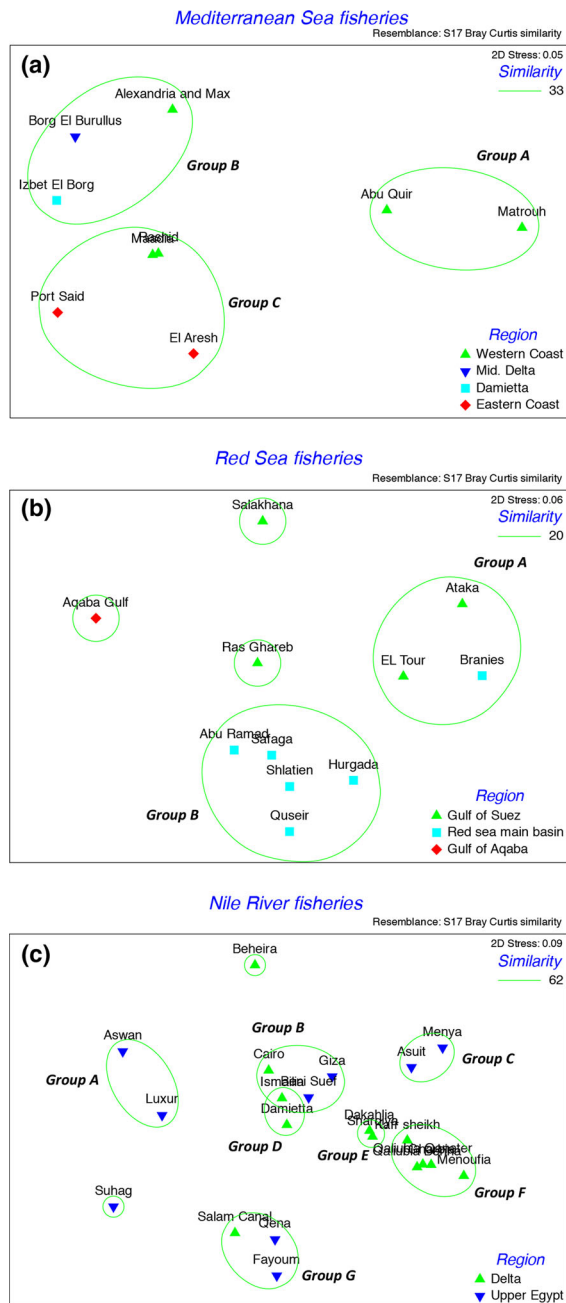


Fig. 5 Two dimensional nMDS ordination of samples (tonnes landings site⁻¹ year⁻¹) used to analyse spatial (between landings sites) differences in the structure of catch composition. Fisheries regions: **a** Mediterranean fisheries, **b** Red Sea fisheries, and **c** Nile river fisheries. Groups A, B and C are separated according to the similarity percentage outlined in the figure legend

composition. The nMDS showed a clear separation between groups at similarity levels of 33 % in the Mediterranean Sea (Fig. 5a), 20 % in the Red sea

(Fig. 5b) and 62 % in the Nile river (Fig. 5c). The separation makes sense in most cases due to the proximity of landing sites, the closer the landing sites the greater similarity in species landed. Table 3 shows the species that contributed to these differences and their average abundance in each group by region.

According to the FAO Fisheries Statistics, Egypt produced 477,458 tonnes in 2008 of Nile tilapia from aquaculture, which is approximately 13.8 % of the world's cultured tilapias (FAO 2010a, b). In 2012 the farmed tilapia *O. niloticus* reached 768,752 tonnes which accounts for more than 75.5 % of all aquaculture production (Fig. 6) and makes it by far the most predominant cultured species. Tilapia is followed in quantity by mullets (Saleh 2008; FAO 2010b) and together both species contributed more than 88 % of total aquaculture production (FAO 2010b; GAFRD 2012). Egypt is the world's top producer of farmed mullets (FAO 2010a). Other important species groups include carps (Cyprinids, mainly common carp and grass carp, 10 %) and catfish (*Clarias* spp., 2 %) (FAO 2010b; GAFRD 2012).

Fishing effort

The main fishing ports along the Egyptian Mediterranean coast are Matrouh, Alexandria (Anfoshi), Alexandria (Abu Qir), Madaaia, Rashid, Motobas (Burullus), Baltim, Damietta (Izbet El-Borg), Port Said and Arish. On the Red Sea coast, the main fishing ports are Attaka (inside Suez) and Salakhana (outside Suez); Hurghada, Abu Ramad and Qusair, and in South Sinai: Dahab and El-Tour. Additionally, many small landing sites are used for fishing by small-scale artisanal boats (FAO 2010a).

In 2012 the Egyptian fishing fleet consisted of 4909 motorised vessels, most of these (3046 vessels, 62 %) fish in the Mediterranean Sea. The wide expanse of the continental shelf off the central Delta region and its seabed (flat, muddy and sandy) has therefore favoured trawling along the eastern coast. Hence, there is fishing activity along the continental shelf off the Nile Delta, venturing to the eastern side of Port Said but rarely west of Alexandria, while artisanal fishers exploit inshore areas. Limited trawling grounds are available on the western coast. In the Red Sea (1863 vessels, 38 %) there is a long-standing traditional (artisanal) fishery that exploits coral reefs spreading along the coast and in the Gulf of Aqaba. Fishing

Table 3 Mean biomass (tonnes landings site⁻¹ year⁻¹) and contribution percentage of the species that contributed more than 5 % to the similarity according to SIMPER analysis

| Group A | | | Group B | | | Group C | | |
|------------------------------|-----------|-----------|---------------------------------|-----------|-----------|------------------------------|-----------|-----------|
| Average similarity: 34.03 | | | Average similarity: 37.32 | | | Average similarity: 48.74 | | |
| Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % |
| Mediterranean sea fisheries | | | | | | | | |
| <i>Boops boops</i> | 85.00 | 36.73 | <i>Sardinella</i> spp. | 1210.33 | 22.83 | <i>Sardinella</i> spp. | 1737.75 | 55.06 |
| <i>Pagrus pagrus</i> | 49.50 | 13.78 | <i>Sepia officinalis</i> | 643.67 | 8.63 | Molluscs ^a | 1001.50 | 10.50 |
| <i>Mullus barbatus</i> | 48.00 | 10.20 | <i>Boops boops</i> | 1034.67 | 8.11 | Shrimps ^a | 260.25 | 4.93 |
| <i>Epinephelus</i> spp. | 26.00 | 10.20 | Shrimps ^a | 1853.33 | 6.74 | | | |
| <i>Chondrichthyes</i> spp. | 22.00 | 6.63 | <i>Mullus barbatus</i> | 785.67 | 6.54 | | | |
| | | | <i>Chondrichthyes</i> spp. | 664.00 | 6.54 | | | |
| | | | <i>Portunus pelagicus</i> | 587.33 | 6.51 | | | |
| | | | <i>Pagrus pagrus</i> | 916.33 | 6.03 | | | |
| Group A | | | Group B | | | | | |
| Average similarity: 38.48 | | | Average similarity: 35.74 | | | | | |
| Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % | | | |
| Red sea fisheries | | | | | | | | |
| <i>Decapterus</i> sp. | 2685.67 | 67.65 | <i>Epinephelus</i> spp. | 502.80 | 34.83 | | | |
| <i>Saurida undosquamis</i> | 1278.00 | 11.18 | <i>Caranx</i> spp. | 268.00 | 20.22 | | | |
| <i>Nemipterus japonicus</i> | 1109.67 | 6.24 | <i>Vabiola louti</i> | 228.60 | 18.45 | | | |
| | | | <i>Lethrinus</i> spp. | 325.40 | 14.65 | | | |
| | | | <i>Plectropomus laevis</i> | 197.20 | 7.12 | | | |
| Group A | | | Group B | | | Group C | | |
| Average similarity: 63.23 | | | Average similarity: 74.47 | | | Average similarity: 65.15 | | |
| Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % |
| Nile river fisheries | | | | | | | | |
| <i>Oreochromis niloticus</i> | 192.50 | 71.37 | <i>Clarias gariepinus</i> | 471.33 | 28.40 | <i>Oreochromis niloticus</i> | 1232.00 | 31.40 |
| <i>Lates niloticus</i> | 48.00 | 21.15 | <i>Bagrus bajad</i> | 341.33 | 20.72 | <i>Clarias gariepinus</i> | 1046.00 | 29.08 |
| | | | <i>Oreochromis niloticus</i> | 336.00 | 20.46 | <i>Bagrus bajad</i> | 816.00 | 15.01 |
| | | | <i>Ctenopharyngodon idellus</i> | 324.33 | 20.12 | <i>Lates niloticus</i> | 697.50 | 12.90 |
| | | | <i>Chelon labrosus</i> | 191.33 | 10.31 | <i>Chelon labrosus</i> | 514.50 | 9.73 |

Table 3 continued

| Group D | | | Group E | | | Group F | | |
|---------------------------------|-----------|-----------|---------------------------------|-----------|-----------|---------------------------------|-----------|-----------|
| Average similarity: 76.88 | | | Average similarity: 91.64 | | | Average similarity: 81.55 | | |
| Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % | Species | Av. Abund | Contrib % |
| Nile river fisheries | | | | | | | | |
| <i>Oreochromis niloticus</i> | 614.00 | 49.87 | <i>Oreochromis niloticus</i> | 1329.50 | 39.90 | <i>Oreochromis niloticus</i> | 2515.60 | 41.46 |
| <i>Ctenopharyngodon idellus</i> | 358.50 | 25.61 | <i>Ctenopharyngodon idellus</i> | 745.50 | 21.62 | <i>Clarias gariepinus</i> | 1694.60 | 32.18 |
| <i>Clarias gariepinus</i> | 177.50 | 10.35 | <i>Clarias gariepinus</i> | 516.00 | 14.44 | <i>Ctenopharyngodon idellus</i> | 1087.80 | 20.55 |
| <i>Bagrus bajad</i> | 116.00 | 6.28 | <i>Osteochilus hasselti</i> | 239.50 | 6.62 | | | |
| | | | <i>Bagrus bajad</i> | 248.50 | 6.19 | | | |
| | | | <i>Barbus barbus</i> | 213.00 | 5.82 | | | |
| Group G | | | | | | | | |
| Average similarity: 75.64 | | | | | | | | |
| Species | | | | Av. Abund | | Contrib % | | |
| Nile river fisheries | | | | | | | | |
| <i>Ctenopharyngodon idellus</i> | | | | 889.67 | | 88.91 | | |
| <i>Oreochromis niloticus</i> | | | | 80.33 | | 4.70 | | |

The identified groups are based on nMDS of spatial changes in the structure of catch composition between the main landing sites in Mediterranean, Red sea and Nile fisheries

^a Refers to a group of species, defined in the main text

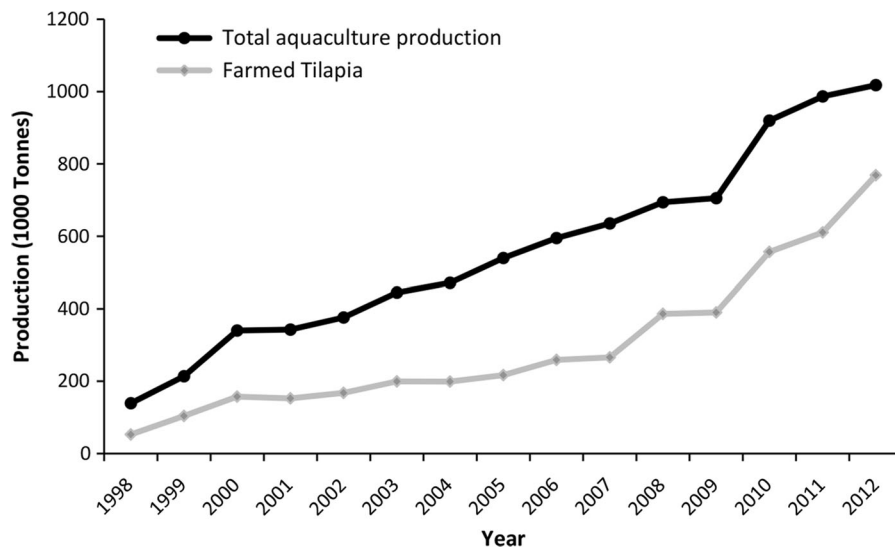


Fig. 6 Temporal evolution of annual total aquaculture production (tonnes) and tilapia aquaculture production for the period 1998–2012 (GAFRD 1998–2012)

total number of motorised vessels are presented. For inland waters, the percentage (*in brown*) of sailing boats registered in each province with regard to the total number of sailing boats

motorised vessels in Egypt (Fig. 7). The same port is considered the most important trawling port with approximately 47 % of the trawlers in Egypt (54 % on Egyptian Mediterranean coast) (Online Resource 1). Ezbet El-Borg was followed by Hurghada with 15 % of the total number of motorised vessels (Fig. 7). Moreover, Hurghada was the most

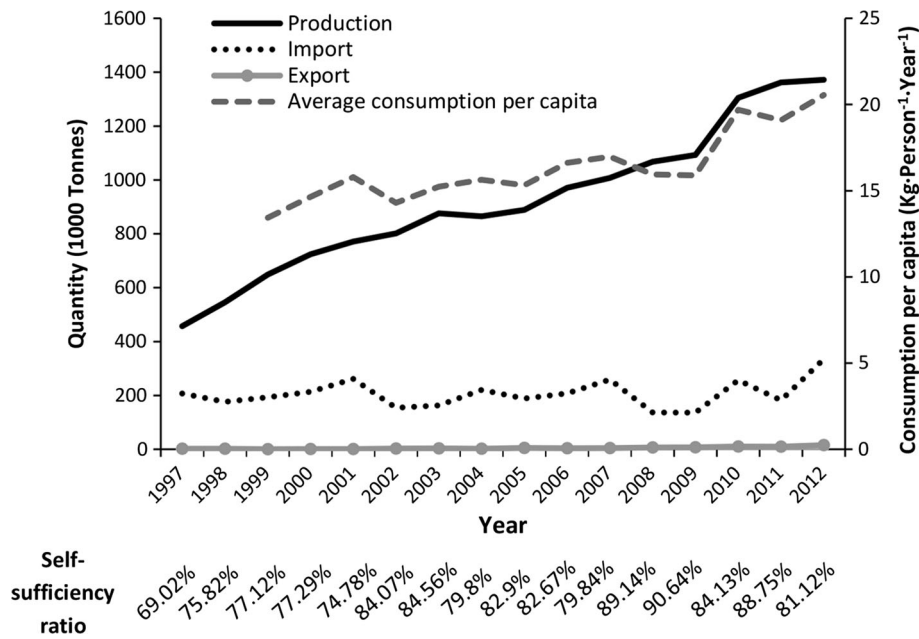


Fig. 8 Total production, imports, exports and average consumption per capita of Egyptian fishery products for the period 1997–2012. Self-sufficiency ratio is the domestic production available for consumption (GAFRD 1997–2012)

important port for longliners, accounting for 24 % of longliners in Egypt (54 % of longliners on Egyptian Red Sea coast). Hurghada was also the highest for trammel nets (27.5 % of all trammels) (Online Resource 1).

Longlines were the most used fishing gear by the motorised vessels, comprising about 45 % of vessels followed by trawlers with approximately 26 %, while trammel nets and purse seiners were 15 and 7.5 % respectively (Online Resource 2a). According to engine power, the great bulk of the trawl fleet was composed of vessels up to 100–200 hp (Online Resource 2b), while the purse seiners showed more variability between 100 and 500 hp (Online Resource 2c). However, the majority of longliners and trammel nets were between 30 and 100 hp and 30–50 hp respectively (Online Resource 2d and e). Furthermore, the number of motorised vessels has increased by approximately 44 % over the study period, from 3415 vessels in 1997–4909 vessels in 2012 (Online Resource 2g). The increase is mainly attributable to the longline, trawl and purse seine fleets with a gradual increase between 2006 and 2012, while trammel nets have declined since 2009 (Online Resource 2h).

In the Mediterranean, the fleet of sail boats consisted of 1418 small boats of which 929 boats were 4–6 m in length, 465 boats 6–8 m in length, and

24 boats longer than 8 m (GAFRD 2012). In the Red Sea the fleet consisted of 177 boats, all between 4 and 6 m. These small sailing boats normally have a crew of 4 fishers or less and fish mostly during daylight (GAFRD 2012).

There were many small sailing boats (24,324) used in inland fisheries (Nile and lake fisheries) (GAFRD 2012). As these boats do not travel far, there are also many landing sites (FAO 2010a). Along the River Nile there are 695 registered landing sites as well as countless unregistered sites (FAO 2010a). The distribution of these boats (Fig. 7) may thus be a reasonable indicator of the spatial allocation of fishing effort. Accordingly, the highest number of sailing boats was registered in Kafr El-Sheikh province, with almost 25 % of the total sailing boats in Egypt. This was followed by the Aswan and Daqahlia provinces, each with almost 10 % of the total number (Fig. 7).

On the River Nile there are approximately 9958 small wooden boats 4–6 m in length, and 17 boats 6–8 m, and 8 boats longer than 8 m. In addition, there are 202 registered fishers without boats who are fishing with artisanal nets (GAFRD 2012). In the lake fisheries the corresponding numbers are: 11,919 boats (4–6 m), 13 boats (6–8 m), 2409 boats (longer than 8 m) and 106 fishers without boats (GAFRD 2012).

Table 4 List of fisheries legislation in Egypt, showing the main laws and their regulatory measures

| Law name | Year of issuing | Main regulatory measure |
|------------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Law 124 | 1983 | Provides the GAFRD with responsibility for: <ol style="list-style-type: none"> 1. The development and management of fishery resources, including aquaculture 2. Issuing fishing licenses 3. Supervising fisheries cooperatives 4. Producing statistical data |
| Art. 2 | | Entails that every vessel should have a fishing license issued by the GAFRD |
| Art. 8 and Art. 9 | | Indicate the gear type used by the vessel and the allowed fishing ground. Prohibit the use of other gear or fishing in different areas than specified in the license |
| Art. 11 | | Prohibits fishing of undersized fish individuals, according to the length and size established by the Minister of Agriculture |
| Art. 13 | | Prohibits the use of destructive, poisonous or illegal fishing practices |
| Art. 19 | | Prohibits the collection and removal of fish fry from the sea or lakes without permission |
| Art. 20 | | Prohibits draining any area of a lake for fishery exploitation |
| Art. 27 | | Entails that licenses should be renewed every year |
| The decree no. 174 | 1989 | Defines the minimum mesh size and length of nets by fishing gear |
| The resolution no. 342 | 1992 | Prohibits the issuing of any new fishing licenses for trawl in either the Red Sea or the Mediterranean from 1st January 1994 |

Socio-economic aspects

Although the fishing industry (excluding aquaculture) has had a relatively minor role in the Egyptian economy, domestic fish production plays an important role in the contribution to the national food supply. Its importance is significant in the coastal regions, especially the Delta, where this sector is the main source of income and employment generation, and provides a livelihood to many people. Its role is even more essential when considering the indirect employment created by the sector (FAO EastMed 2014). Most of the fishing communities live along the Mediterranean and the Red Sea coasts, as well as the shores of the Nile river and the major inland lakes. Fisheries provide livelihoods for fishers and their families, as most of their children help in transport, processing and selling of the fish. Many people who live in communities with aquaculture facilities help during the harvest season (FAO 2010a). One in three fishers in the marine sector are employed in production and two in secondary activities including post-harvest processing, marketing, and distribution. Out of the 89,537 fishers, more than 5079 are involved in the recreational sector (FAO 2010a). The EastMed project highlighted that the revenue of the Egyptian

Mediterranean fleet provides an annual salary of approximately 2662 USD per person to around 22,173 fishers. This is higher than the official minimum wage of the country (1416 USD). This relatively high salary stems from the fact that the industry is heavily subsidised by the very low cost of fuel.

Egypt has the penultimate lowest (ranks 20 out of 21 countries) GDP per capita in the Mediterranean region (2780.9 USD) (The World Bank; UNDP). Furthermore, according to the Central Agency for Public Mobilization & Statistics the average inflation rate in 2011 in Egypt was recorded at 10.2 %. Considering this harsh economic situation in Egypt (including high inflation rate, low salaries and shortage in animal protein supply), fish is the main source of affordable animal protein for the rapidly growing population. Most of the catch is sold through auction markets (56 %) and wholesalers (40 %) (FAO EastMed 2014), and consumed fresh. The high production in the last few years has provided a reliable and sufficient quantity of affordable fish protein to low-income families. The rapid increase in aquaculture production has supplied Egyptians with double the amount of seafood they consumed 20 years ago. The average consumption in 2012 was 20.55 kg of fish products per capita, which is the

highest rate of local consumption in the last decade (Fig. 8).

Domestic supplies are boosted by substantial imports (about 335,000 tonnes, in 2012) of frozen, salted and smoked fish products (Fig. 8). During the last decade imports fluctuated, while exports have slightly increased but are still insignificant in terms of quantity (maximum 15,810 tonnes, in 2012) (Fig. 8). During this period the local supplies had a growing share of local consumption, mainly due to the increase in aquaculture. Tilapias and mullets, the dominant aquaculture species, are more readily accepted in the market than before. The self-sufficiency ratio reached its maximum in 2009 at 90.64 % (Fig. 8). In 1997, the combined value of internationally traded fish reached the equivalent of about 135.37 million USD; which has increased to approximately 378.73 million USD in 2012 (FAO 2010a).

The current status of fisheries management

The Law 124 of 1983 is the legal instrument providing the GAFRD with the responsibility for the development and management of fishery resources, including aquaculture. It is also responsible for issuing fishing licenses, supervising fishery cooperatives and collecting statistical data on fish production, consumption and trade (Table 4). Regarding wild fisheries management, the aforementioned law entails that every vessel should have a fishing license issued by the GAFRD (art. 2), which indicates the type of gear used by the vessel (art. 8) as well as its permitted fishing ground (art. 9). Consequently, both these articles prohibit the use of other gear or fishing in different areas than specified in the license. According to art. 27 these licenses should be renewed every year. Moreover, it also prohibits fishing of undersized fish, according to the length and size established by the Minister of Agriculture (art. 11). It is also forbidden to use destructive, poisonous or illegal fishing practices (art. 13), as well as the collection and removal of fish fry from the sea or lakes without permission (art. 19) or draining any area of a lake for fishery exploitation (art. 20).

The earlier law is mainly an administrative tool lacking clear policy goals for the management of marine fisheries in Egypt. Therefore, more Decrees and Resolutions have been issued to this effect: (i) Decree No. 174 of 1989 defined the minimum

mesh size and length of nets by fishing gear. (ii) The Resolution 342 of 1992 prevented the issuing of any new fishing licenses for trawling in either the Red Sea or the Mediterranean, starting on 1st January 1994. (iii) A closed season was established for trawlers from the 1st of June to the 30th of September each year, as another fishery management tool applied by GAFRD for the protection of spawning seasons. This closed season has been adopted by administrative decision rather than as a decree or resolution. (iv) In the Red Sea, although not established primarily as marine reserves, most MPAs have a positive effect since many of the no-take zones can benefit artisanal fisheries (Samy et al. 2011).

Discussion

It is clear that Egypt has great production capacity in terms of both fisheries and aquaculture. Trends show that fisheries production has significantly decreased in recent years, while aquaculture has gained considerable importance because of the high demand for aquatic food products from an increasing human population. Therefore, the aquaculture industry is a promising sector for the economy in Egypt, while wild fisheries have more challenges to overcome. The geographical location of Egypt bestows a major advantage in supporting a high biodiversity, providing plentiful marine, brackish and fresh water resources to support fisheries and aquaculture. Fisheries also provide fish protein as raw material to the farming and industrial sectors in Egypt, creating further employment opportunities. Despite these socio-economic advantages, fisheries in Egypt are an underdeveloped activity. They remain a poorly managed sector compared to other large western Mediterranean countries (e.g. Spain, France and Italy) or even to neighbouring eastern Mediterranean countries (e.g. Turkey and Greece).

The reported increase in landings in the late eighties is likely attributable to the improvements in fishing technology and increasing effort rather than a clear recovery. There was in fact a similar worldwide increase in fish landings (including the Mediterranean) during the eighties. However, in later years landings have decreased or remained constant despite technological advances, due to depletion of traditional fishing grounds (Pauly et al. 2002). The Egyptian government

started to support fish farms financially in the late nineties (FAO 2010a). Consequently, aquaculture production increased 475 % in the years between 1999 and 2012. At present, Egypt is the world's 8th largest aquaculture producer and the largest producer in Africa. It is also the world's 2nd largest tilapia producer (after China) and first in Africa (FAO 2013). As a result, fish consumption in Egypt rose to 20.55 kg per capita per year, which is close to the average European consumption (22 kg) and higher than the global (15.3 kg) and African (10.4 kg) averages (FAO 2011). It has averaged around 15 kg over the past decade.

Both marine and northern lakes fisheries are the main source (about 68.5 %) of wild production. The aforementioned decline was mainly due to the decrease in both marine and northern lakes fishery landings. In turn, fishing effort gradually increased during the same period. This would inevitably lower the CPUE (catch per unit effort) as more vessels are competing for fewer resources. One of the main difficulties in Egyptian marine fisheries (both Mediterranean and Red Sea), is that they depend highly on seasonal supplies of small pelagic fish species. On a global scale, these species show great fluctuations because they are more susceptible to environmental factors (Fréon et al. 2005). The decline in marine fisheries was more acute in the Red Sea than the Mediterranean. Most of the Egyptian Red Sea coast is protected by a network of MPAs with different levels of protections including various no-take zones (Samy et al. 2011). However, the current fishing regulations are unenforced and illegal fishing techniques, including destructive fishing, are affecting marine resources (Ashworth and Ormond 2005; Samy et al. 2011). Thus, some of these MPAs are now functioning as 'paper parks' (Advani et al. 2015). In turn, Mediterranean fisheries are suffering from unjustified trawl fleet overcapacity. This is most likely driven by the highly subsidised fuel provided by the Egyptian government. Although this results in substantial profits (due to low expenses), it makes the sector extremely vulnerable to any minimal change in the subsidies and/or average price of fuel (FAO EastMed 2014).

Moreover, all the Northern Delta lakes are facing the same challenges: pollution, habitat loss, significant reduction in area, spread of aquatic weeds, declining fish yield and quality, overfishing, illegal fishing

practices like harvesting of fish fry. Added to these is the low awareness among fishers of environmental issues and need for regulation measures (Mehanna 2008). The lack of maintenance of the Boughazes openings (sea connections) cuts the exchange of water masses between lakes and the Mediterranean Sea. This stagnation leads to a decline in salinity and increased anthropogenic nutrients, which together have a serious impact on the catch composition from these lakes. This has changed over recent decades from marine (e.g. mullet) to freshwater (e.g. tilapia) dominated species (Mehanna 2008; Mehanna and Haggag 2010; Pérez-Ruzafa and Marcos 2012).

Stock assessments over the last 10 years show that most commercial species are subject to overfishing: bogue *Boops boops* (Mehanna 2010a), common pandora *Pagellus erythrinus* (Mehanna 2010b; El-Haweet et al. 2011), lizard fish *S. undosquamis* (El-Haweet et al. 2012), cuttlefish *Sepia officinalis* (Mehanna and Haggag 2011), Egyptian sole *Solea aegyptiaca* (Mehanna 2007b), hake *Merluccius merluccius* (Mehanna 2009a), striped red mullet *Mullus surmuletus* (Mehanna 2009b, c), red mullet *Mullus barbatus* (Mehanna 2009d), round sardinella *S. aurita* (Mehanna and Salem 2012), and sea bream *Sparus aurata* (Mehanna 2007c). Most of these assessments have recommended a reduction in fishing mortality of 40 %, via adoption of appropriate management measures. Such recommendations include the improvement of trawl selectivity by increasing mesh sizes, identification and protection of nursery and spawning areas, minimum distance of trawling from the coast, and closed areas and seasons (FAO EastMed 2014).

Like other developing countries, fishery management in Egypt is challenged by the complex nature of the associated social-ecological systems. The fisheries are described as labour intensive, multi-species and multi-gear, they are widely distributed along the coast and associated with high levels of community dependence. In such a context, it is difficult to control fishers' behaviour or to enforce regulations. The demand for fishery resources has been gradually increasing due to the rise in population and tourism development. This has led to increased pressure on stocks and the use of destructive and illegal gear and techniques. Most of the destructive methods are prohibited by law but continue to be used due to lack of surveillance, enforcement, and public awareness. Despite the robustness of the national legislation and

its potential ability to address fishery management issues, these legislations have not been implemented to the fullest extent (FAO EastMed 2014). More licenses have in fact been issued and the mesh-size regulations were set at lower limits than scientists advised. Furthermore, these laws and regulations are relatively old and appear not to consider the recent changes in international policy or regional fisheries agreements. The laws are inconsistent with the General Fisheries Commission for the Mediterranean regulations, despite Egypt being a member. An additional gap in the fisheries legislation is that it does not address Egyptian vessels operating outside Egyptian waters. A license is not required for them to fish on the high seas or in the waters of a third country. Even with these legislative instruments, the policy during the past decades has been centred on encouraging investment in aquaculture to ensure sustainable fish production, rather than manage wild fisheries in a sustainable way. Consequently, the wild fisheries of Egypt are under-regulated with no clear management plans. This has not only had positive results on the amount of national production, but also transformed multi-species production into farmed single-species production, since tilapia farming makes up 60 % of it.

Although fisheries in Egypt appear to be widely studied there is still information needed to address management gaps. Management of fisheries requires detailed data on the fleets and exploited resources. Such information should indicate the status of each fishery, their dynamics, characteristics, as well as temporal and spatial distribution of each fleet and métier (e.g. Forcada et al. 2010; Samy-Kamal et al. 2014). It should also include evidence supporting estimates of maximum sustainable yield, as well as identification of the optimal size and age composition of the standing stock. To generate this information, it is essential that scientists in turn be provided with statistical information on harvests, numbers of fishers, gear types, and vessels, effort (time) and fishing location. In Egypt, fishery statistics collected from the landing sites are still not reliable or comprehensive enough to provide a complete picture of the resources and fleets.

Furthermore, knowledge of the ecology of marine fish communities is sparse and quantitative ecological studies are needed. For instance, there are no data on the impact of the aquaculture farms in the northern

lakes on the nearby marine environment or on the yield of adjacent fisheries. In such intensive coastal aquaculture areas as in Egypt, fish farms may act as small MPAs. For this reason the ecological interactions with the surrounding fishing grounds and influences on the fish stocks should be considered (Dempster et al. 2002). The future of fisheries management in Egypt also lies in improving the current management strategies and measures. It is important to evaluate the effectiveness of management measures (e.g. Samy-Kamal et al. 2015a, b, c) to understand if they are able to achieve their main objectives.

Conclusion

The challenge for fisheries managers in Egypt is not only to provide appropriate plans to improve the current situation in Egypt, but also to monitor the success of management strategies and enforce regulations. Most measures and regulations pertaining to fisheries are old and largely not followed, which makes it difficult to control the situation. In addition, there is little data available on the socio-economic aspects of environmental issues. In general, there is a lack of communication among the three main groups of stakeholders in adaptive management: managers, fishers and scientists. Policy makers, scientists and fishery managers need to consider the different scales and nature of these fisheries, including the context in which they operate. They must then try to develop management strategies suitable for the context of these fisheries. Furthermore, incorporating the fishing sector itself in management decisions and actions is fundamental (Jentoft 1989). This aids in understanding community priorities and behaviour, so as to adapt management tools appropriate to their needs (Gelcich et al. 2009; Pita et al. 2011). Improving enforcement is essential and this involves the need for more effective fishery patrols, which in turn may improve community education regarding environmental and fishery issues.

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