Project information

Keywords

ocean acidification, evolution

Project title

ECOAN WP2-OA-5: Evolutionary rescue from Arctic OA

Year

2017

Project leader

Peter Thor

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

78.9556300, 11.9954600; 78.511535, 16.318572; 69.102461, -53.608253

Participants

Peter Thor, NPI (leader)
Haakon Hop (NPI)
Allison Bailey (NPI)
Sam Dupont (University of Gothenburg, UGOT)
Piero Calosi (Inversity of Quebec at Rimouski, UQAR)
Pierre De Wit (UGOT)
Janne E. Søreide (UNIS).

Flagship

Ocean Acidification

Funding Source

FRAM

NFR

Summary of Results

2015 studies: Widespread ocean acidification (OA) is modifying the chemistry of the global ocean, and the Arctic is recognised as the region where the earliest and strongest impacts of OA are expected. Moreover, while Arctic species show low energetic costs for maintenance at low temperatures, such low costs results in a lower capacity for cellular homeostasis and acid-base regulation rendering them vulnerable to OA. There are forces, however, which may counter detrimental effects of OA. Genetic variation enhances a species' tolerance to environmental changes, and present day genetically based phenotypic differences among isolated populations may enhance species' overall ability to counter future OA. In the present study, we found extant physiological phenotypic differences in OA response across geographically separated populations in *Calanus glacialis*. In copepodite stage CIV, measured reaction norms of ingestion rate and metabolic rate showed severe reductions in ingestion and increased metabolic expenses in two populations from Svalbard (Kongsfjord and Billefjord) whereas no effects were observed in a population from the Disko Bay, West Greenland. At pH_T 7.87, which has been predicted for the Svalbard west coast by year 2100, these changes resulted in reductions in scope for growth scope by 19% in the Kongsfjord and a staggering 50% in the Billefjord. But if the observed metabolic differences among the three populations emerged from differential selection, the Disko Bay population could function as a source of low pH-tolerant genotypes in the face of future OA.

2016 studies: *Calanus glacialis* constitutes a keystone species in the Arctic Ocean and adjacent seas Along the continental shelf this species dominates in terms of biomass, may exert significant grazing pressure on the microplankton community, and is a very important prey item for many Arctic fish species, baleen whales, and marine birds. Previous studies show negative effects on egg hatching of OA and in this year's studies we investigated if such effects are caused by a direct influence on eggs developing in low pH conditions, or delayed hatching is a result of maternal effects. *Calanus glacialis* females were caught in the Kongsfjord and brought to the Kings Bay Marine Lab for experiments. In the lab, the copepods were subjected to either present day conditions or conditions predicted for west Svalbard in the year 2100 for 7 days. Hatching rates of eggs produced under these conditions were compared to hatching rates of eggs transplanted between the two treatments to enable differentiation between direct effects on eggs and effects from mothers. Statistical analysis of results are underway, but a preliminary assessment indicates that effects may be mostly maternal. This study contributes to a more thorough understanding of the ways OA affects copepods in the Arctic. It enables a better focus of future research and further or possibilities to rigorously predict future population development under OA.

2017 studies: Sea water temperature changes constitute one of the most important synergistic stressors with OA. Thus this year's project's general objective was to investigate cumulative effect of temperature increase and OA on the Arctic keystone copepod species Calanus glacialis. Specific objectives had to be revisited due to technical issues with equipment related to the pH aspect of the originally planned experiment, but cumulative effect of long and short term thermal stress became the new objective of the fieldwork and experiment carried out in King's Bay Marine Laboratory in Ny-Ålesund. As metabolism drives the tolerance of organisms to environmental stress and the Arctic environment is predicted to be amongst the most vulnerable to Global Change, the project's specific objective was to characterize the energetic response

to long-term ocean warming and short-term heatwaves of C. glacialis. The energetic response here being defined as individuals' metabolic rate, which was measure via oxygen consumption rate, and metabolomics profile. Copepods were conditioned for 3 weeks to either present day control temperature or predicted 2035 predicted mean temperature for 3 weeks, and were then submitted to a heatwave treatment for 1 week. Survival, metabolic rate, and metabolomics were measured. Metabolomics protocols were successfully applied and preliminary results were produced. Oxygen consumption rates were measured on 113 individuals and metabolomics profiles were extracted from 58 individuals. Highest survival rate occurred in the present-day control temperature condition. Data on metabolic rates and metabolomics are being processes.

Master and PhD-students involved in the project

Allison Bailey (NPI)

Fanny Vermandele, Marie-Helene Carignan, Sarah Jacque, Mathilde Clouet, Cynthia, Thibault (UQAR, Canada)

Marie Deichmann (AU, Denmark)

Published Results/Planned Publications

Published:

1. Thor, P., S. Dupont (in press) Ocean acidification. *In:* Handbook on marine environment protection science. Impacts and sustainable management. M. Salomon and T. Markus (*eds*). Springer Verlag, Germany.
2. Thor, P., S. Dupont, P. Calosi, P. De Wit, J. Søreide, A. Bailey, E. Guscelli, L. Loubet-Sartou, I. Deichmann, M. Candee, C. Svensen, A. King, R. Bellerby, (2017) Contrasting physiological responses to future ocean acidification among Arctic copepod populations. *Global Change Biol.* DOI: 10.1111/gcb.13870. Impact factor 8.50
3. Bischof, K., P. Convey, P. Duarte, J-P Gattuso, M. Granberg, H. Hop, C. Hoppe, C. Jimenez, L. Lisitsyn, B. Martinez, M.Y. Roleda, P. Thor, J. Wiktor, G.W. Gabrielsen (in press) Kongsfjorden as harbinger of the future Arctic: knowns, unknowns and research priorities. *In: Adv. Polar. Ecol. vol 2. The Ecosystem of Kongsfjorden, Svalbard*. H. Hop, C. Wiencke (*eds*). Springer Verlag, Germany.
4. Bailey, A., P. De Wit, P. Thor, H. I. Browman, R. Bjelland, S. Shema, D.M. Fields, J.A. Runge, C. Thompson, H. Hop (2017) Regulation of gene expression underlies tolerance of the Arctic copepod *Calanus glacialis* to CO_2-acidified water. *Ecol. Evol.* DOI: 10.1002/ece3.3063
5. Algueró-Muñiz M., S. Alvarez-Fernandez, L.T. Bach, M. Esposito, H.G. Horn, U. Ecker, J.A.F. Lange, P. Thor, A.M. Malzahn, U. Riebesell, and M. Boersma (2017) Ocean acidification effects on mesozooplankton community development: results from a long-term near-natural conditions experiment. *PLOS One* 12:e0175851.
6. Thor, P., A. Bailey, C. Halsband, E. Guscelli, E. Gorokhova, A. Fransson (2016) Seawater pH predicted for the year 2100 affects the metabolic response to feeding in copepodites of the Arctic copepod *Calanus glacialis*. *PLOS One* e0168735.
7. Calosi, P., P. De Wit, P. Thor, S. Dupont (2016) Will life find a way? Evolution of marine species under global change. *Evol. Appl*. 9: 1035-1042.
8. Bach, L.T., J. Taucher, T. Boxhammer, A. Ludwig, The Kristineberg KOSMOS Consortium, E.P. Achterberg, M. Algueró-Muñiz, L.G. Anderson, J. Bellworthy, J. Büdenbender, J. Czerny, Y. Ericson, M. Esposito, M. Fischer, M. Haunost, D. Hellemann, H.G. Horn, T. Hornick, J. Meyer, M. Sswat, M. Zark, U. Riebesell (2016) Influence of ocean acidification on a natural winter-to-summer plankton succession: First insights from a long-term mesocosm study draw attention to periods of low nutrient concentrations. *PLOS One* e0159068 (as part of the Kristineberg KOSMOS Consortium).
9. Bailey A., P. Thor, H. Browman, D. Fields, J. Runge, A. Vermont, R. Bjelland, C. Thompson, S. Shema, C. Durif, H. Hop (2016) Early life stages of the Arctic copepod *Calanus glacialis* are unaffected by increased seawater pCO_2. *ICES J. Mar. Sci*. 74, 996-1004.
10. Fransson, A., P. Thor, A. Bailey, M. Chierici (2016) Ocean acidification state in Kongsfjorden. Fram Forum 2016.
11. De Wit, P., S. Dupont, & P. Thor (2015) Selection on oxidative phosphorylation and ribosomal structure as a multigenerational response to ocean acidification in the common copepod *Pseudocalanus acuspes. Evol. Appl.* 9: 1112-1123.
12. Wendt, I. and P. Thor (2015) Influence of prey species and concentration on egg production efficiency and hatching success in *Acartia tonsa* (Calanoida: Copepod) Dana. *Crustaceana* 88:675-687
13. Thor, P. and E. Oliva Oliver (2015) Ocean acidification elicits different energetic responses in an Arctic and a boreal population of the copepod *Pseudocalanus acuspes*. *Mar Biol* 162:799-807.
14. Thor, P. and S. Dupont (2015) Transgenerational effects alleviate severe fecundity loss during ocean acidification in a ubiquitous planktonic copepod. *Glob. Change Biol.* 21:2261-2271 Impact factor: 8.22
15. Thor, P., S. Dupont (2015) Hur kommer marina organismer att påverkas av framtidens havsförsurning? Havsutsikt 2015 (in swedish).
16. Thor, P., H. Browman, C. Halsband (2014) Ocean acidification – CO_2 effects in Northern waters. Fram Forum 2014.

Planned:

1. Thor, P., T.G. Nielsen, P. Tiselius, T. Juul-Pedersen, C. Michel, E.F. Møller, E. Selander (in prep) Does copepod grazing activity sustain microbial production during the Arctic post-spring bloom period?
2. Babin, M., F. Vermandele, P. Calosi, P. Thor (in prep). Development of a new metabolomic method for the contemporary detection of concentration changes in specific metabolites, lipids, and low molecular weight proteins in small tissue samples.
3. Thor, P., F. Vermandele, A. Bailey, C: Thibault, M. Babin, S: Dupont, P. Calosi (in prep) Developmental metabolomic plasticity of the copepodite stages of *Calanus glacialis* exposed to ocean acidification conditions.
4. Duarte, P., P. Thor, and A. Bailey (in prep) A coupled individual based dynamic energy budget model to predict impact on copepod populations during ocean acidification and climate change.
5. Thor, P., P. Duarte, and A. Bailey (in prep) Large scale changes to Arctic pelagic communities during future ocean acidification and climate change.
6. Thor, P., F. Vermandele, M.-H. Carignan, S. Jacques, P. Calosi (submitted) No maternal or direct effects of ocean acidification on egg hatching in the Arctic copepod *Calanus glacialis*. *PLOS One*
7. Mittermayer F., M. Stiasny, M. Chierici, T. Reusch, P. Thor, and C. Clemmesen (submitted) Transgenerational effects of ocean acidification on newly hatched larvae of cod *Gadus morhua*: Growth, respiration, and condition. *Global Change Biol.*

Communicated Results

1. Thor, P (2017) Ocean acidification. What does it matter to copepods? *Invited plenary presentation at the International Coneference on Copepoda, Los Angeles, USA.*
2. Thor, P (2017) Biological effects of ocena acidification. *Invited plenary presentation at the ESSAS Open Science Meeting, Tromsø, Norway.*
3. Bailey, A., P. de Wit, **P. Thor**, H.I. Browman, R. Bjelland, S. Shema, D.M. Fields, J. Runge, C. Thompson, and H. Hop (2017) Regulation of gene expression underpins tolerance of the Arctic copepod *Calanus glacialis* to increased pCO_2. Arctic Frontiers, Tromsø
4. **Thor, P.,** S. Dupont, P. De Wit (2016) Fast adaptation to ocean acidification in the copepod *Psuedocalanus acuspes*. *Oral presentation at the Oceans in a high CO2 world conference, Hobart, Australia.*
5. **Thor, P.**, Dupont, S., Calosi, P. De Wit, P., Nielsen, T.G., Søreide, J., Bailey, A., Guscelli, E., Loubet-Sartou, L., Deichmann, I., King, A., Bellerby, R., Candee, M. (2016) Differential adaptation to ocean acidification in sub-populations of an ubiquitous copepod *Calanus glacialis. Oral presentation at the Oceans in a high CO2 world conference, Hobart, Australia*
6. **Thor, P.,** S. Dupont, P. De Wit (2015) Evidence of fast adaptation to ocean acidification in a pelagic copepod. *Oral presentation at the ICES Annual Science Meeting, Copenhagen, Denmark.*
7. **Thor, P.** and S. Dupont (2015) Transgenerational effects alleviate severe fecundity loss during ocean acidification in a ubiquitous planktonic copepod. *Oral presentation at the Aquatic Sciences Meeting, Granada, Spain.*
8. **Thor, P.** and E. Oliva Oliver (2015) Arctic and boreal populations of the copepod *Pseudocalanus acuspes* show different metabolic responses to ocean acidification. *Oral presentation at the Arctic Change Conference, Ottawa, Canada.*
9. **Thor, P.** and S. Dupont (2013) A test of evolutionary effects of ocean acidification on a copepod population. *Oral presentation at the Nordic Marine Science Conference, Oslo, Norway.*

Interdisciplinary Cooperation

Cooperation between biologists and marine chemists

Budget in accordance to results

See overall flagship budget

Could results from the project be subject for any commercial utilization

No

Conclusions

See results presentaiton above