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Abstract

Acute Resilience, Chronic Costs: Metabolic Responses to Warming and Hypoxia in the Sedentary Lusitanian Toadfish, *Halobatrachus didactylus* †

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Abstract

Introduction: Coastal fishes can adapt to water warming and hypoxia; however, acute tolerance does not necessarily predict longer-term performance and survival. This may be especially important in sedentary, site-faithful species with limited escape to escape increasingly unfavorable habitats. We assessed the climate-related stress responses of the Lusitanian toadfish, *Halobatrachus didactylus*, a benthic estuarine fish from the Northeast Atlantic, to water warming and hypoxia. **Objectives**: We aimed to determine the aerobic energy budget, thermal limits (CTmax), and critical oxygen tension (Pcrit), as well as blood indicators of metabolism, altered physiology and systemic stress, as proxies for whole-organism homeostatic state, thereby informing future ecophysiological assessments and bioindicator development in a context of environmental change. **Methodology**: We determined standard, routine, and maximum metabolic rates; aerobic scope; and critical thermal maximum (CTmax) and critical oxygen (Pcrit) thresholds on a set of 134 individuals ranging from 12 to 160 g in weight. On a different set of individuals (n = 48; 76.3 ± 2.6 g; 16.1 ± 0.18 cm), we simulated 30 days of seasonal scenarios combining low and high temperature with normoxia or hypoxia, followed by integrated metabolic, hematological, biochemical, and multivariate analyses. **Results**: Acute trials showed high short-term resilience: *H. didactylus* had an exceptionally low standard metabolic rate and routine metabolic rate, high CTmax (34.82 ± 0.66 °C), and strong hypoxia tolerance (Pcrit 0.59–1.97 mg O_2 L^{-1}), although smaller individuals were more sensitive. After 30 days, however, warming more than doubled standard and routine metabolic rates, while warm hypoxia reduced metabolic output relative to warm normoxia, consistent with metabolic depression under compounded stressors. This treatment also showed shifts in glucose, liver mass, red blood cell count, and hematocrit, identifying warm, oxygen-poor water as the most physiologically costly scenario for this species. **Conclusions**: Together, these results show that high acute tolerance does not guarantee resilience to climate change. In sedentary fishes, survival may depend less on surviving extremes than on maintaining energetic balance, oxygen transport capacity, and physiological homeostasis in increasingly warm, oxygen-poor coastal habitats.

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