Rentrée 2021

PROPOSITION DE SUJET DE THESE

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

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Identification du projet

Acronyme du projet *(8 caractères maximum)* **: MIArc**

Intitulé du projet *en langue française* :

Identifier les paramètres modulant la mixotrophie en Arctique et les conséquences sur les flux de C, N et Si

Intitulé du projet en langue anglaise :

Identify the parameters modulating mixotrophy in the Arctic and the consequences on C, N and Si fluxes.

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

Établissement porteur du projet : Université de Bretagne Occidentale

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

Identification du responsable du projet (futur directeur de thèse)

Nom du laboratoire d'accueil : LEMAR
Code du laboratoire (U/UMR/USR/EA/JE/…) : UMR6539
Directeur[1] du Laboratoire : Luis Tito de Morais
Nom de l'équipe de recherche :

- Nombre HDR dans le laboratoire : **49**
- Nombre de thèses en cours : **49**
- Nombre de post-docs en cours : **12**

Nom et prénom du directeur* de thèse (HDR), porteur du projet : Moriceau Brivaëla

- **e-mail :** moriceau@univ-brest.fr
- **Téléphone :** 02 98 49 87 87
- **Publications récentes du directeur de thèse** *(nb total et 5 références max au cours des 5 dernières années)* **:**
15 publications

Toullec J, Vincent D, Frohn L, Miner P, Le Goff M, Devesa J and Moriceau B (2019) Copepod Grazing Influences Diatom Aggregation and Particle Dynamics. *Front. Mar. Sci.* 6:751. doi: 10.3389/fmars.2019.00751

Moriceau B., Iversen, M. H., Gallinari, M., Evertsen, A.-J. O., Le Goff, M., Beker, B., et al. (2018). Copepods Boost the Production but Reduce the Carbon Export Efficiency by Diatoms. *Front. Mar. Sci.* 5. doi:10.3389/fmars.2018.00082.

[1] Ce formulaire est rédigé en style épicène

Tréguer P, Bowler C, Moriceau B, Dutkiewicz S, Gehlen M, Aumont O, Bittner L, Dugdale R, Finkel Z, Ludicone D, Jahn O, Guidi L, Lasbleiz M, Leblanc K, Levy M, Pondaven P (2018): Influence of diatom diversity on the ocean biological carbon pump, Nature Geosciences 11, 27-37. doi:10.1038/s41561-017-0028-x.

Lalande C, Moriceau B, Leynaert A, Morata N (2016): Spatial and temporal variability in export fluxes of biogenic matter in Kongsfjorden. Polar Biology.

Boutorh J, Moriceau B, Gallinari M, Ragueneau O and Bucciarelli E (2016) Effect of trace metal-limited growth on the post mortem dissolution of the marine diatom *Pseudo-nitzschia delicatissima* Global Biogeochemical Cycles (30), 57-69, doi:10.1002/2015GB005088.

- Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)
(nom des doctorants dirigés et en cours et antérieurement, sur les 6 années passées : sujet, financement, date de soutenance, et situation professionnelle actuelle si connue)

Directrice de thèse :

Jordan Toullec **2017-2020** : « Ré-évaluer le rôle des diatomées dans la pompe biologique de carbone en tenant compte de l'impact des limitations en nutriments prédites par les modèles de changement climatique » co-financement LabexMER et ANRJCJC BIOPSIS (P.I. B. Moriceau)
En post-doctorat à Wimereux au LOG puis au Canada dès que le confinement le lui permettra

Co-directrice de thèse :
Valentin Siebert **2019-…** : « *Pecten maximus*, archive multi-proxies, haute résolution, de la production primaire en rade de Brest » co-financement ARED et ANR HIPPO (P.I. J. Thébaut co directeur de thèse)

Co-directeur de thèse (HDR ou équivalent étranger) éventuel : Marcel Babin

Laboratoire de recherche : (nom + code U/UMR/USR/EA/JE/…): Université de Laval unité mixte Takuvik UMI 3376

- e-mail : marcel.babin@takuvik.ulaval.ca
- Téléphone : 418 656-2339
- Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)
(nom des doctorants dirigés et en cours et antérieurement, sur les 6 années passées : sujet, financement, date de soutenance, et situation professionnelle actuelle si connue)

Directeur de thèse :
Mathieu Ardyna (soutenu 12/2015) : « Phytoplankton communities in a changing Arctic Ocean: Biogeography, phenology, productivity » ;
En post-doctorat à l'université de Stanfort depuis 2018 dans le département des Sciences du système terrestre.

Gauthier Vérin (soutenue le 18/02/2019) : « Propriétés physiques et optiques du manteau neigeux sur la banquise»

Srikanth Ayyala Somayajula (soutenu le 11/2019) : «Study of the optical properties of the Arctic Ocean and application to remote sensing of ocean colour"
En post doctorat à l'université du Mississippi du Sud ; dans le département « Ocean optics and remot sensing »

Théo Sciandra (Janvier 2017-*en cours*): « Polar diatom's (*Fragilariopsis cylindrus*) physiological and molecular adaptative mechanisms to prolonged darkness (the polar night) and subsequent return to light »

Co-directeur de thèse :

Julien Laliberté (soutenu le 06/11/2020) : « La lumière disponible pour les microalgues dans l'océan Arctique : une perspective satellitaire. » (Simon Bélanger, UQAR co-directeur thèse)

Juan Li (2018-*en cours*) : « Developing a new ocean color algorithm of the Pan-Arctic Ocean : A synthetic approach» (Xiaoping Pang, co-directeur de thèse)

Et/ou co-encadrant-e scientifique : Jean-François Maguer
Laboratoire de recherche co-encadrant (nom + code U/UMR/USR/EA/JE/…) : UMR, IUEM, LEMAR

- **e-mail :** maguer@univ-brest.fr
- **Téléphone :** 02 98 49 87 78
- **Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)**
  (nom des doctorants dirigés et en cours et antérieurement, sur les 6 années passées : sujet, financement, date de soutenance, et situation professionnelle actuelle si connue)

  Le cas échéant, autres collaborations (co-encadrant et laboratoire concerné) :

Financement du projet de thèse

En cas de financement à 50 %, le cofinancement est-il déjà identifié *(oui/non)* **:** *OUI*

Si oui, préciser la nature du cofinancement (*ANR, partenaire privé, Ademe, etc.*) : Université de Laval UMI Takuvik

Si le cofinancement n'est pas encore confirmé, date prévue de réponse du cofinanceur :

En cas de non-obtention du cofinancement demandé, une autre source de cofinancement est-elle identifiée *(oui/non)* **:** *OUI*

Si oui, laquelle : ISBLUE ou UBO

Sollicitez-vous un co-financement Is-Blue (y compris ARED Is-Blue) *(oui/non)* **?** *OUI*

Important : Veillez à bien compléter les différents co financements sollicités sur le serveur Thèses en Bretagne Loire lors du dépôt de votre dossier.

Projet de thèse en cotutelle internationale

S'agit-il d'un projet de thèse en cotutelle internationale dans le cadre d'une convention *(oui/non)* **:** *OUI*

Si oui, préciser l'établissement pressenti (*et le pays de rattachement*) : Takuvik, Canada

Ce projet de thèse fera-t-il l'objet d'un cofinancement international *(oui/non)* **:** *OUI*

(Rémunération du doctorant par l'établissement implanté sur le territoire régional (18 mois sur 36 mois), et l'établissement étranger, qui s'engage également à rémunérer le doctorant dans le cadre de son séjour à l'étranger, soit durant 18 mois -a minima-)

En cas de cofinancement international, préciser -*si vous en avez connaissance***- l'organisation du calendrier des périodes de séjour :**

La période de séjour se déroulera la deuxième année de la thèse, avec une partie préparation de l'expédition et une partie expédition

Préciser quel est le stade du projet international (joindre une lettre d'engagement du partenaire)

Présentation du projet (en langue française ou anglaise, 2 à 3 pages)

merci de respecter ce format maxi compatible avec extranet région:

Résumé du projet (4000 caractères maxi espaces compris) : The ocean's capacity to absorb carbon dioxide (CO2) depends on primary production by photosynthesis and the structure of surface communities that regulate the export of organic carbon into the water column. Phytoplankton, in addition to its photosynthetic metabolism, can have other modes of nutrition, notably osmotrophy and phagotrophy, which enable them to exploit most forms of energy available. Trophic interactions in general, play a major role in carbon export, such as the grazing of macrozooplankton organisms, which rather promote the export of organic matter to the ocean floor, while at the opposite end of the size spectrum, the microbial loop participates in surface remineralization (Tréguer et al. 2018). For a long time considered

marginal, mixotrophy is still very rarely taken into account to estimate ecosystem productivity, although it plays a fundamental role in the efficiency of the biological pump. In the Arctic, mixotrophy appears to be an important link in trophic transfer to intermediate trophic links with strong implications for carbon export (Stoecker et al. 2018). Nevertheless, the evolution of this trophic mode with the consequences of climate change and its implications on the C, N and Si cycle should be explored. Mixotrophic species modulate their feeding mode according to the availability of resources and environmental parameters. Indeed, dinoflagellates can use mixotrophy to compensate for nutrient (N, P) deficiencies (Smalley et al. 2003) and their diverse photosynthetic capacities (permanent endosymbiotic chloroplast and kleptoplasty, Mitra et al., 2006) make them competitive in many environments. They possess various capture methods (filament, organelle, Li et al., 1999) that are adapted to diverse prey (diatoms, cyanobacteria, ciliates, Christaki et al. 2002; Jeong et al., 2005, Sherr and Sherr, 2007). Some studies suggest that mixotrophy increases organic carbon fixation thereby decreasing dissolved organic carbon and then influences the average size of organisms and consequently trophic transfer to higher levels resulting from an increase in vertical carbon flux and potentially the biological carbon pump (Stoecker et al. 2017, Mitra et al. 2014, Ward and Follows 2015).

In the Arctic, the highly variable environmental conditions (temperature, light, nutritive resources) favour mixotrophy over strict nutrition modes (autotrophy/heterotrophy)(Stoecker and Lavrentyev, 2018). Dinoflagellate grazing regulates phytoplankton communities in many ocean areas (Sherr and Sherr, 2007; Safi et al., 2002); in particular populations of cyanobacteria and diatoms, two key phytoplankton groups in the global ocean and in the cycles of major elements including silicon (Sherr and Sherr, 2007). Diatoms are micro-algae that dominate production in the Arctic and are strongly involved in primary production and oxygen production. They produce a biogenic silica frustule that protects them from their predators, ballasts and facilitates carbon export; their overall contribution to the biological carbon pump averages 20%. But in Arctic ecosystems where they are dominant in the ice and water column, this contribution can increase significantly, especially when the ice melts (Boetius et al. 2013). In the context of climate change leading to increased stratification of the water column, the availability of nutrients is limited (nitrate and silicate), modifying the distribution of phytoplankton groups and thus the majority actors in primary production (Krause et al. 2018, Tremblay et al. 2002); this is the case in the Arctic during spring blooms, where non-siliconified species such as Phaeocystis sp. participate more widely in primary production (Assmy et al., 2017; Lalande et al., 2016; Li et al., 2009; Pavlov et al., 2017; Tremblay et al., 2009; Wassmann & Reigstad, 2011). These changes in phytoplankton communities and environmental conditions are all factors likely to modulate mixotrophy in the Arctic.

The overall objective of this thesis is to explore the intensity of mixotrophy in the Arctic and its variability in face of 1) changes in the structure of the phytoplankton community, and 2) modifications of the physico-chemical parameters predicted as a result of climate change (limitations, temperature, light).

Detailed presentation of the project :

1 - Hypothèse et questions posées, état de l'art, identification des points de blocages scientifiques (4000 caractères maxi espaces compris)

The paper by Sherr and Sherr (2007) shows that dinoflagellates are predators capable of regulating the phytoplankton community in many ocean areas including the Arctic Ocean. The fluctuating Arctic environment leads to an evolution of its populations according to the plasticity of the communities. Mixotrophic dinoflagellates are known to have a high plasticity according to various limitations. Indeed, mixotrophy makes it possible to compensate for a lack of availability of major elements such as C, N or P or vitamins (Smalley et al., 2003). The dual objective is to assess which physico-chemical conditions influence the predation of a species, and/or a community, and how the evolution of communities caused by climate change modifies mixotrophy.

This theme will be studied in the form of two work packages; the first will study the factors controlling mixotrophy (**WP1**), and the second will evaluate its impact during the establishment and evolution of the spring bloom in the Arctic (**WP2**).

WP1. Factors controlling the intensity of the mixotrophy

In this first Work package, we will have three specific objectives:

1- What is the impact of the type of prey on mixotrophy?

2- What is the impact of nutrient and light limitations on mixotrophy ?

3- What happens to the ingested matter?

WP2. The mixotrophy in Arctic: an in situ study

In this work package, our objective is to quantify mixotrophy in the Arctic and to understand the consequences of climate change on this trophic mode.

2 - Approche méthodologique et techniques envisagées : (4000 caractères maxi espaces compris)

WP1. Factors controlling mixotrophy: To answer these questions, we will compare the grazing rates of dinoflagellates on different types of prey using the methodology of Jeong et al (2005) which we will couple to isotope labelling (^{13}C, ^{15}N and ^{32}Si). We will use model prey varying in size and nutritional quality (non-silicon species vs. diatoms) and physiological state (dead vs. alive). The influence of physico-chemical parameters (light and nutrients) on the distribution of nutritional modes of mixotrophic organisms (autotrophy vs. heterotrophy) will be evaluated in parallel using isotopes (^{13}C, ^{15}N). The modification of autotrophy under the conditions described above will also be followed by analyses of photosystems and electron fluxes using multi-PAM and carbon-13 labelling.

Physiological changes such as pigment evolution (kleptoplasty; endosymbiosis, chloroplasts), will be observed in predators through microscopic observations and pigment quantification such as HPLC and fluorimetry.

Isotopic labelling experiments will aim at understanding the fluxes of elements between organisms and the environment (autotrophy) between prey and predators (heterotrophy) and between particulate and dissolved (recycling) following mixotrophy.

WP2. The role of mixotrophy on the biogeochemical cycles of major elements and the biological carbon pump: The methodology developed for WP1 will be adapted to study the communities in situ. The collaboration with the UMI Takuvik will allow us to access the facilities developed during the GreenEdge project in Qiqiktarjuaq (Baffin Island, Canada). From the village it is possible to access privileged sites where we will be able to take the necessary water and ice samples. A request for interest has also been submitted to participate in a campaign in the Baffin Sea aboard the icebreaker the Amundsen. Whether from the ice pack at Qikiqtarjuaq or aboard the Amundsen, we will have the opportunity to harvest natural planktonic communities. Incubations under in situ light and temperature conditions will allow us to quantify the fluxes of C, N and Si using the isotopes of these elements (^{13}C, ^{15}N and ^{32}Si). We will thus be able to follow the evolution of the mixotrophy during the development of the spring bloom until the melting of the ice pack and to test with parallel incubations how changes in light and nutrients concentrations modify the heterotrophy and autotrophy of the community.

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

This co-directed project with Canada plans to study mixotrophy in the Arctic and its role in major biogeochemical cycles. It is therefore in line with INSU's prospects and more specifically with the challenges 7 "organisms in cycles" and challenge 8 "the poles". The techniques used can be adapted to other ecosystems such as that of the Bay of Brest. Certain key species of the bay, such as *Alexandrium minutum*, form potentially toxic blooms that influence the regional economy by impacting for example aquaculture (oyster farming; fish farming) and therefore are of great interest to one of our collaborators. Discussions with IFREMER (Aurore Regaudie de Gioux; DYNECO) will take place regularly in order to establish protocols that can be adapted to these two contrasting ecosystems. A close collaboration with LOPS (Mathilde Cadier and Thomas Gorgues) will allow us to carry out the modeling experiments necessary for a better quantification of the impact of mixotrophy on C export and on the functioning of the food web at the regional scale.

4 - Contexte scientifique et partenarial : éléments généraux (ERC, CPER, FEDER, Breizhcop …) (4000 caractères maxi espaces compris)

This thesis is a France-Canada co-supervision with the UMI of Takuvik, financed for half by a Discovery Grant from the Natural Sciences and Engineering Research Council of Canada awarded to Marcel Babin (UMI takuvik, see the attached

letter of commitment). It will start with funds from ANR BIOPSIS and will be carried out in the context of the projects that will be funded thereafter. Currently we have made 2 applications: a LEFE-CYBER (SILICYANO) project submitted in 2020 and an ISBLUE EMERGENCE project submitted this year. A discussion is underway with the idea of submitting an ANR project on mixotrophy with LOPS and DYNECO.

Vous sollicitez un financement ISblue, ou une ARED ISblue :

Précisez le lien du sujet avec les thèmes ISblue

Thème ISblue	Thème principal	Thème secondaire (si nécessaire)	Autre (si nécessaire)
la régulation du climat par l'océan	X		
les interactions entre la Terre et l'océan			
la durabilité des systèmes côtiers			
l'océan vivant et les services écosystémiques		X	
les systèmes d'observation à long terme			

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 (4 lignes maxi)
This topic is a major advance in the understanding of mixotrophy in general, and in the Arctic in particular, and its role in the cycles of carbon and other major elements (Si, N).
It will bring a major breakthrough in the understanding of the food web in the Arctic, on the capacity of this ocean to export C from the atmosphere and on its evolution in the face of climate change.

2- Positionnement international du sujet, cotutelle ou co-encadrement international (4 lignes maxi)

This cotutelle thesis is based on an active collaboration with Canada where a large part of the *in situ* experiments will take place (Marcel Babin, Takuvik, Canada) and will create a dynamic precursor of a larger scale project.

3- Effet intégrateur entre unités de recherche et / ou interdisciplinarités (4 lignes maxi)

This project in connection with the proposed Emergence project is a springboard that aims to strengthen exchanges between the different teams of the IUEM working on this theme using different tools: process experiments (Aurore Regaudie De Gioux, DYNECO and Brivaëla Moriceau, LEMAR), C, N (Stephane l'Helguen and Jean-François Maguer, LEMAR) and Si (Brivaëla Moriceau, LEMAR) element fluxes and in collaboration with the modelers: Mathilde Cadier and Thomas Gorgues, (LOPS) and Laurent Memery (LEMAR).

4- Potentiel d'insertion à un haut niveau dans la communauté académique ou non académique du docteur (4 lignes maxi)

The PhD student will work in the framework of a France Canada collaboration, in co-supervision with Laval University, but also possibly in the framework of collaborations with Uta Passow currently at the Memorial University of Newfoundland (Canada) and Karl Safi of NIWA in New Zealand. Mixotrophy is a trophic mode still poorly understood, intervening in the biological pump of carbon, the skills developed by the PhD student to study it during this thesis will open many opportunities thereafter.

Le candidat

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

The candidate must have a strong background in biology and biogeochemistry, knowledge of the physiology of

mixotrophic organisms and the cultivation of different phytoplankton species in the laboratory under controlled conditions. Expertise in autotrophy quantification techniques (analysis of photosynthetic systems, use of MAP) and heterotrophy quantification techniques (grazing experiment Jeong et al., 2005) is desired.

ATTENTION :

Tout dossier non déposé sur le serveur dans les délais indiqués, ne pourra être pris en compte notamment par les instances ISblue, conseil de l'EDSML.

Bibliographie

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