InterRidge Student and Postdoctoral Fellowship Program 2017

Report by Julia Machon

I applied for the InterRidge fellowship program as a PhD student to initiate a research project with a laboratory abroad, in the field of hydrothermal vent animal biology. It ended on a successful scientific collaboration, which has led to new insights in our topic, the publication of results in a large-audience journal, a postdoctoral opportunity, and also with a great outcome it has extended the deep sea research community.

As a context, I conducted my PhD at Sorbonne Université (Paris, France) in the “Adaptations to Extreme Environments” team, to focus on the sensory abilities and adaptations of shrimps living at deep hydrothermal vents. Hydrothermal vents are usually considered as “extreme” environments (from a human perspective) because of high hydrostatic pressure, darkness and steep variations of temperature and concentrations in potentially toxic chemicals, and how vent shrimps cope with these conditions is fascinating. Notably, vent shrimps may present specific senses to detect the hydrothermal environment and to select a microhabitat. They could for example use olfaction to exploit the hydrothermal fluid chemical signature as an orientation cue. But overall, their sensory abilities have been poorly investigated despite their importance in understanding the biology and evolutionary success of these animals.

To investigate whether vent shrimps present sensory adaptations in relation with their unique lifestyle, I studied the chemosensory system of several vent species from the Mid-Atlantic Ridge (*Rimicaris exoculata, Rimicaris chacei, Mirocaris fortunata* and *Alvinocaris markensis*), in comparison with a shallow-water closely related species (*Palaemon elegans*). I focused mainly on the structure and function of their antennal appendages, which are major chemosensory organs in crustaceans. Following on from research on a peripheral sensory system, a logical follow-up was to consider the central nervous system, because the brain architecture can provide significant information relative to the sensory abilities and lifestyle of an organism.

Thanks to the InterRidge fellowship, I could spend one month at the University of Greifswald (Germany), at the Cytology and Evolutionary Biology department which has a strong expertise in crustacean neuroanatomy. Working on specimens sampled during the BICOSE 2 cruise (2018, Ifremer) on the Mid-Atlantic Ridge, we conducted a comparative study on the brain architecture of several vent and shallow-water species, with the aim to search for anatomical differences that could reflect sensory adaptations in vent shrimps. The brain structure was thoroughly described using classical histology, immunochemistry and 3D-reconstructions from X-ray micro-computed tomography scans.

A crustacean brain is divided into different regions (called neuropils) that are devoted to different sensory functions, such as the olfactory neuropils that process the olfactory input from the antennules, or the visual neuropils that process the visual input from the eyes. Although functional interpretations from anatomical features must be undertaken with caution, the relative size and structure of a neuropil can reflect the dominance of a sensory modality. For example, in blind crustaceans from caverns, the olfactory neuropils are more voluminous than those of their sighted relatives, suggesting that olfaction likely plays an important role for the cave lifestyle. Similarly, we could expect that the olfactory neuropils are more developed in vent shrimps than in shallow-water shrimps, which would support that vent shrimps may have an especially performant olfactory sense in order to exploit efficiently the chemical landscape at vents.

Figure: Dorsal view of the hydrothermal vent shrimp Rimicaris exoculata (right) and 3D-reconstruction of its central nervous system and antennal nerves (left) (Credits: Magali Zbinden, Julia Machon).

But, on the opposite, our results showed that the olfactory neuropils in vent shrimps are rather similar in size and structure with those of shallow-water species, which doesn't suggest that olfaction is a dominant sensory modality for vent shrimps. Also, their visual neuropils are poorly developed, which is consistent with their rather underperforming visual abilities (as an adaptation to their dark habitat, vent shrimps possess a modified retina that cannot form images but detect very dim light sources). Unexpectedly, the most interesting result came from the higher integrative centers, which are neuropils that integrate altogether the sensory information, such as the sensory inputs from the olfactory and visual neuropils. In the vent shrimp *R. exoculata*, we found that these integrative centers neuropils take up a significant higher proportion of the total brain volume compared to other crustaceans from shallow-waters. Considering that the olfactory and visual inputs in *R. exoculata* are not overly substantial, and that in contrast the integrative centers are especially voluminous, it suggests that these later neuropils may fulfill other functions in addition to higher sensory processing. Such large and complex integrative centers have been previously observed in crustaceans that have sophisticated navigation skills (e.g. hermit crab or giant coconut crab), which made us hypothesize that these neuropils could play an important role in place memory for *R. exoculata*. For survival in the extreme and lightless habitat of vent shrimps, an excellent place memory may be essential for avoiding the dangerously hot vent chimneys and memorizing emission sites of fluids rich in those chemicals on which this species depends as a source of energy.

Overall, this project conducted by means of InterRidge has provided a large amount of data relative to the neuroanatomy of vent shrimps, which gives further insights into adaptations to the specific sensory landscape of the vent habitat. The results have led to a publication in a high impact journal[1], and a second paper is in preparation. This InterRidge program was also very rewarding for me as a young researcher, since it came to a research experience abroad and most importantly to a postdoctoral opportunity to keep up with this project. Furthermore, the InterRidge fellowship was a key triggering factor to initiate this international partnership, which has demonstrated that ridge-crest science can benefit from collaborations with laboratories from other fields.

[1] *Machon J, Krieger J, Meth R, Zbinden M, Ravaux J, Montagné N, Chertemps T, Harzsch S. 2019. Neuroanatomy of a hydrothermal vent shrimp provides insights into the evolution of crustacean integrative brain centers.* ***eLife****, accepted.*