Climate Variability and Change's Effects on Estuarine Ecosystems

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Opinion

Climate change has a huge impact on ecosystems (at the macro-level) and individual species, as is well documented (at the micro-level). Estuaries are the most sensitive and affected ecosystems among the former. Despite the strong links between climate change and estuaries, there is a gap in the literature when it comes to international studies that look at the effects of climate change and variability on estuaries in various geographical zones. This paper fills that gap by examining the effects of climate change, variability, and extreme weather on estuaries. We looked at the effects of climatic factors on estuary hydrology, biological processes, and individual species in estuarine ecosystems in various geographical regions, as well as their long-term ramifications [1].

The findings indicated that immediate action is required to lessen estuaries' vulnerability to climate stressors, including altering river flows, storms, and sea-level rise. We described a set of adaptation measures to build climate resilience and adaptive capacity as a contribution to addressing current issues (e.g., early-warning systems, dam management to prevent overflows and adaptive fisheries management). The significance of this paper is twofold. For starters, it highlights a range of issues that estuaries face as a result of changing climate circumstances. Second, the report emphasises the importance of employing appropriate adaptive management measures to protect the integrity of such essential ecosystems [2].

According to recent studies, increases in average global temperature, erratic precipitation regimes, and frequent and high-magnitude weather extremes pose a hazard to the natural ecosystem. For example, the globally averaged combined land and ocean surface temperature data show a rise of 0.99 (0.88 over the ocean) between 1850 and 1900 and 2001-2020. Over the Northern Hemisphere's mid-latitude land areas, precipitation has increased (high confidence after 1951) other latitudes have low confidence in area-averaged long-term positive or negative trends.

Between 1900 and 2010, the Global Mean Sea Level (GMSL) rose at a pace of 1.7 mm yr-1 on average and at a rate of 3.2 mm yr-1 from 1993 to 2010. The GMSL climbed by 0.20 m between 1901 and 2018. Between 1901 and 1971, the average rate of sea-level rise (SLR) was 1.3 mm yr-1, increasing to 1.9 mm yr-1 between 1971 and 2006, and then to 3.7 mm yr-1 between 2006 and 2018 (high confidence) [3]. Since at least 1971, human involvement has most certainly been the dominant driver of these increases.

Except for RCP 2.6, all Representative Concentration Pathways (RCPs) scenarios expect global surface temperature changes to exceed 1.5 by the end of the century (e.g., 2 for RCP 6.0 and RCP 8.5). The average temperature in the moderate (SSP 2-4.5) and very high (SSP 5-8.5) emission scenarios will very likely exceed 2 and 3 , respectively, when compared to the 1850-1900 average. Furthermore, during the period 2021-2040, all scenarios predict a highly likely increase of 1.5 or greater [4].

The IPCC created sub-regional hexagons to represent regional changes in hot extremes, heavy precipitation, and ecological droughts, such as South-Eastern South America (SES), Western and Central Europe (WCE), and South Asia (SAS), which correspond to the Rio de la Plata (RdlP), Mondego, and Megnha estuaries, respectively. In all three sub-regions, heat extremes and heavy precipitation increased; only WCE exhibited a consistent decrease in droughts.

Climate change has an impact on marine ecosystems all over the world. Indeed, along with low-lying coastal areas and tiny islands, estuaries are among the ecosystems most endangered by climate change, mostly because to the SLR, storms, and changes in rainfall. Kelman discussed how to depoliticize development challenges for small islands that are being distracted by climate change, such as emphasising the hazard and shifting focus away from opportunities for reducing vulnerability, which are beneficial in estuaries facing uncontrollable climatic threats in the near term (e.g., 2021-2040) [5].

Fresh water (FW) and marine ecosystems will be affected by changes in important hydro climatic processes, with estuaries serving as a transition zone. Estuaries are semi-enclosed transition zones between rivers and the sea, containing coastal habitats where ocean saltwater mixes with freshwater from rivers or streams. The main causes of seawater incursion in estuaries are tides and buoyancy (related to the density difference between seawater and river water). As a result, it determines the habitats and species that can thrive in these settings. In addition, turbidity and sedimentation in estuaries are influenced by density-driven currents and salt.Estuaries provide physiologically rich fish nursery environments while also protecting many coastal settlements from storms and sea level rise. They serve as biological filter zones for sediments and pollutants, as well as providing a livelihood for millions of people. Changes in precipitation patterns, sea surface water temperature (SST), acidification, SLR (including erosion, flooding, habitat contraction, loss of functionality and biodiversity, and salinization), the frequency and severity of weather extremes, and non-climate stressors all have an impact on the structure, function, biodiversity, and services of estuarine ecosystems (e.g., agriculture, overfishing and eutrophication). Heavy precipitation increased in the SES, WCE, and SAS regions, which are home to the RdlP, Mondego, and Megnha estuaries, respectively (at least medium confidence).Only WCE shows an agreed-upon rise during droughts, but SES and SAS show no consensus. Despite the fact that these effects are dependent on estuary geomorphology and management conditions, the residual and potential impacts would degrade estuaries' ecological, economic, and aesthetic benefits while increasing management costs. As a result, knowing the effects of climate change and variability on the biophysical conditions and sensitivity of estuaries is critical for a well-informed and proactive response. Estuarine ecosystems and the species that live/visit within them are useful markers of coupled climate–environmental changes because of their high natural variability and broad, but limited, coping capacity [6].

This section goes over some basic concepts related to climate threats and their effects on estuaries. Then we summarised how future increased variability and changes in river inflow (QF), wind regime, SLR, salinity distribution and stratification, salt-front location, environmental changes, and species distribution (examples from plankton and fishes, particularly those migrating between seawater and FW or vice versa to spawn and/or complete their life cycles) would affect current estuarine dynamics (qualitatively) [7].

Estuaries are widely recognised as one of the most important, yet fragile, ecosystems in the world, with frequent disturbances ranging from short-term tidal water levels and salinity changes to longer-term climatic changes caused by the ENSO/NAO, as well as extreme events like floods, droughts, and storm surges. Furthermore, the ENSO and the NAO have been linked to a slew of long-term ecological changes in the maritime environment, including the extinction of certain estuary fish stocks.

Estuarine spatial patterns alter over time scales of variability (hours, days, months, and years) due to variations in tides, wind, and river inflow, as well as the interchange with coastal seas. Species-specific adaptations to distinct salinity ranges and behavioural responses to environmental variability determine the spatial distribution of motile creatures in these locations [8].

A recent study sheds insight on the fast changes that are taking place in estuarine ecosystems. The authors discovered that temperature and acidification increases in Southeastern Australian estuaries occurred faster than predicted by regional ocean or atmosphere models over the last 12 years, and that these increases occurred more quickly in small and shallow estuaries with enclosed entrances and longer retention times.

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While the NAO had an indirect influence on climate patterns in the Mondego, Portugal, monthly fluctuations in rainfall and runoff are the main drivers of fish and larval abundance in the estuary. Because of the increased productivity, ERs and marine-estuarine-dependent (and commercially significant) species (e.g., European sea bass, European flounder, and common sole) increase their abundance with increasing rainfall/runoff. Landings of the latter species from coastal fisheries benefit from such conditions as well. During drought years, FW species are scarce. Marine straggler species (including sub-tropical species) benefit from an inward flow of saltwater into the estuary, which increases the overall number of species in the estuary by expanding their potential habitats.

Due to lower planktonic and benthic productivities and a reduction in the extent of river plumes in coastal areas, further reductions in the intensity and frequency of rainfall will reduce river runoff into coastal areas, affecting the recruitment of commercially important species, of which the juveniles rely on estuaries. The early life cycle of cold-temperate species, whose southern distribution limit is the Portuguese coast, may be impacted by rising sea surface temperatures.

Environmental changes in the RdlP estuary (Argentina-Uruguay) are likely to alter plankton and fish distributions and abundances. For 2050, increased rainfall, southeastern winds, and sea-level rise will have contrasting effects, such as decreased/increased seawater intrusion/salinity, and inward/seaward displacement of the EFS. They would have an impact on the mixing-stratification cycle, primary productivity, and oxygen levels in the estuarine front when combined with rising water temperatures. These changes in the environment are likely to alter plankton and fish distributions and abundances, affecting the availability of fisheries resources and the long-term viability of fishing communities.

Climate change (warming and SLR), variability (seasonal, ENSO, and NAO), and extreme weather (storms, droughts, and floods) have all had an impact on the following: I estuarine hydrological and ecological processes; and (ii) a sample of estuaries from three different geographical regions. It has shown that, despite the fact that estuaries provide a variety of important ecosystem services in their particular regions, they are all under strain from climatic change and fluctuation to varying degrees. River flow fluctuations, particularly droughts, have a significant impact on the hydrology, ecology, and fish capture of the three systems analysed.

Despite the fact that the investigated estuaries' climatic, socioeconomic, and ecological environments are vastly varied, there are a few universally useful adaptation strategies. Water management upstream to reduce the risks of abrupt and severe changes in FW flows, as well as adaptive management of fisheries, are critical strategies for reducing the ecological and economic impacts of a changing, erratic, and less predictable climate, in addition to improving climate prognosis and early warning systems.

Because estuarine habitats support a diverse range of species, from microorganisms to crustaceans, fish, shorebirds, and marine mammals, as well as their economic, environmental, climatic (CO2 sink), and recreational value, mechanisms to monitor and evaluate estuarine conditions over longer time periods, such as numerical models, are needed. These could be used to measure current and projected changes in water volumes, salinity, or impacts on individual species as precipitation and discharge rise [10].

Although this report has a drawback in that only three locations were investigated, it gives a framework that may be used to study a wider sample of estuaries around the world. Because of the complexity of estuaries and the numerous ways that climate change, fluctuation, and extreme weather can negatively impact them, attempts to conserve them must include a combination of technical and management challenges as well as effective policymaking.

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