The influence of climate variability on the spread of aquatic infectious diseases

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Abstract

Climate Variation (CV) will influence aquatic animal well-being in several ways, including intensified production, diversity of organisms and genetics, and extension outside the usual geographic boundaries of species. CV influences the creation setting, affecting pathogen frequency and infectiousness, host vulnerability, propagation dynamics, and the possibility of breakouts from storm-affected storage infrastructure, whether terrestrial or marine. Infectious Diseases (ID) often occur in marine habitats; nevertheless, the impact of CV on aquatic microorganisms remains little understood. This study focuses on the existing understanding of the influence of climate on the relationship between hosts and pathogens and the emergence of ID outbreaks. CV-related effects on aquatic illnesses are recorded in coral reefs, oysters, and mammals; these effects are less distinctly associated with other taxa. The relationship between oceans and humanity is inseparable, with marine ID potentially affecting human wellness, livelihoods, and general well-being. This work advocates for a flexible management strategy to enhance the durability of aquatic ecosystems susceptible to marine ID in a CV.

Keywords: Climate variation, Infectious diseases, Aquatic, Coral reefs, Oysters, Flexible management strategy

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Overview of the Study

CVs in maritime systems are already significant and anticipated to intensify. Numerous facets of aquatic environments and their human elements are experiencing significant impacts, and historically sufficient strategies for adapting to alterations are being critically tested. Societal reactions to such transformation have included prevention and mitigation, with the former predominating in national and international objectives. At the same time, the latter is more prevalent at local, sector-specific, and neighborhood levels. The requirement for social system adaptability that optimizes possibilities while mitigating economic, ecological, and societal repercussions will escalate swiftly. This is essential, especially under typical regular operations climate forecasts (Pecl *et al.,* 2017; Naseer and Mini Devi, 2019) to preserve the sustainability of biological aquatic ecosystems and related livelihoods.

Adapting human systems to CV necessitates choices within a possibly intricate multi-agent framework that includes personal and governmental entities. Private persons may instigate resilience for personal gain. Still, governments may also launch it for the collective benefit. Individuals, corporations, peak organizations, ecological NGOs, social organizations, administration agencies, and authorities at diverse territorial and legislative levels make adaptation choices in the maritime setting (Arulkarthick and Vinothkumar, 2019).

Decisions about changes in maritime systems are governed by factors such as strategy, timeframe, costs, and other constraints (Miller *et al.,* 2018). Actors vary in the degree and character of their investment in aquatic ecosystems, their experiences of change, and their ability and authority to take action. They also vary in their principles, opinions, and views, as seen by these communities' vast array of procedures, behaviors, activities, and acts. CV requires both the readiness to change and the feasible capacity to change concerning agency, strength, and assets (Huntington *et al.,* 2017).

For diverse reasons, CV acts and procedures have been classified according to several schemas. The difference between both public and private players is based on their intent, timing, chronological and geographical scopes, shape, function, and effectiveness in attaining desired goals. A difference is often made about the degree of an actor's purpose to adapt, with some acts occurring instinctively and without careful consideration in reaction to the effects of CV on the environment and human society. At the opposite end of the intention to modify spectrum is scheduled to change, which arises from a deliberate decision informed by the recognition that conditions have altered or are imminent to change, necessitating action to revert to, sustain, or attain an ideal situation (Maldia *et al.,* 2023).

The sea environment presents unique problems in understanding human ecosystem change (Miller *et al.,* 2018). The manifestation of CV in aquatic ecosystems is intricate, with shifts in sea temperatures, pH levels, and currents functioning independently and collectively to create unpredictable circumstances that affect the functioning and efficiency of all stakeholders (Pecl *et* *al.*, 2017). The issues related to potentially opposing adaptation measures and the disputes they may incite are exacerbated by the multitude of non-governmental entities that profit from maritime resources and often possess divergent values.

The significant involvement of governmental entities in aquatic administration and oversight is also noteworthy (Saidova *et al.*, 2024). The growing significance of shared management methods and collaborative models in essential aquatic sectors, particularly fisheries, has seemingly enhanced acknowledged aquatic users' power and adaptive ability (Nursey-Bray *et al.*, 2018). Nevertheless, several theorists (Pinkerton, 2019) have observed that the power dynamics between governmental and non-governmental entities remain contentious, as these mechanisms—typically employed only literally or technically—have largely failed to alter the dynamics of power meaningfully. This may inadvertently lead to the increased marginalization of non-governmental entities, such as Indigenous fishermen, thereby affecting the feasibility of user-driven independent change. IDs are significant influencers throughout ecosystems.

Numerous extensively reported terrestrial instances exist where ecosystems have been altered by extensive outbreaks of ID, including Dutch elm disease and walnut blight (Archana Menon and Gunasundari, 2024). ID may affect aquatic environments by altering community composition, age ranges, predatory relationships, hydraulics, and biological structures, as shown by studies on ocean grasses, coral reefs, oysters, and fishes (Byers, 2021). ID significantly affects both cultivated and wild populations of economically valuable species, including salmon, as shown by Ichthyophonus illnesses in maritime and infections with viruses in Atlantic and Pacific salmon. In both land and water ecosystems, the relationships among hosts, pathogens, and the surroundings dictate ID outbreaks, and alterations in any of these elements may alter the equilibrium towards or away from a high-intensity disease state (Baker *et al.*, 2022).

Numerous interactions between hosts and pathogens are significantly susceptible to environmental changes; hence, CV may modify the probability of ID outbreaks. CV has modified the danger of agricultural diseases on land and may influence the risk of human diseases (Shichkina *et al.*, 2020). Our comprehension of the impacts of ID in marine environments and the influence of CV on interactions between hosts and pathogens is still in its infancy, both essential for guiding preservation and administration initiatives.

The Effects of CV on the Interactions Among Aquatic Hosts, Pathogens, and their Environment

Figure 1, entitled "The consequences of CV on the interactions among aquatic hosts, pathogens, and their environment," depicts the intricate relationships between CV, aquatic species, and microbial infections. The central Venn diagram illustrates the interrelated dynamics among the environment, host organisms, and pathogens. Surrounding this core are four principal climate-induced stressors—rising temperatures, ocean acidification, changes in precipitation, and storm exposure—depicted graphically and quantitatively connected to comprehensive explanations of their biological effects. Every climatic element impacts hosts and diseases, modifying susceptibility, virulence, dispersion, and overall ecosystem dynamics.

(A) Temperature Elevation: Climate-induced temperature escalation, represented by a thermometer icon, increases pathogen activity and virulence. This warming enhances the metabolism and reproduction rates of pathogens, facilitating the creation of novel diseases, invasions, and changes in geographic distribution. Concurrently, host species exhibit heightened vulnerability owing to physiological stress, modified behavior, and potential range alterations, which may influence predator-prey and host-pathogen dynamics. The cumulative impacts may eventually disturb the ecological equilibrium and elevate the prevalence of infectious illnesses in aquatic environments.

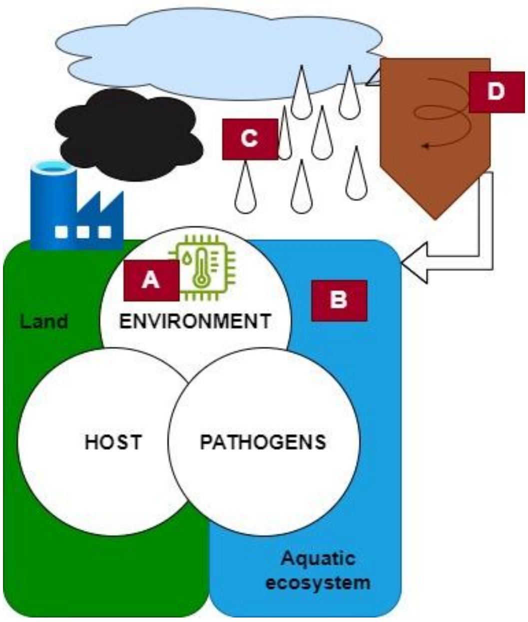

Figure 1: The effects of CV on the interactions among aquatic hosts, pathogens, and their environment.

(B) Ocean Acidification (Elevated CO_2 and Reduced pH): Denoted by chemical symbols, elevated CO_2 concentrations result in ocean acidification, affecting host health and pathogen interactions. Acidified environments may diminish host variety and larval recruitment, hindering early growth and disease resistance. Lower pH levels may affect the virulence and abundance of infections, perhaps increasing their ability to infect susceptible hosts. The chemical alterations in water chemistry illustrate how indirect climate factors may significantly impact biological outcomes across trophic levels.

(C) Alterations in Precipitation Patterns and (D) Storms: Alterations in precipitation patterns, including drought and floods, modify salt levels and nutrient availability, exerting stress on aquatic organisms and promoting the establishment of novel diseases. Hosts encounter dietary deficiencies and pollutant exposure, compromising immune responses. Storms and cyclones, characterized by whirling clouds and waves, inflict physical harm on organisms and resuspend pathogens from sediments into the water column. This disruption elevates the likelihood of infections, facilitates pathogen invasions, and expands their geographical distribution. These environmental disturbances exacerbate the susceptibility of aquatic ecosystems to disease outbreaks in the context of CV.

The Effect of CV on Coral Reefs

Hermatypic CRs have developed in tropical environments that, in recent years, saw very modest fluctuations in temperature and pH levels. In the last forty years, escalating ecological strain from rapidly evolving climate-related and human causes has disturbed the equilibrium among hosts, representatives, and surroundings essential for CR's health. The breakdown of CR-microbial symbioses and the resulting diminished resistance to ID have significantly contributed to the decline of CR populations globally. The decline of CRs is most extensive and severe in the Caribbean Sea, which is a hotspot for ID, marked by prevalent temperature-induced mass CR bleaching (a lack of photo-symbionts), the swift growth of various new and infectious diseases, and generally more significant ID prevalence compared to other reef areas (Edwards, 2021).

Temperature-induced strain has been a significant component in widespread mortality linked to bleaching and ID in CR species. The host variety and prevalence of black band ID, a CR disease susceptible to temperature and minerals, have escalated globally, likely due to the synergistic effects of diminished resistance in the host and heightened pathogen virulence linked to rising seawater temperatures and decreasing water quality. The quality of water, which includes viscosity, mineral load, debris, and pollutants, is a crucial determinant of CR health, affected by CV, with considerable consequences for the onset and proliferation of coral ID. CR epizootics demonstrate how interconnected ecological and human-induced disturbances may significantly modify community organization in CR ecosystems, necessitating administration and remediation efforts.

The detection of pathogens and the environmental factors associated with coral ID are essential knowledge gaps for comprehending the management of CR health during CV. Effectively controlling water quality is crucial for mitigating environmental impacts associated with CV. Research is mounting that oceanic protected zones (OPAs), including intact CR ecosystems and decreased fishing impacts, may contribute to preserving CR health. While OPAs may not shield CRs from climate-induced risks, OPA networks might provide significant mechanisms to enhance ecological resilience, perhaps facilitating the reseeding of adjacent damaged reefs. O PAs will gain significance in addressing the escalating array of new hazards to the long-term viability of CR environments, which are essential for both developing and established economies reliant on these ecosystems' ecological services. Regional CR outbreaks of diseases, massive bleaching, and non-infectious episodes provide opportunities for early discovery to address risks and execute management strategies.

The Effect of CV on Oysters

The aquatic mollusk hosts most extensively researched about ID are oysters, which have a much higher prevalence of fatal infections than other economic aquatic organisms (Neokye *et al.*, 2024). Oysters have ecological significance due to their contributions to reef ecosystems, benthic-pelagic interaction, water filtering, and serving as prey for other creatures. Consequently, oyster ID inflicts economic devastation and impairs overall ecological efficiency and health. Consequently, oysters, and perhaps other organisms, reaction to climatic fluctuations in a specific area does not reflect the reaction seen over the species' entire distribution. The cyclical characteristics of climatic patterns have been proposed as the cause for the absence of growth in resistance to Dermo illness despite elevated death rates and recurrent infectious diseases.

Sporadic, decadal, and persistent shifts in ecological circumstances combine to regulate the frequency, severity, and geographical spread of the two principal IDs impacting eastern oyster species. Recent investigations indicate that illness restricts the capacity to sustain oyster reefs since death rates are very high for reef accumulation to transpire throughout most of the coastal salinity variation inhabited by oysters, even without fishing pressures. Consequently, heightened mortality due to illness has diminished the resilience of oyster species against exploitation. The widespread occurrence and extensive dispersion of oyster infections complicate prevention and control efforts. The administration of contemporary oyster assets, including water and fishing operations, must include the impacts of illnesses and ecological fluctuations across many scales. Regulation of upstream freshwater intake may regulate downstream estuary salinity, hence mitigating ID-related oyster death. Furthermore, fisheries may use flexible governance by using strategies such as temporarily decreasing harvests during elevated disease-induced mortality to guarantee the long-term viability of oyster communities.

The Effect of CV on Aquatic Mammals

CV affects the ID pattern in aquatic ecosystems, yet no research has shown a convincing causal link between any aspects of CV and the rise of ID in aquatic organisms (Nelms et al., 2021). This is mostly due to insufficient adequate data and the probable indirect effects of CV on these illnesses. CV may influence the probability or rate of infections, the extent or seriousness of epizootics, and/or the degree of severity or occurrence of clinical illness in infected persons. Several possible processes have been identified by which this may occur. CV may alter haul-out sequences, affecting disease transmission risk due to variations in host density, haul-out length, and/or interactions with continental hosts. Temperature fluctuations might alter species distributions, diversity, or communities, thus increasing the likelihood of interaction between vulnerable people and disease reservoirs.

CV may alter food sources' distribution and/or availability, resulting in inadequate nutrition and immunodeficiency. Variations in sea-surface salinity and temperature may influence the survival of pathogens by affecting their persistence or distribution. Alterations in land use or precipitation patterns might enhance the transfer of terrestrial pathogens to the maritime zone, elevating marine mammals' vulnerability. Ultimately, warming may influence pathogen development, perhaps yielding strains more adept at penetrating and staying in marine animals.

Identification is challenging since several impacts on these illnesses ascribed to CV might be linked to changes in non-climatic causes. Acquiring information regarding the frequency and incidence of infections in untamed, free-ranging populations poses significant logistical challenges; consequently, assessing alterations in long-term disease patterns within marine mammal groups and determining the impact of CV on these variations can be exceedingly difficult and frequently unfeasible with the presently accessible information. Enhanced, comprehensive preliminary information obtained from targeted, long-term aquatic health initiatives is essential for a clearer understanding of the influence of CV on the pattern of ID in marine mammals.

Moreover, pinpointing sources of pathogen spread might facilitate intervention efforts. The conservation and reconstruction of marshes may mitigate marine infection by pathogens, such as T. gondii, carried in polluted runoff. Vaccination, population management, and the regulation of mobility near phocid haul-out locations may mitigate the risk of disease transfer, including canine distemper virus, to vulnerable marine animals.

Conclusion

A number of factors, such as increased production, diversity of organisms and genetics, and expansion beyond the typical geographic bounds of species, will impact the well-being of aquatic animals due to climate variation (CV). There is a correlation between CV and the creation setting, which impacts the frequency and infectiousness of pathogens, the vulnerability of hosts, the dynamics of propagation, and the risk of outbreaks from storm-affected storage infrastructure, whether it be terrestrial or marine. However, the impact of CV on aquatic microorganisms is still not well understood, even though infectious diseases (ID) frequently occur in marine ecosystems.

The purpose of this study is to investigate the current understanding of climate's impact on the relationship between hosts and pathogens, as well as the emergence of infectious disease outbreaks. There is evidence that cardiovascular disease (CV) is associated with aquatic illnesses in coral reefs, oysters, and mammals; however, these effects are less clearly correlated with other species. In addition to being able to influence human health, livelihoods, and overall well-being, marine identification can impact the interaction between mankind and the oceans. The purpose of this work is to advocate for a flexible management strategy to improve the durability of aquatic ecosystems that are susceptible to marine ID in a country.

Minimal efforts are being made to incorporate climate-related impacts on marine illnesses into management strategies, including ecosystem-based management, marine protected area creation and execution, and managing fisheries. Incorporating climate and disease factors into management will guarantee the sustainability of ocean ecosystems and the advantages they provide to humanity for future generations.

References

Archana Menon, P. & Gunasundari, R., 2024. Deep feature extraction and classification of Alzheimer's disease: A novel fusion of Vision Transformer-DenseNet approach with visualization. *Journal of Internet Services and Information Security, 14*(4), pp.462–483. https://doi.org/10.58346/JISIS.2024.I4.029.

Arulkarthick, V.J. & Vinothkumar, T., 2019. High-performance block cipher using flexible architecture. *International Academic Journal of Science and Engineering*, *6*(1), pp.188–193. https://doi.org/10.9756/IAJSE/V6I1/1910019.

Baker, R.E., Mahmud, A.S., Miller, I.F., Rajeev, M., Rasambainarivo, F., Rice, B.L., ... & Metcalf, C.J.E., 2022. Infectious disease in an era of global change. *Nature Reviews Microbiology*, *20*(4), pp.193–205.

Byers, J.E., 2021. Marine parasites and disease in the era of global climate change. *Annual Review of Marine Science*, *13*(1), pp.397–420. https://doi.org/10.1146/annurev-marine-031920-100429

Edwards, A.J., 2021. Impact of climatic change on coral reefs, mangroves, and tropical seagrass ecosystems. In: *Climate Change Impact on Coastal Habitation*. CRC Press, pp.209–234.

Huntington, H.P., Begossi, A., Gearheard, S.F., Kersey, B., Loring, P.A., Mustonen, T., ... & Vave, R., 2017. How small communities respond to environmental change: patterns from tropical to polar ecosystems. *Ecology and Society*, *22*(3).

Maldia, L.S., Combalicer, M.S. & Tinio, C.E., 2023. Plants' anatomical and genetic responses to anthropogenic climate change and human-induced activities. In: *Plant Diversity in Biocultural Landscapes*. Singapore: Springer Nature Singapore, pp.403–441.

Miller, D.D., Ota, Y., Sumaila, U.R., Cisneros-Montemayor, A.M. & Cheung, W.W., 2018. Adaptation strategies to climate change in marine systems. *Global Change Biology*, *24*(1), pp.e1–e14. https://doi.org/10.1111/gcb.13829

Naseer, A. & Mini Devi, B., 2019. Effect of organisational climate on employees' motivation in university libraries in Kerala: An investigative study. *Indian Journal of Information Sources and Services*, *9*(1), pp.71–75. https://doi.org/10.51983/ijiss.2019.9.1.590.

Nelms, S.E., Alfaro-Shigueto, J., Arnould, J.P., Avila, I.C., Nash, S.B., Campbell, E., ... & Godley, B.J., 2021. Marine mammal conservation: over the horizon. *Endangered Species Research*, *44*, pp.291-325. https://doi.org/10.3354/esr01115

Neokye, E.O., Wang, X., Thakur, K.K., Quijon, P., Nawaz, R.A. & Basheer, S., 2024. Climate change impacts on oyster aquaculture - Part I: Identification of key factors. *Environmental Research*, p.118561. https://doi.org/10.1016/j.envres.2024.118561

Nursey-Bray, M., Palmer, R. & Pecl, G., 2018. Spot, log, map: Assessing a marine virtual citizen science program against Reed's best practice for stakeholder participation in environmental management. *Ocean & Coastal Management*, *151*, pp.1–9. https://doi.org/10.1016/j.ocecoaman.2017.10.031

Pecl, G.T., Araújo, M.B., Bell, J.D., Blanchard, J., Bonebrake, T.C., Chen, I.C., ... & Williams, S.E., 2017. Biodiversity redistribution under climate change: impacts on ecosystems and human well-being. *Science*, *355*(6332), p.eaai9214. https://doi.org/10.1126/science.aai9214

Pinkerton, E., 2019. Legitimacy and effectiveness through fisheries co-management. In: *The Future of Ocean Governance and Capacity Development*. Brill Nijhoff, pp.333–337. https://doi.org/10.1163/9789004380271_056

Saidova, K., Ashurova, M., Asqarov, N., Kamalova, S., Radjapova, N., Zakirova, F., Mamadalieva, T., Karimova, N. & Zokirov, K., 2024. Developing framework for role of mobile app in promoting aquatic education and conservation awareness among general people. *International Journal of Aquatic Research and Environmental Studies*, *4*(S1), pp.58–63. https://doi.org/10.70102/IJARES/V4S1/10.

Shichkina, Y.A., Kataeva, G.V., Irishina, Y.A. & Stanevich, E.S., 2020. The use of mobile phones to monitor the status of patients with Parkinson's disease. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications*, *11*(2), pp.55–73. https://doi.org/10.22667/JOWUA.2020.06.30.055