Assessing the Effects of Climate Change on Aquatic Ecosystems

[1] Wondimagegn Assegid, College of Health Sciences, Addis Ababa University, Ethiopia.

[2] Girma Ketema, College of Health Sciences, Addis Ababa University, Ethiopia.

Abstract: Climate Change (CC) is affecting the functionality and geographical distribution of ecosystems utilized by maritime, coastline, and freshwater species. Anticipated future intensification of recent climate-induced physio-chemical alterations seen in Aquatic Habitats (AH) globally is anticipated. Modifications in critical environmental variables of AH, including water supply, conciseness, temperature, glacier cover, periodic stream regimes, external loads, and oxygen level, will inevitably result in a wide array of immediate and secondary biological repercussions. Inevitable, expected consequences may be analogous across various AHs, while others may be particular to the system. This study performed a CC threat evaluation for 25 maritime, coastal, and freshwater habitats to provide an ecosystem-scale comprehension of the effects of CC on these environments. The trait-based evaluation evaluates an AH's total threat to CC due to two primary elements, susceptibility, and visibility, using a method of skilled collection. The climatic sensitivity rankings varied from low to extremely high, with living environments designated as the most sensitive. This analysis provides local officials and researchers with a resource to guide AH preservation, rehabilitation, research goals, and aquaculture and endangered species administration.

Keywords: Climate Change; Aquatic Habitats; Maritime; Coastal; Freshwater Habitats; Threats.

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I. Introduction and Related Works

Climate change and invasive species are two of the most impactful drivers of global environmental change. Climate change is expected to significantly alter aquatic systems by increasing water temperatures, modifying stream flow patterns, and intensifying storm events (Ricciardi et al., 2021). These alterations will likely have profound effects on species distribution, phenology, and the overall productivity of aquatic ecosystems. Moreover, human activities like intentional stocking, aquarium releases, canal construction, and international shipping have significantly contributed to the spread of aquatic invasive species (Staudinger et al., 2021). Extensive research has documented the widespread invasion of non-native species and their adverse effects on aquatic ecosystems.

The independent impacts of climate change and non-native species on aquatic systems are often examined separately. However, these primary drivers of global environmental change are likely to interact in complex ways (Noori et al., 2022). For example, global climate change will cause water temperatures to rise in northern-latitude lakes. This could create stressful seasonal conditions for cold water-adapted fish species while providing favorable thermal conditions for non-native warm-water fish species. These non-native species might prey on or compete for food resources with native fish, leading to declines or even losses of native fish populations (Bruhwiler et al., 2021). Thus, the decline in native species and population losses could result from the combined effects of climate warming and the presence of non-native species.

Factors of climate change that may influence aquatic invasive species include altered thermal regimes, reduced ice cover in lakes, changes in streamflow patterns, increased salinity, and intensified water development activities such as canal and reservoir construction (Carosi, 2022). These environmental shifts may subsequently change the pool of potential colonizers, impact the likelihood of non-native species becoming established, alter the effects of existing invasive species, and necessitate the initiation or expansion of prevention and control efforts.

CC is regarded as the paramount worldwide problem of the present century. It affects human and natural systems by increasing their vulnerability at various scales and with adverse severity. Global warming

(GW) has an immediate and extensive influence on the water cycle, affecting AH (Riedel & Weber, 2020). Human endeavors have directly resulted in a significant rise in releases of greenhouse gases, mostly carbon dioxide (CO_2), which predominantly contributes to GW. The total amount of CO_2 is anticipated to increase to double the levels seen during the time before industrialization. AH are vulnerable to pollution, species invasion, land-use alteration, and increasing temperatures.

Scientific investigations underscore a challenging predicament acknowledged by administrators and scientists: (1) ecological reactions to modifications are very unreliable, and (2) the effects of climate change on AH are inconsistent with broad generalizations and predictions. Stress resulting from environmental alterations may induce unpredictable, rapid changes between different ecological states (Farr et al., 2021). Nonetheless, some instances illustrate a deterioration of resilience by enabling unwelcome regime changes to alternative states with unpredictable consequences for the future supply of environmental services. While warning indications for detecting and recognizing regime transitions in many habitats exist, the ambiguity and lack of generalizability across habitats complicate the development and implementation of this strategy (Delaney et al., 2021). Both complementary and adversarial ecological reactions are influenced by extremely context-specific variables, including climatic and manmade elements, which are challenging to interrelate. The primary objective of this evaluation is to provide data for researchers and administrators of natural resources to ascertain research needs and enhance management choices for these AHs and the species dependent on them. Additionally, this work clarifies various secondary impacts of CC on species via their immediate effects on AH.

II. Materials and Methods

This evaluation used a trait-based approach that included susceptibility and visibility. The overarching principle is that an AH's climate risk is determined by the interaction between its susceptibility and prospective visibility to future changes. Numerous sensitivity evaluations have an adaptability element. Adaptability and responsiveness in biological structures are intertwined; conversely, a feature indicating great susceptibility may be seen as poor resilience. Consequently, it has been included in the susceptibility factor.

Collection of AH

The evaluation defines AH as the rivers, coastal areas, and marine environments, encompassing the active, substrate and water line, along with the physical, chemical-based, and biological aspects of an AH upon which a species relies to fulfill its entire life cycle — reproduction, growth, maturation, and existence. It has been involved in 25 AHs according to their significance. AH occurring in multiple environments (e.g., underwater plant life present in all ecosystems) was evaluated independently to identify variations in climate and non-climate factors affecting that AH. Classes for AH in rivers, coastal, and maritime environments were added. The categorization method facilitates the comparison of climatic sensitivity across AH spanning various habitats, sub-habitats, groups, sub-groups, and geographic regions, therefore uncovering trends and principal determinants of susceptibility.

Susceptibility

The susceptibility of AH to CC was assessed using qualities including various features that indicate how AH may react to forthcoming climatic alterations. AH situation and splitting indicate a habitat's capacity to sustain an organic and fully operational sustainable community. In contrast, Mobility/Ability to Disperse or Dissipate Resilience and the vulnerability to modifications in anaerobic variables assess a habitat's responsiveness to CC. The susceptibility and strength of Non-climate pressures have been included to evaluate the impact of various human-made stressors on an AH since these stressors may diminish the biological function and the capacity of AH to endure climate-related pressures. This feature encompasses non-climatic variables that may impact freshwater, coastal, and maritime ecosystems. A documented definition and score categories were established for every feature to guarantee reliability and uniformity in using these susceptibility qualities. The evaluation categories delineate poor, medium, good, and outstanding results for each vulnerability trait.

Visibility

Ten equally distributed visibility parameters have been employed to signify the extent and intersection of anticipated CC with AH dispersion. This technique utilizes a diverse array of exposure characteristics, which may augment the susceptibility of an AH rather than concentrating on just one parameter (e.g., heat). This strategy has been implemented because of the likelihood that distinct ecosystems may react differently to the predicted changes associated with CC. This multifactorial method enabled us to discern possible progressive or compounding effects of various exposure components. It is essential to recognize that not all aspects of exposure directly influence each of these AHs. Only the relevant parameters for each environment were evaluated. For instance, visibility to sea level rise was assessed for coastal, shallow-water ecosystems but not for isolated environments (e.g., underwater corals and sponges). Various temperature and salinity variables were included to address circumstance variations based on altitude and locality. Only the most relevant temperature or saltiness visibility factor was recorded to prevent duplicate counting within every AH.

Consequences of CC on the Sustainable Management of AH

The examples mentioned above are not the only mechanisms via which CC may influence the structure and movement of AH, and the significant uncertainty surrounding current estimates about these AHs' reactions to CC has been reiterated. Nevertheless, it has been asserted that there are tangible strategies for regulating AH in light of these prospective alterations. We specifically represent (1) management strategies that enhance diversity at multiple organizational levels, which includes people, groups, neighborhoods, and habitats; (2) ongoing research to refine our capacity to predict the impacts of CC on environmental factors in AH, particularly regarding their interaction with different anthropogenic factors affecting aquatic life, groups, and neighborhoods; and (3) the implementation of a precautionary stance in oversight plans, prioritizing the conservation of systems and groups that seem vulnerable to decline due to CC, despite significant uncertainty surrounding this threat.

III. Results

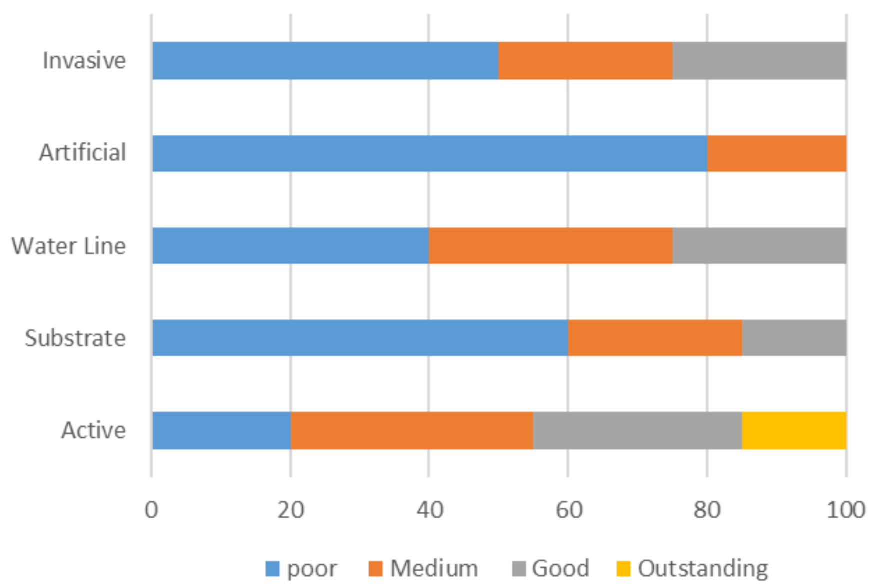

Figure 1: Evaluation of CC on Susceptibility Across Various AH

Figure 1 depicts the evaluation of CC on susceptibility across various AHs. Figure 1 illustrates the varying responses of several habitat types to CC, categorized by susceptibility ratings: poor, medium, good, and outstanding. Active environments provide a balanced distribution, with a significant 15% attaining exceptional performance. The Substrate and Water Line categories exhibit heightened susceptibility, with several classifications rated as bad or medium and no exceptional ratings present. Artificial ecosystems have the lowest resilience and are mostly classified as poor. Invasive habitats likewise face challenges, exhibiting considerable presence in poor and medium categories, although demonstrating somewhat improved performance in the good category.

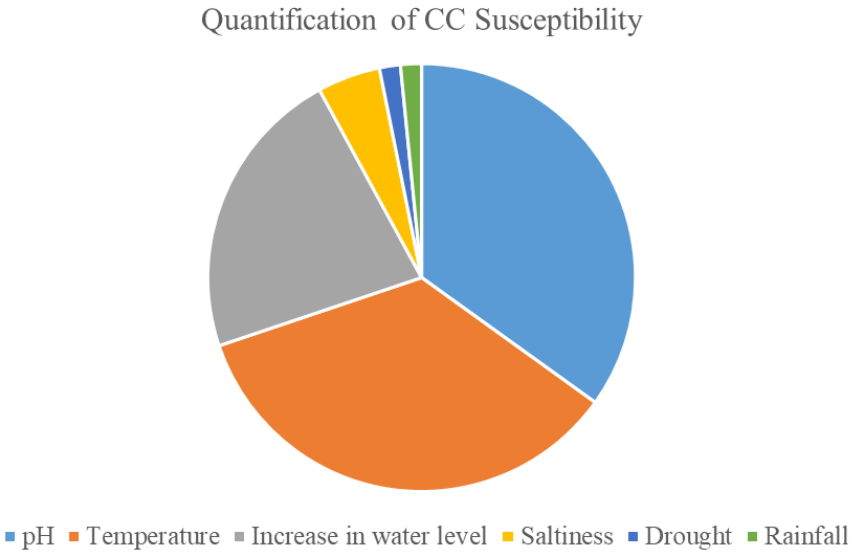

Figure 2: The Varying Impacts of Different Visibility Factors on Climate Susceptibility

Figure 2 shows the varying impacts of different visibility factors on climate susceptibility. Both pH and temperature fluctuations have the greatest number of linked vulnerabilities, underscoring their substantial impact on environmental circumstances. Sea level rise is a significant problem associated with 14 vulnerabilities. Conversely, salinity alterations, flooding, droughts, and precipitation have very little effects, with vulnerabilities of 3, 2, 1, and 1, respectively. These results underscore the need to mitigate pH and temperature variations in CC measures.

IV. Conclusion

This research conducted a climate change danger assessment for 25 marine, coastal, and freshwater habitats to provide an ecosystem-level understanding of the impacts of climate change on these settings. Using an expert collecting technique, the trait-based assessment determines an AH's overall danger to CC based on susceptibility and visibility. The grades of climate sensitivity ranged from low to very high, with habitats identified as the most susceptible. This report offers local authorities and researchers a resource to inform the preservation, rehabilitation, research objectives, and management of aquaculture and endangered species. The Substrate and Water Line categories exhibit heightened susceptibility, with several classifications rated as bad or medium and no exceptional ratings present.

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