

Reporting Period is January 2011 – December 2011

1. Key scientific SOLAS-relevant highlights/findings (you may include figures and references)

In 2011 BIOACID published 23 papers on the impacts of ocean acidification on marine organisms and communities and the impacts of biological responses on biogeochemical cycling (see point 4 below). Much of this work is only marginally relevant to SOLAS. Two research highlights are selected based on the overall importance to marine sciences:

Ocean Acidification effects on commercially important fish species (Frommel et al. 2011)

While it is common knowledge that commercial fish stocks are globally threatened by over-fishing, a new study shows that they may also be vulnerable to ocean acidification. In the past, scientists have primarily focused on calcifying organisms, which are believed to be particularly at risk due to the dissolution of their calcium carbonate structures. A recent study by an international research group led by GEOMAR shows that commercial fish species may also be threatened by increasing acidification. Cod offspring were exposed to three different carbon dioxide concentrations (380, 1800 and 4200 μatm) to examine the influence of ocean acidification. In order to mimic natural conditions for the larvae, the experiment was carried out in large open-air mesocosms in Bergen, Norway. The larval development was monitored for a time span of seven weeks after hatching. Tissue damage with possible lethal consequences was documented in a range of vital organs in the larvae. During this critical stage many structural alterations take place in the larvae, requiring a large amount of energy. As larvae hatch without functional gills, the main site for effective acid-base regulation, the mechanisms to cope with a low pH environment are particularly costly. Therefore, they may not have the energy needed for development, making them more prone to damage. As the larval stage is the bottleneck to recruitment in commercial mass-spawning fish, ocean acidification must be considered as yet another anthropogenic stressor in future stock analysis of already exploited fish.



Fig.1: Cod larvae as reared in the mesocosm experiment (left); Mesocosm facility at Marine Biological Station at Espeyrend, Norway (right) Photo source: GEOMAR

Frommel, A.Y., R. Maneja, D. Lowe, A.M. Malzahn, A.J. Geffen, A. Folkvord, U. Piatkowski, T.B.H. Reusch, and C. Clemmesen, 2011: Severe tissue damage in Atlantic cod larvae under increasing ocean acidification. *Nature Climate Change*, doi: <http://dx.doi.org/10.1038/NCLIMATE1324>.

A joint SOPRAN/BIOACID mesocosm experiment on ocean acidification was conducted in the Raunefjord in southern Norway. Stationed at the Marine Biological Station of the University of Bergen, 26 scientists from 8 German, Norwegian and UK institutes followed the development of the enclosed plankton community over a 5-week period.

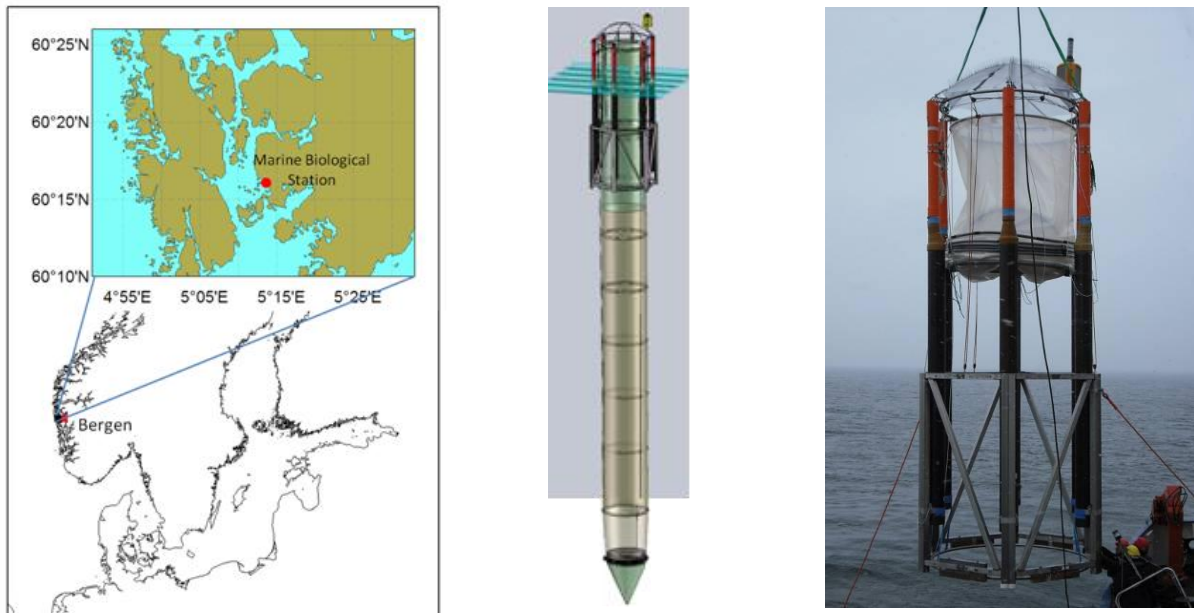


Fig. 1.: Location of the Bergen mesocosm experiment, sketch of a mesocosm, deployment, and view of the nine moored mesocosms in the Raunefjord.

Preliminary results show major changes in plankton community composition and biogeochemical cycling in response to ocean acidification. Some of the surprising community-level responses to ocean acidification include:

- strong CO₂ fertilization effect on picophytoplankton and dinoflagellates
- reduced productivity of diatoms under high CO₂ (probably due to nutrient competition)
- absence of coccolithophores under high CO₂
- reduced abundance of pteropod larvae and juveniles

The fact that some of these responses could not be predicted based on results obtained in laboratory experiments highlights the importance of community-level experiments.

2. Activities/main accomplishments (research projects, cruises, special events, workshops, remote sensing used, model and data intercomparisons etc)

The 2nd Annual Meeting of BIOACID took place on September 26th - 30th, at the University of Bremen, Germany (please see agenda at http://www.bioacid.de/front_content.php?idart=716&idlang=22). The last two days of the meeting were used to discuss the joint proposal of the second phase of BIOACID (2012 – 2015)

A pre-proposal for a BIOACID phase 2 (2012-2015) was prepared and submitted to the German Ministry for Education and Research (BMBF). The proposal is presently under review. A decision about a possible extension of the project is expected for June/July.

3. Human dimensions (outreach, capacity building, public engagement etc)

Capacity building



BIOACID scientists contributed to preparing the *Guide for best practices in ocean acidification research and data reporting*, an initiative led by the European Project on Ocean Acidification. This guide is intended to provide the rapidly growing community of researchers working on ocean acidification with guidelines and recommendations on best approaches, agreed standards, and minimum requirements for research in this field.

Outreach and communication

BIOACID has played an active role in various outreach activities. In 2011 these included:

- producing a brochure and CD describing 8 simple experiments to visualize and explain the process of ocean acidification; this brochure is intended for teachers and school children grade 5-7, the experiments can easily be conducted with the materials available in school; 10.000 copies of the brochure were printed and are being distributed to schools in the framework of school programmes by various BIOACID partners
- working together with school teachers to incorporate aspects of ocean acidification in the natural sciences curricula of local schools
- producing a TV-quality animation visualizing ocean acidification; the animation is without copyright and freely available to all BIOACID partners for use with TV reports, in outreach activities and for institutional purposes; the clip has already been used in a recent TV production and in a GEOMAR film on ocean acidification (<http://www.ifm-geomar.de/index.php?id=6109>).
- working together with the International Ocean Acidification Reference User Group (IOA-RUG) to disseminate its various outreach products, including translating the latest brochure *Questions answered* into German; 5000 copies were printed and distributed among BIOACID partner institutes
- presenting public lectures on ocean acidification at various occasions
- giving interviews to newspaper, radio and TV journalists; these have led to various high profile reports on ocean acidification, including leading articles in *Zeit-Wissen* and *GEO*, a 45-minute TV documentary on ocean acidification in the WDR-series *Quarks & Co*, contributions to 90-minute documentary by SPIEGEL TV „Klimawandel: Ist die welt noch zu retten“, a portrait in the NDR-series *DAS!* and various radio reports in Deutschlandradio, NDR 1, WDR, BR, and RBB.

As a regular form of outreach, BIOACID has produced and distributes a flyer and maintains a multifactorial website.

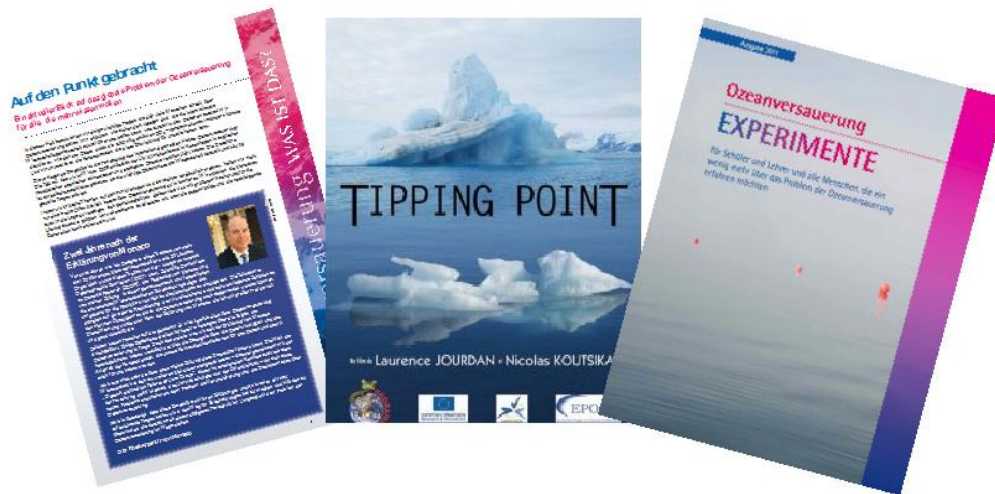


Fig. 2: Examples of BIOACID outreach activities; the German translation of the IOA-RUG brochure Questions answered, the documentary Tipping Point, and the brochure for school teachers and school children describing 8 simple experiments visualizing ocean acidification

Reference User Group

The formation of the EPOCA Reference User Group (RUG) has enabled a two way exchange of information between research scientists and the user community. This has ensured that the knowledge is provided in a format and style suitable for the target audience. As the RUG has recently been adopted also by the UKOA programme and BIOACID and to some extent by MedSeA, it has evolved to become the International Ocean Acidification Reference User Group (IOA-RUG) and as such continues is very successful work now representing an even broader community of ocean acidification researchers. Ultimately, a successful program will have an approach that integrates basic science with decision support.

4. Selection of publications in 2011 (Reports, articles, models, datasets, products, website etc)

Bach, L.T., Riebesell, U., Schulz, K.G. (2011): Distinguishing between the effects of ocean acidification and ocean carbonation in the coccolithophore *Emiliania huxleyi*. *Limnology and Oceanography*, 56 (6). pp. 2040-2050. DOI 10.4319/lo.2011.56.6.2040

Büdenbender, J., Riebesell, U., Form, A. (2011) Calcification of the Arctic coralline red algae *Lithothamnion glaciale* in response to elevated CO₂. *Marine Ecology Progress Series* 441, 79-87

Denman K., J. Christian, N. Steiner, H.O. Pörtner, and Y. Nojiri (2011) Potential impacts of future ocean acidification on marine ecosystems and fisheries: present knowledge and recommendations for future research. *ICES J. Mar Sci.* doi:10.1093/icesjms/fsr074

Fabricius, K.E., Langdon, C., Uthicke, S., Humphrey, C., Noonan, S., De'ath, G., Okazaki, R., Muehllehner, N., Glas, M.S. and Lough, J.M. (2011) Losers and winners in coral reefs acclimatized to elevated carbon dioxide concentrations. *NATURE CLIMATE CHANGE*; DOI: 10.1038/NCLIMATE1122

Form, A. & Riebesell, U. (2011) Acclimation to ocean acidification during long-term CO₂ exposure in the cold-water coral *Lophelia pertusa*. *Global Change Biology* . DOI 10.1111/j.1365-2486.2011.02583.x

Franke, A. and Clemmesen, C. (2011) Effect of ocean acidification on early life stages of Atlantic herring (*Clupea harengus* L.) *Biogeosciences Discuss.*, 8, 7097–7126.

Haynert, K., Schönfeld, J., Riebesell, U, Polovodova, I. (2011) Biometry and dissolution features of the benthic

foraminifer *Ammonia aomoriensis* at high pCO₂. *Marine Ecology Progress Series* 432, 53-67

- Hofmann LC, Yildiz G, Hanelt D, Bischof K (2011). Physiological responses of the rhodophyte, *Corallina officinalis* (L.), to future CO₂ levels. *Marine Biology*; DOI 10.1007/s00227-011-1854-9
- Hoppe, C.J.M., Langer, G., Rost, B.(2011). *Emiliana huxleyi* shows identical responses to elevated pCO₂ in TA and DIC manipulations, *Journal of Experimental Marine Biology and Ecology*, 406(1-2), 54-62., doi:10.1016/j.jembe.2011.06.008
- Hu, M.Y., Tseng, Y.C., Stumpp, M., Gutowska, M. A., Kiko, R., Lucassen, M., and Melzner, F. (2011) Elevated seawater Pco₂ differentially affects branchial acid-base transporters over the course of development in the cephalopod *Sepia officinalis*. *Am J Physiol Regul Integr Comp Physiol* 300:R1100-R1114, 2011. First published 9 February 2011; doi:10.1152/ajpregu.00653.2010
- Joassin, P., Delille, B., Soetaert, K., Harlay, J., Borges, A.V., Chou, L., Riebesell, U., Suykens, K., Grégoire, M. (2011). Carbon and nitrogen flows during a bloom of the coccolithophore *Emiliana huxleyi*: modelling a mesocosm experiment. *Journal of Marine Systems* 85, 71-85
- Koeve, W., Kim, H.-C., Lee, K., Oschlies, A., Potential impact of DOC accumulation on fCO₂ and carbonate ion computation in ocean acidification experiments. (*Biogeosciences Discussions*, 8 (2). pp. 3797-3827. DOI 10.5194/bgd-8-3797-2011.
- Krug, S. A., Schulz, K. G., and Riebesell, U. (2011) Effects of changes in carbonate chemistry speciation on *Coccolithus braarudii*: a discussion of coccolithophorid sensitivities, *Biogeosciences* 8, 771-777
- Langer, G., Bode, M.(2011).CO₂ mediation of adverse effects of seawater acidification in *Calcidiscus leptoporus*, *Geochem. Geophys. Geosyst.*, 12, Q05001, doi:10.1029/2010GC003393.
- Langer, G., Probert, I., Nehrke, G., Ziveri, P.(2011).The morphological response of *Emiliana huxleyi* to seawater carbonate chemistry changes: an inter-strain comparison, *Journal of Nannoplankton Research* 32 (1), 29-34
- Lischka, S., Büdenbender, J., Boxhammer, T., Riebesell, U. (2011) Impact of ocean acidification and elevated temperatures on early juveniles of the polar shelled pteropod *Limacina helicina*: mortality, shell degradation, and shell growth. *Biogeosciences*, 8, 919–932
- Müller, N.M., Kısakürek, B., Buhl, D., Gutperlet, R., Kolevica, A., Riebesell, U., Stoll, H., Eisenhauer, A. (2011) Response of the coccolithophores *Emiliana huxleyi* and *Coccolithus braarudii* to changing seawater Mg²⁺ and Ca²⁺ concentrations: Mg/Ca, Sr/Ca ratios and ⁴⁴Ca/⁴⁰Ca, ²⁶Mg/²⁴Mg of coccolith calcite. *Geochimica et Cosmochimica Acta* 75, 2088–2102
- Parker, L.M., P.M. Ross, W.A. O'Connor, B. Larissa, D.A. Raftos, and H.O. Pörtner (2011) Adult exposure influences offspring response to ocean acidification in oysters. *Global Change Biology* in press.
- Pörtner H.O., M. Gutowska, A. Ishimatsu, M. Lucassen, F. Melzner and B. Seibel (2011) Effects of ocean acidification on nektonic organisms. In: *Ocean Acidification* (ed. J.-P. Gattuso, L. Hansson). Oxford University Press, Oxford.
- Specht, M. et al., 2011. Concerted action of the new Genomic Peptide Finder and AUGUSTUS allows for automated proteogenomic annotation of the *Chlamydomonas reinhardtii* genome. *Proteomics*, p.n/a-n/a. Available at: <http://doi.wiley.com/10.1002/pmic.201000621> [Accessed March 14, 2011].
- Specht, M. et al., 2011. Proteomics to go: Proteomatic enables the user-friendly creation of versatile MS/MS data evaluation workflows. *Bioinformatics*. Available at: <http://bioinformatics.oxfordjournals.org/cgi/content/abstract/btr081v1> [Accessed February 20, 2011]. Stanke, M. et al., 2004. AUGUSTUS: a web server for gene finding in eukaryotes. *Nucleic acids*

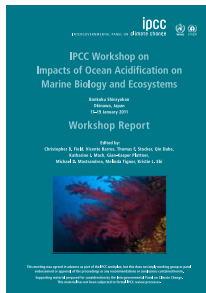
research, 32(Web Server issue), pp.W309-12. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15215400>.

Suffrian, K., Schulz, K.G., Gutowska, M., Riebesell, U., Bleich, M. (2011) BCECF measurements in *Emiliana huxleyi* reveal dominant membrane proton permeability. *New Phytologist* 190, 595–608

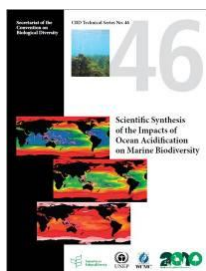
Walther, K., F.J. Sartoris, H.O. Pörtner (2011) Impacts of temperature and acidification on larval calcification of the spider crab *Hyas araneus* from different latitudes (54° vs. 79°N) *Marine Biology* 158:2043-2053.

5. International interactions and collaborations (including contributions to international assessments such as the IPCC, links with observation communities etc)

Assessment and decision support:



Assessment Report (2007) mentions ocean acidification for the first time in an IPCC report. Since then an IPCC WGII/WGI Workshop on Impacts of Ocean Acidification on Marine Biology and Ecosystems was held in Okinawa, Japan 17-19 January 2011, with participation by several BIOACID scientists. The findings of this meeting are in a workshop report. The 5th IPCC Assessment Report due in 2014 will include a more in depth assessment of both ocean climate change and acidification. BIOACID scientists serve as coordinating and lead authors and reviewers of this report.



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International Cooperation

International collaboration provides an opportunity for BIOACID to broaden and strengthen its research portfolio. Since its launch in 2009, BIOACID worked in close collaboration with the European Project on Ocean Acidification (EPOCA). Several of the BIOACID members are also active in EPOCA. A close collaboration has also been established with the UK Ocean Acidification Research Programme (UKOA). The coordinators of EPOCA, UKOA and BIOACID maintain an open information flow between the three programmes and closely work together in various outreach and communication activities. To facilitate this exchange, the coordinators of each project serve as members of the executive board or scientific advisory board of each of the other projects. Cooperation of the three projects encompasses joint training workshops, student exchange, joint experiments and exchange of samples, joint annual meetings and the shared Reference User Group (RUG), a group of key stakeholders interested the knowledge gained in ocean acidification research. In addition, EPOCA and BIOACID use the same data portal at WDC-MARE/PANGEA.

The EPOCA-UKOA-BIOACID partnership has been further broadened to include the recently launched EU-project Mediterranean Sea Acidification in a Changing Climate (MedSea).



UK Ocean Acidification
Research Programme



BIOACID partner programmes on ocean acidification.

To further strengthen the international partnership in ocean acidification research the UK funding agencies opened an opportunity for participants in the UKOA programme to seek additional financial support for international research collaborations, in particular with BIOACID. In turn, BIOACID has offered its members additional financial support to establish and/or strengthen active collaboration with UK partners funded through the UKOA Programme. Several BIOACID partners have responded to this offer and will receive funding ear-marked for UKOA-BIOACID collaboration during phase 2 of the BIOACID project.

6. Goals, priorities and plans for future activities/events

The growing evidence of potential biological impacts of ocean acidification affirms that this global change phenomenon may pose a serious threat to marine organisms and ecosystems. Despite a wealth of knowledge on specific effects of acidification and the related changes in seawater chemistry on the physiology of individual marine taxa, many uncertainties still remain. Because the majority of studies are based on single species experiments, little is presently known about possible impacts on natural communities, food webs and ecosystems. Moreover, few studies have addressed possible interacting effects of environmental changes occurring in parallel, such as ocean acidification, warming, and deoxygenation and changes in surface layer stratification and nutrient supply. Almost completely unknown at present is the potential for evolutionary adaptation to ocean acidification. To pave the way for a more encompassing assessment of future biological responses to ocean change and their possible socio-economic consequences phase 2 of BIOACID will

- strengthen the integration within the BIOACID community to allow for more realistic community-level experimentation and field observation
- focus more strongly on interacting affects through multiple stressors
- expand evolutionary biology to assess the potential for adaptation of key taxa
- integrate socio-economic assessments and stakeholder involvement

The overarching focus of BIOACID II will be to address and better understand ***the chain from biological mechanisms, through individual organism responses, through food web and ecosystem effects, to economic impacts***

7. Other comments

Data management

The data management in BIOACID is carried out by the World Data Center for Marine Environmental Sciences WDC-MARE (www.wdc-mare.org) at the University of Bremen. WDC-MARE uses the information system PANGAEA (Publishing Network for Geoscientific & Environmental Data – www.pangaea.de), which is a system for acquisition, processing, long-term storage, and publication of geo-referenced data related to all earth science fields. Specifically, WDC-MARE is responsible for

1. Coordination of data capture, integration and quality control activities for the five BIOACID Themes.
2. Archiving and publishing data sets and data collections online and as offline products (DVD) using persistent Digital Objects Identifiers (DOI).
3. Implementation of the BIOACID data infrastructure
 - enabling a distributed storage of observational and model simulation data within a common networked structure, and
 - establishing a robust and long lasting data network which can be extended by or integrated into ongoing projects and programmes.
4. Maintain the website and data portal for BIOACID.