Journal of Applied Veterinary Sciences, 9 (2): 87-90 (April, 2024).
ISSN: Online: 2090-3308, Print: 1687-4072
Journal homepage : https://javs.journals.ekb.eg

A mini-review on Fish mass kills within the Egyptian Fisheries and Aquaculture Sectors: Impacts and Proposed Solutions

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ABSTRACT

Mass fish kills are abrupt events in which a significant number of fish of different ages and species perish in a specific aquatic region. Dramatic waves of mass kills have involved a large variety of economic fish species in both Egyptian fisheries and the aquaculture sector. Several episodes of mass mortalities of various infectious and noninfectious aetiologies have targeted a wide spectrum of freshwater and marine fish in both open-water and captive environments. Kafr El-Sheikh, Sharkia, Dakahlia, Fayoum, Alexandria and Giza were the most affected Egyptian provinces. The Mediterranean basin, Lake Manzala, Lake Mariott, Lake Burullus, River Nile, and some provincial water streams and municipal water drains were all reported to have had one or more episodes of mass kills over the past two decades. These mass kills were mainly attributed to different types / magnitudes of aquatic environmental pollution, which was explicitly aggravated by poor aquaculture / fishing practices. Further, the frequent absence of veterinary guidance has had a great negative impact on providing possible solutions for this disaster in the near future. Ultimately, adopting Good Aquaculture Practice (GAP), competent biosecurity strategies, and regular veterinary supervision will be the most practical solutions that ensure the reliable growth and sustainability of both Egyptian fisheries and aquaculture sectors.

Keywords: Aquaculture, Biosecurity, Mass Mortalities, Photobacteriosis,Vibriosis.

Review Article:
DOI:https://dx.doi.org/10.21608/javs.2024.262508.1308
Received : 13 Janaury, 2024.
Accepted :24 Feruary, 2024.
Published in April, 2024.

J. Appl. Vet. Sci., 9(2): 87-90.

1. Mortality Curves

"Mass fish kills" is a sudden event accompanied by mass deaths of fish of different ages and species in a specific aquatic environment **(La and Cooke, 2011; Eissa *et al.*, 2021)**. Their impacts on aquatic environments involve open water bodies like, rivers, canals, and lakes, and closed aquatic systems such as aquaculture facilities **(Eissa *et al.*, 2013; Eissa *et al.*, 2021)**. The shape of the mortality curve for these episodes often varies from one case to another, depending on the primary cause of death **(Krkošek, 2017; Overstreet and Hawkins, 2017; Irshath *et al.*, 2023)**. For example, in cases of mass mortalities resulting from acute infection with one or a group of pathogens, the shape of the curve is closer to an inverted bell, as deaths gradually increase simultaneously along with the increase in the severity of the infection until it reaches its maximum and then begins to decrease gradually until it ceases completely as the infection recedes **(La and Cooke, 2011; Eissa, 2016)**. However, in cases of kills resulting from acute toxicity with one of the chemical environmental toxicants such as methyl mercury, chlorinated pesticides, organophosphates, or biological noxious poisons such as toxic dinoflagellates, the curve is steep in its height. These kinds of mass kills are associated with an acute episode of mass mortality, which includes all aquatic organisms, all sizes, and all stages **(Sorensen, 1991; Ochoa *et al.*, 1997; Scholin *et al.*, 2000)**.

2. Frequent etiologies of mass kills

2.1. Environmental hypoxia

Low dissolved oxygen (DO) concentrations are sometimes blamed for fish kills in tropical climates. However, the circumstances bringing about these events vary greatly based on numerous environmental factors and local life forms **(Pollock *et al.*, 2007)**. In the marine environment, acute oxygen deficiency happens when DO is less than 2.0 mg/L, while chronic oxygen deficiency happens when levels of DO fall between 2.0 and 3.0 mg/L **(Pollock *et al.*, 2007)**. Conditions known as "no-oxygen" or anoxic conditions arise when DO levels drop below 0.2

mg/L. According to **Rose *et al.*, (2009)**, hypoxic conditions negatively impact marine species, resulting in slower growth rates, increased stress levels, decreased productive capacity, and in severe cases, heavy mortality **(Eissa *et al.*, 2013; Roman *et al.*, 2019)**. Aquatic systems that have low DO conditions usually differ in terms of persistence, seasonality, and temporal frequency. Although naturally occurring habitats with low DO have always existed, human activities largely associated with nutrient and organic enrichment have increased the levels of hypoxia and anoxia in both freshwater and marine systems **(Eissa and Zaki, 2011; Roman *et al.*, 2019)**. Lakes and coastal regions that experience seasonal stratification are frequently more vulnerable to the negative effects of anthropogenic nutrient loading **(Eissa and Zaki, 2011; Richards, 2011)**.

2.2. Infectious etiologies

Locally, several episodes of mass fish kills occurred during the period from 2008 to 2020 **(Eissa *et al.*, 2013; Eissa *et al.*, 2021)**. One of these examples is what happened in the autumn of 2008, when thousands of groupers died along several kilometers of the shores of Marsa Matrouh and Salloum Bay. At that time, there was intense controversy about the causes of this phenomenon. Photobacteriosis and mycobacteriosis were suggested as the main causes of death, but this was not particularly confirmed especially during the appearance of leaks of cyanide illegally used by some fishermen in fishing dusky grouper (*Epinephelus marginatus*) between the rocks of Egyptian Salloum Bay and the areas adjacent to it **(Marzouk *et al.*, 2009; Eissa *et al.*, 2011)**.

Another incidence of mass kills occurred at the beginning of the winter season in 2010, when an ample number of dead Nile tilapia were reported at the Mariotteya stream (Ellibini drain) along the extension of the drain from the areas of Badrashin, Shabramant, Harrania, Saqqara and Mariotteya. Many official and unofficial organizations competed to conduct various research to uncover the real causes of this disaster, which was concluded to be synergistic biological and chemical pollution, as described by **Eissa *et al.*, (2013)**. Successive events of fish mass kills continued to target the most important commercial Egyptian fish species, where earthen ponds' cultured Nile tilapia had drastically impacted Kafr El-Sheikh, Sharkia, Dakahlia, and Fayoum provinces. The incriminated aetiologies included *Streptococcus agalactiae, Enterococcus feacalis, Aeromonas hydrophila, Pseudomonas fluorescence,* and *Yersinia ruckeri* **(Eissa *et al.*, 2008; Eissa *et al.*, 2013; Enany *et al.*, 2019)**.

Several events of mass mortality among farmed marine and brackish water fish species have occurred in the Deeba Triangle over the past few years **(El-mezayen *et al.*, 2018)**. Numerous academic works have provided an overview of the primary reasons why mass die-offs occur so frequently, which include environmental degradation and infectious diseases. One key stressor that may have contributed to the huge microbial invasion is the degradation of the aquatic ecosystem **(Abu-Elala *et al.*, 2015; Eissa, 2016; Mahmoud *et al.*, 2016; El-Jakee *et al.*, 2020)**. Numerous outbreaks in wild and farmed fish have been linked to a number of infectious diseases, including photobacteriosis, vibriosis, and streptococcosis **(Abdelsalam *et al.*, 2009; Abdelsalam *et al.*, 2015; Eissa *et al.*, 2016; Abdelsalam *et al.*, 2017; Eissa *et al.*, 2021)**.

2.2.1. Photobacteriosis

Within the *Vibrionaceae* family, *Photobacterium damselae* is classified into two subspecies: *P. damselae* subsp. damselae and *P. damselae* subsp. piscicida **(Gauthier *et al.*, 1995)**. *P. damselae subsp. damselae* has been linked to mass aquatic animal deaths in the Mediterranean basin **(Marzouk *et al.*, 2009; Wang *et al.*, 2013; Essam *et al.*, 2016; Eissa *et al.*, 2021)**. The other subspecies, *P. damselae* subsp. *damselae,* is well-known as a zoonotic pathogen that causes deadly infections in humans **(Aigbivbalu and Maraqa, 2009)**. Additionally, it has been identified as the primary bacterial pathogen responsible for deaths in European seabass (*Dicentrarchus labrax*) and Gilthead seabream (*Sparus aurata*) in Egypt, Spain, and Tunisia, as well as in the Turkish Black Sea region **(Labella *et al.*, 1991; Khouadja *et al.*, 2014; Essam *et al.*, 2016; Eissa *et al.*, 2021)**. According to **Labella *et al.* (2011)**, *P. damselae* subsp. *damselae* is a significant fish pathogen endangering the Mediterranean fish sector. Photobacteriosis, often known as pseudotuberculosis, is mostly caused by *P. damselae subsp. piscicida* **(Wang *et al.*, 2013; Essam *et al.*, 2016)**. It has been linked to multiple mass deaths of marine fish raised in the Mediterranean region. As a result, the seafood sector in the Mediterranean region is thought to be at risk from this infection. In Egypt, Spain, Greece, and Italy, this disease kills a huge number of seabass (*Dicentrarchus labrax*), cultured seabream (Sparus aurata), and thinlip grey mullets (*Mugil cephalus*) **(Essam *et al.*, 2016; Romalde, 2002)**.

2.2.2. Vibriosis

Many commercially significant finfish and shellfish species, are susceptible to the deadly bacterial infection known as vibriosis, which is caused by *Vibrio alginolyticus*. The halophilic *V.*

alginolyticus is a ubiquitous bacterium found in marine aquatic habitats. This pathogen frequently affects coexisting aquatic organisms when unfavourable environmental conditions occur **(El Zlitne *et al.*, 2022; Ragab *et al.*, 2022)**. This pathogen exhibits several virulence factors, including strong extracellular products that result in severe infections in wild and farmed fish **(Balebona *et al.*, 1998)**. Numerous fish species, including grouper, trout, sea bream, and European seabass, have been linked to high mortality outbreaks related to *V. alginolyticus* **(Zorrilla *et al.*, 2003; Eissa *et al.*, 2022; Ragab *et al.*, 2022)**. The infected fish usually show the classic symptoms of bacterial hemorrhagic septicemia, including extensive bleeding on the outside of their bodies, in the guts, on the head, and around the base of their fins. Young fish outbreaks are frequently linked to malnutrition, discoloration, and sudden death as the ultimate fate of infection **(Ragab *et al.*, 2022)**.

2.2.3. Amyloodiniosis

Ragab *et al.*, (2022) reported high mortalities among hatchery-reared European seabass in a private fish hatchery located in the vicinity of Mariotte Lake, Alexandria. Those authors identified an obligatory ectoparasitic dinoflagellate known as *Amyloodinium ocellatum* as the primary cause of death. The debilitating protozoal condition known as "velvet disease" is brought on by the obligatory ectoparasitic dinoflagellate *A. ocellatum*, which infects the skin, gills, and oral cavity of many fish species in brackish and marine settings, including D. labrax **(Brown 1934; Cruz-Lacierda *et al.*, 2004)**. Three developmental life stages are known for *A. ocellatum*: a trophont that clings to fish tissues and feeds on them, a tomont that divides on the substrate to multiply, and an infectious dinospore that swims freely and infects new hosts. Salinity ranging from 1 to 60 ppt is one of the many aquatic environmental factors that *A. ocellatum* can withstand. Because of its extraordinary resistance to environmental changes, *A. ocellatum* can spread aerosolly. Dinospores of *A. ocellatum* may be spread by aerosol droplets that travel at least 4 meters from their source infecting new fish.

Conclusions and Future Aspects

Given the economic, environmental, and social impacts associated with fish mass kills, we found it wise to carefully search for the direct and indirect aetiologies behind these disasters. The thorough inspection of all reported events and all available data has helped us to explicitly declare that environmental pollution is the direct cause of these disasters, with a difference in the type of pollution as well as the types of influences and interactions that lead to it. The intensity of these disasters has been aggravated by farmers's erratic pond management. Faulty feeding of trash fish, animal manure, unregistered fish diets, decreasing the water column to less than 1 meter, increasing stocking densities, and rearing different animal species as an integrated type of farming are all anthropogenic factors that drastically worsen the condition. Therefore, developing competent biosecurity strategies in aquaculture facilities, whether farms or hatcheries, and adopting Good Aquaculture Practices (GAP) in the aquaculture sector is the most practical solution to ensure the sustainable growth of Egyptian aquaculture. These practices can be augmented by regular veterinary inspection, supervision, and intervention. Veterinary supervision can positively lead to timely control / prevention of disease outbreaks, proper application of therapeutants within the fish facility, and last but not least, the spread of the culture of preserving natural resources from pollution. Ultimately, aquatic veterinary interference can deliberately minimize the risk of mass kills and thus avoid potential economic loss.

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How to cite this article:
Alaa Eldin Eissa, 2024. A mini-review on fish mass kills within the Egyptian fisheries and aquaculture sectors: Impacts and proposed solutions. Journal of Applied Veterinary Sciences, 9 (2): 87-90.
https://dx.doi.org/10.21608/javs.2024.262508.1308