Warm edge kelp populations show high volatility to marine heatwaves

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In the face of intensifying climate extremes, reliable predictions of species and ecosystem responses to warming are crucial. Currently, a lack of empirical evidence for how heat stress differentially impacts species across their distribution, limits our ability to calibrate predictions with real-world ecological change. Here we use three decades of empirical observations in kelp abundance across cool, central and warm-edge populations, to assess how different populations respond to marine heatwaves (MHWs) and compare these realised observations with predictions based on species distribution modelling and experimental approaches. Cool, central and warm-edge populations displayed consistent patterns of decline in abundance with increasing magnitude of MHWs, however, warm-edge populations displayed steeper rates of decline in abundance compared to central and cool-edge populations under comparable heat stress. Our results support a hybrid model of thermal performance whereby thermal limits differ between populations, but volatility in thermal performance increases toward a species' warm-edge, resulting in heightened vulnerability of warm-edge populations to MHWs. Realised impacts of MHWs occurred at much smaller thermal anomalies than predicted by experimental approaches and thermal distribution modelling, highlighting the importance of calibrating experimental and modelling approaches with realised ecological change.