International Max Planck Research School on
EARTH SYSTEM MODELLING

**INTEGRATION: Integrated assessment of changes in the Thermohaline Circulation**

# *Economic impacts of changes in population dynamics of fish species in the Barents Sea*

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## Background and model characteristics

Besides climatological and ecological consequences, a weakening or breakdown of the thermohaline circulation also has distinct **economic impacts** on important industries in the North Atlantic region. The **fisheries** in the Barents Sea and the Norwegian Sea are directly affected by changes in the commercially exploited fish stocks in these waters.

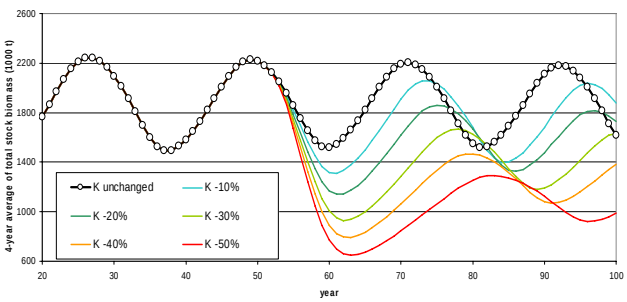
The assessment of the economic consequences of changes in population dynamics of the interacting species **cod** (*Gadus morhua*) and **capelin** (*Mallotus villosus*), which may occur because of changes in hydrographic conditions, is conducted using a **bioeconomic simulation model** of the fisheries exploiting these fish stocks.

Cod is caught by **trawlers** and by smaller **coastal vessels**, while capelin is harvested by a fleet of **purse seine vessels**.

Simulations are conducted for **two different harvesting strategies** of the fishermen: with **adaptive harvesting strategies** the fleets adjust their fishing effort based on the harvesting success in the previous fishing periods. If a **profit maximizing harvesting strategy** is applied, the fleets set their fishing effort to seek the highest possible net present value of profits over a chosen number of fishing periods.

All simulations cover a time period of 100 years. The change in hydrographic conditions is simulated by a sudden reduction of the rate of reproduction and/or the environmental carrying capacity of the fish species, which occurs in year 50 of each simulation.

## Impacts with adaptive harvesting strategies




The cod stock declines substantially in size if the carrying capacity is reduced. For large reductions of the carrying capacity the stock is unable to recover from the initial reduction. The same holds for the capelin stock.

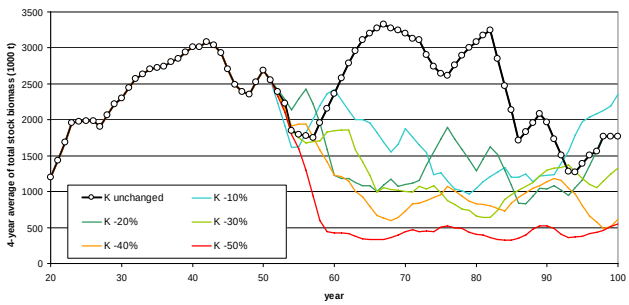
| time period<br>change of the carrying capacity | **trawlers** (cod) average annual catch (kt) | change from ref. scen. | **coastal vessels** (cod) average annual catch (kt) | change from ref. scen. | **purse seiners** (capelin) average annual catch (kt) | change from ref. scen. |
|---|---|---|---|---|---|---|
| *years 30-44* | 168.7 | | 74.1 | | 1022.3 | |
| *yrs 50-64* reference | 164.7 | | 98.1 | | 977.5 | |
| *yrs 50-64* K -10% | 167.8 | +1.9% | 91.8 | -6.4% | 966.4 | -1.1% |
| *yrs 50-64* K -20% | 157.8 | -4.2% | 93.6 | -4.6% | 928.1 | -5.1% |
| *yrs 50-64* K -30% | 156.9 | -4.7% | 87.6 | -10.7% | 888.8 | -9.1% |
| *yrs 50-64* K -40% | 147.2 | -10.6% | 83.9 | -14.5% | 821.7 | -15.9% |
| *yrs 50-64* K -50% | 137.6 | -16.5% | 80.1 | -18.3% | 745.7 | -23.7% |
| *yrs 70-84* reference | 150.8 | | 123.1 | | 949.0 | |
| *yrs 70-84* K -10% | 148.6 | -1.5% | 84.9 | -31.0% | 848.3 | -10.6% |
| *yrs 70-84* K -20% | 100.3 | -33.5% | 89.8 | -27.1% | 792.1 | -16.5% |
| *yrs 70-84* K -30% | 84.3 | -44.1% | 50.9 | -58.7% | 753.8 | -20.6% |
| *yrs 70-84* K -40% | 54.7 | -63.7% | 39.1 | -68.2% | 720.5 | -24.1% |
| *yrs 70-84* K -50% | 32.6 | -78.4% | 22.4 | -81.8% | 679.5 | -28.4% |

Annual catches are only marginally affected in the first decade after the change in the carrying capacities. In the long run, there are substantial reductions of landings, which are much more pronounced in the fisheries of cod, the species with the higher commercial value.

| time period,<br>change of the carrying capacity | **trawlers** (cod) net present value of profits (mio. NOK) | **coastal vessels** (cod) net present value of profits (mio. NOK) | **purse seiners** (capelin) net present value of profits (mio. NOK) |
|---|---|---|---|
| *years 30-44* | 581.9 | 413.4 | 695.1 |
| *yrs 50-64* reference | 212.8 | 448.9 | 616.7 |
| *yrs 50-64* K -10% | 211.9 | 448.4 | 614.8 |
| *yrs 50-64* K -20% | 210.3 | 447.9 | 612.8 |
| *yrs 50-64* K -30% | 208.8 | 447.2 | 610.8 |
| *yrs 50-64* K -40% | 207.0 | 446.5 | 608.8 |
| *yrs 50-64* K -50% | 205.1 | 445.7 | 606.7 |
| *yrs 70-84* reference | -199.8 | 577.3 | 613.4 |
| *yrs 70-84* K -10% | -547.5 | 11.5 | 642.6 |
| *yrs 70-84* K -20% | -899.4 | -84.9 | 684.2 |
| *yrs 70-84* K -30% | -962.9 | -245.6 | 739.3 |
| *yrs 70-84* K -40% | -1079.3 | -312.1 | 718.4 |
| *yrs 70-84* K -50% | -1189.6 | -375.9 | 672.6 |

The cod fishery is severely affected by reductions of the carrying capacities, rendering the cost-intensive trawl fishery unprofitable in most scenarios. In contrast, the capelin fishery is practically unaffected and can even profit of the change in population dynamics in some scenarios.

## Impacts with profit-maximizing fishing strategies




The cod stock declines drastically in all scenarios with a change in the carrying capacity with little chance of recovery. In contrast, the capelin stock increases in size because of decreased predation pressure by cod.

| time period<br>change of the carrying capacity | **trawlers** (cod) average annual catch (kt) | change from ref. scen. | **coastal vessels** (cod) average annual catch (kt) | change from ref. scen. | **purse seiners** (capelin) average annual catch (kt) | change from ref. scen. |
|---|---|---|---|---|---|---|
| *years 30-44* | 96.5 | | 76.9 | | 425.0 | |
| *yrs 50-64* reference | 136.8 | | 32.9 | | 666.1 | |
| *yrs 50-64* K -10% | 225.0 | +64.5% | 59.0 | +79.6% | 714.4 | +7.2% |
| *yrs 50-64* K -20% | 204.9 | +49.8% | 78.5 | +138.8% | 829.2 | +24.5% |
| *yrs 50-64* K -30% | 162.1 | +18.5% | 111.9 | +240.4% | 686.6 | +3.1% |
| *yrs 50-64* K -40% | 214.7 | +57.0% | 64.0 | +94.6% | 712.8 | +7.0% |
| *yrs 50-64* K -50% | 232.8 | +70.1% | 48.2 | +46.5% | 911.1 | +36.8% |
| *yrs 70-84* reference | 121.3 | | 99.4 | | 385.9 | |
| *yrs 70-84* K -10% | 231.5 | +90.9% | 76.9 | -22.6% | 1294.6 | +235.5% |
| *yrs 70-84* K -20% | 133.0 | +9.6% | 71.8 | -27.7% | 981.7 | +154.4% |
| *yrs 70-84* K -30% | 142.6 | +17.6% | 23.1 | -76.7% | 1243.9 | +222.3% |
| *yrs 70-84* K -40% | 87.4 | -27.9% | 40.1 | -59.6% | 1032.1 | +167.5% |
| *yrs 70-84* K -50% | 97.6 | -19.5% | 20.8 | -79.0% | 1123.6 | +191.2% |

Average annual catches are initially not adversely affected by a reduction of the carrying capacities and even increase for all fleets in all scenarios. In the long run, overall cod landings decline, while catches of the capelin fishery multiply despite impaired population dynamics.

| time period,<br>change of the carrying capacity | **trawlers** (cod) net present value of profits (mio. NOK) | **coastal vessels** (cod) net present value of profits (mio. NOK) | **purse seiners** (capelin) net present value of profits (mio. NOK) |
|---|---|---|---|
| *years 30-44* | -1242.4 | 227.8 | 433.0 |
| *yrs 50-64* reference | -218.0 | -201.8 | 530.6 |
| *yrs 50-64* K -10% | 921.9 | 1511.6 | 603.7 |
| *yrs 50-64* K -20% | -1445.5 | -498.6 | 490.2 |
| *yrs 50-64* K -30% | -581.1 | 373.6 | 523.2 |
| *yrs 50-64* K -40% | -975.5 | 299.6 | 509.2 |
| *yrs 50-64* K -50% | -1002.2 | 1532.7 | 531.8 |
| *yrs 70-84* reference | -1168.9 | 2434.8 | 197.5 |
| *yrs 70-84* K -10% | -950.1 | -354.3 | 933.7 |
| *yrs 70-84* K -20% | -1446.4 | -410.5 | 1004.2 |
| *yrs 70-84* K -30% | -417.8 | -494.5 | 983.5 |
| *yrs 70-84* K -40% | 287.9 | -514.0 | 896.5 |
| *yrs 70-84* K -50% | -1363.7 | -813.9 | 989.2 |

When the joint profits of all fleets are maximized over a two-year time horizon, the fishing activities of the cost-intensive trawl fishery are reduced in favor of the other fleets. There is no apparent trend in the development of the net present value of profits for reduced carrying capacities.

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