Rythmes biologiques de la modiole profonde *Bathymodiolus azoricus*, de l'organisme à la communauté, et impact de la pollution lumineuse.

Biological rhythms of the vent deep-sea mussel *Bathymodiolus azoricus*, from the organism to the community, and the impact of light pollution.

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Location: The PhD will mainly be hosted at Ifremer, in Brest, France but will include lab work and regular visits to the University of Vienna, funded through the HFSP grant.

To apply please send a CV and a motivation letter to all three supervisors

Key-words: hydrothermal, biological rhythms, physiology, behaviour, light perception, light pollution

Project context and objectives

The deep sea, viewed as an acyclic realm until relatively recently, holds biological rhythms that challenge this perception (Cuvelier et al., 2017; Girard et al., 2022; Lelièvre et al., 2017; Nedoncelle et al., 2015). At hydrothermal vents, such as the Lucky Strike site 1,700 meters below the surface, tidal changes in local currents create drastic, yet predictable shifts in environmental conditions (Barreyre et al., 2014). Recent discoveries suggest that vent organisms, including the key engineer mussel *Bathymodiolus azoricus*, exhibit biological rhythms synchronized with tidal cycles (Mat et al. 2020). But how do these rhythms function in such environments? What role do they play at both the behavioural level of individual organisms and the broader community level?

Additionally, as human interest in deep-sea resources grows, the potential impacts of activities such as mining on these fragile ecosystems remain a pressing concern

(Boschen et al. 2013, Van Dover et al. 2020). One key question we will address is how artificial light, introduced during deep-sea operations, affects organisms like *Bathymodiolus azoricus*. Indeed, it has been shown that while tidal cycles predominate in the transcriptome and behaviour of mussels fixed directly on the seafloor at deep-sea vents, daily cycles prevail in mussels sampled after laboratory acclimation under a 12h:12h light:dark cycle (Mat et al. 2020). The project therefore aims at exploring how *B. azoricus* perceives light, and assessing how such exposure might disrupt their natural rhythms and behaviours.

By characterizing the effects of light and the mechanisms of light perception in the deep sea, our research will provide critical insights into the resilience of these ecosystems. This work not only deepens our understanding of life in the planet's least accessible frontier but also informs sustainable approaches to managing and protecting deep-sea environments in the face of emerging human activities.

The objectives of the thesis will be to:

1. Characterize the behaviour of *B. azoricus* from the individual to the population level, in situ and in the lab,
2. Determine the impact of light on deep-sea mussels at the transcriptomic level,
3. Understand how *B. azoricus* perceives light.

The objectives of the thesis may be adjusted depending on the results of the sea cruises. Biological samples and transcriptomic data are already available in the laboratory, and future samples are already planned for the 2025 cruise.

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Methodology

Individuals of *B. azoricus* (from Lucky Strike) that survive long enough at atmospheric pressure, and visibly in good health (> 6 months; A. Mat, unpublished data), will be maintained in an aquarium for the study of endogenous rhythms at the individual level using video analysis, or combined accelerometers (e.g. Axy-Trek Marine HD). The mussels will either be kept under ecologically-relevant cyclic conditions (temperature for example) or under constant conditions to explore their biological rhythm(s) and potential clock(s). Additionally, their behaviour will be compared between constant darkness and exposure to light.

In parallel, an experiment will be conducted at the seafloor during the Momarsat cruise 2026 (ranked priority one by the National Commission of the French Fleet) to assess the impact of light on *B. azoricus* gene expression. To this end mussels will be submitted to artificial light at decreasing distance using the ROV and autonomous cameras. Mussels will then be fixed at the seafloor using RNA later and their transcriptome will be sequenced and analysed.

Finally, tissue cultures of *B. azoricus* (preliminary work carried out in the laboratory of Prof. Kristin Tessmar-Raible has demonstrated the feasibility of such an approach; A. Mat, unpublished data) will enable a more detailed analysis of the molecular basis of light perception. Additional molecular work includes characterization of potential genes/proteins highlighted in the transcriptomic analyses.

Collaborations

This thesis is part of an international project funded by The Human Frontier Science Program and entitled « Temporal structures in complex deep-sea versus surface marine life: from molecules to communities ». Work will involve collaboration with Dr. Orti Peleg at the University of Colorado in USA (video analyses and mathematical modelling), Kristin Tessmar-Raible at the University of Vienna (molecular work, chronobiology) and Todd Oakley at the University of Santa Barbara, USA (characterisation of light at the seafloor).

Preferred profile of the PhD student:

Desired: Master in ecology, preferably marine, or marine biology
Required: R or Python or Matlab, molecular biology, statistics, English
Will include travels for collaboration and work at sea.