

information

Keywords

Calanus spp., Salmon louse; Lepeophtheirus salmonis, ocean acidification, physiology, behaviour, energetics, growth, development, lipid content, proteomics, genomics

Project title

Prosjekt OA-3: Physiological effects of OA in Arctic copepods

Year

2017

Project leader

Howard Browman

Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)

60.086N, 5.262E

Participants

Howard Browman, Haakon Hop, Peter Thor, Allison Bailey, David Fields, Steve Shema, Jeffrey Runge, Cameron Thompson, Andrew Mount, Vera Chan

Flagship

Ocean Acidification

Funding Source

Fram Centre + Institute of Marine Research + Research Council of Norway

Summary of Results

2015 experiment. Samples and data from experiments investigating the interaction between temperature and pH on growth and respiration of the planktonic copepod, *Calanus finmarchicus*, have been analyzed and a manuscript is in the final stages of preparation (Runge et al., in preparation). *C. finmarchicus* were reared from eggs to adult at 12°C and 16°C in seawater with non-limiting food and near ambient (600 µatm) and high (1200 µatm) CO₂ concentrations. The high temperature and high CO₂ treatment represents extreme conditions likely to be encountered by the species at the southern margins of its biogeographical range in the future. Dry weight, C and N mass, lipid content and respiration were measured on stages CV and adult female immediately after molting into the stage. By measuring at a precise marker in the copepod life cycle, this new approach allows accurate comparison of growth and respiration across treatments. The results show a significant increase in mass and respiration rate at 12°C and high CO₂ concentrations. At the higher temperature, respiration rates were significantly increased but body mass was unchanged. These findings indicate that elevated CO₂/lower pH in the future ocean will have 1) a beneficial effect on *C. finmarchicus* growth rates at expected temperatures within the copepod's habitat and 2) inconsequential effects on growth rate at extreme temperatures expected at its southern margin.

2016 experiment and 2017 sample and data analysis. We investigated the potential impacts of high pCO₂ condition on the parasitic sea lice (*Lepeophtheirus salmonis*) using the same approach as described above for *Calanus finmarchicus*. Developmental rate, growth, lipid reserves, carbon-to-nitrogen ratio, fatty acid profile and oxygen consumption were measured at the population level. Performance and variation of the salmon lice population was also investigated at a higher resolution using correlative microscopy methods to understand the individual responses in terms of metabolic status, availability of lipid reserve and signs of carapace damage. Sample processing and data analysis are now complete and a manuscript is in preparation (Thompson et al., in preparation).

Master and PhD-students involved in the project

Allison Bailey

For the Management

The project management went according to plan.

Published Results/Planned Publications

- Maneja, R.H., A.Y. Frommel, H.I. Browman, C. Clemmesen, A.J. Geffen, A. Folkvord, U. Piatkowski, C.M.F. Durif, R. Bjelland & A.B. Skiftesvik. 2013. The swimming kinematics of larval Atlantic cod, *Gadus morhua* L., are resilient to elevated seawater pCO_2 . *Marine Biology* 160:1963-1972.
- Bellerby, R.G., H.I. Browman & R. Sumaila. 2013. [AMAP Assessment 2013: Arctic Ocean Acidification](#). Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. viii + 99 pp.
- Browman, H.I., S. Dupont, J. Havenhand & L. Robbins. 2013. Biological responses to ocean acidification. Pp: 37-54, In: Bellerby, R.G., H.I. BROWMAN, R. Sumaila et al. 2013. Impacts of ocean acidification in the Arctic ocean. Arctic Monitoring and Assessment Program, Arctic Ocean Acidification Assessment, Oslo.
- Maneja, R.H., R. Dineshram, V. Thiyagarajan, A.B. Skiftesvik, A.Y. Frommel, C. Clemmesen, U. Piatkowski, A.J. Geffen, A. Folkvord and H.I. Browman. 2014. The proteome of Atlantic herring (*Clupea harengus* L.) larvae is resistant to elevated pCO_2 . *Marine Pollution Bulletin* 86: 154-160.
- Maneja, R.H., A.Y. Frommel, H.I. Browman, A.J. Geffen, A. Folkvord, U. Piatkowski, C.M.F. Durif, R. Bjelland, A.B. Skiftesvik & C. Clemmesen. 2015. The swimming kinematics and foraging behavior of larval Atlantic herring, *Clupea harengus* L., are resilient to elevated pCO_2 . *Journal of Experimental Marine Biology and Ecology* 466: 42-48.
- Browman, H.I. 2016. Applying organized scepticism to ocean acidification research. *ICES Journal of Marine Science*. 73: 529-536.
- Browman, H.I. (Ed.) 2016. Towards a broader perspective on ocean acidification research. *ICES Journal of Marine Science* 73(3).
- Runge, J.A., D.M. Fields, C. Thompson, S. Shema, R.M. Bjelland, C.M.F. Durif, A.B. Skiftesvik & H.I. Browman. 2016. Vital rates of an ecologically critical planktonic species in North Atlantic ecosystems, *Calanus finmarchicus*, are unaffected by high CO_2 . *ICES Journal of Marine Science*. 73: 937-950.
- Bailey, A., J.A. Runge, D.M. Fields, P. Thor, C. Thompson, R.M. Bjelland, C.M.F. Durif & H.I. Browman. The early life stages of the Arctic copepod *Calanus glacialis* are unaffected by increased seawater pCO_2 . *ICES Journal of Marine Science* 74: 996-1004.
- Bailey, A., P. de Wit, P. Thor, H.I. Browman, R.M. Bjelland, S. Shema, D.M. Fields, J.A. Runge, C. Thompson & H. Hop. Regulation of gene expression underpins tolerance of the Arctic copepod *Calanus glacialis* to increased pCO_2 . *Ecology and Evolution* 2017;00:1-16. <https://doi.org/10.1002/ece3.3063>.
- Browman, H.I. (Ed.) 2017. Towards a broader perspective on ocean acidification research - Part 2. *ICES Journal of Marine Science* 74(4).
- Dineshram, R., V. Thiyagarajan, D.M. Fields, J.A. Runge, C. Thompson, S. Shema, R.M. Bjelland, C.M.F. Durif, A.B. Skiftesvik & H.I. Browman. The proteome of *Calanus finmarchicus* is unaffected by elevated pCO_2 . in preparation.

Fields, D.M., H.I. Browman, A.B. Skiftesvik & S. Shema. Effect of ocean acidification on

the grazing rates of *Calanus spp.* feeding on lithed and delithed coccolithophores. in preparation.

Runge, J.A., D.M. Fields, C. Thompson, C.M.F. Durif, S. Shema, R.M. Bjelland, A.B. Skiftesvik and H.I. Browman. Interaction between temperature and pH on growth and respiration of the planktonic copepod, *Calanus finmarchicus*. In preparation.

Thompson, C., J.A. Runge, D.M. Fields, C. Thompson, S. Shema, R.M. Bjelland, C.M.F. Durif, A.B. Skiftesvik, M. Arts, A. Mount, V. Chan & H.I. Browman. Vital rates of the salmon louse, *Lepeotheirus salmonis*, are unaffected by high CO₂ but are affected by temperature. In preparation.

Communicated Results

06/2017- Runge, J.A., David Fields, Cameron Thompson, Caroline Durif, Steven Shema, Reidun Bjelland, Anne-Berit Skiftesvik and Howard I. BROWMAN. Interaction between temperature and pH on growth and respiration of the planktonic copepod, *Calanus finmarchicus*. Ecosystem Studies of Subarctic and Arctic Seas, 3rd Open Science Meeting on Subarctic and Arctic Science, Tromsø, Norway

01/2017- Bailey, Allison, De Wit, Pierre, Thor, Peter, Browman, Howard, Bjelland, Reidun, Shema, Steven, Fields, David M., Runge, Jeffrey, Thompson, Cameron, Hop, Haakon. Regulation of gene expression underpins tolerance of the Arctic copepod *Calanus glacialis* to increased pCO₂. Arctic Frontiers, Tromsø

12/2016- Browman, H.I. Applying organized skepticism in ocean acidification research. Second interdisciplinary symposium on ocean acidification and climate change. University of Hong Kong.

05/2016- Browman, H.I., J.A. Runge, D.M. Fields, C.R.S. Thompson, S.D. Shema, R.M. Bjelland, C.M.F. Durif & A.B. Skiftesvik. End of the century CO₂ concentrations do not have a negative effect on vital rates of *Calanus finmarchicus*, an ecologically critical planktonic species in North Atlantic ecosystems.

6th International Zooplankton Symposium, Bergen, Norway

05/2016- Bellerby, Richard, Howard I. Browman, Wenting Chen, Andrew Constable, Sam Dupont, Haruko Kurihari, Mario Hoppema, Andrew Lenton, Nikki Lovenduski, Claire Lo Monaco, Jeremy Mathis, Eugene Murphy, Elizabeth Shadwick, Coleen Suckling & Scarlett Trimborn. Development and delivery of scientific knowledge and policy guidance on high latitude ocean acidification through different international organizational platforms.

Bailey, A. Pierre de Wit, Peter Thor, Howard I. Browman, David Fields, Jeffrey Runge, Alex Vermont, Reidun Bjelland, Cameron Thompson, Steven Shema, Caroline Durif, Haakon Hop. Gene expression responses to increased pCO₂ during the larval development of the Arctic copepod *Calanus glacialis*.

4th International Symposium on the Oceans in a High CO₂ World, Hobart, Tasmania

11/2015- Browman, H.I. Applying organized skepticism to ocean acidification research, or some marine organisms will do just fine in a high CO₂ world.

Bailey, A., P. Thor, H.I. Browman, D. Fields, J. Runge, A. Vermont, R.M. Bjelland, C. Thompson, S. Shema, C. Durif & H. Hop. Arctic copepod *Calanus glacialis* larvae are tolerant to lowered pH. ***Received best poster award***

Fram Science Days, Tromsø, Norway

10/2015- Bellerby, R., J. Mathis, W. Chen, K. Azetsu-Scott, L. Miller, S. Dupont, H. Browman. Arctic Ocean acidification: present understanding, management requirements and future research strategies

PICES Annual Meeting, Qindao, China

09/2015- Browman, H.I. Applying organized skepticism to ocean acidification research, or some marine organisms will do just fine in a high CO₂ world.

ICES Annual Science Conference, Copenhagen

02/2015- Bailey, Allison, P. Thor, H.I. Browman, D. Fields, J. Runge, A. Vermont, R. Bjelland, C. Thompson, S. Shema, C. Durif. The effects of projected ocean acidification on the early development of the key Arctic copepod, *Calanus glacialis*.

ASLO Aquatic Sciences Conference, Granada, Spain

12/2014- Bailey, Allison, P. Thor, H. I. Browman, D. Fields, J. Runge, A. Vermont, R. Bjelland, C. Thompson, S. Shema, C. Durif. The effects of projected ocean acidification on the early development of the key Arctic copepod, *Calanus glacialis*.

Arctic Change 2014, Ottawa, Ontario, Canada

09/2013- Runge, J.A., C. Thompson, R.M. Bjelland, H.I. Browman, C.M.F. Durif, D.M. Fields, S. Shema & A.B. Skiftesvik. Effects of ocean acidification on growth and development of the planktonic copepod, *Calanus finmarchicus*. U.S. National Science Foundation, 2nd U.S. Ocean Acidification Principal Investigator's Meeting, Washington, D.C., USA

05/2013- Browman, H.I., J. Havenhand, S. Dupont & L. Robbins. AMAP Arctic Ocean Acidification White Paper, Chapter 3, Biological responses to ocean acidification. AMAP International Conference on Arctic Ocean Acidification, Bergen, Norway - the talk can be viewed [HERE](#), at the 16.00 minute time point

12/2012- Browman, H.I., R.H. Maneja, C.M.F. Durif, R.M. Bjelland, A.B. Skiftesvik, D.M. Fields, S. Shema & J.A. Runge. Effects of ocean acidification on boreal and sub-Arctic fish larvae and zooplankton. Interdisciplinary symposium on ocean acidification and climate change. The Swire Institute of Marine Science, Hong Kong.

07/2012- Maneja, R.H., Frommel, A.Y., Clemmesen, C., Piatkowski, U., Geffen, A.J., Folkvord, A., Browman, H.I., Durif, C.M.F., Bjelland, R., Skiftesvik, A.B. Effects of ocean acidification on the swimming kinematics of larval Atlantic cod (*Gadus morhua*) and Atlantic herring (*Clupea harengus*).

36th Annual Larval Fish Conference, Bergen, Norway.

06/2011- Browman, H.I. Assessing the effect of ocean acidification on marine organisms. Research Seminar on Ocean Acidification, High North Research Centre on Climate and the Environment. Tromsø, Norway

09/2010- Browman, H.I. Assessing the effect of ocean acidification on marine organisms. Research Seminar on Ocean Acidification, Opening Conference of the High North Research Centre on Climate and the Environment, Tromsø, Norway

09/2010- Browman, H.I. Assessing the effect of ocean acidification on marine organisms. Workshop on Polar, Environmental and Climate Change Research, Sino-Norwegian Cooperation to meet global challenges, Shanghai
Interdisciplinary Cooperation

David Fields - Bigelow Laboratory for Ocean Sciences
Jeffrey Runge and Cameron Thompson - University of Maine
Andrew Mount and Vera Chan - Clemson University

Budget in accordance to results

As planned.

Could results from the project be subject for any commercial utilization

No

If Yes

No.

Conclusions

A temperature increase consistent with global climate change predictions for the Arctic is a more important driver for *Calanus* spp. and salmon lice populations than is ocean acidification.