



Site-specific responses underscore the value of natural gradients for predicting Ocean Acidification impacts on macroalgae

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Volcanic activity provides natural laboratories for investigating macroalgal response to ocean acidification. *Dictyota dichotoma*, a widespread brown macroalga in the North Atlantic and Mediterranean, represents an ideal model organism. This study compares its physiological, structural, and ecological responses across two distinct natural pH gradients: the volcanic CO₂ vent system at Ischia Island in the Tyrrhenian Sea (pH 6.25—acidified, 7.14—transitional, 8.13—control) and the persistent CO₂ degassing associated with acidified coastal groundwater discharge at Fuencaliente in La Palma, Canary Islands (pH 7.4—acidified, 7.6—transitional, 8.0—control).

For the ecological assessment, algal cover, photosynthetic efficiency, antioxidant defenses, thallus functional (dry matter content-TDMC, surface thallus area -STA) and anatomical traits (length and cortical thickness) were evaluated across these CO₂-enriched environments. The results indicate that *D. dichotoma* dominated the most acidified zones, showing higher abundance compared to less acidified and control sites. TDMC increased while STA decreased along the acidification gradients, suggesting a conservative strategy aimed at reinforcing thallus structure. At Fuencaliente, a progressive thinning of the thallus was observed under acidic conditions, mainly due to a reduction in the cortical cell layer.

In both CO₂-enriched systems, antioxidant defenses and phenolic content increased under low pH conditions, likely mitigating oxidative stress. The coordination of functional and structural adaptive strategies enabled the maintenance of stable photosynthetic efficiency across both pH gradients. These findings highlight the high plasticity of *D. dichotoma* in response to environmental change and identify key traits underlying its dominance under chronic ocean acidification. Comparative insights from Mediterranean and Atlantic systems further reveal context-dependent responses, supporting the role of this species as a model for understanding marine adaptation in high-CO₂ scenarios.