LIPIDS IN THE OCEAN

Structure, function, ecological role and applications

20-22 Nov 2018

Brest, France

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Welcome

Welcome to *Lipids in the Ocean*, the first international conference focusing exclusively on marine lipids. This conference will strengthen the position of international research on marine lipids toward broad scientific questions, ranging from cellular-level to marine ecosystems functioning. One of the aims of this multidisciplinary event is to stimulate discussions on concepts related to the role of lipids from lower up to higher trophic levels. Four keynote speakers have been engaged to provide a perspective of how the research landscape has evolved in marine lipid science and provide perspective on where we can go in the future.

The program will focus on several key topics, including lipid structure and function at cellular and sub-cellular levels, recent advances in lipid analytical chemistry, stable isotope analysis of specific lipid compounds, lipid involvement in trophic ecology, lipids in finfish and shellfish aquaculture, influence of global change on marine lipid synthesis and fate, as well as benefits and applications of bioactive lipids and omega 3 fatty acids. This conference will stimulate the development of international collaborative projects and push the boundaries of knowledge on marine lipids and their applications.

Integrating different disciplines is key to better defining the consequences of global changes on ecosystem sustainability. There is an urgent need to better connect the experts looking at the biochemical and physiological roles of lipids, and those interested on their effects on energy flow in food webs, fisheries and aquaculture, and human health.

Lipids in the Ocean will enable the participation of graduate students, academic and government researchers, and industrial and resource managers interested in lipids in aquatic ecosystems.

Delegates from 18 countries will participate in this event to bring a truly global aspect to the meeting. We welcome you all to Brittany and hope you take advantage of the hospitality and amenities the region has to offer. We thank all of you for taking time to come to this meeting and sharing your results with all of us and hope you enjoy the meeting and associated workshops.

We would like to extend a special thanks to all our sponsors who have helped keep costs down for all delegates by allowing low cost registrations. Their generous support has also allowed the participation of 30 Master students to the conference.

Thank you all for helping to make this meeting a success

Conference Organising Committee

Philippe Soudant (CNRS)
Lydie Couturier (UBO)
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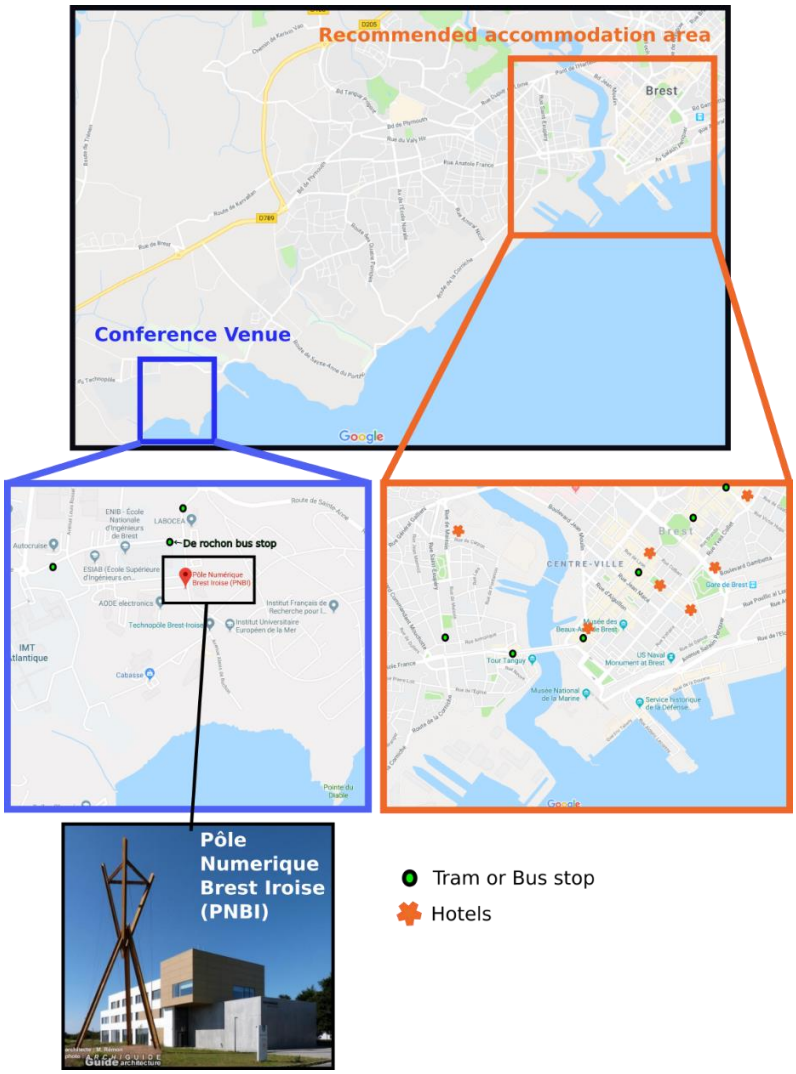
Meeting information

The venue

Pôle Numérique Brest Iroise, 305 Avenue Alexis de Rochon 29280 Plouzané, 29280 Plouzané

Coordinates: 48°21'36.0"N, 4°33'51.6"W (48.360002, -4.564337)
This building is right across the street from the IUEM (European Institute for Marine Studies)



Meeting rooms

Workshop sessions on Saturday 17th and Sunday 18th Nov will be held in the Amphitheatre D within the IUEM building. Sign will be placed to signal the room location. The workshop session on Monday 18th will be held in room 207 of the Pôle Numérique Brest Iroise (PNBI).

Plenary sessions and talk sessions will be held in the Amphitheatre at ground level of the PNBI. Poster sessions will be held in the reception hall of the PNBI.

During all sessions please turn off mobile phones or set to vibrate.

Two small meeting rooms (121, 123 at the PNBI) will be made available for the duration of the conference if delegates wish to have a space to work, or to organise short meetings.

Registration desk

The registration is open on Tuesday (8:30am – 9:30am), Wednesday and Thursday (8:30am-9am).

Internet access

Internet access will be provided by Wifi:

Network : Invite
Login : npnbi
password : gadrV4=j

Food and beverage

Morning and afternoon tea break will be held in the reception hall of the PNBI. Lunch will be provided to all registered delegates in the same room (buffet).

Limiting our impact

In an attempt to host an environmentally responsible meeting, the organizing committee has endeavored to avoid the use of single-use plastic and to promote recycling of all other waste during the conference. Delegates that do not wish to keep their name badges or conference bags are asked to return those items to the registration desk so they can be recycled.
Lipids in the Ocean is committed to making a difference by taking action on climate change now and working toward a clean energy future

Group photo

A photo of all delegates will be taken on **Wednesday 21/11 at 4:20pm** in the PNBI hall

Presenter information

Oral presenter

Presenter should submit their talk in the break period prior to their presentation, at the latest. Speakers can review their slides at the time of loading to ensure formatting is retained.

Please save your files in either **.PPTX** (PowerPoint 2016) or **.PDF** format. We'll be using a Windows 7 or 10 based PC so if you have used another OS for your presentation, please check that it still looks as you intended when viewed on a PC. Keynote talks will be 30 minutes + 10 min for questions. **Standard oral presentations will be 15 min + 4 min for questions**. Session chairs will be strict with timing, so please practice your talk in advance.

Poster presenter

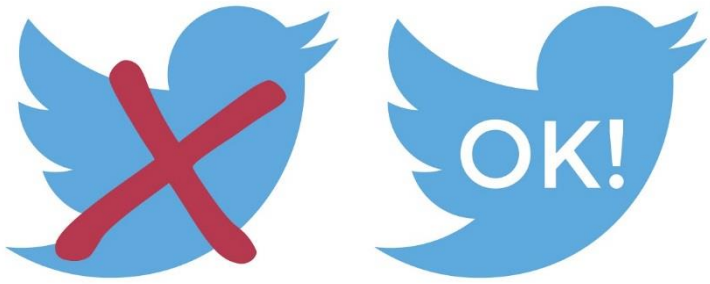
The poster sessions will be held on Tuesday and Wednesday evening. Presenters are asked to place their poster on the assigned board on Tuesday to allow delegates time to view them. Each poster board will be labeled with a number, the author should place their poster in the appropriately numbered place. **Posters should be printed in A0 Portrait** (Width x Height = 841 x 1189 mm; 33.1 x 46.8 inches).

Meeting prizes

Two prize categories are available during the conference: Student best talk and Student best poster. All prizes will be announced and awarded on Thursday afternoon during the closing ceremony.

Social media

Social media is playing an increasing role in scientific conferences, and we expect (and hope) that there will be much discussion and diffusion of studies presented at *Lipids in the Ocean* via social media such as Twitter, Facebook and Instagram (#MarineLipids2018). If you do not want people to discuss your work on social media, please make this clear. This is absolutely understandable, and if so you could do this by including this image in your presentation. Alternatively, if you are happy, you can let us know!



Keynote speakers

Christopher Parrish

Memorial University of Newfoundland, Canada

Chris Parrish is a University Research Professor in the Department of Ocean Sciences at Memorial University of Newfoundland, Canada. He is cross-appointed to MUN's Departments of Chemistry and Biology and is the Graduate Officer of MUN's Marine Biology Program. He is also an Adjunct Professor at Université Laval, Québec, and an External Graduate Faculty Member at the School of Marine Sciences, University of Maine. His research focuses on the production, transport, fate and effects of hydrophobic organic matter in the marine environment. He has developed analytical methods and numerical approaches for lipids that have been widely used to trace formation and consumption of energy and essential nutrients in marine systems. Together with students in several academic programs he studies food web connections, aquaculture nutrition, and environmental impacts of aquaculture and their mitigation. Their work has produced key findings on the ecological importance of marine lipids as energy sources and as essential nutrients, and on effects of marine oils in aquaculture leading to ways to minimize environmental impacts of aquaculture and to maximize the healthfulness of the food product.

Email: cparrish@mun.ca

Keynote talk: **Nutritional and biomarker lipids in marine food webs**

Peter Nichols

CSIRO, Australia

Peter Nichols leads new initiatives with signature lipid technology and environmental applications, and on marine oils, with particular emphasis on the health-benefitting omega-3 oils. The latter research involves detailed characterization of fish-derived and novel microbial oils, process development for the utilization of oils, development as part of a wider CSIRO team of novel land plant sources of long-chain omega-3 oils, and transfer and application of these know-how to industry and the wider community.

This research has led to better utilisation of substantial national fisheries resources and wastes, and to new oilseed crops. He has contributed to the development of the Australian marine oils industry, with CSIRO research resulting in novel national and international marine oil products (wax ester, omega-3 and shark liver oils). Other innovations have been the development and use of unique chemical (lipid) signatures in microbial ecology, environmental (e.g., fecal pollution) and food-chain studies, and new discoveries and applications in marine microbial biotechnology. He has worked closely with a number of Australian and overseas Universities including actively co-supervising and mentoring over 30 PhD students to graduation, with a further 10 students presently underway. He is also involved in a number of international collaborations across the above research fields, including sponsoring sabbaticals and visits by overseas scholars.

Email: Peter.Nichols@csiro.au

Keynote talk: **Sources and biotechnology of long chain n-3 polyunsaturated fatty acids**

Elena Palacios

CIBNOR, Mexico

Elena Palacios is the group leader of the lipid metabolism lab at researcher center Centro de Investigaciones Biológicas del Noroeste, in La Paz, Mexico. Her research focuses on physiology and lipid metabolism in aquatic animals, with emphasis on secondary markers of stress and reproduction, including eicosanoid production, heat shock proteins and apoptosis. Other interest are production and utilization of lipid-rich marine by-products from fisheries and aquaculture for feed production in aquaculture. She is also working on the effects of marine lipids and lipidic contaminants on human health, particularly on milk production and obesity.

Email: epalacio@cibnor.mx

Keynote talk: **Arachidonic acid in wild and cultured aquatic organisms in relation to adaptation to stress**

Martin Kainz

Danube University Krems, Austria

Martin Kainz is a research scientist and working group leader of the LIPTOX research team (Aquatic lipid and ecotoxicology) at WasserCluster Lunz, an Inter-university Center for Aquatic Ecosystems Research in Austria. He also teaches at the University of Vienna. His group's research focuses mainly on food web ecology, how aquatic food webs are functioning, how dietary energy is synthesized, transferred and converted, and affecting life in aquatic ecosystems. His team investigates trophic interactions using biochemical tracers (stable isotopes, lipids, compound-specific stable isotopes) and potential contaminants in experimental setups (lab experiments, mesocosms) and natural ecosystems, such as streams, lakes, reservoirs, and fish ponds to elucidate how diet sources and physico-chemical parameters act within aquatic food webs. LIPTOX recently started investigating how environmental change, including changes in temperature, shifts in precipitation, and supply of terrestrial matter to aquatic ecosystems affects biodiversity, life history traits in zooplankton, insect larvae and fishes, and trophic transfer and retention of essential nutrients. In addition to using bulk stable isotopes and fatty acids, his team applies radioactive isotopes and compound-specific stable isotopes to scrutinize how fatty acids are converted within consumers of various aquatic ecosystems, including streams and lakes in subalpine Europe, aquaculture ponds in China, and subtropical streams in Australia.

Email: Martin.Kainz@donau-uni.ac.at

Keynote talk: **Discerning dietary lipid sources and their ecophysiological fate in fish tissues**

Sponsors and partners

Tuesday 20/11/2017

08:30 - 09:00		**Registration - Come and register in the PNBI hall**
08:55 - 09:00		Housekeeping information
09:00 - 09:30		Welcome talk - Heads of host organisations
09:30 - 10:30	Session	**Transfer, upgrading and role of polyunsaturated fatty acids and sterols in aquatic food webs** - Chair: Chris Parrish & Lydie Couturier
09:30 - 10:10		› Nutritional and biomarker lipids in marine food webs - *Christopher Parrish*, *Department of Ocean Sciences, Memorial University of Newfoundland*
10:10 - 10:30		› Phytoplankton essential lipids as an indirect link between water column mixing depth and zooplankton dynamics in a global change scenario - *Patrick Fink*, *University of Cologne*
10:30 - 10:50	**Break**	**Coffee break**
10:50 - 12:30	Session	**Transfer, upgrading and role of polyunsaturated fatty acids and sterols in aquatic food webs** - Chair: Chris Parrish & Lydie Couturier
10:50 - 11:10		› Assimilation efficiencies of essential fatty acids in marine zooplankton - *Suzanne Budge*, *Dalhousie University*
11:10 - 11:30		› Potential relationships between organic matter (OM) quality and quantity on the nutritional ecology of abyssal holothurians inferred from stable isotopes and lipid compositions - *Teresa Amaro*, *University of Porto*
11:30 - 11:50		› Improving specificity of dietary fatty acid inclusion for optimal EPA and DHA storage in farmed salmon - *Stefanie Colombo*, *Dalhousie University*
11:50 - 12:10		› The role of lipids in early ontogeny of the daubed shanny *Leptoclinus maculatus* (Stichaeidae family) from Svalbard - *Svetlana Pekkoeva*, *IB KarRC RAS*
12:10 - 12:30		› Food web dynamics of fatty acids and persistent organic pollutants in Greenland's priority marine conservation regions - *Igor Eulaers*, *Aarhus University*
12:30 - 14:20	**Break**	**Lunch**
14:20 - 14:40	Speech	Summary of Workshop 3 - Stable isotopes in marine lipid science
14:40 - 15:40	Session	**Advances in analytical chemistry of lipids - Compound specific stable isotope analysis of lipids** - Chair: Elena Palacios & Loic Michel
14:40 - 15:00		› What is the effect of lipid extraction methods and tissue dry storage on lipids classes and fatty acids from marine animals? - *Fany Sardenne*, *Fisheries and Oceans Canada*
15:00 - 15:20		› Habitat use and trophic competition among shark species from oceanic islands in the Northeastern Pacific - *Gaël Le Croizier*, *Université de Bretagne Occidentale*
15:20 - 15:40		› Investigating the activity of methanogenic archaea in marine sediments by lipid radioisotope probing - *Sarah Coffinet*, *University of Bremen*
15:40 - 16:00	**Break**	**Coffee break**
16:00 - 17:00	Session	**Advances in analytical chemistry of lipids - Compound specific stable isotope analysis of lipids** - Chair: Elena Palacios & Loic Michel
16:00 - 16:20		› Local and oceanic inputs into the trophic ecology of two bivalve species in a coastal lagoon: evidences from stable isotope, fatty acid, and compound specific isotope analyses - *Margaux Mathieu-Resuge*, *Université de Bretagne Occidentale*
16:20 - 17:00		Summary of Workshop 1 – Sample conservation and associated problems for lipid extractions
17:00 - 18:30	**Session**	**Poster Session**

Wednesday 21/11/2018

08:55 - 09:00		Housekeeping information
09:00 - 10:20	Session	**Environmental effects on lipid metabolism in marine organisms and on trophic transfer** - Chair: Martin Kainz & Gauthier Schaal
09:00 - 09:40		› Arachidonic acid in wild and cultured aquatic organisms in relation to adaptation to stress - *Elena Palacios-Mechetnov*, *Centro de Investigaciones Biológicas del Noroeste*
09:40 - 10:00		› Daily cycles in oceanic fat concentrations reveal that phytoplankton use a 'crash diet' to maintain growth in the face of energy limitation - *Kevin Becker*, *Woods Hole Oceanographic Institution*
10:00 - 10:20		› Adaptation to phosphate starvation: a comparison between plants and two marine algae - *Phaeodactyllum tricornutum* and *Nannochloropsis oceanica* . - *Juliette Jouhet*, *Centre National de la Recherche Scientifique*
10:20 - 10:40	**Break**	**Coffee break**
10:40 - 12:20	Session	**Environmental effects on lipid metabolism in marine organisms and on trophic transfer** - Chair: Martin Kainz & Gauthier Schaal
10:40 - 11:00		› How nitrogen availability drives lipid composition in the haptophyte Tisochrysis lutea : new highlights - *Matthieu Garnier*, *Ifremer*
11:00 - 11:20		› First evidence of the impact of nanoplastics in lipid composition of marine phytoplankton - *Carmen González-Fernández*, *Université de Bretagne Occidentale*
11:20 - 11:40		› Lipid dynamics and ecophysiology of a marine protist (*Auriantiochytrium limacinum*) involved in the decomposition of mangrove leaves. - *Fabrice Rebeillé*, *CEA*
11:40 - 12:00		› Allelopathic exudates from the dinoflagellate Alexandrium minutum modify membrane lipids composition of the diatom Chaetoceros sp. - *Marc Long*, *Université de Bretagne Occidentale, University of Wollongong*

12:00 - 12:20		› Effects of temperature on lipid synthesis of diatom *Chaetoceros Pseudocurvisetus* and the Northern Adriatic plankton community - *Blaženka Gašparović, Ruđer Bošković Institute*
12:20 - 14:00	**Break**	**Lunch**
14:00 - 16:00	Session	**Environmental effects on lipid metabolism in marine organisms and on trophic transfer**- Chair: Marie Vagner & Karine Salin
14:00 - 14:40		› Discerning dietary lipid sources and their ecophysiological fate in fish tissues - *Martin Kainz, Donau-Universität Krems*
14:40 - 15:00		› Lipid and fatty acid constituents state of the ecological important aquatic organisms from the Arctic and sub-Arctic marine ecosystems - *Svetlana Murzina, The Russian Academy of Sciences*
15:00 - 15:20		› Lipid load triggers migration to diapause in Arctic Calanus copepods – insights from underwater imaging - *Frédéric Maps, Université Laval*
15:20 - 15:40		› Fatty Acids Composition of Zooplankton in Peruvian Upwelling Area - *Elda Pinedo Arteaga, Instituto del Mar del Peru*
15:40 - 16:00		› Unusually high levels of n-6 polyunsaturated fatty acids in giant tropical planktivores: dietary markers or physiological indicators? - *Lydie Couturier, Université de Bretagne Occidentale*
16:00 - 16:20		Summary of workshop 2 - Numerical tools for lipid composition data analysis
16:20 - 16:30		**Group photo, in the PNBI Hall**
16:30 - 17:00	Session	Discussion around: Marine Lipids Conferences, to be continued?
16:30 - 19:00	**Session**	**Poster Session**
16:30 - 19:00	Tour	Visit of the Institute - in small groups
19:00 - 21:30	**Break**	**Conference dinner**
		Thursday 22/11/2018
08:55 - 09:00		Housekeeping information
09:00 - 10:20	Session	**Marine lipids, human health and ecosystem services - Lipids in emerging biotechnology and blue economy** - Chair: Peter Nichols & Philippe Soudant
09:00 - 09:40		› A journey through signature lipid profiling to marine and plant biotechnology - *Peter Nichols, CSIRO Oceans and Atmosphere*
09:40 - 10:00		› Benefits and risks of seafood consumption in Peru: quantitative analysis of fatty acid and micro-contaminant intake - *Ivan Loaiza Alamo, Universiteit Gent*
10:00 - 10:20		› Health starts in the plate: Screening of microalgal strains with high potential in polyunsaturated fatty acid (PUFA) production. - *Ana Camila Dos Santos Dias, Ifremer*
10:20 - 10:40	**Break**	**Coffee break**
10:40 - 12:00	Session	**Marine lipids, human health and ecosystem services - Lipids in emerging biotechnology and blue economy** - Chair: Peter Nichols & Philippe Soudant
10:40 - 11:00		› Comparative effects of the marine microalgae *Phaeodactylum tricornutum* and *Diacronema lutheri* on metabolic disorders associated with metabolic syndrome and obesity in the Wistar rat - *Claire Mayer, Le Mans Université*
11:00 - 11:20		› Fatty acid profile and biochemical composition of *Odontella aurita* (Lyngbye) C. Agardh (Bacillaryophyta) from the Gulf of California, Mexico. - *Bertha Olivia Arredondo-Vega, Centro de Investigaciones Biológicas del Noroeste.*
11:20 - 11:40		› Variation of prostaglandin metabolism along the growth of the diatom *Thalassiosira rotula* - *Valeria Di Dato, Stazione Zoologica Anton Dohrn*
11:40 - 12:00		› Enzymatic synthesis of structured phospholipids rich in docosahexaenoic acid - *Florence Hubert, Le Mans Université*
12:00 - 12:20		Summary of workshop 4 - Marine lipids for medical and biotechnological applications : targeted vs non targeted approaches
12:20 - 14:00	**Break**	**Lunch**
14:00 - 14:40	Session	**Marine lipids, human health and ecosystem services - Lipids in emerging biotechnology and blue economy** - Chair: Peter Nichols & Philippe Soudant
14:00 - 14:20		› Seaweeds lipids in health-promotion: Lipidomics holding with lipid diversity - *Elisabete da Costa, University of Aveiro*
14:20 - 14:40		› Selective extraction of bioactive lipids from seaweeds - *Nolwenn Terme, Université Bretagne Sud*
14:40 - 15:40	Session	**Structure, metabolism and function of lipids** - Chair: Gabriel Markov & Edouard Kraffe
14:40 - 15:00		› Elucidation of aminolipids biosynthesis in marine bacteria and their role in lipid remodelling - *Yin Chen, University of Warwick*
15:00 - 15:20		› A $^{13}CO_2$ enrichment experiment with protists to study the synthesis pathways of two essential healthy polyunsaturated fatty acids - *Marine Remize, University of North Carolina Wilmington, Université de Bretagne Occidentale*
15:20 - 15:40		› Characterization and quantification of isoprostanoids from three microalgae species produced at 5 000 L scale - *Antoine Delbrut, Microphyt*
15:40 - 16:00	**Break**	**Coffee break**
16:00 - 17:20	Session	**Structure, metabolism and function of lipids** - Chair: Gabriel Markov & Edouard Kraffe
16:00 - 16:20		› Use of FIB-SEM tomography to unravel the membrane architecture and organelle interactions of the diatom *Phaeodactylum tricornutum* - *Denis Falconet, CEA*
16:20 - 16:40		› Evolution of synthesis of specialized and unusual lipids in toothed whales, and their roles in echolocation - *Heather Koopman, University of North Carolina*
16:40 - 17:00		› A patchwork model for cholesterol synthesis from cycloartenol in the red alga *Chondrus crispus* - *Gabriel Markov, Station Biologique de Roscoff*
17:00 - 17:20		› Structure and Dynamics of a unique tethered fluid lipid membrane. An experimental approach to shed some light on the interactions between a single lipid bilayer and a colloid. - *Guillaume Brotons, Université du Maine*
17:20 - 18:00	Speech	**The conference conclusion and awards**

Table of contents

Transfer, upgrading and role of polyunsaturated fatty acids and sterols in aquatic food webs

Potential relationships between organic matter (OM) quality and quantity on the nutritional ecology of abyssal holothurians inferred from stable isotopes and lipid compositions

Teresa Amaro[1,2*],Roberto Danovaro[3,4], Yohei Matsui[5], Eugenio Rastelli[3,4] , George A. Wolff[6], Hidetaka Nomaki[5]

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Benthic megafauna and specially holothurians play a key role in deep-sea ecosystem functioning, particularly on the processing of the sedimentary organic matter (OM). Changes in their abundances have been reported to be related with environmental factors, such as OM flux. However, the effects of the pelagic-benthic coupling and the specific link between changing seasonal OM inputs and structure of the mega-benthic community remain unclear.

In this study we identified OM differences in quality and quantity at two abyssal seafloor regions in the western Pacific Ocean and their effects on deep-sea holothurians. Phytopigment concentrations of the sediment were up to 16-times greater at the high productivity area (39N) than at the oligotrophic area (1N). Total carbohydrates and protein concentrations were also significantly higher at 39N than 1N, although to a lesser extent than for phytopigments. Holothurian abundances were almost 100 times higher at 39N than 1N. Significant differences were detected in the lipid compositions of holothurians in terms of concentration of the main food-source indices (phytoplankton, zooplankton and bacterial fatty acids), indicating different food sources in the two areas. Phytodetritus and bacteria were the most important dietary sources at 39N and 1N, respectively. Stable isotopic compositions also suggest that holothurians fed on both fresh OM and bacteria in the sediments.

Results presented here show that surface productivity and subsequent OM composition in surface sediments may lead to different abundances and food sources of deep-sea holothurians. Since holothurians are a primary consumer of phytodetritus on the abyssal seafloor, our results contribute to improve our understanding into the complex interactions between OM quality and quantity and ecosystem functioning in abyssal plains.

Keywords: Abyssal holothurians, lipids composition, OM quality and quantity, Stable isotopes.

Assimilation efficiencies of essential fatty acids in marine zooplankton

Budge, S.M.[1*], Helenius, L.[1], Johnson, C.L.[2] and Devred, E.[2]
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2 Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, B2Y 4A2

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All organisms have an absolute requirement for specific long chain omega-3 fatty acids (FA); however, most animals cannot synthesize these essential FA (EFA) in sufficient amounts to meet their needs and must rely on provision in their food. Marine phytoplankton is the major producer of EFA. To link EFA production at the base of the food web to their supply to higher trophic levels, we must know the efficiency of EFA transfer within food webs but data are lacking in this area. To fill that gap, we carried out a series of controlled feeding experiments to estimate assimilation efficiencies using stable isotopic labelling. Here, we report on the transfer from phytoplankton to copepods, a crucial link in the energy exchange between primary production and planktonic fish. We have compared assimilation efficiencies in two copepod species with contrasting life histories – *Calanus finmarchicus*, a large calanoid copepod that focuses feeding and reproductive effort on the spring diatom bloom and stores lipid, and *Eurytemora herdmani*, a much smaller, generalist feeder. The copepods were fed three phytoplankton species with distinct EFA profiles, *Thalassiosira weissflogii*, *Heterocapsa triquetra*, *Rhodomonas salina*, and at 12^{o}C, we found that long chain EFA had low assimilation efficiencies, ranging from 4-15% depending on FA structure, with highest values in *C. finmarchicus*. These data provide a foundation to add these essential nutrients to ecosystem models and to begin to estimate an EFA budget for the marine environment.

Keywords: energy transfer, production, stable isotope tracers, food webs

Improving specificity of dietary fatty acid inclusion for optimal EPA and DHA storage in farmed salmon

Colombo, S.M.[1*], Parrish, C.C.[2], Wei, M.[1], and Rise, M.L.[2]

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Farmed Atlantic salmon (*Salmo salar*) require a dietary source of the long chain-polyunsaturated fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), at a level of ~2% of the diet. Both EPA and DHA contribute to normal health and growth and are critical to survival. However, a major challenge is providing a sustainable dietary source of EPA and DHA. The use of terrestrial plant oils reduces the level of EPA and DHA in the diet. One strategy to improve synthesis and storage of EPA and DHA in salmon is to optimize the dietary levels and ratios of the ω3 and ω6 precursors. Using a data synthesis approach of four studies with salmonids, we found that DHA was optimally stored with a dietary ω3: ω6 ratio of 1.03: 1. We also found that EPA and DHA linearly correlated between diet and muscle tissue ($p < 0.001$; $r^2 > 44\%$), indicating proportional storage after consumption. The retention rate (based on the slope), was highest for docosahexaenoic acid (DHA) at 1.23, indicating that an additional 23% of DHA was stored in the muscle; however, less than 50% of EPA retained. It has yet to be determined if dietary DHA can satisfy the requirement for both DHA and EPA via retro-conversion. In a new study, we used microalgae oil with high levels of DHA, and only trace levels of EPA. Four treatments were fed to salmon that contained decreasing levels of EPA and increasing levels of DHA, to determine the impact that reduced dietary EPA has on overall health and growth, as well as fillet lipid and fatty acid content. Improving the specificity of dietary fatty acid requirements and inclusion levels can help optimize the storage of EPA and DHA, which are important for fish health, as well as the health of human consumers.

Keywords: aquaculture, docosahexaenoic acid, eicosapentaenoic acid, microalgae, salmon

Food web dynamics of fatty acids and persistent organic pollutants in Greenland's priority marine conservation regions

Eulaers I.[1]*, Dietz R. [1], Covaci A.[2], Letcher R. J.[3], McKinney M. A.[4], Rigét F. F.[1], Sonne C.[1] and Mosbech A.[1]

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Several Greenlandic ecoregions have been proposed recently for adoption under the UNESCO's World Heritage Convention due to their critical value in safeguarding high biological activity and diversity. Nonetheless, these ecoregions are not only subject to ongoing rapid change in sea ice dynamics, possibly altering food web dynamics, but have moreover been acting as environmental sinks for long-range transported industrial chemicals.
We will present results on food web pathways of fatty acids (FAs) and persistent organic pollutant (POPs), and their temporal variation linked to climate forcing, in four candidate heritage sites, the Northwater, Northeast Water and Scoresby Sound polynyas and the Disko Bay. We have been compiling FA and POP data from a variety of sampling campaigns, spanning research cruises since the 1990s as well as long-term monitoring initiatives such as the Arctic Monitoring and Assessment Programme.
Among our preliminary analyses is a time trend study using quantitative FA analysis of Scoresby Sound polar bear *Ursus maritimus* blubber to explain temporal variation in trophic pathways of FA and POPs. Our first results show how the dominant presence of ringed seal *Pusa hispida* in the polar bear diet has been significantly substituted by hooded seal *Cystophora cristata*, a subarctic species acting as a biovector of POPs into the Greenland food web.
These first data will be joined by spatiotemporal data on FAs and POPs in Greenlandic marine species of ecological and subsistence value to the local inhabitants. As such, we will present an evaluation of FA and POP food web pathways, possible climate forcing, and the human health relevance for the indigenous people in Greenland's priority marine conservation regions.

Keywords: Greenland, fatty acid, food web, persistent organic pollutant, quantitative fatty acid analysis

Phytoplankton essential lipids as an indirect link between water column mixing depth and zooplankton dynamics in a global change scenario

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Sea surface temperatures increase with global warming. One predicted consequence of this is a stronger stratification of the water column and a decrease of mixing depth. This will affect the dynamics of marine plankton communities. We experimentally manipulated mixed water column depths in mesocosms (volumes approx. 2 – 12 m³) deployed in the Bay of Hopavågen, Norway, which has a tidal supply with offshore plankton. This allowed us to investigate the effects of increasing water column stratification on plankton dynamics. Specifically, we hypothesized that a decrease in mixing depth will favour flagellated algae over diatoms and thus affect phytoplankton community composition. Such a shift in the phytoplankton species assemblage will affect the suite of essential polyunsaturated fatty acids (PUFAs) delivered from the phytoplankton to the herbivorous zooplankton. As PUFAs are known to mediate the food quality of phytoplankton for herbivorous zooplankton, we expected indirect effects of mixing depth on zooplankton community composition and dynamics mediated by the dietary supply of essential lipids. As hypothesized, mixing depth affected phytoplankton community and fatty acid composition as well as the zooplankton species composition. In particular calanoid copepods that depend on large diatoms with high sinking losses decreased in the shallow mixing scenario, probably due to both low food quantity and quality. As these diatoms are particularly rich in essential PUFAs, low supply of these compounds can partially explain shifts in the crustacean zooplankton. This negative effect on copepod zooplankton could even be worsened by an increased abundance by zooplanktivorous jellyfish at low mixing conditions. Overall, our data suggest that phytoplankton food quality mediated by essential PUFAs can play an important indirect role in affecting the response of plankton communities to global change.

Keywords: Calanoida; Copepoda; diatoms; jellyfish; polyunsaturated fatty acids

Nutritional and biomarker lipids in marine food webs

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We work at the interface of chemistry and biology in the area of aquatic lipid research with an emphasis on nutritional and biomarker lipids in marine food webs. We have been looking at marine ecosystems and aquaculture nutrition as well as where these two themes interact in terms of the impacts of aquaculture on the environment. Lipids are of particular interest in marine research as they provide the densest form of energy which is transferred from algae to vertebrates via zooplankton. These carbon-rich compounds are also a solvent and absorption carrier for organic contaminants and thus can be drivers of pollutant bioaccumulation in marine ecosystems. Among the lipids, certain essential fatty acids and sterols are considered to be important determinants of ecosystem health and stability. Fatty acids and sterols are also susceptible to oxidative damage leading to cytotoxicity and a decrease in membrane fluidity. The physical characteristics of biological membranes can be defended from the influence of changing temperature, pressure, or lipid peroxidation by altering the fatty acid and sterol composition of the lipid bilayer. Marine lipids are also a valuable tool to measure inputs, cycling, and loss of materials. Their heterogeneous nature makes them versatile biomarkers that are widely used in marine trophic studies, often with the help of multivariate statistics, to delineate carbon cycling and transfer of materials. Integrating stable isotope data with lipid data can facilitate the interpretation of both data sets and can provide a quantitative estimate of transfer across trophic levels. We apply this approach using both bulk and compound specific isotopes in the field and in the lab. Of the lipids, fatty acids and sterols are among the most widely employed compounds because of the large number of unique structures synthesized and because of their nutritional value. In this context we have recently been investigating regional differences in essential fatty acids in marine food webs and the importance of temperature. We have also been studying the particle field associated with finfish aquaculture and how benthic organisms interact with it in land-based and cage site facilities. Farms enrich the local environment and analyzing the quality and quantity of material exiting and its uptake by surrounding macroinvertebrates indicates the effectiveness of multi-trophic culturing systems where waste from one species is recycled as food for others.

Advances in analytical chemistry of lipids - Compound specific stable isotope analysis of lipids

Comparing LC-MS and extraction methods for analysis of large datasets of intact polar lipids

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Intact polar lipids (IPLs) are frequently used as markers for living microbial cells in marine environments. Understanding which microorganisms produce which specific lipid biomarkers is essential for the use of biomarkers both in the present-day environment as well as in paleo studies. IPLs can be analyzed with analytical techniques based on liquid chromatography coupled to mass spectrometry (LC-MS), and recent developments of these techniques provide the opportunity to detect a wide variety of IPLs as well as aid the search for novel biomarkers. Different methods are used to analyze IPLs, each of which has its own method biases leading to incomplete assessments of the IPLs present in environmental samples (cf. Weber et al., 2017). We tested different extraction methods and LC-MS methods on water column particulate matter from the North Atlantic Ocean and Black Sea. Furthermore, we compared the output from different lipidomic software to analyze the MS data. Our results reveal the advantages and disadvantages for various classes of IPLs of the different extraction techniques and analytical methods tested and we conclude which methods are best suited for marine particulate matter. We also present and compare the preliminary lipidomic data arising this study.

Weber, Y., Sinninghe Damsté, J. S., Hopmans, E. C., Lehmann, M. F., & Niemann, H. (2017). Incomplete recovery of intact polar glycerol dialkyl glycerol tetraethers from lacustrine suspended biomass. Limnology and Oceanography: Methods, 15(9), 782–793.

Keywords: lipidomics, intact polar lipids, analytical chemistry of lipids

Submission type: Oral presentation

Investigating the activity of methanogenic archaea in marine sediments by lipid radioisotope probing

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Methanogenesis is a terminal step in the remineralization of organic matter and one of the major microbial processes in marine sediments. However, the relative importance of different carbon and energy sources involved in this process are largely unconstrained. To this aim, we applied a novel technique, the lipid radioisotope probing (lipid-RIP), to follow methanogen activity in marine sediments through lipid biosynthesis. The high sensitivity of RIP makes it particularly suitable to follow microbial activity at short timescales. Incubation was performed in marine sediments from the Rhone delta to trace the synthesis of three specific archaeal lipids in their core and intact polar forms – glycerol dialkyl glycerol tetraethers (GDGTs), butanetriol dialkyl glycerol tetraethers (BDGTs) and diphytanyl diethers (archaeols) – during methanogenesis. Sediments from two depths (0-12 and 135-140 cmbsf) were incubated for 21 days with either ^{14}C-bicarbonate (DIC) or 2-^{14}C-acetate (ACE) as carbon source, and H_2 as major energy source. A second set was additionally amended with non-labeled methanol to track the use of non-competitive, methylated substrates as additional energy source for methanogenesis. ^{14}C-incorporation into the three archaeal lipid types was detected in all incubated samples. For all depths, DIC resulted in stronger ^{14}C incorporation into lipids than ACE, possibly indicating the preference of the active archaea to an autotrophic lifestyle. Methanol amendment had a positive effect on methanogenesis in the surface sediments (0-12 cm) but seemed to inhibit it at depth. The three lipid types show different incorporation trends relative to depth and carbon source implying that different archaeal communities were stimulated and/or that they developed adaptative processes. This study demonstrates the potential of the lipid-RIP technique to monitor *in situ* activity of microorganisms as well as to better understand the biosynthesis of membrane lipids. This work further supports the utility of specific archaeal polar lipids such as archaeols and BDGTs as biomarkers for methanogenesis.

¥ The corresponding authors contributed equally to this work.

Keywords: analytical chemistry; radiocarbon; biosynthesis; biomarkers; archaea

Habitat use and trophic competition among shark species from oceanic islands in the Northeastern Pacific

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Chondrichthyans have experienced increasingly intensive fishing and habitat degradation pressure over recent decades. It is estimated that over-fishing has resulted in the loss of over 90% of sharks and large predatory fish across all ocean basins. In the Northeastern Pacific, oceanic islands have been identified as aggregation sites for various shark species, leading to the creation of many marine protected areas such as the Galapagos, the Revillagigedo, Cocos and Clipperton Islands. Even though shark movements have been observed between these areas, suggesting connectivity among populations, little is known about the spatial ecology of the local shark species, compromising the ability to effectively manage their populations. In this context, the trophic ecology of four large shark species (the Tiger shark *Galeocerdo cuvier*, the Galapagos shark *Carcharhinus galapagensis*, the Silvertip shark *Carcharhinus albimarginatus* and the Silky shark *Carcharhinus falciformis*) was investigated in two different areas: the Revillagigedo Archipelago and Clipperton Island. A multi-tracer approach combining stable isotope analysis (SIA), fatty acid (FA) composition, and FA compound-specific stable isotope analysis (FA-CSIA) was used. Trophic tracers showed different signatures between the two areas, suggesting site fidelity for these species, which are nevertheless able to realize large migrations. For sharks from a same area, overlap was observed based on SIA and FA composition, highlighting trophic competition between top-predator species within these oceanic habitats. Finally, FA-CSIA allowed determining the main trophic sources for different fatty acids, revealing the ability for some individuals to forage on a wide range of habitats. The present study thus brought important results concerning the use of protected marine areas by shark species, which is critical for developing effective conservation measures for these threatened species.

Keywords: trophic ecology; habitat use; biochemical tracers; FA-CSIA; sharks

Local and oceanic inputs into the trophic ecology of two bivalve species in a coastal lagoon: evidences from stable isotope, fatty acid, and compound specific isotope analyses

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Coastal lagoon ecosystems play important ecological and economic roles, providing habitat to many resident and migratory species, and supporting fisheries of importance for local communities. At the interface between land and ocean, their productivity originates from both terrestrial and marine inputs, as well as from local processes. Suspension-feeding bivalves are major components of coastal lagoons and reflect, because of their feeding mode and sessile lifestyle, biogeochemical processes underlying ecosystem functioning. The Ojo de Liebre lagoon (Baja California, Mexico) is a 30 km long and 10 km wide lagoon facing the Southern California Current upwelling system. Although the lagoon lacks freshwater inputs owing to the arid climate, it supports one of the largest eelgrass (*Zostera marina*) beds in the Northeast Pacific. The trophic ecology of two bivalve species (*Nodipecten subnodosus* and *Spondylus crassiquama*) was studied seasonally and throughout their distribution range in the lagoon, using a multi-tracer approach combining stable isotope (SI), fatty acid (FA), and compound specific analyses (CSIA). The results highlighted seasonal and spatial patterns, with individuals from the entrance of the bay relying on ^{15}N-enriched oceanic phytoplankton, including diatoms (FA biomarkers 20:5n-3 and 16:1n-7) after the upwelling season, while those located the furthest from the entrance of the bay appeared to rely on local production (FA biomarkers 18:3n-3, 18:4n-3, 18:1n-9), including the microbial food web (bacteria, flagellates). Based on SI, FA and CSIA analysis, no significant contribution of seagrass detritus to the diet of bivalves was found. During summer, the contribution of benthic organic matter, originating from local processes, in the diet of individuals inside the bay; as well as the role of oceanic inputs near to the mouth of the bay, was confirmed by CSIA on diatoms and flagellates markers. Overall, our results illustrate the spatial and temporal heterogeneity affecting the trophic functioning of such large coastal lagoons, where both oceanic inputs and local processes play a key role. Moreover, this study highlights the complementarity of the three analytical tools, where SI were able to track nitrogen fluxes, while FA and CSIA were more powerful to characterize the nature and the origin of food sources.

What is the effect of lipid extraction methods and tissue dry storage on lipids classes and fatty acids from marine animals?

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Lipids are extensively studied in marine ecology but various protocols are currently used for lipid extraction and dry tissue storage. To assess these protocols and insure correct ecological conclusions, we compared lipid classes and fatty acids (FA) obtained from six lipid extraction protocols based on different extraction methods (pressurized automat *vs* manual potter *vs* leave solvent work on tissue) and tissue state (dry *vs* wet). These protocols were applied on seven marine animals, including lean and fat fishes, crustacean, cephalopod and shellfish. Differences among protocols were species and lipids dependant. For instance, the highest total lipid content of tuna and mussel tissues was obtained by laying the solvent to work on tissue overnight. Acetone-mobile polar lipids are best extracted from wet tissues in lean species such octopus and spiny lobster, while polar lipids are best extracted from dry tissues with the pressurized automat method in all species. No large differences in FA profile (i.e. express in percent) were however observed among methods. Overall, to leave the wet tissues into Folch mixture for 24 h was the best and simplest protocol for lipid extraction. We also compare three storage methods for dry tissues (-20°C freezer *vs* gas nitrogen *vs* dry room) after one and three months. Dry tissues can be store for one month at -20°C without degradation. Beyond one month, or using other storage modes, degradation occurs for polar and neutral lipids and poly-unsaturated FA.

Keywords: Fatty acids, Freeze-drying, Lipid classes, Protocols

Environmental effects on lipid metabolism in marine organisms and on trophic transfer

Daily cycles in oceanic fat concentrations reveal that phytoplankton use a 'crash diet' to maintain growth in the face of energy limitation

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Marine phytoplankton are a diverse group of photosynthetic microbes that drive carbon and energy fluxes in the ocean through biosynthesis of organic matter. On rapid timescales, the availability of sunlight is the primary control on phytoplankton biosynthetic activity because darkness effectively starves them of their primary external energy source. Their physiology has evolved to store energy captured from sunlight during the day to drive required biochemical processes during the dark. Diel cycles in phytoplankton gene expression patterns reveal widespread, coordinated pathways for internal biochemical energy allocation, yet the attendant changes in the biochemical composition of phytoplankton communities and the biogeochemical consequences of these changes for the ocean carbon cycle remain poorly elucidated. This is mainly because obtaining *in situ* metabolic measurements of sufficient resolution for even dominant microorganisms remains a considerable challenge. We performed Lagrangian diel sampling with measurements of primary productivity, lipid profiles and transcription over eight days in the North Pacific Subtropical Gyre (NPSG). The lipid data reveals that biosynthesis of energy-rich triacylglycerols (TAGs) by eukaryotic phytoplankton during the day and the subsequent consumption of TAGs at night drives a large and previously unrecognized daily carbon cycle. Oscillations in TAG concentration over the diel cycle in subtropical gyres comprise 23 ± 11% of daily net primary production by nanophytoplankton (2-20 μm size class), representing a global carbon flux of about 2.4 Pg C yr^{-1}. Metatranscriptome analyses of the plankton community indicate that eukaryotic haptophytes and dinoflagellates dominate the transcriptional patterns for two genes encoding key enzymes required for TAG biosynthesis. We estimate these two groups of organisms contain about 30% more calories at sunset than at sunrise, which make them favorable prey items and could help explain the observed vertical migration of zooplankton from depth to the surface to graze on phytoplankton at night.

Keywords: microbial oceanography; North Pacific Subtropical Gyre; marine lipidomics; oceanic carbon cycle

Unusually high levels of n-6 polyunsaturated fatty acids in giant tropical planktivores: dietary markers or physiological indicators?

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Planktivorous elasmobranchs, such as the whale shark *Rhincodon typus* and mobula rays *Mobula spp,,* are giant filter-feeders globally distributed in tropical and subtropical waters. These species can travel large distances and dive at great depths (up to 2000m deep). Yet, they have long been presumed to feed predominantly on near-surface tropical zooplankton. Using fatty acid (FA) analysis, we investigated the trophic ecology of these species on a global scale by contrasting their fatty acid profiles with those of tropical zooplankton, other sympatric pelagic taxa and other elasmobranchs. The FA profiles of all giant planktivorous elasmobranchs (muscle and connective tissue) were distinctively separate from other taxa (muscle tissue). Dissimilarities were mainly due to lower proportion of long-chain (LC, $>C_{20}$) n-3 polyunsaturated FA (LC-PUFA) and higher proportions of n-6 LC-PUFA in giant planktivores' tissues compared to other groups. Mobula rays had relatively high levels of docosahexaenoic acid (DHA, 22:6n-3; 10.6% of total FA) while whale sharks had low levels of both essential n-3 LC-PUFA - eicosapentaenoic acid (EPA, 20:5n-3; 1.8% of total FA) and DHA (4.1% of total FA). All species contained relatively high levels of arachidonic acid (ARA, 20:4n-6; 9.2 – 14.7% of total FA) in their tissues compared to all other groups. Such atypical profiles may indicate that giant planktivores feed on undetected food sources rich in n-6 PUFA that may include demersal, including coastal, or deep-sea prey. High proportions of n-6 LC-PUFA in these tissues could also indicate a FA allocation strategy in muscle and skin for specific ecophysiological functions that are linked with environmental conditions these species encounter (e.g. low O_2 concentration, high pressure, important temperature variation).

Keywords: planktivorous elasmobranch, n-3 fatty acids, n-6 fatty acids, arachidonic acid, tropical zooplankton

How nitrogen availability drives lipid composition in the haptophyte *Tisochrysis lutea* : new highlights

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Haptophytes are a diverse monophyletic group with a worldwide distribution, known to be significantly involved in global climate regulation. They produce alkenones used as biomarkers for the reconstruction of marine paleoclimatology, high amounts of long chain poly-unsaturated fatty (LC-PUFAs) acid of importance for health and some species accumulate large amounts of triacylglycérides (TAGs) for energy storage during nitrogen starvation. Because nitrogen is a major limiting macronutrient for phytoplankton in oceans and for cultures of microalgae, understanding the involvement of nitrogen availability in haptophyte lipid productions is of global and biotechnological importance. *Tisochrysis lutea* is traditionally grown for aquaculture feed. This specie have high PUFAs content (i.e. mainly docosahexanoic acid, DHA) as well as a high accumulation of TAGs during nitrogen starvation. Here, we tried to identify the molecular mechanisms that drive lipid composition and accumulation depending on nitrogen limitation. We made an ecophysiological study coupled with comprehensive large scale proteomic analysis to examine differences of behavior in reaction to nitrogen availability changes between a wild type strain of *T. lutea* (WT) and a mutant strain (2X) known to accumulate 2-fold more storage lipids during nitrogen starvation. In WT, 9 to 28% of the storage lipids were alkenones, whereas alkenones were very low (< 2% of SL) in 2X strain. Short changes of nitrogen availability triggered changes of lipid composition in 2X, with a correlation between TAG accumulation and membrane lipid degradation. No change of lipids composition was recorded in the WT strain suggesting a higher sensibility of the mutant strain to the changes of ecophysiological conditions. Deep proteomic analysis identified and compared the abundance of 4332 proteins, i.e. 25% of the genes. Results suggest that calcic signalization could be involved in the mediation of nitrogen changes. Storage lipid accumulation seems to be not the result of an activation of the lipid anabolism but looks favored by an overall reorganization of carbon partitioning in 2X cells that increases the metabolism of carbon and energy acquisition, decreases mitochondrial activity and decrease metabolic conversion of storage lipids to phosphoenolpyruvate. These results give new insights on the lipid metabolism of the model haptophyte *T. lutea*.

Keywords : Lipids ; Nitrogen ; Haptophyts ; Metabolism ; Proteomic.

Effects of temperature on lipid synthesis of diatom *Chaetoceros Pseudocurvisetus* and the Northern Adriatic plankton community

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We investigated the influence of rising temperature on lipid production by Northern Adriatic plankton community. To test how marine phytoplankton would respond to predicted increasing temperature we conducted monoculture batch experiments in laboratory on model diatom *Chaetoceros pseudocurvisetus* at five different temperatures from 10 to 30°C. We have chosen *Chaetoceros pseudocurvisetus* as a model culture since it is important component of NA phytoplankton community, but also *Chaetoceros* genus of diatoms is most abundant in wide range of marine ecosystems. We conducted annual sampling of the Northern Adriatic particulate matter that covers the same temperature range as for the batch experiments. Samples were taken during a year on a monthly basis. Lipid were characterized with thin–layer chromatography–flame ionization detection and electrospray ionization (ESI) MS and tandem mass spectrometry (MS/MS). Data are supported by particulate organic carbon (POC), chlorophyll a (Chl *a*) concentrations and phytoplankton taxonomy and cell abundances.

Keywords: lipids, temperature rise, diatom Chaetoceros Pseudocurvisetus, Northern Adriatic Sea

First evidence of the impact of nanoplastics in lipid composition of marine phytoplankton

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The potential increase of nanoplastics (NPs) concentration into aquatic environments represents a growing concern for their possible impact on aquatic organisms. However, today, very little is known about the impact of nano-sized plastics on marine organisms, especially on marine phytoplankton. The aim of this work was to identify, for the first time, the impact of small nanoplastics (50 nm) on the lipid class composition of a marine diatom, *Chaetoceros neogracile*. For this purpose, phytoplankton cultures were exposed for 4 days to two nanoplastics concentrations: a NP environmental relevant concentration equivalent to 0.05 µg ml^{-1} and a high NP concentration of 5µg ml^{-1}. Microalgae were exposed at two different moments of their growth cycle: during exponential and stationary growth phases. Results evidenced a stronger effect of NPs on *C. neogracile* at exponential phase than stationary phase. At exponential phase, a modification of the cell content of membrane and reserve lipid classes was observed after exposure of *C. neogracile* to both NP concentrations. A decrease of the quantity per cell of DGDG[i] (-64%), MGDG[ii] (-73%), PC[iii] (-52%), the sum of PE + PG + SQDG[iv] (-51%) and FST[v] (-48%) was observed after exposure to the high NP concentration. Conversely, an increase of 69% and 71% of FFA[vi] cell content was observed after exposure to both NP concentrations as well as a 78% increase of the TAG[vii] cell content, but only at low NP concentration. At stationary phase, only TAG and MGDG cell contents were affected by NP exposure showing a dose-response increase of 9 % and 35% for TAG and 24% and 45% for MGDG, after exposure to 0.05 and 5 µg ml^{-1} respectively. Altogether, these results evidenced that lipid class composition is a sensitive marker to evidence impact of NP exposure and highlighted that environmental relevant dose of such contaminant by impacting phytoplankton lipids may propagate at higher trophic levels

Keywords: Nanoplastics, phytoplankton, diatoms, lipid composition

[i] DGDG : Digalactosyl-diacylglycerol;
[ii] MGDG : Monogalactosyl-diacylglycerol
[iii] PC: phosphatidylcholine
[iv] PE+PG+SQDG : Phosphatidylethanolamine, phosphoglycerols and Sulfoquinovosyl-diacylglycerol
[v] FST: Free sterols
[vi] FFA: Free fatty acids
[vii] TAG: Triglycerides

Adaptation to phosphate starvation: a comparison between plants and two marine algae - *Phaeodactyllum tricornutum* and *Nannochloropsis oceanica*.

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Phosphate (Pi) starvation is a common situation in plant and algae due to the phosphate scarcity in soil and in ocean. Plant and algae cells have developed safety mechanisms circumventing this shortage, including decrease of their Pi consumption and mobilization of their Pi reserve. Phospholipids are a main form of cellular Pi reserve and their content markedly declines in cells during Pi starvation. In plant, at the cellular level, phospholipids from extraplastidial membrane are recycled into glycolipids. Glycolipids are synthesized in the chloroplast and will replace phospholipids in the chloroplast with a phosphatidylglycerol-to-sulfolipid exchange and outside the chloroplast with a phosphatidycholine-to-digalactosyldiacylglerol exchange. Algae are known to respond to environmental changes by an accumulation of triacylglycerol, but the relative changes occurring in membrane glycerolipids were not very well known. The lipid composition of extraplastidial membrane is different of higher plant with the presence of non-phosphorus glycerolipid called betaine lipid. To establish, the adaptation of marine algae lipid metabolism to Pi starvation, we have first defined the glycerolipidome of *Phaeodacylum tricornutum* and *Nannochloropsis oceanica*. We have shown that Pi deprivation induced a stepwise adaptive response. The timescale of phenotypic changes were consistent with an exhaustion of unknown primary Pi-storage molecules (possibly polyphosphate) and a transcriptional control of some genes coding for specific lipid synthesis enzymes. Phospholipids are then secondary Pi-storage molecules, broken down upon Pi deprivation, while non-phosphorous lipids are synthesized, consistently with a phosphatidylglycerol-to-sulfolipid and a phosphatidycholine-to betaine lipid exchange. In this presentation, we discuss the strategies to replace phospholipids in membranes in plants and algae, based on the presence or absence of betaine lipids.

Keywords: glycerolipid, lipid trafficking, oil droplet, phosphate starvation

Discerning dietary lipid sources and their ecophysiological fate in fish tissues

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Dietary energy is essential for growth, reproduction, and survival of organisms. In this talk, I will present current and upcoming methods and concepts about dietary energy sources and physiological implications for aquatic consumers and will focus on dietary carbon and lipids as energy sources for various organisms. Among lipids, some polyunsaturated fatty acids (PUFA) are considered essential for consumers, yet in certain aquatic ecosystems their dietary provision may be too low to meet the consumers' physiological demand. I will present how consumers along an altitudinal gradient of a subalpine stream networks utilize and rework lipids of allochthonous and autochthonous sources to possibly meet their physiological requirements. In our current research, we analyze fatty acids and compound-specific stable isotopes (CSSI) in leaf litter, periphyton, and macroinvertebrates, as well as in fish muscle tissues and organs (liver, gonads, brain, eyes). Our CSSI results indicate that macroinvertebrates preferably consume lipids of autochthonous sources (periphyton) and retain their long-chain PUFA eicosapentaenoic acid, whereas long-chain saturated fatty acids, used as indicators of allochthonous carbon sources, decrease in their concentrations with increasing trophic levels, and remain isotopically unaltered. Fishes, however, convert dietary PUFA to the highly unsaturated docosahexaenoic acid (DHA) in their liver and, based on lighter isotopic del13C values of DHA in fish brain and eyes than in fish liver, we suggest that neural fish tissues can further synthesize DHA from precursor PUFA. These results suggest that hepatocytic DHA production may not suffice neural DHA requirements in fishes. In general, dietary energy seems to get steadily reworked in consumers of aquatic food webs and even further in fish organs. This presentation will round up with some future implications and perspectives for nutritional aquatic ecology and more sustainable aquaculture.

Allelopathic exudates from the dinoflagellate *Alexandrium minutum* modify membrane lipids composition of the diatom *Chaetoceros* sp.

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Among the environmental factors structuring plankton communities, chemical interactions play an important role. Allelopathy refers to the adverse effects of chemicals (allelochemicals) released by a phytoplankton species on the physiology of co-occurring phytoplankton. Toxic dinoflagellates of the genus *Alexandrium* are known to exhibit allelopathic activity that may favor dense algal blooms. However, the physiological mechanisms of allelopathy remain poorly described. Previous studies highlighted that allelochemicals produced by *Alexandrium* are likely to interact with membranes of the target cells. However the precise effects on membranes are still unknown. Here we investigated the short-term effects (within one hour) of an allelopathic filtrate from *Alexandrium minutum* on the physiology of the common diatom *Chaetoceros* sp. Lipid classes and fatty acid composition of the diatom were analyzed in relation with other physiologic and biochemical parameters such as the photosynthetic yield, pigment composition, and cellular metabolism. Exposure to *A. minutum* filtrate resulted in an increase of intracellular reactive oxygen species (ROS), a decrease in esterase activity, and modifications in membrane composition (both lipids and pigments) within the first 30 min. Membrane lipid class proportions were modified, resulting in decreases of phosphatidylcholine (PC) and monogalactosyldiacylglycerol (MGDG) content in presence of allelochemicals. Changes in glycolipids were indicative of photosynthetic damages. In parallel, fatty acid compositions changed in presence of allelochemicals with a significant increase of membrane lipid unsaturation. While damages to the membranes may be linked to the decrease in esterase activity, saturation of membranes could be an attempt to maintain membrane integrity in response to increasing ROS. Further analyses are required to understand the specific impact of allelochemicals on membranes. Overall, this study also highlights the potential for allelopathic interactions to modulate membrane lipid composition of phytoplankton species with potential implications for the higher trophic levels.

Keywords – *Allelopathy; Alexandrium; Chaetoceros; Membranes; Toxicity*

Lipid load triggers migration to diapause in Arctic *Calanus* copepods – insights from underwater imaging

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Copepod lipids fuel the Arctic marine ecosystem, but information on the fine-scale distribution of copepods and lipids is nonexistent. This study investigated the fine-scale (1 m) vertical distribution of the copepods *Calanus hyperboreus*, *Calanus glacialis* and *Metridia longa* during a Lagrangian drift in the North Water Polynya using the Lightframe On-sight Keyspecies Investigation (LOKI) imaging system. A copepod species- and stage-specific automatic identification model based on machine learning, a subcategory of artificial intelligence, was used to identify images taken by LOKI. Lipids were measured from images of copepods taken over the whole water column (1m resolution). Diel vertical migration (DVM) in all three species was detected. In *C. hyperboreus* and *C. glacialis* C4-females as well as *M. longa* C5-females lipid load of deep copepod individuals was significantly higher than that of shallower individuals. Vertical distribution profiles and individual lipid loads suggested that individuals with lower lipid load continued DVM, while others with high lipid load ceased migrating, remaining at depth. *Calanus hyperboreus* individuals seemed to migrate to diapause at lower lipid fullness (50%) than *C. glacialis* (60%). A bioenergetics model showed that *Calanus* females had enough lipids to diapause for over a year, highlighting the significant lipid overhead they use for capital breeding.

Keywords: copepods; lipids; diapause; underwater imaging; Arctic Ocean

Lipid and fatty acid constituents state of the ecological important aquatic organisms from the Arctic and sub-Arctic marine ecosystems

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Lipids are fundamental and essential biochemical molecules in any organism. There are more than thousands diverse lipids in the metabolic network act as energy producers, main structural elements of biomembrane, as bioeffectors in cells to maintain the general state of the organism. Lipids and their fatty acids (FA) are participants in cell signaling, immune response, osmoregulation etc. FA as the components of lipid metabolism are the most sensitive, dynamic and significant in terms of adaptive reactions that take place on the level of macromolecules and cells. For aquatic organisms, poikilothermic ones, the relation between an organism and the environment is tight and complex. Hydrobionts adapt to changing environmental conditions through modification of biochemical structure and metabolic reactions. In these processes, lipids and FA play an important role – "biochemical adaptations" – especially for aquatic organisms inhabiting extreme and specific marine ecosystems of northern latitudes. We research seasonal dynamic of lipids and FA, as metabolic and trophic markers, of the key marine organisms of the White Sea that are connected by food relations: invertebrates, copepods, and vertebrates, fishes - slender eelblenny (*Lumpenus fabricii*), the White Sea herring (*Clupea pallasi marisalbi*) and three-spined stickleback (*Gasterosteus aculeatus*) in relation to certain ecological factors – temperature, salinity, food availability and quality. The results, in the line "zooplankton-fish", were compared to species of polar marine ecosystems - daubed shanny, *Leptoclinus maculatus*, and for species from freshwater ecosystems – young's of Salmonids. The evaluation of the lipid status was based on: total lipids, lipid classes (triacylglycerols, wax esters, cholesterol esters, and cholesterol), total and individual phospholipids, and FA. The research was carried out using the facilities of the Equipment Sharing Centre KarRC RAS. We used high-performance thin layer, thin layer, liquid and gas chromatography. As general as specific features of seasonal and annual FA dynamic in copepods and fishes under study were revealed. The multidirectional changes of certain phospholipids, storage lipids and their FA were reflected as functional role in the organism to maintain metabolic needs, as adaptational shift as response to environment. The results demonstrate the differences in the trophic and ecological (thermal) and hydrobiological (currencies) conditions of biotopes, physiological importance of lipids, and indicate the features of genetically determined processes of biosynthesis and modifications of certain lipids and FA. This research was made in the frame of KarRC RAS state assignment 0221-2017-0050 and supported by RFBR 17-04-00466, and the Russian Science Foundation 14-24-00102 (the research on Salmonids).

Keywords: zooplankton, fish, fatty acids, lipids, the North

Arachidonic acid in wild and cultured aquatic organisms in relation to adaptation to stress

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Arachidonic acid (ARA) tends to be higher in the phospholipid fraction in several tissues, including muscle, of some wild fish and shrimp compared to animals of the same specie bred in captivity. When ARA was supplied in higher levels in the feed to captive organisms, most ARA was stored as triglycerides (TG), and a very small fraction, if any, was incorporated to phospholipids (PL). This was so when the ARA offered in the feed was attached to PL or TG. ARA is freed from PL and used by cyclooxygenase (COX) isoenzymes to produce inflammation-inducing prostaglandins (PG), or by lypoxygenase (LOX) to produce leukotrienes. However, PG is also synthesized by non-enzymatic pathways, such as oxidation by reactive oxygen species (ROS) or oxidized lipids. In chronic stressed animals, COX activity/synthesis can be decreased, preventing PG increase. But when captive organisms are subjected to an acute stress, such as handling or air-exposure, there is an increase ROS production and increased PG levels in several tissues. A continuous production of PG in the absence of a pathological trigger can weaken and ultimately kill the animal; blocking enzymatic PG synthesis using nonsteroidal anti-inflammatory drugs (NSAID) that lodge into the active site of COX meant for ARA can decrease mortality of shrimp after an acute stress. Here, we theorize on the possibility that animals store ARA in TG over PL and that this provides them with an advantage during the event of an acute stress. In case of chronic stress, ARA can be transferred as needed to PL.

The role of lipids in early ontogeny of the daubed shanny *Leptoclinus maculatus* (Stichaeidae family) from Svalbard

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Leptoclinus maculatus is a circumpolar fish from Stichaeidae family and an ecologically important as intermediate link in the Arctic trophic food webs. Daubed shanny has complex life cycle with prolonged postlarval development (until 3-5 years). A unique feature of the fish is «lipid sac» in which the pelagic postlarvae store large amounts of triacylglycerols, as dominant lipid class. Lipid sac is used to maintain buoyancy as joint function. Juveniles are demersal like adults, have no lipid sac. Changes in the content of lipids and fatty acids (FA) components and their role during ontogeny of fishes in the Arctic ecosystems have been poorly reported. Lipid and FA spectrum of total and individual lipids (phospholipids, triacylglycerols) of muscles and lipid sac of *L. maculatus* from Kongsfjord in winter under extreme conditions was studied. The research was carried out using the Equipment Sharing Centre of KarRC RAS. The development of daubed shanny from pelagic postlarvae L1 stage to demersal juvenile L5 is accompanied by a significant increase in the level of triacylglycerols in the muscles. It was shown that the level of phospholipids (phosphatidylcholine and its lysophosphatidylcholine, sphingomyelin) increases in lipid sac in L4* stage, that may be related to the onset of resorption of the lipid sac. FA profile of lipids especially triacylglycerols reflects trophic relationship and physiological fitness of organism. The polyunsaturated 20:5n-3, 22:6n-3 FAs were dominant in muscles of daubed shanny due to their physical properties maintain phase of lipids in such severe conditions as low temperatures, starvation and change in mode of life from pelagic to bottom during development. Among monounsaturated FAs (MUFA) in hatched postlarvae 18:1n-9 FA is abundant due to feeding on phytoplankton while older stages have large amount of 20:1n-9 and 22:1n-11 FAs – biomarkers for zooplankton *Calanus*. Interesting, that certain 18:1n-9, 18:1n-7 and 16:1n-7 FAs dominated in muscles of adult *L. maculatus* show the feeding by benthos. The results of this study show significant role of MUFA as source of energy that can be used in a period of starvation; PUFA are essential for supporting of normal functioning of membranes in low temperatures. Changes of lipids in tissues during ontogeny reflects trophic relationship, physiological fitness of organism. Thus, the polar species has a special strategy of adaptation that provides normal development under the Arctic conditions. The research was made in the frame of the KarRC RAS state assignment № 0221-2017-0050 and supported by RFBR No. 17-04-00466.

Key words: fish, fatty acids, adaptations, development

Fatty Acids Composition of Zooplankton in Peruvian Upwelling Area

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Zooplankton is the main dietary component of anchovy and the fatty acids (FA) of zooplankton are a determinant factor of its food quality. Between Chicama (8 ° S) and Malabrigo (9 ° 10 ') an area of intense upwelling is located, in addition for reporting the largest anchoveta spawnings. For this reason, samplings were taken in that area to know the content of the FA and its variability associated with the environmental characteristics and to understand the dynamics of these lipids within the trophic web. Samples were collected by baby bongo net of 300µ mesh during August -September 2015 and March-April 2016. For that study, species more abundant were counted and separated. Temperature, salinity, oxygen and chlorophyll data were taken by CTD and water samples. Three FA groups were found: 3 saturated (SAFA), 3 monounsaturated (MUFA) and 7 polyunsaturated (PUFA). The PUFAs represented between 3.1 and 76.4% of the total, followed by the SAFA (19-75%) and the MUFA (6.2-26%). Within the PUFAs, the DHA and EPA acids displayed a higher concentration; however, they were low in March-April 2016. Likewise, palmitic (16:00) and palminoleic (16:1nω7) acids showed significant concentrations. Copepod *Calanus chilensis* and euphausiids *Euphausia mucronata* and *Nyctiphanes simplex* displayed high concentrations of DHA and EPA. During the sampling period, the environment presented strong El Niño conditions that could have impacted on the dynamics of fatty acids of zooplankton.

Keywords: Fatty acids, Upwelling area, Zooplankton.

Lipid dynamics and ecophysiology of a marine protist (Auriantiochytrium limacinum) involved in the decomposition of mangrove leaves.

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Microbial decomposition of mangrove leaves is strongly dependent on the availability of nitrogen relative to carbon, and largely relies on Thraustochytrids such as Auranthiochytrium limacinum. Auranthiochytrium limacinum is a heterotroph marine protist belonging to the Stramenopile group (secondary endosymbiosis). This microalga displays a complex life cycle with mononucleated, multinucleated and flagellated (zoospores) cells, this last stage being important to colonise new areas. A. limacinum may also accumulate large amount of triacyglycerols (TAGs) containing mostly ω3 fatty acids (DHA ≥ 50%), and is therefore an attractive target for biotechnological exploitations. Using various media aimed to mimic mangrove environments such as a decomposing fallen leaf or open sea, we aimed to understand the ecological parameters that trigger zoospore production and TAG accumulation. In a rich medium representing the proximity of a decaying leaf, cells divided rapidly then accumulated large amount of TAGs when nitrogen became limiting. At the end of the growth period, more than 90% of lipids were TAGs and cells were mainly multinucleated, but no zoospore was produced. Once released in sea water, zoospores were massively produced from the multinucleated cells. Zoospores could swim for at least 6 days consuming their TAGs in the process, which illustrates the physiological role of these lipids. When they encounter a source of organic carbon (mimicked by the addition of glucose) they mature into mononucleated then, if the N:C ratio is adequate, rapidly divide consuming the rest of their TAGs to start a new life cycle. On the basis of these data, we propose a scheme representing the in situ life cycle of A. limacinum that integrates the potential perturbations/changes surrounding a mangrove leaf and leading to TAG accumulation, production of zoospores and colonization of new areas.

Keywords: glycerolipids, lipid dynamics, ecophysiology, Thraustochytrids

Marine lipids, human health and ecosystem services - Lipids in emerging biotechnology and blue economy

Fatty acid profile and biochemical composition of *Odontella aurita* (Lyngbye) C. Agardh (Bacillaryophyta) from the Gulf of California, Mexico.

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Microalgae are organisms widely distributed in different habitats; are responsible for 40–50% of the photosynthesis and contribute with the global primary productivity in aquatic ecosystems. Diatoms importance in aquaculture as a food for aquaculture as food for larvae of mollusk, crustaceans and fishes due to their fatty acid content (EPA, eicosapentaenoic acid, ω3). Some diatoms belong to the category of "*organisms generally recognized as safe"* (GRAS status), and can be used for human nutrition. Up to today, the global demand for ω3 fatty acids has significantly increased year by year, but there is also a concern about proper management to achieve a sustainable exploitation of the major source of fish oils, which are being depleted. Microalgae are postulated as a natural source of PUFAs ω3, and also can be cultured and grown in a wide variety of conditions. The objective of the work was to isolate, identify, cultivate and carry out biochemical characterization of the *Odontella aurita* biomass. This diatom was collected from La Ribera, Baja California Sur, Mexico. It was identified by compound microscope with contrast phase optics, scanning electron microscopy, and confirmed by phylogenetic analysis (18S and RbcL genes; Neighbor-Joining, 1000 bootstrap replicates). The cultures were performed outdoor. Columns were inoculated with the 15% of inoculum volume and growing during 10 days. HOBOs sensors were introduced inside the culture to measure the temperature and light intensity. The maximum temperature was 30°C and minimum of 18°C. While maximum irradiance was 123, and minimum 3 µmol photon m^{-2} s^{-1}. The growth rate was 0.162 d^{-1} with a yield at 1.7 g L^{-1}. The highest content of proteins (23±3%), lipids (38±2.8%), ash (45±4.2%), chlorophyll *a* (13.2±2.3 µg mL^{-1}), chlorophyll *c* (12.94±3.1 µg mL^{-1}), and fucoxanthin (5.5±1.2 µg mL^{-1}) were at day 6 without significant differences among days. Carbohydrates increased at day 10 with the value of 26.6±6). The fatty acids profile were constituted mostly by saturated (57.7%). HUFA were represented by a maximum of EPA at 20% of total fatty acids at day 4. The 3:1 ω3:ω6 ratio makes it a viable candidate to be used as a dietary and therapeutic complement, also because of its EPA content (11.22 µm mg^{-1}). EPA is a precursor of eicosaenoids that regulate anti-inflammatory and cardiovascular processes. Moreover, the antioxidant properties of fucoxanthin, and the GRAS status enhancing food with *O. aurita* engineered to produce functional ingredients.

Keywords: Diatom, EPA, GRAS, scaning electron microscopy, phylogenetic analysis.

Health starts in the plate: Screening of microalgal strains with high potential in polyunsaturated fatty acid (PUFA) production.

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Over the past few decades, extensive research has been conducted concerning properties of fish oils and marine products in human health, especially the anti-inflammatory, cardioprotective and anti-neurodegenerative disorders activities. Most of those activities of fish oils were attributed to the ω3 polyunsaturated fatty acids (PUFA), mainly due to the presence of eicosapentaenoic acid (EPA, 20: 5n-3) and docosahexaenoic acid (DHA, 22: 6n-3). Microalgae form the basis of food chain of fishes and shellfishes and are the origin of these PUFAs. They are the principal indicators of the nutritive quality of fish for humans, for example. Currently, several nutritional studies suggest that the bioavailability of these PUFAs is higher when they are linked to polar lipids. Those molecules could be interesting to increase nutritional content in food. To increase the nutritional quality of microalgae, one of the solutions is to select strains rich in PUFA. To explore the inter specific and intra specific diversity of microalgae, it looks promising to develop medium and high throughput screening process with high control of ecophysiological conditions of cultures. Our laboratory implemented a set of automated and instrumented photobioreactors allowing the cross analysis of 24 cultures grown in totally identical conditions. To explore diversity in our culture collection, fifteen strains of the species Tisochrysis lutea (Tiso), commonly used in aquaculture with its recognized food quality, were chosen. Those strains were isolated from cold and hot water environments around the globe. Screening was performed to select candidates rich in PUFA, especially DHA, linked to polar lipids. After extraction, lipid crude extracts were analyzed by GC-FID and HPTLC to obtain fatty acid profiles and lipid classes, respectively. They were then compared to select the more interesting strains. This approach quickly characterize strains and we can select those which are richer in PUFA and thus to bring new interesting candidates in animal and human nutrition.

Keywords: Microalgae; PUFA; DHA; Polar lipids; Screening.

Variation of prostaglandin metabolism along the growth of the diatom *Thalassiosira rotula*

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Marine diatoms are a vast and diverse group of marine phytoplanktonic organisms. They are able to produce a great variety of biomolecules, some of which are involved in the primary metabolism, while others are devoted to chemical defence and to counteract external stress conditions. Previous studies of our group revealed, for the first time in marine phytoplanktonic diatoms, the occurrence of lipid-derived bioactive compounds, collectively named oxylipins, capable of inducing birth defect and high mortality in the offspring of copepods, their principal consumers. More recently, we also demonstrated the presence, in the centric diatom specie *Skeletonema marinoi*, of other bioactive lipid mediators, well known in higher organisms, but never identified before in unicellular organisms: the prostaglandins (PGs). Prostaglandins are hormone-like mediators in many physiological and pathological processes in mammals, playing a pivotal role in inflammatory responses. They are also present in some macroalgae and invertebrates, where they act as defence and communication mediators. Intriguingly, PGs types and amount were different in the two clones of the same *Skeletonema* specie analysed. Here we report on the presence of PGs and their metabolites also in another centric diatom, namely *Thalassiosira rotula*. We showed the occurrence of a modulation of the PGs pathway expression along the growth, with a progressive decrease of the expression level of all the enzymes involved in the pathway and a corresponding decrease in PGE2 concentration released in the medium.

Keywords: lipid mediators: prostaglandins; diatoms; gene expression.

Enzymatic synthesis of structured phospholipids rich in docosahexaenoic acid

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Marine microalgae are well-known for their ability to produce omega-3 long chain polyunsaturated fatty acids (PUFAs) such as docosahexaenoic acid (DHA). Among these microalgae, *Tisochrysis lutea* has received increasing interest. Therefore, lipids from *T. lutea* can be used for the enzyme catalyzed production of structured phospholipids containing one DHA and one medium chain fatty acid in order to combine interesting therapeutic and biological benefits. The enzymatic synthesis of structured phospholipids enriched in docosahexaenoic acid (DHA) and caprylic acid (PC DHA-C8) is studied. Two different ways are studied, acidolysis and esterification. An enzymatic screening led to the choice of the immobilized lipase from *Thermomyces lanuginosa* (TL-IM) for the 2 reactions. Parameters of the acidolysis reaction between caprylic acid (C8:0) and sunflower phosphatidylcholine (PC) were optimized by means of an experimental design. The optimum conditions determined are a temperature of 38°C, an a_w of 0.7, an amount of enzyme of 15% of the mass of substrate and a molar ratio of C8:0/PC of 18. These conditions were applied to the acidolysis of microalgal phospholipids from *T. lutea,* rich in DHA, in order to produce PC DHA-C8. The other studied reaction is the lipase catalyzed esterification of GPC with C8:0 and DHA in a solvent-free medium. This reaction has been optimized by studying each factor independently. The parameters studied are the temperature, the amount of lipase, the molar ratio GPC/C8:0/DHA and the use of reduced pressure. In order to obtain PC DHA-C8, each of these parameters are respectively set at: 45°C, 20% of enzyme, a molar ratio of 1/3/15 and a pressure of 100 mbar. The production of PC DHA-C8 has been optimized. However, during this experiment, a higher production of lysophosphatidylcholine rich in DHA is observed.

Keywords: Acidolysis, Esterification, Lipases, Docosahexaenoic acid, Structured phospholipids

Benefits and risks of seafood consumption in Peru: quantitative analysis of fatty acid and micro-contaminant intake

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Seafood consumption is associated with both beneficial and risks effects to human health. Omega-3 fatty acids (PUFAs) which improve mental development and cognition, and reduce the risk of cardiovascular disease, are found in high concentrations in marine organisms, but they also contain persistent contaminants that have accumulated. We therefore assessed concentrations of PUFAs (EPA + DHA) and metal contaminants (Mn, Fe, Cu, Ni, Zn, As, Cd, Pb) in 13 potentially edible species from Peru. Mantis shrimp (*Squilla* sp.) and octopus (*Octopus mimus)* were the species with the highest PUFA concentrations (182.8 and 158.2 mg/100g wwt respectively), which are comparable and in some cases higher than in commercial fish species (i.e. cod, hake, whiting). Nevertheless, *Squilla* sp. exhibited also the highest concentration of Cd which was 5.2 µg/g wwt. We simulated four exposure scenarios resulting from consumption of the above species, to assess the benefits of PUFA intake and the risks of metal exposure for seafood consumers. The first two exposure scenarios evaluate PUFA and metal intake when consuming species with low (a) and high (b) metal concentrations and a fixed ingestion rate. The latter two scenarios evaluate PUFA intake combined with low (c) and high (d) metal exposure, which is calculated based on the actual metal intake per species, i.e. by combining the metal content and estimated ingestion rate (FAO, 2018) per seafood species. Scenario (c) was found optimal for seafood consumption, providing nutritious PUFAs levels (~350 mg/day) and reduce the metal uptake to <0.61 and <0.31 ug/kg bw/day wwt. for inorganic As and Cd, respectively. In scenario (d) conversely, the PUFA' intake was less than half and the uptake of metals about 6-fold much higher than in (c) (4.11 and 1.80 ug/kg bw/day wwt respectively for inorganic-As and Cd). Scenarios (a) and (b) led to low PUFA (< 140 mg/ day) and high inorganic-As uptake (up to 4.74 ug/kg bw/day wwt) and where thus not suitable for human seafood consumption. Therefore, it is strategic to combine the most safe species (*Argopecten purpuratus*, *O. mimus*, *Romaleon sestosum*, *Pagurus* sp) at different ingestion rates to maximize the uptake of beneficial EPA and DHA. Nevertheless, the provisional tolerance daily intake (PTDI) and RfD must be considered for each metal intake, as well as other toxic persistent organic contaminants that accumulated in seafood. In conclusion, fatty acid profiling in combination with the analysis of micro-contaminants allowed to get insight in the quality of seafood.

Keywords: Seafood consumption, omega-3 fatty acids, metals, Peruvian populations

Comparative effects of the marine microalgae *Phaeodactylum tricornutum* and *Diacronema lutheri* on metabolic disorders associated with metabolic syndrome and obesity in the Wistar rat

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Cardiovascular disease (CVD) is the first cause of mortality in the world and is a public health major problem. CVD is a consequence of metabolic syndrome (MS) associated with obesity development. Omega-3 long chain polyunsaturated fatty acids (ω3 LC-PUFAs) from fish oils have been recognized for their preventive effects against CVD. In an unfavourable economic and environmental context of fish oil production, marine microalgae could be an alternative source of ω3 LC-PUFAs and have an interest for human nutrition. Therefore, the aim of this study was to compare the effects of *P. tricornutu*m, a microalga rich in EPA (eicosapentaenoic acid, 20:5ω3) and *D. lutheri,* which contains both EPA and DHA (docosahexaenoic acid, 22:6ω3), used as a dietary supplement at the dose of 12%, on metabolic disorders associated to MS and obesity in the Wistar rat.

Four male Wistar rats groups (n=8) were submitted for 8 weeks to a standard diet (CTROL) or high fat diet (HF) with 10% fructose in drinking water, supplemented or not with 12% of *P. tricornutum* (HF+P) or *D. lutheri* (HF+D). Nutritional monitoring was performed daily. Insulin tolerance test (ITT) and glucose tolerance test (GTT) were performed during the 8th week of diet. *Ex vivo*, plasma lipid parameters and liver glutathione antioxidant activity (GPx) were determined with enzymatic tests. Plasma levels of leptin, insulin, pro- and anti-inflammatory cytokines were quantified by ELISA tests.

After 8 weeks of treatment, results showed a body weight loss in HF+P and HF+D rats compared to HF group despite a food consumption similar to HF group. A basal restoration of triglyceridemia, leptinemia, anti-inflammatory cytokines levels in plasma and adipose tissue was observed in HF+P and HF+D rats. Moreover, HOMA-IR (Homeostasis Model Assessment of Insuline Resistance) and AIP (Atherogenic Index of Plasma) were re-established in HF+P and HF+D rats and revealed an insulin-resistance and CVD prevention. Liver GPx activity and plasma levels of HDL-cholesterol increased with a supplementation of *P. tricornutum* and *D. lutheri* associated to an improvement of insulinemia and glucose homeostasis. Whereas cholesterol, pro-inflammatory cytokines plasma levels were restored in HF+P rats, they increased with *D. lutheri* compared to others groups. At the opposite, insulin sensitivity was similar between HF+D and CTROL groups and was higher in HF+P group.

To conclude, this study highlighted the beneficial effects of both microalgae in the prevention of MS and obesity with greater efficiency for *P. tricornutum,* as a dietary supplement compared to *D. lutheri*.

Keywords: microalgae, omega-3 fatty acids, metabolic syndrome, insulin resistance, inflammation

A journey through signature lipid profiling to marine and plant biotechnology

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Our research team at CSIRO has developed and applied signature lipid methodologies to a range of food web and environmental studies, with overlap occurring in marine biotechnology, the latter married to plant biotechnology. The origins were in the RB Johns and DC White laboratories at Melbourne University and Florida State University and covered a forty year journey. These approaches were used to gain insights into microbial communities and in the marine food web, not obtainable by classical approaches. Selected examples included: use of a specific dimethyl disulphide (DMDS) derivatization procedure with monounsaturated fatty acids (MUFA) to precisely determine double bond position and geometry; application of the DMDS procedure in taxonomic and environmental studies including the degradation of pollutant halogenated hydrocarbons in groundwater and subsurface aquifers; development of rapid and non-destructive approaches such as FT-IR to follow biofilm formation in a manner not possible with other approaches, and signature sterol applications to trace and distinguish various forms of fecal inputs. The foundations laid were applied in applications in microbial ecology, marine food chain and biotechnology research, the latter with an emphasis on omega-3 long-chain (LC, $\geq C_{20}$) polyunsaturated fatty acids (LC-PUFA, also termed LC omega-3).

In addition to their role in the marine food web, the omega-3 LC-PUFA - EPA (eicosapentaenoic acid, 20:5ω3) and DHA (docosahexaenoic acid, 22:6 ω 3) - have key roles in marine species and also in human health and development. Numerous studies have shown that deficiencies in these key fatty acids can increase the risk or severity of cardiovascular and inflammatory diseases in particular. These health-benefitting fatty acids are largely sourced from marine (fish and krill) and to a lesser extent algal oils. To meet the increasing demand for the LC omega-3 oils, particularly in aquaculture and a range of human health applications, there is a recognized real and urgent need for new and sustainable sources of EPA and DHA. In the case of aquaculture, the markedly changed diets presently used see many farmed seafood products containing more omega-6 than omega-3 oil. In the search for new sources of LC omega-3, a CSIRO-wide team was formed and over a 20 year period of discovery and development has initiated then transitioned DHA production in seed from the model species *Arabidopsis* through to *Camelina*, *Brassica juncea* and the target crop *Brassica napus* (canola). A commercial partner – Nuseed-Global joined the project in 2010. DHA levels that exceed the amount typically found in bulk fish oil have been achieved in all these plant species. The project has included gene selection, development of transgenic plants, and enhancing seed oil profiles, and assessment of the characteristics of this new oil in the context of potential applications. The training of young scientists has been included within the various signature lipid and biotechnology activities, and also ensures that unique approaches and the quest for new and or novel methodologies for use in environmental, food web and biotechnology R&D will continue.

Selective extraction of bioactive lipids from seaweeds

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The lipid composition of seaweeds is commonly studied for its content of polyunsaturated fatty acids but the total lipid content is poorly examined, maybe due to the complexity of this fraction. Lipidome includes various types of lipids like triglycerides, sterols, phospholipids, glycolipids among others. These lipid classes contain promising bioactive molecules. Glycolipids displayed anti-inflammatory, antimicrobial or anti-proliferative activities. Phospholipids are known to be key components of lipid bilayer membranes and to exhibit nutritional benefits related to the essential polyunsaturated fatty acids. Activities of neutral lipids have been reported on cardiovascular diseases and obesity. General procedures for lipid extraction correspond to solid/liquid methods and employ organic solvents. New eco- and biocompatible methods can be used to extract lipids like supercritical carbon dioxide (sc-CO_2). sc-CO_2 allows a faster and deeper penetration into the seaweed particles, and lead to a non-toxic extract. The main limitation of sc-CO_2 is its application to the extraction of polar compounds. However, an addition of biocompatible polar solvent such as ethanol can improve the extraction efficiency or enlarge the molecular diversity of extracted molecules. In this study, the lipid fractions of *Solieria chordalis* (C. Agardh) J. Agardh, a red seaweed, and *Sargassum muticum* (Yendo) Fensholt, a brown seaweed, are produced according to different procedures and the lipid compositions (total lipids, glycolipids, phospholipids, sterols, fatty acids, unsaponifiable fraction) are determined. The comparison between the use of organic solvents, sc-CO_2 and sc-CO_2 supplemented with co-solvent is performed to compare the lipid extraction yields and the selectivity of the procedures. *Solieria chordalis* and *Sargassum muticum* exhibit low total lipid content around 3% dry weight by using solvent extraction. However further analysis reveal diversity in lipid class distribution. *S. muticum* contains mostly glycolipids (69%) whereas equivalent amounts of neutral lipids (37%) and glycolipids (38%) were detected in *S. chordalis*. The sc-CO_2 extractions lead to lower extraction yields and to a drastic change in lipid class distribution for *S. chordalis*. With sc-CO_2 (without co-solvent), glycolipids compose the main fraction (60%) of the extracted lipids, while neutral lipids and phospholipids are in the same proportion around 20%. When ethanol is added, the neutral lipid class is the main fraction (more than 50%) and phospholipid is the lowest one (10%). Extract free-radical scavenging activities demonstrate also a variability according to the method used to obtain fractions. These results highlighted the relationships between the extraction process and the lipid class distribution.

Keywords: supercritical carbon dioxide; lipid classes; free-radical scavenging.

Seaweeds lipids in health-promotion: Lipidomics holding with lipid diversity

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Seaweeds are important marine organisms that produce natural compounds such as lipids with recognized biological activities. Lipids from seaweeds have nutritional value, in particular polyunsaturated fatty acid (PUFA). Polar lipids from seaweeds, glycoglycerolipids (GLs) and phospholipids (PLs), are the main carriers of the omega-3 and omega-6 PUFA being important for nutrition and some display bioactive properties, namely as antibacterial, anti-inflammatory, and antitumor effects with interest for human health and pharmaceutical and biotechnological utilization. Their bioactivities are related to their structural features, such as the polar head and the acyl chain composition, which varies according to phyla.
The mass spectrometry-based lipidomics combining LC-MS and MS-MS analytical tools has been used to identify the lipidomic signature of seaweeds produced under a land based integrated aquaculture framework, namely *Codium tomentosum*, *Porphyra dioica*, *Gracilaria* sp., and *Fucus vesiculosus*. Among these, some GLs were identified and previously reported as bioactive molecules. In addition, lipid extracts from *Gracilaria* sp. showed anti-inflammatory and antiproliferative properties.
This presentation offers our current knowledge of lipid biochemistry in seaweeds and a survey of lipidomic-based strategies for analysis and screening of seaweeds´ lipids with potential benefits for health-promotion.

Keywords: Lipidome; glycolipids; phospholipids; mass spectrometry; bioactive compounds

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Structure, metabolism and function of lipids

Structure and Dynamics of a unique tethered fluid lipid membrane. An experimental approach to shed some light on the interactions between a lipid bilayer and a colloid.

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In order to study the dynamics of colloids and nanoparticles in the vicinity or contact with lipid membranes, we developed a new experimental approach where a single model phospholipid bilayer is kept fluid and partially tethered to a flat electrode, and where model colloids are individually tracked in 4D (space and time) as they diffuse towards a membrane.

To achieve such experiments, we first had to self-assemble a single tethered lipid bilayer at a perfectly flat solid interface. We proposed an original anchoring surface functionalization that is highly reactive to –OH terminated molecules. In this way we avoided complex organic chemistry and grafted commercial Brij non-ionic surfactants chosen for: i) their appropriate hydrophilic chain length that forms an aqueous cushion for the membrane; ii) their hydrophobic alkyl block that anchors the lipid bilayers by insertion in their core, acting like a harpoon. In this way we kept the membrane fluidity in full immersion and presence of salts. This method appears to be a simple and cheap way to prepare supported membranes with tuneable anchoring densities on various supporting materials.

Using transparent electrodes (ultra-flat and thin metal layers on glass), we could check the membrane fluidity and lipids dynamics from fluorescence techniques (such as *in-situ* FRAP for measuring the lateral diffusion of inserted fluorescent lipids). The transparent electrodes are also designed for high resolution structure investigation of the single membrane using x-ray, neutron and light scattering methods (microscopies, Surface plasmon resonance, fluorescence).

On such membrane biochip we can explore the Brownian motion of colloids near the membrane using 3D digital video microscopy and reconstruction of single colloids trajectories in 3D over time. Satisfying agreements between data and published theoretical models were found for the simplest interface cases. In addition, we proposed a theoretical approach able to transit from the free interface configuration (water-air undulations) to a rigid interface (bound condition water-glass). From the stabilization of phospholipid model bilayer, we also studied the colloidal and hydrodynamic interactions with a soft fluid (DOPC) or gel phase (DMPC) membrane. Our goal is now to track individual interactions and possible translocation of a microplastic pollutant and a model marine membrane.

Keywords: phospholipid membranes, biosensors, dynamics of colloids and nanoparticles.

Elucidation of aminolipids biosynthesis in marine bacteria and their role in lipid remodelling

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Marine microorganisms employ multiple strategies to cope with transient and persistent nutrient limitation, one of which, for alleviating phosphorus (P) stress, is to substitute membrane glycerophospholipids with non-P containing surrogate lipids. Such a membrane lipid remodelling strategy enables marine phytoplankton and heterotrophic bacteria to adapt successfully to nutrient scarcity in marine surface waters. An important group of non-P lipids, the aminolipids which lack a diacylglycerol backbone are poorly studied in marine microbes. Here, using a combination of genetic, lipidomics and metagenomics approaches, we reveal, for the first time, the genes required for the formation of the glutamine-containing aminolipid. Construction of a knockout mutant in *glsB* in a model marine bacterium completely abolished glutamine lipid production. Moreover, the mutant showed a considerable growth cost under P-deplete conditions and the mutant which is unable to produce aminolipids ceased to grow under P-deplete conditions. Analysis of sequenced microbial genomes show that *glsB* is primarily confined to the *Rhodobacteraceae* family, which includes the ecologically important marine Roseobacter clade that are key players in the marine sulphur and nitrogen cycles. Analysis of the genes involved in glutamine lipid biosynthesis in the Tara ocean metagenome dataset revealed the global occurrence of *glsB* in marine surface waters and a positive correlation between *glsB* abundance and N* (a measure of the deviation from the canonical Redfield ratio), suggesting glutamine lipid plays an important role in the adaptation of marine *Rhodobacteraceae* to P limitation.

Keywords: aminolipids, marine bacteria, lipid remodelling

Characterization and quantification of isoprostanoids from three microalgae species produced at 5 000 L scale

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By their diversity, microalgae are one of the greatest potential natural sources of active molecules. These autotrophic microorganisms are capable of synthesizing a wide range of fatty acids (FA), up to long chain PUFAs whose profile is specific to each species. Otherwise, it is well recognized that PUFAs are highly reactive species prone to oxidation, due to the presence of numerous bis-allylic systems present in their backbone. Oxidative stress (OS) is the main biological imbalance responsible for PUFAs peroxidation and in plants might come from several environmental factors (e.g. dryness, pollution or thermic stress). In the case of the excessive formation of Reactive Oxygen Species (ROS), those ROS degrades the PUFA following radical chemistry rules leading to isoprostanes/isofurans (from EPA/ AA), neuroprostanes/neurofurans (from DHA), and to phytoprostanes/phytofurans (from ALA) which are called isoprostanoids. Isoprostanoids not only serve as markers of oxidative damage in plants or animals but also exhibit a wide range of bioactivities (e.g. anti-inflammatory, neuroprotective, anti-arrhythmic) by acting as lipid mediators. In addition, isoprostanoids have emerged as indicators of OS in humans (biomarkers of diseases or dysfunctions) and their environment. If the formation of isoprostanoids in macroalgae is described, to the best of our knowledge, nothing is known in microalgae. However, it can be assumed that non-enzymatic oxygenated metabolites of PUFAs may be present in such species. The first aim of our study was to assess the assumption by analyzing the isoprostanoid content of three microalgal biomasses. *Phaeodactylum tricornutum*, *Porphyridium cruentum* and *Tisochrysis lutea* were produced in Microphyt's photobioreactors Camargue© at 5 000 L scale. These species have been chosen due to their specific FA profile. Indeed, they accumulate mainly eicosapentaenoic acid (EPA), arachidonic acid (AA) and docosahexaenoic acid (DHA) respectively. The second objective of this study, in connection with the first, was to develop a methodology for the measurement of these isoprostanoids from algal matrix extraction to LC-MS-MRM methodology. This talk will explore an overview of research in the field of isoprostanoids from a chemical to biological point of view, from our experiments and from the literature. We will also present our most recent results about microalgae.

Keywords: PUFAs; oxidative stress; biomarkers; lipid mediator

Use of FIB-SEM tomography to unravel the membrane architecture and organelle interactions of the diatom *Phaeodactylum tricornutum*

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Phytoplankton comprises photosynthetic organisms (microalgae and cyanobacteria) living in suspension in water (freshwater and oceans). Phytoplankton store energy through the process of photosynthesis and contribute to about half of the atmospheric oxygen release and are promising organisms for biotechnological applications (food, feed and biofuel). Phytoplankton responses to the environment are poorly understood, partly because of the lack of well-established imaging approaches. We have used cell-imaging techniques to unravel the membrane architecture and organelle interactions of the diatom *Phaeodactylum tricornutum* known for its high photosynthetic performances. FIB-SEM (Focused Ion Beam-Scanning Electron Microscopy), which was developed for material science and recently applied to biological samples, was used in this study. FIB-SEM is a state-of-the-art advanced scanning electron microscope integrated with high-resolution focused ion beam milling that enables photographic, chemical, and structural analysis of many inorganic and organic samples. Among different features FIB-SEM allows 3D tomography with nanometer-scale resolution thus becoming an instrument of choice for obtaining 3D information at the electron microscopy (EM) level. We obtained high definition cellular structures, with a particular focus on organelles. Analysis of 4 nm ultrathin sections of disrupted *Phaeodactylum tricornutum* allowed for the detection of membrane connectivity in the three dimensions and thus the ultrastructure scanning of single organelles (chloroplast, mitochondrion or nucleus). Images processing and 3D modelling allowed revealing specific organelle interactions via membrane contact points. Contact points between the chloroplast and mitochondria could facilitate energetic exchanges for optimum CO2 assimilation and contacts between the nucleus inner membrane and the periplastidial membrane of the chloroplast likely facilitates exchanges between these two organelles. Reconstruction of the three-dimensional architecture of the chloroplast in *Phaeodactylum tricornutum* allows proposing a structural model for the arrangement of photosynthetic complexes in this chloroplast. This model challenges the classic view of the organization of the photosynthetic membranes in chloroplasts derived from a secondary endosymbiosis, and accounts for partitioning of absorbed light between the photosystems, without restraining electron flow capacity, as required for optimum photosynthesis.

Keywords: Phaeodactylum tricornutum; FIB-SEM tomography; membrane architecture; organelle interaction

Evolution of synthesis of specialized and unusual lipids in toothed whales, and their roles in echolocation

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The toothed whales (Odontocetes) have evolved some exceptionally unusual lipids for echolocation and hearing. All toothed whales possess specialized cranial adipose tissues, termed the "acoustic fat bodies": the fatty "melon" in the forehead region, and the fat bodies that sit in and around the lower jaws ("mandibular fats") which are directly connected to the earbones – these serve to transmit and receive sound, respectively. The acoustic fats contain a suite of entirely endogenous lipids that have complex, heterogeneous distributions, and are not seen in the adipose of other mammals. The acoustic fats contain high amounts of wax esters (up to 90% of total lipids), and branched-chain fatty acids (BCFA) and alcohols that are derived from branched-chain amino acids (BCAA) – here, the normal mammalian pathways of BCAA degradation have been modified to yield unusual, short, BCFA. Within the fat bodies, the waxes and branched-chain elements are found in higher concentrations in the centre of the tissue, with more triacylglycerols and longer chain acids and alcohols in the peripheral tissue. Since the waxes and shorter BCFA cause decreases in sound speed, functionally this serves very effectively to collimate (focus) sounds. Sound waves travel slowly through the centre of the fat bodies compared to the more rapid speed through the outer shell, forming a narrow beam of outgoing high-frequency sound from the melon, and similarly focusing the incoming sound in the mandibular fats directly to the earbones. Interestingly, different toothed whales use different BCAA $\rightarrow$ BCFA conversions; these patterns are phylogenetically linked. Beaked whales have high levels (20-40 mol%) of isolauric acid (*i*-12:0), while in contrast dolphins and porpoises have high levels (50-95 mol %) of isovaleric acid (*i*-5:0) in their acoustic fat bodies. These have different origins: *i*-12:0 (and even-numbered BCFA) are formed from valine, and *i*-5:0 (and odd-numbered BCFA) come from leucine metabolism. Despite these large differences in BCFA, almost all Odontocetes possess some amount of isopalmitic (*i*-16:0; of valine origin) alcohol in their wax esters, suggesting that valine BCAA-BCFA conversion is conserved in all species, but that a different pathway arose in dolphins and porpoises. In addition, the acoustic fats develop ontogenetically, reaching the adult conformation around the end of the maternal care period. This leads to many questions involving gene regulation/loss, the arrangements of waxes and BCFA within acoustic fat adipocytes, control of BCAA and wax ester metabolism during growth, and how these tissues behave in a diving, echolocating animal.

Keywords: branched-chain fatty acids, wax esters, branched-chain amino acids, acoustics

A patchwork model for cholesterol synthesis from cycloartenol in the red alga *Chondrus crispus*

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Model species with a fully sequenced genome are promising to integrate knowledge regarding metabolic pathways, because identified metabolites can be connected with candidate enzymes that may be involved in their biosynthesis. During a work dedicated to the genome-scale reconstruction of the metabolic network in the model red alga *Chondrus crispus*, using both bioinformatic tools and MS-based targeted metabolic profiling, we found an original pathway for the biosynthesis of cholesterol from a cycloartenol precursor. This pathway shares some common features with the one proposed in tomato, but differs also in other aspects. Due to secondary gene losses, some enzymes may have been replaced either by paralogs or by genes from entirely different families, as was already shown in yeast. Also, changes is the order of conserved reactions may have produced new intermediates, which led us to formalize new logical reasoning approaches to cope with this issues. This plasticity can also be observed in other pathways that are considered to be conserved, and is consistent with evolutionary biology concepts indicating that phenotypes can remain conserved even when the underlying molecular mechanisms are changing.

Keywords: biosynthesis, cholesterol, cycloartenol, red alga, metabolic pathway evolution

A $^{13}CO_2$ enrichment experiment with protists to study the synthesis pathways of two essential healthy polyunsaturated fatty acids

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Polyunsaturated fatty acids (PUFA) have been associated with numerous health benefits especially for humans where they can help fighting against cardiovascular diseases, hypertension, autoimmune and mental disorders and they can also be useful for neural development. Currently, marine organisms and especially primary producers are the most common source of these long chain n-3 PUFAs. They are then transferred through marine food webs and ultimately consumed by humans in fish or seafood. Most eukaryotes are not able to synthetize EPA and DHA in sufficient quantities to insure their growth and development so they need to collect them from their prey or food intakes. PUFAs synthesis uses different metabolic pathways for both prokaryotes and unicellular marine eukaryotes. The conventional pathway called fatty acid synthase pathway (FAS pathway) is found in most eukaryotes. Fatty acids are synthesized from acetyl-CoA and malonyl-CoA in aerobic conditions thanks to multiple enzymes of the complex. Some other no-oxygen dependent pathways exist too. The polyketide synthase pathway (PKS pathway) allows producing 22:6n-3 (DHA) by bacteria and heterotroph protists such as Thraustochytrids. As microalgae species share all or part of these pathways, the PUFAs composition of primary producers vary according to species assemblages: diatoms produce more 20:5n-3 (EPA) than 22:6n-3 (DHA) while dinophytes are richer in 22:6n-3. Thus, any disruption in n-3 PUFAs production at the basis of the marine food webs linked with global changes could affect the availability of EPA and DHA to upper trophic levels and especially humans. To better understand the origin and production of these two polyunsaturated fatty acids 20:5n-3 (EPA) and 22:6n-3 (DHA) by autotroph and heterotroph protists, we performed a stable isotope enrichment (^{13}C) experiment in batch monoculture. Three species have been selected: 2 autotroph species, *Tisochrysis lutea* and *Chaetoceros neogracile* and 1 mixotroph species *Alexandrium minutum*. These 3 species have been chosen for their different EPA and DHA production but also for their suspected preferential fatty acids pathway synthesis (FAS pathways for *T. lutea* and *C. neogracile* and PKS pathways for *A. minutum*). The incorporation of enriched $^{13}CO_2$ into fatty acids (from precursors to final PUFAs of interest) has been monitored over time and will be used to assess the production pathway(s) of theses essential healthy PUFAs.

Keywords: PKS pathway, FAS pathway, protist, EPA, DHA

Transfer, upgrading and role of polyunsaturated fatty acids and sterols in aquatic food webs - POSTERS

Phytosterols as tracers of terrestrial and wetland carbon: Implications for trophic resource usage in the eastern oyster, *Crassostrea virginica*

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Oysters are highly valued as a marketable species around the world. The eastern oyster (*Crassostrea virginica*), is a natural component of estuaries along the eastern seaboard of the United States. In addition to its economic value, oysters provide critical functions within the estuary ecosystem by filtering the water column, creating a reef structure for habitat and/or refuge, and providing a food source. This filtration role coupled with the secondary habitat provided by oyster reefs makes oysters a key species in benthic–pelagic coupling and in maintaining a healthy ecosystem. As such, oysters are now used as "canaries in a coal mine" to gauge the overall health of some of the estuaries in the United States. Previous studies have shown that water quality can affect the growth and development of healthy oyster reefs by affecting the diet of the oysters. For the filter-feeding eastern oyster, preferred diet is typically "higher quality" labile particulate organic matter (POM) such as autochthonous phytoplankton and not terrestrial-derived refractory material that may comprise urban inputs. Additionally, in estuarine environments, labile particulate organic matter sources may comprise other primary producers such as wetland plants (e.g. mangroves, salt marshes), seagrasses or benthic microalgae. The Greater Everglades, Florida is a mangrove-dominated wetland ecosystem that has seen unprecedented changes in hydrology and landscape due to agriculture and urban development. These changes have resulted in impacts on the delivery of the amount of water to the coastal waters of the Everglades as well as the quality of that water. In this study, we used lipid biomarker analyses to identify possible food sources and food quality to *C. virginica* diet in the Greater Everglades, Florida. Using phytosterols, we traced sources of terrestrially and aquatically derived organic matter from plant material, POM, benthic microalgae, sediments, and oyster tissue. We compared data from three hydrologically distinct bays, during the wet and dry seasons. Results indicate an input of common mangrove-derived phytosterols in sediments and POM. Additionally, POM samples also comprised of algal, other plankton and terrestrial sterols. Benthic microalgae samples also comprised mainly of algal sterols. Oyster digestive tissue however comprised mainly of algal-derived sterols found in diatoms, prymnesiophytes, and green algae. These results indicate that *C. virginica* feeds mainly on autochthonous phytoplankton rather than terrestrial POM. The ability of *C. virginica* to selectively ingest higher quality material even under the stressful conditions of altered hydrology highlights the importance of improving overall water quality.

Keywords: sterols, diet, POM, BMA, oyster

Trophic ecology of spiny lobsters in the Seychelles: insights from fatty acid analysis

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As an island nation that rely highly on marine resources, the Seychelles are particularly vulnerable to climate change, and as such have established policies in order to better manage their resources. In spite of that, catches of spiny lobster, which is one of the main resources for artisanal fisheries, have kept decreasing in the recent years. Although the overall ecology of spiny lobsters has been widely reviewed, information on spiny lobsters in the Seychelles is scarce and mainly based on field observation. The factor responsible for such a stock collapse is thus still undetermined, and it could be caused by a change in habitat and/or diet, as the Seychelles have recently faced a major coral bleaching episode and a rapid increase of the macroalgal cover. This study focuses on the two species that comprise most of the catches, *Panulirus penicillatus* (pronghorn spiny lobster) and *Panulirus longipes* (longlegged spiny lobster), and examines their foraging ecology in the Seychelles food web. For this, fatty acids (FA) were analyzed in liver tissues retrieved from individuals of both species, sampled in 2016 and in 2017. FA profiles were similar between both sampling years and for each species, suggesting no major change in diet between both years. There was also no significant difference between FA profiles of both species, suggesting similar trophic niches, although *P. penicillatus* seemed to feed on more diverse preys than *P. longipes*. Observed FA profiles were consistent with the previously observed opportunistic diet of spiny lobsters.

Keywords: Spiny lobster ecology; Seychelles; climate change

Advances in analytical chemistry of lipids - Compound specific stable isotope analysis of lipids - POSTERS

Does a coastal community utilize inland carbon as dietary sources? Approach of stable carbon isotope ratios of essential fatty acids.

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Coastal ecosystems receive trophic subsidies such as nutrients and organic matters from inland ecosystems through river discharges. Dietary contribution of inland carbon sources for coastal food webs is poorly understood. Stable isotope ratios of bulk carbon and nitrogen, fatty acid compositions, and stable carbon isotope ratios of essential fatty acids of red seabream, *Pagrus major* was analyzed to assess whether inland carbon sources was assimilated or not. *P. major* was sampled monthly from June to October, 2017 in north coasts of Japan Sea. In addition, particle organic matter was collected from an adjacent eutrophic freshwater lake, Lake Hachiro, which is one of the main freshwater discharge to the investigated area in Japan Sea. Bulk stable carbon isotope ratios of *P. major* was -18.7±0.7‰, indicating main dietary carbon sources for this species was marine origin. *P. major* contained 7.9±1.2% of 20:5ω3 and 23.9±4.6% of 22:6ω3, which are biomarker fatty acids for diatom and dinoflagellate, respectively. Stable carbon isotope ratios of these fatty acids were -26.6±1.3‰ in 20:5ω3 and -25.8±0.9‰ in 22:6ω3. Because stable carbon isotope ratios of these fatty acid in freshwater particle organic matters from Lake Hachiro were more depleted (20:5ω3:-33.8±2.1‰, 22:6ω3:-32.0±2.3‰), these two essential fatty acids in *P. major* seem to be marine origin. Contribution of 18:3ω3 in *P. major* was less than 1.1% for total fatty acids with depleted isotope ratios (-31.3±1.9‰). Stable carbon isotope ratios of 18:3ω3 in the discharged particle organic matters, which were consist of mainly freshwater cyanobacteria from Lake Hachiro was -32.8±2.7‰, which are relatively close to the value of *P. major*. This indicates that inland carbon sources (i.e. freshwater cyanobacteria) may be assimilated by the coastal food web even though their contribution was minor comparing with marine origin organic matters.

Keywords: Food web, Lake Hachiro, Compound specific isotope analysis, Fatty acids

Late Holocene occupation history, population movements, and diet in Adélie penguins as inferred from ornithogenic soils from the northern Ross Sea region, Antarctica

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The Adélie Penguin (*Pygoscelis adeliae*) is highly abundant and widely distributed throughout the Antarctic. During the austral winter Adélie Penguins utilize offshore waters that surround the pack ice and migrate to ice-free land along the Antarctic coastline or surrounding islands for the summer breeding season. This species is an important bio-indicator of marine environmental conditions due to ecological constraints during the breeding period, in which ice-free terrain, open water access, and a proximate reliable food source are critical to colony formation and recurrent occupation. Environmental conditions optimal for breeding over time can lead to the development of ornithogenic soils (bird-formed), where the cold and often dry climate in Antarctica facilitates the preservation of penguin bones, feathers, eggshells, as well as hard parts of their prey in guano (squid beaks, fish bones and otoliths) ranging in age from hundreds to thousands of years. Thus, these soils form a natural archive of biological remains that can be analyzed for information on past ecosystems. Here, we present results from excavations and sample collection from modern and abandoned Adélie Penguin colonies located in the Ross Sea during the 2015/16 austral summer field season. In particular, we use radiocarbon dating and bulk stable isotope analysis (natural abundances of carbon and nitrogen) on preserved tissues recovered from ornithogenic soils to test the hypothesis that Adélie Penguins underwent a major population shift, and perhaps a dietary change, at 2000 BP when the southern Ross Sea was abandoned. This abandonment also corresponds with the first occupation of major breeding localities in the northern Ross Sea, implying that changing environmental conditions were responsible for the large-scale population movement. These sites are particularly rich in well preserved organic remains and provide new information on the occupation history and population movements of Adélie Penguins in the late Holocene. Our analyses also provide a broader knowledge of the marine environment over the past 2000-7000 years in the Ross Sea. Additionally, the relative abundance and $\delta^{13}C$ signature of fecal sterols (cholesterol, epicoprostanol, cholestanol) in penguin guano (modern) and ornithogenic soils (residual biochemical constituents) will be presented. Our objective is to investigate the influence of external factors (flora and fauna) and diagenetic processes on the $\delta^{13}C$ of penguin derived guano within ornithogenic soils obtained from bulk stable isotope analysis to assess the applicability of this method in the study of Adélie Penguin paleoecology.

Keywords: Victoria Land, stable isotope analysis, Antarctic paleoecology

Environmental effects on lipid metabolism in marine organisms and on trophic transfer - POSTERS

Coastal waters freshening and extreme seasonality affect the quality and sources of organic matter in a High Arctic fjord (Young Sound, Greenland)

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Arctic fjords experience strong modifications of their physical environment due to climate change such as increase of freshwater inputs associated to a water column stratification strengthening as well as nutrients supply changes. Although such modifications are known to influence phytoplankton dynamics together with benthic-pelagic coupling in these ecosystems, their impacts on the sources and quality of organic matter are still poorly understood. In this study, we have conducted organic matter seasonal sampling in a high arctic fjord (Young Sound, NE Greenland) on both surface (s-POM) and bottom waters (b-POM) as well as in sediment (SOM). Stable isotope ($\delta^{13}C$ and $\delta^{15}N$), fatty acid and compound specific isotope analyses were performed in order to assess organic matter sources and quality. Results point out the huge impact of seasonality on Young Sound shifting from autotrophic functioning during a short summer to heterotrophic functioning during winter. Associated to this shift, a huge decrease of the organic matter quality is observed during winter, as shown by the ultra-dominance of saturated fatty acids. In parallel, summer sampling highlights the influence of ice-melting on organic matter quality especially for surface waters and the inner fjord stations. Thus, summer S-POM composition is homogenous among stations which underlines the large contribution of terrestrial organic matter from Young Sound's rivers. On the opposite, b-POM composition is more variable among stations, especially in the outer station, characterized by an intense diatom bloom. Finally, SOM shows also various compositions as terrestrial runoff provide the main part of organic matter in the inner station whereas the two others stations are mainly fueled by carbon originating from both marine pelagic and benthic primary producers. Under an increase of freshwater input scenario, these results suggest a possible decline of the organic matter quality and production in the Young Sound with potentially subsequent impacts on benthic food webs and on the functioning of the whole ecosystem.

Keywords: Arctic benthic ecosystems – Environmental gradients – Trophic functioning – Fatty acids – Compound specific isotope analysis

TAG:Chol and PC:PE as proxy of plaice larval condition in the North Sea and English Channel

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Plaice (*Pleuronectes platessa*) is a commercially important species in The English Channel and the North Sea. Mortality during the early life stages is one of the main causes of variability in the recruitment of fish stocks and can be linked to critical periods like the shift between endogenous (yolk sac) and exogenous (predation) nutrition. Moreover flatfish larvae change from a pelagic to a benthic lifestyle leading to physical, physiological and behavioral modifications, which start during the planktonic larval stages. In this study, total lipids and lipid class composition [Triacylglycerol (TAG), Cholestérol (Chol) and Phospholipids (PL)] were used to quantify the energy reserves and condition of fish larvae (n= 123). The total amount of lipids was linearly related to the quantity of structural PL, suggesting that growth is favored over lipid storage. The commonly used lipid condition index TAG:Chol ratio showed interannual variability in the condition of fish larvae between 2017 and 2018, probably related to prey quality or quantity. Larvae with low levels of TAG:Chol could be either growing or under starvation. Only the combination of this index with phospholipids class analysis [e.g., Phosphatidylcholine (PC): Phosphatidyléthanolamine (PE)], which can also be reduced during starvation allowed truly the identification of larvae in poor condition. Our results indicate that plaice larvae were globally in good condition but suggest that larvae in 2017 had a lower potential to withstand environmental stressors than larvae in 2018. Moreover, TAG storage at advance larval stages could be essential for improving the probability of survival during and after the metamorphosis. The TAG:Chol index coupled with PC:PE ratio appeared as a useful tool to monitor interannual nutritional condition and can have a widespread applicability for other larval fish species.

Keywords: flatfish – phospholipids – nutrition – lipid condition index – energy allocation

Copepod diapause and the biogeography of the marine liposphere

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One of the primary characteristics that determines the structure and function of marine food webs is the utilization and prominence of energy-rich lipids. The biogeographic pattern of lipids throughout the ocean delineates the marine "liposphere," which supports lipid-rich fish, mammal, and seabird communities. While the importance of lipids is well appreciated, there are no synoptic measurements or biogeographic estimates of the marine liposphere. Productive lipid-rich food webs in the pelagic ocean depend on the critical diapause stage of large pelagic copepods, which integrate lipid production from phytoplankton, concentrating it in space and time, and making it available to upper trophic levels as particularly energy-rich wax esters. As an important first step toward mapping the marine liposphere, we compared four different modeling approaches of copepodid diapause, each representing different underlying hypotheses, and evaluated them against global datasets.

Through a series of global model runs and data comparisons, we demonstrated the potential for regional studies to be extended to estimate global biogeographic patterns of diapause. We compared four modeling approaches each designed from a different perspective: life history, physiology, trait-based community ecology, and empirical relationships. We evaluated the model results against global measurements of copepodid diapause.

In general, models were able to resolve more than just the latitudinal pattern of diapause (i.e. increased diapause prevalence near the poles), but to also pick up a diversity of regions where diapause occurs, such as coastal upwelling zones and seasonal seas. The life history model provided the best match to global observations. The predicted global biogeographic patterns, combined with carbon flux estimates, suggested a lower bound of 0.031 – 0.25 Pg C yr^{-1} associated with copepodid diapause.

Results indicated a promising path forward for representing a detailed biogeography of the marine liposphere and its associated carbon flux in global ecosystem and climate models. While complex models may offer advantages in terms of reproducing details of community structure, simpler theoretically based models appeared to best reproduce broad-scale biogeographic patterns and showed the best correlation with observed biogeographic patterns.

Keywords: diapause; copepod; trait; global biogeography; liposphere

Temperature-induced changes in the fatty acid profile of the benthic copepod Platychelipus littoralis of the Westerschelde estuary

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Current climate change predictions expect coastal ecosystems, such as estuaries, to be particularly vulnerable to rising temperatures. In these estuaries, benthic harpacticoid copepods (Crustacea, Copepoda) are the main consumers of primary producers (diatoms) and serve as an important food source for higher trophic levels (fish). Due to their high levels of energy-rich fatty acids taken up from their diatom diet, harpacticoids play an essential role in trophic energy transfer and in the maintenance of physiological functions in many organisms in estuarine food webs. In view of their trophic importance, stable fatty acid profiles in harpacticoid copepods are indicators for a healthy and stable ecosystem and any changes in these profiles are expected to cascade through the food web. This study examines the effects of temperature changes on the fatty acid profile of *Platychelipus littoralis*, one of the most abundant harpacticoid copepods in the Westerschelde estuary (The Netherlands). Temperatures in this temperate estuary are highly variable throughout the year and we expect that changing temperatures will alter the fatty acid content of harpacticoid copepods. *P. littoralis* was subjected to different temperature treatments in accordance to the climate change predictions for the North Sea. Our first results indicate that with increasing temperature, concentrations of essential fatty acids such as EPA and DHA decrease in *P. littoralis*. This can induce unfavorable effects on organisms at higher trophic levels, which rely on these primary consumers for most of their fatty acid uptake.

Keywords: climate change, Harpacticoida, lipidomics, North Sea

Marine lipids, human health and ecosystem services - Lipids in emerging biotechnology and blue economy - POSTERS

Induction of carotenogenesis in the *Dunaliella salina* strain (Chlorophyta) isolated from Guerrero Negro, Baja California Sur, Mexico.

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There is a high interest in the cultivation of microalgae as a source of high value, naturally synthesized products such as β-Carotene. The later is overproduced in the Chlorophycea algae *Dunaliella salina a*s much as 14% of the cellular dry weight. Regulatory mechanisms have been proposed, including the hypothesis that β-carotene overproduction is driven by the formation of lipid globules under certain extreme environmental conditions, such as high light intensity, nutrient deprivation, high salinity, and extreme temperatures. This work aims to select the salinity and irradiance needed to induce carotenogenes is in *D. salina* and the effect of these conditions on total lipid content and fatty acid profile. The strain was collected from the salt mine Exportadora de Sal S.A. de C.V. in Guerrero Negro, Baja California Sur, Mexico. It was grown in a batch system in F/2 medium with the following treatments: a) low salinity (0.6M NaCl) and low irradiance (150 μmol photon $m^{-2}s^{-1}$) LS-150-control; b) high salinity (4M NaCl) and low irradiance (150 μmol photon $m^{-2}s^{-1}$) HS-150; c) low salinity (0.6M NaCl) and high irradiance (300 μmol photon $m^{-2}s^{-1}$) LS-300 and d) high salinity (4M NaCl) and light irradiance (300 μmol photon $m^{-2}s^{-1}$) HS-300. Pigment, lipid, and fatty acid contents were evaluated in the phase of cellular decay. β-carotene 11-cis production was reached at treatments HS-150 y HS-300 with 19±2 mg L^{-1} y 15±2 mg L^{-1}, respectively. However, β-caroteno 9-cis significantly increased only at HS-150 with 10±4 mg L^{-1}. Total lipids increased significantly in HS-150 (86 pg $cell^{-1}$), LS-300 (428 pg $cell^{-1}$), and HS-300 (338 pg $cell^{-1}$), compared to the control LS-150 (LS-150). Also, total fatty acid content significantly increased at high salinity HS-150 (178 pg $cell^{-1}$), and HS-300 (79 pg $cell^{-1}$), equivalent to 13 and 6 times the control content LS-150 (13 pg $cell^{-1}$). In contrast, high irradiance affected the fatty acid profile, especially increasing C16:0, C18:0 y C16:1 ω9t and decreasing C16:2 ω6, C16:3 ω6, C18:3 ω6 and C18:3 ω3 compared to LS-150. In conclusion, an irradiance of 150 μmol photon $m^{-2}s^{-1}$ and a salinity of 4M (NaCl) were enough to induce carotenogenesis and lipid content, suggesting that β-carotene overproduction is driven by the formation of lipid globules manly formed by saturated fatty acids, despite the fact chloroplast associated fatty acids decreased.

Fatty acid composition and nutritional value of halophytes found in New Caledonia

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The declining freshwater resources for agriculture and the worldwide expanding area of salinized soils have led to the development of new crops that are able to tolerate higher salt concentrations than conventional agricultural crops. These productions, named “saline agriculture”, aim to save these resources by exploiting seawater and salt-affected soils for sustainable food production from salt tolerant plants, named “halophytes”. Saline agriculture is widely reported to become an innovative agricultural system with triple performance : economic, ecological and social. This study is part of a general project aimed at the agronomic characterization of food with high nutritional and medicinal value ("functional foods") from halophytes found in New Caledonia. In fact, halophytes have a nutritional value that is often much higher than traditionally crops because of combination of high contents in vitamins, antioxidant compounds and polyunsaturated fatty acids (n-3, n-6, n-9) in their tissues. This study aims specifically to search for functional lipid sources from halophytes. Nevertheless, the existence of a link between the composition and distribution of membrane lipids and the ecophysiological status of plants has been clearly established in the scientific world. As such, tolerance to salinity in halophytes is enhanced by higher membrane contents of polyunsaturated fatty acids, the majority of which are linolenic acid (18:3n-3). So, the objective of this study is to assess the effects of abiotic factors on fatty acid composition in seedlings and plants of 5 species of caledonian halophytes (*Amaranthaceae, Aizoaceae, Portulacaceae*) in field (lower and upper salt marsh, shrimp pond environments) and in controlled conditions.

Keywords: saline agriculture, water reuse, salt tolerance, polyunsaturated fatty acid, human health

Effect of nitrogen limitation on the biochemical composition, lipid production and fatty acid profile of *Ettlia oleoabundans* (Chlorophyta).

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Microalgae are photosynthetic organisms that produce compounds of biotechnological interest. *Ettlia oleoabundans* is an oleaginous microalgae that has a high lipid content. Due to its metabolic versatility, it is considerated a candidate for the production of biomass rich in lipids to obtain biofuels. *E. oleoabundans* had been adapted to seawater salinity, observing an increase in neutral lipids in a previous work. The goal of this work was to evaluate the effect of nitrogen limitation on biochemical composition and fatty acid profile in *E. oleoabundans*. The cultures were carried out for 5 days at 25°C, 12: 12h light: dark, 62 µmol photon m^{-2} s^{-1} and continuous aeration, with 6 replicates per treatment. Final volume was 1.7 L with a 40% inoculum volume. Fertiplus® agricultural fertilizer was used as a culture medium. Treatments included two nitrogen concentrations, control 882µM and 20µM for nitrogen limitation. All results were expressed as dry weight bases. Nitrogen limitation decreased the growth rate from 0.12 d^{-1} to 0.07 d-^{1}, biomass yield from 246 mg L^{-1} to 104 mg L^{-1}, and biomass productivity from 49 mg $L^{-1}d^{-1}$ to 21 mg $L^{-1}d^{-1}$. Similarly, there were a decrease in protein content from 27±1% to 17.0±0.4%, chlorophyll *a* from 1.6 ±0.4 µg mg^{-1} to 0.6±0.1 µg mg^{-1}, chlorophyll *b* from 0.73±0.2 µg mg^{-1} to 0.22 ± 0.1 µg mg^{-1}, and total carotenoids from 1.4±0.5 µg mg^{-1} to 0.5±0.1 µg mg^{-1}. In contrast, an increase of carbohydrates from 15±2% to 26±2%, and lipids from 16±3 to 28.4±0.2% were observed. The fatty acid profile did not show significant differences on saturated and polyunsaturated in both treatments. Moreover, monounsaturated fatty acids increased from 7.1±0.4% in control to 18±2% in nitrogen limitation. The results obtained will contribute to the knowledge about the behavior of this strain for its subsequent biotechnological application, such as the generation of high value-added compounds, like as nutraceuticals and biofuels.

Keywords: biofuels, yield, productivity.

Effects of processing conditions on lipids and fatty acids of red seaweed *Solieria filiformis*

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Marine algae, or seaweeds, are harvested worldwide from wild populations and aquaculture and used as raw material for human nutrition. This group is extremely diverse and constitutes a rich source of bioactive ingredients such as vitamins, pigments, polysaccharides, polyphenols, sterols and polyunsaturated fatty acids (PUFAs). A diet rich in seaweeds in Asian countries has been consistently associated with a low incidence of cancers, and with cardioprotective, neuroprotective and anti-inflammatory effects. Because seaweeds are often consumed after some type of processing, it is important to investigate the effect of such treatments on their biochemical composition, in particular on lipids and fatty acids (FAs), since dietary lipids have a strong links with health. Although seaweed lipid content is relatively low (<6%) when compared to oil seeds, they can be a good source of essential FAs. They are a rich in long chain n-3 and n-6 PUFAs. The purpose of this study was to investigate the effect of different processing methods (oven drying, blanching, salting and pickling) in terms of lipids and FAs content in the edible red seaweed *Solieria filiformis*. Lipids were extracted with dichloromethane/methanol (7:3 v/v) and evaluated by gravimetric method. The FAs from the total lipids were obtained by one-step direct transesterification method (treated with 5 mL of acetyl chloride/methanol 1:19 v/v and esterified at 80°C for 1 h). The FAs methyl esters (FAMEs) were analyzed by gas chromatography coupled with mass spectrometry (Agilent, Model 7000C, Palo Alto, CA, USA). FAMEs peaks were identified by comparison of their retention times with those standards Supelco 37 Component FAME Mix (SUPELCO, St. Louis, MO, USA), and their mass spectra with those from the NIST/EPA/NIH Mass Spectral Library version NIST 2.2 (Agilent, Palo Alto, CA, USA). The findings of this study are discussed in terms of indicating the most healthier and appropriate methods for the preparation of *S. filiformis* for later use in human nutrition. Financial support CONACYT 2015-01-118.

Keywords: *Solieria filiformis;* edible seaweeds; PUFAs

Consumption, nutritional value and economic potential of *Caulerpa racemosa* (Forsskal) and *Ulva fasciata* (Delile) in the Philippines

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Philippines is known for its rich flora, and its marine algae are significant and diversified natural vegetable production. Its littoral zones have 893 species of marine macrobenthic algae with (197, 153, and 543) species of greens, browns, and reds currently listed respectively. Of 350 species considered as economic importance, only 5% of these are being used, most have still to be developed. *Caulerpa* and *Ulva* present many uses as human or animal food, source of vitamins and minerals. In 1960s, *Caulerpa* spp. were cultured sufficiently but has now been banned due to destruction of mangroves as its culture area, while *Ulva* spp. has now been encouraged by Philippine government to be developed as a potential human and animal food, and biogas feedstock. Regular seafood consumption is associated with beneficial health effects and viewed as potential reservoir for such compounds. However, little is known for its nutritional properties, and biological activities of *Caulerpa* and *Ulva* species in the Philippines. Total lipids content from *Caulerpa racemosa* was 5% dry weight, while 6% dry weight for *Ulva fasciata*. Polyunsaturated fatty acids (PUFA), monounsaturated fatty acids (MUFA), and saturated fatty acids (SFA) revealed (21.6%, 34.6%, 41.33%) and (10.49%, 12.67%, 72.11%) of the total lipids from *C. racemosa* and *U. fasciata* respectively. Oleic acid or C18:1ω9 found to be highest in *C. racemosa* (28.13%) followed by C16:0 or palmitic (27.59%). Butyric acid or C4:0 (5.27%), C22:0 or behenic (1%), C15:1 pentadecanoic (0.48%), C17:1 or heptadecenoic (0.96%), and C24:1ω9 or nervonic (0.21%) were not found in other *Caulerpa* species. MUFA of *C. racemosa* was three times higher than most of the *Caulerpa* species. In the present study of *Ulva fasciata*, butyric acid or C4:0 (0.85%), C12:0 (0.13%), and C20:0 (0.19%) of SAF; palmitoleic or C16:1 (2.95%), oleic or C18:1ω9 (5.88%), eicosenoic or C20:1ω9 (0.73%), erucic or C22:1ω9 (1.67%), and nervonic or C24:1ω9 (1.24%) of MUFA; while C20:2ω6 (0.4%) and C20:3ω6&ω3 (0.27%) of PUFA were all found in the present study but not in the other *Ulva* species. Also C16:0 (59.85%) was found highest in *Ulva fasciata*. High C18/C20 PUFA ratio as common trait of green seaweed was found to be true in both studied species. EPA and DHA were found in small amount (0.69 and 1.84 %) for *C. racemosa*, while ω6/ ω3 ratio value (1.74-4.19 and 2.37-70.59) suggest a positive and negative characteristic of WHO recommendation (<10) daily intake for *C. racemosa* and *U. fasciata* respectively.

Keywords: PUFAs; sea grapes; sea lettuce; human food; nutrition

Omega-3 index in the Czech Republic: no difference between urban and rural population

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Naturally occurring long-chain omega-3 PUFA, namely eicosapentaenoic acid (EPA; 20:5 ω-3) and docosahexaenoic acid (DHA; 22:6 ω-3), exert multiple effects on health that are related to the nutritional intake of these lipids, and correlate with the levels of omega-3 PUFA in organism. These levels are marked by omega-3 PUFA index, i.e. the EPA and DHA content as % of all fatty acids in red blood cells. Aim of this study was to evaluate omega-3 index in the Czech Republic, using blood samples collected from capital city (n = 476) and rural region (n=388). The mean omega-3 index was 3.56 mol % with maximal value 8.10 % and minimal value 1.12 %. There was no difference in the index value between the rural and the urban / industrial region, but this value was higher in the subjects with reported consumption of fish or intake of omega-3 PUFA supplements. In conclusion, the results indicated suboptimal values of omega-3 index in the Czech population independent on the sampling region.

Keywords: omega-3 index, red blood cells, nationwide survey

Evaluation of lipidic content, fatty acids and biochemical composition of the diatom *Nanofrustulum shiloi*, native from Baja California Sur, Mexico

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Microalgae are organisms with high photosynthetic efficiencies which satisfy important functions in aquatic ecosystems trophic chains. They have great metabolic plasticity, which allows them to adapt to different environments and to produce several biomolecules of biotechnological interest, such as lipid compounds like fatty acids and pigments. Diatoms are used as live food in the aquaculture industry due to their elevated contents in highly unsaturated fatty acids (HUFA) like eicosapentaenoic acid (EPA, 20:5ω3). Currently, there is an interest in finding new organisms with high nutritional content, for its use in the food industry, both human and animal, thus, reducing the impact on natural resources. The aim was to identify, to cultivate and to analyze the biochemical composition of the marine benthonic *Nanofrustulum shiloi*, grown in an outdoor production system. This diatom was collected from Balandra bay, Baja California Sur, Mexico. The taxonomic identification was done by compound microscope with contrast phase optics, scanning electron microscopy, and confirmed by phylogenetic analysis (18S and RbcL genes; Neighbor-Joining, 1000 bootstrap replicates). It was grown outdoors for 7 days in 80 L columns. A percentage of 17.5% inoculum was used, the agricultural fertilizer Fertiplus® plus silicates were used as culture medium and daily additions of CO_2 were made. HOBOs sensors were introduced inside the culture to measure the temperature and light intensity. A maximum temperature of 30°C and minimum of 20°C were registered. The irradiance varied from a minimum of 0.31 µmol photon m^{-2} s^{-1} to a maximum of 377 µmol photon m^{-2} s^{-1}. A growth rate of 0.17 d^{-1} was obtained with a dry weight (DW) biomass yield of 322 mg L^{-1}. A significantly higher content of proteins (27±1% DW), carbohydrates (20±2% DW) and chlorophyll *c* (0.9±0.2 mg L¯1) was obtained on day 7 compared to the initial time ($p<0.05$). In contrast, the content of chlorophyll *a* (0.4±0.2 mg L¯1), fucoxanthin (0.3±0.1 mg L¯1) and lipids (19 ±3% DW) did not show significant differences. The fatty acid profile was composed of saturated (25.65%), monounsaturated (36.09%), polyunsaturated (10.14%) and highly unsaturated (22.07%) which were represented mostly by EPA (16.84%). EPA is one of the main fatty acids needed for rapid growth, optimal feed conversion and good reproductive capacity. N. shiloi can be considered as a potential nutritional supplement in the diet of aquatic organisms.

Keywords: yield, HUFA, EPA, fucoxanthin.

Structure, metabolism and function of lipids - POSTERS

Fat embolism and whale ship collisions in the Canary Islands

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The Canary Islands is a geographical area with an important overlap of high cetacean diversity and maritime traffic, including high-speed ferries. Sperm whales are present all year round in the Canarian waters and are listed as vulnerable species. Most stranded sperm whales in the Canaries present signs of ship strikes. Findings such as hematomas, hemorrhages or edema, point to an antemortem trauma. Nevertheless, it can be difficult, especially when carcasses are very decomposed, to distinguish if a whale was already dead when hit by a vessel. In these cases, lipids may play an important role to determine "in vivo" severe trauma, as it has already been demonstrated in other species. A ship strike might cause bone fractures or severe soft tissue damage, disrupting the tissue and enabling the entry of fat into the circulatory system. Lung is the target organ to detect those fat emboli as they get easily trapped in the pulmonary microvasculature. In the present study, we have studied the presence of fat emboli by histochemistry in lungs of fifteen sperm whales with signs of ship collision stranded and necropsied in the Canaries between 2000 and 2015. Many of these whales (n=11) were in advanced autolysis. As lipids substances are soluble in the processing solvents used when embedding tissues in paraffin, osmium tetroxide was used to fix the lipids within the tissue. Samples were stained with hematoxilin-eosin. Histological examination revealed the presence of fat emboli with different degrees of severity in 12 out of the 15 animals studied. These results demonstrate 1) the usefulness of fat as a diagnostic tool for in "vivo" trauma, even in decomposed tissues kept in formaldehyde for long periods of time; and 2) that, during this 15-year period, 80% of the sperm whales studied were alive at the moment of the collision and have died due to vessel collision in Canarian waters. This information is extremely important in order to implement proper mitigation measures in this area.

Keywords: fat embolism, strikes.

Mobilization of isotopically labelled arachidonic acid and subsequent prostaglandin production in relation to acute temperature stress in oyster larvae *Crassostrea gigas*.

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Larvae that are subjected to a thermal stress undergo increased metabolism, with increased production of reactive oxygen species (ROS). ROS can cause oxidation of fatty acids present in the cell membrane, producing molecules known as Isoprostanes (IsoPs). These molecules are more differ from prostaglandins formed enzymatically from arachidonic acid (ARA) through the cyclooxygenase enzyme (COX): the later are synthetized enzymatically and in very controlled circumstances, usually in response to an immune stress and produce apoptosis, while the former can cause inflammation and necrosis. Some marine invertebrates in aquaculture conditions accumulate more ARA in the triglycerides than their wild counterparts, and mobilize it under chronic, but not acute stress, since ARA stored in triglycerides is less susceptible to the attack of ROS and therefore, there is less production of IsoPs. The objective of the present study is to evaluate if isotopically labelled ARA will accumulate in triglycerides or phospholipids, and if it will be mobilized to produce PG or IsoPs under an acute thermal stress in oyster larvae *Crassostrea gigas*. Oyster larvae were acclimated to 20 °C for one week, using *Chaetoceros calcitrans* (5% of biomass) twice a day as feed. After the acclimation period, a group of larvae (six replica) were fed *C. calcitrans* with isotopically labelled ARA bound to the membrane phospholipids. Another group of larvae (six replica) were fed free isotopically labelled ARA (Cayman Chemicals). 24 h after the feeding, three replicates from each group were subjected to an acute temperature increase of 5 °C/h until reaching 40 °C, while the controls were left at 20 °C. Oysters were sampled for extraction of fatty acids and subsequent isotopic analysis of fatty acids using gas chromatography coupled to mass spectrophotometry. The analysis of (PGE_2) and IsoPs was performed by enzymatic kits, and larvae morphology was analysed using an electronic microscope.

Keywords: PGE2, *Chaetoceros calcitrans*, mollusc, fatty acids.

Quantitative GC-MS profiling of the sterol synthesis pathways in model macroalgae

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Macroalgae are multicellular photosynthetic organisms, which develop using mineral nutriments, atmospheric carbon and light. From an evolutionary point of view, macroalgae group together in three main lineages, the brown, red and green algae. The IDEALG research project aims at completing and integrating the chemical data on the metabolism of several seaweeds of biological or ecological interest. Metabolic networks models can now be built from complete genomes, but require an experimental check of the presence of molecules predicted from the genomic data. The targeted profiling of metabolites belonging to well characterized pathways, such as sterol biosynthesis, allows the validation of those metabolic models. On the platform METABOMER-CORSAIRE, the gas chromatography coupled with mass spectrometry (GC-MS), after saponification and derivatization of extracts, enables to establish the sterol profiles for various macro-algae. The main differences in distant lineages, such as the red alga *Chondrus crispus* and the brown algae belonging to the *Ectocarpus* genus, correlate with lineage-specific losses of otherwise conserved enzymes. But other factors are also important, as indicated by qualitative and quantitative differences in the second most abundant sterols in four different species from the *Ectocarpus* genus. Two of those species have their genome already sequenced, and the fully identical candidate gene sets cannot explain the observed metabolite variations.

Keywords: sterols, metabolic pathways, macroalgae, GC-MS

Lipid composition of central nervous system tissue from marine and terrestrial mammals

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Breath-hold diving behavior of air breathing vertebrates exposes individuals to increased partial pressure of gases. This type of gas exposure can result in the formation of nitrogen gas emboli, which are known to cause injuries ranging from impaired movement to death. The severity of these injuries is related to the duration of gas exposure and location of emboli, with more serious injuries caused by emboli formed within the central nervous system (known as Type II decompression sickness). However, marine mammals appear to be immune to the negative effects of nitrogen gas emboli, despite regular, rapid ascents from depths as deep as 2000 meters, where the animal has foraged or avoided predation. Nitrogen gas is five times more soluble in lipid than water, and lipid composition is known to affect nitrogen gas solubility in the acoustic tissue of marine mammals. In contrast to the relative wealth of knowledge available on the lipid composition of central nervous system tissue of terrestrial mammals, there are no data on the lipid composition of the central nervous system of marine mammals. In this study, the lipid composition of central nervous system tissue (brain and spinal cord) of terrestrial and marine mammals was determined using a combination of TLC and HPTLC. For ease of comparison with other studies, the pig *Sus domesticus*, was chosen as the terrestrial mammal representative. Marine mammals representing a coastal, shallow diver (*Tursiops truncatus*, bottlenose dolphin), a pelagic, mid-depth diver (*Delphinus delphis*, common dolphin), and a pelagic deep diver (*Mesoplodon europaeus*; Gervais' beaked whale) were examined. Brain and spinal cord tissues contained cholesterol, sphingolipids, ceramides and sulfatides, in proportions that were species-specific. Fatty acid composition of the identified lipid classes as well as the determination of the nitrogen gas solubility of these lipids will be conducted to explore the connection between lipid composition and avoidance of gas emboli.

Keywords: marine mammals, polar lipids, diving

Effect of highly unsaturated fatty acids (HUFA) in the expression of related genes in growth shrimp *Litopenaeus vannamei*

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Shrimp farming has developed exponentially throughout the world, with nutrition being one of the most important research areas. Free fatty acids (saturated or unsaturated) are the main energy source, so they are essential nutrients in the diet. Animals cannot synthesize de novo unsaturated fatty acids at positions n-6 and n-3 and it is necessary to incorporate them into the feed. Marine oils are a source of essential fatty acids (EFA) of the n-3 series. Vegetable oils are deficient in EFA of the n-3 series but are rich in n-6 fatty acids. The highly unsaturated fatty acids (HUFA) in the diet of shrimp play a decisive role in growth. Currently, there is no research where the effect of shrimp diets with high or low levels of HUFA on the growth and expression of genes related to growth is correlated. Therefore, the objective of this study is to determine the effect of HUFAS on the growth and transcriptional expression of *L. vannamei shrimp*, so a feed bioassay with three experimental feeds will be conducted to determine the productive performance of the shrimp. Muscle samples will be extracted to perform fatty acid profile analysis and transcriptomic analysis. The data obtained will be subjected to ANOVA tests ($P < 0.5$).

Keywords: Shrimp, *Litopenaeus vannamei*, fatty acids, transcriptome.

Starvation modulates omega-3 production and molecular markers related to lipid metabolism in the diatom *Pheodactylum tricornutum*

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This research focused on the study of some molecular markers and bioactive compounds related to the central metabolism of the marine diatom *Phaeodactylum tricornutum*, in order to improve the knowledge for the optimization of culture condition and utilization of this algae in pharmaceutics, nutraceutics and cosmetics.
When microalgae are maintained in conditions of metabolic stress, the ability to produce bioactive compounds changes, from qualitative and quantitative point of view, compared to organisms maintained in standard conditions. Among the molecules produced from microalgae, lipids, and in particular, polyunsaturated fatty acids of the omega-3 series (omega-3 PUFA), are the most interesting for their beneficial effects in animal health and nutrition.
The aim of this work was to evaluate the effects of culture conditions on lipid biosynthesis of *P. tricornutum*, in particular, on fatty acids composition and levels of some proteins related to central metabolism. The obtained results demonstrated that the lots maintained under stress condition, through nitrogen starvation, produced a significantly higher amount of total lipids, respect to control lots, maintaining high levels of omega-3 PUFA, that represent markers of lipid quality. At the same time, a modulation of some proteins related to glucose transport and adipogenesis was observed, indicating their involvements in energy management and lipid biosynthesis, suggesting its possible utilization as biomarkers.

Keywords: Lipidogenesis, diatoms

Effect of depletion in dietary omega 3 on mitochondrial efficiency in mullet

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There is increasing evidence that climate change critically depletes crucial nutrients in food web. In particular, a reduction in the production of Omega 3 fatty acids in microalgae as a result of climate change can alter the fatty acid composition of biological membranes of consumers. This is particularly true for marine fish as they are unable to produce Omega 3 *de novo*. Decreases in Omega 3 content in membranes have been shown to impair fish performance, however the underlying mechanisms remain obscure. The likelihood that changes in the composition of membrane fatty acids of mitochondria affect their efficiency has been overlooked. It is now evident that organisms that have less efficient mitochondria are less able to maintain ATP production, a feature that is likely to affect the overall animal performance. Here, we have evaluated how reductions in dietary Omega 3 availability affect mitochondrial efficiency of upper consumers using mullet *Liza aurata*. Because of their role of microalgae grazers, mullets play a crucial role in the transfer of Omega 3 across the food chain, from the microalgae toward human. Mullets have been exposed for 2 months to an enriched or depleted Omega 3 diet. The Omega 3 content in the animal membranes can be strongly affected by diet. A global estimate of the mitochondrial efficiency of major tissues (liver, white muscle and red blood cells) obtained from measurement of the mitochondrial ATP produced per unit of mitochondrial oxygen consumed (ATP/O ratio).

Keywords: DHA, EPA, energy metabolism, ATP/O ratio, fish

Unveiling the strategies of thermoregulation of the membrane lipid composition in the marine picocyanobacteria *Synechococcus*

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Marine cyanobacteria of the genus *Synechococcus* are important primary producers. They display a wide latitudinal distribution that is underpinned by a diversification into temperature ecotypes. The objective of this study is to better understand the physiological bases of this ecotypic differentiation. In many organisms, regulation of membrane fluidity is crucial for acclimating to variations in temperature. Here, we analyzed the composition of the membrane lipids of four ecologically representative marine *Synechococcus* strains, isolated from various thermal niches of the Northern Atlantic Ocean. Unlike freshwater cyanobacteria, membranes are almost devoid of C18, mainly containing C14 and C16 chains with no more than two unsaturations. In response to cold, two strains displayed a rarely observed process of acyl chain shortening that induces membrane thinning, likely regulating membrane fluidity. Ecotype specific desaturation processes were observed. In particular, *Synechococcus* ecotypes adapted to warm waters showed higher capacities to induce a double desaturation on the C16 chains of the galactolipids, whereas strains adapted to cold environments rather deployed monodesaturation processes of the acyl chains, especially those located at the *sn*-1 position of the glycolipids. In addition, we performed a metagenomic study of the global distribution of the main four lipid-desaturase genes in the ocean using the *Tara* Oceans dataset. The results suggest that DesC3 (Δ9) is a core lipid desaturase enzyme used by all marine *Synechococcus*, whereas DesC4 (Δ9) and DesA3 (Δ12) are enzymes mainly used by ecotypes adapted to cold waters and DesA2 (Δ12) is used by ecotypes inhabiting warm waters. This study thus unveils for the first time aspects of the strategies of thermoregulation of the membrane lipid composition, likely a key cell component for the diversification of temperature ecotypes in the marine *Synechococcus* radiation.

Keywords: Cyanobacteria, temperature, ecotype, glycolipid, desaturase

Depletion in dietary omega 3 HUFA affects escape performance of the golden grey mullet

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N-3 highly unsaturated fatty acids (omega 3 HUFA) are poorly synthesised *de novo* in marine fish but are essential to maintain their vital functions. They must consequently be supplied by food. In natural environments, HUFA are mainly provided by aquatic microalgae. In response to global change, HUFA production is expected to decrease because of modified microalgae communities (switches in the composition of species producing HUFA) and physiology (altered fatty acid synthesis pathways). The potential consequences of such reductions on the physiology of consumers are largely unknown. As HUFAs (particularly eicosapentaenoic acid EPA and docosahexaenoic acid DHA) are the main components of cell membranes in fish, their availability in diet can lead to modifications of membrane composition, and finally may thus affect physiological performance, with consequences on ecosystem functioning. In this context, the aim of the study was to evaluate the effect of a depletion in HUFA dietary content on the escape performance from predator of the golden grey mullet (*Chelon aurata*). The escape response governs the predator-prey relationships and is thus essential for the ecosystem functioning. Two replicated groups of fish were fed either on a standard HUFA (17.6% EPA + DHA, % of total lipids) or a depleted-HUFA (1.2% EPA+DHA, % of total lipids) diet during two months at 20°C. Fish were then individually subject to an artificial predator. Locomotion variables (cumulative distance, maximum swimming speed, maximum acceleration), as well as behavioral variables (responsiveness, response latency, directionality of the escape response) were measured, in parallel to the fatty acid composition of both reserve and membrane lipids in muscle and brain, two tissues involved in the escape response. Results show that brain FA composition was similar in both groups, indicating a regulation of this composition, while muscle FA composition reflected the diet. Depleted fish selectively retained in their tissue the HUFA present in their diet in order to compensate the deficiency. This selective retention was higher in brain than in muscle, probably in order to primarily preserve cognitive capacities. The similar brain cell lipid signature in the two groups was associated with similar behavioral variables, while the depleted HUFA content in muscle was associated with significantly different locomotion variables during the escape response between groups, with a longer escape duration, as well as a longer cumulative distance swum during the escape response in depleted fish. These results, which show the link between HUFA cell content and physiological performance, will be discussed in an ecological context.

Keywords: omega 3 highly unsaturated fatty acids, escape response, Chelon aurata, brain, muscle

Isoprostanoids quantitative profiling of macroalgae submitted to copper stress

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Macroalgae are living organisms inhabiting a broad range of particularly hostile aquatic environments that can cause them to undergo oxidative stress (OS). Considering that isoprostanoids derivatives (phytoprostanes, phytofuranes, isoprostanes) constitute the most relevant oxidative stress biomarkers, we are interested in this work to their qualitative and quantitative profile in six macroalgae submitted to a heavy metal exposure (copper). Thus, 9 phytoprostanes, 3 phytofuranes (observed for the first time in such matrices), and 3 isoprostanes are quantified through a new micro-LC-MS/MS method. The isoprostanoids profiles vary greatly among all the samples, the *ent*-16(*RS*)-9-*epi*-ST-Δ^{14}-10-PhytoF and the 5(*RS*)-5-F_{2t}-IsoP being the major compounds for most of the macroalgae studied. Concentrations of these metabolites, at basal conditions range from 2.5 to 342.6 ng/g of algal tissue. After 24h exposure of macroalgae to cupric action, as expected, in response to copper-induced stress, an increase of lipid oxidation biomarkers is observed in the majority of cases, corroborating the original hypothesis. Only *L. digitata* seems to derogate from the rule with a reduction in the content of ent-9-L1-PhytoP.

Keywords: PUFAs, oxidative stress, biomarkers, micro-LC-MS/MS

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