Snails on the menu?: Characterizing the resilience of an emerging California shellfish species to marine heatwaves

Caracoles en el menú?: Caracterizar la resiliencia de una especie emergente de mariscos de California a olas de calor marinas

Escargots au menu?: Caractériser la résilience d'une espèce émergente de crustacés de Californie aux vagues de chaleur marines

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EXTENDED ABSTRACT

Marine heatwaves (MHWs)—defined as prolonged periods of anomalously high seawater temperatures (Hobday et al ,2016)—have emerged as influential, and disruptive, climate-change driven disturbances in coastal oceans, threatening marine biodiversity worldwide (Oliver et al 2020). Although first noted in the Southern Hemisphere (Wernberg et al 2013), MHWs have recently impacted coastal ecosystems in the Northern Hemisphere [Cavanaugh et al (2019), Reed et al (2016) , 6Rogers-Bennett,, and Catton, (2019), Sanford et al (2019), Seuront et al (2019), Shanks et al (2020)]. California's kelp forests are one of our planet's most productive and dynamic ecosystems, supporting private industry in the form of large and small-scale fisheries. Thermal stress induced by marine heatwaves has been documented to have impacts on the productivity of coastal ecosystems. However, there is limited understanding on how thermal stress will affect economically important shellfish species at early life stages. In this study, we tested the tolerance to marine heatwave temperatures of early life stages of the Kellet's whelk, *Kelletia kelletii*, an emerging seafood species in California temperate reefs.

K. kelletii undergo mixed development: from intracapsular development (30-35 days) to planktonic development (~5.5 - 9 weeks), to benthic settlement. Adult whelks collected from the Santa Barbara Channel (SBC) reproduced in the laboratory where their larvae were reared under ambient conditions in order to investigate thermotolerance. Egg capsules maintained on a 12 to 12 light to dark schedule were collected randomly from egg clutches as they were laid to sample whelk larvae for thermal tolerance trials. Whelks laid egg capsules from April to July 2019. Since whelks may rely on chemical cues during oviposition and development, egg capsules remained in tanks with adult whelks through oviposition, larval development, and hatching. To evaluate thermal tolerances of larvae in their final week within their egg capsule, and at the moment of hatching, we examined two larval stages critical to the whelk's pelagic journey: veligers and hatchlings.

Results from thermotolerance trials were scored to estimate the levels of developmental abnormality and mortality induced by thermal stress. By exposing larvae to a range of temperatures (15-38 ˚C) in acute thermotolerance trials (1 hr.), we found that mortality for veligers and hatchlings was observed at similar temperatures. In addition, temperatures that induced developmental abnormalities for both stages were lower than temperatures that caused mortality. Specific temperatures where larval abnormality occurred were different between stages. Adding our data to a literature review of the larval thermotolerance studies for a SBC marine invertebrate fishery species, this study revealed *K. kelletii* to have the highest thermal tolerance on average in comparison to other fished species in the SBC. While this may be the case for larval mortality thresholds, other components of this study show that *K. kelletii* larvae exhibit significant abnormalities at present day MHW temperatures. Our results provide some of the first insights on early stage thermotolerances of a molluscan kelp forest shellfish species.

Understanding how economically important species respond to marine heatwaves will enable us to ensure sustainable livelihoods at sea as well as food security. The impacts of MHWs on important marine invertebrate fisheries and the coastal marine ecosystems that harbor them are now starting to be revealed and understood. Overall, marine heatwaves present conditions that may decrease the quality of performance necessary for larvae to make it through early development. MHW impacts are thus far determined to be wide-ranging, from disease outbreaks in farmed stock, to mortality in wild stock.

Recent studies have shown MHWs can influence long term and short term population-level success via deleterious effects on spawning, reproduction, and recruitment of marine invertebrates leading to ongoing challenges in managing invertebrate fishery species. For example, a study from Coos Bay estuary in Oregon that investigated winter spawning by coastal invertebrates in larval plankton samples (representing at least five phyla including gastropods) shows that during the winters of 2015-16, after the Northeastern Pacific MHW ("Blob"), many invertebrate taxa failed to spawn [Caputi et al (2016). This study clearly shows the effects of MHWs on immediate reproduction in a single season. Such population level impacts of MHWs will also affect management considerations for fished invertebrate species. While "closed vs. open seasons" are helpful as a management tool when ocean temperatures follow historical seasonal trends—the irregularity of MHWs show that we must adapt new approaches to fishing behavior and management that reflect the increasingly unpredictable nature of our environment. Sustainable fishing calls for special management under extreme temperature events that can implement harvest strategies that allow for quick responses to the health of larval, juvenile, and reproducing populations that support invertebrate fisheries as they withstand MHWs Shanks et al (2020).

Future work needs experimentation on the transgenerational plasticity and adaptability of whelk larvae to uphold essential body functions over prolonged exposure to MHW temperatures. In addition, future physiological studies would benefit from focusing on metrics such as respirometry and feeding rates, of adults and larvae in order to help predict how an organism might "prevail or perish" in the face of a heatwave. As an example of this work, a study on *Turbo militaris*, a large harvested Australian turbinid snail, evaluated the influence of MHW temperatures on nutritional properties of body tissue and immune health Mamo et al (2019). Additional physiological studies such as these described will help small and large scale shellfish industry mitigate climate change threats. In the case of *K. kelletii*, due to their greater thermal tolerances, data from this study are suggestive that *K. kelletii* larvae may be more resilient to oncoming thermal stress, and may be a sustainable shellfish species (i.e., a potential "climate proof" species for aquaculture).

Nevertheless, larval physiology and studies that highlight the adaptive capacity of fisheries species allow us to examine the resilience of economically important species in their first window of life to ensure their continued role in ecosystem services that support human society. Preliminary findings from this study on *K. kelletii* can be applied to building a stronger sense of the biology of an emerging shellfish species during a life stage most vulnerable to a warming sea and simultaneously provide insight to a growing shellfish fishery.

KEYWORDS: Marine heatwaves, ocean warming, shellfish, larval development, thermal tolerance

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