Integrating climatic controls and dispersal to project mangrove dynamics at a rapidly-changing range limit

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Warming winter temperatures are driving the range expansion of tropical, cold-sensitive mangroves into temperate ecosystems. The resulting shifts in dominant coastal wetland species are expected to substantially modify wetland ecosystem function and structure. Along the Atlantic coast of North America, the mangrove range limit is particularly sensitive to climate variability. The poleward expansion of mangroves, at the expense of cold-tolerant salt marsh species, occurs as a threshold response to the decreased frequency of extreme cold events. Historical data demonstrate that the mangrove-saltmarsh ecotone on this coast has shifted recurrently during recent centuries due to natural climate variability. However, climate projections suggest that recent mangrove expansion may represent a more permanent regime shift due to anthropogenic climate change. While previous studies have focused on physiological threshold experiments and climate modeling, a comprehensive understanding of mangrove distribution and range dynamics in this region also requires information on dispersal. Here, we combine correlative species distribution models with high-resolution oceanographic dispersal simulations to advance our understanding of mangrove range dynamics along the northeastern coast of Florida, USA. Additionally, we consider the potential of hurricanes to increase the probability of long-distance dispersal and facilitate the poleward range expansion. To do so, we use hurricane data from 1851 to 2023 and examine patterns in the directionality and intensity of these events alongside reported propagule presence in the field.

Our future scenario analyses support the hypothesis that warming winter temperatures will drive the continued poleward expansion of mangroves along North America's Atlantic coast, potentially transforming adjacent ecosystems. With ongoing climate change, suitable mangrove habitat is projected to expand beyond the current range limit, and dispersal simulations suggest successful colonization of these sites from established mangrove populations. Interestingly, we find that mangrove populations along the Atlantic coast of Florida may also act as source populations for reported mangrove expansion hotspots across the Gulf of Mexico, including coastal areas of Texas, Louisiana, and northwest Florida. These results highlight the importance of integrating dispersal models into the context of 21st century range shifts, enabling a more accurate assessment of potential climate-change-driven mangrove encroachment into temperate ecosystems.

Keywords
Mangrove Forest; Range Limit; Climate Change; Species Distribution Modeling; Lagrangian Particle Tracking; Numerical Ocean Modeling