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The 'golden kelp' *Laminaria ochroleuca* under global change: Integrating multiple eco-physiological responses with species distribution models

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Abstract

1. The loss of marine foundation species, in particular kelps at temperate latitudes, has been linked to climatic drivers and co-occurring human perturbations. Ocean temperature and nutrients typically covary over local and regional scales and play a crucial role on kelp dynamics. Examining their independent and interactive effects on kelp physiological performance is essential to understand and predict patterns of kelp distribution, particularly under scenarios of global change.
2. Crossed combinations of ocean temperatures and availability of nutrients were experimentally tested on juveniles of the 'golden kelp', *Laminaria ochroleuca*, from the northwestern Iberian Peninsula. Eco-physiological responses included: survival, growth and total N content. Results were embedded into a Species Distribution Model (SDM), which relates presence records and climatic and non-climatic data to forecast distribution patterns of *L. ochroleuca* under different climate change scenarios.
3. Temperatures above 24.6°C were lethal irrespective of nutrients. Optimal growth of juvenile sporophytes occurred between 12 and 18°C and no nutrient limitation. The SDM, where ocean temperature was the main predictor of kelp distribution in line with temperature thresholds given by eco-physiological responses, suggests a future expansion towards northern latitudes and a retreat from the southern limit/boundary of the current distribution.
4. *Synthesis.* Range-shifting of the golden kelp can have severe ecological impacts at regional and local scales. The expansion or retraction of the species along the European coast seems to be modulated mainly by temperature, but nutrient availability would be a key to maintain optimal physiological performance. Our work highlights that the combination of empirical and modelling approaches is accessible to researchers and crucial to building more robust predictions of ecological and biogeographic responses of habitat-forming species to forecasted environmental change.

KEYWORDS
brown seaweed, climate change, Laminariales, macrophytes, modelling, multiple perturbations, nutrients, Portugal, southern Europe, temperature