ACTION TRANSVERSE Pollution et Contaminants La Méditerranée sous pression anthropique : sources, transferts et impacts des contaminants sur les écosystèmes

19-21 Nov 2018
Marseille
France

Table of contents

1. Keynote talk: The Mercury Cycle in the Mediterranean Sea. Specificities, temporal trends, and research perspectives, Daniel Cossa 2

2. Mercury in the Mediterranean atmosphere, Ian M. Hedgecock [et al.] 3

3. Mercury in Mediterranean waters and sediments, Paul Layoun [et al.] 4

4. Role of microorganisms in marine mercury cycling: current knowledge and future directions, Andrea G Bravo [et al.] 6

5. Factors influencing the biological transfer of mercury in the Mediterranenan Sea, Daniela Banaru [et al.] 8

6. Mercury modeling in the Mediterranean Sea: state of the art and future research needs., Ginevra Rosati [et al.] 10

7. Modelling the biogeochemical cycle of mercury in the marine environment, Giovanni Denaro [et al.] 11

List of participants **11**

Author Index **14**

1. Keynote talk: The Mercury Cycle in the Mediterranean Sea. Specificities, temporal trends, and research perspectives

Daniel Cossa * [1]

[1] ISTerre Institut des Sciences de la Terre – Université Grenoble Alpes – France

Mediterranean physical and biogeochemical characteristics induce specific properties in the Mediterranean mercury cycle. We review our understanding of mass budgets for both inorganic and methylated Hg species in this specific environment. A large anthropization of the Mediterranean Hg cycle is demonstrated. Sediment core analyses suggest that a massive increase in Hg loading has occurred during the last two centuries. However, a significant decrease in Hg concentrations in the last decades is evidenced in waters. Both phenomena are clearly related to successive modifications in atmospheric Hg deposition and inputs from rivers. In this context, we explore the possible future Hg trends induced both by variations of anthropogenic Hg emissions and changes in climate conditions. Impacts on fish contamination are mentioned. Guidance is given for future researches.

*Speaker

2. Mercury in the Mediterranean atmosphere

Ian M. Hedgecock * [1], Katharina Gardfeld [2], Jeroen Sonke [3], François Dulac [4], Martin Jiskra [5], Christian Marlière , Nicola Pirrone [6], Francesca Sprovieri [6], Joze Kotnik [7], Vesna Fajon [7]

[1] Istituto sull'Inquinamento Atmosferico – Italy
[2] Chalmers University of Technology [Göteborg] – Sweden
[3] Géosciences Environnement Toulouse (GET) – Observatoire Midi-Pyrénées, CNRS : UMR5563 – Observatoire Midi-Pyrénées 14 Avenue Edouard Belin 31400 Toulouse, France
[4] Laboratoire des Sciences du Climat et de l'Environnement [Gif-sur-Yvette] (LSCE - UMR 8212) – Université de Versailles Saint-Quentin-en-Yvelines (UVSQ), CEA, CNRS : UMR8212 – LSCE-CEA-Orme des Merisiers (point courrier 129) F-91191 GIF-SUR-YVETTE CEDEX LSCE-Vallée Bât. 12, avenue de la Terrasse, F-91198 GIF-SUR-YVETTE CEDEX, France
[5] University of Basel – Switzerland
[6] IIA CNR – Italy
[7] JSI – Slovenia

The "Mercury Fountain" by Alexander Calder, an American sculptor, which can be found at the Joan Miró Foundation in Barcelona, mirrors many of the reasons for which the global atmospheric burden of mercury (Hg) has increased dramatically over the last few thousand years. And why the Mediterranean region has been at the heart of this increase since classical times. Mercury and its compounds have been used in art, war, metallurgy, industry and in funding the expansion of empire. The Mercury Fountain was commissioned by the Republican government of Spain for the 1937 World Exhibition in Paris, and commemorates the siege of Almadén by General Franco's forces, which deprived the government of both funds from the sale of mercury produced by the mine, and the mercury required for arms production. The government also commissioned "Guernica" by Picasso and "The Reaper" by Miró, for the same exhibition.

The current atmospheric mercury cycle in the Mediterranean atmosphere involves less art, industry and war than previously (the "Mercury Fountain" has been enclosed in a sealed glass case). Numerous changes due to legislation have reduced the number of chlor-alkali plants (these are being phased out completely), reduced mercury emissions from coal combustion (partly due to measures to reduce other atmospheric pollutants), and reduced mercury use in products. Scientific investigations focus mostly on understanding the exchange of mercury between environmental compartments, particularly air-vegetation, air-land and air-sea, and the conversion of elemental mercury to inorganic and organic mercury compounds. The aim being primarily to understand the relationship between atmospheric mercury concentration and deposition and the levels of mercury which make their way into biota, potentially entering the human food chain. This talk will briefly cover some of the recent advances in understanding the atmospheric mercury cycle as it impacts Mediterranean ecosystems and peoples today.

*Speaker

3. Mercury in Mediterranean waters and sediments

Paul Layoun [1], Mariia Petrova [1], Willy Abouga Abouga Bodo [1], Nicolas Layglon [1], Benjamin Oursel [1], Gaël Durrieu [1], Heleen Vaneste [1], Bastien Thomas [2], Nicolas Briant [3], Aurelie Dufour [1], Erwann Tessier , Vesna Fajon [4], Nathalie Patel [1], Emmanuel Tessier [5], Mathilde Monperrus [7,6], Noureddine Zaaboub [8], Thibaut Wagener [9], David Amouroux [5], Cecile Guieu [10], Stéphane Mounier [1], Cédric Garnier [1], Milena Horvat [4], Daniel Cossa [11], Joël Knoery * [3], Lars-Eric Heimbürger-Boavida *

1

[1] Institut méditerranéen dócéanologie – Institut de Recherche pour le Développement : UMR$_D235, AixMarseilleUniversité : UM110, UniversitédeToulon :$ $UMR7294, CentreNationaldelaRechercheScientifique : UMR7294 - -France$

[2] Laboratoire de Biogéochimie des Contaminants Métalliques – Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) – France

[3] Laboratoire de Biogéochimie des Contaminants Métalliques (LBCM) – Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) – Rue de l'Ile d'Yeu 44300 Nantes, France

[4] Jozef Stefan Institute [Ljubljana, Slovenia] – Slovenia

[5] Laboratoire de Chimie Analytique Bio-Inorganique et Environnement (LCABIE) – CNRS : UMR5254, Université de Pau et des Pays de l'Adour [UPPA] – HELIOPARC - 2 Avenue du Président Angot 64000 PAU, France

[7] UNIV PAU PAYS ADOUR/ E2S UPPA, UFR Sciences et Techniques de la Côte Basque – 1 Allée Parc Montaury, 64600 Anglet, France – Université de Pau et des Pays de l'Adour [UPPA] – France

[6] CNRS/ UNIV PAU PAYS ADOUR/ E2S UPPA, INSTITUT DES SCIENCES ANALYTIQUES ET DE PHYSICO-CHIMIE POUR L'ENVIRONNEMENT ET LES MATERIAUX – MIRA, UMR5254, 64600, ANGLET, France – IPREM-UMR 5254/LCABIE – France

[8] Laboratoire Milieu Marin – Institut National des Sciences et Technologies de la Mer (INSTM) 28 Rue 2 Mars 1934 Carthage Salambo 2025 Tunis, Tunisia

[9] Institut Méditerranéen d'Océanologie (MIO) – Institut de Recherche pour le Développement : UMR$_D235, AixMarseilleUniversité : UM110, Institutderecherchepourledéveloppement[IRD] :$ $UMR235 : UMR_D235, UniversitédeToulon : UMR7294, CentreNationaldelaRechercheScientifique :$ $UMR7294 -$ $-M.I.O.InstitutMéditerranéend'OcéanologieCampusdeLuminyCase90113288MARSEILLEcedex09, France$

[10] Laboratoire d'océanographie de Villefranche – CNRS : UMR7093, INSU, Sorbonne Université UPMC Paris VI – France

[11] Institut des sciences de la Terre (ISTerre) – CNRS : UMR5275, IFSTTAR, IFSTTAR-GERS, Université de Savoie, Université Joseph Fourier - Grenoble I, INSU, OSUG, Institut de recherche pour le développement [IRD] : UR219, PRES Université de Grenoble – BP 53 38041 Grenoble cedex 9, France

Mercury is global pollutant and a neurotoxin with a serious health risk for humans, mainly

*Speaker

via the consumption of marine fish. Anthropogenic Hg emissions have largely altered natural Hg levels. Procaryotes feeding on sinking marine organic matter in the mesopelagic zone are thought to produce the toxic methylmercury species (MeHg) that bioaccumulates along the marine trophic chain to harmful levels. The direct links of anthropogenic Hg emissions and changing climate to marine fish Hg levels, and ultimately human exposure remain ill-understood. The Mediterranean Sea is under the influence of anthropogenic emissions and changing climate, both affecting the biogeochemical Hg cycle. The Mediterranean Sea is one of the best covered areas in terms of observational Hg data (Cossa et al. 1991, 1994, 1997, 2005, 2017a,b, Horvat et al. 2003, 2005, Kotnik et al. 2007, 2009, Heimburger et al. 2010). Seawater data comprises over 1500 data points and the new data acquired during the 2017 GEOTRACES PEACETIME cruise added another 200 data points. The wealth of observational Hg data and the well-studied circulation and biogeochemistry (MERMEX group, 2011) make the Mediterranean Sea the ideal place to implement marine biogeochemical models (Ayache et al., 2016). We will give a general overview of the marine mercury cycling. A review of all known availble data of mercury species in seawater and the sediments of the Mediterranean Sea will be gathered and critically analyzed. We will present the most recent advances in the field and give perspectives for future research.

4. Role of microorganisms in marine mercury cycling: current knowledge and future directions

Andrea G Bravo * [1], Claudia Cosio [2], Lea Cabrol [3], Benjamin Misson [3], Cynthia Gilmour [4], Marisol Goñi-Urriza [5], Marianne Quéméneur [3], Remy Guyoneaud [5], Lars-Eric Heimbürger-Boavida [6], Silvia G Acinas [1], Alexandre J Poulain [7]

[1] Department of Marine Biology and Oceanography, Institut de Ciències del Mar, CSIC, Barcelona, Catalunya, – Spain
[2] Université Reims Champagne Ardenne, UMR-I 02 SEBIO, Reims, – UMRI – France
[3] Université de Toulon, Aix Marseille Université, CNRS, IRD, Mediterranean Institute of Oceanography (MIO), – CNRS-MIO, UM 110 – France
[4] Smithsonian Environmental Research Center, Edgewater, Maryland, USA – United States
[5] CNRS/ Univ Pau Pays Adour/ E2S UPPA, IPREM, UMR5254, Pau – IPREM-UMR 5254/LCABIE – France
[6] Institut méditerranéen dócéanologie – Institut de Recherche pour le Développement : UMR$_D$235, $AixMarseilleUniversité : UM110, UniversitédeToulon :$ $UMR7294, CentreNationaldelaRechercheScientifique : UMR7294 - -France$
[7] Department of Biology, University of Ottawa, Ottawa, Ontario – Canada

Anthropogenic perturbations have alarmingly tripled the mercury (Hg) content of surface Earth reservoirs compared to pre-anthropogenic conditions. Its organic form, methylmercury (MeHg) is a potent neurotoxin produced by anaerobic microbes that bioaccumulates in organisms and bioamplifies in food webs. Millions of people are exposed to MeHg through fish or rice consumption. The concentration and dynamics of MeHg in the ocean is the net result of three major processes: 1) formation of MeHg by methylation of inorganic-Hg (HgII) 2) MeHg degradation and 3) dimethylmercury degradation. The amount of HgII available for methylation is controlled by inputs from inland waters (e.g. rivers or groundwater), dry and wet atmospheric HgII deposition, as well as its reduction to Hg0 and subsequent evasion to the atmosphere. Recent work showed that Hg0 can be a substrate for HgII methylation suggesting that redox reactions can also affect Hg cycling away from the air/water interface. Microbes are known to play a central role in all reactions of Hg cycling including redox and methylation/demethylation. MeHg production in pelagic environments appears to be limited either to large anoxic water layers or to anoxic microenvironments encountered in oxic surface waters but more concentrated in oxygen minimum zones. Biological HgII methylation is dependent on the presence of the *hgcAB* gene cluster. MeHg might be degraded both biotically and abiotically. While abiotic photochemical MeHg degradation might govern its fate in euphotic surface marine waters, bacterial and archaeal demethylation are likely to dominate at depth or when light is absent. MeHg degradation can involve the *mer* operon (i.e., reductive demethylation) with the combinatorial action of MerB and MerA proteins sustaining a system for simultaneous MeHg degradation and

*Speaker

HgII reduction, respectively. Oxidative demethylation can also occur; it does not rely on the *mer* operon but rather results from cometabolic processes associated with carbon metabolism. Biodiversity studies relying on classical PCR amplification approaches targeting *hgcAB* and *merAB* sequences have significantly improved current knowledge on the diversity of organisms involved in Hg cycle. Such approaches can be biased, however. First, not all transformations conducted by microbes have been associated with genetic determinants, preventing the application of high throughput molecular tools to target such transformations. Furthermore, when a genetic target is available, the results of PCR amplification can be biased by the primer set used. This problem is inherent to the PCR method and is exacerbated when the genes studied present high variability and have not well localized conserved regions for primers hybridization, which is the case for *hgcAB gene cluster* and the *mer operon*. Finally, in the case of HgII methylation, the lack of a relationship between the abundance of the *hgcAB* gene cluster, its expression level and the associated reaction rate, has up to now impeded predictions of MeHg concentrations in complex environmental matrices. Microbial metagenomics/metatranscriptomics enable not only to screen for *hgcAB* and *mer* genes presence and activity in diverse ecosystems but can also reconstruct bacterial and archaeal metagenomes-assembled genomes (MAGs) to link taxonomy with metabolic potential. Unfortunately, experimental validations are still lacking to disentangle the role of putative methylators and demethylators in ocean Hg cycling. In this presentation, we review current approaches used to describe the presence and activity of microorganisms involved in Hg redox and methylation/demethylation transformations and their limitations for mechanistic understanding of Hg cycling in the environment, with a particular emphasis on marine ecosystems and the Mediterranean Sea.

5. Factors influencing the biological transfer of mercury in the Mediterranenan Sea

Daniela Banaru * [1], Mireille Harmelin-Vivien [1], Jérôme Baudrier [2], Sebastien Biton-Porsmoguer [1,3], Christophe Brach-Papa [4], Marine Briand [1], Marc Bouchucha [5], Charles-François Boudouresque [1], Paco Bustamante [6], François Carlotti [1], Fabienne Chavanon [5], Chia-Ting Chen [1], Tiphaine Chouvelon [5], Carine Churlaud [7,8], Pierre Cresson [9], Aurelie Dufour [1], Lars-Eric Heimbürger-Boavida [1], Ivan Dekeyser [10], Marie-Claire Fabri [11], Gael Guillou [8], Angélique Jadaud [12], Joël Knoery [13], Benoît Lebreton [8], Célia Losson [1], Francoise Marco-Miralles [11], Aurelle Mauffret [11], Benoît Mialet [8], Mélanie Ourgaud [1], Nathalie Wessel [11], David Point [14], Daniel Cossa [15]

[1] Institut Méditerranéen d'Océanologie (M.I.O.), UM110 – Aix-Marseille Université - AMU – France
[2] Ifremer (ODE/VIGIES) – Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) – Centre Atlantique - Rue de l'Ile d'Yeu - BP 21105 - 44311 Nantes Cedex 03, France
[3] Universitat de Girona (UdG) – Spain
[4] Laboratoire Biogéochimie des Contaminants Métalliques (LBCM) – Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Centre atlantique, Nantes – Rue de l'Ile d'Yeu, 44311 Nantes, France
[5] Laboratoire Biogéochimie des Contaminants Métalliques (LBCM) – Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) – France
[6] LIttoral ENvironnement et Sociétés [La Rochelle] (LIENSs) – CNRS : UMR7266, Université de La Rochelle – Bâtiment Marie Curie Avenue Michel Crépeau 17 042 La Rochelle cx1 - Bâtiment ILE 2, rue Olympe de Gouges 17 000 La Rochelle, France
[7] LIENSS – Université de La Rochelle – France
[8] Littoral Environnement et Sociétés (LIENSs) – Université de La Rochelle – France
[9] Ifremer, Laboratoire Ressources Halieutiques Manche Mer du Nord (RHBL) – Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) – 150, Quai Gambetta BP 699 62321 Boulogne sur Mer, France
[10] OSU Pytheas – Aix-Marseille Université - AMU – France
[11] Ifremer – Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Institut Français de Recherche pour l'Exploitation de la MER - IFREMER – France
[12] UMR 212 Ecosystèmes marins exploités – Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) – France
[13] Laboratoire de Biogéochimie des Contaminants Métalliques (LBCM) – Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) – Rue de l'Ile d'Yeu 44300 Nantes, France
[14] Géosciences Environnement Toulouse (GET) – Observatoire Midi-Pyrénées, Institut de recherche pour le développement [IRD] : UMR239 – Observatoire Midi-Pyrénées 14 Avenue Edouard Belin 31400 Toulouse, France
[15] Institut des sciences de la Terre (ISTerre) – CNRS : UMR5275, IFSTTAR, IFSTTAR-GERS, Université de Savoie, Université Joseph Fourier - Grenoble I, INSU, OSUG, Institut de recherche pour le développement [IRD] : UR219, PRES Université de Grenoble – BP 53 38041 Grenoble cedex 9, France

*Speaker

The transfer of mercury in food webs from sources to top predators is dependent of bioconcentration, bioaccumulation and biomagnification processes. The influence of species, tissues, age, size, sex, food and trophic level (δ15N), physiology and metabolism, as well as the environment and the sources will be presented through examples. Differences in accumulation of Hg in marine organisms will be shown in pelagic and benthic communities and in different trophic conditions (oligo-, meso-, eutrophic). Assessment of knowledge on the factors that influence the biological transfer of Hg will allow starting discussions on the methodological challenges and the study of some compartments and less known biological mechanisms. Trophic modelling could eventually integrate this knowledge in ecosystem models ranging from physics, to biochemistry and to fisheries resources. Le transfert du mercure dans les réseaux trophiques à partir des sources et jusqu'aux prédateurs supérieurs est dépendant de plusieurs processus: bioconcentration, bioaccumulation et bioamplification. A travers des exemples, seront montrés l'influence de l'espèce, du tissu, de l'âge, de la taille, du sexe, de l'alimentation et du niveau trophique (δ15N), de la physiologie et du métabolisme, ainsi que de l'environnement et des sources. Des différences d'accumulation du Hg dans les organismes marins seront montrées entre milieux pélagiques ou benthiques et entre catégories trophiques du milieu (oligo-, méso-, eutrophe). Ce bilan des connaissances sur les facteurs influençant le transfert biologique du Hg permettra de démarrer des discussions sur les défis méthodologiques, les compartiments et les mécanismes biologiques peu ou pas connus. La modélisation trophique pourrait à terme intégrer ces connaissances dans des modèles écosystémiques allant de la physique, à la biochimie et aux ressources exploitées par les pêcheries.

6. Mercury modeling in the Mediterranean Sea: state of the art and future research needs.

Ginevra Rosati * [1], Donata Melaku Canu [1], Amina Schartup [2], Johannes Bieser [3], Jean-Claude Dutay [4], Yelva Roustan [5], Mario Sprovieri [6]

[1] National Institute of Oceanography and Applied Geophysics (OGS) – Italy
[2] Harvard University – United States
[3] Institute for Coastal Research – Germany
[4] LSCE – Laboratoire des Sciences du Climat et de l'Environnement (LSCE) – France
[5] Centre d'Enseignement et de Recherche en Environnement Atmosphérique – EDF, Ecole des Ponts ParisTech, Université Paris-Est – France
[6] Istituto per lo studio degli impatti Antropici e Sostenibilità in ambiente marino (IAS-CNR) – Italy

Biogeochemical models are valuable tools to investigate the fate and transport of pollutants in the environment. Prompting a synthesis effort of available knowledge into a rigorous framework, they help highlighting gaps in processes understanding and/or data availability. Studies of mercury (Hg) cycling in marine environments are crucial to the understanding of monomethylmercury (MMHg) bioaccumulations and biomagnification along the marine food webs, up to humans. Mediterranean fish display high Hg concentrations which, according to a bioenergetic models study, is due both to chemico-physical and trophic factors. Integrated models are needed to further clarify sources and distribution of Hg species in different subareas of the Mediterranean Sea with different oceanographic and biogeochemical features. The latest budget of Hg species for the Mediterranean Sea (2014) was based on extrapolation from the literature of observed concentrations and transformation rate constants. The authors indicated diffusive sediment fluxes as the main source of methylated Hg species (MeHg) to the water column, in contrast with other observations made in the Northwestern Mediterranean Sea. To date, only one paper has sought to model the Hg cycle in the Mediterranean Sea at the basin scale, highlighting a poor understanding of Hg methylation and demethylation processes at that time (2007). Other modeling efforts have been focused on smaller areas; either regional seas (e.g. Adriatic Sea and the Gulf of Trieste) or coastal sites (e.g. Marano Grado Lagoon, Haifa Bay), in an attempt to clarify Hg species mobility and bioavailability in contaminated areas as well as to quantify their role as sinks or sources to the open sea. Indeed, a comprehensive assessment of 'legacy Hg' -released from coastal and former industrial areas- is still missing for the Mediterranean basin.

*Speaker

7. Modelling the biogeochemical cycle of mercury in the marine environment

Giovanni Denaro * [1], Daniela Salvagio Manta [2], Alessandro Borri [3], Maria Bonsignore [2], Davide Valenti [1,4], Andrea De Gaetano [3], Mario Sprovieri *

2

[1] Istituto di Biomedicina e Immunologia Molecolare "Alberto Monroy" (IBIM-CNR) – Italy
[2] Istituto per lo studio degli impatti Antropici e Sostenibilità in ambiente marino (IAS-CNR) – Italy
[3] Istituto di Analisi dei Sistemi ed Informatica "A. Ruberti" (IASI-CNR), Laboratorio di Biomatematica – Italy
[4] Dipartimento di Fisica e Chimica, Università degli Studi di Palermo – Italy

Modelling the biogeochemical cycle of mercury in marine environment has recently become a challenge of paramount importance for the scientific community. In the last years some authors reproduced the mass balance of Hg in the marine ecosystems by using biogeochemical models based on interconnected zero dimensional boxes (e.g. WASP models). In particular, we used this approach in previous studies, to calculate the mass balance of mercury in the highly contaminated AugustaBay (southern Italy). This work aims to reproduce the biogeochemical cycle of different mercury species (elemental, inorganic, methyl-Hg) in 3D domain of the AugustaBay by applying innovative mathematical tools. Specifically, an advection-diffusion-reaction model for Hg in seawater was coupled with a diffusion-reaction model for Hg in sediment pore water, in which the metal partition coefficients between dissolved (water and pore water) and particulate phases (Suspended Particulate Matter and sediment particles) were taken into account. Also, the effects on mercury concentration induced by seasonal variations of the most important environmental variables and the dynamics of de-adsorption of total mercury in the solid phase of the sediment were intensively explored. In order to better simulate the Hg chemical-physical processes, we calibrated the model parameters on the basis of both the experimental data collected in the Augusta Bay from May 2011 to October 2017, and the data reported for other polluted areas. Hence, we reproduced the spatio-temporal behaviour of (i) the concentrations of mercury species dissolved in the seawater and in pore water, (ii) the total mercury concentration in seawater, (iii) the total mercury adsorbed in sediments, and (iv) the horizontal and vertical mercury fluxes at the boundaries of the Augusta basin. A quantitative and statistical analysis between the theoretical results and field observations was made for the mercury concentration both in seawater and in pore water, and for the vertical and horizontal mercury fluxes at the boundaries of the 3D domain. The results showed a good agreement between the numerical and the experimental data. Finally, theoretical results evidenced a key role played by seasonal changes of environmental variables in terms of Hg geochemical dynamics and fluxes at the various interfaces.

*Speaker

List of participants

- Abouga Bodo Willy Karol
- Alleman Laurent
- Annesi-Maesano Isabella
- Baldy Virginie
- Banaru Daniela
- Bancon-Montigny Chrystelle
- Béjaoui Mustapha
- Bieser Johannes
- Bouchoucha Marc
- Bravo Andrea G
- Briant Nicolas
- Chaabane Hanene
- Chen Chia-Ting Salomé
- Chifflet Sandrine
- Chouvelon Tiphaine
- Cossa Daniel
- D'anna Barbara
- Delpoux Sophie
- Denaro Giovanni
- Desboeufs Karine
- Dufour Aurélie
- Dulac François
- Durrieu Gaël
- Dutay Jean-Claude
- El Houssainy Amonda

- El Idrissi Ouafa
- Garcon Guillaume
- Grunberger Olivier
- Harmelin-Vivien Mireille
- Hedgecock Ian M.
- Heimbürger-Boavida Lars-Eric
- Jacquet Schintu Stéphanie
- Jungas Colette
- Layglon Nicolas
- Lejeusne Christophe
- Lozingot Aurélia
- Melaku Canu Donata
- Migon Christophe
- Misson Benjamin
- Mounier Stéphane
- Ormeno Lafuente Elena
- Oursel Benjamin
- Pasqualini Vanina
- Petrova Mariia
- Pringault Olivier
- Proffit Magali
- Radakovitch Olivier
- Renault Pierre
- Rigaud Sylvain
- Rosati Ginevra
- Sakka Asma
- Schartup Amina
- Schmidt Natascha
- Sciare Jean
- Sempere Richard
- Sicre Marie-Alexandrine
- Sonke Jeroen

- Tedetti Marc
- Tedetti-Guigue Catherine
- Tronczynski Jacek
- Uzu Gaelle
- Vanneste Heleen
- Zaaboub Noureddine

Author Index

Abouga Bodo, Willy Abouga, 5
Acinas, Silvia G, 7
Amouroux, David, 5

Banaru, Daniela, 9
Baudrier, Jérôme, 9
Bieser, Johannes, 11
Biton-Porsmoguer, Sebastien, 9
Bonsignore, Maria, 12
Borri, Alessandro, 12
Bouchucha, Marc, 9
Boudouresque, Charles-François, 9
Brach-Papa, Christophe, 9
Bravo, Andrea G, 7
Briand, Marine, 9
BRIANT, Nicolas, 5
Bustamante, Paco, 9

Cabrol, Lea, 7
Carlotti, François, 9
Chavanon, Fabienne, 9
Chen, Chia-Ting, 9
Chouvelon, Tiphaine, 9
Churlaud, Carine, 9
Cosio, Claudia, 7
Cossa, Daniel, 3, 5, 9
Cresson, Pierre, 9

De Gaetano, Andrea, 12
Dekeyser, Ivan, 9
Denaro, Giovanni, 12
Dufour, Aurelie, 5, 9
Dulac, François, 4
Durrieu, Gaël, 5
Dutay, Jean-Claude, 11

Fabri, Marie-Claire, 9
Fajon, Vesna, 4, 5

Gardfeld, Katharina, 4
Garnier, Cédric, 5
Gilmour, Cynthia, 7
Goñi-Urriza, Marisol, 7
Guieu, Cecile, 5
Guillou, Gael, 9
Guyoneaud, Remy, 7

Harmelin-Vivien, Mireille, 9
Hedgecock, Ian M., 4
Heimbürger-Boavida, Lars-Eric, 5, 7, 9
Horvat, Milena, 5

Jadaud, Angélique, 9
Jiskra, Martin, 4

Knoery, Joël, 5, 9
Kotnik, Joze, 4

Layglon, Nicolas, 5
Layoun, Paul, 5
Lebreton, Benoît, 9
Losson, Célia, 9

Marco-Miralles, Francoise, 9
Marlière, Christian, 4
Mauffret, Aurelle, 9
Melaku Canu, Donata, 11
Mialet, Benoît, 9
Misson, Benjamin, 7
Monperrus, Mathilde, 5
MOUNIER, Stéphane, 5

Ourgaud, Mélanie, 9
Oursel, Benjamin, 5

Patel, Nathalie, 5
Petrova, Mariia, 5
Pirrone, Nicola, 4
Point, David, 9
Poulain, Alexandre J, 7

Quéméneur, Marianne, 7

Rosati, Ginevra, 11
roustan, yelva, 11

Salvagio Manta, Daniela, 12
Schartup, Amina, 11
Sonke, Jeroen, 4
Sprovieri, Francesca, 4
Sprovieri, Mario, 11, 12

Tessier, Emmanuel, 5
Tessier, Erwann, 5
Thomas, Bastien, 5

Valenti, Davide, 12
Vaneste, Heleen, 5

Wagener, Thibaut, 5

Wessel, Nathalie, 9

Zaaboub, Noureddine, 5