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Article Review

Impact of climatic change on emergence of bacterial fish diseases

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ABSTRACT

Climate change is the most influential threat facing the life of all creatures on the Planet Earth. Such change is an ongoing degrading process that has been running for more than three centuries since the global industrial revolution. The climate change has been tightly linked to carbon dioxide and other green gas emissions with consequent colossal rise in average global temperatures causing what is called “Global Warming". Global warming has critical impacts on all forms of terrestrial and aquatic creatures. Sea level rise, ocean acidification, eutrophication, coastal erosions, invasive species and disease emergence are all the deleterious end products of global warming.. Bacterial pathogens are among the most changeable disease agents due to the direct effects of climate change. Mesophilic bacteria such as countable members of streptococci, enterococci, lactococci, aeromonads, vibrios, flavobacteria and few members of family Enterobacteriaceae are considered the most eminent product of global warming. In aquatic life either in open water or captive environments, several events of mass kills among fish, shrimps, oysters, and corals have been recently linked to mesophilic bacterial pathogens invasion. *Streptococcus agalactiae, Enterococcus faecalis, Lactococcus garviae*, *Aeromonas hyrophila*, *V. anguillarum, Vibrio vulnificus, Vibrio alginolyticus*, *Yersinia ruckeri*, *Tenacibaculum maritimum*, *Flavobacterium maritimus* and *Mycobacterium* species are ideal examples for such dominance of mesophilic pathogens with deleterious impacts on aquatic animals' health. Ultimately, the unexpected emergence of highly virulent strains of these bacterial pathogens could drive uncountable aquatic species to be endangered. Therefore, the wise search for national, regional and international forums for counteracting the future negative impacts of climate change on wild and captive aquatic species should be mandated by all country leaders of southern hemisphere.

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INTRODUCTION

The aquaculture industry, which accounts for over 50 percent of global fish production, is an important component of the human diet, providing high-quality aquatic food for global or local consumption **(Kaleem&Sabi 2021)**. Over the past two decades, world aquaculture has developed tremendously to become an economically significant industry. The industry continues to grow at an average global annual growth level of 8.8 percent per year compared with all other animal food production industries **(Onada&Ogunola 2017).**

Aquaculture in Egypt, which is the largest aquaculture industry in Africa, is currently considered the main source of fish supply, with total production quantities around 1.8 million tons **(Kaleem&Sabi 2021)**. Egypt is the seventh-largest aquaculture producer in the world by production quantity and the largest in Africa, accounting for 73.8 percent of aquaculture in Africa by volume and for 64.2 percent by value **(Feidi 2018)**.

Climate change is the term used to describe changes in the climate brought about by anthropogenic (caused by humans) activities that influence the composition of the atmosphere either directly or indirectly. By altering the composition of the atmosphere, human activities like the use of fossil fuels, deforestation, improper land use, agriculture, and industrial processes contribute to climate change **(Yerlikaya et al. 2020)**. In addition to human activities, the burning of fossil fuels has increased atmospheric concentrations via producing greenhouse gas effects **(Fahad et al. 2019a, b).**

Global food production is currently seen to be at risk from climate change, which also poses a serious threat to the amount and quality of production. Climate change is expected to have a significant impact on food security, especially on the availability of dietary protein **(Kandu 2017)**. Due to aquaculture's major contribution to global food security, nutrition, and livelihoods, the implications of climate change on sustainability have attracted a lot of attention recently **(FAO 2020).**

The productivity of the sea can vary dramatically as a result of changes in the global climate, particularly at higher latitudes where ocean current patterns are affected. Climate change in aquatic ecosystems can lead to several consequences, such as variations in the concentration of phytoplankton, an increase or decrease in ocean acidity, and a fluctuation in oxygen levels **(Cheung et al. 2021; Galappaththi et al. 2022)**.

Climate change can impact aquatic creatures' health standards by altering pathogen properties, in addition to the physical changes in the environment. A rise in freshwater temperature can affect fish pathogens directly by altering their biological processes, or indirectly by altering the distribution and population of fish that are influenced. Increased temperature fluctuations can have a significant impact on the amount of potentially hazardous native and foreign microbiota present in aquatic species, such as fish. This may make it easier for these bacteria to locate, multiply, and enter fish tissues, which could result in widespread disease and mortality **(Chiaramonte et al.2016).**

Egypt is among the nation's most susceptible to the possible effects of climate change, particularly with regard to the aquaculture industry. One of the most pressing issues of our day is climate change, which has had detrimental effects on various water bodies. Inland freshwater aquaculture is threatened by climate change because of changes in water availability, a drop in water quality, the passage of salt water upstream due to rising sea levels, and the salinization of groundwater supplies. Similar to this, rising temperatures brought on by climate change cause fish output to decline as a result of lower dissolved oxygen levels, higher fish metabolic rates, increased risk of disease transmission, and higher fish mortality. Aquaculture operations may also be indirectly impacted by climate change; for instance, a lot of lowland aquaculture ponds may be extremely vulnerable to floods due to increasing sea levels **(Mehrim&Refaey 2023).**

Disease outbreaks are one of the biggest obstacles to aquaculture output. Fish and fish products become scarce as a result, resulting in financial losses. The primary cause of mortality in aquaculture, especially in the hatchery, is bacterial diseases. The type of feed fed to the fish and its water supply are the two key factors that determine the existence of bacteria in aquaculture **(Ragab et al. 2022)**.

In Egypt, bacterial infections are the cause of severe mortality and morbidity in a variety of freshwater and marine fish farms, and summertime water temperature increases have a major impact on mortality **(Kaleem&Sabi 2021)**. Bacterial diseases in fish are present with a higher prevalence of mortalities when compared to the parasitic infestations. Infections with *Aeromonas hydrophila*, *Flavobacterium maritimus Vibrio* spp, *Streptococcus* spp, *Pseudomonas fluorescens*, *Yersinia ruckeri*, *Edwarsiella tarda* and *Edwardsiella ictaluri* were reported in Egyptian farms **(Shaheen 2013, Abdelsalam et al. 2023).**

Major climatic changes with impact on aquaculture

The global community as well as national and regional governments are currently facing one of their biggest challenges: climate change **(Khalil et al. 2022)**. The aquaculture sector faces several predicted threats to its production and sustainability due to climate change, including increased temperatures, ocean acidification, altered rainfall and precipitation patterns, sea level rise, unpredictability of external input supplies, altered sea surface salinity, and extreme weather events **(Tanahara et al. 2021)**.

2.a. Rising Temperature (Global warming):

The Mediterranean region is experiencing global warming more quickly than other regions of the world, which is causing noticeable changes in temperature and precipitation as well as other climatic factors **(Lionello and Scarascia 2018)**. The possible effects of climate change on several industries, including water resources, energy production, and agriculture, must be carefully evaluated **(Tramblay et al. 2020)**.

Global climate change is currently hindering aquaculture productivity, especially in the Mediterranean region. Global warming is one of the most important environmental problems that negatively affects both the environment and human lives. The average annual increase in global temperature since 1950 has been 0.13 ^{o}C. From 2016 to 2035, the global mean surface temperature is predicted to rise by 0.3 to 0.7 ^{o}C **(Mehrim&Refaey 2023)**.

Temperature plays an essential role in the growth and development of aquatic species. Due to their poikilothermic nature, fish may be especially vulnerable to temperature changes brought on by climate change. As a result, extended heat stress may have a variety of effects on aquaculture productivity, the main one being decreased output. Chronic stress, for instance, may impact the neuroendocrine and osmoregulatory systems, changing the capacity for aerobic scope and cardiorespiratory performance, as well as the immunological responses of a number of commercially significant species **(Zhang et al. 2019)**. Additionally, most finfish and shellfish species' growth, feeding patterns, physiology, and metabolism are probably going to be influenced **(Maulu et al. 2021)**.

In addition, rising temperatures from climate change events reduce dissolved oxygen levels and increase fish metabolic rates, consequently leading to an increase in the mortality rate of fish, decreased production of fish, and/ or increased feed requirements, as well as increased risk and spread of disease **(FAO 2020).**

Temperature increases will have a detrimental effect on water quality. Water quality deteriorates due to the proliferation of microorganisms caused by a rise in temperature and low flow. Water reservoir biological activities are impacted by temperature increases. Water reservoir oxygen concentrations can be impacted by global warming. **(Tanahara et al. 2021)**. The severity of hypoxia as well as the frequency and duration of toxic algal blooms in estuaries and bays may worsen with rising temperatures **(Morris et al. 2022).**

2. a.1. Impact of temperature on the Fish Immune System

Two of the primary variables that are known to impact fish immunological response are temperature and stress **(WendelaarBonga 1997).** As poikilotherms, the metabolism of fish is directly related to their surrounding water temperature, and changes in water temperature are known to affect their immune system. Different fish species have specific immunologically temperature ranges. As a result, various parameters important to the fish's immune response can be negatively affected by temperature changes at either end, or outside of their permissive temperature range. This is reflected in the seasonal variations seen in the incidence of disease outbreaks on fish farms as water temperatures change throughout the year **(Cascarano et al. 2021)**.

The impact of temperature on the innate or adaptive characteristics of fish immune systems has been the subject of several investigations **(Magnadóttir 2010; Abram et al. 2017)**. It is frequently stated that, in bony fish, innate immunity is more active at lower temperatures, whereas at lower temperatures, adaptive immunity is inhibited and becomes more active at higher temperatures **(Ellis 2001)**.

The environment affects the susceptibility of hosts to disease **(Murray et al. 2022)**. Changes in environmental salinity and pH may affect the immune reactivity of mucosal immune molecules or may change the viscosity of mucus **(Roberts and Powell 2005)**, increasing adhesion ability of bacteria to host surfaces. Periods of high temperature and hypoxia will result in the production of a stress response in finfish with a direct immune suppressive effect **(Tort 2011)**.

Alternative complement pathway activity (ACP) is an important component of the fish's humoral innate immune response involved in pathogen killing. It has been suggested that ACP is well adapted to low temperatures **(Sunyer and Tort 1995)**.

It can be speculated that we will see an increase of skin lesions as a result of increased water temperatures. Intensive aquaculture practices can lead to the formation of skin abrasions, epidermal wounds or damaged mucus layers, resulting in increased accessibility of environmental opportunistic pathogens (favored by high water temperatures) **(Kiron 2012)**.

2. b. Ocean Acidification

Ocean acidification is the outcome of atmospheric CO_2 absorption causing a prolonged drop in the pH of ocean water **(Bahri et al. 2018)**. The oceans are predicted to store about 50 times more CO_2 than the atmosphere. Numerous aquatic species will experience severe effects on growth, development, calcification, survival, and abundance due to the anticipated rise in CO_2 uptake by seas **(IPCC 2018)**.

Increased accumulation of CO_2 in water could result in increased water acidity levels which endangers the environmental sustainability of aquaculture production through water quality deterioration leading to poor productivity **(Maulu et al. 2021)**.

Furthermore, as ocean acidity rises, less carbonate is available for shell-forming creatures like prawns, mussels, oysters, and corals to build their coral skeletons, a process known as calcification, which potentially endangers marine aquaculture production **(Kibria et al. 2017)**. Increasing acidity levels in saltwater may have a substantial impact on aquatic animals' physiology and metabolism by altering intercellular transport pathways **(Pörtner et al. 2004)**.

2. c. Changes in Rainfall (Precipitation) Pattern

Rainfall patterns that shift will have two directly opposing effects on aquaculture productivity and sustainability: periods of high rainfall (Flooding) and periods of low or no rainfall (Drought) **(Maulu et al. 2021)**. According to the **IPCC (2018),** risks resulting from droughts events are likely to be higher at 2° C compared with 1.5 ° C of global warming in a given region.

Raising rainfall, especially in the form of heavier events, will make lowland areas more susceptible to production concerns. These hazards include fish loss from ponds during floods, and unwanted species invading the pond **(Rutkayova et al. 2017)**. The introduction of invasive fish species and deterioration of water quality are the main ways in which the mixing of pond water and fish with those wild could have a detrimental impact on the environmental sustainability of aquaculture output. Additionally, because fish losses from ponds reduce producer profits and spread poverty throughout communities, they pose a danger to the social and economic aspects of aquaculture sustainability **(Maulu et al. 2021)**.

Droughts can cause water stress, which can have a detrimental impact on aquaculture productivity due to shortages and declining quality **(Kibria et al. 2017)**. The predicted water shortages driven by climate change will lead to increased conflicts for water among the different user groups, such as aquaculture, agriculture, domestic, and industries **(Barange et al. 2018)**. This will affect all the dimensions of aquaculture sustainability.

2. d. Changes in Sea Surface Salinity

Salinity is a variable characteristic that reflects the freshwater input from evaporation, river runoff, precipitation, ice melting, and the mixing and circulation of surface water in the ocean with underground water. Changes in ocean circulation and rising temperatures can lead to higher evaporation, which in turn can cause variations in sea salinity. The majority of aquatic species can only survive at certain salinity levels; changes to this range may result in mortality and decreased productivity **(Jahan et al. 2019).**

Salinity levels over the ideal range have been shown to impair red blood cells, growth, and survival in stripped catfish, which may have an impact on the immune system of the fish **(Jahan et al. 2019)**. This means that variations in sea salinity are anticipated to have a detrimental impact on the profits realized by some aquaculture species, which may have an adverse effect on the social and economic dimensions of the sustainability of aquaculture production. However, in downstream coastal areas, there is a substantial correlation between the increased salinity effect and aquaculture production systems **(Nguyen et al. 2018)**.

In general, Water salinity variations result in greater mortality rates for a number of species, which could have an impact on the sector's social and economic sustainability through higher management expenses and a rise in species losses **(Maulu et al. 2021)**.

Impact of climatic change on aquaculture in Egypt

Egypt is one of the nations that are thought to be most vulnerable to climate change impacts. These effects will have severe effects on all sectors of the country including the aquaculture. Climate change may influence aquaculture through changes in fish species and stocks as well as decreased land used for aquaculture, increased output and efficiency, improved water quality, and increased fish prices. The consequences of climate change pose a threat to the expansion of sustainable aquaculture as well, necessitating the development of solutions for adaptation and mitigation **(Soliman 2017).**

The effects of climate change on aquaculture can be classified as direct or indirect. Direct effects include changes in temperature, water availability, and damage from extreme weather events. Indirect effects include higher costs for fishmeal and other aquaculture feeds **(Maulu et al. 2021)**. Temperature variations have a direct impact on the biochemical reaction rates that control the rates of fish cellular functions, feeding, digestion, and metabolic performance. These changes in turn impact the growth performance of fish **(Magouz et al. 2022)**, physiological status **(Yilmaz et al. 2021)**, immune responses **(Feidantsis et al. 2021)**, reproduction, behavior **(Servili et al. 2020)**, and resistance to disease **(Cascarano et al. 2021)** of different fish species in the wild and in aquaculture.

Thus, this could negatively affect Egypt's food security by having a large impact on aquaculture productivity. Furthermore, climate change may result in a drop in Egypt's precipitation; with some modelling suggests an annual decline of up to 5.2% by 2030 and 7.6% by 2050. Thus, it would be wise for Egypt to identify adaptable methods for controlling climate risks in susceptible regions **(Islam et al. 2022)**.

In general, it is widely believed that fish stocks in Egypt have drastically decreased recently. The dramatic reduction in these resources is a result of numerous obstacles that Egyptian fisheries face in their development. Several authors list the following as challenges: excessive fishing effort, high levels of exploitation, destructive fishing practices (like using small mesh gear and fishing for juveniles), growing tourism and industrial expansion that destroyed habitat, pollution, climate change, and global warming **(Mohamed et al. 2020).**

The potential impact of climate change on the infectious diseases:

Disease is the main global challenge to the aquaculture industry, with financial losses from it estimated to be in the billions of US dollars annually. Because intense aquaculture production involves stressful conditions, farmed fish are more susceptible to infectious illnesses than wild fish **(Oliveria et al. 2021).**

Bacterial infections have been a serious hazard to the majority of the aquatic environment for many years. Potential direct threats from bacteria to aquatic animals include the development of clinical diseases that result in large-scale deaths. Indirect threats can also arise from secondary infections with opportunistic organisms that are driven by environmental stress and the suppression of fish's acquired and cellular immune barriers **(Eissa et al. 2013)**.Infectious disease incidence can also be impacted by climate change since it can shorten pathogenic agent generation times and/or increase their survival rates, improve disease transmission, and increase the vulnerability of the host to the infections **(Marandi et al. 2022)**.

The connection between infectious disease pathogens and their hosts, as well as the ways in which environmental factors such as temperature, salinity, and human disturbances impact this relationship, are widely recognized. Some researchers believe that anthropogenic stresses are the fundamental cause of the increasing number of diseases in aquaculture, as they have in some cases altered the frequency, geographic distribution, and severity of disease **(Rowley et al. 2014)**.

Poikilothermic animals, such as fish, are immediately impacted by environmental temperature in all aspects of their physiology, including the immune system. In a similar manner, pathogens have ideal temperature ranges for reproduction. Temperature plays a major role in many fish diseases, determining whether an infection causes illness and death or immunity and recovery. For this reason, it is very possible that fish may be more severely and sooner affected by climate change than homoeothermic species **(Marcos-López et al. 2010)**.

One environmental factor contributing to these newly emerging infectious diseases is global warming. Variations in climate can be attributed to different types of parasite/ pathogen–host relationships and the regions in which they occur. Higher summer temperatures in northern latitudes have an impact on the potential for increased proliferation of microbial pathogens, including bacteria and fungi. At the same time, these temperatures stress fish immune systems and make them more susceptible to infection **(Marcos-López et al. 2010)**.

Many reverse biological processes have emerged as a reaction to the world's first-ever sharp increases in temperature, the ensuing low levels of dissolved oxygen and the alteration of other chemical properties of water, and the numerous erratic farm management practices, including the improper use of chemicals, hormones, antibiotics, improper nutrition, improper water treatments, scarcity of water, and primary reliance on agricultural drainage water. Fish immune systems have been suppressed by such reversible dynamic processes, leaving them extremely vulnerable to microbial infection even in the presence of those common-place microorganisms that are always present in pond water **(Eissa et al. 2013; Eissa et al. 2016)**.

Common bacterial disease models with tight link to climate change

The majority of raised fish in the Mediterranean region and around the world suffer from vibriosis, a common systemic disease caused by bacteria of the genus *Vibrio*. The most researched Vibrio pathogen is *Vibrio anguillarum*, which causes significant financial losses in fish raised for food. This pathogen multiplies quickly at 25–30 °C **(Woo and Bruno 1999)**, with an optimum around 25 °C, being characterized by a polar flagellum essential for the motility, chemotaxis and host invasion **(Ormonde et al. 2000)**. The chemotaxis of various *Vibrio* strains towards mucus extracted from gilthead seabream surfaces (skin, gills, and intestinal mucus) has been investigated at various temperatures (15, 22, and 27 ° C). For both *V. anguillarum* and *V. alginolyticus*, the chemotactic reaction to skin mucus had a positive correlation with temperature; this relationship was less pronounced but still evident for gill and intestinal mucus. A different investigation discovered that at 25 °C, chemotactic reactions were greater **(Larsen et al. 2004)**.

Vibrio alginolyticus is linkedto epizootic vibriosis in gilthead seabream in the Mediterranean region **(Kahla-Nakbi et al. 2006; Castillo et al. 2015)**. Temperature-related adhesion is a significant pathogenicity component, as was previously established. Adhesion of *V. alginolyticus* to intestinal mucus happens at 30 °C. Since the pathogen may be isolated at both 37 °C (on *V. alginolyticus* agar) and 15–25 °C (on TCBS agar), disease outbreaks have been documented in all seasons **(Yan et al. 2007)**. This disease has been linked to a number of deaths in cultured gilthead seabream in Eilat, Israel. The deaths occur in both earthen ponds, where water temperature changes are greater (i.e., 12–21 °C in winter and 23–33 °C in summer), and tanks with temperatures between 22 and 26 °C **(Colorni et al. 1981)**. In Greece, gilthead seabream vibriosis caused by *V. alginolyticus* is typically noticed in the winter at chilly temperatures **(Bellos et al. 2015)**, In contrast, *V. alginolyticus* has been observed in mixed infections with *V. harveyi*, *V. fischeri*, and *V. splendidus* in Spain during the spring and summer **(García-Rosado et al. 2007)**. The production of peritrichous flagella by *V. alginoliticus*, which cause swarming movements on solid surfaces, is primarily influenced by salt content and temperature. Similarly, research revealed that the pathogen may develop at temperatures between 20 and 44 °C, but that at temperatures higher than 28 °C or 0.7% NaCl, no peritrichous flagella develop **(Du et al. 2007)**.

The common bacterium that causes pseudotuberculosis, also known as photobacteriosis or pasteurellosis, is *Photobacterium damselae subsp. piscicida*. Previously known as *Pasteurella piscicida*, it is the cause of granulomatous formations and numerous white nodules, or pseudotubercles, on the surface of internal organs, particularly the kidney and spleen. Given that this illness frequently has no symptoms, it is also linked to abruptly high fatalities. Pasteurellosis outbreaks are known to happen in the summer **(Woo and Bruno 1999)** and have thus been connected to the rise in water temperatures in Spain (mid-summer, 25 °C) and Japan (beginning of summer, 20–25 °C). The first documented case of *P. damselae subsp. piscicida* in juveniles gilthead seabreams was in Spain during the summer, with 40% of deaths occurring overall **(Toranzo et al. 1991)**. The pathogen has also been observed in European seabass at lower temperatures (18–19 °C) in Turkey and along the French Mediterranean shore. The bacteria grow best in vitro at temperatures between 22.5 and 30 °C, although they can grow at temperatures between 15 and 32 °C. Asymptomatic gilthead seabream broodstock can vertically transfer the infection to larvae, which then get ill when the water temperature rises. Raising the temperature from 15 °C to 18–20 ° C raises mortality rates, whereas lowering the temperature from 20 °C to 15 °C lowers mortality, indicating that temperature manipulation can be used as a disease control strategy **(Romalde 2002)**.

The opportunistic bacterium *Tenacibacu-*

lum maritimum, formerly known as *Flavobacterium maritimus*, is the cause of "gliding bacterial disease," also known as tenacibaculosis, which results in epidermal lesions on the mouth, fins, and tail that can become ulcers, as well as gill and eye necrosis. *T. maritimum* is an opportunistic pathogen that has been found worldwide in several fish species. It is primarily observed during stressful situations that affect fish stocks. Temperatures from 15 to 34 ° C are suitable for its growth, with 30 °C being the ideal range **(Avendaño-Herrera et al. 2006)**.

This disease has been known to kill European seabass, and deaths have been reported in Corsica and along the French Mediterranean coast. The latter caused juvenile mortality to cumulatively reach 25% at 12 °C (winter–spring). Along Turkey's Aegean coast, spring and summer temperatures above 15 °C have been linked to mortality in all age groups of European seabass **(Yardımcı et al. 2017)**.

Mycobacterium species are the cause of numerous fish diseases known as piscine TB, or mycobacteriosis, which has been reported globally. Focal granulomas and nodular lesions are the result of chronic and subchronic infections of the skin and internal organs, primarily the spleen, liver, and kidney **(Jacobs et al. 2009).** In Eilat, Israel, 7-year-old farmed fish raised at 24 ± 2 °C were found to have the first incidence of systemic mycobacteriosis in European seabass. After being plated on Löwenstein-Jensen media at various temperatures (15, 20, 24, 30, 35, and 45 °C), the isolates showed the best growth at 24 ± 0.5 °C after three weeks, slower growth at 15 and 20 °C, and no growth at 30 °C **(Colorniet al. 1992)**.

Inshore farms in the Tyrrhenian and south Adriatic regions, where the water temperature ranges from 19 to 21 °C, have recorded multiple cases of mycobacteriosis on European seabass **(Mugettiet al. 2020)**. cultured meagre is also vulnerable to mycobacteria, with an outbreak stated in meagre in Turkey during September 2013. Bacteria were isolated and grown at 24–25 °C **(Timuret al. 2015)**, While *Mycobacterium* sp. was isolated and cultured at 30 ° C from a summer outbreak that same year **(Avseveret al. 2014)**. *M. marinum* fish isolates show significant strain variation **(Ucko et al. 2002)**, which probable contributes to detected alterations in their temperature requirements.

Aeromonas spp. are common bacterial infections in finfish aquaculture and have been extensively studied due to their wide host range (affecting both warm and cold water species as well as marine and freshwater species) and severe clinical symptoms that result in high fish mortalities. Hemorrhagic septicemia, cutaneous hemorrhages (mainly on the fins and trunk), exophthalmia, stomach distension, and significant interior lesions (hemorrhagic catarrh) are caused by a variety of virulence factors possessed by these bacteria. While 28 °C is generally the ideal temperature for *A. hydrophila* development, growth can also occur at 37 °C **(Woo and Bruno 1999)**, a temperature that permits zoonotic transmission of this bacteria. Outbreaks in aquaculture are typically linked to a variety of stresses, including as abrupt temperature changes and high temperatures. According to reports, *Aeromonasveronii* is a significant newly discovered infection that affects European seabass in Greece. When the water temperature rises above 21 °C, this infection severely kills adult fish **(Smyrliet al. 2019)**. Due to *A. veronii* bv. *sobria's* ability to cause morbidity at temperatures above 18 °C in the Aegean Sea, outbreaks often take place in June through August, when temperatures are between 24 and 26 °C. These bacteria don't seem to develop at temperatures lower than 12 °C, with an optimal growth temperature of 30 °C **(Smyrliet al. 2017**). Infections with *Aeromonas* spp. have been previously reviewed as the main source of bacterial illnesses in Greek wild and farmed fish. Specifically, a greater prevalence of aeromonads was noted in European seabass fry and gilthead seabream adults, respectively. *A. sobria* was the primary *Aeromonas* sp. recovered from these fish **(Yiagnisisand Athanassopoulou 2011)**.

The systemic disease known as yersiniosis, which affects many fish species in temperate and cold-water aquaculture in freshwater and marine habitats, is caused by *Yersinia ruckeri*. One of the aquatic bacterial flora in aquatic ecosystems, *Y. ruckeri* is responsible for economic losses in numerous nations, including Great Britain, Canada, Switzerland, Denmark, and Iran **(Marandi et al. 2022).** Temperatures ranging from 9 to 37°C are suitable for *Y. ruckeri* development, with 22 to 25 °C being the ideal range. When the water temperature rises above 15°C, which stresses the fish, the disease in salmonids gets worse and results in higher morbidity and mortality rates. Because of this, changes in the global climate, where the water temperature rises throughout the summer, might lead to an increase in disease outbreaks in aquaculture **(Kumar et al. 2015)**. Despite the majority of bacterial isolates cultured at 37 °C are not harmful to fish, biotype II strains have the ability to infect temperate and tropical fish species, thus making the disease as a reemerging bacterial disease **(Wrobelet al. 2019).** The degree of environmental stress and certain virulence features of the bacterial strains determine how severe the outbreaks are. According to the risk framework, which was created to look into how climate change would affect the introduction of diseases in aquaculture, fish yersiniosis was predicted to become more common and more challenging to control in the event of global warming **(Marcos-Lópezet al. 2010)**.

Streptococcal infection, which was found to be a serious fish illness and to infect nearly all major farmed fish. In streptococcaceae, a family of Gram-positive bacteria, pathogens retrieved from diseased fish include mainly *S.agalactiae*, *S. dysgalactiae, S. iniae,* and *Lactococcus garvieae* **(Liao et al. 2020)**. *S. agalactiae* is a fish species pathogen that can infect freshwater and saltwater fish, such as tilapia, catfish, eels, mullet, seabass, ornamental fish, wild fish, and prawns. Recent findings have shown that this species can cause significant economic losses in aquaculture **(Chou et al. 2019)**. *Streptococcus* species can be identified from healthy fish and are commonly found in water, which can result in the incorrect diagnosis of pathogenic strains. The symptoms of infection include loss of appetite, erratic swimming behavior, exophthalmia, corneal opacity and hemorrhage on skin and fins, internally including hemorrhage, ascites, and kidney, spleen, and liver enlargement**(Kitao 1993)**. A risk factor for *S. agalactiae* outbreaks in tilapia is water temperature above 27°C. The elevated mortality rates in fish may be attributed to suppression of immunity brought on by the release of cortisol as a result of thermal stress, which influences both specific and non-specific immune responses **(Marcusso et al. 2015).** The incidence of lactococcosis and streptococcosis in freshwater farms in Iran is closely linked to variations in water temperature, with the highest rate in summer at 16–18 °C **(Soltani et al. 2015)**. **Liao et al. (2020**) concluded that the sharp change in the temperature of the surrounding environment can cause tilapia fish to have a marked fall in white blood cell count, which may be the reason for the fish's increased vulnerability to streptococcal infection.

CONCLUSION

Today, one of the biggest issues facing the entire world is climate change, to which the world is growing more susceptible. Several environmental phenomena have been linked to climate change such as flooding, drought (water scarcity), extreme heat, increase sea surface salinity and ocean acidification, which have had detrimental effects on the spread of infectious diseases, food security, and financial losses. Climate change has negatively impacted the aquaculture industry in a number of ways, either directly or indirectly affecting the resources required for aquaculture or the farmed fish. Temperature and precipitation variations have an impact on water quality factors like pH, salinity, and oxygen, which are predicted to have an effect on growth, survival, and reproduction. Additionally, the increased physiological stress brought on by climate change increases the susceptibility to disease. Egypt is among the nations most impacted by the detrimental consequences of climate change due to its massive population. Egypt is especially vulnerable to the effects of climate change and variability, especially in terms of water security, agriculture, and fisherie. Furthermore, Egypt's economy may suffer severely from climate change.

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