Physiological stress responses in fish exposed to marine heatwaves

Hook, S., R. Farr, J. Su, A. J. Hobday, C. Wingate, L. Woolley and L. Pilmer (2025). Transcriptional profiles reveal physiological mechanisms for compensation during a simulated marine heatwave in Yellowtail Kingfish (*Seriola lalandi*). BMC Genomics: https://doi.org/10.1186/s12864-025-11283-9

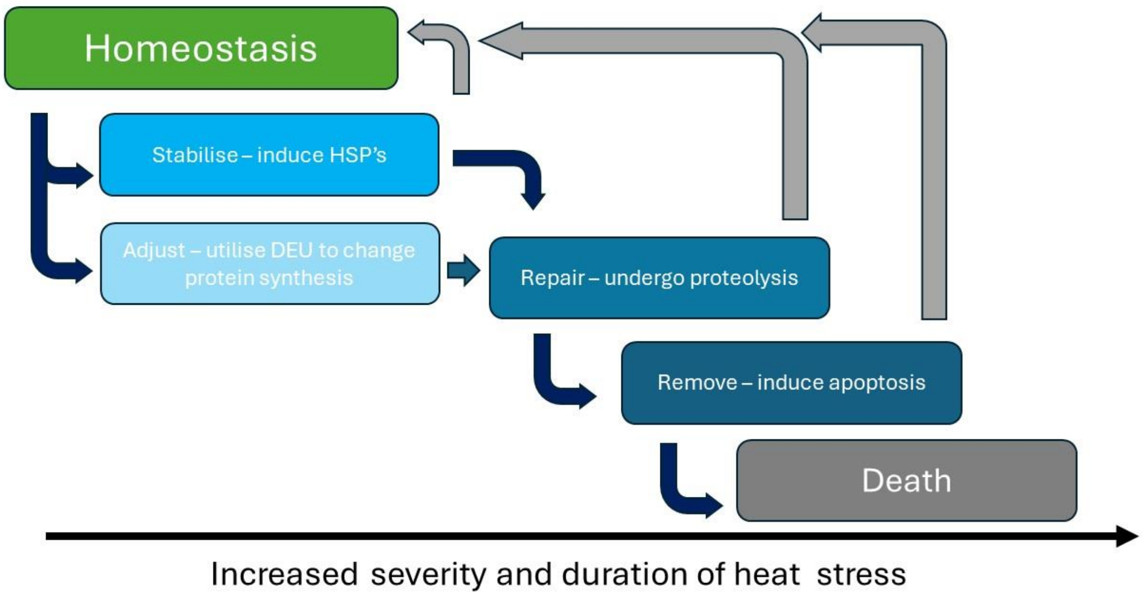
The article investigates how Yellowtail Kingfish respond physiologically to heat stress mimicking a marine heatwave. Changes in gene activity (transcriptome) and gene regulation (exon usage) in gill and muscle tissues over time show how these fish acclimate to elevated temperatures. The data reveal an initial stress response involving heat shock proteins, followed by longer-term adjustments in metabolic pathways, protein maintenance, and cellular signalling. Notably, results suggest that alternative splicing (differential exon usage) may play a crucial role in the fish's ability to cope with thermal changes, highlighting a mechanism for phenotypic plasticity. This research contributes to understanding how marine species might withstand future ocean warming.

Climate Change and Marine Heatwaves

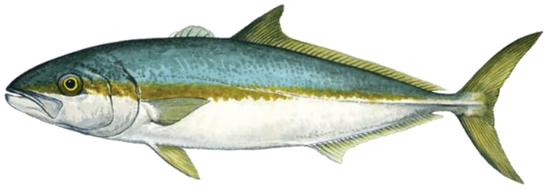
Marine species, particularly those with narrower temperature ranges, are particularly vulnerable to changes in environmental conditions, including short-term extreme warming events like marine heatwaves. Sudden temperature increases caused by marine heatwaves could alter the physiology of marine organisms, particularly for those with narrow temperature tolerances or living close to their thermal maximum. This may affect growth, reproduction, and ultimately, survival. New genomic approaches can reveal whether species can adjust to environmental stress.

How do animals respond to stressful environmental conditions?

The cell maintains homeostasis. To maintain this, animals employ the well-characterised cellular stress response. Under heat stress, the initial response is to stabilise heat sensitive proteins. If that is insufficient, damaged proteins are degraded and replaced (proteolysis). If that is insufficient, damaged cells are degraded and replaced. Each step requires progressively more energy and can cause increasing amounts of metabolic depletion. If all the of these mechanisms are insufficient to restore homeostasis, the animal dies.



Key points from the research



The study investigated how the Yellowtail Kingfish adjusts its physiology in response to sublethal heat stress. While this is a globally distributed species in tropical and subtropical environments, indicating a wide temperature tolerance, recent studies have found different temperature optima depending on the organisms' thermal history, suggesting that it is a good model for investigating thermal plasticity.

Experimental Design Simulates a Marine Heatwave:

- The study focused on sublethal stress, confirmed by the lack of mortality or differences in growth.
- Juvenile Yellowtail Kingfish were exposed to a sudden temperature increase from ambient (20°C) to 27°C.
- Gill, muscle and blood were collected at 6, 24, and 72 hours after the initiation of the heat stress.

Heat Stress Induces a Classic Cellular Stress Response:

- Heat shock protein 70 (HSP70) was induced in blood of warmed fish, confirming sublethal heat stress.
- Transcriptomic analysis revealed an initial (6 hours) upregulation of multiple isoforms of HSP70 and HSP90 in both gill and muscle, indicating cellular efforts to stabilise proteins.

Physiological Compensation Involves Altered Transcriptomic Patterns:

- Beyond the initial stress response, the study observed significant changes in transcriptomic profiles at 24 and 72 hours, indicating compensatory mechanisms such as protein degradation, membrane transporters, and primary metabolism.

Profound Changes in the Regulation of Transcription and Differential Exon Usage:

- Significant modulation of transcripts involved in the "regulation of transcription" (e.g., spliceosome components, RNA binding proteins) in both tissues across all time points.
- Differential exon usage (DEU) – where different mRNA isoforms are produced from the same gene, leading to different protein products – was widely employed
- DEU could be an important mechanism for conferring phenotypic plasticity and acclimation, by modulating transcriptional efficiency or transcript stability or by allowing for subtle conformational changes in proteins without necessarily altering their primary function.

Implications for Acclimation, Plasticity, and Resilience:

- Phenotypic plasticity, mediated by transcriptomic regulation (including differential exon usage), plays a crucial role in the ability of organisms to cope with changing environmental conditions.
- Understanding these mechanisms is vital for predicting species responses to climate change and for informing aquaculture practices, including the selection of resilient strains.

Recommendations

- Research is needed to investigate the role of genome regulation, particularly alternative splicing, in conferring resilience to temperature changes.
- Further studies should confirm whether the observed differential exon usage translates to differences in protein structure and function, and ultimately, animal performance.

Additional information

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