Proposition de sujet de thèse
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Present and future metabolism of mesophotic benthic communities (Project DEEPLIFE)

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Benthic mesophotic ecosystems, located between 30 and 200 m depth, have recently received increasing attention from the scientific community. This is because 1) they remain globally poorly known, 2) they may harbor important biodiversity, and 3) they may represent a refuge for many species more exposed to environmental changes in surface waters. Despite low irradiance, these ecosystems shelter a large diversity of calcifying and non-calcifying phototrophic organisms (kelp and calcareous algae) which together with autotrophic ones (coral, gorgonians, etc.) have been little characterized until now. The metabolism of these communities is unknown, although it is undoubtedly one of the most important ecological processes to assess the response of marine ecosystems to climate change. Community metabolism is governed by two relationships: 1) net production and 2) net calcification of the community. These two major processes control air-sea CO_2 fluxes, contributions to biogeochemical cycles, and the availability of carbon and calcium carbonate for burial in sediments. Their characterization is therefore essential to assess the functioning of these communities.

This thesis project aims to determine the functioning of mesophotic benthic communities under climate change by combining several disciplines such as ecology, geochemistry, chemistry, physiology, and modelling. The hypotheses tested will be 1) mesophotic ecosystems are net sources or sink of CO_2 depending on the functioning of the community and 2) future environmental conditions will alter communities composition and therefore their balance between net primary production and net calcification. To test these hypotheses, the project will combine *in situ* measurements of community metabolism and diversity, underwater drone surveys as well as AI assisted image recognition, laboratory experiments, and modelling work. This topic is part of the BNP PARIBAS DEEPLIFE project, which starts in 2024 for a period of 4 years, and the Under The Pole program. This project focuses on mesopelagic benthic ecosystems of the Mediterranean and the Caribbean and aims to quantify their biodiversity, to examine their capacity to generate a microclimate, and to determine their present and future metabolism, to set up conservation actions based on the function in addition to the species. During this thesis project, the metabolism of communities will be determined *in situ* with a gradient flux approach, which has been used so far only in coral reefs. This non-invasive approach simultaneously quantifies community net primary production and calcification of complex benthic communities. It will be complemented by a census-based approach that aims to determine the primary production and calcification of an ecosystem based on individual metabolic rates and species-specific abundances. For both approaches the student will be supported by professional SCUBA divers (including the co-supervisors) who will set up the instruments and collect the abundance data. The abundances will also be determined by underwater drones and images will be analysed with AI assisted technologies. Studies on different communities reconstructed in the laboratory will also be conducted at LOV in a new experimental system. These studies will aim to determine the effects of future environmental conditions on the metabolism of key organisms in the communities of interest. Results of these experiments will be used to model the future metabolism and composition of mesophotic communities. All studies will be conducted with logistical and financial support from DEEPLIFE and other ongoing projects in which the supervision team is involved.

This project is in line with the second core guidelines of the Institut de l'Océan that focus on the risks and adaptation of marine organisms to climate change. The multi-disciplinary approach proposed here combining ecology, geochemistry, chemistry, physiology, and modelling will yield to significant advancements in our understanding of the poorly studied mesophotic communities. Using novel methodology (gradient flux, AI assisted image analyses, etc.) this research will notably provide the first estimates of the contribution of these communities to the carbon cycle under present and future conditions. With access to state-of-the-art experimental facilities, the student will also gather the first data on the response and adaptation to climate change of a range of mesophotic organisms.

The student will beneficiate from the supervisions of Frédéric Gazeau and Steeve Comeau at the LOV and Lorenzo Bramanti at the LECOB. F. Gazeau is a marine biogeochemist with extensive knowledge in carbonate chemistry and experience in carrying out multi-drivers experiments on pelagic and benthic communities using a large range of experimental systems. S. Comeau is a marine biologist who works on the effects of climate change on benthic community's metabolism using both *in situ* and experimental studies in the Mediterranean Sea, the tropics, and the Arctic. F. Gazeau and S. Comeau also have expertise in carbon fluxes and particularly blue carbon. L. Bramanti is an ecologist/modeller with extensive experience working on the functional ecology of a range of mesophotic communities specifically applying the concept of marine animal forest to include terrestrial ecology theories and methods in marine environment. He is a highly experienced scuba-diver that will lead the field work activities.

Publications related to the project:

Cox, T. E., **Gazeau, F.,** Alliouane, S., Hendriks, I. E., Mahacek, P., Le Fur, A., & Gattuso, J.-P. (2016). Effects of *in situ* CO_2 enrichment on structural characteristics, photosynthesis, and growth of the Mediterranean seagrass *Posidonia oceanica*. *Biogeosciences*, *13*(7), 2179–2194. https://doi.org/10.5194/bg-13-2179-2016
Gazeau, F., Alliouane, S., Bock, C., **Bramanti, L.**, López Correa, M., Gentile, M., Hirse, T., Pörtner, H.-O., & Ziveri, P. (2014). Impact of ocean acidification and warming on the Mediterranean mussel (*Mytilus galloprovincialis*). *Frontiers in Marine Science*, *1*, 62.
Cornwall, C. E., **Comeau, S.**, et al. (2021). Global declines in coral reef calcium carbonate production under ocean acidification and warming. *Proceedings of the National Academy of Sciences*, *118*(21). https://doi.org/10.1073/pnas.2015265118
Comeau, S., Carpenter, R. C., Lantz, C. A., & Edmunds, P. J. (2015). Ocean acidification accelerates dissolution of experimental coral reef communities. *Biogeosciences*, *12*(2), 365–372.
Bramanti, L., Manea, E., Giordano, B., Estaque, T., Bianchimani, O., Richaume, J., Mérigot, B., Schull, Q., Sartoretto, S., Garrabou, J. G., & Guizien, K. (2023). The deep vault: A temporary refuge for temperate gorgonian forests facing marine heat waves. *Mediterranean Marine Science*, *24*(3), Article 3. https://doi.org/10.12681/mms.35564
Edmunds, P. J., Nelson, H. R., & **Bramanti, L.** (2018). Density-dependence mediates coral assemblage structure. *Ecology*, *99*(11), 2605–2613. https://doi.org/10.1002/ecy.2511