Mangrove forests are facing challenges from global seawater density changes

Climate change affects sea surface density via changes in the sea surface temperature and salinity. These projected sea surface density changes are likely to affect the dispersal patterns of widely distributed mangrove species and are expected to be largest in the Indo West Pacific, the primary hotspot of mangrove diversity.

This is a summary of:
Van der Stocken, T. et al. Mangrove dispersal disrupted by projected changes in global seawater density. *Nat. Clim. Change* https://doi.org/10.1038/s41558-022-01391-9 (2022).

Published online:
Published online: 30 June 2022

The question

Mangroves are highly productive intertidal forests that occur along tropical, subtropical and some temperate coasts, and support a broad variety of ecosystem goods and services. In response to warming winter air temperatures, mangroves are expected to expand poleward, but changes in the geographical range of mangroves in response to changing environmental conditions ultimately depends on dispersal. In several wide-ranging mangrove species, oceanic dispersal is accomplished by propagules with densities near to that of seawater[1]. Whether these propagules float or sink depends on the difference between the densities of the propagules and that of the surrounding water. The biogeographic implications of such density differences were recognized more than a century ago by Henry Brougham Guppy, who discussed the far-reaching influence of the relationship between the weight of seeds and the density of seawater on the distribution and development of plants[2].

Since Guppy's early observations, climate change caused by human activities has driven pronounced changes in ocean temperature and salinity, with further changes predicted to occur throughout the twenty-first century. Although previous studies have underscored the potential impact of sea-level rise, altered precipitation regimes, and increasing temperature and storm frequency on mangrove ecosystems[3,4], the potential effects of climate-driven changes in the properties of seawater on mangroves have not yet been examined.

The observation

By combining global- and species-level data on the distribution of mangrove forests with present (2000–2014) and future (2090–2100) sea surface properties from the Bio-ORACLE database, we investigated predicted future changes in sea surface temperature, salinity and density, for coastal mangrove waters. We derived sea surface density estimates from the temperature and salinity data using the EOS-80 equation of state for seawater.

Our study provides evidence that the sea surface density will decrease in coastal mangrove waters by the end of the twenty-first century. This predicted decrease is a factor of two larger in the Indo West Pacific region, the primary hotspot of mangrove diversity, than that predicted in the Atlantic East Pacific. For mangroves in large parts of the Indo West Pacific, as well as the Gulf of Guinea in the Atlantic East Pacific, declines in sea surface density could affect dispersal patterns through changes in propagule floating orientation. Sea surface density changes may also increase local propagule sinking rates and reduce the probability of successful long-distance dispersal because propagules may sink before they reach suitable establishment zones (Fig. 1). Since dispersal can affect forest structure, composition and regeneration, and modulates climate-driven changes in the geographical range of mangrove forests, the effects of oceanographic changes on dispersal have implications for each of these ecological and biogeographical aspects.

Future directions

Our results highlight the importance of considering future changes in sea surface properties when evaluating the effects of climate change on mangrove ecosystems. Although we considered mangroves as a model system, our findings may also be relevant for other coastal plant species that produce sea-drifted propagules, such as seagrasses and coastal strand communities.

Besides the effects of changes in sea surface density, the dispersal of mangrove propagules may also be directly affected by changes in sea surface salinity or sea surface temperature. For example, projected increases in sea surface temperature may facilitate mangrove expansion to higher latitudes in some regions by reducing the negative effects of low ocean water temperature on the germination ability of the propagules[5]. However, empirical data on the direct effects of changes in sea surface salinity and temperature on mangrove propagule dispersal are currently lacking. Therefore, further investigation into the effects of sea surface salinity and temperature on propagule viability and dispersal is required to better understand their role in the dispersal process and the potential effects of climate change on mangrove ecosystems.

It is important to note that our study uses present and future environmental conditions based on monthly averages and that the actual variability in sea surface density around these mean values could be higher than that predicted in this study. Although our results suggest that mangrove dispersal patterns will change following climate-driven changes in coastal and open-ocean surface-water properties, the effects of these changes also depend on the capacity of the plant species to adapt to the changing conditions; however, our study does not account for this potential adaptive aspect of mangrove dispersal.

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EXPERT OPINION

"This is an important and detailed study examining the influence of future sea surface properties (temperature, salinity, and density) on mangrove propagule dispersal. It provides an excellent first step in highlighting both expected changes and discussing the future research directions needed. This work is a welcome contribution to not only mangrove and coastal specific literature, but also climate change and ecological studies examining dispersal." **Erik Yando, Old Dominion University, Norfolk, VA, USA.**

FIGURE

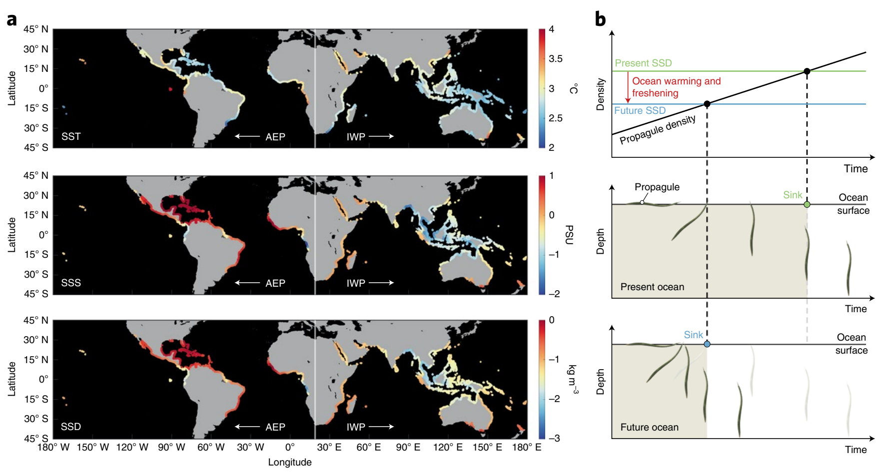

Fig. 1 | Projected climate-induced changes in the properties of the sea surface and the potential effect of future reductions in sea surface density on mangrove dispersal. a, Global maps of changes in sea surface temperature (SST), sea surface salinity (SSS) measured in practical salinity units (PSU) and sea surface density (SSD) between the present (2000–2014) and future (2090–2100). The future properties were modelled using the high carbon emissions representative concentrations pathway (RCP8.5). The vertical line (19° E) separates the two major mangrove bioregions: the Atlantic East Pacific (AEP) and Indo West Pacific (IWP). **b**, A schematic of the time taken for a propagule with a specific density to sink under present and future surface-ocean conditions, showing that reduced SSD may reduce floatation time (shaded area).

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This paper examines mangrove forest development at the Western South Atlantic limit and analyses the potential responses of these communities to global warming.

BEHIND THE PAPER

The idea to study changes in sea surface density in the context of mangrove propagule dispersal dates back several years. Previous work performed within our team focused on changes in mangrove propagule floatation characteristics linked to changes in propagule density, illustrating how the interplay between the density of the mangrove propagules and the surrounding water determines propagule dispersal characteristics. Although recent studies had investigated the links between climate change and dispersal in other ecologically important marine organisms such as zooplankton and fish species, the potential effects of climate-driven changes in sea surface water properties on mangrove dispersal had not been studied. We took advantage of marine data layers to fill this gap, and we hope that our study will help to inspire new research that will quantify the effects of changes in the properties of the ocean surface on propagule floating periods, dispersal and connectivity. **T.V.d.S.**

FROM THE EDITOR

"This manuscript follows through on an interesting question — if some plants have designed their propagules to float in seawater, what happens when the density of the seawater changes. The impacts of sea salinity changes have been less studied than other climate change impacts in the ecological sphere, and this paper looks at the effect of sea density changes on the dispersal of an important blue carbon group — mangroves." **Editorial Team, *Nature Climate Change*.**