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<p>Cecilie Hansen (IMR)</p></dd><dt class="elflagship
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sdx/0A9_2015_Fig2.png" alt="" width="1437" height="799" /></p><p class="MsoNormal">Figure 2. SINMOD bidecadal average ice cover (i.e. number of days per year with >0 ice thickness, upper) and primary productivity integrated over the euphotic zone (lower), averaged over 1980-2000 (left), 2045-2065 under A1B scenario (middle), and the differences (right). </p>

<p class="MsoNormal"> </p>

<p class="MsoNormal"> Figure 3. SINMOD bidecadal average dissolved inorganic carbon (upper) and total alkalinity (lower) averaged over 0–50m and 1980-2000 (left), 2045-2065 under A1B scenario (middle), and the differences (right). </p>


<p> <br

Figure 4. SINMOD bidecadal average dissolved inorganic carbon (upper) and total alkalinity (lower) averaged over 0–50m and 1980–2000 (left), 2045–2065 under A1B scenario (middle), and the differences (right).

NORWECOM results

From NORWECOM.E2E two different simulations are now available forced by downscaled physics using ROMS for two different climate models and emission scenarios. In the first one the ROMS model is used to downscale the GISS-AOM climate model under A1B for the period 1980–2000 and 2046–2065, while in the second one the NorESM model is downscaled for the period 2006–2070 under RCP4.5. Focusing on the change on pH (Figure 1), both simulations give equal patterns with a mean decrease in most areas between 0.1 and 0.2, and with a higher reduction along the Norwegian coast. The main differences is in the Arctic and in the Fram strait where the NorESM simulation give an increase in pH, while the GISS-AOM give a decrease.

A



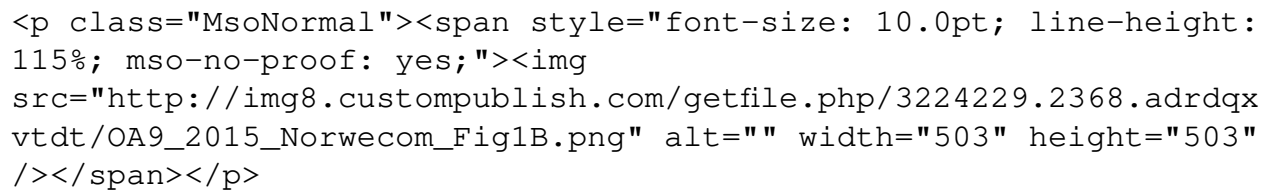
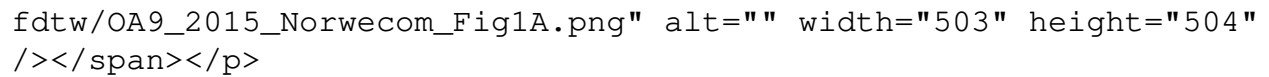


Figure 1:
Change in surface pH between control and future climate for the two different NORWECOM.E2E realisations. A: 2065–2000 forced by downscaled the GISS-AOM. B: 2069–2006 forced by the downscaled NorESM model.

NoBa results

Running NoBa with impact of ocean acidification on large zooplankton (ZL)

To explore direct effects of ocean acidification on lower

trophic levels and indirect effects on higher trophic levels and potential implications for management, an end-to-end model, NoBa, has been implemented and run for the Nordic and Barents Seas. Impact of ocean acidification is implemented in NoBa using a pH-scalar which is multiplied with the growth rate and consumption rate, whereas the mortality rate is divided by it. Here, we will only present results from the Barents Sea. NoBa was in these scenarios run for two periods using physical (salinity, temperature, volume fluxes) from ROMS (Table 1). These two periods represent the years 1980–2001 and 2046–2065. The first period (1980–2001) was run as a control run. For the second period, three simulations was performed; first a control run including no effects of pH, thereafter one run where the pH scalar was 1.36, and in the last one the pH scalar was 0.64. On the 24th November, a group of experts were gathered for one day in Tromsø; to define a set of pH scalars that NoBa will use to run a range of realistic scenarios exploring potential effects of ocean acidifications.

For the two runs including an effect of ocean acidification, we chose to apply the pH scalar only on large zooplankton. For all simulations we present effects of ocean acidification or physical forcing itself on a few selected components in the system; the commercially important (cod, saithe, haddock and herring) and important prey items (polar cod and capelin). All simulations are 45 years long, with a spinup time of 25 years. In the spin-up period, the physical forcing is held constant at the first year of the period (1980 or 2045).

Identifying the ‘most important’ zooplankton group in the system

Large zooplankton, which in NoBa represents all zooplankton with a length above 2 mm, was

chosen based on a small sensitivity study, where the total effect on the ecosystem by decreasing one zooplankton group at a time was measured by exploring the total changes in the biomasses of the other components in the system. The simulations performed are described in Table 1.

Table 1: Overview of the runs performed exploring the sensitivity of the ecosystem to the four different classes of zooplankton; Large (ZL), medium (ZM), small (ZS) and gelatinous (ZG). The parameters tuned are growth rates (μ_{XXX} ; mgN d^{-1}), mortality rates (m_Q ; d^{-1}) and consumption rates (C_{XXX} ; mgN d^{-1}). In the simulations where we determine which zooplankton group is most important for the flow in the ecosystem, we have decreased the growth rates of all the four zooplankton groups by 25%.

<p>Run</p>	<p>Period</p>	<p></p>
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<p class="MsoNormal" style="text-align: center;" align="center">mum_ZL, C_ZL, mQ_ZL</p>

</td>

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<p class="MsoNormal" style="margin-bottom: 0.0001pt; text-align: center;" align="center">0.272,</p>

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<p class="MsoNormal" style="text-align: center;" align="center">As in run 6</p>

</td>

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</td>

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width="99">

<p class="MsoNormal" style="text-align: center;" align="center">mum_ZL, C_ZL, mQ_ZL</p>

</td>

<td style="width: 78.15pt; border-top: none; border-left: none; border-bottom: solid windowtext 1.0pt; border-right: solid windowtext 1.0pt; mso-border-top-alt: solid windowtext .5pt; mso-border-left-alt: solid windowtext .5pt; mso-border-alt: solid windowtext .5pt; padding: 0cm 5.4pt 0cm 5.4pt;" valign="top" width="130">

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<p class="MsoNormal" style="margin-bottom: 0.0001pt; text-align: center;" align="center">8e-1</p>

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<p class="MsoNormal" style="margin-bottom: 0.0001pt; text-align: center;" align="center">0.128,</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt; text-align: center;" align="center">1.25e-9</p>

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<p> </p>

<p class="MsoNormal">In the sensitivity runs, the changes in average biomass of the last 10 years were

calculated for all components in the system. We thus identified the large zooplankton group as the zooplankton group that the ecosystem was most vulnerable to.</p>

<p> </p>

<p class="MsoNormal"> </p>

<p> </p>

<p> </p>

<p class="MsoNormal">The expected changes in the runs would be that the simulation including a negative impact on ZL would yield lower fish biomass than the one with the positive effect by OA on ZL. However, this is not always the case. Here, we find that decreasing the large zooplankton introduced increases in most of the species that we have explored, with the exception of haddock and saithe (Table 3 and Table 4). The changes are small though, for all species except capelin, which has an increase of 85% in the negative run. Looking at Figure 2, this is explained by the large peak that the population experiences around year 17. The recruitment success of this particular period needs to be thoroughly explored before we draw any further conclusions about it.</p>

<p class="MsoNormal"> A</p>

<p class="MsoNormal"> </p>

<p class="MsoNormal"> </p>

<p class="MsoNormal">B</p>

<p class="MsoNormal"> </p>

<p class="MsoNormal">Figure 1: The development over the last 20 years of the simulations. The figures shows that there are differences introduced by the physical forcing alone, this should be kept in mind when looking at the results from the ocean acidification runs.</p>

A

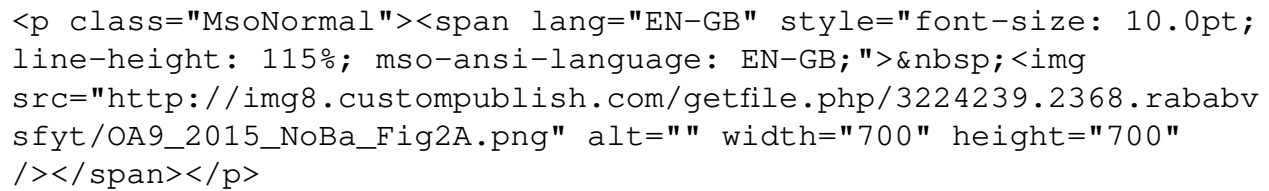




Figure 2: The development of the biomass of cod and capelin over the last 20 years of the simulation.

Table 3: Changes (%) in average biomass over the last 10 years of the simulation compared to the average biomass in the last 10 years of the 20C3M control run.

Species

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align="center"><span style="font-size: 10pt; line-height:
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115%;">-3.1</p>
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<p class="MsoNormal" style="text-align: center;" align="center">-8.4</p>
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</td>
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<p class="MsoNormal"> </p>
<p class="MsoNormal">Table 4<span lang="EN-GB" style="font-size: 10.0pt;

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width="177">
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valign="top" width="177">
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line-height: 115%; mso-ansi-language: EN-GB;">Capelin</span></p>
</td>
<td style="width: 106.45pt; border-top: none; border-left: none;
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width="177">
<p class="MsoNormal" style="text-align: center;"
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windowtext .5pt; padding: 0cm 5.4pt 0cm 5.4pt;" valign="top"
width="177">
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<p class="MsoNormal" style="text-align: center;" align="center">63.6</p>
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</td>
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<p class="MsoNormal" style="text-align: center;" align="center">-5.5</p>
</td>
<td style="width: 106.45pt; border-top: none; border-left: none; border-bottom: solid windowtext 1.0pt; border-right: solid windowtext 1.0pt; mso-border-top-alt: solid windowtext .5pt; mso-border-left-alt: solid windowtext .5pt; mso-border-alt: solid windowtext .5pt; padding: 0cm 5.4pt 0cm 5.4pt;" valign="top" width="177">
<p class="MsoNormal" style="text-align: center;" align="center">15.0</p>
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</tr>
<tr>
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<p class="MsoNormal">Herring</p>
</td>
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border-left-alt: solid windowtext .5pt; mso-border-alt: solid
windowtext .5pt; padding: 0cm 5.4pt 0cm 5.4pt;" valign="top"
width="177">
<p class="MsoNormal" style="text-align: center;"
align="center"><span style="font-size: 10pt; line-height:
115%;">-1.8</span></p>
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width="177">
<p class="MsoNormal" style="text-align: center;"
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<tr>
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valign="top" width="177">
<p class="MsoNormal"><span lang="EN-GB" style="font-size: 10.0pt;
line-height: 115%; mso-ansi-language: EN-GB;">Haddock</span></p>
</td>
<td style="width: 106.45pt; border-top: none; border-left: none;
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windowtext .5pt; padding: 0cm 5.4pt 0cm 5.4pt;" valign="top"
width="177">
<p class="MsoNormal" style="text-align: center;"
align="center"><span style="font-size: 10pt; line-height:
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</td>
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windowtext .5pt; padding: 0cm 5.4pt 0cm 5.4pt;" valign="top"
width="177">
<p class="MsoNormal" style="text-align: center;"
align="center"><span style="font-size: 10pt; line-height:
```

115%;">-1.0</p>
</td>
</tr>
<tr>
<td style="width: 106.45pt; border: solid windowtext 1.0pt; border-top: none; mso-border-top-alt: solid windowtext .5pt; mso-border-alt: solid windowtext .5pt; padding: 0cm 5.4pt 0cm 5.4pt;" valign="top" width="177">
<p class="MsoNormal">Saithe</p>
</td>
<td style="width: 106.45pt; border-top: none; border-left: none; border-bottom: solid windowtext 1.0pt; border-right: solid windowtext 1.0pt; mso-border-top-alt: solid windowtext .5pt; mso-border-left-alt: solid windowtext .5pt; mso-border-alt: solid windowtext .5pt; padding: 0cm 5.4pt 0cm 5.4pt;" valign="top" width="177">
<p class="MsoNormal" style="text-align: center;" align="center">-1.1</p>
</td>
<td style="width: 106.45pt; border-top: none; border-left: none; border-bottom: solid windowtext 1.0pt; border-right: solid windowtext 1.0pt; mso-border-top-alt: solid windowtext .5pt; mso-border-left-alt: solid windowtext .5pt; mso-border-alt: solid windowtext .5pt; padding: 0cm 5.4pt 0cm 5.4pt;" valign="top" width="177">
<p class="MsoNormal" style="text-align: center;" align="center">-2.5</p>
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<p class="MsoNormal"> </p>
<p class="MsoNormal">Based on these preliminary results, we cannot conclude that impact of ocean acidification on large zooplankton will have any impact on management of the large commercial stocks in the Barents Sea. It also has to be noted that the largest introduction of changes in the biomass comes when changing the physical forcing, not by introducing effects of ocean acidification. The buffering effect in the Barents Sea has also been shown in literature to be rather strong, and we might not see any effects before perturbing several parts of the ecosystem at the same time.</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;"> </p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">References</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{1}Keup-Thiel, E., Gottel, H., Jacob, D. 2006. Boreal Environment Research. 11(5): 329-339.</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{2}Dankers, R., Middelkoop, H. 2008. Climatic Change, 87: 131-153.</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{3}Tjiputra, J. F., Assmann, K., Bentsen, M. et al. 2010. Geoscientific Model Development, 3: 123-141.</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{4}Key, R. M., Tanhua, T., Olsen, A. et al. 2010. ESSD 2, 105-121.</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{5}van Heuven, S., Pierrot, D., Rae, J. W. B. et al. 2011. In ORNL/CDIAC-105b. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S., Department of Energy, Oak Ridge, Tennessee</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{6}Millero, F.J. 2010. Marine and Freshwater Research 61(2) 139-142.</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{7}Dickson, A.G., 1990. J. Chemical Thermodynamics, 22:113-127. </p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{8}Uppstrøm, L.R., 1974. Deep Sea Research I, 21(2) 161-162.</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{9}Riley, J. P. and Tongudai, M., Chemical Geology 2:263-269, 1967.</p>

<p class="MsoNormal" style="margin-bottom: 0.0001pt;">^{}</p>

10>Skogen, M. D. et al. 2014. Journal of Marine Systems 131, 10–20.

<p>For the Management</p>	<p>The project has progressed as planned in the proposal and all milestones and deliverables have been met.</p>
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<p>Published Results/Planned Publications</p>	<p>Published Results/Planned Publications</p>
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<p>A peer-review paper on the SINMOD projections is planned for 2016.</p>	<p>A peer-review paper on the SINMOD projections is planned for 2016.</p>
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<p>Communicated Results</p>	<p>Communicated Results</p>
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<p>SINMOD projections were presented in a poster at the FRAM Science Days conference.</p>	<p>SINMOD projections were presented in a poster at the FRAM Science Days conference.</p>
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<p>Interdisciplinary Cooperation</p>	<p>Interdisciplinary Cooperation</p>
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<p>This project has demanded collaboration between biogeochemical modellers (SINMOD, NORWECOM), ecosystem modellers (NoBa), the socioeconomic modellers in ECOAN-WP4 as well as the</p>	<p>This project has demanded collaboration between biogeochemical modellers (SINMOD, NORWECOM), ecosystem modellers (NoBa), the socioeconomic modellers in ECOAN-WP4 as well as the</p>
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observationalists in ECOAN-WP1 and ECOAN-WP2. A workshop on Calanus sensitivity to climate change and acidification took place in November to promote this collaboration and gather information needed for future work in WP3 and WP4.</p></dd><dt class="elcould_results_from_the_project_be_subject_for_any_commercial_utilization ">Could results from the project be subject for any commercial utilization</dt><dd style="" class="elvalcould_results_from_the_project_be_subject_for_any_commercial_utilization " >No</dd><dt class="elconclusions Editor">Conclusions</dt><dd style="" class="elvalconclusions Editor" ><p>The project has progressed in line with the proposal, and is providing important insights into projected climate change, acidification, and possible ecosystem responses. Interdisciplinary collaborations with other workpackages have been established and utilized.</p></dd></dl></fieldset></body></html>