**SCOR Working Group Proposal Template**
**(max. 5000 words, excluding Appendix)**

**Title:**

# Rheology, nano/micro-Fluidics and bioFouling in the Oceans.

**Acronym:**

# RheFFO

**Summary/Abstract (max. 250 words)**

**Scientific Background and Rationale (max 1250 words)**

The sea is a non-Newtonian biofluid. Yet most oceanographers are still unaware of this, or if they are aware, they do not have the training to apply these findings to their own research and models.

Twentieth-century engineers successfully applied the Derjaguin-Landau-Verwey-Overbeek (DLVO) model of "no wall slip" to fluids in most industrial processes. This model was not designed for plankton. As recent developments in nano- and microfluidics, including "lab-on-a-chip", have shown, surfaces in fluids exert influence from nanometre to millimetre scale into the fluid. (Jenkinson, in press). This is extremely relevant to nano- and microplankton, particularly the micrometre-scale feeding appendages of copepods and other zooplankton.

Encounter and fouling of surfaces by plankton, including their larvae, take place largely in near-surface layers. Recent developments in "green" (i.e. non-toxic) methods of antifouling on ships and other marine structures, can be applied to investigate adhesion, recognition, and repulsion by plankton.

GEOHAB (2011) posed the question, "How can we quantify modifications in turbulence by phytoplankton through changes in the viscosity of its physical environment?" At that time, the state-of-the-art was that viscosity $\eta$ of seawater and freshwaters was composed of an aquatic component $\eta_W$ due to water (and salts) plus an excess organic component , $\eta_E$ due mainly to EPS.

Total viscosity,

$$\eta = \eta_W + \eta_E \qquad \text{[Pa s]} \qquad (1)$$

Broadly, $\eta_E$ shows a negative relationship power-law relationship with shear rate $\dot{\gamma}$, so that

$$\eta_E = k.\dot{\gamma}^P \qquad \text{[Pa s]} \qquad (2)$$

where $k$ is a coefficient related to EPS concentration and type. $P$ can vary from 0 to ~-1.4 (shear thinning), and has exceptionally been found positive (shear thickening). $\eta_E$ also varies with phytoplankton concentration. Using chlorophyll *a* concentration *chl* as a proxy for phytoplankton,

$$\eta_E = chl^Q.\dot{\gamma}^P \qquad \text{[Pa s]} \qquad (3)$$

where $Q$ is the phytoplankton concentration exponent, found to about 1.3 generally. Further research, however, has shown the $Q$ can vary locally with the growth phase of the bloom, and even become negative (negative correlation between viscosity and *chl* locally in a *Phaeocystis* bloom) (Seuront et al., 2006). EPS also imparts elasticity to the water. Swimming trajectories of copepods over scales of mm to cm are also greatly changed by viscosity from *Phaeocystis* EPS (Seuront & Vincent, 2008).

EPS thickening, moreover, is generally lumpy; this produces length-scale dependent viscosity, which can be modelled using a lumpiness exponent.

Eq. 3 can now be "corrected" for length scale by a third exponent:

$$\eta_E = k.chl^Q.\dot{\gamma}^P.(L/M)^d \qquad \text{[Pa s]} \qquad (4)$$

where $L$ is the length-scale of interest, $M$ is the length scale of measurement, and $d$ is the length-scale exponent. A model of whether lumpy EPS could thicken the water enough to stabilize a pycnocline found (Jenkinson & Sun, 2011a) found that the value of $d$ in Eq. 4 was very critical. To investigate $d$, $\eta$ of phytoplankton and bacteria (PB) cultures was measured in capillaries of different radii (Jenkinson & Sun, 2014). While $\eta$ was increased in some combinations of shear rate, capillary radius, 0.35 to 1.5 mm, and PB) species, presumably by EPS, $\eta$ was reduced in other combinations, including in low Reynolds-number flows, suggesting superhydrophobic drag reduction (SDR) at the surfaces of plankton and or aggregates of exopolymeric substance (EPS). SDR is well known on the surfaces of lotus leaves and many other natural and manufactured surfaces (Rothstein, 2010), where it can be associated with protection against dirt and fouling organisms (Durr & Thomason, 2010), while changing surface electrical fields (Qiu et al., 2011; Wang et al., 2014). These effects are active from nanometres to up to 25 µm (Ou et al., 2004) from surfaces.

**Some effects** of increased viscosity and elasticity, as well as nano- and microfluidics (NMF) (with suggested primary length scales) include:

| | **Effect(s)** | **References** | **Associated scales** |
|---|---|---|---|
| 1. | Damping of turbulence and of sub-Kolmogorov-scale water movement | Jenkinson (1986) | 1 nm – 1 m |
| 2 | Due to elasticity and lumpiness, complex changes to patterns of water movement, and de-coupling of shear rate from dispersion: | Jenkinson (1986) | 1 nm – 1 m |
| 3 | Partial and/or total clogging of the gills of fish, molluscs, tunicates, sponges, polychaetes, etc. | Jenkinson (1989), Jenkinson et al. (2007) | 1 nm – 1 mm |
| 4 | Due to rising organic matter and adsorption to the air-sea surface, reduction of air-sea gas exchange, wave and ripple damping. | Carlson (1987), Calleja et al. (2009) | 10 µm – 10 m |
| 5 | Complex situations, illustrated by *Phaeocystis*, which produces closely associated stiff mucus holding cells together in colonies, while also producing looser diffuse mucus that increases viscosity at larger scales, as studied in sludge organic aggregates. | Seuront et al. (2006), Liu et al. (2010). | 50 µm- 1 m |
| 6 | Flocculation into mucous aggregates, thus increasing sinking or rising speed and hence vertical organic flux. | Mari et al. (2012) | a.~100 µm<br>b. up to ~1000 m |
| 7 | Reinforcement of pycnoclines by PB EPS | Jenkinson & Sun (2011, 2014) | 10 cm-10 m |
| 8 | Trapping of toxins close to metabolically active surfaces, such as cell membranes and gills | Jenkinson (1989) | 10 nm-1 mm |
| 9 | Changes in electrical fields at surfaces of organisms, non-living organic structures and non-organic structures, relative to protection against corrosion, dirt and fouling | Qiu et al. (2011), Wang et al. (2011, 2014). | 1 nm-1 mm |
| 10 | Changes in viscosity and elasticity by coordinated swimming in plankton | Thutupalli et al (2011) | 1 µm- 1 mm |

For references, please see both “Key References” and “Members’ Key Publications”.

**Investigation techniques** of seawater and lakewater to be considered by the *RheFFO* WG include:
**Rheology**

1. Rheometry: a) concentric cylinder; b) sliding piston; c) capillary flow; d) ichthyoviscometry;

2. Studies of fluid movement at small scale: a) 3D particle image velocimetry (PIV); b) 3D particle tracking velocimetry (PTV);
3. Studies of small forces at small scale: Atomic Force Microscopy (AFM)
4. Combination of electrochemical techniques with rheometry, microscopy and PIV/PTV, ***in situ* if and when possible**;
5. Taking advantage of high biomass in many harmful algae blooms (HABs) to use high-viscosity, marked surface effects and intense cell-cell ecological, physiological, biogeochemical and encounter interactions.

**Nano- and microfluidics of biosurfaces (particularly sticking layers and slip layers at surfaces)**

6. High-speed video with PIV and PTV of flow through capillaries coated with organic sculptured layers of hydrophobic (Rothstein, 2010), hydrophilic (Bauer & Federle, 2009) and omniphobic (Wong et al., 2011) surfaces. To be combined with transmission electron microscopy (TEM), scanning electron microscopy (SEM), pressure/flow curves, and possibly standard rheometry of the test materials.
7. Scanning electrochemistry of organic matter film dynamics: Hanging mercury drop.
8. Use of electrochemical techniques developed to study the effects of biological coatings on corrosion dynamics;
9. Studies of attraction-repulsion fields, electrical double layers (EDLs).
10. Immunological type radicle-radicle recognition and adhesion.
11. Impact of phytoplankton and EPS on clogging microfiltration apparatus particularly in relation to desalination plants and harmful algal blooms (HABs). (See also following section.)

**Biofouling, with adhesion, recognition and repulsion**

12. Fouling organisms need to encounter suitable surfaces, recognise them as suitable, then initiate a series of actions to adhere to the surface, and possibly to use means to penetrate it. Organisms subject to fouling are likely to have evolved antifouling mechanisms to avoid being fouled. Related to fouling and antifouling actions can be considered:
    a) Predation and avoidance of predation
    b) Sexual encounter and its defeat;
    c) Parasitism/symbiosis and its defeat;
    d) Pathogenic infection (by bacteria, viruses) and its defeat.

13. Techniques developed largely for “green” biomolecule-modulated industrial antifouling techniques (for ships, cooling intakes, fish-farm cages and nets, etc.) need to be used to investigate fouling of organisms by other organisms and of living and non-living substrates in the sea (plankton, fish and benthic organisms, organic aggregates, sediment, rocks, etc.).
14. Impacts of biofouling and antifouling techniques on clogging of microfilters and its mitigation, particularly in relation to desalination plants.

**Rheology modification by co-ordinated swimming**

15. Consideration of rheology modification by “swarmers” (Herminghaus, 2011)

**Terms of Reference (max. 250 words)**

**Vision:** The ocean science community lacks expertise in (1) Rheology; (2) Nano- and microfluidics; (3) Fouling and antifouling, adhesion, recognition and protection in relation to trophic, sexual, parasitic pathogenic and other types of encounter, that take place close to electrically controlled surfaces including glycocalyxes. Without this knowledge among ocean researchers, modellers and engineers, future models of how the oceans will react ecologically and biogeochemically to future changes will be unnecessarily flawed.

**Objectives:**

**A** To create a corps of ocean researchers, modellers and engineers literate in (1) Rheology, (2) Nano- and microfluidics; (3) Fouling and antifouling at surfaces, expertise that they will teach to their students, graduate students and postdocs.

**B**. During the lifetime of the WG, carry out expert-to-expert interdisciplinary CB and brainstorming sessions, to allow the WG members to carry this expertise to other oceanographic problems, to involve the members' students in theoretical and empirical research, published in scholarly papers, books, multimedia, and incorporated in outreach material across the globe.

**Deliverables**

See Working Plan below.

**Working plan (logical sequence of steps to fulfil terms of reference, with timeline. Max. 1000 words)**

**Kick-off time**, can be discussed with SCOR, perhaps September 2015, OSM in Qingdao in April 2016.

| **Year** | **Actions** |
|---|---|
| 1 | To kick off the WG an advanced draft of the RheFFO WG Core Research Programme and Recommendations will be created, by the members before any meeting..<br><br>Back-to-back two-day Open Science Meeting and two-day restricted Brainstorming Workshop 1, both held in the Chinese Academy of Sciences, Institute of Oceanology, Qingdao, China.<br><br>**Six to 12 months from beginning of WG in spring or autumn**<br>**Two-day Open Science Meeting on RheFFO:** Invitations widely disseminated internationally.<br>Anticipated attendance 50-70.<br>Sponsorship sought in Chinese science organizations, city, province and national governments, cultural and scientific organizations, private and public companies.<br>Publication of refereed proceedings in ***Chinese Journal of Oceanology and Limnology*** **(CJOL)** (Ian Jenkinson is Editor in Chief), including summary and conclusions and recommendations paper by the committee of experts.<br><br>**RheFFO Workshop 1**<br>Immediately following the Open Science Meeting;<br>This is a **Two-day restricted workshop on RheFFO.** (1 day - science reports, discussion and expert-to-expert interdisciplinary CB; 0.5 day writing the summary, conclusions, recommendations; 0.5 day WG organization, and preparation for Year 2).<br>Anticipated attendance 10 (all full members participate.)<br><br>After the OSM and workshop, the experts will work together to write a paper on a designated aspect of RheFFO, for a high-impact, open-access, scholarly journal, led by designated chair.<br><br>Decide on time and place of next workshop in about 12 months.<br><br>Finalise the RheFFO Core Research Programme, with recommendations for future ocean research, CB.<br><br>Progress report 1 for SCOR leadership. |
| 2 | **RheFFO Workshop 2:** time and place decided at previous workshop.<br><br>All experts participate, with their PGs and PDs as deemed suitable.<br>Anticipates attendance 10 to 20. |

| | |
|---|---|
| | Continued expert-to-expert interdisciplinary CB – One lecture per expert.<br><br>Decide time and place of next workshop<br><br>After the workshop, the experts will work together to write a paper on a designated aspect of RheFFO different from that in Year 1, for a high impact open access scholarly journal, led by designated chair.<br><br>Progress report 2 for SCOR leadership |
| 3 | **RheFFO Concluding Workshop 3:** time and place decided at previous workshop.<br><br>All experts participate, with their PGs and PDs as deemed suitable.<br>Anticipates attendance 15 to 25.<br><br>Continued expert-to-expert interdisciplinary CB –. One lecture per expert.<br><br>Decide whether a future workshop is needed, and if so, its time and place.<br><br>After the present workshop, the experts will work together on a paper on a designated aspect of RheFFO different from that in Years 1 and 2, with overall conclusions for a high impact open access scholarly journal, led by one or two designated chairs.<br><br>Progress report 3.for SCOR leadership |
| 4 | **In Year 4, collaboration will be done by electronic contact, and physical encounters of opportunity, unless a designated meeting is deemed necessary.**<br><br>All the publications and reports shall be completed or in press by the end of Year 4.<br><br>Final report of the WG for SCOR leadership.<br><br>In additional to this final WG report, a final paper for high-level publication will be prepared, that will be a scientific review of new conclusions derived from results obtained by members and others, made during the WG leading to conceptual advances in rheology, nano- and microfluidics, and biofouling, pointing out new questions and gaps in knowledge, and recommendations for future research. |

**Deliverables (state clearly what products the WG will generate. Should relate to the terms of reference. Max 250 words). A workshop is not a deliverable.  Please note that SCOR prefers that publications be in open-access journals.**

Proceedings of the Kick-off OSM in Year 1, with 10-20 refereed papers, to be published as a special edition of *Chinese Journal of Oceanology and Limnology.*

1 Kick-off Core research programme for the RheFFO WG

4 papers in top learned journals.

3 annual progress reports

1 Final Report for publication by SCOR.

**Capacity Building (How will this WG build long-lasting capacity for practising and understanding this area of marine science globally. Max 500 words)**

Capacity building (CB) will be intense in this WG, and partly atypical.

Because the WG will be highly interdisciplinary, initial CB will concentrate on the experts building capacity in each other to produce a world-wide corps of scientists with expertise in rheology, nano- and microfluidics, and biofouling and antifouling, along with the electrochemistry tools to do some of this research, all in relation to plankton ecology, biogeochemistry and other aspects of oceanography. This expert-to-expert CB will continue throughout the WG to progressively deepen interdisciplinary understanding.

In addition, from year 2 to year 4, more classical CB will kick in, with the different experts building interdisciplinary capacity in younger scientists. Interdisciplinary expertise will furthermore be built in these young scientists by teaching and co-mentoring of PDs and PGs by several experts, as well as other exceptional young scientists invited into the WG workshops.

**Working Group composition (as table). Divide by Full Members (10 people) and Associate Members, taking note of scientific discipline spread, geographical spread, and gender balance. (max. 500 words)**

Full Members (no more than 10, please identify chair(s))

| Name | Gender | Place of work | Expertise relevant to proposal |
|---|---|---|---|
| 1 Ian R. Jenkinson<br>Initiator, possible chair | M | Chinese Academy of Science Institute of Oceanology, Key Laboratory for Ecology and Environmental Sciences, Shandong, Qingdao, China | Physical-Chemical-Biological coupling, particularly related to plankton. Pioneer on measuring the rheology (viscosity and elasticity) of seawater, particularly in relation to phytoplankton and harmful algal blooms.<br>Rheology and ocean turbulence.<br>Superhydrophobic surfaces.<br>engineering;<br>Early-career research on algal biofouling. |
| 2 Elisa Berdalet<br>Possible chair | F | Institut de Ciències del Mar (CSIC). Pg. Marítim de la Barceloneta, 37-49. Barcelona, Catalunya, Spain | Physical-biological interactions. - Harmful Algal Blooms. - Biochemical methods. - Microplankton physiology.<br>Vice-chair of the Scientific Steering Committee of the SCOR/IOC-UNESCO program GEOHAB, Global Ecology and Oceanography of Harmful Algal Blooms (since 2009). |
| 3 Stephen Herminghaus | M | Max Planck Institute of Dynamics and Self-Organization, Dept. Dynamics of Complex Fluids, Göttingen, Germany | Head of large research group at Max-Planck-Institut. Fields relevant to this WG are dynamics of complex systems, surface effects on deformation, effects of swarmers on liquid rheology. |
| 4 James G. Mitchell<br>Possible chair | M | School of Biological Sciences, University of Flinders, Adelaide, South Australia | His research group consists of 27 people, including postdoctoral fellows and scientific staff from all over the world. Research in his group focuses on the influences of nanometer to micrometer scale processes on marine ecosystems. The ocean is a complex environment on this scale. Lessons they have learned have been applied to nanotechnology, including microfluidics and nanofabrication. |
| 5 Qiu Ri | M | State Key Laboratory for Marine Corrosion and Protection, Luoyang Ship Material Research Institute, Qingdao, Shandong, China | Assistant professor. Research interests are prevention of marine biofouling and corrosion, particularly using “green” organic techniques and surface properties.<br>Superhydrophobic surfaces.<br>Electrochemistry as a tool to measure ion migration and as for changing behaviour of fouling organisms. |
| 6 Laurent Seuront<br>Possible chair | M | Centre National de la Recherche Scientifique, | Phytoplankton, zooplankton, coastal oceanography, multiscaling and |

| | | | |
|---|---|---|---|
| | | Laboratoire d'Océanologie et de Géosciences, Université de Sciences et de Technologies de Lille, Station Marine, Wimereux, France. | (multi)fractals in physical, biological and economic systems, and particularly in marine ecology, seawater viscosity in relation to phyto- and bacterioplankton. |
| 7 Peng Wang | M | Chinese Academy of Science Institute of Oceanology, Key Laboratory for Marine Corrosion and Protection, Qingdao, Shandong, China | Assistant professor. Research interests are prevention of marine corrosion and biofouling, particularly using "green" organic techniques and surface properties. Electrochemistry. Superhydrophobic surfaces. |

Possibility for adding member(s)

Associate Member (no more than 10)

| Name | Gender | Place of work | Expertise relevant to proposal |
|---|---|---|---|
| 1 Tim Wyatt | M | CSIC, Institut de Investigaciones marinas, Vigo, Galicia, Spain | HABs,<br>fisheries,<br>organic matter and ecological engineering;<br>eclecticism and excellent writing style. |
| 2 Li ZHUO | F | Tongji University, College of Environmental Science & Engineering, Shanghai, China | |

Possibility for adding member(s).

**Working Group contributions (max. 500 words)**

Detail for each Full Member (max. 2 sentences per member) why she/he is being proposed as a Full Member of the Working Group, what is her/his unique contribution?

**BERDALET, Elisa.**

1. Elisa Berdalet is an expert on the modulation of the ecology and physiology of different microplankton groups by physico-chemical processes especially at small spatio-temporal scales.
2. She shall contribute to the WG through her experience in biochemistry (including dissolved organic compounds), physiology of phytoplankton and dynamics of harmful algal blooms, as well as using her recent experience of biofouling experiments related to desalination plants.

**HERMINGHAUS, Stephen**

1. Stephan Herminghaus heads the department 'Dynamics of Complex Fluids' at the Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, that performs research on collective behavior and pattern formation in soft matter systems, which are of central relevance in many geoscience problems, in particular for understanding the dynamics of self-propelled entities, such as some plankton.
2. SH shall provide expertise and guidance in microfluidics, rheology and structure formation in complex matter to the WG, will provide equipment and be instrumental outside the WG for the study of the interaction of active swimmers with the surrounding flow fields.

**JENKINSON, Ian R.**

1. Ian Jenkinson is a pioneer on measuring the viscoelasticity of seawater and algal cultures, in relation to turbulence and nano- and microfluidics in plankton, as well as to ecology, biogeochemistry and evolution, and he is now a researcher at the Chinese Academy of Science, Qingdao, China, and ACRO, France, as well as journal editor (Oxford University Press, Springer Publications).
2. IJ shall guide the WG particularly in respect to rheological aspects of seawater, and to the composition and subject composition of the WG deliberations.

**MITCHELL, James G.**

1. James Mitchell specialises in microscale structures and to biodynamic relations, particularly in plankton.
2. JG shall guide the WG in water flow and biodynamics at small scales, as well as in microfluidics and nutrient flux at rough and sculptured surfaces.

**QIU, Ri**

3. Ri Qiu has been using electrochemical tools to work on marine antifouling based on superhydrophobicity and slippery liquid-infused porous surfaces (SLIPS) for over 5 years, and he has 4 recent publication related to marine fouling and corrosion control.
4. Ri Qiu shall thus guide the WG particularly in relation to surface-based and electrochemically-based control by organisms, both of surface fouling and its defeat.

**SEURONT, Laurent**

1. L. Seuront is internationally recognized for his expertise in micro-scale patterns and processes in the ocean.
2. LS's 5 recent publications describing (i) the origin of biologically-driven viscosity and its temporal dynamics and (ii) inferring the potential impact of this excess viscosity on structure and function in pelagic ecosystems, shall allow him to guide the WG in relation to bioproduction of excess viscosity, as well as its effects on structure and function in pelagic ecosystems.

**WANG, Peng**

1. Peng Wang has worked for several years on the effects of superhydrophobic surface structure on modifying electrical fields and reducing corrosion. He is an expert in electrochemistry.
2. PW shall use his expertise for helping the WG to understand biomodification of surfaces and electrical fields at the surfaces of plankton organisms, and shall build capacity in the biologist members of the WG.

**Relationship to other international programs and SCOR Working groups (max. 500 words)**

- Air-sea exchange, ripple and wave dynamics, air-sea gas exchange, including GLOBEC, SOLAS, WOCE...
- Ocean turbulence programmes, including GOTM, GETM, FABM.
- Programmes related to ocean ecosystem ecology and biogeochemistry, related to global human population and lifestyle, such as IMBER.
- Programmes on dynamics of erosion-and deposition, dredging, etc. of cohesive sediment and fluid mud dynamics.
- Plankton encounter dynamics, trophic dynamics, mating and social dynamics in plankton.
- Programmes in Rheology
- Programmes in nano- and microfluidics.
- Programmes on protection against corrosion and biofouling of ships, aquaculture facilities, and other marine structures.

**Key References (max. 500 words)**

**Please see also "Key Publications" by WG members.**


Bauer, U. & Federle, W. The insect-trapping rim of Nepenthes pitchers: surface structure and function. Plant Signaling & Behavior, 2009, 4, 1019-1023

Berdalet, E., McManus, M.A., Ross, O.N., Burchard, H., Chavez, F., Jaffe, J.S., Jenkinson, I., Kudela, R., Lips, I., Lucas, A., Rivas. D., Ruiz de la Torre, M.C., Ryan, J., Sullivan, J. & Yamazaki, H. (2014). Understanding harmful algae in stratified systems: reviews of progress and identification of gaps in knowledge. Deep-Sea Research, II, 101: 4-20.

Calleja, M.L.; Duarte, C.M.; Prairie, Y.T.; Agustí, S. & Herndl, G.J., 2009. Evidence for surface organic matter modulation of air-sea $CO_2$ gas exchange. Biogeosciences, 6, 1105-1114

Carlson, D.J. 1987, Viscosity of sea-surface slicks Nature, 329, 823-825.

Durr, S. & Thomason, J.C. (eds.) (2010) Biofouling Wiley-Blackwell, Chichester, England, 450 pp.

GEOHAB, 2011. Modelling: A Workshop Report. D.J. McGillicuddy, Jr., P.M. Glibert, E. Berdalet, C. Edwards, P. Franks, and O. Ross (eds). IOC and SCOR, Paris and Newark, Delaware.

Jenkinson, I.R. 1989. Increases in viscosity may kill fish in some blooms. *In*: Okaichi, T.; Anderson, D. & Nemoto, T. (eds.) Red Tides, Elsevier, pp. 435-438.

Jenkinson, I.R. & Sun, J. 2011. A model of pycnocline thickness modified by the rheological properties of phytoplankton exopolymeric substances J Plankton Res, 33, 373-383

Liu, X.-M.; Sheng, G.-P.; Luo, H.-W.; Zhang, F.; Yuan, S.-J.; Xu, J.; Zeng, R.J.; Wu, J.-G. & Yu, H.-Q. Contribution of Extracellular Polymeric Substances (EPS) to the Sludge Aggregation Environmental Science & Technology, 2010, 44, 4355-4360.

Mari, X.; Torréton, J.-P.; Trinh, C.B.-T.; Bouvier, T.; Thuoc, C.V.; Lefebvre, J.-P. & Ouillon, S. (2012) Aggregation dynamics along a salinity gradient in the Bach Dang estuary, North Vietnam. Est cstl mar Sci, 96, 151-158.

Ou, J.; Perot, B. & Rothstein, J. P. (2004) Laminar drag reduction in microchannels using ultrahydrophobic surfaces Phys Fluids, 16, 4635 (9 p.)

Qiu, Ri; Wang, Peng; Zhang, Dun & Wang, Yi, (2011) Anodic aluminium oxide matrix encapsulating nonivamide for anticorrosion and antifouling application Advanced Materials Research, 189-193, 786-789.

Rothstein, J. P. Slip on superhydrophobic surfaces Ann Rev Fluid Mech, 2010, 42, 89-209.

Yamasaki, Y., Shikata, T., Nukata, A., Ichiki, S., Nagasoe, S., Matsubara, T., Shimasaki, Y., Nakao, M., Yamaguchi, K., Oshima, Y., Oda, T., Ito, M., Jenkinson, I.R., Asakawa, M. & Honjo, T., 2009. Protein-polysaccharide complexes of a harmful alga mediate the allelopathic control within the phytoplankton community. ISME-J. 3: 808-817.

Wong, T.-S.; Kang, S.H.; Tang, S.K. Y.; Smythe, E.J.; Hatton, B.D.; Grinthal, A. & Aizenberg, J. Bioinspired self-repairing slippery surfaces with pressure-stable omniphobicity Nature, 2011, 477, 443-447.

Wyatt, T. & Ribera d'Alcalà, M. (2006). Dissolved organic matter and planktonic engineering. IESM Workshop Monographs, No. 28, 13-23.


## Appendix

For each Full Member, indicate 5 key publications related to the proposal.

**BERDALET, E.**

Simon, F. X., E. Berdalet, F. A. Gracia, F. España, J. Llorens. (2014). Seawater disinfection by chlorine dioxide and sodium hypochlorite. A comparison of biofilm formation. Water, Air, & Soil Pollution: 225:1921-1932.

Simon, F. X., E. Rudé, E. Berdalet, J. Llorens, S. Baig. (2013) Effects of inorganic nitrogen (NH4Cl) and biodegradable organic carbon (CH3COONa) additions on a pilot-scale seawater biofilter. Chemosphere 91: 1297-1303. http://dx.doi.org/10.1016/j.chemosphere. 2013.02.056.

Berdalet, E., Llaveria, G., Simó, R. (2011) Modulation of small-scale turbulence on methylsulfoniopropionate (DMSP) concentration in an Alexandrium minutum (Dinophyceae) culture: link with toxin production. Harmful Algae 10: 88-95. doi:10.1016/j.hal.2011.08.003.

Llaveria, G., Garcés, E., Ross, O.N., Figueroa, R., Sampedro, N., Berdalet, E. (2010) Significance of small-scale turbulence for parasite infectivity on dinoflagellates. Mar. Ecol. Prog. Ser. 412: 45-56. doi: 10.3354/meps08663.

Llaveria, G., Figueroa, R., Garcés, E., Berdalet, E. (2009) Cell cycle and cell mortality on Alexandrium minutum (Dinophyceae) under small-scale turbulence. J. Phycol. 45(5): 1106-1115. DOI: 10.1111/j.1529-8817.2009.00740.x.

**HERMINGHAUS, S.**

K. Thomas, S. Hermminghaus, H. Porada, L. Goehring; (2013). Formation of Kinneyia via shear-induced instabilities in microbial mats, Phil. Trans. A 371 20120362.

Hermminghaus, S (2012) Universal Phase Diagram for Wetting on Mesoscale Roughness. Phys. Rev. Lett. 109, 236102.

S. Thutupalli, R. Seemann, S. Hermminghaus; (2011). Swarming behavior of simple model squirmers, New J. Phys. 13 073021.

Uppaluri S, Heddergott N, Stellamanns E, Hermminghaus S, Zöttl A, Stark H, Engstler M, Pfohl T. (2012). Flow loading induces oscillatory trajectories in a blood stream parasite, Biophys. J. 103, 1162-1169.

Anupam Sengupta, Stephan Herminghaus, and Christian Bahr (2012) Opto-fluidic velocimetry using liquid crystal microfluidics. Appl. Phys. Lett. 101 164101.

**JENKINSON, Ian R.**

Jenkinson, I.R. (in press). Nano- and microfluidics, rheology, exopolymeric substances and fluid dynamics in calanoid copepods. In: Seuront, L. (ed.), *Copepods: Diversity, Habitat and Diversity*, Nova Science Publishers, Inc., 43 p.

Jenkinson, I.R. & Sun, J. (2014). Laminar-flow drag reduction found in phytoplankton and bacterial culture: Are cell surfaces and hydrophobic polymers producing a Lotus-leaf Effect? Deep-Sea Research II, 101, 216-230.

Jenkinson, I. R. & Sun, J. (2010). Rheological properties of natural waters with regard to plankton thin layers. A short review J mar Syst, 2010, 83, 287-297.

Jenkinson, I. R. & Biddanda, B. A. (1995). Bulk-phase viscoelastic properties of seawater: relationship with plankton components Journal of Plankton Research, 17, 2251-2274.

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