Updated: July 2025

Effect of Temperature on Abalone Condition as a Function of Seasons, Location and rate of Change

Lead Agency: Institute for Marine and Antarctic Studies (IMAS)

Funding: $375,476

Start Date: 1 September 2021 End Date: 25 June 2025

Status: COMPLETED

Aims and Objectives:

The principal aim of this project is to determine the primary factors contributing to the seasonal decline in condition of blacklip abalone on eastern Tasmanian rocky reefs. A secondary aim is to determine the effect of sub-lethal exposure to elevated temperatures as potential cause of recruitment failure.

Specific objectives are:

- Quantify change in physiological status of abalone across seasons in relation to maximum temperature and rate of change in temperature.
- Determine whether re-conditioning of abalone is feasible prior to live export.
- Determine the effect of sub-lethal physiological response to key organism functions (growth, reproductive output).
- If time permits, use abiotic conditions (temperature, swell) as predictors of stress in population dynamic predictive models under future climate change scenarios.

FINAL REPORT – *Executive Summary*:

Abalone found along the southern Australian coast encounter a variety of thermal and environmental conditions. Temperature plays a crucial role in regulating their metabolic processes. Due to their stationary nature, abalone must either adapt to changes in their surrounding environment or face the risk of perishing. Elevated seasonal temperatures have been linked to stress and poor condition in abalone. Additionally, the southeast coast of Australia is a global hotspot for climate change and ocean warming, having experienced several marine heatwave (MHW) events that have led to significant mass mortality of abalone. Understanding how abalone

adapt to environmental variability is critical especially with the expected increase in the magnitude and frequency of MHWs. This project aimed to quantify the physiological status of abalone in relation to maximum temperature and rate of change in temperature, determine the sub-lethal effect of temperature change on key physiological functions, and to determine whether re-conditioning is feasible prior to live export.

Blacklip abalone (Haliotis rubra) were collected from various ecologically distinct sites along Tasmania's east coast. Their metabolic condition was assessed in multiple tissues using LC-MS metabolomics analysis. A series of manipulative experiments were also conducted to examine the effects of temperature in simulated MHW conditions and live transport on their metabolic physiology. Additionally, re-conditioning of abalone prior to live transport was explored through an experimental trial using encapsulated feed.

We identified a diverse array of metabolites in gill, muscle, and haemolymph tissues, with significant variation observed by site and season. Our findings reveal that annual temperature averages, habitat substrate characteristics, wave exposure, and macroalgal communities all influence abalone metabolic profiles. Notably, metabolic clustering among paired sites with similar temperatures emphasises the combined influence of thermal conditions and substrate characteristics, with northern, warmer sites exhibiting enhanced metabolic activity likely associated with thermal stress. Site-specific analyses, particularly at the most southerly site, demonstrate distinct seasonal shifts in metabolites related to energy production, oxidative defence, and amino acid metabolism in summer, indicating heightened metabolic demands and stress adaptations.

Experimental simulation of a MHW and focus on the central carbon metabolism (CCM) of haemolymph and gill tissues revealed how thermal stress and water flow affect the metabolic response of abalone. Water flow had minimal impact on metabolic responses, as there were no significant differences in CCM metabolite profiles between slow and high-water flow conditions. However, thermal stress significantly affected 18 CCM metabolites in haemolymph and 148 in gill tissue, with higher metabolite levels at 19°C compared to 14°C and 16°C. Pathway analysis revealed that thermal stress impacted 4 pathways in haemolymph and 37 in gill tissue, involving amino acid, carbohydrate, energy, lipid, nucleotide, vitamin, and cofactor metabolism. These changes suggest oxidative stress, tissue damage, disruptions in membrane fluidity, osmotic and redox imbalances, and a shift from aerobic to anaerobic metabolism.

Simulation of live transport conditions and sampling of gill tissue collected at different time points: post-harvesting (pre-transporting), post-transporting, post-immersion (water holding period), and post-live exporting transport revealed most differences occurred between post-transport and post-immersion times, indicating strong impacts of transport stress on abalone metabolism. Metabolites such as lactic acid, succinic acid, L-hydroxyglutaric acid, uric acid, and myo-inositol increased during transportation, suggesting their potential as stress biomarkers. Abalone acclimatised in holding tanks

and transported with oxygen supply showed fewer metabolic changes compared to non-acclimatised and non-oxygen-supplied abalone, highlighting the importance of acclimatisation and oxygen supply in reducing transport stress. Enrichment analysis revealed 12 significantly impacted pathways in haemolymph and 34 in gill tissues, indicating metabolic disturbances in energy-related pathways, amino acid metabolism, carbohydrate metabolism, vitamin metabolism, oxidative stress, and others.

In an attempt to re-condition abalone post-harvest abalone were given an innovative encapsulated feed, a commercially available feed, or no feed as a control over six-weeks. Metabolomics analysis showed that abalone fed with the encapsulated feed had higher levels of amino acids, nucleotides, carbohydrates, and other organic acids, indicating a more comprehensive nutrient composition compared to those on commercial feed or under starvation. Proteomics data revealed that the encapsulated feed enhanced energy generation, improved muscle function, and reduced oxidative stress, leading to better growth and overall health. Integration of metabolomics and proteomics data showed high correlations, with notable positive and negative correlations between metabolites and proteins. The study also found differences in intestinal microbiota diversity among the groups, with abalone on the encapsulated feed having more Fusobacteriia and fewer Bacilli sequences.

This study underscores the complex physiological responses of abalone to environmental factors, providing valuable insights into resilience strategies for adaptive management of abalone populations amid changing climate conditions. Additionally, the findings shed light on the physiological responses of abalone to transport stress, guiding improved management practices to ensure their quality during transportation. Furthermore, the study highlights the beneficial effects of encapsulated feeds on abalone metabolism and physiology, particularly in enhancing the health and resilience of abalone kept in holding tanks before live export. Collectively, these findings can assist both management and the harvest sector in making more informed decisions regarding the harvest practices of H. rubra in a changing climate.

Full Final Report