The marine fisheries in the Barents Sea:

Impacts of changes in thermohaline circulation strength on profitability

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Shutdown of the THC

The anthropogenicially induced climate change generally leads to warming of the North Atlantic ocean. Increased precipitation and a melting of glaciers in Greenland are the source of additional freshwater input in that region. This can cause a weakening or even a complete shutdown of the deep water formation, which drives the thermohaline circulation (THC).

A shutdown of the THC has severe consequences for the North Atlantic region, since the reduced heat transport to higher latitudes could cause a regional cooling of several degrees. Furthermore, the local circulation patterns in the Nordic Seas would be altered (Fig. 1), which has important implications for the development of the fish stocks in the Barents Sea.

The bioeconomic simulation model

The impacts of possible changes in THC strength on the most important fisheries in the Barents Sea (Fig. 2) are assessed using a bioeconomic simulation model. This model (Fig. 3) considers the commercially harvested species cod (*Gadus morhua*) and capelin (*Mallotus villosus*). Changes in the environmental conditions near the spawning grounds influence the recruitment success and the survival rates of the different age classes of both species. A close predator-prey-relationship also relates cod growth rates to capelin abundance.

Both stocks are exploited by fishing fleets with different catch efficiencies that target different age groups. Within the limit of a maximum total allowable catch the fleets can freely compete for the resource. Fishermen can follow either a purely stock size based harvesting strategy, in which the necessary fishing effort is determined based on harvest success in previous fishing periods, or a coupled hydrography-stock size based harvesting strategy, in which the economic returns are optimized over a specific number of fishing periods.

Consequences for the fish stocks

Climate change leads to changes in hydrographic conditions in the Barents Sea that can have two qualitatively different consequences for the fish stocks. The warming of the spawning grounds (Fig. 4) generally increases chances of successful recruitment of new age classes, particularly for cod. In contrast, the weaker THC (Fig. 5) leads to changes in local circulation patterns that drastically diminishes the survival rates of young cod. The long-term development of the fish stocks is critically dependent on which of these trends turns out to have the larger influence on them.

The results show that the influence of the warming of the spawning grounds on stock development is comparably small. In contrast, the cod stock declines drastically if the THC shuts down (Fig. 6). The capelin stock can benefit to some extent from the reduced predation pressure. However, the variability in capelin stock size increases with time as well.

Impacts on the fisheries

In general, cod catches remain stable throughout the simulation period despite changes in hydrographic conditions (Fig. 7). The fishery is dominated by the large trawlers, while the importance of the coastal vessels remains marginal. Total cod catches decline somewhat over time but remain high enough to secure the profitability of the fishery. Only if the THC shuts down, catches decline to such low levels that the entire cod fishery becomes unprofitable (Tab. 1).

Overall, the capelin fishery remains untouched by the consequences of a possible shutdown of the THC. Catches and profits show less variability than the cod fishery (Tab. 2). The strong increase in capelin landings in the THC shutdown scenario coincides with the substantial decline of the cod population (Fig. 7). Consequently, less capelin falls prey to cod and can be harvested by the fishermen. However, this increase in returns from fishing is insufficient to offset the losses incurred by the cod fishery in case of a shutdown of the THC.

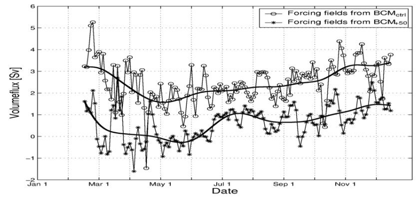

Fig. 1: Inflow into the Barents Sea with a stable and a weakened THC (Vikebø *et al.* 2007)

Fig. 2: The ranges of cod and capelin in the Barents Sea

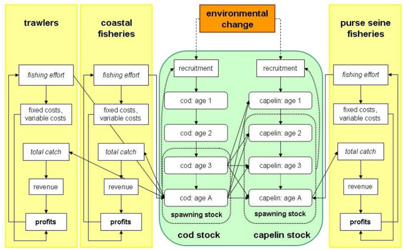

Fig. 3: The bioeconomic simulation model

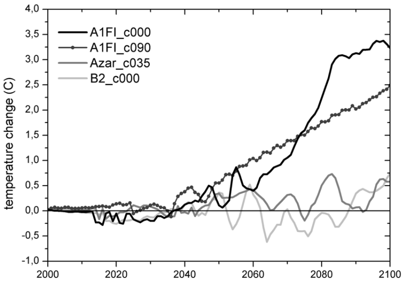

Fig. 4: Development of temperature in the spawning grounds

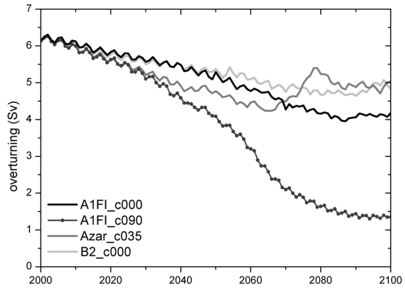

Fig. 5: Development of THC strength in the different scenarios

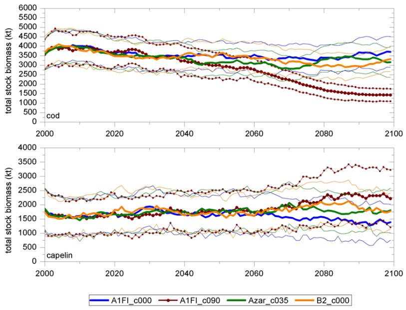

Fig. 6: Development of the fish populations

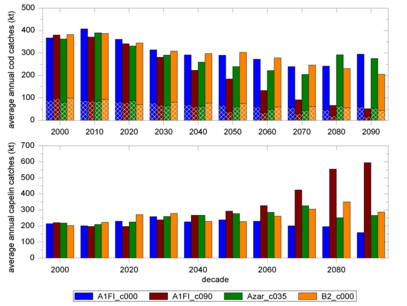

Fig. 7: Development of the amount of fish harvested

	A1FI_c000 average annual profit [million Nkr]	A1FI_c000 average fleet size [no. of vessels]	A1FI_c090 average annual profit [million Nkr]	A1FI_c090 average fleet size [no. of vessels]	Azar_c035 average annual profit [million Nkr]	Azar_c035 average fleet size [no. of vessels]	B2_c000 average annual profit [million Nkr]	B2_c000 average fleet size [no. of vessels]
trawlers								
2000s	1750.40	58	1785.06	58	1798.56	58	1802.23	58
2010s	2258.79	57	1893.61	57	2094.39	57	1939.10	56
2020s	1838.35	56	1749.32	56	1503.44	56	1792.97	55
2030s	1457.80	55	1242.38	54	1397.52	54	1402.66	54
2040s	1319.09	54	798.78	52	1141.88	53	1374.22	53
2050s	1422.00	52	691.84	50	970.54	51	1468.63	51
2060s	1294.48	51	277.58	47	981.01	48	1372.53	49
2070s	1118.69	49	-38.57	43	880.17	46	1079.78	47
2080s	1239.89	46	-130.09	38	1596.96	44	1047.17	46
2090s	1655.64	44	-166.92	34	1550.61	43	921.97	43

Tab. 1: profitability of the cod fishery: trawlers

	A1FI_c000 average annual profit [million Nkr]	A1FI_c000 average fleet size [no. of vessels]	A1FI_c090 average annual profit [million Nkr]	A1FI_c090 average fleet size [no. of vessels]	Azar_c035 average annual profit [million Nkr]	Azar_c035 average fleet size [no. of vessels]	B2_c000 average annual profit [million Nkr]	B2_c000 average fleet size [no. of vessels]
purse seiners								
2000s	143.44	75	148.02	76	146.48	76	132.85	75
2010s	127.17	79	123.72	79	136.20	80	147.79	79
2020s	153.79	82	124.61	82	147.63	84	193.95	83
2030s	181.02	88	161.20	86	181.56	89	199.70	89
2040s	149.53	93	190.97	90	187.26	93	150.16	95
2050s	160.57	97	212.37	94	197.81	98	148.59	100
2060s	151.78	101	245.20	99	202.57	103	178.52	104
2070s	124.00	104	343.09	102	242.90	108	223.55	110
2080s	121.43	105	480.35	109	167.02	114	264.33	119
2090s	86.86	105	518.29	119	181.21	120	198.25	128

Tab. 2: profitability of the capelin fishery

Link, P.M. & Tol, R.S.J. (2009): Economic impacts on key Barents Sea fisheries arising from changes in the strength of the Atlantic thermohaline circulation, *Global Environmental Change*, doi:10.1016/j.gloenvcha.2009.07.007

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