Impact of Global Warming on Aquaculture: A Comprehensive Review

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Abstract

A crucial issue that needs research is how global warming affects the welfare and production of aquaculture. Understanding how global warming affects aquatic ecosystems is urgent given the well-documented implications of mass migration, habitat loss, and deforestation on biodiversity. While our current knowledge points to a tenuous connection between global warming and naturally occurring migrations, a number of simulations have shown that global warming has a detrimental effect on aquatic biodiversity. Other elements including predation, a lack of food, and overfishing can increase the climate effects on aquaculture biodiversity in addition to the influence on habitat. Establishing worldwide legislation and an action plan based on the agreement of scholars is essential to addressing these concerns. The application of these laws should be enforced by regulatory bodies in both developed and developing nations. These programs are essential for the preservation of aquaculture, the long-term expansion of food security, and the general upkeep of the planet's ecology.

Keywords: Global Warming, Aquaculture, Welfare, Productivity, Biodiversity

Introduction

By causing glacial melting, sea level rise, increased lake evaporation, greenhouse effects, an increase in ocean acidity, and biological invasions, global warming has a detrimental influence on natural ecosystems (Eissa and Zaki, 2011). Climate changes brought on by global warming have an impact on land and water resources both directly and indirectly, primarily through upsetting the habitat balances of aquatic and terrestrial species. Global climate change is having an impact on the nature and dynamics of flora and fauna. The two most notable examples are the longer agricultural growing season and earlier spring equinox, which are commonly seen in many parts of the world (Porter et al., 2013).Recent research suggests that the main causes of the decline in habitat quality and marine biodiversity are organic matter (OM) pollution, pollution load, and global warming (GW) (Reddy et al., 2007; Pasha et al., 2012; Abdullah et al., 2013). Algal blooms and sea water acidification are consequences of these climatic changes. Various regions of the world, including Australia, Japan, the USA, and Europe, have recorded such algal blooms (Beaufort et al., 2011; Yates and Rogers, 2011). Aquatic-terrestrial ecotones are said to be vulnerable to climate change in a long-term project (Alahuhta et al., 2011). Significant ecological issues were brought about by the destruction of wetlands, freshwater habitats, and terrestrial ecosystems that contained emergent aquatic macrophytes. The prevalence and percentage coverage of boreal emergent aquatic vegetation were evaluated using several climate scenarios. According to a prediction made by Alahuhta et al. (2011), cumulative climate change would result in an extension of their distributions in Finland by the

2050s.A recent study by Bond et al. (2012) found an indirect relationship between cattle's time spent by riversides in England and the number of feces they produce. Contrary to what one might think, there may be some effects of global warming, such as a decline in animal-mediated breakdown of organic matter and nutrient recycling (Wu et al., 2011). Additionally, they noted a correlation between the moisture content of the dung, which was decreased experimentally by heating, and the survival of coprophagous beetles. According to reports, there are several invasive species that go from one continent to another and numerous lessepian species that move from oceans to seas. 2007 (Anonymous). There is, however, a dearth of evidence on their effects on invaders or lessepsians that relocated from one habitat to another for a number of causes other than climate. This brings up the crucial issue of how much and in what ways climate change may affect non-native animals in their new environments. may this be justified for such animals if they transfer to another location where they may easily expand or if they return to their native habitats? To answer these problems, several investigations into logical phenomena have been performed (Oral, 2010; Willigalla et al., 2012). The majority of these studies are based on the discovery of numerous such species, particularly in the Mediterranean Sea, but they were unable to lay the groundwork for population conservation.

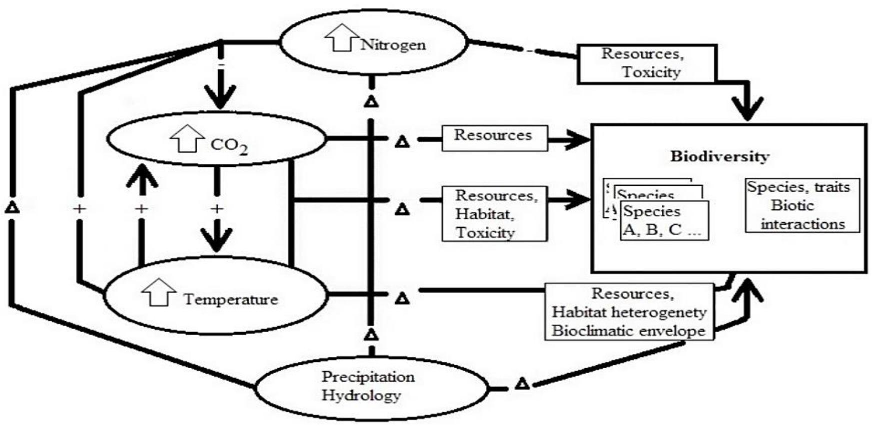

Fig. 1. Conceptual model for direct and indirect effects of global changes on biodiversity

The primary and most pressing issue of our day is global warming, for which a number of summits have been arranged and national or continental-level legislation has been created. With the aforementioned considerations in mind, the current review discusses earlier research on climate change and its consequences on the biodiversity of aquatic creatures. This analysis will aid scientists in their planning and preparation for future initiatives to counteract the possible impacts of global warming. Additionally, it aims to determine how human activities and global warming interact, particularly with regard to aquatic biodiversity. The current review's final goal is to describe the most recent information that has been published about modeling initiatives that use sources, factors, methods, potential long-term effects, and corrective actions to preserve aquatic species' migratory populations. The vital ecological services that biodiversity provides, which have been adversely impacted by global warming in recent decades, support human health and well-being (Millennium ecological Assessment, 2005). According to reports, the pollutant nitrogen led to declines in both terrestrial and aquatic biodiversity as a result of global warming (Fig. 1). De Vries et al. (2011) also came to the conclusion that, in contrast to non-agricultural systems, N2O emissions have an impact on biodiversity and eutrophication. By amplifying global warming in agricultural systems, anthropogenic enrichment of reactive nitrogen (Nr) deposition also has a detrimental effect on human health. Effects of human activity (Vidal-Dorsch et al., 2012) and climate change (Mostofa et al., 2012) on marine ecosystems create significant issues that want attention. In order to lessen the consequences of climate change, the European Union (EU) has produced a number of recommendations and legislative measures (Papadaskalopoulou et al., 2016).

Objective of the study:

- Evaluate the vulnerability of aquaculture systems to the effects of global warming, such as temperature changes, ocean acidification, and sea level rise.
- Investigate the direct and indirect impacts of global warming on aquaculture production, including changes in growth rates, reproduction, and disease susceptibility.
- Assess the ecological consequences of global warming on aquaculture ecosystems, including shifts in species composition, loss of biodiversity, and changes in food webs.
- Identify adaptive strategies and mitigation measures that can be implemented to minimize the negative effects of global warming on aquaculture, such as improved water management practices, selective breeding of resilient species, and the use of sustainable feed and energy sources.
- Provide recommendations for policymakers, industry stakeholders, and aquaculture practitioners to promote the development and implementation of climate-resilient and sustainable aquaculture practices in the face of global warming.

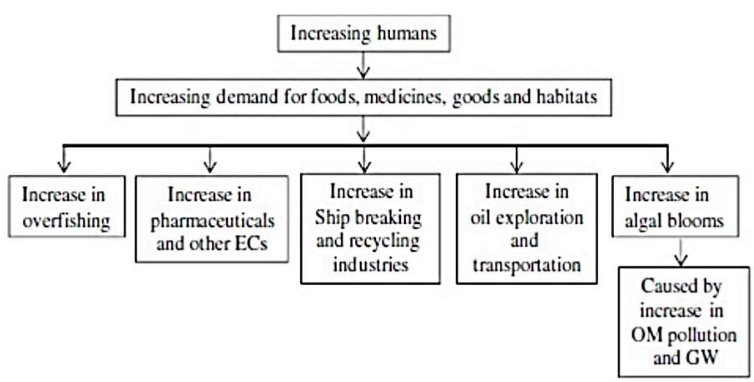

Fig. 2. Effects of human on marine ecosystems (adapted from Khan *et al.* 2013).

Marine Biodiversity

Global warming is apparently having an impact on coastal marine habitats and their biodiversity. Additionally, due to the global food shortage (Fig. 2), sea pollution, particularly that caused by breaking and recycling industry pollutants, excessive production and improper disposal of pharmaceuticals, and over-shing have negatively impacted marine diversity (Rooker et al., 2008; Srinivasan et al., 2010). In the Baltic Sea, temperature has an impact on the bacterioplankton's metabolic rates as well as its composition (Vaquer-Sunyer et al., 2015). Amounts of algal toxins and naturally occurring toxic emerging contaminants (ECs) have been documented to be fatal to aquatic species and people who consume tainted fish or shellfish (Vaquer-Sunyer et al., 2015). According to Graham and Harrod (2009), climate change will continue to endanger ecosystem biodiversity, structure, and function. The groups and people who make up an ecosystem will be impacted by global warming. Numerous direct, indirect, and intricate effects will be felt on their physiological and ecological systems. Based on its tolerances and life phases, each species will react to these elements in a variety of ways that are difficult to anticipate. Aquatic animals may not all be equally able to adapt to the predicted changes in climate, but they will nonetheless travel both horizontally and vertically to live and procreate in water sources. It's possible that certain animals without moving habitats may become extinct soon or turn into food for predators. Williams (1999) promoted the restoration of wildlife habitats, which act as wildlife corridors, boost biodiversity, and reduce soil erosion, by re-establishing bottomland hardwood forests and coastal wetland grasses.

Natural and Anthropogenic Factors Affecting Marine Biodiversity

Aquatic ecosystems, particularly their nitrogen and carbon cycles, are impacted by changes in environmental conditions brought on by pollution, dam building, increased deposition of woody waste from human activities, and climate change. When considering medicines as contaminants, it is possible that their overproduction or improper disposal contributed significantly to the water contamination. Shipbreaking and recycling industries (SBRIs), over-harvesting, organic matter (OM) pollution, and global warming (GW) are additional contributors of water pollution. These lead to algal blooms and acidification, which impair ecosystems and marine biodiversity. According to research by Hyde et al. (2016), freshwater lignicolous fungi in Asian and Australian locations are severely impacted by changes in environmental conditions.

Response of Invertebrates and Vertebrates to Climate Change

According to a niche modeling analysis, the range size of pulmonate freshwater snails in Central Europe will be smaller by 2080 if their capacity for dispersal does not keep pace with the rate of climate change (Cordellier et al., 2012). In Austria, it was hypothesized that millennia of climatic warming caused changes in the invertebrate ecology of Lake Moaralmsee (Luoto et al., 2012). Direct-developer eggs of 20 different anuran frog populations living in four different breeding habitats in a tropical montane rain forest have been found to be more sensitive to climate warming than both metamorph and adult life-history stages in the Philippines (Scheffers et al., 2013). Additionally, stream ecosystems with a high concentration of ectothermic residents located in dangerous dendritic networks are said to be negatively impacted by climate change (Isaak et al., 2013).

While Fengqing et al. (2013) reported that stream insects such as Ephemeroptera, Odonata, Plecoptera, and Trichoptera diversities are effected by global warming in South Korea, Kolicka et al. (2015) reported native and alien Rotifera, Copepoda, Polychaeta, Acari, and Insecta larvae in greenhouses of Poznan in Poland. Overall, they predict that by 2080, insect populations would either increase by 66.7% or reach an extinction threshold of 71.4% due to global warming. In a different research, it was shown that macroinvertebrate communities including mayies, stoneies, and caddisies of benthic species residing in river ecosystems had a significant potential for sensitivity to climate change. This study was based on the biodiversity of macroinvertebrates from 521 locations throughout Korea. Furthermore, it was expected that macroinvertebrates would be less affected by global warming in the 2060s; but, 55% of these species would go extinct by the 2080s under the premise that average global temperatures would rise by 3.4°C by 2090. Warm-water species are predicted to multiply while the number of cold-water species will decline. Their population will grow temporarily between 2000 and 2040, then gradually decline by 2080 (Fengqing et al., 2013).

Using the stream insect orders Ephemeroptera, Plecoptera, and Trichoptera, Shah et al. (2014) proposed a genus-by-genus approach to assess the effects of climate change on freshwater biota throughout North America. In a different research, Tisseuil et al. (2012) created a unique technique by integrating statistical downscaling and sh species distribution modeling and assessed how local riverine sh diversity in France is affected by global climate change. By assuming a 15% reduction in the average annual stream flow and a 1.2°C increase in average global temperature by the year 2100, they predicted that the majority of cool- and warm-water species would expand their geographic range within the basin, while the number of cold-water species would decline. In line with this, Willigalla et al. (2012) came to the conclusion that recent increases in Mediterranean species may be to blame for changes in the richness of Odonata species.

The impacts of on biodiversity and functional changes in soil ecosystems have been described by Zaitsev et al. (2016). Four sequential and complementary processes linked to the upward dispersion of species and colonization of new habitats were proposed as a novel way to protect freshwater biodiversity in the Alps in the context of global warming (Oertli et al., 2014).

CLIMATE CHANGE AND BREEDING

GROUND OF FISHES

Climate Change and Breeding Ground of Fishes

According to Yvon-Durocher et al. (2012), there are significant relationships between seasonal temperature change, community size structure, and carbon dioxide levels. They proposed that we comprehend the connections between individual species and biogeochemical cycles in order to forecast how important ecosystem functions would respond to upcoming environmental changes. In their study, Sommer et al. (2012) used the AQUASHIFT research program to analyze shifts in geographic distribution, seasonal changes, temporal mismatch in food chains, biomass responses to warming, responses of growth, harmful bloom intensity, changes of biodiversity, and the dependence of shifts to temperature changes during critical seasonal window to determine effects of global warming on aquatic ecosystems (both marine and freshwater) in the temperate zone.The impacts of re on biodiversity and functional changes in soil ecosystems have been described by Zaitsev et al. (2016). Four sequential and complementary processes linked to the upward dispersion of species and colonization of new habitats were proposed as a novel way to protect freshwater biodiversity in the Alps in the context of global warming (Oertli et al., 2014).

The response rates of 157 non-native species and 204 co-existing native species to potential climatic changes were calculated using a meta-analytical technique under various temperature, CO2, and precipitation circumstances. It was discovered that native and non-native species reacted to environmental changes at about the same rates in terrestrial vegetative systems but at different rates in aquatic animal systems. Climate change puts aquatic systems at greater danger of invasion, as shown by the inhibition of native species' development caused by rising temperatures and CO2 (Sorte et al., 2013). Ostberg et al. (2013) found adverse consequences of climate changes on terrestrial ecosystems using macro-scale analyses.In order to identify and mitigate the impacts of the critical environment on the production of striped cats, Bosma et al. (2011) applied a stakeholder-based screening life cycles assessment (LCA) in an intensive farming system. They came to the conclusion that in Pangasius grow-out farming, employing successfully managing sludge and high quality sh feeds, including low aquatic by-products with low feed conversion ratio reduced adverse impacts of environmental changes.Although it is well recognized that recently introduced non-native species are harmful for biodiversity in any environment, knowledgeable consumers are unable to distinguish between native and invasive species' quality (Caldow et al., 2007). Depending on its preferred temperature, sh often changes its habitat in marine environments. Compared to typical Arctic residents, eurybiontic species can survive a larger variety of climatic circumstances, giving them an advantage for optimal development (Moiseenko et al., 2004).

Anthropogenic Impacts on Fisheries Resources

Anthropogenic impacts on fisheries resources refer to the negative effects caused by human activities on the health and sustainability of fish populations and their habitats. These impacts can have significant consequences for both marine and freshwater ecosystems, as well as for the communities that depend on fisheries for their livelihoods. Here are some detailed examples of anthropogenic threats to fisheries resources:

- Overfishing: Overfishing occurs when fish are harvested from a population at a rate that exceeds their natural reproduction capacity. This can result in the depletion of fish stocks, leading to reduced fish populations and disruptions in the ecosystem's balance. Overfishing is often driven by excessive fishing efforts, inadequate fisheries management, and the use of destructive fishing practices such as trawling.
- Habitat Destruction: Human activities such as coastal development, pollution, and the destruction of wetlands and coral reefs can degrade or destroy important fish habitats. Loss of

seagrass beds, mangroves, and coral reefs deprives many fish species of their breeding grounds, nurseries, and food sources, ultimately impacting their populations.

- Pollution: Industrial and agricultural activities introduce various pollutants into water bodies, including toxic chemicals, heavy metals, and excess nutrients. These pollutants can contaminate fish habitats and bioaccumulate in fish tissues, posing risks to both the fish themselves and the humans consuming them. Pollution can also lead to harmful algal blooms, deplete oxygen levels in the water, and disrupt the overall ecosystem health.
- Climate Change: Rising global temperatures, ocean acidification, and changes in ocean currents and weather patterns associated with climate change pose significant threats to fisheries resources. These changes can alter the distribution and abundance of fish species, disrupt their reproductive cycles, and lead to the loss of critical habitats such as coral reefs. Climate change can also exacerbate the occurrence of extreme weather events, which can directly impact fish populations and fishing communities.
- Bycatch and Discards: Bycatch refers to the unintentional capture of non-target species during fishing operations. It often involves marine mammals, sea turtles, seabirds, and other fish species. Bycatch can result in the injury or death of these species and contribute to their population decline. Discards refer to the practice of discarding unwanted or undersized fish back into the sea, often due to economic incentives or regulatory requirements. Both bycatch and discards contribute to the wasteful use of resources and can have significant ecological consequences.
- Illegal, Unreported, and Unregulated (IUU) Fishing: IUU fishing undermines fisheries management efforts by operating outside of existing regulations and agreements. It depletes fish stocks, distorts markets, and undermines the livelihoods of legal fishing communities. IUU fishing activities, such as the use of illegal gear, fishing in restricted areas, and the trade of illegally caught fish, pose a significant threat to the sustainability of fisheries resources.

Addressing these anthropogenic threats to fisheries resources requires a combination of effective fisheries management, sustainable fishing practices, habitat conservation, pollution reduction, and global cooperation. It is essential to promote responsible fishing practices, implement science-based fisheries management strategies, and raise awareness about the importance of sustainable fisheries for long-term ecological and socio-economic well-being.

Conclusion

The effects of invasionism, lessensianism, and endangerment on aquatic species and their ecology are obvious in view of present understandings and presumptions. Therefore, it is essential to announce that, by 2080 or 2100, climate change would lead to the extinction of certain aquatic creatures as well as some species. While global warming is occurring, the effects of uneven aquaculture transfer, interactions between naturally occurring migrations and global warming-triggered relocation, and the possibility of artificial sand releases in the impacted medium are yet unknown. The effect of climate changes on endangered species locally, nationally, and internationally calls for further investigation. According to the available evidence, it is essential to suggest stringent international law that includes particular safeguards on maintaining reproductive habitats and restricting over-shingling. These laws are essential to protect the ecosystem and delay the aquaculture industry's inevitable climate change effects. Precautions must be taken to prevent the extinction of native and recently imported species in order to preserve species variety and maintain species balance. Prey-predator interactions must also be monitored. The influence of human activities that may change the natural environment and affect the habitat of aquatic creatures must also be evaluated. For instance, it has not been well studied and predicted how opening the Suez Channel could affect the migratory patterns of lesser Egyptian species. To gauge the impact of such actions on natural habitats, study is needed.

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