Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (proposed acronym: P-OBS)

Working Group proposal submitted to SCOR April 2017

1. Summary/Abstract

Measurements to characterize life in the ocean—including its composition, abundance, and changes in distribution—are fundamental to our understanding of marine ecosystems. The abundance of many fish species, sea birds, and marine mammals is critically tied to fluctuations in the abundance of smaller planktonic organisms. Similarly, plankton mediate the cycles of many chemical elements in the ocean that are critical for life, including oxygen, nitrogen, phosphorus, carbon, and many others.

The primary goal of this proposed SCOR Working Group (WG) is to identify measurements that can expand the number of observations of biological stocks, diversity, and rates or fluxes of planktonic organisms. The objective is to identify methods and technologies that can be incorporated into large-scale sampling programs such as GO-SHIP and OceanSITES as well as other similar programs from around the world. Emphasis of the WG would be on methods and technologies that can be implemented in the *short term* without disruption to established observing programs, and identifying gaps and opportunities that can significantly increase the number of routine and sustained observations of life in the ocean in the longer term. A document produced by this WG will identify the rationale for each measurement, associated costs and human investment (e.g., technical expertise and time needed), and data collection, quality control (QC), and data archival protocols.

2. Scientific Background and Rationale

2.1 Why do we need sustained biological observations?

Oceanic plankton, the base of the marine food web, are extremely under-sampled. Their diversity, abundance, and variability are largely unknown at high spatial and temporal resolution. There is a need to establish a baseline of distribution and phenology (change in seasonal timing) in different regions of the ocean. As of today, there is still no clear consensus regarding the processes responsible for phytoplankton and zooplankton phenology. There are incompatible top-down and bottom-up arguments brought to describe the same phenomena (e.g., the North Atlantic spring bloom, or changes in the abundance and make-up of phytoplankton and zooplankton in any region).

Higher-resolution information on changes in phytoplankton and zooplankton is fundamental to constrain ecosystem and biogeochemical models. These models are used to forecast the success and recruitment of organisms such as fish, the efficiency of food webs in cycling elements and transferring energy from one trophic level to another, and understanding and forecasting of water quality and other changes that affect rates and composition of biological stocks. These models require proper parameterization of plankton and their functions at appropriate temporal and spatial resolution, and are important because they help develop fundamental understanding about life in the ocean and its biogeochemical consequences. Models are the only way to evaluate large-scale processes such as the potential expansion of hypoxic areas in the ocean, the modulation of air-ocean exchange of gases (e.g., oxygen, carbon dioxide), and the amount of organic matter that may be sinking to the bottom of the ocean, where food for deep ocean life is otherwise limited. Models are also a powerful tool to predict the response of plankton to climate change, with possible feedbacks to the ecological and biogeochemical functioning of the ocean.

2.2 Emerging technologies to maximize investments in ocean observing

Large investments have been made in long-term ocean measurement infrastructure (e.g., Global Ocean Observing System, GOOS). These include the development of long-term ecological monitoring stations, coordination for repeated observations on ship lines, sustained moorings, deployment of autonomous vehicles, and various other remote data-collection technologies, such as cabled observatories. Many of these are deployed over large geographical domains and are intended for long-term observations. Important developments in technologies to measure physical and chemical parameters (e.g., salinity, temperature, oxygen, pH, currents) have meant that these parameters tend to make up the majority of the observations collected from automated platforms today. Adding the capability to measure biological parameters (e.g., stock, diversity, rates and fluxes) to these existing platforms and programs would fill critical gaps in our knowledge of ecosystem function. Linking such multidisciplinary measurements to ocean color radiometry, other remote sensing technologies, and other global observing systems (e.g., BGC-Argo, CPR surveys) will assist in better characterizing and explaining synoptic changes of life in the ocean. Developments in biological and bio-optical sensors, including genetic analyses, automated microscopy and flow cytometry, provide a pathway for the development and implementation of biological observations as part of global and regional ocean observing systems.

2.3 Benefits:

SCOR can foster progress in a number of areas by convening a Working Group focused on developing a strategy for automated, sustained, and widespread plankton observations. Specifically:

Science: increased biological data are critical to quantify variability of known plankton in space and time, discover and quantify new life forms, constrain models, and better characterize processes leading to ecosystem changes.

Society: data on plankton are critical to quantify marine food webs, detect harmful algal/cyanobacterial blooms, and sustain ecosystem services such as fisheries and nutrient cycling.

Observing systems: increasing the value of these assets to science and society, including developing markets of technology and information transfer. The outcomes from our WG will benefit many other national and international programs (e.g. OOI, bioGEOTRACES) that have similar platforms and interest in sampling biological properties.

Conservation: Establishment of ecosystem-based approaches to marine resource management critically depends on sufficient data to quantify ecosystem members and functions.

Ultimately, developing the strategy to incorporate plankton observations into global observing systems, using well-described and robust protocols, facilitates the development of technology and incorporation of observations in a framework spanning from viruses to fish.

2.4 The challenge:

We propose to develop sets of detailed recommendations to augment existing, large-scale sampling programs with feasible observations of phytoplankton and zooplankton. The recommendations will be prioritized based on science and information content. A strategy will be developed to prioritize the technology so that observations can be ramped up by the systematic incorporation into various Global Ocean Observing System elements. The assessment will include realistic costs and the requirement for capacity development.

The incorporation of biological measurements into regional ecosystem status and trend assessments is not trivial. Scientists, modelers, and resource managers are often not aware of the data available, methods of collection, or other limitations of biological measurements (Everett et al., 2017). Hence, it is critical that data disseminated follow standardized protocols for collection and quality control. Dissemination is incomplete without adequate metadata. Recommendations for the community also need to include suggestions for data repositories, descriptions of what the data represent, and examples of how such data have been used. These examples will help promote the collection of additional observations and will facilitate the application of ocean biology information in research, management, and sustainable development.

This SCOR WG would address the following goals:

1. Provide recommendations to GO-SHIP and OceanSITES regarding instrumentation and water-sample analysis that should be added to their protocols together with their scientific relevance and resource requirements (both in funds and people time). The recommendations would be broadly applicable to other national, regional, and global observing systems.
2. Deliver the appropriate protocol and provide appropriate points of contact for each recommended measurement.
3. Identify databases to curate the data and the associated requirements.
4. Identify synergies with other programs (e.g., BGC-Argo, spaced-based measurements, Continuous Plankton Recorder surveys) to provide complementary measurements and cross-validation.
5. Build capacity in the access to, and use of, biological oceanographic datasets

2.5 The Role of SCOR

SCOR is uniquely positioned to provide credibility, weight, and support to this international and diverse group of experts to trace a viable path to increased observations of life in the ocean.

3.0 Terms of reference

***General*:** To identify best practices (technologies and sampling protocols) and technical feasibility to incorporate plankton measurements into global ocean observing platforms (initially GO-SHIP and for expansion into the mooring array of OceanSITES).

Specific:

1. Identify current technologies (sensors as well as water sample analysis) that can be integrated into existing observing infrastructure to provide input and guide studies of plankton for marine ecosystem and biogeochemistry studies.

2. Provide the necessary details associated with every technology/measurement proposed (e.g., power, cost, and human effort).
3. Document potential applications, including science case studies and lists of publications, and document measurement protocols. Develop adequate protocols when these are not available.
4. Identify synergies with specific measurements done from other observing programs (e.g., BGC-Argo, space-based measurements, Continuous Plankton Recorder surveys) to provide cross-calibration and a better representation of the 4-D distribution of the parameter measured.
5. Identify technological limitations and/or gaps, and identify areas of priority investments to develop and implement the required observation technologies and tools for specific needs.
6. Increase awareness of the availability of biological oceanographic datasets internationally and identify barriers to their access and use, particularly in developing nations.

4.0 Work Plan

The group is planning to convene three times by meeting in conjunction with major ocean science conferences so that some Full Members will be able to self-fund their travel costs and to maximize the likelihood that Associate Members will attend.

Month 1-6: Sep. 2017-Feb. 2018. Focus on planning; Find champions to review existing measurements (Bio-optics, flow-cytometry, genetics, Bio-Acoustics, imaging, HPLC). Contact experts for input and references.

Month 6: Kick off meeting (in conjunction with the Ocean Sciences 2018). Draft an *Eos* article advertising the WG (Deliverable a). Work on chapters associated with above measurements.

Month 6-14: Setup of website with content. Submit *Eos* article. Prepare presentations for OceanObs'19 about adding plankton measurements to GO-SHIP. Work on chapters for manual, website content and identify gaps and people in the community able to contribute relevant expertise. Draft of manual to GO-SHIP.

Month 14: 2nd meeting (in conjunction with the OceanObs'19). Preset draft of manual to GO-SHIP, ask community for feedback. Outline work on OceanSITES manual. Identify community members who could contribute their relevant expertise.

Month 14-27: Answer feedback by month 20Final editing of manual for plankton measurements for GO-SHIP (Deliverable b). Identify gaps in OceanSITES manual.

Month 27 or 32: 3rd (final) meeting (in conjunction with Fall AGU or Ocean Sciences 2020 or spring EGU). Capacity-building workshop for early-career researchers (deliverable e). Final editing of OceanSITES manual (deliverable c) and website (deliverable d). Work on Report to SCOR office.

5.0 Deliverables

a. An *Eos*-type article after the first meeting reporting to the community about the activity and inviting input.
b. A manual with the protocols for plankton measurements on board research vessels (initially GO-SHIP but expandable to Ships of Opportunities).
c. A manual with the protocols for plankton measurements with research buoys (initially OceanSITES but expandable to other programs, including cabled observatories).
d. A website where our findings will be disseminated. The website will include information on ALL the specifics outlined above.
e. A workshop supporting capacity-building for early career researchers.
f. Present progress at conferences associated with the meetings.

We will contact scientific societies and scientific agencies (e.g. IOC) to see if they will be willing to publish the reports we will produce (including assignment a doi), so that the reports' future use could be tracked.

6.0 Capacity Building

The product of this working group will allow observing systems and programs throughout the world to identify measurements that can be added to their infrastructure. The deliverables will help the community understand the expanded scope of the science that the observations will support, the cost and effort associated with the measurements, databases where data could/should be submitted to, and experts available for consultation.

We plan a specific capacity-building workshop for early career researchers (ECRs) in conjunction with the Ocean Sciences meeting in 2020, particularly encouraging participation from developing nations. The workshop will support broader awareness of the availability of bio-oceanographic datasets, and identify specific communication and infrastructure gaps limiting their wider dissemination. We will approach SCOR requesting support for attendance by two ECRs from developing nations, from its grant for travel of developing country scientists. The WG will also ask SCOR to encourage its national committees (from developing and developed countries) to send their early-career scientists to the workshop. The workshop will be modeled on the ECR workshop held at the SCOR-sponsored Goa symposium in December 2015, which was assisted by one of the WG co-chairs (Anya Waite).

7.0 Working Group composition

7.1 Full members (responsible to produce the deliverables)

Name	Gender	Place of work	Expertise
Emmanuel Boss (co-chair)	M	University of Maine, US	Optical oceanography and the use of optics to study ocean biogeochemistry and ecology, in-situ observing systems, BGC-Argo, Ocean Color, Sea-going.

Anya M. Waite (co-chair)	F	Alfred Wegener Institute, Germany	Ocean biogeochemistry; particle dynamics; marine food webs; biophysical coupling; mesoscale dynamics; Sea-going.
Silvia G. Acinas	F	Spanish National Research Council, Spain	Microbial ecology, flow cytometery, microbial genomics, Sea-going.
Ilana Berman-Frank	F	Bar-Ilan University, Israel	Phytoplankton photosynthesis and eco-physiology, aquatic microbial ecology, biological oceanography, marine N_2 fixation, in-situ flow cytometry, Anthropogenic impacts, Sea-going
Marcela Cornejo	F	Pontificia Universidad Católica de Valparaíso, Chile.	Biological rates and biogeochemistry, seagoing.
Katja Fennel	F	Dalhousie University, Canada	Coupled physical-biogeochemical and ecosystem modeling, Data assimilation.
Heidi M. Sosik	F	Woods Hole Oceanographic Institution	Phytoplankton ecology and photophysiology, automated flow cytometry, automated microscopic imaging, ocean color, biological oceanography, single cell to ecosystem. Sea-going.
Sandy Thomalla	F	Southern Ocean Carbon and Climate Observatory CSIR, South Africa	Biological carbon pump and primary productivity and their relation to physical and biogeochemical controls. Sea-going.
Julia Uitz	F	CNRS, Laboratoire d'Oceanographie de Villefranche, France	Phytoplankton functional types, optics, HPLC, Ocean Color, BGC-Argo. Sea-going.
Hidekatsu Yamazaki	M	Tokyo University of Marine Science and Technology, Japan	Bio-Physical interaction, Optical measurements of plankton/aggregates, Microstructures. Sea-going.

7.2 Associate members

Name	Gender	Place of work	Expertise
Sonia Batten	F	SAHFOS, Canada	Plankton dynamics, Continuous Plankton Recorder, Ship of Opportunity plankton sampling, Global Alliance of CPR Surveys (GACS) Chair.
Jørgen Berge	M	UiT The Arctic University of Norway	Arctic marine biology, polar night, zooplankton, organisms associated with the Arctic sea ice, effects of climate change
Herve Claustre	M	CNRS, Laboratoire d'Oceanographie de Villefranche, France	Phytoplankton ecology and pigments. Co-chair BGC-Argo. Sea going.
Gerald Gregory	M	CNRS, Institut Méditérranéen d'Océanographie (MIO), France	Plankton ecology, ion-microscopy, automated flow-cytometry.
Johannes Karstensen	M	GEOMAR | Helmholtz Centre for Ocean Research, Germany	Physical interaction with biogeochemical, biological and meteorological processes. Co-chair OceanSITES.
Frank Muller-Karger	M	University of South Florida, US	Phytoplankton dynamics, marine biodiversity, marine policy, public outreach, in-situ observing systems, ocean color, coastal and pelagic, Sea-going.
Anthony Richardson	M	CSIRO, Australia	Climate change ecology, plankton dynamics and ocean observations.
Bernadette Sloyan	F	CSIRO, Australia	Physical Oceanography, Climate, air-sea flux, GO-SHIP co-chair, in-situ observing systems, Sea-going.
Rik Wanninkhof	M	NOAA, Miami, USA	Chemical Oceanography, Climate, air-sea flux, GO-SHIP co-chair, in-situ observing systems, Sea-going.

7.3 Working Group contributions

Emmanuel Boss: 20 years of using commercial instrumentation on ships and fixed platforms. Physical-Biological interactions from micro-scale to basin scales.

Anya Waite is a biological oceanographer with extensive laboratory and field experience in integrating and interpreting large multidisciplinary datasets across arrays of biological and physical sensors, field sampling at a wide range of time and space scales as well as analytical experience in flow cytometry, image analysis, confocal and conventional microscopy.

Silvia Acinas is a microbial ecologist who is coordinator of the prokaryotic consortium of the Tara Oceans expedition and responsible also for microbial genomics analyses of the Malaspina 2010 global circumnavigation. Her team has been involved of deliver alternative approaches for exploring diversity and community structure of microbial communities and analyses of marine microbial metagenomics.

Ilana Berman-Frank has extensive experience on phytoplankton ecophysiology and specifically on marine N_2 fixation focusing for the past 15 years on the contribution of diazotrophs to production in the eastern Mediterranean Sea (EMS) and northern Red Sea. Has recently set up the first deep-moored station in the Levantine Basin (1500 m depth) to measure production and export and targeted as an ocean observatory platform to provide data for the ultraoligotrophic EMS.

Marcela Cornejo is a biogeochemical oceanographer with interest in carbon, nitrogen and phosphorus cycles in the surface and subsurface waters and the main physical and biological driving factors such as upwelling, phytoplankton bloom, and the shallowing of the oxygen minimum zone. Her work is mainly focused in the upwelling regions and the mesoscale structures.

Katja Fennel has developed and applied numerical models of marine ecosystems and biogeochemistry for over two decades with particular focus on the cycling of nitrogen, carbon and oxygen. In addition, she has developed and applied methods for the assimilation of observations into models in order to improve their predictive capabilities.

Heidi Sosik is a plankton ecologist with extensive experience developing automated instrumentation, in particular submersible flow cytometry and imaging-in-flow cytometry; developing open-source analysis workflows and web-service based information systems to advance accessibility and use of the big data streams resulting from these technologies; serving as coastal ocean observatory science director; and promoting long-term ecological research in the oceans.

Sandy Thomalla is a biogeochemical oceanographer whose research focuses on using bio-optical approaches to parametrize the particle field (dominated by phytoplankton). The primary objective of her work is to develop and apply emerging techniques to derive optimized and regionally robust information from autonomous platforms and satellite ocean colour products in the Southern Ocean.

Julia Uitz is a biogeochemical oceanographer with strong interest in deriving information on phytoplankton diversity based on optical observations from a variety of research platforms such as vessels, profiling floats or ocean color satellites. Her research has mostly focused on the global open ocean and more recently on specific atypical regions (Mediterranean Sea, Southern Ocean).

Hidekatsu Yamazaki is a physical oceanographer. His research interests focus on examining the physical environment of phytoplankton and zooplankton. He is also investigating the relationship between turbulence and other phenomena (internal waves, ocean currents).

8.0 Relationship to other international program and SCOR working groups

GO-SHIP & OceanSITES– We will provide recommendations to GO-SHIP and OceanSITES regarding instrumentation and water-sample analysis that should be added to their protocols together with their scientific relevance and resource requirements (both in funds and people time). Associate Members Sloyan and Wanninkhof are the co-chairs of GO-SHIP and Associate Member Karstensen is the co-chair of OceanSITES.

SOLAS – data to be collected would directly link atmospheric measurements done on research vessels and buoys to plankton-related parameters and rates, providing data to constrain processes at the interface of ocean and atmosphere (Boss is on SOLAS SSC).

IOCCG - data to be collected will provide validation for algorithms using space-based measurements. (Boss is on the IOCCG SSC).

BGC-Argo – Synergies with BGC-Argo are in providing a platform to deploy floats where relevant biogeochemical parameters are collected near to the deployment location to assess measurement accuracy (e.g., many SOCCOM floats have been deployed from GO-SHIP cruises and POC and HPLC pigments have been collected in conjunction as well as oxygen, nitrate, and carbonate chemistry). When float trajectory are in vicinity of cruise tracks or moorings, cross-calibration can be done to assess presence and magnitude of sensor drift. Proposed WG Associate Member Claustre is the co-chair of BGC-Argo.

Global Alliance of CPR Surveys (GACS) – Synergies with GACS are in relating our proposed plankton measurements to their past and present efforts in quantifying global plankton biomass and diversity and lesson learned in curation and dissemination of data. Associate member Batten is the chair of GACS.

SCOR WG 150, translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT) – Optical technologies that will be evaluated by this WG (optical sensors, automated microscopes, cameras) are the same TOMCAT is reviewing. Proposed WG Full Member Thomalla is also a member of WG 150.

Appendix: 5 relevant publication by each Full Member

Boss:

Boss, E. L. Guidi, M. J. Richardson, L. Stemmann, W. Gardner, J. K. B. Bishop, R. F Anderson, and R. M Sherrell, 2015. Optical techniques for remote and in-situ characterization of particles pertinent to GEOTRACES. Progress in Oceanography, 133, 43-54, doi:10.1016/j.pocean.2014.09.007.

Slade, W. H. and E. Boss, 2015. Spectral attenuation and backscattering as indicators of average particle size. Applied Optics, 54, 24, 7264-7277, http://dx.doi.org/10.1364/AO.54.007264.

Behrenfeld, M. and E. Boss, 2014. Resurrecting the ecological underpinnings of ocean plankton blooms. Annual Review of Marine Science, 6, 167-194, DOI: 10.1146/annurev-marine-052913-021325.

Boss, E., M. Picheral, T. Leeuw, A. Chase, E. Karsenti, G. Gorsky, L. Taylor, W. Slade, J. Ras, and H. Claustre, 2013. The characteristics of particulate absorption, scattering and attenuation coefficients in the surface ocean; Contribution of the Tara Oceans expedition. Methods in Oceanography, http://dx.doi.org/10.1016/j.mio.2013.11.002.

Russo, C.R. and E.S. Boss, 2012. An evaluation of acoustic doppler velocimeters as sensors to obtain the concentration of suspended mass in water, Journal of Atmospheric and Oceanic Technology, 29, 755-761.

Waite:

M. A. Janout, J. Hölemann, A. M. Waite, T. Krumpen, W. von Appen, F. Martynov. 2016. Sea-ice retreat controls timing of summer plankton blooms in the Eastern Arctic Ocean. *In press*, *Geophysical Research Letters*. Accepted 1.12.2017

Waite, Anya M., L. Stemmann, L. Guidi, P. H. R. Calil, A. Mc. Hogg, M. Feng, P. A. Thompson, M. Picheral, G. Gorsky. 2016. The wine glass effect shapes particle export to the deep ocean in mesoscale eddies. *Geophysical Research Letters* DOI:1002/2015GL066463

Davies, C.H., A. Coughlan, G. Hallegraeff (& 49 authors + Anya M. Waite) 2016. A database of marine phytoplankton abundance, biomass and species composition in Australian Waters. *Nature Scientific Data* 3

McInnes, Allison Skinner, Shephard, A., Raes, E., Waite, A.M. and Quigg A. 2014. Carbon and nitrogen fixation: Simultaneous quantification of active communities and estimation of rates using *in situ* fluorescence hybridization and flow cytometry. *Aquatic Microbial Ecology* 80(21)6750-6759

Thompson, P.A., Bonham, P., Thomson, P., Rochester, W., Doblin, M.A., Waite A.M. Richardson, A., Rousseaux, C. 2014. Climate variability drives plankton community composition changes: The 2010-11 El Niño to La Niña transition around Australia. *Journal of Plankton Research 37(5):966-984*

Acinas:

Acinas, SG Vanja Klepac-Ceraj, Dana E. Hunt, Chanathip Pharino, Ivica Ceraj, Daniel L. Distel and Martin F. Polz. 2004. Fine Scale Phylogenetic Architecture of a Complex Bacterial Community. Nature. 430:551-554.

Logares R, Shinichi Sunagawa, Guillem Salazar, Francisco M. Cornejo-Castillo, Isabel Ferrera, Hugo Sarmento, Pascal Hingamp, Hiroyuki Ogata, Colomban de Vargas, Gipsi Lima-Mendez, Jeroen Raes, Julie Poulain, Olivier Jaillon, Patrick Wincker, Stefanie Kandels-Lewis, Eric Karsenti, Peer Bork and Silvia G. Acinas. 2014. Metagenomic 16S rDNA Illumina-Tags as a powerful alternative to amplicon sequencing to explore diversity and structure of microbial communities. Environ Microbiol. 9:2659-71.

Sunagawa S, Coelho LP, Chaffron S, Kultima JR, Labadie K, Salazar G, Djahanschiri B, Zeller G, Mende DR, Alberti A, Cornejo-Castillo FM, Costea PI, Cruaud C, d'Ovidio F, Engelen S, Ferrera I, Gasol JM, Guidi L, Hildebrand F, Kokoszka F, Lepoivre C, Lima-Mendez G, Poulain J, Poulos BT, Royo-Llonch M, Sarmento H, Vieira-Silva S, Dimier C, Picheral M, Searson S, Kandels-Lewis S; Tara Oceans coordinators, Bowler C, de Vargas C, Gorsky G, Grimsley N, Hingamp P, Iudicone D, Jaillon O, Not F, Ogata H, Pesant S, Speich S, Stemmann L, Sullivan MB, Weissenbach J, Wincker P, Karsenti E*, Raes J*, Acinas SG*, Bork P*. 2015. Structure and Function of the Global Ocean Microbiome. Science . 348(6237):1261359. doi: 10.1126/science.1261359. *(*lP leading and corresponding author).*

Salazar G, Cornejo-Castillo FM, Benítez-Barrios V, Fraile-Nuez E, Álvarez-Salgado XA, Duarte CM, Gasol JM, Acinas SG. 2016. Global diversity and Biogeography of deep-sea pelagic prokaryotes. ISME J. doi: 10.1038/ismej.2015.137

Cornejo-Castillo FM, Ana M. Cabello, Guillem Salazar, Patricia Sánchez-Baracaldo, Gipsi Lima-Mendez, Pascal Hingamp, Adriana Alberti, Shinichi Sunagawa, Peer Bork, Colomban de Vargas, Jeroen Raes, Chris Bowler[1], Patrick Wincker, Jonathan P. Zehr, Josep M. Gasol, Ramon Massana, and Silvia G. Acinas. 2016. *Cyanobacterial symbionts diverged in the late Cretaceous towards lineage specific nitrogen fixation factories in single-celled phytoplankton.* Nat. Commun. 7:11071 doi: 10.1038/ncomms11071 (2016).

Berman-Frank:

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<u>Cornejo:</u>

Ruz, P, P Hidalgo, R Riquelme-Bugueño, B Franco-Cisterna, M Cornejo. 2017. Vertical distribution of copepod eggs in the oxygen minimum zone off Mejillones Bay (23°S) in the Humboldt Current System Marine Ecology Progresss Series, doi: 10.3354/meps12117 Accepted.

Cornejo, M, R Figueroa, O Parra. 2016. Seasonal N2O dynamic from the pristine to eutrophic zone in Chilean Mediterraneaner: Biobío River. Global and Planetary Change, submitted.

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<u>Fennel:</u>

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Sosik:

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