Development of artificial structures by 3D printing of biosourced materials for reef restoration

Ph.D. opportunity in Ocean and Marine environmental sciences

Scientific context

Coral reefs play a key role in the marine environment, its balance and biodiversity, providing nursery grounds and shelter for a wide range of organisms. They also help protect coastlines from erosion. However, their decline is now a proven fact, accelerated by global warming and ocean acidification. Almost a quarter of these reefs have already disappeared. One strategy for restoring damaged areas is to build and deploy artificial reefs, but several obstacles remain: (i) materials used to date are often not environmentally friendly, (ii) they are shaped according to architectures that do not match to the original, (iii) they poorly take in account the biological and physical factors that aid coral larval navigation, settlement and post-settlement survival.

This PhD thesis is part of the NACRE-3D project, funded by the French National Agency of Research, which aims to overcome these obstacles through the development of biomimetic artificial coral reefs using 3D additive manufacturing based on sustainable, partly recycled materials with a chemical composition close to that of coral. More specifically, NACRE-3D explores the potential of a low-cost 3D printing technology, Binder Jetting, whose flexibility makes it possible to manufacture both small and large structures with multi-scale porosity adapted to different restoration cases. Raw materials used are CaCO3 powders recycled from oyster shells, and binders are biosourced and with a low C-footprint. In addition, 3D structures are functionalized with coral growth boosters using porous CaCO3 microspheres, synthesised on demand, which are loaded with active species and used as delivery vectors.

Objectives

The goal of the thesis is to contribute to the development of artificial structures by 3D printing of biosourced materials for reef restoration. The PhD candidate will : (i) test biomimetic, durable and functionalized 3D structures in the marine environment using an approach combining *ex situ* seeding of sexually propagated corals and *in situ* nursery, (ii) optimize the structures in terms of geometric, chemical and biological characteristics using experiments and/or computational modeling, and (iii) conduct a cost-effectiveness analysis to assess the efficacy of the structures compared to current restoration solutions. Structures will be produced at the CIRIMAT (Toulouse, France) by another PhD candidate. Both PhD candidates will work in close interaction.

Scientific conditions and Financial support

Work will involve scientific diving and field and laboratory experiments in Moorea (French Polynesia) for a long duration (~30 months). The CRIOBE station will provide laboratory and field research facilities (experimental ecology station including *ex situ* larval rearing and seeding facilities and aquaria with controlled parameters, *in situ* coral nurseries, diving and boat operations, imagery and optic laboratories). The project offers an opportunity to collaborate across disciplines at the interface between marine biology, materials science and process

engineering through collaborations with CIRIMAT (Université Toulouse) and IRCER (Université de Limoges). PhD grant and research will be funded by the NACRE-3D project (ANR-24-CE51-2845).

Requirements

Applicants should hold a Master degree in Marine Biological Sciences and a French diving certification (Certificat d'Aptitude à l'Hyperbarie classe 1B or more). Experiences working on coral reefs or marine larval ecology are preferred. Experience in computational modeling and simulations will be an asset. Candidates should be physically fit, willing to work for long hours, fluent in English and/or French, able to work independently in an interdisciplinary setting, and have strong data analysis and scientific writing skills.

Supervision and Doctoral school

PhD supervisor : Maggy NUGUES (CRIOBE, Perpignan)

Co-supervisors : Sophie GUILLEMET (CIRIMAT, Toulouse) and Laetitia HEDOUIN (CRIOBE, Moorea)

Ecole Doctorale 472 PSL-EPHE, doctorat PSL, mention Océanologie biologique et Environnement marin

Duration

Position is due to start on September 1, 2025 for a period of 3 years.

Application

Interested candidates should send a motivation letter, CV with list of 3 referees, and copy of their Certificat d'Aptitude à l'Hyperbarie (CAH) to Maggy NUGUES (maggy.nugues@univ-perp.fr). Only short-listed candidates will be notified.

Closing Date

March 10, 2025 or until a qualified candidate is identified.