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INTERAFRICAN BUREAU FOR ANIMAL RESOURCES

MAPPING STUDY OF AQUATIC ANIMAL DISEASES - NORTH AFRICA

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Acronyms

AAHS	Aquatic Animal Health Services
ANARC	African Network of Aquaculture Research Centres
AU	African Union
AU-IBAR	African Union – Interafrican Bureau for Animal Resources
CAADP	Comprehensive Africa Agriculture Development Programme
CAMFA I	First Conference of African Ministers for Fisheries and Aquaculture
CAMFA II	Second Conference of African Ministers for Fisheries and Aquaculture
CGIAR	Consultative Group for International Agricultural Research
CLAR	Central Laboratory for Aquaculture Research, Abbassa
CNRDPA	Algerian Research Centre for the Development of Fisheries and Aquaculture
CTA	Centre Technique d'Aquaculture
EU	European Union
EUS	Epizootic Ulcerative Syndrome (Aphanomyces invadans infection)
GAFRD	General Authority for Fish Resource Development
GDP	Gross Dpmestic Product
GIFT	Genetically Improved Farmed Tilapia
GIS	Geographic Information System
INSTM	National Institute of Marine Science
KOICA	Korea International Co-operation Agency
LCDV	Lymphocystis Disease Virus
LIMS	Laboratory Information Management System
LNCAPPASM	The National Control Laboratory and Analytical Products of Fishing and Aquaculture and Safety of Communities
PFRS	Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa
NACA	Network of Aquaculture Centres in Asia-Pacific
NEPAD	New Partnership for Africa's Development
NGOs	Non-Governmental Organisations
OIE	World Organisation for Animal Health
ONISPA/MPEM	Office National d'Inspection Sanitaire des Produits de la Pêche et de l'aquaculture
REAG	Regional Expert Advisory Group on Aquatic Animal Health
SDC	Swiss Agency for Development and Cooperation
SPF	Specific Pathogen Free
SVC	Spring Viraemia of Carp
TADs	Transboundary Diseases
TAADs	Trans-Boundary Aquatic Animal Diseases
TLEV	Tilapia larva encephalitis
TiLV	Tilapia Lake Virus
VS/AAHS	Veterinary Service/Aquatic Animal Health Service
VNN	Viral Nervous Necrosis
WAHIS	World Animal Health Information System
WSSV	White Spot Syndrome Virus

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Foreward

The potential of fisheries and particularly for aquaculture in Africa is large but remains not fully realized. However, the sector currently contributes to 6% of the continents agricultural GDP. In recognition of this fact, the Fisheries have been identified as among the key agricultural value chains for transformation under NEPAD'S CAADP framework as well as the Malabo Declaration. Consequently the Policy Framework and Reform Strategy for fisheries and Aquaculture in Africa was endorsed by the Summit of AU Heads of States and Government as a blue print for Africa's fisheries and aquaculture development. The overall goal of this policy framework is to create a conducive and enabling environment for the fish sector to create equitable, social and economic development in Africa that shall result in sectoral growth and the accomplishment of the CAADP goals.

Among the key strategies for expanding the sector and attaining the envisaged socio-economic goals is the promotion of sustainable aquaculture development based upon private-sector led market-oriented aquaculture, the promotion of sustainable fisheries and the improvement of access to markets for Africa's fish and fish products. Establishing a vibrant commercial fisheries and aquaculture sector implies that the movement of fish stock and products within and between countries shall increase due to trade.

Aquatic production systems world over, not least in Africa, can be beset with issues of associated with sustainable environment management, biosecurity and fish diseases control. These issues pose significant threats to the productivity of natural and artificial aquatic systems with concomitant effects on food security, trade and income. Where such situations have occurred on the continent, their effect and impacts have been exacerbated due to inadequate strategies, both national and regional levels, for early response systems in the event of an emergence situation, including perturbations in the ecosystems due to environmental hazards, pollution, disease outbreaks, etc. The human and institutional capacity to effectively keep at bay as well as address any threat in aquatic production systems is grossly insufficient on the continent. There is severe dearth of personnel both in quantity and quality in these critical areas of environmental management, biosecurity governance and diseases control.

The continent has had in the recent past instances of environmental management and biosecurity governance issues arising from the outbreak of White Spot Syndrome Virus in Mozambique and Madagascar in prawn farms and Aphanomyces invadans infection (EUS) in the Zambezi River Basin that is believed to have spread into the Congo River Basin. It is probable that elsewhere on the continent there are diseases that are inhibiting productivity in inland waters and aquaculture systems. The poor status of knowledge on the occurrence of fish diseases and potential risk factors within the various waters bodies and aquaculture systems is a serious gap and inhibitory factor towards formulating appropriate disease control strategies. The first step in developing a strategic disease control program is to establish the occurrence of diseases, the risks of their occurrence and their potential impact on aquatic productivity systems.

Consequently the risk of spread and introduction of new aquatic pathogens, pests and plants shall increase posing a high threat to aquatic production, aquatic environmental health and food safety. The predisposing factors that determine the onset of endemic diseases more often than not arise as a result of stressors in the environment. While drugs and disinfectants may be used to control disease they too may have impacts on environment and the fish produced. The objectives of producers in such a commercial setting sector are to produce fish as food to earn an income. Consumer safety and economic prosperity therefore become primary targets. Incidences of disease reduce productivity, may cause mortality and lower the quality of products produced for sale. Under such circumstance, enterprise performance drops.

To safeguard against the above, one must control diseases in a manner that has minimal impact on the economic viability of establishments as well as products produced. The only way of doing this sustainably is by ensuring environmental integrity, animal welfare, food safety and economic gain; that is to establish biosecurity. The benefits of maintaining the upper-hand over disease conditions through effective Fish Health Management Plans and biosecurity governance include:

i. Prevention and control of aquatic biological hazards (notably pathogens, pests, toxins from algae, new species, etc.)
ii. Increased farm production and efficiency
iii. Access to markets (quality assurance and certification)
iv. Economic benefits (to the producer, community and nation)
v. Sustainable aquatic environmental management.

Biosecurity measures with respect to disease control and surveillance are the set management practices that prevent non-infected healthy stock from being exposed to infectious or parasitic agents. This involves the prevention of entry and control of such agents. Critical control points of concern are areas in the production and marketing process that may present or permit biological hazards, notably pathogens.

Establishing what the biological hazards are along the value chain, the factors that trigger these to result into disease and loss of fish quality and well as those that facilitate their spread are, among the first steps in establishing a biosecurity plan. Establishing a biosecurity program for a specific disease or region for that matter, is not possible if there is incomplete information on the disease status of countries. It is also not possible to set up a disease monitoring program if the precise sanitary condition of national aquatic stocks (wild and farmed) is unknown.

Information on the sanitary status of aquatic stock in Africa and infrastructure to control aquatic animal diseases is very poor. Fortunately, to-date there have been few reported serious outbreaks of fish disease, both in the wild and on farm, on the continent. However, in the last 10 years, outbreaks of trans-boundary notifiable diseases have been reported. At the OIE General Assembly 2015, key concerns for Africa in aquatic animal health were the emergence and spread of the Trans-Boundary Aquatic Animal Diseases (TAADs) like infection with Aphanomyces invadans (EUS), White Spot Syndrome Virus and Abalone herpes Virus from the Southern Africa northwards. Lack of knowledge of the status in neighboring countries and watersheds continues to pose a threat to their fisheries and aquaculture and hinders the establishment of appropriate biosecurity control measures.

It is only when one knows what the potential threats are, that one can develop mitigation measures to protect the stock, environement and markets. Knowing what aquatic animal diseases occur on the continent, where they occure and under what circumstance they have occurred will enable the project develop sanitary maps that shall provide the basis for establishing appropriate aquatic animal disease control, surveillance and biosecurity frameworks.

It is for this reason, that the Regional Fish Disease Mapping Studies were commissioned. The information generated from this study will provide baseline information to to strengthen the capacity of veterinarians in aquatic animal health and develop regionally appropriate aquatic animal disease control, surveillance and biosecurity control mechanisms.

Prof. Ahmed El-Sawalhy
Director, AU-IBAR

1. Background

It is generally recognized that fish resources in Africa have the potential to contribute significantly to national and regional socio-economic growth by ensuring food security, enhancing general wealth and improving the quality of life for the citizens by encouraging and empowering marginalized groups including women and young adolescents to become stakeholders in the various strata of the fisheries sector. Historically, the achievement and sustainability of increased productivity and profitability in the fishery sector has been under threat through incoherent and inadequate policies and ineffective governance, which have resulted in overexploitation of wild fisheries and a poorly developed aquaculture sector.

In recent years the African Union (AU) has acted to improve the performance in the fishery sector through the Comprehensive Africa Agriculture Development Programme (CAADP). The CAADP constitutes a framework to transform agriculture to provide food security and prosperity for all. It was developed as an integral part of the new partnership for Africa's development (NEPAD) and has been endorsed by all the member states. Since 2004 several initiatives, notably the Sirte Summit Declaration (2004), the Abuja 2005 "fish for all" declaration, Banjul Conference of African Ministers for Fisheries and Aquaculture (CAMFA1) and the 2014 Addis Ababa (CAMFA II) meeting, while recognizing the many challenges and opportunities in the sector urged regional co-operation for the development and management of African fisheries resources. The first conference of fishery ministers (CAMFA I) recommended that the AU establish a mechanism for broad-based participatory policy dialogue and fisheries management to ensure conformity of any new fisheries policies and initiatives. This eventually led to the formulation of the Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa (PFRS). The PFRS was finally, endorsed by the African Heads of States and Governments in 2014 as a road map for sustainable reform of Africa's fisheries and aquaculture sector.

The specialised technical office of the African Union Interafrican Bureau for Animal Resources (AU-IBAR) reports to the Department of Rural Economy and Agriculture of the AU Commission. It has been given a mandate to support and co-ordinate initiatives to improve livestock, fisheries and wildlife as a resource for the well-being of citizens and to contribute to the generation of wealth in rural areas of the member states. One of the thematic areas of AU-IBAR's strategic plan to support sustainable development is prevention and control of animal and fish diseases. In the case of the fishery sector this plan is being undertaken through the Fisheries Governance Project under the PFRS policy framework.

Disease is one of the major impediments to the economic production of intensively reared finfish and shellfish and on occasion can lead to the unsustainability of fishery enterprises. Change in disease incidence is one of the suggested indicators for assessing the performance of the PFRS in the policy area of sustainable aquaculture management.

A well-recognized weakness in the fisheries and aquaculture sector is defective information-collection and analysis systems, which prevent sensible decision making processes. Currently in Africa, there is a dearth of information on the occurrence, epidemiology and impact of fish diseases and the risk factors that enable their spread within a country and on occasion trans-nationally. This is inhibiting the institution of appropriate control strategies and the ability of veterinary and fishery regulatory agencies to respond to emergency disease outbreaks. In order to develop a strategic disease control and bio-security programme for the whole continent it is necessary to establish the prevalence and epidemiology of disease occurrence in aquaculture units and wild fisheries. The OIE General Assembly in 2015 expressed concern over many notifiable diseases such as Aphanomyces invadans (EUS), White Spot Syndrome and Abalone Herpes Virus extending their geographical distribution from southern Africa northwards.

Thus AU-IBAR has undertaken a study to map reported aquatic animal diseases as a prelude to the establishment of a continent wide surveillance and bio-security plan for the long-term benefit of the fishery sector.

2. Purpose and scope of the study

A lack of knowledge of the health status of the aquatic animals in the freshwater watersheds, oceans and seas in and around the continent poses a bio-security threat and hinders the development of commercial fisheries and aquaculture. It also prevents putting in place adequate infrastructure for diagnosis and surveillance and developing suitable strategies to cope with any major disease outbreaks that will inevitably occur in the future. It is only when the potential disease threats are known can mitigation measures such as general surveillance and/or monitoring for specific designated pathogens be instituted.

This survey, to elucidate the range and prevalence of aquatic animal diseases in North Africa was part of a larger study undertaken by AU-IBAR to gain a general overview of the diseases, including their epidemiology, currently affecting fish and shellfish on the whole continent. The overall aim of AU-IBAR was to develop a map illustrating the geographical distribution of the diseases and a database of the species affected and the management systems where they occur.

The study was designed as mainly a desk study involving on-line research and correspondence with fishery and aquaculture specialists, private and government veterinarians and university lecturers and research workers in the North African member states of the AU. There was also provision for field visits to two countries to inspect representative commercial aquaculture units, interview stakeholders and to hold regional consultative workshops.

The main objective of the study as previously stated was to determine the current health status of aquatic animals in North Africa. Additional goals were to establish the husbandry and production systems where disease occurred, characterise the risk factors associated with these diseases and also to identify their geographical distribution.

3. Methodology

The study used a modified retrospective observational cross-section epidemiological research method. This method allows information to be collected through questionnaires, interviews with appropriate personnel and from pre-existing disease databases.

3.1. Literature Review

Initially, an extensive search of the scientific literature was carried out for reports on disease outbreaks including zoonosis, contamination with neurotoxins from algal blooms and heavy metals and chemical residues in freshwater and marine cultured and wild fisheries in North Africa over the last 25 years (Appendix 1). The search was confined to the free bibliographic database at PubMed and the subscription Scopus database with a supplementary search using Google. An additional search was also carried out at the library of University College Dublin, Ireland, using the university's "one search "program. It was originally restricted to the periods 2000 to 2015. However, this was found to be restrictive as only a few peer reviewed publications were found for this period in many of the countries. Thus the time period was extended back to 1990. The search terms included fish diseases, shellfish diseases; North Africa, the names of the individual countries, Algeria, Egypt, Libya, Mauritania, Tunisia, Sahrawi Arab Democratic Republic (or Western Sahara), Mediterranean; specific diseases e.g. Aeromonas hydrophila, Spring Viraemia of Carp (SVC), Viral Nervous Necrosis (VNN) etc.; disease syndromes such as mycobacteriosis, flexibacteriosis and vibriosis; bacterial and parasitic zoonoses; dinoflagellate blooms.

3.2. Survey questionnaire:

The information obtained from the review of peer-reviewed publications guided the design for a questionnaire to elucidate the current status of aquatic animal diseases as well as the veterinary/ diagnostic/ regulatory infrastructure vis-à-vis fish diseases in the region (Appendix 2).

The questionnaire comprised 17 questions designed to elucidate information on:

1. Infrastructure associated with disease diagnosis, surveillance and control
2. National and on-farm bio-security practices
3. Aquatic animal health status including disease outbreaks and associated risk determinants.
4. Undergraduate veterinary education and continuing professional developing training courses in fish medicine and disease

Prior to e-mailing the questionnaire to scientists in North Africa it was sent for peer-review and comment to two international experts on world aquaculture and fish diseases in particular, Professor Ronald Roberts, Professor Emeritus, Institute of Aquaculture, University of Stirling, and Dr Hamish Roger, Director of AquaVet International, Galway, Ireland. The questionnaire was modified slightly on receipt of their comments and then sent to scientists in North Africa.

The majority of respondents were identified through the aforementioned review of scientific publications. The e-mail addresses of the senior authors were obtained from the publications and/ or a further search using the Google search engine and/or checking the social/business/ science sites of Linkedin and Research gate. AU-IBAR also supplied contact details for the OIE national representatives and other non-government fisheries and environment organizations (NGOs).

The questionnaire was distributed via e-mail to 72 scientists and veterinarians working in the government departments and national research institutes and other research organizations and university departments as follows:

Algeria:
The questionnaire was distributed to 13 veterinarians and scientists working in institutes such as the University of Annaba and the Veterinary Directorate.

Egypt:
The questionnaire was sent to 25 individuals working in organizations such as the General Organisation for Veterinary Services; Fish Diseases Dept., University of Alexandria; Veterinary Faculty, University of Cairo; National Animal Research Centre, Dokki; National Institute of Oceanography and Fisheries, Cairo; Central Laboratory for Aquaculture Research, Abbassa; Faculty of Science, University of Suez.

Libya:
Nine scientists were identified in Libya and were sent the questionnaire on the 25th January.

Mauritania:
A total of six Mauritanian scientists were sent the questionnaire.

Tunisia:
Nineteen Tunisian scientists were sent the questionnaire and these individuals worked in a number of universities and government research institutes including the Institute of Veterinary Research, La Rabat; Faculty of Science, El Manar; National Veterinary School, Sidi Thabat; Institute of National Marine Sciences and Technologies, Monastir.

Sahrawi Arab Democratic Republic:
It was not possible to identify any individual scientist working on aquatic animal diseases or a research institute or University with an active fish pathology department in this country.

The response rate however, was found to be very low.

3.3. Geo-referencing

The Geographic Information System (GIS) data was acquired from a variety of sources for Egypt and Tunisia. The boundary data was acquired from Geocomm (2016) with the locations of major towns and cities acquired from MapCruzin (2016). Spatial data on rivers and inland water bodies and a 20 m digital elevation model (i.e. topography) were obtained from DIVA-GIS (2016). Any GIS processing (e.g. geo-referencing of pathogens) as well as the creation of all maps was undertaken in the software package ArcGIS (ESRI 2012).

3.4. The world animal health information system of the OIE

The World Animal Health Information System (WAHIS) and the pre 2004 animal health/disease outbreaks database "Handistatus" on the OIE website were accessed in January and March 2016 for information on any outbreak of an OIE aquatic animal listed disease in the Algeria, Egypt, Libya, Mauritania, Tunisia and Sahrawi Arab Democratic Republic.

4. *An overview of aquaculture in North Africa*

The development of aquaculture since the 1980s has become the fastest growing food-producing sector in the world. Consequently, it is perceived to have significant potential for the alleviation of poverty, providing food security and income to rural populations in many countries.

Africa produces about 2.0% of global aquaculture and employs about 1.0% of global fish farmers. Egypt is the largest producer on the continent and the 9th largest in the world (Soliman and Yacout 2016). The increase in aquaculture production in the North Africa in recent years has mirrored the decline, with the exception of Mauritania in the take from wild freshwater and marine capture fisheries (Table 1; Feidi 2013[a]). The value of aquaculture to the Egyptian economy in 2014 was about $ 2.186 billion American dollars (Soliman and Yacout, 2016).

The main species cultivated in North Africa are Tilapia (Oreochromis niloticus), mullet (Mugil cephalus) and carp (Cyprinus carpio). These species are equally comfortable in freshwater and brackish rearing facilities. Other farmed species are sea bream and sea bass and these are grown in cages in sheltered marine sites or in onshore tanks using pumped seawater or in high salinity desert groundwater systems. Invertebrate species such as shrimp and other crustaceans and molluscs are also grown but in limited amounts.

Table 1. *Statistics showing the take (metric tonnes (mt)) from wild capture fisheries and production aquaculture industries in the countries of North Africa during the period 2009 to 2011*

Country	2009		2010		2011	
	Capture (mt)	Aquaculture (mt)	Capture (mt)	Aquaculture (mt)	Capture (mt)	Aquaculture (mt)
Algeria	126,209	2,159	92,389	1,755	100,256	2,238
Egypt	379,115	705,490	376,611	919,585	367,266	986,820
Libya	49,500	240	47,470	240	28,480	240
Mauritania	200,908	-	256,850	-	351,004	-
Tunisia	90,492	4,747	88,324	5,256	91,601	7,965

Modified from Feidi 2013

The characteristics of Tilapia culture systems in North Africa are shown in Table 2.

Young fish are stocked in grow-out facilities during March and April and 200 -300 g fish are harvested in autumn from September to December. The techniques for artificially spawning brood fish and rearing fingerlings and older fry to the stage that they can be transferred to grow out facilities are well established.

Similarly, with carp the breeding cycle is well documented and depending on the sophistication of the farm unit may be either natural or hormonally controlled with gonadotrophin injections. Once hatched, the swim-up fry are placed in prepared nursery ponds at a density of circa 100-400 fry/ m^2. Carp are usually reared in monoculture systems but in North Africa and especially Egypt they are cultivated in semi-intensive polyculture units with Tilapia. In these units, the two species have different feeding habits and occupy different trophic niches in the water. Thus continual fertilization of the pond as well as maintenance of a proper species ratio is essential for maximum utilisation of the pond ecosystem and maximum weight gain of the fish. In optimum growing conditions carp can gain weight at a rate 2-4% body weight/day and in poly-cultural ponds can reach 0.6-1.0 kg in one growing season.

In the case of other species such as mullet, artificial breeding is more problematic although it has been successfully achieved in the United States of America. Wild fry are collected by seine netting in the autumn when they migrate to inshore waters and estuaries. They are then transported in seawater to specialized nursery facilities where they are slowly acclimatized to the local brackish water. They are kept in pre-prepared nursery earthen ponds at high densities (up to 125/m^2) where they depend on natural production of the fertilized pond for food. After 4-5 months when they are about 10g they are transferred to grow-out facilities in various culture systems but usually to semi-intensive ponds where they are often co-cultivated with Tilapia. The growth period is about 7-8 months after which the fish can weigh 0.75-1.0 kg. If stocked at a rate of 2,000 - 3,000 fingerling/ha in semi-intensive polyculture units with Tilapia or carp the final harvest of mullet will be circa 2-3 metric tonnes (mt).

Marine aquaculture is still in its infancy in North Africa, notwithstanding that Egypt produced 14,000 and 17,000 tonnes of sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus auratus*) respectively in 2014 (Anon., 2015a).

The methods for the production of seed and rearing fry to the fingerling stage are well established in the hatcheries of southern Europe. However, this is not the case in Egypt where fry are harvested from the wild and in Tunisia fry are imported from France. There are some hatcheries in Egypt but they are currently still in the experimental stages although it would appear that rearing broodstock and producing fry is well advanced in one dessert farm in Egypt (Anonymus., 2012).

4.1. Fish cultivation systems

Fishing rearing systems in North Africa can be extensive, semi-intensive or intensive.

4.1.1. Extensive systems

Closed extensive systems involving trapping and rearing wild fish in freshwater or brackish lagoons are now prohibited in the countries where they were previously allowed due to the disruption they cause to the ecology of natural waterways.

4.1.2. Semi-intensive systems

The most popular production units are semi-intensive earthen ponds ranging from 0.5 to 12 hectare in size. Animal manure is generally used to fertilise the ponds although on occasion inorganic fertiliser may be used. The natural plant productivity of the pond is sometimes supplemented with either home compounded or commercial diets. The water is static and optimum levels of dissolved oxygen (O_2) are maintained by aeration. Stocking of these ponds with Tilapia is usually at a rate of 0.5 kg/m^3 and annual pond production can be up to 5 mt/ha

Semi-intensive ponds lend themselves to the benefits of polyculture. Polyculture describes the practice of rearing together two complementary species. It is common in North Africa to rear carp and mullet in ponds with Tilapia. Rearing these symbiotic species allows better utilization of the nutritional niches in the pond resulting in increased productivity.

4.1.3. Intensive systems

These can be open, semi enclosed or re-circulation (closed) systems comprising small earthen ponds, concrete or fibreglass tanks, concrete raceways or cages. The earthen ponds are generally about 0.3 - 0.5 ha in size. The cages vary in size from 32m^3 up to 600m^3 and are popular in the lake regions of the Nile Delta. Sometimes very small cages are located in irrigation channels. There is no natural feed only artificial feed and water quality is maintained by daily exchange of up to 10% of fresh or recirculated water. The farms generally have access to an unlimited supply of water from rivers, lakes or groundwater. In some countries e.g. Algeria the groundwater supply is geothermal.

Stocking densities are much higher than semi-intensive systems, about 20,000 Tilapia fingerlings /m^3 (Chakraborty & Banerjee 2010). Average production in these intensive culture systems ranges from 14 to 25 mt/ha.

In Egypt currently, there is an increasing trend for fiberglass tanks and smaller ponds to replace large areas of semi-intensive earthen ponds (Soliman and Yacout, 2016). In addition to increasing production to meet the growing demand for fish products, intensive farming counter-intuitively has less impact on global warming potential, acidification potential and cumulative energy demand than semi-intensive farms (Yacout, Soliman and Yacout, 2016). This is because with semi-intensive ponds there is a high energy i.e. diesel and electricity, requirement for water aeration.

4.1.4. Marine culture

Due to being quite shallow most of the shoreline of North Africa does not appear to be suitable for the inshore cage systems used in southern Europe. However, there are many large saltwater lakes and lagoons that are ideally suited for cage culture (Lacroix 1996). Seabass and seabream are also farmed in the desert using groundwater (underground water) with 26g/l salinity. Production in this dessert farm is about 20 kg/m^3 (Anonymus, 2012).

4.1.5. Integrated agri-aquaculture systems (IAASs)

Integrate agri-aquaculture embodies a range of practices, systems and operations. The basic philosophy is the multiple use of water for both tradition farming and aquaculture in a profitable and ecological sustainable manner.

There are many desert integrated agri-aquaculture units using flow through groundwater to rear fish including catfish, irrigate crops and rear livestock such as sheep (Sadek, 2011). On a desert sea bass and sea bream farm the effluent water is used to grow salt tolerant crops such as Salicornia, Atriblex and Sueda (Anonymus, 2012[a]). The results of a study by Soliman (2000) indicated that rearing ducks on semi–intensive polyculture earthen ponds improved the weight gains and quality of Tilapia, carp and mullet when compared to fish from a non-integrated group of ponds. The water in the integrated ponds was richer in natural productivity i.e. species and density of phytoplankton and zooplankton, than the non-integrated ponds.

Table 2: *Characteristics of Tilapia culture systems in North Africa*

	Extensive	**Semi-intensive**	**Intensive**
System type	Ditches, rice fields, backyard ponds, reservoirs and tanks for irrigation	Specially built earthen ponds	Small earthen ponds, fiberglass tanks, cages, concrete raceways
Stocking densities (No. fish /m3)	<1	2-3	>5, In super intensive farms >20
Source of seed (fingerlings) for stocking	Wild fish	Own broodstock or from commercial hatcheries	Own broodstock or from commercial hatcheries
Reproductive control	None	All male stock	All male stock
Pond fertilisation	None except incidental run-off fertilisation	Manure and inorganic fertilisers	None
Feeds	None except occasional farm by-products and household wastes	Farm by-products such as rice bran etc and sometimes supplementary compound food	Complete compound pellets
Aeration/water exchange	None	Yes, with occasional water exchange	Daily water exchange
Production period		6-9 months	4-6 months
Yield (mt/ha/year)	<1	1-5	5-20
Market	Own consumption	Local and national markets	Local and national markets [There is potential for export if trade rules allow and markets are available]

Modified from Suresh and Bhujel 2012

4.2 Comparison of the aquaculture sector in the countries of North Africa

4.2.1. Algeria

The aquaculture industry in Algeria is considered to be in the early take-off phase (Feidi, 2013b). The Algerian government intends to develop a sustainable fisheries and aquaculture sector and has recently developed a 2012-2014 roadmap "STRAT E-SAID" to encourage collaboration amongst all the stakeholders. In 2010, in collaboration with Spanish and South Korean partners the government with a budget of Dollars USD 33.1 million planned to launch 22 fish farms for mussels, oysters, shrimp and other species. In 2012, the Algerian Research Centre for the Development of Fisheries and Aquaculture (CNRDPA) signed an agreement with the Korean Research Centre to strengthen the scientific and technological capacity of the fisheries sector in Algeria (Anonymus., 2012b). The Korea International Co-operation Agency (KOICA) has provided aid for the development of two shrimp farm projects and recently it provided $USD 5.0 million for a marketing plan to guarantee the sustainability of the aquaculture industry (Anon., 2014).

At present geothermal groundwater in the region north of the Tellian Atlas mountains and south in the Saharan platform is exploited to rear fish usually Tilapia. One of these farms produces 1,5000 mt /year of Tilapia. The moderate to high temperature of the water is conducive for high survival rates of young fry and fingerlings during the winter and faster weight gains for the grow-out stages.

There is limited potential for marine culture in Algeria because the rough unsheltered coast offers few protected sites for cages. However, at present sea bass and sea bream are grown in the desert using brackish groundwater.

The output from the Algerian aquaculture industry in 2012 was 2,648 mt (El Nagger and Jiddou, 2013).

4.2.2. Egypt

The aquaculture industry in Egypt has taken about 30 years to mature and its value to the national economy in 2014 was about USD $2.186 billion (Soliman and Yacout, 2016). It is now the largest aquaculture industry in Africa and produces about 98% of the total North Africa production of farmed fish. Tilapia, carp and mullet represent 95% of the total production with sea bass, sea bream and shrimp making up the remaining 5% (Table 3). Overall, it is ranked eleventh in the world and is the second biggest producer of Tilapia after China.

Table 3: *Annual aquaculture production for 2012*

Species	Production in 2012 (metric tones)
Tilapia	768,752
Mullet	129,651
Carp	67,065
Seabass	13,798
Seabream	14,806
Shrimp	1109
African catfish	Production increasing

From Soliman and Yacout 2016

The majority of farms use semi-intensive earthen ponds and circa 85% of Egyptian production is produced in these systems. Most of farms are situated in the Nile Delta in the governorates of Kafr El Shaikh and Dalmietta, and in the northern lakes of Maruit, Edko, Boruls and Manzala.

There is also an efficient aquaculture industry in the desert comprising 20 large agri-aquaculture integrated commercial farms and 100 small intensive Tilapia farms (Sadek, 2011). The water source is groundwater reserves of variable salinity, ranging from 0.5-26 g/l. All the farms have flow through systems, which in the large commercial farms is adapted to irrigate agricultural land, thus allowing these enterprises to produce three cash crops i.e. fish/ plants/ livestock. The 20 commercial farms produce up to 6,000 mt/year and the remaining small privately owned rural farms contribute another 7,000 mt to the national aquaculture output (Sadek, 2011). Various fish species are reared, Nile Tilapia, Red Tilapia, carp and catfish.

One desert farm rears sea bass and sea bream in water whose salinity is 26 g/l. The high salinity effluent is used to grow salt tolerant crops such as Salicornia etc. Annual fish production on this farm is circa 100 mt.

The General Authority for Fish Resource Development (GAFRD) encourages another more basic system i.e. rice field aquaculture. In 2012 production from this type of integrated culture was 34,537 mt (Shaheen, 2013).

Fish farmers have suggested that poor quality fry was one of factors limiting productivity on Tilapia farms (Nassr-Alla, 2008). However, this may not be the case in the future as a selective breeding programme (Egyptian Aquaculture Genetic Programme), at the Central Laboratory for Aquaculture Research (CLAR), Abbassa, to genetically improve the performance of the Nile Tilapia strain has had some success. The "Abbassa strain" grows up to 28% faster than the current commercial strains. Fifty fish farms and 130 hatcheries were supplied with the 9th generation of the fast growing strain in 2013 and it was expected that over 2000 farms would be supplied with fry in 2014 (Luening, 2013). The project is now further advanced and the 13th generation of the "Abbassa strain" underwent on-farm performance testing under varying environmental and husbandry conditions on a number of sites during 2015 (Anonymus., 2015[b]). The project is a collaborative one with World Fish and funded by the Swiss Agency for Development and Cooperation (SDC), European Union and the Consultative Group for International Agricultural Research (CGIAR) research programme on livestock and fish.

Farmed fish are sold fresh within 24 hours of harvesting. There is no" adding value" to the basic farm product as there is no significant processing sector in the country. There is also no export trade and one of the world's biggest trading blocks is closed to Egyptian fishery products as Egypt has not yet complied with the requirements of the European Union (EU) Directive 91/493/EEC on health conditions under which fish and shellfish are produced and placed on the market for sale (Soliman and Yacout, 2016). It is not unreasonable to assume that some aquaculture products are less than wholesome for humans. This is especially true for fish reared on farms using surface water in agricultural irrigation channels, municipal and industrial wastewater and from rivers that are periodically subjected to episodes of pollution causing wild fish kills (Eissa et al., 2013; Mahmoud et al., 2014).

4.2.3. Libya

Aquaculture production started in the 1990s. Tilapia was raised in small cages (50-200 m^3) in small irrigation reservoirs. The early farmers were initially supplied with free fingerlings and provided with technical assistance from the state. By 2007 there were 250 farmers culturing Tilapia in irrigation reservoirs and channels and production was circa 200-240mt (Otman and Karlberg, 2007). Mariculture also started around this time when the first sea bass and sea bream enterprise was set up, offshore near Tobruk (Anonymus., 1998). A little later a new hatchery with grow-out facilities was constructed at the Farwa Lagoon (Otman and Karlberg, 2007). Since 2004 the output of Libyan aquaculture has remained steady at circa 240mt (El Nagger and Jiddou, 2013).

Lacroix (1996) stated that the potential for aquaculture in Libya was limited due to lack of suitable sites, weakness of scientific and technical background as well as financial constraints due to lack of investors. Otman and Karlberg (2007) also agreed with this assessment and stated that technical and financial constraints were impeding the expansion of the industry. Although Ghebli (2005) suggested that Libya has many advantages for fish farming i.e. suitable climate, low pollution and cheap energy.

4.3.4. Mauritania

Mauritania is noted for the richness of the wild fisheries around its coast and territorial waters. However, it would appear that fish farming is not important economic sector as there are no statistics on the FAO country aquaculture profile for the productivity of the Mauritanian aquaculture industry. This may not be the case in the future because in 2013-2014 at least three projects were in the development stage. One is a combined grouper and shrimp recirculation unit, the second is also a combined grouper and shrimp farm utilizing cages and ponds (Anonymus., 2013[a]). A grouper hatchery and nursery is also planned for the second farm. Recently, the Saudi Arabian agribusiness group "National Aquaculture Group and Al-Rajhi International Company for Investment (Al-Al-Rajhi Alliance)" has agreed a Memorandum of Understanding (MOU) with the government to finance a programme to develop crop and livestock production and fish farming with the view to developing food security for both Mauritania and Saudi Arabia (Anonymus., 2013[b]). One of the first projects under this MOU, a USD 1 billion, 31,000ha shrimp farm proposed by the Saudi National Prawn Company is running into opposition from local villagers, environmentalists and human rights activists (Smallteacher, 2014).

4.3.5. Tunisia

After Egypt, Tunisia has the most developed aquaculture sector of all the other countries in North Africa that are members of the AU. Fish farming was started in the 80s and since then the Tunisian government has endeavoured to develop it and its second National Strategy for Aquaculture Development (2007-2016) is currently on going. The national laboratory infrastructure supporting the aquaculture industry in terms of disease diagnosis and export supports is quite advanced compared to other countries in the region. There are a number of diagnostic and research laboratories and institutes monitoring the environment for heavy metals and hydrocarbons as well as carrying out disease surveillance (Anonymus., 2016[a]). The authorities have also had the foresight to introduce in 1995 a legislative and disease surveillance infrastructure to conform to the European Union's (EU) Directive on fish health, and welfare and the safety of aquaculture products for public health (Cherif et al., 2011).

In their report on the blue-biotechnology potential of Tunisia, Onofri and Briand (2010) suggested that the aquaculture industry might provide a stimulus for applied research in marine technologies. This idea may be about to take hold as the Tunisian government, in December 2015, signed a partnership agreement with the EU to join "Horizon 2020". "Horizon 2020" is the EU's research and innovation programme. Thus Tunisian scientists will be part of a "knowledge transfer" mechanism as well as having access to research funds and an opportunity to collaborate with European scientists. As part of the agreement "work tools" will be made available for Tunisian government officials to harmonise their laws, including those on the control of exotic and zoonotic diseases, animal and fish welfare, public health, with EU legislation.

Aquaculture production was 8,577mt in 2012 (El Nagger and Jiddou, 2013). The majority of this was from mariculture, comprising mainly sea bass, sea bream and clams (Ruditapes decussates). There are 17 sea bass/ sea bream enterprises using offshore cages. Sea bass and sea bream are also reared in concrete raceways in four on-shore farms using pumped seawater (Anonymus., 2013[c]). According to the Tunisian Ministry of Agriculture, Water Resources and Fishing a further 12 offshore farms are about to come on stream (Anon., 2016b). Some marine farms have their own hatcheries but despite this wild and imported fry from Italy are also used for on- growing in sea cages. In 2011 there were no feed mills and all fish feed had to be imported from Europe (Anonymus., 2011[a]).

Fattening bluefin tuna in sea cages started in 2003 and at present there are four farms producing about 2,400 mt (Anonymus., 2016[b]).

Freshwater species such as mullet, carp, Tilapia are reared either extensively or in cages on some dammed lakes and other agricultural and irrigation reservoirs. Tilapia culture is also carried out in the south of Tunisia using geothermal ground water.

Shellfish farming started in the 60's, initially with the Mediterranean mussel (*Mytilus galloprovincialis*) and later the Pacific cupped oyster (*Crassostrea gigas*) was introduced (Anonymus., 2016[a]). Until recently mussel spat was collected locally and the oyster spat was imported from France and Italy. The success of a collaboration started in 2008 between the National Fisheries Research and Development Institute (NFRDI), the Higher Institute of Farming and Aquaculture of Bizerte and Korea International Co-operation Agency (KOICA) means that Tunisia has the technology and expertise to produce 1.5 million shellfish larvae/year (Anonymus., 2011[b]). The native clam (Ruditapes decussates) is also farmed. The total production from shellfish is circa 200 mt (Anonymus., 2016[b]).

The majority of Tunisian aquaculture production, up to 70%, is exported to France, Italy and Spain.

5. An Overview of the Prevalence of Aquatic animal diseases in North Africa

5.1. Information gleamed from the completed questionnaires

5.1.1. Algeria

The National Control Laboratory and Analytical Products of Fishing and Aquaculture and Safety of Communities (LNCAPPASM), Algiers returned and completed the questionnaire.

It stated that the veterinary service offers a fish disease diagnostic service at a central, regional and local level. However, the diagnostic tests are not quality assured.

There was one outbreak of White Spot Syndrome Virus (WSSV) in shrimp (*Marsupenaeus japonicus*) during 2012. The shrimp were kept in a tank and mortality was 100% although there was no clarification that the deaths were due entirely to the disease or as a result of a slaughter/stamping out control policy. The initial diagnosis was by PCR.

Other diseases listed were due to parasites that are ubiquitous worldwide, in all water systems and on all fish farms such as *Icthyophthirius multifilis*, *Gyrodactylus* spp., *Ictyobodo* spp., *Chilodonella* spp., *Trichodina* spp., *Bothricephalus* spp., *Ligula* (*pleurocercoids*), *Acanthocephalus, Lernaeocera*, *Argulus* spp. and *Ergasilus* spp. (Table 4). These parasites with the exception of *Ichyophthirius*, *Gyrodactylus* and *Lernaeocera* only cause disease in situations where the fish are stressed due to poor husbandry practices, poor water quality and overcrowding. They are not inherently pathogenic or infectious and only cause disease in situations of poor management.

There were also three recorded dinoflagellate blooms during 2011, 2014 and 2015 in the Bay of Algiers.

Table 4. *Parasitic diseases present in Algerian fish*

Pathogen	Type	Present /No problem
Ichthyophthirius multifiliis	Protozoa	+
Gryodactylus spp.	Monogenean trematode	+
Trichoina spp. *Chilodonella* spp. *Ichthyobodo* (Costia) spp etc	Protozoa (Parasitising the skin and gill)	+
Henneguya spp	Myxosporean protozoa	+
Bothricephalus spp.	Tapeworm	+
Ligula	Intermediate stage of Diphyllobothrium spp. tapeworm	+
Acanthocephalus spp.	Tapeworm (thorny headed worm)	+
Lernaea spp.	Crustacean/Copepod	+
Lernaeocera spp.	Crustacean /Copepod (marine)	+
Argulus spp.	Crustacean (freshwater)	+
Ergasilus spp.	Crustacean/Copepod (freshwater & marine)	+

Data supplied by LNCAPPASM

Additional responses from the Laboratory of Hygiene and Animal Pathology, Institute of Veterinary Science, University Ibn Khaldoun of Tiaret suggested that the low response rate to the questionnaires was probably due to the small size of the aquaculture industry and a lack of reliable information on aquatic animal diseases. This was also reflected by the CVO.

5.1.4. Egypt:

The Department of Pathology, Faculty of Veterinary Medicine, University of Cairo provided detailed response to the questionnaire. The Department most important disease reported on Tilapia farms is *Aeromonas hydrophila* due to disease outbreaks being invariably precipitated by some element of stress. He also considered mycobacteriosis , due to its chronic nature, as important in Tilapia culture systems. He mentioned that the ability of the monogeneans *Gyrodactylus* spp. and *Spariocotyle chrysophrii* to increase their numbers quite rapidly made them serious pathogens. Other problematic pathogens were *Ichthyopthirius multifilis*, *Henneguya* spp and the ubiquitous external parasites *Trichodina* spp. *Chilodonella* spp. and Ictyoboda ictyoboda. He also provided an indication of the pathogenicity of some of these pathogens in the Egyptian environment (Table 5).

The most serious pathogens though vibriosis, *Psuedomonas* spp. and *Streptococcal faecelis* as the most serious pathogens on Egyptian fish farms.

Table 5: *Diseases present in fish in Egypt*

Pathogen	Type	Present/no problem	Present/problem	Present /severe problem
Flexibacter columnaris	Bacterium	+		
Flavobacterium columnaris	Bacterium	+		
Yersinia ruckeri	Bacterium	+		
Streptococcus iniae	Bacterium	+		
Streptococcus spp. (S. faecelis, S. agalactia)	Bacterium	+		
Pseudomonas spp.				
P. fluorescens	Bacterium	+		+
Epitheliocystis	Chlamydia spp.	+		
Sanguinicola spp.	Trematode (blood)	+		
Acanthocephalus spp.	Cestode (tapeworm)	+		
Mycobacterium spp.	Bacterium		+	
Ichthyophthirius multifiliis	Protozoa		+	
Sparyocotyle chrysophrii	Monogenean (trematode)		+	
Henneguya spp	Myxosporean		+	
Saprolegnia spp.	Fungus		+	
Branchiomyces spp.	Fungus		+	
Aeromonas hydrophila	Bacterium			+
Vibrio anguillarum & atypical vibriosis	Bacteria			+
Gryodactylus spp.	Monogenean (trematode)			+

Data supplied by Professor Aly and Dr Abd-Elsalam

Pathogen	Type	Present/no problem	Present/problem	Present /severe problem
Trichoina spp. *Chilodonella* spp. *Ichthyobodo (Costia)* spp	Protozoa (Parasitising the skin and gill)			+
Lernaea & *Lernaeocera spp.*	Copepods (freshwater & marine)			+
Argulus spp.	Crustacean			+
Ergasilus spp.	Copepod (freshwater and marine)			+

Respondents from the University of Cairo noted that the lack of on-farm bio-security and national disease surveillance and non-existence of information technology to aid the surveillance programme would be major factors in the future spread of aquatic animal disease in Egypt. They also thought that other contributory factors might be the dearth of new drugs and vaccines to combat increasing drug resistance.

5.1.5. Libya:

Response from the Marine Biology Research Centre indicated that there were no fish farms in Libya and provided no further information on the endemic diseases affecting wild fisheries.

5.1.6. Mauritania:

The Directeur ISSM and PRCM/UICN noted that fish diseases were very rare on fish farms in Mauritania. However, information from the Office National d'Inspection Sanitaire des Produits de la Pêche et de l'aquaculture (ONISPA/MPEM) and OIE Focal Point indicated no reported diseases of farmed fish or shellfish but that *Vibrio anguillarum*, atypical vibriosis as well as the protozoan *Henneguya mauritaniensis* were present in marine fish. There was a 10% prevalence of *Anisakis* spp. i.e. *Anisakis simplex*, *Anisakis* typical and *Anisakis begreffi* in the fish caught in the ocean from 17^0N to 20^03^0N.

5.1.7. Tunisia:

Response to the questionnaire from University of Carthage provided details of the veterinary diagnostic laboratory structure only. However, there are reports in literature of *Perkinsus* spp. infection in clams (*Ruditapes decussates*) during 2004 [WAHIS portal of the OIE; see also Chreif et al., 2011 in the literature review (Appendix 2)]

5.1.8. Summary

At present the only creditable data on fish and shellfish diseases in North Africa has come from the trawl through the peer-reviewed literature. The information recorded in these publications has been summarised in a "review of the literature" which has been appended to this report (Appendix 1). The details of the more complete tables from this review have been transferred to GIS maps and included in this section (Figs 1,2,3 and 4).

Only one scientist provided meaningful details on the epidemiology of fish diseases in North Africa (Table. 6). However, since this is the experience of one person it may not represent the disease pattern or true health status of the aquaculture industry in Egypt. The other respondents provided no meaningful data on the biological or environmental factors associated with fish disease.

Originally it was intended to carry out a sophisticated analysis such as spatial correlation (Mantel's correlation) as well as clustering and hot spots and Ripley's K analysis to detect any regional scale distribution of the pathogen. In the end due to the paucity of data on disease incidence and contagiousness, size of affected populations etc the GIS analysis was limited to showing the distribution of outbreaks on country maps.

Finally, the response to the questionnaire was very unsatisfactory. It was all the more disappointing because it had been explained in the letter of introduction that any information supplied would be used to inform the discussions to create a pan-Africa approach to fish health and the prevention of trans-boundary transmission of exotic aquatic animal diseases.

Table 6. *Diseases categorised as being a problem or severe problem in Egypt, number of farms and species infected and level of mortalities experienced during the outbreaks.*

Disease/Pathogen	No. farms infected	Farm site	Species	Mortalities (%)
Aeromonas hydrophila (Bacterial haemorrhagic septicaemia)	6	Freshwater (pond)	*Tilapia spp.* (200g)	40%
Aeromonas hydrophila	5	Freshwater (tank)	Ornamental fish (*Carassius auratus*) (Fingerlings)	70%
Mycobacterium spp	3	*Freshwater (pond)*		10%
Ichthyopthirius multifilis	4	Freshwater (tank)	*C. auratus*	40%
Gyrodactylus spp.	5	Freshwater (pond)	*Tilapia* spp. (100g)	40%
Gyrodactylus spp.	10	Freshwater (tank)	Ornamental fish (fingerlings)	80%
Spariocotyle chrysophri	1	Marine (pond)	Sea bream (400g)	30%
Costia, Chilodonella Trichodina spp.	10	Freshwater (tank)	Ornamental fish (fry)	70%
Henneguya spp	3	Freshwater (pond)	*Clarias gariepinus* (500g)	5%
Vibrio anguilarum	2	Marine (pond)	Epinephelus spp. (Groupers)	-
Saprolegnia	3	Freshwater (pond)	*Tilapia* spp. (150g)	50%
Branchiomyces	4	Freshwater (pond)	*Tilapia* spp. (200g)	70%
Argulus	2	Freshwater (pond)	*C. auratus*	30%

From Professor Aly, pers comm.

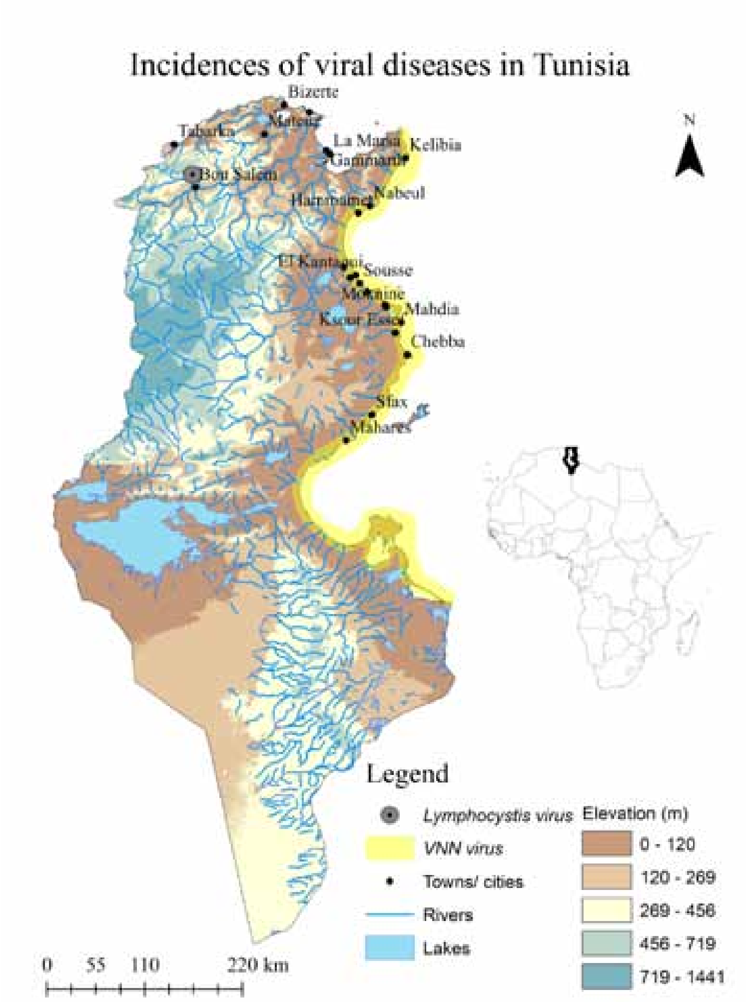

Figure 1: *Lymphocystis and Viral Encephalopathy and Retinopathy [Viral Nervous Necrosis (Nodavirus)] disease in Tunisia.*

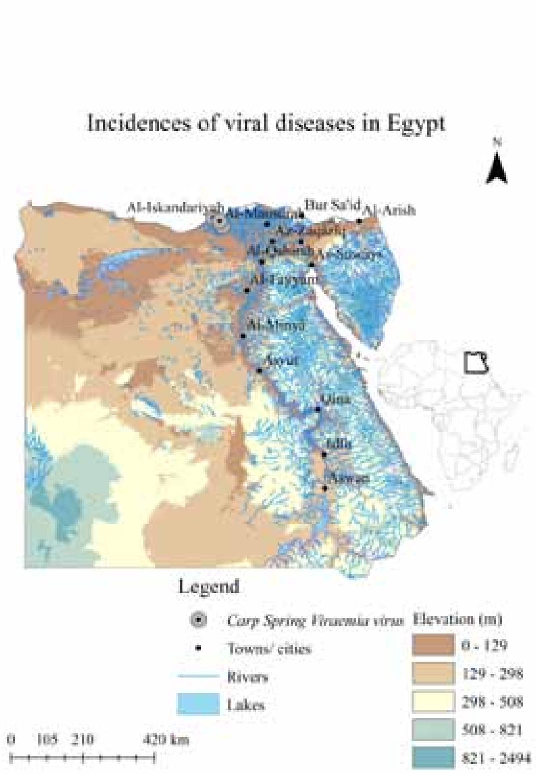

Figure 2. *Locations of an outbreak of spring viraemia of carp virus infection in Oreochromis niloticus in Egypt (taken from a review of the literature on fish diseases in North Africa)*

Pathogen	Species affected	Location	Co-ordinates
Spring viraemia of carp virus (SVC)	*O. niloticus*	Behera Kafr El – Sheikh Alexandria	30⁰ 59'N; 30⁰ 12'E 31⁰ 07' 52"N; 30⁰ 07' 48"E 31⁰ 12' 56"N; 29⁰ 57' 18"E

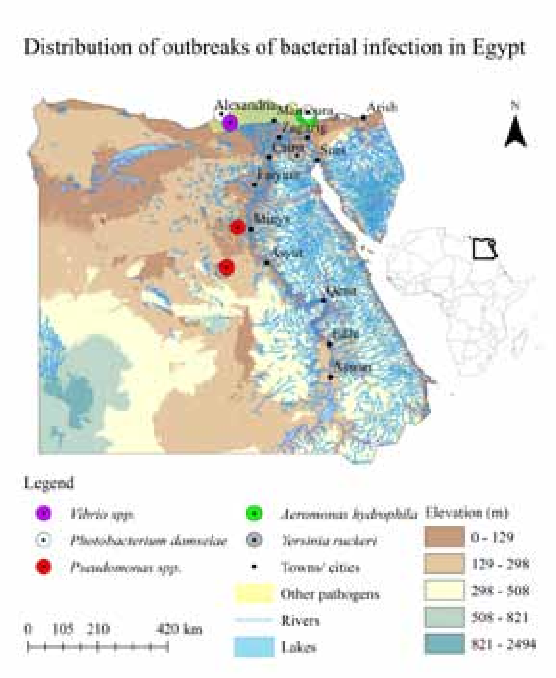

Figure 3. Distribution of outbreaks of bacterial infection in Egypt identified through a review of peer- reviewed publications by Egyptian scientists (see Appendix 1)

Pathogen	Species affected	Location	Co-ordinates
Yesinia ruckeri	*O. niloticus*	Sharkiya	30⁰ 07'N; 31⁰ 63'E
	Tilapia zilli *Gobius* spp. Crabs Shrimp	Qaroun Lake	27⁰ 00'N; 30⁰ 00'E
Psuedomonas fluorescens	*S. aurata*	Northern Egypt	
	T. zilli *Gobius* spp. Crabs & shrimp	Northern Egypt	
Tenacibaculum maritimum	*S. aurata*	Northern Egypt	
	Dicentrarchus labrax (Sea bass)	Northern Egypt	
Vibriosis *Vibrio alginolyticus*	*S. aurata*	Northern Egypt	
V. vulnificus	*D. labrax*	Northern Egypt	
Streptococcus agalactiae	*S. aurata*	Northern Egypt	
	D. labrax	Northern Egypt	

Pathogen	Species affected	Location	Co-ordinates
Photobacterium damselae subsp. *piscida*	*D. labrax*	Alexandria	31⁰ 12’ 56”N; 29⁰ 57’ 18”E
	S. aurata	Port- Said	31⁰ 15’ 23”N; 32⁰ 17’ 02”E
Aeromonas hydrophila	O. niloticus	Port - Said	31⁰ 15’ 23”N; 32⁰ 17’ 02”E
		Barsiq	31⁰ 06’ 36”N; 32⁰ 20’ 11”E
V. anguillarum *V.ordalii* *V. parahaemolyticus*	*Mugil capito* (Thin lipped grey mullet)	Behera	30⁰ 59’N; 30⁰ 12’E
P. fluorescens *P. anguilliseptica*	*O. niloticus*	Qaroun Lake	27⁰ 00’N; 30⁰ 00’E
P. putida *P.aureginosa*		Wadi-El-Rayan	28⁰ 08’ 52”N; 30⁰ 23’ 33”E

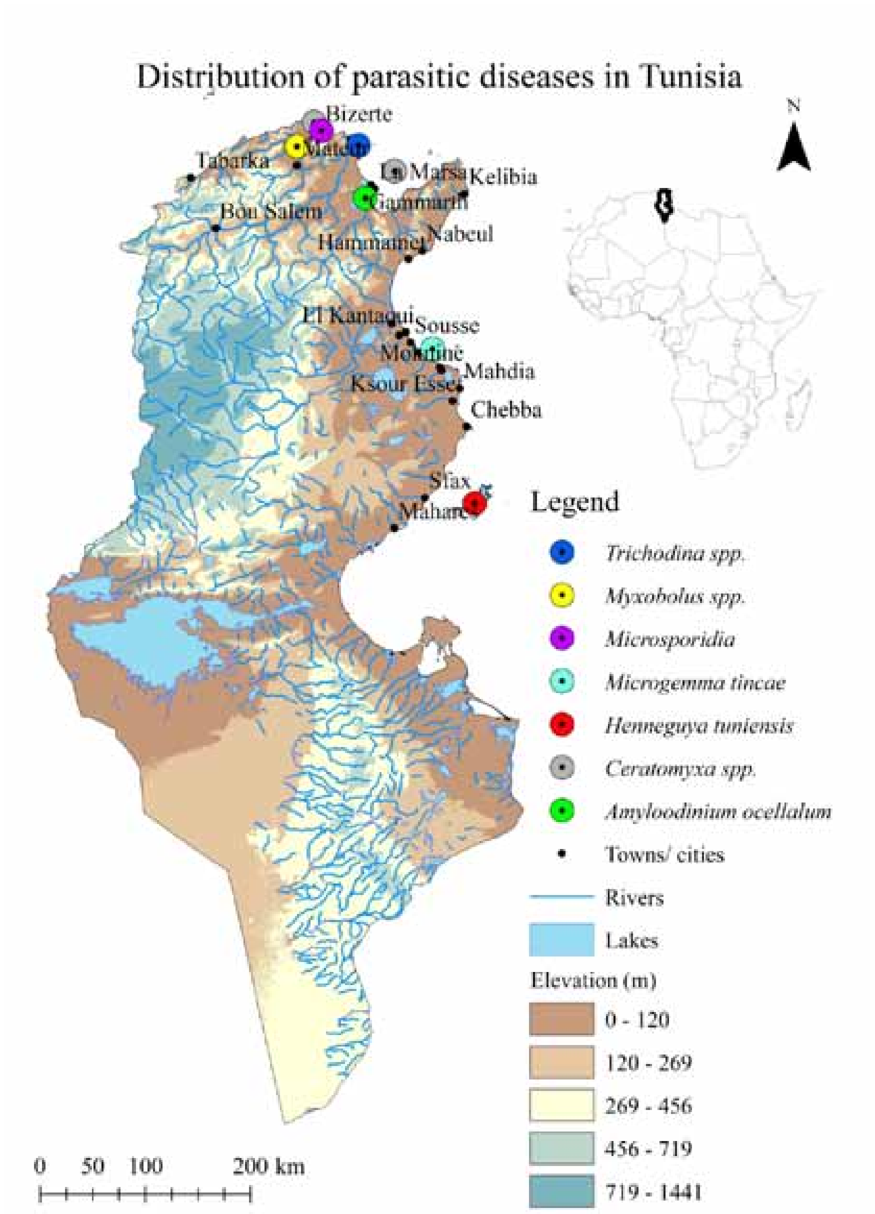

Figure 4. *Location and species affected for a limited number of parasites in Tunisia (details taken from peer-reviewed publications published by Tunisian scientists; see Appendix 1)*

Pathogen	Species affected	Location	Co-ordinates
Amyloodinium ocellalum	*S. aurata*	North Lake of Tunis	36^0 49'N; 10^0 15'E
Trichodina spp. *T. lepri*	*S. aurata*	North Lake of Tunis	
Trichodina gobii *Trichodina puytoraci*	*Solea aegyptiaca* *(Egyptian sole*	Ghar-El- Melh Lagoon	37^0 10' 26"N;10^0 11' 31"E
Henneguya tuniensis	Symphodus tinca (Wrasse)	Kenkennah Islands	34^0 42'N; 11^0 11'E
Ceratomyxa spp.	*Sarpa salpa* (A type of sea bream)	Gulf of Tunis	37^0 00' 00"N; 10^0 30' 00'E
		Bay of Bizerte	37^0 16' 28"N; 09^0 52' 26"E
Myxobolus spp	*M.cephalus*	Ichkeul Lake	37^0 10' 00"N; 09^0 40' 00"E
Microsporidia spp. *Microgemma tincae*	*Symphodus tinca* (Wrasse)	Bizerte	
		Monastir	35^0 46' 40"N; 10^0 49' 34"E

5.2. Aquatic animal disease control infrastructure in North Africa.

Most of the information presented here was taken from the answers in the completed questionnaires to questions on:

a. The countrywide extent of the Aquatic Animal Health Services (AAHS) diagnostic laboratories
b. The level of sophistication of the diagnostic tests used in the AAHS laboratories
c. The availability of an Laboratory Information Management System (LIMS) for recording details of disease outbreaks.
d. To what extent is reporting and recording disease outbreaks (especially OIE listed diseases) compulsory.
e. Presence or absence of a national disease surveillance programme
f. Presence or absence of the building blocks for instituting a risk based surveillance programme.
g. The level farmers adhere to good husbandry and bio-security protocols for disease control..

Completed questionnaires were returned from representatives of the national authority dealing with the aquaculture and wild fisheries in Algeria, Libya and Mauritania. In the case of Egypt and Tunisia because the replies were from University academics and not government officials the answers may not be representative of the current situation with aquatic animal disease throughout both countries.

5.2.1. Algeria

The questionnaire was completed by the National Control Laboratory and Analytical Products of Fishing and Aquaculture and Safety of Communities-LNCAPPASM.

Diagnostic Laboratory Service

The diagnostic service extended from a central laboratory through a number of regional laboratories to local laboratories in all areas. The tests used in these laboratories were not quality assured. No information was provided on the use of modern methods such as PCR etc. In addition there was no database or Laboratory Information Management System (LIMS) to record details of OIE listed or endemic disease outbreaks

Reporting disease outbreaks

There is no mandatory reporting system for any notifiable disease suspected or detected by farmers, veterinary practitioners or veterinary diagnostic laboratories. However, farmers are obliged to keep a register of disease outbreaks and treatment regimes and a system of voluntary reporting of disease outbreaks and/or incidences of high mortalities by farmers is in place.

Legislation dealing with disease control

There is a legislative framework to allow the implementation of emergency disease control measures as well as a compensation mechanism for affected fish farmers.

Risk based surveillance and on-farm bio-security protocols

Good husbandry and bio-security protocols are practiced on a large proportion of fish farms.

Many of the elements (listed in question 7) for setting up an internationally accepted risk based surveillance programme are in place. Two major omissions are the failure to test brood stock for OIE listed and endemic diseases and the non-availability of internationally verified quality assured diagnostic tests.

The measures that are already in place are:

a. Farm registration with location geo-referenced,
b. Routine testing of farm production stock,
c. Official authorisation is required for movement of disinfected eggs and live fish,
d. Farmers obliged to keep a register of disease outbreaks and treatment regimes
e. A system of voluntary reporting of disease outbreaks and/or incidences of high mortalities by farmers is in operation
f. Routine examination of slaughtered fish is also carried out.

5.2.2. Egypt:

The details presented here were provided by Professor Mahmoud Aly (Dept. Pathology, Faculty of Veterinary Medicine, University of Cairo). The information he provided while very much appreciated may not represent the official situation vis-à-vis aquatic animal disease control systems in Egypt.

Diagnostic Laboratory service

He stated that the State Veterinary Service/Aquatic Animal Health Service (VS/AAHS) comprised a central and a number of regional laboratories with smaller laboratories in some local areas. The laboratories that offered a fish disease diagnostic service used accredited modern diagnostic tests. However, he did not distinguish between official laboratories and other private laboratories such as university departments that may also provide a diagnostic service. In the VS/AAHS a LIMS system was in place to record notifiable diseases.

Reporting disease outbreaks

He made no comment on existence of mandatory reporting of notifiable disease outbreaks by farmers, veterinary practitioners etc although he did mention that a system of voluntary reporting of disease outbreaks and/or incidences of high mortalities by farmers is in place

Legislation dealing with disease control

He mentioned that there was no legal framework to allow emergency disease control to be implemented in the event of an exotic disease outbreak. Nor was there a mechanism to financially compensated farmers.

Risk based surveillance and on-farm bio-security protocols

It would appear that there is no official surveillance of cultured and wild fish for disease. In addition there is no obligatory testing of broodstock for OIE listed diseases and endemic pathogens that are transmitted vertically in gametes and other reproductive fluids. However, official authorization is required to move eggs and live fish although they do not require to be specific pathogen free (SPF).

There is no register for farms and their geo-location.

Some of the information provided on disease surveillance and husbandry practices was contradictory. He stated that there was routine testing of the production stock but only 40% of farmers routinely monitored their fish for external parasites and other diseases. Notwithstanding that there appears to be no compulsion to report outbreaks of notifiable diseases, there is a system of voluntary reporting of disease outbreaks and/or incidences of high mortalities by farmers.

He considered the adherence by farmers to on-farm bio-security protocols was variable. Seventy percent of farmers isolated new stock introductions from the resident fish and 60% of them used separate nets etc for each tank/pond/cage. However only 30% of farmers adhered to good personal hygiene and disinfection of equipment after use protocols.

It would appear from the information provided from the University of Cairo that a number of essential elements are missing for the development of a reliable risk based disease surveillance programme. Building blocks such as a farm register, national testing of broodstock, provision of SPF eggs/fingerlings and an education prospectus on farm bio- security need to be put in place to prevent the spread of endemic and exotic pathogens.

5.2.3. Libya

Information on aquatic animal diseases and their control was not forthcoming from the Libyan scientists. An internet search also failed to provide information on the VS/AAHS diagnostic and investigation infrastructure.

5.2.4. Mauritania

The OIE focal point provided details of the infrastructure of the Mauritanian aquatic disease control system.

Diagnostic Laboratory service

The VS/AAHS only provides a diagnostic service at a central laboratory level. There are no regional or local laboratories. The diagnostic tests are quality assured but they do not include molecular assays.

Reporting disease outbreaks

Currently, there is little aquaculture activity in the country and the regulations regarding reporting fish diseases mostly apply to wild fisheries. There is a mandatory reporting system for inspectors of ONISPA and scientists at the Central Laboratory. All the information is relayed through the OIE focal point where there is a LIMS system for managing the details of the disease outbreaks.

Legislation dealing with disease control

There is a legislative framework to deal with emergency disease outbreaks. It is operated through a number of different government departments.

Disease surveillance

The ONISPA oversees the regular inspection of wild marine fish catches for disease and other public health issues.

5.2.5. Tunisia

Due to his position as an academic and researcher from University of Carthage, he was unable to provide any insight into the infrastructure of the aquatic animal disease control system in his country. However, the level of sophistication of the disease control system can be extrapolated from some peer- reviewed publications and by accessing the websites of some of the relevant organisations such as the Centre Technique d'Aquaculture (CTA) and the National Institute of Marine Science (INSTM).

Over 70% of marine aquaculture production is exported to France, Italy and Spain. For this to occur the legislative framework and disease surveillance infrastructures and fish management must be compliant to the EU health requirements (Directives 2006/88/EC and 2008/53/EC). Thus the disease controls in Tunisia must be of an international standard and similar to those in EU member states.

5.2.6. Summary

Tunisia is the only country with access to the EU market for its aquaculture products. At present, in the other countries it would appear that the legislative framework, disease surveillance and health certification may not be up to internationally accepted standards and does not meet EU requirements.

In this situation there is always a danger of trans-boundary transmission of disease. Fortunately, the review of the literature, the analysis of the limited number of completed questionnaires and a trawl through the WAHIS portal of OIE suggest that the main diseases affecting farmed fish are common endemic production diseases. Although highly pathogenic on an affected farm however, in most cases they have limited ability to spread rapidly. Another possible safeguard is that in the largest producer Egypt all the production is sold locally within 24 hours of slaughter.

The greatest danger of disease transmission is the introduction of new fish onto a farm. In some of the countries the seed or young fry for fish farms is recruited from the wild. In these situations there is always a danger of introducing a disease. Those farmers that buy in fry and fingerlings especially sea bream and sea bass from other Mediterranean countries must ensure they purchase fish from a reputable and certified specific pathogen free hatchery.

6.0. Final analysis and summary

6.1. Preamble

The cancellation, due to a poor response to the survey, of the scoping visits, discussions with stakeholders and farm visits prevented getting a first-hand perspective of the interaction of host, pathogen and environment in the development of fish diseases on North African fish farms. The well-known Sneizko three ring diagram illustrates the important epidemiological principal that infectious disease is generally a three way interaction requiring the components of host, pathogen and environment (Fig.5). Non-infectious disease e.g. nutritional deficiencies, toxicities is an interaction between the fish and its environment be it diet, poor quality water etc.

Infectious diseases can be caused by opportunistic or obligate pathogens. Opportunistic pathogens become pathogenic following a disturbance in the fish host's physiology/immunity due to some element of environmental stress. These pathogens can also be transmitted from one host to another without inducing disease. Mortalities are low but often occur over an extended period of time so can reach significant levels. They are usually part of the aquatic environment so are impossible to eliminate.

The obligate pathogens are a more threatening group as they are inherently pathogenic and do not require environmental stress to induce clinic disease. They must cause disease in order to be transmitted from host to host. Obligate pathogens usually have a high transmissibility with a propensity to spread rapidly within a population and cause high mortalities. They have a limited ability to live outside the host and do not tend to persist in an environment. Eliminating the diseased population and disinfection of the ponds and tanks can control them. In theory, they can be avoided by controlling the introduction of suspected carrier fish originating from a population known to harbour the pathogens.

6.2. Endemic Fish Diseases in North Africa

International Perspective

Tilapia is the number one commodity aquaculture species in the world and it is also the major cultured fish in North Africa. Worldwide, Tilapia farms experience disease and to date four major bacterial diseases Strptococcus agalactiae, S. iniae, Flavobacterium columnare and Francisella spp., one viral disease iridovirus and two major groups of parasites i.e. monogeneans such as Gyrodactylus spp. and external protozoa such as Trichodina spp. and Chilodonella spp. are considered to be the most important pathogens. These diseases with the exception of the iridovirus are prevalent in Tilapia culture in North Africa. They can also cause disease in mullet and carp, two species, which are commonly co-cultivated with Tilapia in this region. Koi Herpes Virus (KHV) is considered the most serious threat to carp farming in Europe and Asia with up to 100% mortality on affected farms.

The most serious disease affecting farmed sea bass in the Mediterranean is viral nervous necrosis (VNN). It is highly pathogenic not least because it chiefly affects fry, the vulnerable early stage of the life cycle. In sea bream culture the most threatening diseases internationally are Pasteurellosis and the monogenean Sparicotyle chrysophrii.

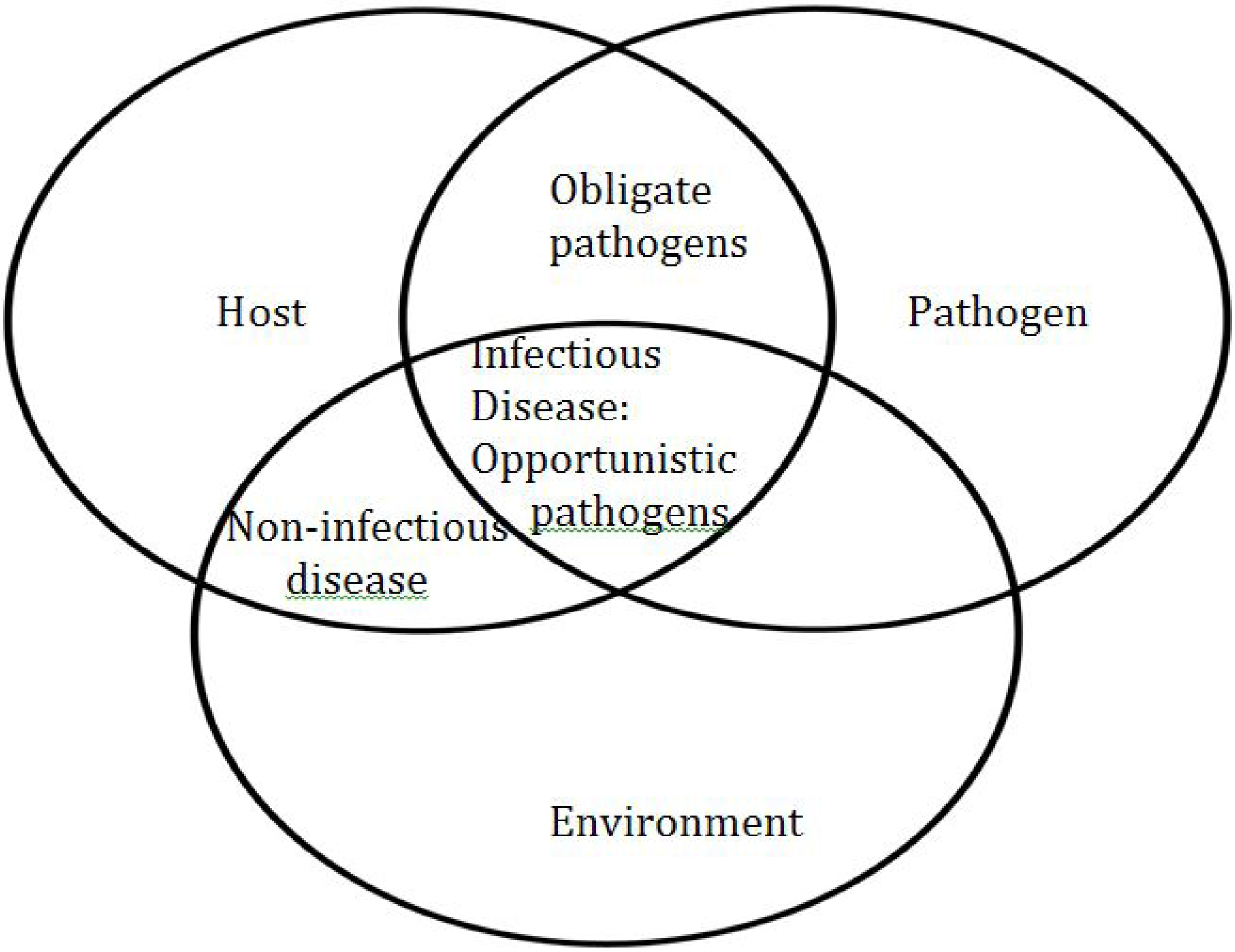

Figure 5: *Modified Sneizko's three-ringed model showing the interaction between host, environment and the pathogen*

6.2.1. North African Perspective

One of the aforementioned diseases KHV is currently exotic to North Africa.

The majority of the remaining diseases and those listed in tables 4, 5 and 6 and figures 3 and 4 are opportunistic pathogens. The exceptions are the nodaviruses VNN and the red spotted grouper nervous necrosis virus (Cherif et al., 2011), *Mycobacterium* spp. and the parasites with an indirect life cycle, which are obligate pathogens. They can all however, be classified as endemic production diseases persistently reoccurring in certain geographical locations and farms.

There are several biological factors directly associated with the fish and environmental factors related to the water bodies and culture systems that influence the prevalence and severity of these diseases. The biological factors include age and stress levels, which compromise the immune system, inadequate nutrition and high stocking densities. Water quality is most important environmental factor. Parameters such as water temperature, high organic matter, high ammonia, reduced levels of dissolved oxygen and high bacterial load can cause stress in fish. Salinity influences the type of pathogen especially parasites, that fish are exposed to. The different culture systems also favour the availability of certain pathogens. Earthen ponds, which are very common in Tilapia culture in North Africa, have a complex environment and the vegetation is an ideal milieu for the survival of the infective stages of many protozoan and crustacean parasites.

For all appearances, the information presented in the literature review and provided by the respondents to the questionnaire suggests that the range of pathogens in North Africa is no different to the pathogens that occur in similar aquaculture enterprises in the rest of the world. On account of the poor response from official veterinary sources, the limited disease databases and the failure to carry out the scoping visits it was not possible to determine the actual level of endemic disease. It would not be presumptuous to assume that from time to time adverse environmental conditions occur on most fish farms in North Africa leading to a disease outbreak caused by one of the opportunistic pathogens listed in tables 4, 5 and 6 and figures 3 and 4. One example of this is the propensity of Aeromonas hydrophila to cause disease in young tilapia fry during the winter when the water temperature is low (Saad et al., 2014)

6.2.2. Fish Zoonoses

Bacterial Zoonoses

All the bacterial pathogens that are known to be zoonoses are present on fish farms in North Africa.. The principal ones are *A. hydrophilla, Edwardsiella tarda, Mycobacterium marinum, S. iniae* and *Vibrio vulnificus*. Fish farmers and workers in fish markets and wholesalers are the group most prone to being infected through handling fish and not observing good personal hygiene. Disease is usually manifested by skin infections, the organisms gaining entry through cuts and abrasions. Generalised systemic infection is not the norm and only occurs in individuals that are debilitated or otherwise immuno-compromised (Haenen, Evans and Berthe, 2013).

A targeted education programme instructing fish workers on good personal hygiene procedures such as wearing gloves will contribute greatly to reducing further the already low prevalence of these zoonoses.

Parasitic Zoonoses

Heterophyiasis caused by an intestinal trematode is endemic in Egypt (Youssef and Uga, 2014). *Heterophyid* infections of fish occur in brackish lagoons and freshwater ponds, a milieu which supports the intermediate snail host, Pironella spp. The cercariae are found in the musculature of farmed Tilapia, mullet and cichlid fish as well as wild mullet. The definitive hosts are fish eating cats, dogs and some birds. Undercooked fish is the main source of infection for humans.

Heterophyses spp are particularly prevalent in the Nile Delta region and according to Professor Aly prevalence, depending on the location, can be up to 80%. Youssef and Uga (2014) reported that the highest intensity of infection was found among fishermen (33.8%) and up to 3% of feral cats were also infected in this region.

It is a difficult task to present advice on the prevention/ control of any fish borne intestinal parasitic zoonoses on account of the long pre-patent period and the insidious sub-clinical nature of the infection. An additional difficulty is that prevention invariably requires changing cooking and eating behaviour.

The infective L3 larvae of the zoonotic nematodes Anisakis spp. have been detected in *Epinephalus* spp (Grouper). Caught in Egyptian coastal waters and in circa 10% of the wild fish caught off the coast of Mauritania. The definitive hosts are marine mammals and so control is problematic. It is best achieved during post harvesting handling by cooking the fish thoroughly before consumption. In some countries if the fish is to be consumed raw, marinated or smoked than it required to be rapidly blast frozen to -35^{0}C and stored at this temperature for a further 15 hours (Pozio, 2013).

Shellfish Poisoning

The respondents to the questionnaire have reported that dinoflagellate blooms have been recorded in the coastal waters of Algeria and Egypt. They have been recorded in Tunisia and they probably occur also in the other countries, as marine biotoxins are very common in waters above 30^{0}N. In order to protect the public and to avoid major outbreaks of paralytic and other shellfish toxins many countries have set up Shellfish Control Authorities. These authorities classify coastal waters for the presence or absence of biotoxins and algal blooms. They also establish and supervise shellfish monitoring programmes. Testing the shellfish is usually carried out weekly, during the critical period for toxin contamination, using a range of internationally validated tests including mouse bioassays, high performance liquid chromatography etc. The decision to allow or prohibit commercial harvesting of the shellfish beds is based on the results of the monitoring tests. Cherif et al. (2011) mentioned that a phytoplankton monitoring network was started in Tunisia in 1995 and they now know the main dinoflagellate species causing red tides and contamination of shellfish with algal toxins.

6.2.3. Capacity of the laboratory services for diagnosis and surveillance of endemic diseases

The poor response to survey militated against making an unequivocal assessment of the veterinary diagnostic and surveillance capability for aquatic animals in nearly all of the North African countries. The exception was Tunisia, where sufficient information was gleamed from published documents and from the EU website to suggest that the capacity of the veterinary diagnostic infrastructure in this country was sufficient to meet the criteria to allow export of aquaculture products into the EU.

The capacity of the laboratory diagnostic service in some of the other countries may not be sufficient to investigate every incident of disease or increased mortalities. There also appears to be a limited facility for typing viral and bacterial isolates at central, regional or university laboratory level. The majority of peer-reviewed papers sourced for the literature search just reported the primary isolation of specific pathogens with no information on their molecular subtypes, serotypes, phage type etc. A database of the various pathogen strains and types in a geographical region is fundamental to the ability to detect any future change in the biotypes and their epidemiology. This is important for many reasons to do with disease control, not least in identifying transboundary spread of pathogens.

Limited capacity to design and implement programmes of surveillance and control of disease is one of the constraints restricting countries promoting their aquaculture products. A critical component of any aquatic animal disease management strategy is the existence of a strong and efficient veterinary service and laboratory network. It must have the capacity to detect both known and unknown pathogens early in order to identify incidences of disease with the potential for severe morbidity and mortality. The diagnostic capability can be at many levels but the most essential element is a national/central laboratory supporting regional and local diagnostic laboratories (Table 7). The central laboratory should be staffed with appropriate trained/educated personnel using the gamut of isolation and identification methods including molecular techniques such as PCR and sequencing as well as serology. A LIMS system for recording and storing data preferably geo-referenced is also an integral component of any efficient diagnostic /surveillance system.

A well functioning diagnostic and disease surveillance system is critical to providing evidence-based information for implementing and monitoring aquatic animal health strategies. Creating a laboratory network such as the standard international model described in table 7 is expensive and takes time. However, in most countries the health network for livestock is well established so collaboration, during the early stages of setting up an aquatic animal surveillance network, with the terrestrial animal laboratory system will provide increased efficiency and a large workforce of trained personnel. In addition to the obvious costs covering building construction, equipment, salaries and running costs, third level educational institutions will also require supporting to ensure continued recruitment of suitably trained personnel.

Table 7. *Capacity building for an integrated disease recognition, diagnosis, investigation & surveillance laboratory network*

Level of diagnostic capacity	Participants	Resource requirements	Site
Level I Diagnosis based on clinical signs & environmental conditions	Farmer Extension officer Veterinary practitioner [routine parasitology exam. on farm; collection of appropriate samples]	In-service training for Farmers, Extension officers. Veterinary Practitioners, Veterinary officials.	On -farm Local Laboratories (Basic aquatic animal health laboratories)
Level 2: Routine Parasitology Bacteriology Virology Histology Some Serology	Technicians, Vet. Pathologist.	Technical and University training. In-service courses to up-skill technicians; Significant investment in buildings, equipment, library facilities. On-going maintenance costs LIMS system	Regional Laboratories
Level 3. Parasitology Bacteriology Virology Histology Serology Molecular diagnosis & typing of isolates Electron microscopy	Technicians Veterinary & other graduates with specific microbiology specialities Molecular biologists Vet. pathologists	Technical and university education; In-service training to up-skill in various specialist disciplines; Significant investment in buildings, equipment, library facilities, LIMS On- going maintenance costs; Research capacity	National/Central Laboratory (Referral and OIE/FAO reference laboratory)

Every country in North Africa should strive to instigate a disease surveillance plan to establish the prevalence and geographical distribution of the various endemic diseases. It should involve staff trained in disease recognition that collect samples from suspected diseased aquatic animals and report their findings to designated regional or national health management personnel. The scientific support then tests the samples for known pathogens and the tests used should be quality assured and capable of indicating the emergence of new diseases.

The investment in setting up such a scheme will benefit the national economy greatly over time. A robust surveillance programme supports import risk analysis, justifies import health certification requirements, enables export health certification and provides evidence to substantiate claims of absence of a particular disease. It also ensures that decisions that have to be predicated on aquatic animal health will be evidence and scientifically based.

6.3. Notifiable/ OIE listed diseases

In the last few years there has been no report of notifiable aquatic animal disease in North Africa. However, in the recent past Perkinsosis has been recorded in clams (*R. decussates*) in Tunisia. The Perkinsus protist species was initially detected in 2004 during routine sampling as part of an official shellfish screening programme. The screening was carried out using histology.

There was an outbreak of white spot virus (WSV) in a shrimp (*Marsupenaeus japonicus*) farm near Skikda, Algeria in 2012. The disease was diagnosed using PCR.

There is little documented information i.e. type of surveillance, diagnostic tests, quarantine and control/eradication protocols, relating to these outbreaks. However, it would appear that whatever disease monitoring and diagnostic system is in place in these two countries that it was efficient with regards to controlling these two notifiable diseases.

6.4. Transboundary and emerging diseases

A broad definition of transboundary diseases (TADs) is the introduction of any infectious pathogen into a country, region or zone where it had not been present previously. However, the official definition of TADs only considers OIE listed epoizootic diseases that are highly contagious, spread rapidly trans-nationally and locally from farm to farm. They can often escape into the surrounding aquatic habitats causing disease in wild aquatic animals. They also have severe socio-economic consequences for the aquaculture industry and sometimes for the general public. Pathogens that cause limited mortality in affected populations and generally can be controlled by improved husbandry and also have little socio-economic consequences for the wider public are excluded. The increased intensification and commercialisation of aquaculture has created a constant danger of transporting novel and exotic pathogens within and between countries through the movement of brood stock, fry and fingerling as well as bivalve mollusc and crustacean spat and seed and the adoption of new species for fish farming development.

There are no published reports of outbreaks of TADs occurring in Egypt. It would appear from this study that disease is more likely to spread within this country for a number of reasons including use of wild fish for aquaculture, cage rearing in major waterways and water bodies and the wide distribution of Genetically Improved Farmed Tilapia (GIFT) fry from the research institute at Abassa. In the case of Tunisia the situation is more problematic because Tilapia fry have been imported from Egypt and in marine culture Lymphocystis virus has been introduced through the importation of sea bass fry from Southern Europe. There are no reports of TADs being introduced into the other countries.

The majority of the rivers in North Africa do not flow trans-nationally and are often dry at some period during the year and are unlikely to be a conduit for TADs transmitted via wild fish carriers or escapees from fish farms. The exceptions are the international Nile, which traverses about 11 countries and the Medjerda River which flows from Algeria through Tunisia into the Mediterranean.

In the future, movement of live aquatic animals will become necessary for the development of the aquaculture industry in Africa. Co-operation and goodwill between governments, national disease experts as well as junior officials is a sine qua non for the prevention of TADs. The guiding principal for responsible movement is to reduce the risk of exotic disease establishing and spreading to naïve native aquatic animals to a manageable level in the importing country. Honest, conscientious and transparent reporting is required, hence the importance of having an efficient surveillance system with a high level of expertise and consistent and regular reporting of disease incidences in both the exporting and importing country. One of the causes for the spread of TADs is a slow awareness of or a failure to recognise an emerging disease in the exporting country.

The failure to carry out scoping visits and gather information from local stakeholders prevents making a definitive statement on the level of preparedness of North African countries for an epizootic disease outbreak. In recent years Algeria and Tunisia experienced an outbreak of serious disease, WSD in shrimp and VNN in sea bass fry respectively and appeared to have coped quite well. However, it behoves every country to strive to improve their ability to comply with the international regulations on the movement of live aquatic animals. As a first step in improving their bio-security vis-à-vis TADs all countries should adopt the various OIE, FAO and ICES codes of practice relating to the introduction and transfer of freshwater and marine organisms. Underpinning every efficient national bio-security policy is a national aquatic animal disease management strategy to implement OIE, FAO and other organisations' technical guidelines. . This national strategy or framework should include elements such as national co-ordination structures, legislation and policy, list of pathogens, institutional resources, diagnostics, health certification and quarantine, surveillance and reporting, disease zoning, contingency planning, import risk analysis, capacity building, awareness building and communication with junior state officials, other personnel, farmers and the wider aquaculture sector, farmer/private sector involvement, financial resources, monitoring and evaluation and regional co-operation (Bondad-Reantaso et al., 2005).

The African nations should follow the example of the Asian-Pacific countries and set-up an intergovernmental organisation along the lines of the Network of Aquaculture Centres in Asia-Pacific (NACA, www.enaca.org). This could be organised through the auspices of AU-IBAR and in collaboration with FAO. The role of NACA in Asia is to implement development projects with research centres, governments, development agencies and farmer associations. It supports technical exchange between members, capacity building, institutional strengthening and policies for a sustainable aquaculture sector and aquatic resource management. The governing council of NACA has also established an Asia Regional Advisory Group (RAG) on Aquatic Animal Health to provide advice on aquatic animal health management (Anonymus, 2016[a]). The group comprises invited local and international aquatic animal disease experts, experts from OIE, FAO and other collaborating organisations. It provides an aquatic animal health resource at three levels, individual experts on either specific fish species or disease, regional research centres and regional reference laboratories. They produce technical manuals on TADs, organise workshops on diagnostic standards, proficiency testing and laboratory accreditation procedures and develop multi-laboratory proficiency testing for prioritised diseases.

If a network of African aquaculture centres is not feasible at present, perhaps AU-IBAR should consider advising the national governments to set up an advisory group on aquatic animal health similar to the RAG group in Asia.

Its remit should be to:

a. Evaluate disease trends and emerging threats
b. Identify developments with global aquatic animal disease issues of importance to Africa
c. Review quarterly aquatic animal disease reports from each member country across the list of diseases of regional concern
d. Provide guidance and leadership on regional strategies to improve aquatic animal health in the region
e. Produce technical manuals and guideline documents on capacity building for laboratory networks, disease surveillance and national/regional biosecurity and for the implementation of international codes of practice on TADs.
f. Monitor and evaluate progress on the implementation of technical guidelines.
g. In situations such as multi-national river catchments, bays, oceans, coastlines etc which require multi-national, multi-jurisdictional collaboration ensure that health management zones are delineated according to ecological, geographical, hydrological or climate barriers and not political borders.
h. Set up a laboratory network to build capacity in member countries similar to the FAO/IAEVA VETLAB Network for TADs of terrestrial animals (www.fao.org/3/a-i4728e.pdf).
i. Facilitate co-ordination and communication of the progress on regional aquatic animal health programmes.
j. Harmonise health certification and quarantine measures throughout the continent.
k. Advise on the identification and designation of resources such as regional research centres and regional reference laboratories.
l. Identify issues of relevance to the region that require an in-dept review and propose the appropriate response /action needed.
m. Encourage open communication and co-operation between competent authorities and ensure all the international regulations on trade etc are complied with.

One of the first requirements of such a group should be to draft a code of practice for TADs on the major trans-national waterways on the continent which in North Africa these would include the Nile and Medjerda rivers. In the case of these rivers it behoves neighbouring countries to divide the catchment systems into management units based on geography, hydrology and ecosystems for surveillance rather than adhering strictly to political borders.

6.5. Emerging diseases

The reasons for emerging diseases and the re-emergence of old diseases have been well rehearsed in the peer-reviewed and popular scientific press (Wentholt et al., 2012). As previously stated the greatest danger with emerging diseases is failure to recognise them as novel pathogens early enough to prevent their establishment and spread. Routine microbiological tests are often of limited value for diagnosis. In such cases and in a laboratory system with limited capacity, histopathology is possibly the most appropriate conventional diagnostic method to define the pathology and pathogenesis and to identify the category of microorganism involved. An alternative method is to use the recently developed whole genome sequencing in conjunction with bioinformatics to identify gene sequences and immunogenic proteins of the new pathogen (Bacharach et al., 2016; Malboeuf et al., 2013).

However, this requires expensive equipment and a molecular biology expertise that is probably beyond the resources most African nations. In cases of emergency it may be necessary that the veterinary authorities of the affected African country seek outside assistance from a laboratory with experience in high throughput sequencing, bioinformatics and proteomics.

At present two recently isolated viruses are causing serious mortalities on Israeli Tilapia farms. These are Tilapia Lake Virus (TiLV; Eyngor et al., 2014) and Tilapia Larva Encephalitis (TLEV). An international scientific team comprising scientists from Columbia University (USA) and Tel Aviv University recently identified TiLV in Tilapia in Ecuador and they suspect the virus is also present on Tilapia farms in Columbia (Anonymus, 2016[b]). The virus was identified using high throughput sequencing to detect the viral genome and mass spectroscopy to characterise the viral proteins in infected tissue, which matched those proteins they expected to find based on the genetic sequence.

The circulation of these viruses in a neighbouring country poses a danger to Tilapia fish farms in North Africa but especially to farms in Egypt. It is possible that TiLV may be more widespread than first thought, as it has now been isolated on two continents. The virus can be transmitted both horizontally and vertically and thus can be easily spread from an infected hatchery via the distribution of fingerlings.

Another emerging pathogen, which may pose a threat to Mediterranean aquaculture in the future, is a newly identified intracellular β-proteobacteria related to *Chlamydia* spp. the causal agent of Epitheliocystis (Seth-Smith et al., 2016). It was isolated from sea bream on farms in Crete and Greece (Seth-Smith, 2016).

There was no obvious consensus amongst the respondents to the questionnaire on the question dealing with the drivers for local and trans-national spread of aquatic animal disease. However, they all agreed that the emergence of new diseases and vectors was a major danger and they either agreed or strongly agreed that the introduction of exotic fish or shellfish of known or unknown health status was also a factor in the trans-boundary spread of disease.

Interdisciplinary research is needed to understand the drivers for emerging infectious diseases. International collaboration is required to prevent their spread. Political will and commitment from government officials as well as good communication between scientific and veterinary experts in the various countries to promote exchange of information is essential to minimise the risk of new, old and established diseases spreading. An early warning system such as quarterly regional reports, over time, will help to build up background information on endemic disease patterns and provide a reliable foundation on which to judge any change in the nature of the disease outbreaks.

If the lack of co-operation experienced with this study is an indication of limited bio-security capacity and an unenthusiastic commitment of scientists to the aquaculture sector in North Africa then it may take time for such a reporting system to evolve. Nevertheless it should over time prove beneficial to all governments and fishery officials in this region.

7.0. Conclusion

Aquatic animal health management is a shared duty for all involved in the fisheries and aquaculture sector and the contribution of each stakeholder is essential for an efficient disease control and preventative programme. Because of this, the lack of co-operation from the majority of individuals contacted for this survey was very disappointing. More so, because it was mentioned in the letter of introduction that this initiative was part of the PFRS for the future development of the fisheries and aquaculture industries in Africa.

All the continent's Heads of State had endorsed the PFRS strategy in 2014. It is possible that the individuals contacted for this study may not have been aware of these endorsements and the recommendation of the Fisheries' Ministers to involve all stakeholders in the implementation of the PFRS. Consequently, they may have felt no obligation to fill out the questionnaire. In order to prevent a similar breakdown in communications occurring again in the future it is suggested that senior civil servants ensure that all government and ministerial recommendations relating to co-operation on fisheries and aquaculture topics in general and fish and shellfish disease in particular are officially passed on to junior officers and other appropriate individuals in government research and 3rd level educational institutes.

It is generally accepted that collaboration between nations is fundamental for controlling emerging diseases and TADs and facilitating trade. An essential component of any international collaboration on disease control is transparent reporting of diseases and sharing information on the aquatic animal health status of the respective countries. Attitudes amongst the technical experts will have to change if the North African countries are to have any success in minimising the spread of aquatic animal diseases. Organisations and individuals, influential in the region, must give priority to persuading fish disease experts to co-operate at all levels to generate data to support continental bio-security assessments in order to minimise the spread of disease and enhance trade.

Finally, the majority of diseases identified in this study are those that are normally considered endemic and are usually amenable to on-farm control by improving husbandry. There appears to be little trade in live fish between the countries, so at present the danger of TADs occurring is low. The return rate for completed questionnaires was quite poor so it was not possible to comment with any certainty on the on-farm bio-security practices, national disease surveillance infrastructure and on the overall preparedness of the countries to cope with an emerging disease episode and TADs.

The following recommendations if acted on should over time provide high-level support to enabling development and implementation of guidelines designed to improve the bio-security and surveillance capacity in North Africa:

8.0. Recommendations

8.1. Recommendation 1.

Set up a Regional Expert Advisory Group on Aquatic Animal Health (REAG) in collaboration with FAO on the lines of the Asia-Pacific model. It could be created as a stand-alone unit or incorporated into an African network of aquaculture centres.

The African Network of Aquaculture Research Centres (ANARC) should be based on the blueprint used for a similar intergovernmental network designed to strengthen institutional and personal links amongst national and regional aquaculture centres in Asia-Pacific [http://library.enaca.org/PDF/NACA-GC14-final.pdf]. The mission of the African network should be to expand the aquaculture sector by sharing responsibility for research and, training and information exchange.

Gathering and dissemination of information, planning research and training as well as provision of advice on fish and shellfish diseases could be carried out by a separate advisory group on aquatic animal health (REAG), formed within ANARC. If this is not possible then the REAG should be set up as a separate unit under the auspices of AU-IBAR in collaboration with FAO and OIE and agreed by the governments. In either case the remit of the REAG should be as previously outlined in Section 7.4.

8.2. Recommendation 2.

Institute a system for collection and reviewing quarterly disease reports from all the North African states.

AU-IBAR should encourage the competent national authorities for fisheries and aquaculture to regularly collect data on disease incidences and submit them to the REAG when it is formed. Prior to the formation of a REAG, the disease reports should be collated and stored on a database by AU-IBAR for future reference.

It will take time for the system to evolve and in the early stages allowance should be made for the different standard of disease surveillance and laboratory capacities in the various countries. Standard operating procedures should be put in place to ensure over time a consistent reporting format.

8.3. Recommendation 3.

Nominate an existing laboratory or set up a new laboratory as a regional reference laboratory for designated aquatic animal diseases in Africa. Funding and support for this important piece of infrastructure should be sought from OIE, FAO and European and American government and other development aid agencies.

In addition to ensuring that reference laboratory has the relevant expertise and laboratory bench skills, equipment, test reagents etc efforts should also be made to incorporate capacity for microbial bio-safety and containment facilities. The bio-secure unit should be built to Level 3 containment standards for live aquatic animal work. This bio-containment unit should be modelled on the Charlotte Aquatic Animal Pathogen and Biocontainment Laboratory of the National Aquatic Animal Health Laboratory system of Fisheries and Oceans Canada (Anon., 2011). Such a facility will provide some independence for the African aquaculture sector and its scientists, as it will enable research and investigation of notifiable aquatic pathogens as well emerging diseases to be carried out safely on the continent.

The reference laboratory should also develop a collaboration with a high powered molecular biology group in a foreign laboratory to cover for the possibility of ever having to use whole genome scanning to identify an emerging pathogen.

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APPENDICES

Appendix 1: Review of scientific literature

This literature search and review is part of a larger study to map the occurrence of fish and shellfish diseases in the countries of North Africa. The information obtained from the review of peer-reviewed publications provided the basis for a questionnaire to elucidate the current status of aquatic animal diseases as well as the veterinary/ diagnostic/ regulatory infrastructure vis-à-vis fish diseases in the region.

The search topic was defined as the presence or occurrence of microbial and parasitic pathogens and diseases, fish and shellfish species affected, whether cultured or wild and the geographical location where diseases occurred in North Africa. The search was confined to the free bibliographic database at PubMed and the subscription Scopus database with a supplementary search using Google. An additional search was also carried out at the library of University College Dublin, Ireland using the "one search" programme. It was initially restricted to the period 2000 to 2015. However, this was found to be restrictive as only a few peer reviewed publications were found for this period in many of the countries. Thus the time period was extended back to 1990. The search terms included fish diseases, shellfish diseases; North Africa, the names of the individual countries, Algeria, Egypt, Libya, Mauritania, Tunisia, Sahrawi Arab Democratic Republic (or Western Sahara), Mediterranean; specific diseases e.g. Aeromonas hydrophila, Spring Viraemia of Carp (SVC), Viral Nervous Necrosis (VNN) etc.; disease syndromes such as mycobacteriosis, flexibacteriosis and vibriosis; bacterial and parasitic zoonoses; dinoflagellate blooms.

A total of 100 papers relating either directly or indirectly to aquatic animal diseases in North Africa were identified (Table 1). The majority of them were relevant to the study. However, it was only possible to download 32 full papers, the remainder were downloaded as abstracts.

Table 1. *Number of peer reviewed papers identified with relevance to the study to map fish and shellfish diseases in North Africa*

Country	No. Papers identified	No. Papers relevant to the study	No. Papers not relevant to the study	No. Full papers downloaded	No. Abstracts only downloaded
Algeria	3	1	2	1	2
Egypt	70	56	14	19	51
Libya	2	2	-	2	-
Mauritania	1	1	-	-	1
Tunisia	24	21	3	10	14
Sahrawi (SADR)					

Algeria:

One of the three papers reported mortalities in wild groupers in the Gulf of Annaba due to the nervous necrosis virus (VNN; Table 2; Kara et al., 2014). Parasitology was the topic of the other publications. One described the digeneans parasitising European pilchards in the western Mediterranean off the coast of Oran. (Marzoug et al., 2012). The third paper dealt with the morphology and some aspects of the biology of the crustacean parasite Argulus vittatus found on the skin of gilthead bream, bogues and common pandora species in the Gulf of Bejaia.

Table 2: *Pathogens found in fish along the coast of Algeria and reported in the peer reviewed scientific literature.*

Pathogen	**Species affected**	**Location**	**Co-ordinates**
Virus: Viral nervous necrosis (VNN)	Groupers: Epinephalus marginatus Epinephelus costae	Gulf of Annaba	36^0 58'N; 8^0 15' E
Digeneans: *Parahemiurus merus* *Aphanurus stossichii* *Aphanaurus virgula* *Pronoprymna ventricosa* *Hemiurus luehei*	Pilchard: *Sardina pilcardus*	Western Mediterranean near the coast of Oran	35^0 42'N; 00^0 38'W
Fish lice: Arguilidae *Argulus vittatus*	*Boobs boobs* [Bogue] *Sparatus aurata* [Gilthead sea bream] *Pagellus erythrinus* [Common Pandora]	Gulf of Bajaia	36^0 45'N; 05^0 04' E

Egypt.

A total of 70 peer-reviewed articles by Egyptian scientists were identified. Fourteen of these were rejected as not being relevant as many of them described studies on the pharmokinetics of antibiotics and the bioactivity of probiotics and different solvent extracts of medicinal plants and microalgae (Table 1.). Two papers on vibriosis and another one on tenacibaculosis outbreaks in the aquarium of the National Institute of Oceanography and Fisheries were also not included as were papers describing new hosts and geographical locations for parasites as well as morphological and molecular taxonomy studies.

A wide- ranging review of fish diseases on Egyptian fish farms prepared for CGIAR Consultative Group for Agricultural Research was also identified through the supplementary Google search (Aly, 2013). This report covered the period 2000 to 2013 and was published in 2013. It included information taken from university Ph.D. and M.V.Sc. theses as well as a number of other unpublished reports. A large number of pathogens affecting cultured fish are listed in the review. Many of them have a worldwide distribution but the author however, failed to present any information on their epidemiology, pathogenesis and other adverse effects on the Egyptian aquaculture industry.

Much of the data in the following two tables were transcribed from the tables in Dr Aly's report and modified to include the geo co-ordinates of the various locations where each pathogen was isolated (Tables 3 and 4).

Table 3: *Bacterial pathogens isolated from fish on Egyptian fresh and brackish water fish farms during the period 2000 to 2013 (modified from Aly, 2013).*

Pathogen	**Species affected**	**Location**	**Co-ordinates**
Aeromonas hydrophila	*Oreochromis niloticus* (Nile Tilapia) *Mullet spp.* *Mugil cephalus* (Grey mullet) *Clarius lazera* (African Catfish) *Cyprinus carpio* (Common Carp)	Dakahlia Sharkia	31⁰ 03'N; 31⁰ 23'E 30⁰ 07'N; 31⁰ 63'E
Flavobacterium columnare	*O. niloticus* *Mullet spp.* *C. lazera*	Dakahlia; Behera Dakahlia Abbassa Sharkia	30⁰ 59'N; 30⁰ 12'E
Vibrio anguillarum	*O. niloticus* *Mullet spp.* *C. lazera*	Dakahila Sharkia	
Pseudomonas fluorescens	*O. niloticus* *C. lazera* *Carassius auratus* (Goldfish) *C. carpio*	Abbassa, Ismalia Sharkia Fayoum Abassa	30⁰ 35'N; 32⁰ 16E 29⁰ 19'N; 30⁰ 48'E
Streptococcus iniae	*O. niloticus*	Ismalia Sharkia Fayoum Kafr El Sheik	31⁰ 07' 52"N; 30⁰ 07' 48"E
Yersinia ruckeri	*O. niloticus* *C. carpio* *C. lazera* *C. auratus*	Abbassa Behera Kafr El - Sheikh	
Klebsiella pneumonia	*O. niloticus*	Kafr El – Sheikh	
Enterococcus faecelis	*O. niloticus*	Kafr El - Sheikh	
Pseudomonas aureginosa *P. anguilliseptica* *P. pseudoalkaligenes*	*O. niloticus* *C. lazera* *Hypopthalmichthys moltrix* (Silver carp) *Mugil cephalus* (Grey mullet)	Kafr El-Sheik	
Streptococcus faecelis	*O. niloticus* *C. lazera* *C. carpio* *M. cephalus*	Behera Kafr El-Sheikh Alexandria	31⁰ 12' 56"N; 29⁰ 57' 18"E
Edwardsiella tarda	*O. niloticus* *C. lazera* *C. carpio* *M. cephalus*	Behera Kafr El-Sheikh Alexandria	
Edwardsiella ictaluri	*O. niloticus* *C. lazera* *C. carpio* *M. cephalus*	Behera Kafr El-Sheikh Alexandria	

Parasitic infections are a common problem in cultured fish worldwide and the aquaculture industry in Egypt is no exception. Dr Aly (2013) in his review presented a litany of ecto and endo parasites found in Egypt. He records a prevalence of parasitism ranging from 38% to close to 100% in African catfish, Nile tilapia, common carp, silver carp, grey mullet and eel (Table 4). Parasitism appeared to be more prevalent in the winter than in any other season.

Table 4: *Parasites found in cultured and wild freshwater fish in Egypt (modified from Aly, 2013)*

Parasite	Site of infection	Species affected	Location	Co-ordinates
Ectoparasites: **Protozoa:** *Trichodina spp.* *Chilodonella spp.* *Ichthyoboda spp.* *Ichthyophthirius multifiliis* *Ambiphyra (Scypidia) spp.* *Apiosoma spp*	Gill and skin	*O. niloticus* *C. carpio* *C. lazera* *C. auratus* *H. moltrix* *M. cephalus*	Behera Dakahlia Sharkia Giza	30^0 59'N; 30^0 12'E 31^0 03'N; 31^0 23'E 30^0 07'N 31^0 63'E 30^0 01'N 31^0 13'E
Ectoparasites **Monogenean trematodes:** *Macrogyrodactylus congloensis* *Cichlidogyrus tiberinaus* *C. magnus* *C. arthracanthus* *C. euzeti* *C. lonicornis longicornis* *C. thurstonae* *Heterothecium dicrophallum* *Gyrodactylus rysavyi* *Quadriacanthus clariadis* *(Dactylogryidae)*	Gill and Skin Skin and gills	O. niloticus C. carpio C. lazera C. auratus H. moltrix M. cephalus Oreochromis aureus (Blue tilapia) Tilapia zilii (Red belly tilapia) O. niloticus C. lazera	Abassa farm Sharkia Giza Dakahlia	30^0 07'N; 31^0 63'E 30^0 01'N; 31^0 13'E 31^0 03'N; 31^0 23'E
Digenean trematode *Orientocreadium spp*	Intestine	*C. lazera?* *Clarias gariepinus* (African sharptooth catfish)	Dakahlia	31^0 03'N; 31^0 23'E
Nematode: *Anguillicolacrassus crassus*	Swim-bladder	*Anguilla anguilla* (Eel)	Alexandria	31^0 12' 56"N; 29^0 57' 18"E

In his review Dr Aly mentioned a high prevalence of trematode metacercariae present in the musculature of fish examined in the Dakahila, Sharkia and Ismailia regions. He also reported hetrophyid metecercariae in Nile tilapia in the Giza area but failed to mention if they were infectious to humans. The freshwater copepod *Lernaea cyprinacea* was found parasitising hatchery fry and adult Silver, Grass and Mirror carp in the Sharkia, Beni-Suef, Domiata and Abbassa regions (Aly, 2013).

Viral infections

In a specific search for viral diseases only one paper was identified and this had to be rejected as it described the potential dangers of importing goldfish vis-à-vis transmission of exotic pathogens to native Egyptian fish. One other paper from the conference proceedings of the "8th International Symposium on Tilapia in Aquaculture" was found during the Google supplementary search. This reported the isolation of spring viraemia of carp virus (SVC) in Nile tilapia on farms in El-Behera, Alexandria and Kafr El-Sheikh governorates (Table 5, Soliman et al. 2008). Aly (2013) mentioned that there was little information about viral infections in fish but that there was evidence of previous IPNV infections as well as SVC in fish cultured on fresh water sites.

Table 5: *Locations of outbreaks of spring viraemia of carp virus infection in Oreochromis niloticus in Egypt*

Pathogen	**Species affected**	**Location**	**Co-ordinates**
Spring viraemia of carp virus (SVC)	*O. niloticus*	Behera Kafr El – Sheikh Alexandria	30⁰ 59'N; 30⁰ 12'E 31⁰ 07' 52"N; 30⁰ 07' 48"E 31⁰ 12' 56"N; 29⁰ 57' 18"E

Bacterial infections:

Yersinia ruckeri (Enteric red mouth):

There was only one paper on this bacterium. It described a *Yersinia ruckeri* outbreak amongst Nile tilapia on a semi-intensive farm in Sharkiya province. The fish, 150 in total, were kept in an earthen pond and the prevalence of infection was over 65% (Table 6; Eissa et al., 2008).

Psuedomonas spp.

The authors of the papers on *Psuedomonas* spp. infection considered these organisms a serious impediment to the economic production of farmed fish (Table 6). However, in all the reported disease outbreaks in which *Pseudomonas* spp. were implicated the causal agent was never confined to one species. *Psuedomonas* spp. occurred frequently in various combinations with other species from the same genus or with pathogens from other genuses. In one incident where the prevalence of *Psuedomonas* spp infection, in Nile tilapia in the Qaroun and Wadi-El- Rayan lakes, was 30%, *Psuedomonas fluorescens* was isolated with *P. anguilliseptica*, *P. putida*, *P. aureginosa* (Eissa et al., 2010). Further challenge studies with these isolates suggested that the most pathogenic one was P. anguilliseptica as it induced over 90% mortality. In another case of high mortalities amongst gilthead sea bream *P. fluorescens* was isolated in combination with *Vibrio alginolyticus*, *V. vulnificus*, *Streptococcus agalactiae* and *Tenacibaculum maritimum* (Moustafa et al., 2015). *Psuedomonas fluorescens* has also been found in combination with *V. alginolyticus*, *V. vulnificus*, *S. agalactiae* and *T. maritimum* during an outbreak of disease in sea bass kept in sea cages in Northern Egypt (Moustafa et al., 2014).

Aeromonas hydrophila

Infections with *Aeromonas hydrophila* appear to be more prevalent in the winter in cultured fish and in late spring and summer in wild fish. *Aeromonas hydrophila* is considered one of the main diseases affecting cultured Nile tilapia in Egypt (Saad et al., 2014). Overwintering is a precarious time for tilapia and the lower water temperatures experienced at this time induce a high level of stress that the fish especially young fish are very susceptible to opportunistic pathogens including *A. hydrophila* (Elgendy et al., 2015). A high prevalence of antibiotic resistant *A. hydrophila* isolates, usually to oxytetracycline, was recorded in tilapia farms in the Port- Said Governorate (Farag, 2011).

Vibriosis

Vibrio anguillarum was isolated in conjunction with *A. hydrophila* from Nile tilapia on a farm in Barsiq in Northern Egypt during an unusual period of cold temperatures. The water temperature fell to 5.2^{0}C and losses occurred amongst the younger smaller fish (Elgendy et al., 2015). Three different *Vibrio* spp., *V. anguillarum*, *V. ordalii* and the zoonotic strain *V. parahaemolyticus*, were found in mullet (Mugil capito) on a number of farms in the Behera province. (Ismail et al., 2010).

Vibrio harveyi, *V. anglinolyticus*, *V. vulnificus* and *V. mimicus* were isolated from farmed shrimp experiencing high mortalities precipitated by disturbed seas due to inclement weather on Lake Manzala (Elgendy et al., 2015).

Bacterial and fungal infections secondary to pollution, algal blooms and external parasitism

An algal bloom in Qaroun Lake caused high morbidity and mortality in resident *Tilapia zilli* and *Gobius* spp as well as in the crab and shrimp populations. Secondary pathogens isolated from moribund fish included *Y. ruckeri*, *P. fluroscens*, *Streptococcus pyogenes* and *Vibrio anguillarum* (Abou El-Geit et al., 2013). *Candida albicans* and *P. fluorescens* were isolated from moribund Nile tilapia and sharp toothed catfish (*Clarias gariepinus*) fish exposed to effluent discharged, into a stream, from a sugar factory at Shubramant and Aboul Noumros (Eissa et al., 2013).

Photobacterium damselae subspecies *piscicida* was isolated from sea bass broodstock heavily parasitised with the marine copepod *Caligus elongatus* (Elgendy et al., 2015). Abu- Elala (2015) reported another outbreak of *P. damselae* subspecies piscicida amongst yearling and broodstock gilthead sea bream on a farm near Port- Said.

Table 6: *Distribution of outbreaks of bacterial infection in Egypt identified through a review of peer- reviewed publications by Egyptian scientists*

Pathogen	Species affected	Location	Co-ordinates
Yesiiia ruckeri	*O. niloticus*	Sharkiya	30^0 07'N; 31^0 63'E
	Tilapia zilli *Gobius spp.* *Crabs* *Shrimp*	Qaroun Lake	27^0 00'N; 30^0 00'E
Psuedomonas fluorescens	*S. aurata*	Northern Egypt	
	T. zilli *Gobius spp.* Crabs Shrimps	Northern Egypt	
Tenacibaculum maritimum	*S. aurata*	Northern Egypt	
	Dicentrarchus labrax (Sea bass)	Northern Egypt	
Vibriosis *Vibroio alginolyticus* *V. vulnificus*	*S. aurata*		
	D. labrax		
Streptococcus agalactiae	*S.aurata*	Northern Egypt	
	D. labrax	Northern Egypt	
Photobacterium damselae subsp. piscida	*D. labrax* *S. aurata*	Alexandria Port- Said	31^0 12' 56"N; 29^0 57' 18"E 31^0 15' 23"N; 32^0 17' 02"E

Pathogen	Species affected	Location	Co-ordinates
Aeromonas hydrophila	*O. niloticus*	Port - Said	31^{0} 15' 23"N; 32^{0} 17' 02"E
		Barsiq	31^{0} 06' 36"N; 32^{0} 20' 11"E
V. anguillarum *V.ordalii* *V. parahaemolyticus*	*Mugil capito* (Thin lipped grey mullet)	Behera	30^{0} 59'N; 30^{0} 12'E
P. fluorescens *P. anguilliseptica* *P. putida* *P.aureginosa*	*O. niloticus*	Qaroun Lake	27^{0} 00'N; 30^{0} 00'E
		Wadi-El-Rayan	28^{0} 08' 52"N; 30^{0} 23' 33"E

Parasites

Myxozoa:

The majority of papers were concerned with myxozoan infection in wild fisheries. *Myxozoan* parasites have a worldwide distribution. They can be found in most of the fish tissues including skin, heart and somatic muscle, epithelium, endothelium and cartilage.

The prevalence of myxozoan parasites in the resident fish of the Nile was circa 61%. The most prevalent were *Myxobolus* spp., which were found parasitising Nile tilapia and Nile carp (*Labeo niloticus*) (Abdel- Ghaffar et al., 2015).

Seventeen percent of wild and farmed catfish (*C. gariepinus*) in the Ismailia governorate were parasitised with *Henneguya branchialis* (Sabri et al., 2010). Sabri et al. (2010) also reported that the highest rate of infection occurred during the spring and that more females were parasitised than males. A number of other papers reported finding *Henneguya suprabranciae* and *H. ghaffari* in the cartilage of the gill lamellae of wild catfish (*Clarias gariepinus*) and Nile perch (*Lates niloticus*). The parasitised fish were found in the River Nile in the Beni-Suef Governorate and the Cairo and Giza provinces (El-Mansy and Bashtar, 2002: Abdel-Baki et al., 2014). The most common pathological change was degeneration and atrophy of the cartilage of the gill and sloughing of the gill epithelium (Morsy et al., 2011). Henneguya ghaffari was also found in the intestine and gills of Nile perch (*Lates niloticus*) in Lake Wadi-El- Raiyan and the myxozoan was thought to have spread from the River Nile to this lake via drainage streams (Mohamad, 1999; Abdel-Baki et al., 2014).

One paper described Kudoa pagrusi infection in the Red Sea fish *Pagrus pagrus* (Seabream). The plasmodia were found in cardiac muscle and appeared to cause a distortion of the heart structure with possible implications for the health of the fish (Abdel –Ghaffar et al., 2009).

Ciliated protozoa:

The ciliated protozoan species *Ichthyophthirius*, *Trichodina*, *Chilodonella*, *Ambiphyra*, *Apiosoma*, *Epistylus, Ichthyoboda* and *Amyloodinium* are ubiquitous and a serious problem for fish health on freshwater and marine fish farms worldwide. There appeared to be no publication on health implications of these parasites in Egyptian aquaculture units. Two papers were found which dealt with infection in wild fish on the River Nile. One described the morphology Trichodinid gill parasites on a number of different fish species caught 120km south of Cairo at Beni-Suef (Al-Rasheid et al., 2000). The second reported on the infection pressure on Nile tilapia and catfish (*C. gariepinus*) in the Kafrelsheikh province, with a number of *Trichodinid* spp. and also *Chilodonella hexastica* and *Ichthyopthirius multifillis* as well as other monogenean parasites (El-Seify et al., 2011).

Monogenean parasites:

Like the ciliated protozoa no papers were found that dealt with the effects of monogenean parasites in an aquaculture environment. One study, which spanned wild fisheries and fish culture compared the abundance of *Cichlidogyrus* spp in wild and farmed *Tilapia zillii* (Redbelly tilapia) on Lake Manzala. The results suggested a greater prevalence of the monogenean species in the farmed fish (Ibrahim, 2012).

Acanthocephalans:

Acanthogyrus tilapiae was also present in the fish examined by Dr Ibrahim (Ibrahim, 2012). These parasites cause irritation in the intestine and induce hyperplasia of the goblet cells resulting in increased mucus secretion and focal areas of eosinophil infiltration.

Nematodes:

A study of red anus syndrome (RAS) in the European eel (*Anguilla anguilla*) from the Domiat coast region, reported that 64% of affected fish had the nematode *Anguilla crassus* in their swimbladder. However, yeast, amoeba and myxozoa were also found in the skin around the anus of affected fish thus complicating the aetiology of RAS in this situation (Tamam, 2014).

Zoonotic parasites:

Heteropyhid encysted metacercariae:

Encysted heterophyidae metacercariae were more prevalent during the summer reaching a peak level of 72% and 43% in brackish and freshwater fish respectively in the Dakahlia Governorate (Hegazi et al., 2014). Metacercariae of *Heterophyes heterophyes*, *Heterophyes aequalis*, *Pygidiopsis genata*, *Haplorchis yokogawai* and *Ascocotyle* (*Phagicola*) *ascolonga* were identified in over 20% of *Tilapia niloticus* and *T. zilli* taken from the river Nile at El-Qanater, Qalyobia and from the brackish Lake Manzala in the Dakahlyia governorate (Lobna, et al., 2010). Encysted metecercariae were also found in mullet from Lake Manzala (Elsheikha and Elshazly 2008). The prevalence of metacercariae was highest in the summer and the majority of cysts were found in the musculature in the caudal third of the fish (Lobna et al., 2010). Additionally, heteropyhid eggs were detected in 13% of the humans living in these areas. (Lobna et al., 2010).

Anisakiosis:

Morsy et al. (2015) recorded a new host in the Red Sea for *Anisakis* spp. larvae. Larvae of *Hysterothylacium patagonense*, an *Anisakis* Sp (Type II) and *Echinocephalus overstreeti*, an gnathosome were detected in the greater lizard fish (Saurida undosquamis) (Morsy et al., 2015)

Capillaria philippinensis

Although *Capillaria philippinensis* infection has been diagnosed in humans living in the Assuit and El Menia Governorates and in the Cairo and Menouf areas the evidence for an endemic infection cycle in local fish is equivocal. This due to the possibility of the infection being picked up through eating imported fish from South-east Asia (Attia et al., 2012).

Parasitic infection secondary to the impacts of environmental pollution:

An investigation of mortalities amongst Nile tilapia in the Maariotteya River, a tributary of the River Nile, found a high level of parasitism in the dead and moribund fish (Mahmoud et al., 2014). The pollutants were identified as organic and inorganic chemical waste and sewage effluent. The parasitic fauna ranged from the common ciliated protozoa, the mongenean *Cichlidogyrus arthacanthus*, *Ergasilus* spp. and most importantly zoonotic *Cryptosporidium* and *Balantidium* spp.

Indications of environmental pollution

Organophosphates including diazinon and malthion were detected, albeit at levels below the maximum residue limit, in fish tissue (*T. niloticus*) taken from a number of water supply and drainage canals on the River Nile catchment in the El-Menofiya governorate (Malhat and Nasr, 2011).

Libya:

Only two publications were found from Libyan scientists. The report by Soliman et al. (2011) details the bacterial pathogens found in various wild grouper species and water samples collected on the east coast near Tobrok and El-Bordy. They reported a prevalence of 65% for Pasteurella piscidia and 15% and 10% for *Vibrio anguillarum* and *Aeromonas salmonicida* respectively (Table 7). The microsporidian protozoan *Glugea* spp and *Plistophora* spp were also found in the abdominal tissues of these fish. A survey of flathead mullet taken from the waters near Missurata found that 23% of the fish were infected with the trematode parasites *Vitellibaculum girella* and *Lecithocladium exisum* (Al-Bassel et al., 2012).

Table 7: *Pathogens found in fish along the coast of Libya and reported in the peer reviewed scientific literature.*

Pathogen	Species affected	Location	Co-ordinates
Pasteurella spp *Vibrio spp* *Aeromonas spp* *Staphylococcus spp* *Streptococcus spp* *Glugea spp* *Plistophora spp*	Groupers (wild): *Ephinephelus guaza* *E. aneus* *E. Alexandrines* *E. caninus*	Tobrok and El-Bordy	32^0 05' N; 23^0 58' E
Trematodes: *Vitellibaculum girella* *Lecithocladium exisum*	Flat head mullet (wild): *Mugil cephalus*	Coast near Missurata	32^0 22' N; 15^0 05' E

Mauritania:

Just one publication relating to fish diseases was found. This was a report on the morphology and phylogenic analysis of the newly discovered myxozoan *Henneguya mauritaniensis*. The myxozoan was isolated from the arterial bulb of the heart of bluespotted seabream in the Atlantic Ocean near Nouakchott (Table 8; Khlifa et al., 2012). There was no description of any pathological changes in the heart associated with the parasite.

Tunisia

Viral infections

An outbreak of Lymphocystis Disease Virus (LCDV) during 2011 in fingerling gilt-head sea bream recently imported from Southern Europe highlighted the danger of importing fish of unknown health status (Haddad-Boubaker et al., 2013a). Mortalities, which reached a level of 45%, started within two weeks of the 5-9g fish being introduced onto the farm site in the Sahel region. Molecular analysis of the isolate suggested that it was similar to a previously isolated French strain (SA22.Fr09) of LCDV.

Table 8: *Potential pathogen found in fish along the coast of Mauritania and reported in a peer reviewed scientific paper.*

Pathogen	Species affected	Location	Co-ordinates
Henneguya mauritaniensis	Bluespotted seabream (wild) *Pagrus caeruleostictus*	Coast off Nouakchott	18^0 6'N;15^0 57'W

The first report of Nodavirus (viral encephalopathy and retinopathy) infection in Tunisia was in 2009 (Cherif et al., 2009). It produced severe losses in sea bass hatcheries where the stocking density was high (Cherif et al., 2011). A later second study found symptomatic and asymptomatic infected fish in the majority of farms surveyed along the Tunisian coast (Haddad-Boubaker et al., 2013b). Molecular analysis of the isolates from the various farms found that they were highly related to each other and to isolates obtained from wild fish in the Mediterranean.

Vibriosis

Vibrio parahaemolyticus was isolated from sea bass during an outbreak of vibriosis on two marine farms near Sousse. The isolates were identified as common environmental strains and not infectious to humans (Khouadja et al. 2013).

There is evidence in the scientific literature that amongst *Vibrio* spp. virulence genes can be transferred from one species to another. The results of virulence studies on Tunisian *Vibrio alginolyticus* isolates from cultured sea bass and sea bream as well as environmental seawater samples from Monastir (Bay of Khenis) found they had homologues of virulent genes from *Vibrio cholerae*.(Kahla-Nakbi et al. 2009; Snoussi et al. 20008).

Parasites

As with other North African countries the papers emanating from Tunisian parasitologists and fish biologists mostly dealt with taxonomy including molecular taxonomy and the recording of either the first observation of a species or a new host for known species.

The pathological changes in the gill induced by *Trichodina* spp. in flathead mullet and Egyptian sole (*Solea aegyptiaca*) were described in two papers which also reported the presence of *Trichodina* gobii and *Trichodina puytoraci* in the Ghar El Melh Lagoon for the first time (Table 9;Yemmen et al., 2010/11; Yemmen et al., 2011). The first observation of a number of ciliate and myxozoan spp. in gilthead sea bream was recorded by Bahri (2012). An interesting aspect of this study was that the prevalence of *Amyloodinium ocellalum* was highest in the summer whereas the usual epidemiological pattern in North Africa is for protozoan parasites, in general, to be more prevalent during the winter.

Routine surveillance identified *Perkinsus* spp. infection in clams (*Ruditapes decussates*) during 2004 (Chreif et al., 2011; WAHIS portal of the OIE).

Zoonotic parasites

Over 50% of the gadiform species *Phycis blennoides* (Greater foxbeard) and *Phycis phycis* (Foxbeard) caught off the coast of Tunisia were found to have *Anisakis* spp. larvae (Farjallah et al., 2006)

Disease conditions due to pollution

Spinal deformities such as kyphosis, scoliosis and lordosis in grass gobies (*Zosterisessor ophiocephalus*) were attributed to heavy metal pollution of the Gulf of Gabes (Messaoudi et al., 2009). The authors reported that cadmium and zinc levels were higher in the livers of deformed fish than in normal fish.

Table 9: *Location and species affected for a limited number of parasites (details taken from peer-reviewed publications published by Tunisian scientists) in Tunisia*

Pathogen	**Species affected**	**Location**	**Co-ordinates**
Amyloodinium ocellalum	*S. aurata*	North Lake of Tunis	36^0 49'N; 10^0 15'E
Trichodina spp *T. lepri* *Trichodina gobii* *Trichodina puytoraci*	*S. aurata* *Solea aegyptiaca* (Egyptian sole)	North Lake of Tunis Ghar-El- Melh Lagoon	37^0 10' 26"N; 10^0 11' 31"E
Henneguya tuniensis	*Symphodus tinca* (wrasse)	Kenkennah Islands	34^0 42'N; 11^0 11'E
Ceratomyxa spp	*Sarpa salpa*	Gulf of Tunis	37^0 00' 00"N; 10^0 30' 00'E
		Bay of Bizerte	37^0 16' 28"N; 09^0 52' 26"E
Myxobolus spp	*M.cephalus*	Ichkeul Lake	37^0 10' 00"N; 09^0 40' 00"E
Microsporidia *Microgemma tincae*	*Symphodus tinca*	Bizerte	
		Monastir	35^0 46' 40"N; 10^0 49' 34"E

Appendix 2. Survey to map aquatic animal diseases in Algeria, Egypt, Libya, Mauritania, Tunisia and the Republic of Saharawi

Welcome to this survey to elucidate the range and prevalence of aquatic animal diseases in North Africa. It is part of a larger study undertaken by the African Union-Interafrican Bureau for Animal Resources (AU-IBAR) to gain a general overview of the diseases and their epidemiology currently affecting fish and shellfish on the continent. The overall aim of AU-IBAR is to develop a map illustrating the geographical distribution of the diseases and the species affected.

Commercial fisheries and aquaculture contribute 6% to the agriculture GDP of Africa and have been identified by the New Partnership for Africa's Development (NEPAD), a technical body of the Africa Union (AU), as a sector with potential to foster equitable socio-economic development throughout the continent. The AU-IBAR, another specialized unit of the AU, has been mandated to support and co-ordinate the improvement of livestock, fisheries and wildlife in order to contribute to the food security and economic development in rural areas of the member states.

Disease is a major impediment to the economic production of fish and shellfish. In Africa at present, there is a dearth of knowledge on the occurrence of fish diseases and the risk factors that enable their spread within a country and on occasion, trans-nationally. The OIE General Assembly in 2015 expressed concern over many notifiable diseases such as *Aphanomyces invadans* (EUS), White Spot Syndrome and Abalone Herpes Virus extending their geographical distribution from southern Africa northwards.

A lack of knowledge of the health status of the aquatic animals in the freshwater watersheds, oceans and seas in and around the continent poses a bio-security threat and hinders the development of commercial fisheries and aquaculture. It also prevents putting in place adequate infrastructure for diagnosis and surveillance and developing suitable strategies to cope with any major disease outbreaks that will inevitably occur in the future. It is only when the potential disease threats are known can mitigation measures such as general surveillance and/or monitoring for specific designated pathogens be instituted. For this reason AU-IBAR under their Fisheries Governance Policy is seeking to gather information on the occurrence of aquatic animal disease in the wild and in the various aquaculture production systems used on the continent. Additionally, it is seeking to establish the geographic location of these diseases and the risk factors for their occurrence.

As a key contributor to the fields of ichthyology, fish pathology and fishery management, we ask you to complete the attached questionnaire. It is suggested that if you work in a University or Research Institute that you only answer the questions appropriate for your interest, expertise and experience. Some of the earlier questions are targeted for veterinarians/biologists/microbiologists working in a regulatory agency. The later questions from question 6 onwards are designed for the wider veterinary/scientific community working in aquatic animal medicine and the aquaculture industry.

Questions about the survey should be addressed to Dr Tom Murphy (tmmurph@eircom.net) and copied to Dr. Nelly Isyagi (nelly.isyagi@au-ibar.org).

There are 17 questions and these are the topics you will be asked to consider:

1. Infrastructure associated with disease diagnosis, surveillance and control
2. National and on-farm bio-security practices

3. Aquatic animal health status including disease outbreaks and associated risk determinants.
4. Undergraduate veterinary education and continuing professional developing training courses in fish medicine and disease

Name	
e-mail address	
Position	
University/Research institute Or other affiliation	

Questionnaire

1. Do the laboratories of the veterinary service (VS)/aquatic animal health service (AAHS) provide diagnostic testing, surveillance and an advisory service to the aquaculture industry at a:

	Yes/No/Don't know
National (central) level only?	
National and regional levels only?	
National, regional and some local levels?	
National, regional and all local levels?	

2. Do the laboratories offering a fish disease diagnostic service use:

	Yes/No/Don't know
Accredited/quality assured diagnostic tests?	
New diagnostic techniques such as PCR and other molecular methods?	

3. Does the VS/AAHS

	Yes/No/Don't know
Have a database of farms, with their locations and geo-reference, where disease outbreaks have previously occurred?	
An information management system for recording details of notifiable disease outbreaks?	
An information management system for recording details of non-reportable disease outbreaks?	

4. Reporting system:

Is there a mandatory reporting system for notifiable/ OIE listed diseases that are detected by	**Yes/No/Don't know**
Private veterinary practitioner	
Vet. Service/AAHS field officer	
National/Regional Veterinary Investigation/ Diagnostic Lab.	
University research workers/labs	
Local Fish Biologist	

5. Legislative framework for disease control

Are there appropriate laws and a legislative framework to allow the implementation of emergency disease control measures (including compensation mechanisms for affected fish farmers)?	**Yes/No/Don't know**

6. On a scale of 1-3 rate the use of the fish disease services, listed below, by finfish and shellfish farmers.

1 (low) = zero use,

2 (medium use) = periodic health checks and during some incidences of mortalities

3 (high use)= regular health checks and during every disease outbreak

Aquatic animal disease service	Routine health checks	Disease outbreaks/ incidences of high mortalities
Private veterinary practitioner		
Vet. Service/AAHS field officer		
National/Regional Veterinary Investigation/ Diagnostic Lab.		
University research workers/labs		
Local Fish Biologist		

7. Are the following building blocks present in your country and/or region/province for a risk based surveillance programme for finfish and shellfish diseases?

Building blocks for risk based surveillance of aquatic animal diseases	Yes/No
Farm registration with location geo-referenced	
Testing brood stock for OIE listed diseases and endemic diseases that are transmitted vertically via fertilized ova e.g. Channel Catfish Virus (CCV), IHHNV & White Spot Syndrome Virus in shrimp	
Routine testing of farm production stock	
Official authorisation required for movement of disinfected eggs and specific pathogen free (SPF) live fish	
Farmers obliged to keep a register of disease outbreaks and treatment regimes	
A system of voluntary reporting of disease outbreaks and/or incidences of high mortalities by farmers is in place	
Routine examination of slaughtered fish	
Surveillance and testing of wild fish for endemic and exotic disease	

8. From your experience of the aquaculture industry make an educated guess of the percentage of finfish and shellfish farmers, in your region/province, who practice the farm bio-security protocols listed below:

Bio-security protocol	Approx. percentage (%) of farms where policy is practiced
Farmer/staff received training on fish diseases	
Farmer/staff adhere to good personal hygiene: disinfect hands, clothing, boots and equipment after handling fish	
Separate equipment (nets etc) for each tank/pond/cage	
Disinfect equipment after use	
Only disinfected eggs from a SPF source introduced onto the farm	
Only live fish from a certified SPF source introduced onto the farm	
Newly introduced eggs and fish kept in separate rearing tanks/ponds	

Bio-security protocol	**Approx. percentage (%) of farms where policy is practiced**
Recording and removal of daily mortalities	
Removal of uneaten food (if fish holding facilities allow)	
Routine examination of fish stocks for external parasites and other diseases	

9. What is the current disease status in your country/region/province vis-à-vis the OIE- Listed diseases that were in force in 2015?

Disease/ pathogen	**Disease status**		**Number of farms infected**	**Location or geo-co-ordinates (if known) of infected farms**	**Control / eradi-cation proce-dure put in place during outbreak**	**Presence of eradica-tion plan (E) or con-tingency plan (C) for control**	**Surveillance**		
	Never occurred or date of last outbreak	**Species affected**					**Passive +/-**	**Active +/-**	**Target species**
Epizootic haematopoietc necrosis									
Aphanomyces invadans (Epizootic ulcerative syndrome)									
Salmonid alphavirus									
Infectious haematopoietic necrosis virus									
Koi herpes virus									
Red sea bream iridovirus									
Spring viraemia of carp									
Abalone herpesvirus									
Bonamia exitiosa									
Bonamia ostreae									
Marteilia refringens									
Perkinsus marinus									
Perkinsus olseni									
Xenohaliotis									
californiensis									
Infectious hypodermal and haematopoietic necrosis virus									
Acute Necrotising Hepatopancreatitis [Eary Mortality Syndrome (EMS)]									

Disease/ pathogen	Disease status		Number of farms infected	Location or geo-co-ordinates (if known) of infected farms	Control / eradi-cation proce-dure put in place during outbreak	Presence of eradica-tion plan (E) or con-tingency plan (C) for control	Surveillance		
	Never occurred or date of last outbreak	Species affected					Passive +/-	Active +/-	Target species
Taura syndrome Virus (TSV)									
White spot disease									
Syndrome Virus									
(WSSV)									
Whitetail disease									
Infection with Batrachochytrium dendroatidis									
(Amphibians)									
Infection with Ranavirus									
(Amphibians)									
Crayfish plague (Aphanomyces astaci)									
Infection with Yellowhead virus									

10. Categorise the OIE non-reportable/endemic diseases/pathogens listed below as either being absent from your region or being present and causing no problem, present and causing a problem or present and causing a severe problem.

Disease/pathogen	**Absent**	**Present - no problem**	**Present - problem**	**Present - severe problem**
Aeromonas hydrophila (Bacterial haemorrhagic septicaemia)				
Other Aeromonad spp (including furunculosis)				
Flexibacter columnaris				
Flavobacterium columnaris				
Cyptophaga spp				
Yersinia ruckeri				
Enterococcus spp. (e.g. *E. faecelis*)				
Streptococcus iniae				
Streptococcus spp. (e.g. S. faecelis)				
Edwardsiella tarda				
Edwardsiella ictaluri				
Pseudomonas fluorescens				
Pseudomonas aureginosa				
Pseudomonas anguilliseptica				
Pseudomonas pseudoalkaligones				
Klebsiella pneumoniae				
Streptococcus pneumoniae				

Disease/pathogen	Absent	Present - no problem	Present - problem	Present - severe problem
Mycobacterium fortuitum, M. marinum and other *Mycobacteria spp*				
Epitheliocystis				
Lymphocystis				
Viral nervous necrosis (VNN)_				
Infectious pancreatic necrosis virus (IPNV)				
Ichthyophthirius multifilis				
Gyrodactylus spp				
Sparyocotyle chrysophrii				
External protozoan parasites of the gill and skin *(Costia, Chilodonella, Trichodina spp)*				
Henneguya spp				
Cultivated catfish virus (CCV)				
Marine Flexibacteriosis				
Tenacibaculum maritinum				
Pasteurellosis				
Photobacterium damselae subspecies piscida				
Vibrio anguillarum				
Vibriosis (Atypical)				
Flavobacterium psychrophilium				
Lactococcus garvie (Lactococcosis)				
European eel viruses (EVE, EVEX & AngHV1)				
Saprolegnia				
Branchiomyces				
Ichthyophonus hoferi				
Enterocytozoon hepatopenaei (EHP)				
Hepatopancreas microsporidiosis				
Neoparamoeba/ Paramoeba spp. (Amoebic Gill Disease)				
Sanguinicola spp. (Blood Fluke)				
Bothricephalus spp.				
Proteocephalus spp.				
Nesolecithus africanus				
Ligula spp. (pleurocercoids)				
Philometra spp.				
Contracaecum spp.				
Acanthocephalus spp.				
Lernaeocera spp.				
Argulus spp.				
Ergasilus spp.				

11. Please fill in the following details (as shown in the example) for those diseases/pathogens in the previous section that you categorised as being a problem or a severe problem

Disease/ Pathogen	No. farms infected	Farm site Marine (M) Fresh (F) River (r) /lake (l) Brackish (B)	Rearing unit Cage (C) Pond (P) Tank (T)	Geo-Reference or location of farm	Species affected	Age & approx no. of fish at risk	Approx no. of fish infected	Approx no. of mortalities (% mortality)	Infected farms up and/or downstream from the main outbreak Yes/No
IPNV	4	F	T	Cairo 300. 3'N 310. 14'E	Rainbow trout	Fry 200,000	20,000	10,000 (5%)	Yes

**Please add extra rows as necessary and fill them out, include also any disease/ diseases that occur (s) in your region/province that has (have) not been listed in the previous section and that you consider are important.*

12. Have the farmed and wild finfish and shellfish in your country/region been identified as carriers of the following zoonotic parasitic diseseases. Add extra rows and include also any other zoonotic microbial pathogens that have not been listed previously in question 10.

Zoonosis	Cultered finfish & shellfish		Wild finfish and shellfish		Prevalence (Approx.)	Geo-reference or location
	Present Yes/No	Species	Present Yes/No	Species		
Heterophyiosis (including *Heterophyes spp* *Haplorchis sp.* *Pygidiopsis sp.* *Phagicola sp.* *Stictodora sp.* Etc)						
Capillaria philippinensis						
Echinostomdiidae						
Anisakiasis						
Anisakis sp.						
Paragonimus spp						

13. Identify the pathogens on your list in Question 11 that in your opinion have the potential to spread locally within your country/region and possibly into neighbouring countries. Give one reason to support your judgement for each pathogen selected.

Pathogen	Reason for selection

14. Have there been any recorded Dinoflagellate and Cyanobacteria toxic blooms in marine and freshwater sites in your region/province in the previous five years?

	Yes/No /Don't know	If yes, no. of blooms	Geo-reference (if known) or name of location
Marine Dinoflagellate toxic bloom			
Freshwater Cyanobacteria toxic bloom			

15. Do you agree or disagree that the factors listed below may have an influence on the future spread of aquatic animal diseases locally within a country or across national boundaries into neighbouring countries in the North African region.

Factor for the spread of infectious disease	Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
New strains of existing pathogens arising through genetic change					
Increased population of known disease vectors					
Emergence of new disease vectors					
Increased number of accidental introductions of existing pathogens into areas that were previously free					
Increased role of waterborne route for pathogen spread					
Emergence of new diseases from wild fish and shellfish reservoirs					
Failure to develop innovative and rapid diagnostic tests					
Lack of innovative techniques to detect and identify new emerging diseases					
Increased pathogen resistance to drugs					
Lack of new drugs to control disease					
Increased fish to fish transmission due to increased stocking densities					

Factor for the spread of infectious disease	Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
Lack of genetically modified disease resistant fish					
Lack of adequate on-farm systems for disease control					
Lack of adequate disease surveillance systems					
Lack of innovative information technology for disease surveillance and communication					
Lack of or poor implementation of national and international legislation on bio-security					
Lack of new vaccines					
Increasing temperature					
Increased frequency of heavy rainfall and flooding					
Increased frequency of drought					
Introduction of exotic fish/shellfish spp. of unknown or known disease status					

16. Education

	Yes/No/Don't know
16a. Is Fish Medicine/Fish Pathology part of the syllabus of the veterinary medicine undergraduate course?	
16b. Are fish disease training courses available for veterinarians in general practice and for fish farmers and fish farm staff?	

17. Details of in-service and continuing professional development courses (CPD) on fish diseases

	Details of in-service and CPD courses for veterinarians and farmers
If you answered "yes" to question 16b, please give details of the in-service/CPD courses	

Appendix 3: Inventory of aquatic animal diseases as reported by the respondents to a questionnaire on disease incidences in North Africa

Table 1: *Pathogens of farmed Tilapia (Oreochromis niloticus) considered important by an Egyptian respondent (Professor Aly) to the questionnaire.*

Pathogen	Type	Common name of disease	Production system
Aeromonas hydrophila	Bacterium	Bacterial haemorrhagic septicaemis	Freshwater pond
Mycobacterium spp.	Bacterium		Freshwater pond
Gryodactylus spp.	Monogenean trematode		Freshwater pond
Saprolegnia spp.	Fungus		Freshwater pond
Branchiomyces spp.	Fungus		Freshwater pond

Table 2: *Pathogens of the common goldfish (Carassius auratus) considered important by an Egyptian respondent (Professor Aly) to the questionnaire.*

Pathogen	Type	Common name of disease	Production system
Aeromonas hydrophila	Bacterium	Bacterial haemorrhagic septicaemis	Freshwater pond
Ichthyopthirius multlifiliis	Protozoa	White Spot	Freshwater tank
Gryodactylus spp.	Monogenean trematode		Freshwater tank
Ichthyobodo (Costia) spp. *Chilodonella spp.* *Trichodina spp.*	Protozoa	Skin and gill parasites	Freshwater tank
Argulus spp.	Copepod		Freshwater pond
Lernaea spp.	Copepod		Freshwater pond

Table 3: Pathogen of farmed African catfish (Clarius gariepinus) considered important by an Egyptian respondent (Professor Aly) to the questionnaire.

Pathogen	Type	Common name of disease	Production system
Henneguya spp.	Protozoa (myxosporean)		Freshwater pond

Table 4. Pathogen identified as being important in sea bream (Sparus aurata) aquaculture units by an Egyptian respondent (Professor Aly) to the questionnaire.

Pathogen	Type	Common name of disease	Production system
Spariocotyle chrysophrii	Monogenean trematode		Marine pond

Table 5: Pathogen identified as being important in groupers (Epinephalus spp.) aquaculture units by an Egyptian respondent (Professor Aly) to the questionnaire.

Pathogen	Type	Common name of disease	Production system
Vibrio anguilarum	Bacterium	Vibriosis	Marine pond

Table 6. OIE listed disease outbreak in shrimp in Algeria

Pathogen	Type	Common name of disease	Production system
White spot syndrome virus	Virus		Marine tank

Appendix 4: List of contacts

Algeria

Name	Affiliation
Dr Zouhir Ramdane	Universite A/Mira-Faculte des Sciences, Targa Ouzemour, Bejaia
Dr L. Aggad	National Agriculture and Veterinary Institute
Dr Hamid Benderradjii	Ministere de la Peche et des Resources Halieutques
Dr Bouguerra Fatiha	Ministry of Fishing and Fish Resources
Dr Karim Mezoli	Abdelhamid Ibn Badis University
Prof. Zitourni Boutiba	Universite d'Oran
Dr Kridech Abdelhamid	Abdelhamid Ibn Badis University, Mostaganem
Dr Souhila Alouache	Faculty of Biological Sciences, University of Science & Technology Houari, Boumediene
Dr DouniazedMarzoug	Universite d'Oran
Dr Hichem Kara	University of Annaba
Dr N. Touarigt	Societe Algrienne de Medecine Veterinaire

Egypt

Name	**Affiliation**
Dr Abdallah Elbialy	Veterinary Research Division, National Research Centre
Dr Mohamed Fathi Osman	Ains Shams University (World Fish)
Dr Ibrahim Mahrous Saleh Mohamed	General Organisation for Veterinary Services (GOVS), OIE Representative
Prof. M.A. Mahoud	Faculty of Veterinary Medicine, University of Cairo
Dr Safaa Z. Arafa	Dept. Zoology, Mansoura University
Dr F. Abdel-Chaffer	Dept Zoology, University of Cairo
Dr Alaa Eldin Eissa	Dept. Fish Diseases & Management, University of Cairo
Dr Mahmoud Abou Okada	Faculty of Veterinary Medicine, University of Cairo
Dr Omar A.S. Tamam	Dept. Natural Resources, University of Sadat City
Dr M.M. Azza	Dept of Fish Health & Management, Central Laboratory for Aquaculture Research
Dr Ahmed El Ashram	Dept of Fish Health & Management, Central Laboratory for Aquaculture Research
Dr Mamdouh Elgendy	Dept. Hydrobiology, National research Centre
Dr H.E.M. Farag	
Dr Mona Zaki	Dept. Hydrobiology, Veterinary Division, National Research Centre, Dokki.
Dr T.T. Saad	Dept. Poultry & Fish Diseases, Faculty of Veterinary Medicine, University of Alexandria
Dr Maha El-Hady	National Research Centre, Dokki
Dr Kareem Morsy	Dept. Zoology, University of Cario
Dr A. El-Morsy	National Institute for Oceanography & Fisheries, Cairo
Dr Mohamid A. Ali	National Institute for Oceanography & Fisheries, Cairo
Dr Nisreen E. Mahmoud	Dept. Parasitology, Faculty of Veterinary Medicine, University of Cario
Dr Mohamed M. Ibrahim	Dept. Zoology, Suez Canal University
Prof. Mahmoud Aly	Dept. Pathology, Faculty of Veterinary Medicine, University of Cario
The Director	Veterinary Division of the National Research Centre
Dr El Dessouky	Egyptian Veterinary Medicine Association
Dr Kechrid Faouzi	EuroArab Veterinary Medicine Association
Dr Ahmed Fathy	
Prof. Morsy	General Organisation for Veterinary Services, Alexandria
Prof. Ahmed Said Diab	Central Aquaculture Laboratory

Egypt

Name	**Affiliation**
Dr Ali Ahmed El-Fituri	Marine Biotechnology Research Centre
Dr Ali Mesbah Ahmed Derar	
Dr M.A.M. Sharif	University of Omar Al-Mukhtar
Dr Abdulwahab Kammon	Faculty of Veterinary Medicine, University of Tripoli; National Centre for Animal Health, Zawia.
Dr Ibrahim eldaghayes	Faculty of Veterinary Medicine, University of Tripoli; National Centre for Animal Health, Zawia.
Dr W.S. Soliman	Dept. Poultry & Fish diseases, Faculty of Veterinary Medicine, Al-Fatah University
Dr D.A.H. Al-Bassel	Dept Zoology, Faculty of ScienceFayoum University
Dr A. Watig	Marine Biology Centre, Tajura.
Dr Abu Bakr Sowihly	Faculty of Veterinary Medicine, University of Tripoli

Mauritania

Name	Affiliation
Dr Mohamad Ould Baba Gueya	National Veterinary Services, OIE Representative
Mme Azza Mint Jiddou	Deputy Director, Mauritanian Institute of Oceanographic & Fisheries Research.
Mohammed Fal Weld El-Sheikh	
CNERV	La Centre Nationl d'Elevage et de Recherche Veterinaires
President	Ordre National des Veterinaires de la Mauritania
Dr Ahmed Salem Elarbi	Director adjoint des Services Veterinaires, Ministere de l'Elevage
Lamine Camara	Deputy Director, Resource Management & Oceanography, Ministry of Fisheries &Maritime Economy.
Sidi Ould Khalifa Khlifa	Office National d'Inspection Sanitaire des Produits de la Peche et de l'aquaculture (ONISPA/MPEM), OIE Focal Point

Tunisia

Name	Affiliation
Dr Malek Zreli	National Veterinary Service, Ministere de l'Agriculture
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Dr Ammar Yaakoubi	Institute de Recherché Veterinaire de Tunis
Prof. Mejdoddine Kraiem	Institute Nationale des Sciences et Technologia
Prof. Raouf Dhaouadi	Ecole Nationale de Medicine Veterinaire
Prof. Lassad Neifar	Universite Sfax
Dr Chiraz Yemmen	Faculty of Science University of Tunis El-Manar
Dr Foued Mestiri	Institute de la Recherche Veterinaire de Tunisia
Dr Amel Ben Kahla-Nakbi	Institute National des Sciences et de Technologia de la Mer, Momnastir.
Dr Salah Hammami	Institute de la Recherche Veterinaire de Tunisia
Director	Institute de la Recherche Veterinaire de Tunisia
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Dr Mohammed Ben Salem	Dept. Zoology, University of Tunis
President	Veterinary Medical Association of Tunisia
Mr Naoufel Haddad	Association Tunisienne pour le Development de la Peche Artisanale

Nongovernment organizations

Name	Affiliation
Ahmed Senhoury	Director of Programme Regional de Conservation de la Zona Cotiere et Marine
Mrs Faouzia Chakiri	Dept. Food Security, Arab Maghreb Union
Dr Abdelouahed Benabbou	COMHAFAT
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