Rentrée 2021

OMEGA PhD PROPOSAL- English Version

Project identification

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

Intitulé du projet *en langue française* : Effets des scénarios de changement global sur l'accumulation des acides gras polyinsaturés à longue chaîne n-3 et les performances des poissons - Approche expérimentale

Intitulé du projet en langue anglaise : Effects of global change scenarios on n-3 LC PUFA accumulation and fish performances – Experimental approach

Presentation of the lead institution (beneficiary of regional aid)

Lead institution : Université de Bretagne Occidentale

PhD school : EDSML ☒ SPI ou MATHSTIC pour les projets ISblue ☐

Identification of the project leader (future PhD director)

Name of the host laboratory: Laboratoire Environnement Marin
Code du laboratoire (U/UMR/USR/EA/JE/…) : UMR LEMAR 6539
Lab director[1]: Luis Tito de Morais
Name of the scientific team : PANORAMA

Nombre HDR dans le laboratoire : 51 Nombre de thèses en cours : 47 Nombre de post-docs en cours : 16

Surname and first name of the PhD director* (HDR), project leader: Philippe SOUDANT

- **e-mail :** philippe.soudant@univ-brest.fr
- **Phone :** 02 98 49 86 23
- **Recent publications** *(nb total et 5 références max au cours des 5 dernières années)* **:**

Total number : 169 publications

- Salin, K., Mathieu-Resuge, M., Graziano, N., Dubillot, E., Le Grand, F., **Soudant, P.,** & **Vagner, M.** (**2020**). The relationship between membrane fatty acid content and mitochondrial efficiency differs within-and between-omega-3 dietary treatments. *Marine Environmental Research,* 163, 105205. https://doi.org/10.1016/j.marenvres.2020.105205
- Couturier, L. I. E., Michel, L. N., Amaro, T., Budge, S. M., da Costa, E., De Troch, M., Di Dato, V., Fink, P., Giraldo, C., Le Grand, F., Loaiza,I., Mathieu-Resuge, M., Nichols, P. D., Parrish, C. C., Sardenne, F., **Vagner, M.**, Pernet, F.*, and **Soudant, P**. (**2020**). State of art and best practices for fatty acid analysis in aquatic sciences. – ICES Journal of Marine Science, doi:10.1093/icesjms/fsaa121. https://www.researchgate.net/publication/343833498_State_of_art_and_best_practices_for_fatty_acid_analysis_in_aquatic_sciences#fullTextFileContent
- Marchetti, J., da Costa, F., Bougaran, G., Quéré, C., **Soudant, P.,** & Robert, R. (**2018**). The combined effects of blue light and dilution rate on lipid class and fatty acid composition of *Tisochrysis lutea*. ***Journal of Applied Phycology***, 1483-1494. https://doi.org/10.1007/s10811-017-1340-yhttps://www.researchgate.net/publication/321297383_The_combined_effects_of_blue_light_and_dilution_rate _on_lipid_class_and_fatty_acid_composition_of_Tisochrysis_lutea
- González-Fernández, C., Lacroix, C., Paul-Pont, I., Le Grand, F., Albentosa, M., Bellas, J., Vinas, L., Campillo, J.A., Hégaret, H., & **Soudant, P.** (**2016**). Effect of diet quality on mussel biomarker responses to pollutants. *Aquatic*

[1] Ce formulaire est rédigé en style épicène

Toxicology, 177, 211-225. https://doi.org/10.1016/j.aquatox.2016.05.027 https://www.researchgate.net/publication/303712986_Effect_ of_diet_quality_on_mussel_biomarker_responses_to_pollutants

- da Costa F., Robert R., Quéré C., Wikfors GH., **Soudant, P.** (**2015**). Essential fatty acid assimilation and synthesis in larvae of the bivalve *C.gigas*. *Lipids* 50(5) 503-511. https://doi.org/10.1007/s11745-015-4006-zhttps://www.researchgate.net/publication/273640118_Essential_Fatty_Acid_Assimilation_and_Synthesis_in_L arvae_of_the_Bivalve_Crassostrea_gigas

- Supervision experiences and co-supervision of doctoral students (past and ongoing):

- **2020-2023** : Mickaël Péron, Financement ARED – EDSML. Rôle de l'habitat actuel et du stade ontogénique sur la capacité du bar *D. labrax* à faire face au scenario futur de réchauffement et de baisse de disponibilité en oméga-3 polyinsaturés à longue chaine dans le réseau trophique. Co-direction : M. Vagner, F. Le Grand, D. Mazurais. Soutenance prévue en 2023.
- **2019-2022** : Mariana VENTURA, financement Interreg NWE – UBO. Production d'acides gras polyinsaturés n-3 (Omega 3) par la culture des Thraustochytrides sur des effluents issus de la méthanisation. Soutenance prévue fin 2022.
- **2017 – 2020** : Sarah ITOIZ, financement Région Bretagne-UBO. Écologie fonctionnelle de micro-parasites eucaryotes invasifs en rade de Brest. Co-direction : A. Chambouvet (CNRS). Soutenance prévue février 2021.
- **2016 – 2019** : Marine REMIZE, financement UBO-UNCW. Origine et production des acides gras polyinsaturés essentiels 20:5n-3 et 22:6n-3 par les protistes autotrophes et hétérotrophes et transferts dans les chaines trophiques marines pélagiques. Co-direction: F. Planchon (UBO), A.-L. Loh (UNCW), A. Volety (UNCW), F. Le Grand (UBO). Soutenue le 24 janvier 2020. Situation actuelle : Chef de projet à GREENSEA
- **2015 – 2018**. Justine CASTREC, financement Région Bretagne-UBO. Impact des efflorescences de dinoflagellés toxiques sur la reproduction des huîtres d'intérêt économique en Rade de Brest. Co-direction : H. Hégaret et C. Fabioux. Soutenue décembre 2018. Situation actuelle : ATER
- **2013 - 2017** : Sonia GASMI, financement Université Bordeaux. Écologie trophique et reproduction d'une population sauvage d'huître creuse Crassostrea gigas dans un écosystème macrotidal, peu profond : cas du bassin d'Arcachon. Co-direction : V. David. Soutenue Juin 2017. Situation actuelle : Post-doc Université NANCY
- **2014 – 2017** : Floriane BOULOT, financement Région-UBO, Implication des canaux sodium voltage-dépendant dans la réponse aux toxines chez l'huître creuse *Crassostrea gigas* : le cas des PST. Co-direction : P. Boudry (Ifremer), H. Hégaret (CNRS) et C. Fabioux (UBO). Soutenue décembre 2017. Situation actuelle : ATER UBS

Scientific co-supervisor : Marie VAGNER

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- Supervision experiences and co-supervision of doctoral students (past and ongoing):

- **2020-2023** : Mickaël Péron, Financement ARED – EDSML. Rôle de l'habitat actuel et du stade ontogénique sur la capacité du bar *D. labrax* à faire face au scenario futur de réchauffement et de baisse de disponibilité en oméga-3 polyinsaturés à longue chaine dans le réseau trophique. Co-direction : P. Soudant, F. Le Grand, D. Mazurais. Soutenance prévue en 2023.
- **2020-2023** : Mireia Kohler, Financement Etablissement La Rochelle Université - ANR PAMPAS. Ichtyofaune des marais côtiers des Pertuis charentais face à l'aléa de submersion marine : caractérisation, fonctionnement écologique et fonction patrimoniale. Co-direction : N. Bécu, E. Réveillac. Soutenance prévue en 2023.
- **2018-2021** : Marie Angelica Martinez Silva. Financement canadien (CRSNG). Indicateurs physiologiques de la croissance et du métabolisme chez des poissons d'intérêt commercial. Co-direction : C. Audet (ISMER, Rimouski, Canada). Soutenance prévue fin 2021.

Funding of the PhD

This PhD is 100% funded (functioning and salary) by ISblue as a part of the emblematic OMEGA Flagship project funded over the period 2021-2024.

Presentation of the Project

Abstract of the project*:*

For human populations, fish is a major source of long-chain n-3 polyunsaturated fatty acids (n-3 LC PUFAs), commonly known as omega-3, which are necessary for the maintenance of vital functions. Small pelagic exploited fish (SPFs), mainly from the Eastern Boundary Upwelling Systems (EBUS, Humboldt, Benguela, Canary Islands and California), are the main contributors to the consumption and direct use of n-3 LC PUFAs by the world's human population. The exploitation of this resource is now reaching a plateau in the face of an ever-increasing human population.
The richness of marine organisms in n-3 LC PUFAs depends almost entirely on the production of these molecules at the base of marine trophic networks (primary producers), and their transfer through the trophic chain. Global change is leading to a reduction in the overall production of n-3 LC PUFAs at the base of the marine food web by altering the species assemblages of primary producers and their physiology. Such disruption of n-3 LC PUFA production could spread to higher trophic levels, including SPFs and humans.
Thus, climate change, combined with the increase in human population, currently leads to a clear warning that the supply of n-3 LC PUFAs could become insufficient by 2040. There is an urgent need to assess the impact of environmental changes on the accumulation of n-3 LC PUFAs by SPFs and their consequences on SPF populations in order to maintain ecosystem functioning and the supply of n-3 LC PUFAs to the human population. This scientific question, although fundamental from an ecological, socio-economic and public health point of view, has not yet been considered on a global scale.
In this context, the objective of the PhD will be to assess how the main physiological and behavioural performances of SPFs, which are determinant for population growth and recruitment, will be affected by changes in food availability in n-3 LC PUFAs, using a biological model of SPFs from the Bay of Biscay, the sardine *Sardina pilchardus*.
This PhD project is part of a larger project, OMEGA (2021-2024, 400 k€), funded by EUR ISblue and focusing initially on the Bay of Biscay as a reference study site to develop an interdisciplinary research methodology, which will then be disseminated to the four EBUS (Humboldt, Benguela, Canary Islands and California). OMEGA combines observations, experimentation, modelling, economic and sociological analyses to assess (1) the spatio-temporal variability of n-3 LC PUFA content in SPFs, (2) the influence of trophic availability of n-3 LC PUFAs on the physiology and behaviour of SPFs, and (3) its population-wide impacts and potential future changes in the supply of n-3 LC PUFAs, (4) the effects of fishery production methods on fish quality in terms of n-3 LC PUFAs, and (5) fishermen's and consumers' representations and acceptable alternative sources of n-3 LC PUFAs for consumers.
The experimental results obtained during this PhD, coupled with *in situ* observations conducted in OMEGA, will then contribute to (i) develop mathematical models at the individual level that include the transfer of n-3 LC PUFAs to SPFs and its impact on fish growth and development, reproduction and mortality risk, (ii) extrapolate these effects to the population scale to (iii) present first-order assessments of future global reserves of n-3 LC PUFAs by SPF populations.

Detailed presentation of the project:

1 - Hypothesis and questions asked, state of the art, identification of scientific blocking points:

Long-chain n-3 polyunsaturated fatty acids (n-3 LC PUFAs or omega-3 LC PUFAs) are essential molecules for humans [1]. They are major components of cell membranes and therefore play a key role in many vital functions (e.g. cerebral, cardiovascular and immune functions)[1–3] ; EPA (ecosapentaenoic acid) and DHA (docosahexaenoic acid) being the most beneficial. Humans cannot synthesize these molecules from their precursors in sufficient quantities, and they must therefore be provided through food to meet our health needs[4].
The main sources of n-3 LC PUFAs for humans are marine resources and small pelagic fish (SPFs) in particular [5], which represent the largest group of species landed in marine fisheries. They are mainly fished in the highly productive Eastern Boundary Upwelling Systems (EBUS) (Humboldt, Benguela, Canary Islands and California), both for human consumption and for animal feed. While the weekly consumption of fish is recommended by many health authorities (FAO, FDA, ANSES)[4], its supply has reached a plateau, with stocks being fully exploited or overexploited in some regions. This entails a clear risk that these molecules will become insufficient for a growing world human population by 2040[6].
The richness of marine organisms in n-3 LC PUFAs depends almost entirely on the production of these molecules at the base of marine trophic networks (primary producers), and their transfer along the trophic chain. Most marine fish at trophic levels above SPF have very poorly functional n-3 LC PUFA biosynthesis pathways. [7,8]. But we don't know

whether SPFs, which are plankton-eaters, have functional biosynthetic pathways or not. However, it is assumed that their high n-3 LC PUFA content also depends almost entirely on the production of these molecules at the base of marine food webs and on their transfer into the food chain.
Global change (warming, acidification, hypoxia)[9–11] leads to a reduction in the overall production of n-3 LC PUFAs at the base of the marine food web, altering the assemblages of primary producer species and their physiology [11,12]. This reduction would change the membrane composition of higher organisms [13], with wide-ranging consequences, by modifying their physiological functions at different life stages (e.g. growth, reproduction, locomotion), with consequences on recruitment and fitness[14–21]. In addition, this reduction would interact negatively with a rise in temperature on the membrane composition, further altering the physiological functions of ectothermal organisms such as fish [20,21], and underlining the need to consider these factors in combination, particularly in the context of warming waters. These alterations at the individual level are likely to cascade through population dynamics and ecosystem functioning, and alter the availability of n-3 LC PUFAs to humans. But so far, these effects have not been studied in SPFs, either experimentally or from a modelling point of view.
The hypothesis is that a limitation of n-3 LC PUFAs in the diet resulting from a global change will reduce the body condition of SPFs, change their behaviour with consequences on population dynamics, and the availability of n-3 LC PUFAs to humans.
The objective of this PhD will therefore be to assess how the key physiological and behavioural performance of SPFs, which are determinants of growth and recruitment and population dynamics, will be affected by changes in food availability of n-3 LC PUFAs and temperature.

2 - Methodological approach and techniques :

An experimental approach will be carried out to test the combined effect of food availability in n-3 LC PUFAs and temperature on physiological and behavioural performance critical for growth and recruitment of SPFs.
The experiments will be conducted on a SPF model, the sardine *Sardina pilchardus* from the Bay of Biscay, a reference site for the OMEGA project in which this PhD is being carried out. Like the EBUS, the Bay of Biscay is characterized by a rich primary production, and supports a high abundance and exploitation of CP (30,000 T of sardines landed in 2017). The choice of sardines from the Gulf is also reinforced by the current unexplained decline in the body condition of anchovies and sardines observed since 2008 [22–24]. The potential causes of this decline have never been studied through the prism of variability in n-3 LC PUFA content in fish, and its potential consequences on physiology and recruitment.
Sardine rearing will be set up using mature gonads taken from wild fish and brought immediately to the laboratory for fertilization. The resulting larvae and juveniles will be fed respectively with enriched Artemia and granules with different levels of n-3 LC PUFAs until gonad maturation (~1 year). In order to evaluate the effects of variation in n-3 LC PUFAs on sardines, different scenarios will be tested:

- A scenario in which animals will be fed with a current level of PUFAs covering the ranges of these compounds in natural plankton (currently being studied at LEMAR),
- A scenario in which animals will be fed with a lower n-3 LC PUFA content to test the hypothesis that EPA and DHA will decrease in plankton due to global changes [11].

These food scenarios will be combined with two acclimation temperatures, which simulate future environmental conditions (i.e. the current real average temperature of the Bay of Biscay, and +2.5°C relative to this temperature).
The accumulation, trophic origin and molecular regulation of n-3 LC PUFAs will be evaluated in pooled larvae and in different tissues of interest to juveniles and adults (eyes, brain, muscles and gonads) by carrying out: i) fatty acid analyses by GC-FID (Gas Chromatography Flame Ionisation detector) [25] , and isotope analyses of specific compounds (CSIA) by GC-c-IRMS (Gas chromatography-Combustion- Isotope Ratio Mass Spectrometry)[25,26], and (ii) measuring the expression of genes encoding the enzymes involved in the biosynthesis of n-3 LC PUFAs (such as desaturases and elongases) by quantitative PCR [27,28]. The CSIA will make it possible to differentiate between the incorporation of preformed n-3 LC PUFAs from diets and the synthesis of endogenous n-3 LC PUFAs from precursors.
Behavioural and physiological data that are difficult to obtain in the field will be collected: individual monitoring of survival and growth rates, reproductive performance, etc. [29,30]. Measures of metabolic rates[19] and digestive capacity (specific dynamic action)[31] could be considered. The molecular and cellular mechanisms at the origin of these key metabolic responses (transcriptomic and enzymatic analyses) will be evaluated in the different tissues of interest. Behaviour will be studied through (i) swimming behaviour[18], (ii) predator avoidance [32,33], (iii) other behavioural traits such as phototaxis (light orientation decision), rheotaxis (turning to face a current) and rotational optokinetic response (eye movement in response to movement)[34].

3 - Positioning and scientific environment in the regional, national and international context:

Understanding the response of marine organisms to global change is at the heart of global concerns. In particular, understanding the future of fish populations is both an economic and public health challenge for human populations, for whom they are the main source of n-3 LC PUFA. The dynamics and resilience of the n-3 LC PUFA content of small pelagic fish is still far from being understood, although it may have considerable consequences for human health in the near future (e.g. shortage of fish oil by 2040). A better understanding of this content and how it may be modified by global change will help to preserve ecosystem services, with direct implications for human health and food security. This PhD, based on an experimental approach, is integrated in a larger international project, OMEGA (2021-2024, 51 members, 400 k€), funded by the ISblue University Research School, and whose objective is to study the effects of the trophic shortage of long chain n-3 polyunsaturated fatty acids on small pelagic fish and human populations through the development of an interdisciplinary framework combining physical, biological, economic and sociological approaches. OMEGA is initially focusing on the Bay of Biscay as a reference site to develop an interdisciplinary research methodology, which will then be disseminated to the four EBUS (Humboldt, Benguela, Canary Islands and California). OMEGA combines observations, experimentation, modelling, economics and sociological analyses to assess (1) the spatio-temporal variability of n-3 LC PUFA content in SPFs, (2) the influence of trophic availability of n-3 LC PUFAs on the physiology and behaviour of SPFs, and (3) its population-wide impacts and potential future changes in the supply of n-3 LC PUFAs, (4) the effects of fishery production methods on fish quality in terms of n-3 LC PUFAs, and (5) fishermen's and consumers' representations and acceptable alternative sources of n-3 LC PUFAs for consumers.
Thus, coupled with the *in situ* observations made in this project, the experimental results obtained during this PhD will contribute to (i) develop mathematical models at the individual level that include the transfer of n-3 LC PUFAs to SPFs and its impact on fish growth and development, reproduction and mortality risk under different environmental scenarios, (ii) extrapolate these effects to the population scale, and (iii) present first-order assessments of future global reserves of n-3 LC PUFAs by SPF populations.

4 - Scientific and partnership context: general elements (ERC, CPER, FEDER, Breizhcop …)

As previously mentioned, this project is part of an international OMEGA project (2021-2024), which brings together more than 50 scientists from 7 regional laboratories (UMR LEMAR, Ifremer-STH, UMR AMURE, UMR LOPS, LP3C, Audencia Business School), 2 national laboratories (LOCEAN, UMMISCO), 7 foreign academic laboratories (UCAD & CRODT, in Senegal; UCT & DAFF, in South Africa; IMARPE in Peru; CICIMAR & CIBNOR in Mexico), and an economic partner (Conserverie Chancerelle-Connetable). This PhD project will therefore enable us to effectively pursue the integration of our laboratory into the regional, national and international network of research labs working in this field. During the project, a close dialogue will be conducted between modelers (LEMAR, Ifremer-STH) and experimenters/physiologists for the subsequent use of the physiological data obtained in the individual and population models. Also, our Peruvian collaborators are very interested in developing the experimental techniques developed during the PhD, privileged exchanges will be conducted with them.

References:

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The candidate

Desired profile of the candidate (main speciality/discipline, required scientific and technical skills):
The ideal candidate should have experience in animal physiology, ecophysiology or biochemistry at Master's level, be willing to learn a variety of laboratory and animal handling methods, have strong time management and communication skills, and be able to work independently and in a team environment. Previous experience in fish handling or lipid metabolism would be an asset, but is not mandatory. Fluency in English is required. Particular attention will be paid to the candidate's geographical mobility (academic years abroad, gap year...). He/she will have to show sufficient maturity before choosing to invest in this project.

Applications should be sent to philippe.soudant@univ-brest.fr and marie.vagner@univ-brest.fr