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The increased likelihood of plankton community changes following marine heatwaves

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When modelling any climatic system, it is important to carefully consider the relation between the many timescales that govern its evolution, since a certain change in their interplay can drastically affect the likelihood of observing critical transitions to distinct environmental regimes. In this study, we present how the onset of marine heatwaves - that are responsible for inducing prolonged periods of positive temperature fluctuations - can weaken state-based resilience leading to noise-induced shifts between species' concentration levels in plankton communities. This is shown in a modified Truscott-Brindley model, a stochastically forced fast-slow system that encapsulates the interaction between phytoplankton and zooplankton species during red tide events in marine environments. Deterministically, the system can be bistable, possessing stable states with high and low phytoplankton biomass, or in an excitable monostable regime, where phytoplankton blooms form following perturbations. Environmental perturbations to the (temperature-dependent) species' growth rates are modelled using multiplicative noise terms, namely Ornstein-Uhlenbeck processes with a correlation time parameter τ. During marine heatwaves, the correlation time τ of the external perturbations will increase. With ensemble Monte Carlo simulations of phytoplankton collapses, we demonstrate how mean first-exit times from the domain of attraction scale as the noise intensity weakens, across different prescribed values for the correlation time τ. These results yield numerical approximations for the systems' quasipotential barrier heights - a concept from Freidlin and Wentzell's theory of large deviations that quantifies resistance to noise-induced escape from a given domain - which elucidates a non-monotonic relation between the system vulnerability to critical transitions and the correlation time τ of the external perturbations. Indeed, initially there is a notable drop in system resilience as the correlation time τ grows from zero, although as τ increases further beyond a critical value, the system resilience begins to then increase. This non-monotonic relation is also reflected in the action values of most probable transition paths for escaping the domain of attraction, found using an augmented Lagrangian method to overcome the degenerate noise present in the system. These findings are compared and contrasted with results from other studies exploring how climate tipping points, or stochastic escapes from a domain of attraction, depend on the correlation time of the external perturbations. Finally, we consider candidate time-series for correlation times constructed from temperature records for the North Sea across periods including anomalously high values, and discuss whether - subject to these - varying system vulnerability to critical transitions is more sensitive to the rate of emergence or duration of the

marine heatwaves.