Rentrée 2021

PROPOSITION DE SUJET DE THESE

Formulaire demande de financement : ARED - ISblue - ETABLISSEMENTS - …

Identification du projet

Acronyme du projet : COLONIZE

Intitulé du projet *en langue française*: Processus de **COLON**isation en périphér**I**e des sources hydrothermales : **Z**ones potentiellement convoitées pour leurs r**E**ssources minérales

Intitulé du projet en langue anglaise: COLONization processes at the per**I**phery of hydrothermal vents: **Z**ones that are potentially targeted for their mineral r**E**sources

Présentation de l'établissement porteur (bénéficiaire de l'aide régionale)

Établissement porteur du projet :

Ecole Doctorale : EDSML ☒ SPI ou MATHSTIC pour les projets ISblue ☐

Identification du responsable du projet (futur directeur de thèse)

Nom du laboratoire d'accueil : Laboratoire Environnement Profond
Code du laboratoire (U/UMR/USR/EA/JE/…) : LEP/EEP
Directeur[1] du Laboratoire : Daniela Zeppilli
Nom de l'équipe de recherche : Unité Etude des Ecosystèmes Profonds Ifremer

Nombre HDR dans le laboratoire: 2 Nombre de thèses en cours: 4 Nombre de post-docs en cours: 2

Nom et prénom du directeur* de thèse (HDR), porteur du projet : Jozée Sarrazin

- **e-mail :** jozee.sarrazin@ifremer.fr
- **Téléphone :** 0298224329
- **Publications récentes du directeur de thèse:** 76 publications, 1780 citations. H-index 25.

1. Girard Fanny, Sarrazin Jozee, Arnaubec Aurelien, Cannat Mathilde, Sarradin Pierre-Marie, Wheeler Benjamin, Matabos Marjolaine (2020). Currents and topography drive assemblage distribution on an active hydrothermal edifice. Progress in Oceanography, 187, 102397 (13p.). https://doi.org/10.1016/j.pocean.2020.102397
2. Alfaro Lucas Joan Manel, Pradillon Florence, Zeppilli Daniela, Michel Loic, Martinez‐arbizu P, Tanaka H, Foviaux M, Sarrazin Jozee. High environmental stress and productivity increase functional diversity along a deep‐sea hydrothermal vent gradient. Ecology. https://doi.org/10.1002/ecy.3144
3. Girard Fanny, Sarrazin Jozee, Olu Karine (2020). Impacts of an Eruption on Cold-Seep Microbial and Faunal Dynamics at a Mud Volcano. Frontiers Marine science, 7(241), 15p. https://doi.org/10.3389/fmars.2020.00241
4. Sarrazin Jozee, Portail Marie, Legrand E., Cathalot Cecile, Laes Agathe, Lahaye Noe, Sarradin Pierre-Marie, Husson Berengere (2020). Endogenous versus exogenous factors: What matters for vent mussel communities? Deep-sea Research Part I, 160, 103260 (19p.). https://doi.org/10.1016/j.dsr.2020.103260
5. Lelievre Yann, Sarrazin Jozee, Marticorena Julien, Schaal Gauthier, Day Thomas, Legendre Pierre, Hourdez Stephane, Matabos Marjolaine (2018). Biodiversity and trophic ecology of hydrothermal vent fauna

[1] Ce formulaire est rédigé en style épicène

associated with tubeworm assemblages on the Juan de Fuca Ridge. Biogeosciences, 15(9), 2629-2647.

- Expériences d'encadrement et co-encadrement de doctorants

1. Supervision de la thèse de doctorat de Marie Portail portant sur « Etude comparée de la structure et du fonctionnement des communautés de macrofaune associées aux sources froides et aux sources hydrothermales en environnement marin profond. 2012-2015. Co-encadrement J Sarrazin/K Olu (Ifremer). *A abandonné la recherche.*
2. Supervision de la thèse de Bérengère Husson portant sur « Fonctionnement et dynamique des écosystèmes hydrothermaux en environnement marin profond : vers l'élaboration d'un premier modèle»». 2013-2016. Co-encadrement J Sarrazin/PM Sarradin (Ifremer). *En poste en Norvège.*
3. Supervision de la thèse de Yann Lelièvre. Doctorat en Sciences Biologiques, Université de Montréal. Caractérisation des facteurs contrôlant la dynamique de la macrofaune associée aux sources hydrothermales à partir des données issues des observatoires fond de mer. 2014-2017. Co-encadrement J Sarrazin/M Matabos (Ifremer), P Legendre (U de Montréal). *En recherche de poste.*
4. Supervision de la thèse de Joan Manel Alfaro Lucas. Doctorat UBO. Rôle de l'activité hydrothermale et de la nature du substrat sur les processus de colonisation de la faune (du microorganisme à la macrofaune) en milieu marin profond. 2016-2019. Co-encadrement J Sarrazin, D Zeppilli, F Pradillon (Ifremer). *En post-doc en Allemagne.*
5. Supervision de la thèse de doctorat de Julien Marticorena. Doctorat UBO. Restauration écologique dans les grands fonds: résultats d'une expérience de perturbation au sein du champ hydrothermal Lucky Strike. 2017-2020. Co-encadrement J Sarrazin, M Matabos (Ifremer). *Soutenance prévue en février 2021.*
6. Supervision de la thèse de doctorat de Loïc Van Audenhaege. Doctorat UBO. Multi-scale spatio-temporal distribution of faunal communities and habitats on the deep-sea hydrothermal field of Lucky Strike. 2019-2022. Co-encadrement J Sarrazin, M Matabos (Ifremer). *En cours.*

Co-directeur de thèse (HDR) éventuel : Marie-Anne Cambon

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- Expériences d'encadrement et co-encadrement de doctorants

1. Cyrielle Jan, european funding MAMBA, 2009-2012, co-direction MA Cambon (Ifremer) Mohamed Jebbar (UBO). « Approche métagénomique de la chimiosynthèse en système hydrothermal océanique profond ». Thèse soutenue le 19 décembre 2012. Institutrice.

2. Perrine Cruaud, financement Ifremer/Région Bretagne, 2010-2014, MA Cambon et co-direction Anne Godfroy (Ifremer). « Influence des communautés microbiennes sédimentaires sur la répartition faunistique dans les sites hydrothermaux et les zones d'émissions de fluides froids du bassin de Guaymas ». Thèse soutenue le 1er avril 2014.

3. Simon Le Bloa, financement Ifremer/Région Bretagne Labex Mer, 2013-2016, Direction MA Cambon (Ifremer) et co-encadrement A. Bazire (Université de Bretagne Sud). « Mode de reconnaissance hôte-symbiontes en milieux extrêmes : cas de Rimicaris exoculata ». Thèse soutenue le 15 Décembre 2016. Enseignant en microbiologie ETSL Paris.

4. Iván Hernández Ávila, Bourse Campus France/Vénézuela, 2013-2016, Direction MA Cambon et co-encadrement F. Pradillon (Ifremer) : « Dispersion larvaire et cycles de vie en milieu profond ». Thèse soutenue le 28 Novembre 2016. Researcher at the Universidad Autónoma del Carmen, Mexico.

5. Vincent Apremont, financement Ifremer/Université Paris VI, 2014-2017, Direction MA Cambon (Ifremer) et co-encadrement M. Zbinden (U. Paris VI). « Etude des symbioses chez les Alvinocaridae, fonctionnement et adaptation aux variations physico-chimiques de l'environnement ». Thèse soutenue le 29 Novembre 2017.

6.Pierre Methou, financement Ifremer/Région Bretagne, 2016-2019, Direction MA Cambon et co-encadrement F. Pradillon (Ifremer). « Life cycles of two different Rimicaris species: reproduction, population structure and acquisition of symbiosis ». Soutenance décembre 2019. En post doctorat pour 3 ans au Jamstec.

7. Valérie Cueff-Gauchard, financement Ifremer 2018-2022 Direction MA Cambon. « Fonctionnement des communautés symbiotiques chez la crevette hydrothermale Rimicaris sp. Par approches in situ. »

8.Marion Gueganton, Ifremer/Brittany region funding, 2019-2023, Direction MA Cambon et co-supervision F. Pradillon: « Acquisition of symbiotic partners: modalities and consequences on establishment, distribution and ecology of vent species». PhD defence in the spring 2023.

Et co-encadrant-e scientifique : Florence Pradillon

Laboratoire de recherche co-encadrant : Laboratoire Environnement Profond (LEP/EEP)

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- **Expériences d'encadrement et co-encadrement de doctorants**

1. Iván Hernández Ávila, Funding Campus France/Vénézuela, 2013-2016, co-supervision M.-A. Cambon. « Dispersion larvaire et cycles de vie en milieu profond ». PhD defence on 28th November 2016. Researcher at the Universidad Autónoma del Carmen, Mexico.
2. Pierre Methou, Ifremer/Brittany region funding, 2016-2019, co-supervision M.-A. Cambon : « Life cycles of two different Rimicaris species: reproduction, population structure and acquisition of symbiosis ». PhD defence on 10th December 2019. Post-doc in Jamstec, Japan.
3. Joan Manel Alfaro Lucas, Ifremer/Labex Mer Funding, 2016-2019, co-supervision J. Sarrazin & D. Zeppilli : « Influence of hydrothermal vent activity and substratum types on faunal colonization processes in the deep sea ». PhD defence on 10th December 2019. Post-doc at the Senckenberg Research Institute, Germany.
4. Marion Gueganton, Ifremer/Brittany region funding, 2019-2023, co-supervision M.-A. Cambon : « Acquisition of symbiotic partners: modalities and consequences on establishment, distribution and ecology of vent species». PhD defence in the spring 2023.

Financement du projet de thèse

En cas de financement à 50 %, le cofinancement est-il déjà identifié : oui

Si oui, préciser la nature du cofinancement : Département REM, Ifremer

En cas de non-obtention du cofinancement demandé, une autre source de cofinancement est-elle identifiée :

Si oui, laquelle : oui ARED

Sollicitez-vous un co-financement Is-Blue (y compris ARED Is-Blue) ? oui

Projet de thèse en cotutelle internationale

S'agit-il d'un projet de thèse en cotutelle internationale dans le cadre d'une convention : non

Si oui, préciser l'établissement pressenti : N/A

Ce projet de thèse fera-t-il l'objet d'un cofinancement international : non

Présentation du projet

Résumé du projet

Processus de colonisation en périphérie des sources hydrothermales : zones potentiellement convoitées pour leurs ressources minérales- Ce projet vise à mieux comprendre les processus de colonisation en milieu marin profond à proximité des sources hydrothermales actives. Pour ce faire, différents substrats ont été déployés pendant quatre ans sur les champs Snake Pit et TAG (dorsale médio-Atlantique) en périphérie proche et éloignée des zones actives au sein d'habitats susceptibles d'être la cible de projets miniers.

Les objectifs spécifiques sont de (i) caractériser la diversité microbienne et faunistique ainsi que les traits fonctionnels (incluant le réseau trophique) associés aux différents substrats et conditions physico-chimiques locales, (ii) évaluer le rôle des facteurs environnementaux et des types de substrats sur la biodiversité, les traits et la distribution, (iii) examiner le rôle des microorganismes sur la structure des communautés de faune et (iv) évaluer le potentiel des substrats pour favoriser la restauration des milieux impactés en environnements profonds. La diversité microbienne et faunistique sur les substrats organiques et inorganiques sera déterminée à l'aide d'approches de morphologie, de

NGS et de métabarcode.

Cette thèse sera réalisée dans le cadre du projet Ifremer REMIMA sur les ressources minérales marines et du futur projet européen DEEP-REST portant notamment sur la restauration des écosystèmes profonds. Les résultats devraient améliorer notre compréhension des processus de colonisation dans ces environnements difficilement accessibles, données fondamentales à la gestion, à la conservation et à la protection des écosystèmes des grands fonds.

Mots-clés: colonisation, microorganismes, macrofaune, méiofaune, biodiversité, traits fonctionnels, conditions environnementales, sources hydrothermales, restauration, périphérie, exploitation

Colonization processes at the periphery of hydrothermal vents: zones that are potentially targeted for their mineral resources- This project aims at better understanding biological colonization and successional processes in deep-sea environments in the vicinity of active hydrothermal vents. It is based on an extensive colonization experiment of substrata deployed for four years at the near and far peripheries of the Snake Pit and TAG vent fields (Mid-Atlantic Ridge) within habitats that may potentially be targeted by the industry if mining projects proceed in the future.

Specific objectives are to (i) characterize microbial and faunal diversity as well as functional traits (including trophic network) associated with different substrata and local physico-chemical conditions, (ii) evaluate the role of environmental factors and substratum types on biodiversity, traits and distribution, (iii) examine the role of microorganisms on meio- macrofaunal community structure, (iv) evaluate the potential of substrata to favour the restoration of impacted deep-sea environments. Microbial and faunal diversity will be determined on organic and inorganic substrata using morphology, NGS and metabarcoding approaches.

This thesis will be carried out in the frame of the Ifremer REMIMA project on mineral resources and the future European project DEEP-REST particularly dealing with restoration processes. Results should significantly increase our understanding of colonization processes in these hardly accessible environments, a fundamental pre-requisite for the management, conservation and protection of deep-sea ecosystems.

Keywords: colonisation, microorganisms, macrofauna, meiofauna, biodiversity, functional traits, environmental conditions, hydrothermal vents, restoration, periphery, exploitation

Présentation détaillée du projet

1 - Hypothèse et questions posées, état de l'art, identification des points de blocages scientifiques

Hydrothermal vents are islands of biomass in a sparsely populated deep marine environment. As the deep environments shelter a mosaic of habitats that promote population connectivity[1], the deployment of colonization substrata allows us to better understand colonization patterns and the potential use of stepping stones to ensure colonization of new sites[2]. For nearly 40 years, the scientific community has been interested in these colonization processes through the deployment of experiments near chemosynthetic ecosystems[3-14]. These studies showed a significant influence of local environmental conditions and proximity of active vent areas[4] on the recruitment of fauna and emphasized the role of biological interactions in structuring communities[6,10,11,15].

In such experiments on the Mid-Atlantic Ridge (MAR), it was shown that the level of hydrothermal activity had more influence on the taxonomic composition of new communities than substratum type and that biodiversity was lower in areas of higher hydrothermal activity[16,17]. Different patterns linked to deployment duration were observed: after 9 months, the types of substratum best explained the composition of nematode communities while after two years, vent activity had a greater impact on their structure[18]. Similarly, a focus on copepods showed that communities clustered by site rather than by substratum, supporting a greater effect of environmental conditions on community structure[17]. More recently, we showed that hydrothermal activity enhanced functional richness while patterns where surprisingly different at inactive sites[19]. There, despite high species diversity, environmental conditions filtered for specific traits, thereby reducing functional richness. The presence of exclusive species and functional entities lead to a high turnover between inactive sites, producing

highest β-diversities[19]. The observed faunal overlap and energy links between active and inactive sites suggest that rather than operating as separate entities, these environments may be considered as strongly interconnected. Low functional richness suggests that inactive areas may be especially vulnerable to environmental changes related to natural and anthropogenic impacts, such as deep-sea mining. However, almost nothing is known about these sites, located at the periphery of active vents.

Several questions concerning the potential impacts of mining on these communities and their capacity to cope and recover from such impacts are pending. We thus need to acquire fundamental knowledge about the structure and functioning of communities associated with sites that are located at the near and far peripheries of vents and evaluate their potential to face disturbances. In 2014 and 2018, two vent fields located on the MAR within the French exploration permit issued by the International Seabed Authority and targeted for their mineral resources, were studied. Substratum experiments were chosen to investigate colonization processes and the ecological connectivity of biological communities across several spatial scales.

Questions raised are: What are the links between active and inactive environments in the vicinity of vents in terms of microbial and faunal biodiversity and functional traits? What are the role of environmental factors and substratum types on the observed patterns? What are the links between microorganisms, meiofauna and macrofauna in the near and far periphery of vents? Can we use artificial substrata to restore impacted ecosystems in the deep sea. The acquisition of new knowledge about these barely known ecosystems at risk of imminent exploitation is an essential prerequisite for their management, conservation and protection.

2 - Approche méthodologique et techniques envisagées :

The main scientific objectives of this thesis are to (i) characterize microbial and faunal diversity and functional traits (including trophic network) associated with different organic and inorganic substrata deployed at the near and far peripheries of active hydrothermal sites at two vent fields, (ii) evaluate the role of environmental factors and substratum types on biodiversity, traits and distribution; (iii) examine the links between microorganisms, meiofauna and macrofaunal community structures and (iv) evaluate the potential of substrata to favor the restoration of impacted deep-sea environments. To fulfill these objectives, a series of organic (wood) and inorganic (slate, synthetic sponge) substrata was deployed in 2014 at two hydrothermal fields – TAG and Snake Pit- located at 3600m depth on the MAR. The substrata were placed at the near and far peripheries of active vent sites and were recovered in 2018. A total of 36 substrata were conditioned on board for further analyses. Substratum pieces and samples of the most dominant macrofaunal species were placed at -80°C. The rest of the samples were sieved and preserved either in 4% formalin for meiofauna or in 96% alcohol for macrofauna.

During the thesis, microbial diversity will be analyzed using NGS approaches on 16S rDNA partial sequences. Eukaryote diversity will be analyzed through species morphology, barcoding and metabarcoding using COI and 18SrDNA partial sequences. Trophic network will be assessed using $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ isotopic analyses. Colonization processes will be evaluated by comparing, at three distinct scales, the composition, diversity and traits of microorganisms and faunal communities: (1) between different substrata on a single sampling site, (2) between substrata across several sampling sites, (3) between sampling sites from the two vent fields. The role of environmental factors (depth, temperature, pH, Fe, H_2S) on diversity, distribution and functional traits will be assessed using canonical redundancy analyzes. These baseline data will be used to identify shared taxa, biodiversity hotspots as well as potential endemicity areas within each field, information that are essential to address conservation issues. As artificial substrata appear to harbor higher diversities than natural communities near vents, their potential to be used as restoration tools will be evaluated[20].

The approaches envisaged (organic/inorganic colonization substrata, links between all biological compartments, combination of molecular and classical taxonomy, functional traits) are innovative and will most probably lead to original results. Our previous studies show that these experiments contribute significantly to the description of marine biodiversity with the discovery of several new species and also, on the understanding of the geographical distribution of specialist taxa such as bivalve borers or *Osedax* worms.

In addition to the acquisition of baseline data on biodiversity at great depths (3600m), this project will bring significant insights in the understanding of colonization processes and ecological connectivity in the deep sea. Identifying the relationships between different biological compartments (microorganisms/meiofauna/macrofauna) is also an essential part of understanding the factors influencing larval settling and recruitment. Assessing the role of organic substrata in colonization processes in the deep sea is also a major issue since they could favor the dispersal and establishment of larvae and species and ensure ecological connectivity between sites. The data acquired should significantly increase our understanding of these hardly accessible environments, a fundamental pre-requisite for the management, conservation and protection of deep-sea ecosystems. To this end, assessing restoration potential is quite timely as the International Seabed Authority is currently drafting the regulations for future exploitation permits in the Area.

3 - Positionnement et environnement scientifique dans le contexte régional, national et international :

Society depends on a healthy sea as it provides supporting, provisioning, regulating and cultural services. However, the so far "pristine" deep sea is at risk of biodiversity and ecosystem function loss due to anthropogenic activities, including deep-sea mining. To date, the International Seabed Authority (ISA) has issued 30 mineral exploration licenses in the Area among which two are supervised by Ifremer in the name of France. The first concerns polymetallic nodules from the Clarion-Clipperton zone in the Pacific Ocean and the second, Seafloor Massive Sulfides (SMS) on the MAR. In addition to these zones, located in areas beyond national jurisdiction, numerous mineral exploration activities in European national waters of e.g. France, Portugal, Ireland and Norway are underway. Recent policy developments to regulate deep-sea mining and avoid biodiversity and ecosystem function loss include the ISA's Regional Environmental Management Plans (REMP) and mining code as well as negotiations towards a new UN treaty for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction (BBNJ). Only by basing regulations and management on up-to-date scientific knowledge will ensure healthy deep-sea ecosystems for future generations. The thesis will provide innovative solutions to the current and future societal challenges that deep-sea ecosystems and their biodiversity are facing. The acquisition of new knowledge about these almost totally unknown ecosystems at risk of imminent exploitation is an essential prerequisite for the management, conservation and protection of ecosystems. This research is quite timely as ISA is now drafting the regulations for future exploitation permits. In this context, the potential of substrata to be used as a restoration strategy will be evaluated.

At the regional level, this thesis is totally in line with **IS Blue Theme 2** "*Ocean Earth Interactions*" which aims at describing and understanding the unique biology of the deep ocean microbial and animal biosphere *through in situ* monitoring of species and their physical and chemical environment and meta-omics techniques. The substratum experiment will also provide new insights about geobiological interactions and life in extreme environments. It also complies to **IS Blue Theme 4** "*Living Ocean and Ecosystem Services*" by identifying the environmental drivers of biodiversity in particular environments of the deep sea and evaluating the use of artificial substrata as potential restoration measures. The use of substrata to monitor colonization processes and connectivity also contributes to **IS Blue Theme 5 "***Long-term observing systems for ocean knowledge***"** as these approaches are complementary to fixed point observatories by up-scaling data acquisition of the often spatially-restricted ecological studies in the deep-sea.

At the local scale, the data acquired within this thesis will contribute to the research questions addressed in REMIMA, one of the leading research program of our REM Department (Ressources Physiques et Ecosystèmes fond de Mer) which focus on deep-sea mineral resources. They will contribute to the understanding of the proposed links between the different environments (active/inactive) around vents and will bring fundamental data that will contribute to fulfill Ifremer's obligations to the ISA and up-coming regulations concerning deep mineral resources. The project will also help consolidate Ifremer's role in the assessment of marine biodiversity, particularly in deep environments which are becoming major strategic issues. The project will also add value to the samples collected during two major deep sea cruises (BICOSE 2014 and BICOSE2 2018) sponsored by the French Oceanographic Fleet. Finally, the student will benefit from an extensive network of renowned scientists as it is part of the future BIODIVERSA European project DEEP-REST.

4 - Contexte scientifique et partenarial : éléments généraux (ERC, CPER, FEDER, Breizhcop …)

A network of local, European and international collaborations will ensure the success of this multidisciplinary project. These collaborations include at the local level, colleagues from our lab (Dr D. Zeppilli, meiofaunal specialist, PM Sarradin, chemist, LEP), our research Unit (Drs. E. Roussel and A. Godfroy, microbiologists, LM2E) and our Department (Drs. C. Cathalot & A. Laes, geochemists, GM & RDT). A special collaboration will be done with Dr C. Rommevaux (Institut Océanologique de Marseille) who specializes in microorganism/rock interactions in the vent environment that will pilot a 3-month internship during the thesis. At the international level, this thesis will benefit from our established network of taxonomists. The results obtained will potentially allow the development of new taxonomic keys in collaboration with world experts including Dr. D Zeppilli (nematode taxonomy, Ifremer), Prof P Martinez Arbizu (copepod taxonomy, Senckenberg Institute), C. Romano (wood boring bivalve taxonomy, CEAB, Spain), Dr. L Corbari (crustacean taxonomy, MNHN, Paris) to cite a few. The thesis will also benefits from an extensive network of renowned deep-sea scientists, especially working in deep-sea ecosystems threatened by mining, as part of the future BIODIVERSA European project DEEP-REST. Finally, this project is in line with international agreements aimed at protecting and conserving vulnerable marine ecosystems (VME; UN, resolution 61/105) and ecologically and biologically sensitive areas (ESA, BSA; Convention on Biological Diversity).

Vous sollicitez un financement ISblue, ou une ARED ISblue

Précisez le lien du sujet avec les thèmes ISblue

Thème ISblue	Thème principal	Thèmes secondaires	Autre
la régulation du climat par l'océan			
les interactions entre la Terre et l'océan	x		
la durabilité des systèmes côtiers			
l'océan vivant et les services écosystémiques		x	
les systèmes d'observation à long terme		x	

Expliquez/précisez <u>en quelques lignes</u> dans quelle mesure votre demande correspond à l'un ou plusieurs des critères ISblue ci-dessous :

1- Originalité, impact potentiel du projet
In addition to the acquisition of baseline data on the biodiversity of microorganisms and fauna in two deep vent fields, this thesis will bring groundbreaking results about colonization processes and connectivity between active vents and their unknown near and far peripheries, providing essential data for ecosystem management. This project is timely as ISA is now drafting the regulations for future exploitation permits.

2- Positionnement international du sujet, cotutelle ou co-encadrement international
This thesis is part of the future European BIODIVERSA project DEEP-REST whose objectives are to develop a novel approach to improve our capacities for science-based spatial planning and management in deep-ocean ecosystems threatened by deep-sea mining. Collaborations with a network of renowned European deep-sea research specialists and contribution to policy measures are planned.

3- Effet intégrateur entre unités de recherche et / ou interdisciplinarités
The proposed co-direction by scientists from two Ifremer laboratories (LEP/LMEE) will reinforce the synergy between our research themes (ecology/microbiology). Collaborations with other Ifremer scientists and researchers from internationally renowned research centers such as MIO, MNHN, Senckenberg Institute and CEAB will provide greater visibility for our research and foster new expertise.

4- Potentiel d'insertion à un haut niveau dans la communauté académique ou non académique du docteur
The future PhD student will gain a good understanding of policy and management issues in the deep sea in the context of mining and develop abilities to provide innovative solutions to the societal challenges posed by the exploitation of its resources. It the context where mineral resources are in increasing demand worldwide and in

which new regulations will soon be issued by the International Seabed Authority, this type of profile should be highly sought after at the international and national levels both in the academics and private industries.

Le candidat

Profil souhaité du candidat (spécialité/discipline principale, compétences scientifiques et techniques requises) :

Preferred profile of the PhD student

- Master's in marine biology and ecology
- Ecology and taxonomy of benthic fauna
- Strong deep-sea ecological background
- Skills in molecular biology and bio-informatics
- Strong English level

References : 1. Génio et al. (2013) Biogeosciences 10 : 5159–5170, 2. Distel et al. (2000) Nature 403(6771):725–726 12, 3. Shank et al (1998) Deep-Sea Res II 45 :465–515, 4. Van Dover et al. (1988) Deep-Sea Res 35:1833–1849, 5. Mullineaux et al. (1998) Deep-Sea Res II 45:441–464, 6. Mullineaux et al. (2003) Ecol Monogr 73:523–542, 7. Mullineaux et al. (2012) PLoSONE7(12), e50015, 8. Pradillon et al. (2005) Mar Ecol Prog Ser 302:147–157, 9. Pradillon et al. (2009) Deep-Sea Res II 56:1622–1631, 10. Govenar B, Fisher CR (2007) Mar Ecol Evol Perspect 28:3–14, 11. Kelly et al. (2007) Aquat Biol 1:1, 12. Kelly N, Metaxas A (2008) Aquat Biol 3:271–281, 13. Gaudron et al. (2010) Mar Environ Res 70(1):1–12, 14. Bienhold et al. (2013) PLoSONE8(1), e53590, 15. Mullineaux et al. (2010) Proc Natl Acad Sci 107:7829–7834, 16. Cuvelier et al. (2014) Deep-Sea Res I 87: 70–81, 17. Plum et al. (2017) Deep-Sea Res II 137: 335-348, 18. Zeppilli et al. (2015) Mar Biodiv 45:489-504 25, 19. Alfaro-Lucas et al. (2020) Ecology e03144, 20. Cuvelier et al. (2018) Front Mar Sci 5 : 46