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Review Article

Future Prospects of Biosecurity Strategies in Egyptian Fish Farms

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Abstract

Earthen pond rearing system is the most prevalent type of aquaculture facilities in Egypt due to low construction costs. Such facilities are characterized by open nature which allows large numbers of imposing factors to interact with cultured fishes during the production cycle. Aquatic invasive species (i.e., red swamp cray fish: *Procambrus clarkii*), migratory birds, wild amphibians and reptiles are staggering examples for such interacting factors, which impose severe deleterious impacts on the fish production cycle. The active nature and vast distribution of these species will ultimately violate the rearing regime of the fish farming facility through the establishment, proliferation and spread of pathogens by mechanical, biological and direct infectious routes. Further, the wet nature of aquaculture operations, frequent introduction of new broodstocks, fish meal, reuse of agricultural drainage water and faulty use of animal manure as well as movement of fish from different localities offers a multitude of opportunities for pathogen entry to fish farming operations. Once introduced, pathogens can easily proliferate within the systems leading to potent disease issues, sometimes leading to a complete collapse in production, or more intermittent outbreaks affecting output reliability. Therefore, this study is designated to examine the key role played by invasive species, vectors and reservoirs responsible for pathogen introduction into fish farms. Moreover, the essential needs were discussed for development of practical methods to limit pathogen introduction, spread and proliferation at any level of fish production cycle parallel with the adoption of Good Aquaculture Practice (GAP) and Hazard Analysis and Critical Control Points (HACCP) in Egyptian fish farms.

Key words: Biosecurity, invasive species, earthen pond aquaculture, HACCP, Cryfish

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INTRODUCTION

Despite the fact that other animal rearing systems (i.e., poultry) have fully developed and finely tuned biosecurity procedures in place, yet, biosecurity is a relatively new terminology in the aquaculture dictionary (Lee and O'Bryen, 2003). Initial discussion about the term aquaculture biosecurity has been firstly introduced at the Second International Conference on Recirculating Aquaculture by Bebak (1996). However, the first profound discussion of biosecurity in aquaculture occurred in 1997 at a World Aquaculture Society (WAS) Special Session titled, 'Sustainable shellfish Farming: Emerging Technologies and Products for Biosecurity and Zero Discharge (Guillermo, 2000). By 2003, proceedings of several workshops were published presenting very valuable information on the need, application and problems related to aquaculture biosecurity (Lee and O'Bryen, 2003). Following the year of 2003, several literatures have explicitly discussed the issue of aquaculture biosecurity with different degrees of success (Pruder, 2004; Delabbio *et al*., 2005, Delabbio, 2006; Scarfe *et al*., 2008; Oidtmann *et al*., 2011; Faruk *et al*., 2012; Stentiford *et al*., 2012).

The adoption of biosecurity protocols in tilapia aquaculture has required significant changes in the tilapia stocks and adjustments in feeds, genetic traits for selection and overall production procedures (Delabbio *et al*., 2004; Gutierrez-Wing and Malone, 2006). Biosecurity in aquaculture is a maturing activity, still in need of improved information on diagnostics, disease transmission, clean up and eradication (Hine *et al*., 2010; Bondad-Reantaso *et al*., 2012). Biosecurity, health, nutrition, genetics and environmental quality must be integrated to achieve a uniform and low cost product on demand (Bondad-Reantaso *et al*., 2012).

In general, biosecure operations should have a defined structure and barriers, such as fences and gates in place (Pruder, 2004). The facility should be constructed with materials that can be disinfected easily should a disease outbreak occur and is free from unauthorized access such as vehicles or people (Pruder, 2004; Bondad-Reantaso *et al*., 2012). Structurally, it should also prevent the escape of cultured fish and the entry of other invasive aquatic species (Arechavala-Lopez *et al*., 2013). It should be sited away from hazards that are potential sources of infection or contamination. Untreated surface water (i.e., agricultural drainage water) should not be used as the source water because it may contain pathogens. The ideal system should have appropriate back-up water, life support systems and operational procedures that allow one-way flow, so that nothing can be returned to the facility without disease screening (Scarfe *et al*., 2008; Bondad-Reantaso *et al*., 2012).

Biosecurity is practiced at three intensity levels: (1) Specific pathogen-free (free of defined infectious agents) for vaccine and laboratory reagent production (2) Primary aquaculture industry, (3) Commercial production level. In general terms, the resources for disease control in aquaculture industry involve one or more of the pathogen eradication methods such as disinfection (Torgersen and Hastein, 1995). Routine disinfection is used to reduce the pathogen load in a facility, thereby reducing the risk of spreading an infectious organism between groups of fish in a single facility (Torgersen and Hastein, 1995; Eissa *et al*., 2007, 2013).

An important area of disease prevention and control that is often overlooked in the aquaculture for nets and other shared equipment is one method used to inactivate potential pathogenic organism. However, having separate equipment (nets, feed buckets, water sampling jars etc.) for each production unit would be optimal in helping to eliminate the risk of cross contamination between production systems (Scarfe *et al*., 2008; Bondad-Reantaso *et al*., 2012). Disinfecting live-haul vehicles after delivery of stock to farms or other facilities also helps to avoid bringing back a potential pathogen from these other sites (Eissa *et al*., 2007; Scarfe *et al*., 2008; Can *et al*., 2012; Yanong and Erlacher-Reid, 2012). In addition, cleaning and disinfection of the fish farm facility and associated equipment between production cycles is very important and helps reduce the risk of spreading infectious agent from one production group to the next (Eissa *et al*., 2007; Scarfe *et al*., 2008; Yanong and Erlacher-Reid, 2012). The correct use and selection of disinfectants is very important and ensures that pathogen challenge is minimized, maximizing the fish's natural defense against infection (Torgersen and Hastein, 1995; Eissa *et al*., 2007; Can *et al*., 2012). This, in turn, will dramatically reduce incidences of disease, reducing mortality and saving the farmer's money.

Invasive species is a growing worldwide threat, causing losses in biodiversity, changes in ecosystems and impacts to economic enterprises such as agriculture, forestry, fisheries, power production and international trade (Eissa and Zaki, 2011; Eissa *et al*., 2012). An Invasive species' is a species that is (1) Non-native to the ecosystem under consideration and (2) Whose introduction causes or is likely to cause economic or environmental harm or harm to human health" (Rahel and Olden, 2008). Invasive aquatic species are the toughest enemies to the native species in the aquatic environment either in the open water or under cultured condition (Eissa and Zaki, 2011). Some species that become invasive are intentionally imported and escape from captivity or are carelessly released into the environment (Edgerton, 2002; Padilla and Williams, 2004; Fishar, 2006). Other invasive species are unintentionally imported, arriving through livestock and produce, or by transport equipment such as packing material (Edgerton, 2002; Padilla and Williams, 2004). Fish and shell fish pathogens and parasites have been introduced unintentionally into the Egyptian water basin in infected stock destined for aquaculture (Fishar, 2006). Crates and containers can harbor snails, slugs, mollusks, beetles and other organisms (Edgerton, 2002; Padilla and Williams, 2004).

Stimulated by the expansion of the global transport of goods and people, the numbers and costs of invasive species are surging at an alarming rate (NISC., 2001). The cost to preventing and controlling invasive species is not well understood or documented, but estimates indicate that the costs are quite high, in the range of millions of dollars per year (OTA., 1993; Pimentel *et al*., 2000, 2001). An obvious example for the harmful effects produced by an invasive species such as red swamp crayfish (*Procambrus clarkii*) (Fig. 1) is the damage to the infrastructure of fish farms by burrowing and making tunnels under the bottom layers and borders of fish ponds (Fishar, 2006). Moreover, crayfish are voracious eaters for the fish frys which might predispose to high economic losses and increased possibility of pathogen transmission to the reared fish species (Fishar, 2006). Thus, the development of competent biosecurity strategy for the Egyptian fish farms species from the danger of introduced and invasive aquatic species. Rigorous biosecurity strategy is the only logical solution for infectious diseases, economic as well as public health concerns raised by the inefficient management of fish culture facility that offers an aquaculture product for consumers (Daszak *et al*., 2000).

Aquaculture exports in general are looked upon as potential carriers of harmful chemicals, antibiotics and bacteria by major exporting countries (Avnimelech, 2006; Gutierrez-Wing and Malone, 2006). Therefore, the exporters are continually swamped by new requirements related to labeling, traceability, bioterrorism, assurance of product safety, risk assessment, etc (Reilly and Kaferstein, 1997). This has lead to the creation of Good Aquaculture Practices (GAP) which is tremendously focused on pre-harvest phase for improved production, food safety assurance and preservation of environments (Reilly and Kaferstein, 1997). Emphases has been placed on fish farming practices like pond preparation, disinfection of water, aeration, temperature, pH, alkalinity, salinity, feeding issues, sludge reduction, lowering water exchange, removal of nitrogenous compounds, use of antibiotics, use of probiotics and so on (Avnimelech, 2006; Gutierrez-Wing and Malone, 2006). Based on the heightened expectations and enthusiasm of the aquaculture industry in the producing countries, it is believed that GAP alone will not be adequate but by the implementation of Hazard Analysis

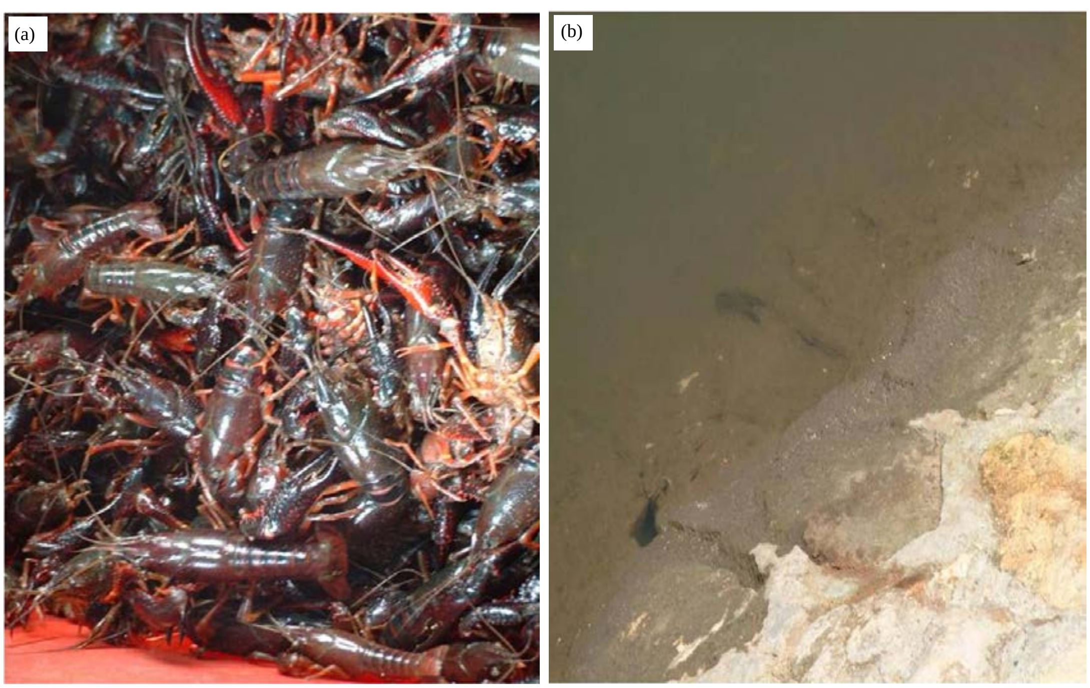

Fig. 1(a-b): (a) Invasive species, red swamp crayfish (*Procambrus clarkii*) and (b) Tunnels made by the red swamp crayfish through the agricultural lands beneath the earthen pond aquaculture facilities and Critical Control Points (HACCP), a competent biosecurity panel can be achieved (Reilly and Kaferstein, 1997; Lie, 2008). This integrated approach primarily for food safety also provides adequate focus on the pre-harvest phase for safe, profitable and sustainable fish farming. Under the HACCP program implementation, critical control points are determined and corrective steps are taken before it becomes a hazard (Lie, 2008). Routine screening of fish samples using recent molecular and serological techniques has come to play an important role in managing pathogens in aquaculture (Scarfe *et al*., 2008).

Despite the fact that earthen pond based aquaculture is the most prevalent type of fish farming in Egypt due to the lower costs of using agricultural lands , water supply , natural food, ideal usage of polyculture/integrated systems and cheap manpower (Can, 2013). Yet, the violation of the fish farm biosecurity is more common. An ideal example of the violated biosecurity in aquaculture and their related aquatic environments is the spread of avian influenza (H5N1) through multiples of aquatic species in open water and semi-intensive earthen pond aquaculture facilities (Feare, 2006; Cristalli and Capua, 2007). Eissa *et al.* (2012) have detected the avian influenza virus in hemolymph of the invasive species red swamp crayfish (*Procambrus clarkii*) from three different aquaculture facilities neighboring migratory birds natural stop stations at three different Egyptian Northern provinces. They also detected the virus in some wild invasive fishes that represent a great threat to mariculture systems such as puffer fish (*Lignocephalus scleratus*) (Fig. 2).

Interestingly, Eissa *et al.* (2012) were able to detect the virus in the blood of catfish (*Clarius gariepinus*) that were erratically fed on dead chicken carcasses dumped into water streams neighboring poultry farms (Fig. 3). They have also detected the virus in poultry manure used for organic fertilization of aquaculture earthen pond facilities and attributed the existence of the virus to the inefficient heat treatment/aeration of the poultry manure before usage (Fig. 4).

Such staggering violation to the biosecurity of aquaculture systems necessitates the wise adoption of competent biosecurity strategies in aquaculture facilities state wide.

DISCUSSION

There are numerous types of aquaculture facilities that exist all-over the world. The earthen ponds are among the most prevalent types in Egypt due to low construction costs (Eissa *et al*., 2012). The earthen ponds represent more than 90% of the culture facilities in Egypt. Such facilities are characterized by open nature which allows large number of extrinsic factors to interact with cultured fishes during the production cycle.

Fig. 2: Pufferfish (*Lignocephalus scleratus*) external topography and dissection

Fig. 3: Sharp toothed catfish predating on dead bird carcasses

Fig. 4(a-b): (a) Poultry manure sample after collection and (b) Poultry manure piles before earthen pond natural fertilization

Numerous interacting factors are incriminated in violating the optimal production capacity of such fish farm facility and dramatically reduce the profitability of the associated aquaculture project (Eissa *et al*., 2008, 2012). Some of the extrinsic factors are related to water used in fish farming such as the bylaw mandatory use of agricultural drainage water as the main water source for the facility which might possibly carry large number of pollutants. Pesticides (Organophosphates, organochlorines), heavy metals (lead, mercury, cadmium and copper) (Eissa *et al*., 2009) and many biological agents (*Streptococcus* species, *Aeromonas* species, coliform and moulds) are the possible threats arising from the agricultural drainage water use (Eissa *et al*., 2008, 2009).

Other factors are related to the introduction of some invasive aquatic species such as freshwater red swamp crayfish (*Procambarus clarkii*) that escapes from the natural water bodies and get access into the fish farm facility (Fishar, 2006). The negative effects of such invasive species are deleterious to the fish production through burrowing at the mud layer of the fish farm facility leading to the development of tunnels that predispose to unexpected physical collapse of the ponds infrastructure (Fishar, 2006). The voracious appetite of such crawfish makes them able to feed on frys and fingerlings of the cultured fishes (Fishar, 2006). Moreover, the sharp claws of the thoracic legs of them could possibly injure the cultured fish which represent some portal of entry for fish pathogens. Further, they might act as possible vectors for specific fish pathogens. However, biological control can be offered as cheap/environmentally safe method for control of invasive crayfish (*Procambrus clarkii*).

Biological control of cray fish refers to the intentional introduction and enterprise or encouragement of natural enemies of crayfish. An exceptional method for decreasing elevated numbers of crayfish is to stock and uphold a healthy population of carnivorous/predator fishes in the infested waters. Catfish and Nile perch eat crayfish and can help to decrease huge numbers (Blake and Hart, 1993). Properly stocked carnivorous/predator ponds seldom have burrowing crayfish problems. Other natural predators that feed heavily on both young and adult crayfish are: amphibians (bullfrogs, salamanders), aquatic birds (herons, kingfishers, ducks and geese). Enhancing wildlife species that prey on crayfish to live near your pond by providing suitable habitat is a good strategy. They provide year-round protection from burrowing crayfish problems without the need for expensive trapping and potentially hazardous chemical use (Bills and Marking, 1988; Frutiger *et al*., 1999; Fishar, 2006). Complete elimination of all crayfish usually is not feasible, rarely practical and certainly unwanted, considering their useful value. Control is successful when the balance between the predators (fish, amphibians and birds) and the prey species (crayfish) is reached and excessive burrowing damage is reduced to an acceptable level.

Trapping crayfish is a very effective control technique. Several types of crayfish traps can be prepared by using one-half inch (1/2") mesh chicken wire. Funnel-end commercial *Tilapia zilli* traps are often modified by enlarging the openings to 2 inches (2") in diameter to permit an easy entry by large crayfish (Cange *et al*., 1986; Bills and Marking, 1988; Fishar, 2006). A string of funnel traps left overnight should produce a good catch. Most other traps are similar to those used to catch saltwater crabs. Any fresh fish or meat serves as an effective bait to lure crayfish to the trap. Meat scraps, fish heads, or almost any high-protein substance can work (Blomquist, 2003). For overnight trap setting times, include the bait in hardware cloth to prevent the trapped crayfish from eating all the bait and reducing trap effectiveness (Cange *et al*., 1986; Bills and Marking, 1988).

The habits of crayfish strongly influence how easily they are caught. Crayfish overwinter in their burrows or the bottom muds or shoreline banks and emerge as the water warms. Mid-April/early May is the time when crayfish first become active (Fishar, 2006). The optimal water temperature range for crayfish is between 4-24°C. As temperatures drop below or rise above this range, crayfish become inactive and stop feeding. Crayfish are nocturnal and are most active at night (Fishar, 2006). Therefore, traps should be set in late afternoon and left overnight. To handle crayfish safely, grasp the body just behind the claws. For beginners, a pair of heavy gloves will ward off pinches (Bills and Marking, 1988).

Trading living male specimens of P. clarkii would encourage the creation of commercial fisheries of this species in areas where populations have been established. Male specimens can be sold live, because release of males only cannot lead to biological invasion by the species, whereas females should be processed (boiled, canned, or packed) before reaching the market (Frutiger *et al*., 1999).

Aquatic birds, amphibians and water snakes are potential natural enemies to the cultured fishes through feeding on young stages of cultured fishes at the rearing ponds. Such nasty intruders are responsible for spread and transmission of numerous fish specific/non specific pathogens including some enteric bacteria (Eissa *et al*., 2008), digenetic termatodes, nematodes, protozoa and viruses. Migratory birds global spread of some global infectious threats such as Influenza viruses from endemic to pristine areas (Eissa *et al*., 2012).

There are number of intrinsic factors that are related to the fish farm management regimen including the faulty use of organic fertilizers (poultry droppings), which could predispose to potential fish diseases through changing the water quality of the fish farm facility (Feare, 2006; Cristalli and Capua, 2007; Eissa *et al*., 2012) . Faulty storage of fish rations could be risky if mycotoxins development were considered (Tal *et al*., 2009; Bondad-Reantaso *et al*., 2012). Moreover, inefficient cooking of the local made fish meal coming from trash fishes, fish evisceration products might be a potential source of some fish specific pathogens (Tal *et al*., 2009; Bondad-Reantaso *et al*., 2012). Irresponsible introduction of questionably infected fish stocks from one farm to another might result in transmission, spread and establishment of some fish pathogens in the fish farm facility (Singh and Lakra, 2011; Yanong and Erlacher-Reid, 2012). Further, ignoring a good hygienic strategy for the fish farm might result in rapid dissemination of the disease agents from one place to another inside the fish farm which will ultimately end with an eminent outbreak of fish disease (Peeler, 2005; Scarfe *et al*., 2008; Yanong and Erlacher-Reid, 2012).

To sum up, bio-securing a fish farm facility is highly required to ensure a competent GAP, HACCP and to exclude the eminent threats of transmission, spread and establishment of diseases in a fish farm. The main goal of competent GAP is the responsible/sustainable production that is safe for the consumer and maintains environmental integrity. The purpose of HACCP i.e., the safe aquaculture zones is to create a cluster of farms within a defined boundary where safe aquaculture practices are undertaken. These future goals can be possibly achieved by:

- Minimizing the outbreak and spread of fish diseases
- Breaking the disease cycle, usually by following competent disinfection at different rearing zones/stage.
- Establishing physical or natural buffers between zones
- Reducing the hazards (chemicals, antibiotics and organic pollution) on the environment
- Controlling of risks (water supply, feed, utilization of chemicals and antibiotics) to fish quality and food safety
- Improving farm productivity by controlling the quality of seeds, water quality and practices of integrated pond management
- Introduction of co-management with the participation of local farmers through the participatory approach to and co-management of the good aquaculture practice

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