Predicting jellyfish blooms in the North Sea: A climate-driven early warning system

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Jellyfish blooms are increasing in frequency and intensity as climate-driven extreme events such as marine heatwaves, salinity anomalies and acidification recur. These blooms can disrupt food webs, compete with other biota, damage coastal infrastructure and pose growing risks to maritime industries, fisheries, aquaculture and tourism. Despite their impacts, the timing and magnitude of jellyfish blooms remain difficult to predict due to their non-linear ecological responses to environmental stressors. This research develops a hybrid early warning system for jellyfish blooms by integrating mechanistic ecosystem models, machine-learning forecasts, and experimental evidence. Long-term oceanographic and biodiversity datasets will be combined with mesocosm experiments on jellyfish and key zooplankton taxa to identify physiological thresholds and tipping points under acute climate stressors. These empirical insights will be used to parameterise hybrid models that merge long short-term memory neural networks (LSTM) with Nutrients-Phytoplankton-Zooplankton-Detritus (NPZD) and species-distribution frameworks to forecast bloom onset, intensity, and spatial distribution. Model performance will be evaluated against historical extreme events. Finalised models will then be translated into a stakeholder-oriented decision-support tool for fisheries, aquaculture operators, and coastal managers. By linking climate extremes to jellyfish bloom dynamics, this project advances predictive models and supports adaptive, climate-resilient management in a changing North Sea.

Keywords

Jellyfish blooms, Climate extremes, Hybrid modelling, Machine learning forecasts, Early warning systems, North Sea