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New study

Climate refugee Cod

High Probability for loss of breeding grounds if temperature increases by more than 1.5 degrees

[28. November 2018] **The latest research conducted by AWI experts that the chances of survival for the offspring of important fish species will dramatically worsen, if the 1.5 ° C target of the Paris Climate Agreement is not achieved. Under conditions of further warming and acidification of the ocean, Atlantic cod and its arctic relative polar cod would be forced to look for new habitats in the far north. Their populations could dwindle. If so, this could be disastrous, as the polar cod is the most important food source for Arctic seals and seabirds. In addition, fishers could lose the world's most productive area for catching Atlantic cod, located to the north of Norway. However, the results of the study in the magazine science advances also show that a stringent climate policy could prevent the worst consequences for animals and humans.**

There are some types of fish that prefer extremely cool water – and can only spawn in cold water. The Atlantic cod, a well-known and favourite food fish, is one of them. Even better adapted to the cold is the polar cod, which overwinters in the Arctic in large swarms below the sea ice. The polar cod spawns at water temperatures between 0 and 1.5 degrees Celsius, because the fertilised eggs / the embryos can best develop at this temperature. In contrast, the Atlantic cod spawns at 3 to 7 degrees, which, from a human standpoint, is still extremely cold. The AWI researchers Flemming Dahlke and Dr Daniela Storch are convinced that this dependency on cold water could prove fateful for both species; as a result of climate change, especially the waters of the North Atlantic and Arctic will warm considerably unless human beings find a way to massively reduce emissions of the greenhouse gas carbon dioxide. In addition, there is the problem of acidification: the more carbon dioxide finds its way into the atmosphere, the more carbon dioxide dissolves in the ocean. Carbon dioxide bonds with water to form carbonic acid, which acidifies the ocean as it decays. "That means Atlantic cod and polar cod will be doubly stressed in the future: their habitat will simultaneously grow warmer and more acidic," explains marine ecologist Flemming Dahlke.

He and project director Dr Daniela Storch, as the first researchers worldwide, have now used painstaking experiments to investigate how a simultaneous acidification and warming would affect the eggs of both species. In this context,

Emptying the fish lift into the tank (Photo: Alfred-Wegener-Institut / Kristina Bär)

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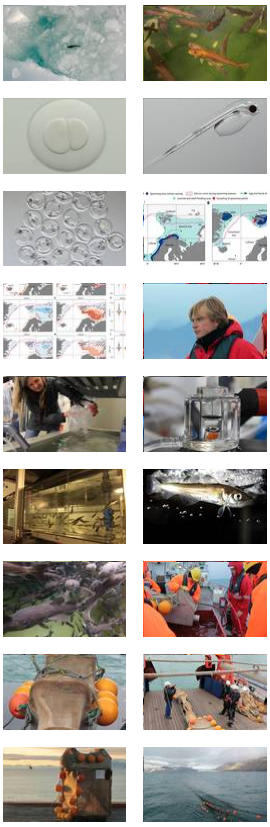

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the two AWI experts have especially concentrated on the embryos' development up to the point where they hatch as larvae, only a few millimetres long. During this stage, they are especially sensitive to changing environmental conditions, which climate change could realistically produce. The researchers' findings are sobering: in both species, even a small rise in temperature can cause the eggs to die or produce deformations in the larvae. "As we can see, the embryos are very sensitive, especially in the early phase of their development," says Flemming Dahlke. As the experiments clearly show, the situation becomes even worse when the water is acidic: the number of embryos that don't survive increases by 20 to 30 percent at a pH level of 7.7, even at optimal temperatures.

Polar Cod: Newly hatched larva (Photo: Alfred-Wegener-Institut / Flemming Dahlke)

In addition, the two AWI researchers' work is unique in that they combined laboratory findings with established climate models. The models predict the extent to which temperatures in various waters will be affected by climate change, and how much they will acidify. In turn, thanks to their experiments the two researchers can now precisely determine in which areas the Atlantic cod and polar cod will no longer be able to spawn in the future. It also becomes clear that we could see shifts in fish populations, because the adults will have to search for new spawning areas where their eggs or embryos can still find viable conditions for normal development. In this regard, Dahlke and Storch have chiefly considered three climate scenarios: the business-as-usual scenario, in which there is no meaningful reduction in carbon dioxide emissions by the end of the 21st century; a climate scenario with moderate warming, and a scenario in which the IPCC's 1.5-degree goal – according to which the Earth's temperature can't be allowed to increase by more than 1.5 degrees in order to avoid the worst effects of climate change – is achieved. Working together with climate modeller Martin Butzin from the AWI, they arrived at some interesting conclusions. According to Flemming Dahlke, "They show that, for the business-as-usual scenario, conditions for the young Atlantic cod will especially deteriorate in the North Atlantic near the end of this century. In the regions around Iceland and Norway, up to 60 percent fewer cod larvae will hatch from their eggs." Generally speaking, the Atlantic cod populations in the Northeast Atlantic will likely shift into the Arctic, where the spawning grounds still offer adequate conditions. This could especially pose problems for the fishing industry, since the coasts of Iceland and Norway are currently home to the world's largest populations of Atlantic cod: Every year, around 800,000 tonnes of cod worth 2 billion euros are harvested here. If these populations dwindle, as the AWI experts' findings indicate, the losses could be enormous.

Polar cod in ice (Photo: Jasmine Nahrgang, UIT The Arctic University of Norway)

What's more, the business-as-usual scenario also looks bleak for the polar cod. If the waters grow warmer, it will retreat north, not only for the business-as-usual scenario but also under the scenario with moderate warming. Since the polar cod depends on sea ice for its overwintering phase, it remains to be seen how the populations will be affected if the sea-ice extent continues to shrink. Nor is it clear to what extent the Atlantic cod will encroach on the polar cod's territory. Given the fact that the Atlantic cod is considerably larger and more aggressive than its polar cousin, the latter may have

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to fight for its food. Whether or not that happens, a drop in the polar cod population would be catastrophic, as it is a staple food for many organisms in the Arctic – including seals, seabirds and even whales.

The limits of fish species' distribution also depend on where the prevalent temperatures are optimal for spawning. Dahlke and Storch's experiments have for the first time confirmed that acidification makes fish embryos more sensitive not only to higher temperatures, but also to lower ones. "We've observed that the young Atlantic cod not only react adversely to warmer temperatures, but also to especially cold ones," says Daniela Storch. "The acidification amplifies this effect." In other words: the added burden of acidification reduces the suitable temperature range for Atlantic cod and polar cod to spawn. As Flemming Dahlke relates: "The fish become more sensitive to extreme temperatures, and consequently to the anticipated warming." This would ultimately mean that the two species' potential spawning grounds shrink, and that they might have less available habitat.

Atlantic Cod (Photo: Alfred-Wegener-Institut / Felix Mark)

Flemming Dahlke stresses that, though the experiments yielded very clear findings, predicting the development of fish populations is extremely difficult. "For instance, whether or not the embryos and larvae survive also depends on the ocean currents and available food." The Atlantic cod now spawn near Lofoten, an archipelago to the northwest of Norway. The current takes the eggs floating in the water, and later the larvae, farther north, where ideal living conditions await them. "If the Atlantic cod populations and their spawning grounds shift to the northeast in the future, the fish will most likely spawn in completely different systems of currents," Dahlke explains. "If that happens, we can't yet begin to gauge the effects."

There is also good news, says Daniela Storch: "Achieving the climate goals of 1.5 ° C can prevent the worst, maintaining important spawning areas and minimizing the risks of both species."

Original publication

Flemming T. Dahlke, Martin Butzin, Jasmine Nahrgang, Velmurugu Puvanendran; Atle Mortensen, Hans-Otto Pörtner and Daniela Storch: Northern cod species face spawning habitat losses if global warming exceeds 1.5 °C. Science Advances (28. November 2018) DOI: 10.1126/sciadv.aas8821

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