Microbial ecology and biogeochemistry of oxygen-deficient marine waters

Supported by the Agouron Institute and the Gordon and Betty Moore Foundation

18–22 March 2013, Santa Cruz, Chile

Steering Committee: Osvaldo Ulloa, Ricardo Letelier, Phyllis Lam, Steven Hallam, Bess Ward, Dave Karl, and Wajih Naqvi

Rapporteur: Jody Wright

Importance: The concentration of dissolved oxygen is a critical organizing principle within marine ecosystems. As oxygen levels decline, energy is increasingly diverted away from higher trophic levels into anaerobic microbial pathways, leading to significant chemical changes in the environment, such as the loss of fixed nitrogen and the production of greenhouse gases. Global warming–induced ocean deoxygenation and anthropogenic alteration of nutrient biogeochemical cycles have currently unconstrained feedbacks on the marine microbiota (the main driver of marine biogeochemical cycles) and the climate system. Current research efforts are defining the metabolic networks underlying nutrient and energy flow patterns within expanding oxygen minimum zones, generating new insights on coupled biogeochemical processes in the global ocean.

Opportunity: Recently completed and ongoing multi-year field campaigns to a variety of low-oxygen marine systems are yielding new insights into the specific roles of microbial communities in responding to and shaping marine biogeochemical cycles in these environments. Low-oxygen marine systems are diverse (e.g. permanently or seasonally sub-oxic / hypoxic), and this symposium provides an opportunity to discuss and compare the microbial ecology and microbially driven biogeochemistry of different low-oxygen systems.

Themes/Questions for the Symposium:

1. What are the key similarities and differences in the physical, biogeochemical and energy flux properties of different oxygen minimum zones? How do microbial community structure and biogeochemical cycling vary spatially and temporally as a function of oxygen/redox conditions? What are the roles/relationships between suspended and sinking organic particles? What are the thresholds of oxygen stress that bound aerobic processes and anaerobic ones?
2. What major changes in ocean microbial diversity and biogeochemistry associated with OMZs do we expect over the rest of the century? How will these impact global oceanic-atmospheric systems?
3. What are the pressing questions and technological needs of OMZ-related research? What would be an appropriate and timely community field experiment or field program?
4. What recommendations can be provided for effective policy development based on scientific evidence (e.g. IPCC synthesis reports)?

Symposium Goals:

1. Compare and contrast the microbial ecology and biogeochemistry of different low-oxygen systems. (Monday)
2. Consider global assessments and/or predictions based on model outputs on, for example, the impact of OMZ expansion. (Tuesday)
3. Identify opportunities for collaboration, including research proposals and cross-training opportunities, among OMZ research teams. (Wednesday and Thursday)
4. Brainstorm about the initial design of a community field experiment, including a clear articulation of the rationale. (Thursday)
5. Develop mechanisms to communicate about, standardize, and/or compare field and experimental protocols. (Thursday)

Participants: Approximately 50 scientists representing multiple disciplines are attending. While the participant emphasis is on microbial ecologists and microbial biogeochemists, others include physical oceanographers, marine chemists, computational modelers, macrofauna ecologists, and more.

Logistics: The meeting runs four full days during the week of 18 March 2013 in Santa Cruz, Chile, a few hours south (185 km) of the Santiago International Airport (SCL). Lodging, meals, and travel to/from the Santiago airport are covered by the meeting sponsors, the Agouron Institute and the Marine Microbiology Initiative at the Gordon and Betty Moore Foundation. An airfare offset of US $450 will be provided to participants traveling internationally. A buffet breakfast is available beginning at 0730 each morning at the hotel. Lunch and dinner will also be provided at the hotel at the designated times on the agenda.

AGOURON INSTITUTE

GORDON AND BETTY MOORE FOUNDATION

Sunday March 17

1800 – 1930 Cocktail reception, hors d'oeuvres, and folkloric group (La Palapa at Hotel Santa Cruz). Dinner on one's own.

…….

Monday March 18

0830 – 0900 Welcome, objectives, opportunities, and logistics (**Osvaldo Ulloa, Jon Kaye, Dave Karl, Klaus Jürgens, Steven Hallam, Jody Wright, and Mónica Sorondo**) – *Salón Colchagua*

Session # 1: Similarities and differences in microbial ecology and biogeochemistry among different oxygen minimum zones (Session Chair: Phyllis Lam)

0900 – 0930 **Johannes Karstensen** "Physical oceanography of different types of OMZs"
0930 – 1000 **Steve Hallam** "Microbial community structure and function across OMZs"
1000 – 1030 **Liz Dinsdale** "The contribution of the prophage to microbial community in the OMZ"

1030 – 1100 Break

1100 – 1130 **Al Devol** "Constraining coupling of biogeochemical cycles in OMZs"
1130 – 1200 **Mak Saito** "The catalytic roles of trace metals in OMZ biogeochemical cycles and considerations for the future"

1200 – 1245 Discussion

1300 – 1430 Lunch

1430 – 1615 **Afternoon Work Groups**

Group 1 *(Salón Colchagua)*: How does microbial community structure vary spatially and temporally as a function of oxygen and redox conditions? (Group Chair: **Ginny Edgcomb**)

Group 2 *(Salón Alcántara)*: How does biogeochemical cycling vary spatially and temporally as a function of oxygen and redox conditions? (Group Chair: **Laura Bristow**)

Group 3 *(Salón Lolol)*: What are the roles and relationships between suspended and sinking organic particles? (Group Chair: **Moritz Holtappels**)

Group 4 *(Salón Vichuquén II)*: What are the thresholds of oxygen stress that bound aerobic and anaerobic processes? (Group Chair: **Niels Peter Revsbech and Wally Fulweiler**)

1630 – 1730 **Late Afternoon Plenary** – *Salón Colchagua*
Report of working groups (Session Chair: **Phyllis Lam**)

1800 – 2000 **Poster Session** – *Salón Colchagua*

2000 Dinner at Restaurant Hotel Santa Cruz

…….

Tuesday March 19

Session # 2: Predictions of changes and impacts (Session Chair: Bess Ward) – *Salón Colchagua*

0900 – 0930 **Sean Crowe** "The redox state of Precambrian oceans: An evolving biogeochemical mosaic"
0930 – 1000 **Nancy Rabalais** "Will climate change aggravate or alleviate coastal hypoxia?"
1000 – 1030 **Gordon Taylor** "What do time-series observations tell us about possible changes in OMZs?"

1030 – 1100 Break

1100 – 1130 **Ken Denman** "How the oxygen cycle is represented in large-scale ocean models, with examples"
1130 – 1200 **Curtis Deutsch** "What do ocean models tell us about the future of OMZs?"

1200 – 1245 Discussion

1300 – 1430 Lunch

1430 – 1615 **Afternoon Work Groups**

Group 1 *(Salón Colchagua)*: What major changes in ocean microbial community structure and biogeochemistry associated with OMZs do we expect in the open ocean over the rest of the century? (Group Chair: **Julie LaRoche**)

Group 2 *(Salón Alcántara)*: What major changes in ocean microbial community structure and biogeochemistry associated with OMZs do we expect in the coastal ocean over the rest of the century? (Group Chair: **Jessika Füssel**)

Group 3 *(Salón Lolol)*: How will changes in microbial community structure and biogeochemistry in the open ocean impact the global ocean–atmosphere system? (Group Chair: **Sam Wilson**)

Group 4 *(Salón Vichuquén II)*: How will changes in microbial community structure and biogeochemistry in the coastal ocean impact the global ocean–atmosphere system? (Group Chair: **Francis Chan**)

1630 – 1730	**Late Afternoon Plenary** – *Salón Colchagua* Report of working groups (Session Chair: **Bess Ward**)
1800 – 2000	**Poster Session** – *Salón Colchagua*
2000	Dinner at Restaurant Hotel Santa Cruz

…….

Wednesday March 20

<u>Session #3: Pressing questions and technological needs (Session Chair: Steven Hallam)</u> – *Salón Colchagua*

0830 – 0900	**Ed DeLong** "Lessons and perspectives from the 'omics' era"
0900 – 0930	**Klaus Jürgens** "Lessons and perspectives from culture work: insights from Baltic Sea redoxcline studies"
0930 – 1000	**Matt Sullivan** "Emerging challenges and opportunities in environmental virology"
1000 – 1030	Break
1030 – 1100	**Karen Casciotti** "Lessons and perspectives from geochemical observational studies"
1100 – 1130	**Bo Thamdrup** "Lessons and perspectives from perturbation and process rate experiments"
1130 – 1200	**Andreas Oschlies** "Lessons and perspectives from large inter-disciplinary research in OMZs"
1200 – 1245	Discussion
1300 – 1430	Lunch
1430	**Free time and optional visit to Viña Mont Gras** (including dinner for those who registered)
2000	Dinner at Restaurant Hotel Santa Cruz for those not on vineyard tour

…….

Thursday March 21

0900 – 0945 Working group instructions and outline of the day: groups self-assemble to develop actions plans according to a matrix of canonical low-oxygen systems and research questions / approaches **(Jon Kaye)**

Announcement of future opportunities and request leaders and co-conspirators **(Jon Kaye)**

Opportunities: Special issue in a journal such as PLoS (Steven Hallam); EOS / ASLO bulletin articles (Dave Karl); ASLO 2014 special session (Klaus Jürgens); SCOR working group proposal on the microbial biogeochemistry of low-oxygen systems; U.S. NSF Research Coordination Network for international convening.

Announcement of attendance by journalist for Chilean press **(Osvaldo Ulloa)**

0945 – 1015 **Dave Karl** "The IPCC process and probable future ocean states" – *Salón Colchagua*

1015 – 1045 Working group and room assignments **(Jon Kaye)**; break

1045 – 1245 **Morning Work Groups Research Questions and Approaches**

(A) Identify a pressing question in OMZ-related research and design a laboratory / microcosm / mesocosm research plan to address it. Leaders: **Alyse Hawley, Steven Hallam, Francis Chan, Klaus Jürgens**.
(B) Identify a current technological and/or methodological need in OMZ-related research and develop an action plan to address the need. Leader: **Frank Stewart**.
(C) Design an appropriate and timely community field experiment OR a global international field effort (location, methods, analyses, approach to synthesis). Leaders: **Sam Wilson, Osvaldo Ulloa**.
(D) Articulate a question that can only be addressed by comparing different low-oxygen systems, and prioritize what methods and approaches need to be standardized to perform such a comparative study. Leader: **Bonnie Chang**.
(E) What can models offer? Leader: **Curtis Deutsch**.

1300 – 1430 Lunch

1415 – 1530 **Alyse Hawley, Steven Hallam, Francis Chan, Klaus Jürgens, Frank Stewart, Sam Wilson, Osvaldo Ulloa, Bonnie Chang, Curtis Deutsch, and Ricardo Letelier** synthesize work group efforts and prepare summary of highlights.

1530 – 1700 Report of working groups (Session Chair: **Ricardo Letelier**) – *Salón Colchagua*

1700 – 1730 Break

1730 – 1900 **<u>Session #4: Final Meeting Synthesis, Reflections on Meeting Objectives, and Recommendations (Session Chair: Osvaldo Ulloa)</u>** – *Salón Colchagua*

2000 Dinner at Restaurant Hotel Santa Cruz

…….

Friday March 22

Departure from Santa Cruz

Participants

1	Bess Ward	Princeton University	bbw@princeton.edu
2	Dave Karl	University of Hawaii	dkarl@hawaii.edu
3	Osvaldo Ulloa	Universidad de Concepción	oulloa@udec.cl
4	Phyllis Lam	Max Planck Institute for Marine Microbiol.	plam@mpi-bremen.de
5	Ricardo Letelier	Oregon State University	letelier@coas.oregonstate.edu
6	Steven Hallam	University of British Columbia	shallam@interchange.ubc.ca
7	Al Devol	University of Washington	devol@ocean.washington.edu
8	Alejandro Murillo	Universidad de Concepción	amurillo@profc.udec.cl
9	Alex Galán	Universidad de Concepción	agalan@coas.oregonstate.edu
10	Alvaro Muñoz	Universidad de Concepción	amunoz1@profc.udec.cl
11	Alyse Hawley	University of British Columbia	alysekh@mail.ubc.ca
12	Andreas Oschlies	GEOMAR	aoschlies@geomar.de
13	Anil Pratihary	National Institute of Oceanography	apratihary@nio.org
14	Annie Bourbonnais	University of Massachsetts, Darmouth	annieb@uvic.ca
15	Benjamín Srain	Universidad de Concepción	bsrain@udec.cl
16	Bo Thamdrup	University of Southern Denmark	bot@biology.sdu.dk
17	Bonnie Chang	Princeton University	bonniec@princeton.edu
18	Chris Klausmeier	Michigan State University	klausme1@msu.edu
19	Curtis Deutsch	University of California, Los Angeles	cdeutsch@atmos.ucla.edu
20	Dan Conley	Lund University	daniel.conley@geol.lu.se
21	Ed DeLong	Massachusetts Institute of Technology	delong@mit.edu
22	Ellery Ingall	Georgia Institute of Technology	ellery.ingall@eas.gatech.edu
23	Francis Chan	Oregon State University	chanft@science.oregonstate.edu
24	Frank Stewart	Georgia Institute of Technology	frank.stewart@biology.gatech.edu
25	Ginny Edgcomb	Woods Hole Oceanographic Institution	vedgcomb@whoi.edu
26	Gordon Taylor	SUNY Stony Brook	gtaylor@notes.cc.sunysb.edu
27	Jack Barth	Oregon State University	barth@coas.oregonstate.edu
28	Jessika Füssel	Max Planck Institute for Marine Microbiol.	jfuessel@mpi-bremen.de
29	Jody Wright	University of British Columbia	jjwright49@me.com
30	Johannes Karstensen	GEOMAR	jkarstensen@geomar.de
31	Julie LaRoche	Dalhousie University	julie.laroche@dal.ca
32	Karen Casciotti	Standford University	kcasciot@stanford.edu
33	Ken Denman	University of Victoria	denmank@uvic.ca
34	Klaus Jürgens	Leibniz Institute for Baltic Sea Research	klaus.juergens@io-warnemuende.de
35	Laura Bristow	University of Southern Denmark	lbristow@biology.sdu.dk
36	Laura Farías	Universidad de Concepción	lfarias@profc.udec.cl
37	Laure Resplandy	Lab. des Sciences du Climate et de l'Environ.	laure.resplandy@lsce.ipsl.fr
38	Liz Dinsdale	San Diego State University	elizabeth_dinsdale@hotmail.com
39	Mak Saito	Woods Hole Oceanographic Institution	msaito@whoi.edu
40	Matt Sullivan	University of Arizona	mbsulli@email.arizona.edu
41	Moritz Holtappels	Max Planck Institute for Marine Microbiol.	mholtapp@mpi-bremen.de
42	Nancy Rabalais	Louisiana Universities Marine Consortium	nrabalais@lumcon.edu

43	Niels Peter Revsbech	Aarhus University	revsbech@biology.au.dk
44	Oscar Pizarro	Universidad de Concepción	opizarro@udec.cl
45	Raquel Vaquer-Sunyer	Lund University	raquel.vaquer-sunyer@geol.lu.se
46	Sam Wilson	University of Hawaii	stwilson@hawaii.edu
47	Sean Crowe	University of Southern Denmark	sacrowe1@gmail.com
48	Véronique Garçon	Lab. of Space Geophysics and Oceanography	veronique.garcon@legos.obs-mip.fr
49	Wally Fulweiler	Boston University	rwf@bu.edu
50	Jon Kaye	Gordon and Betty Moore Foundation	jon.kaye@moore.org
51	Mónica Sorondo	Universidad de Concepción	monica.sorondo@oceanografia.udec.cl