Arctic of the Future

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The latest research indicates that within the next two decades, the Arctic Ocean will become largely ice-free at the end of each summer, covered only by first-year sea ice in winter. How will that affect our planet at large?

Recently, climate warming has become a "hot" topic. The Earth's climate has always been subject to fluctuations, but the changes currently being observed seem very intense. If the temperature continues to rise at the current rate, we should expect to see altered atmospheric and oceanic circulation patterns, different amounts of precipitation, and also higher sea levels – and that entails negative consequences for all inhabitants of our planet.

Glimpsing the future today

As a part of the Arctic Tipping Points (ATP) project, in June 2009 scientists from the Institute of Oceanology, Polish Academy of Sciences, took part in a voyage aboard the research vessel *Jan Mayen* to the Barents Sea and the vicinity of the Svalbard archipelago. The objective was above all to obtain arctic organisms for experimental research on identifying temperature limits beyond which sudden changes may occur to arctic marine ecosystems. The voyage indeed confirmed that the range of warm Atlantic waters is expanding northward

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Research carried out during this Barents Sea cruise will contribute to estimating how much the temperature will have to increase to trigger irreversible changes in Arctic marine ecosystems

and that the boundaries of the occurrence of key groups of arctic marine flora and fauna are shifting into the northern regions of the Arctic Basin. The Polish team's research focused on the reproduction and development of two planktonic copepod crustaceans that are key to the ecosystem: the Arctic species *Calanus glacialis* and the Atlantic species *C. finmarchicus*. Both copepods are lipid-rich sources of food for planktivorous fish and birds, but the former contains on average 8 times more calories than the latter. Thus, the replacement of the Arctic species by the Atlantic one will have a significant impact on the food chain and on the functioning of the entire ecosystem. Might the changes observed during this research voyage offer a glimpse of the Arctic Sea of the future?

Melting ice

The Arctic Ocean and its ecosystems are among the most poorly-studied regions of the world's oceans, which may be surprising if we consider its relatively small surface area and its great importance. Research has shown that the Arctic is getting warmer three times faster than other parts of the Earth. The recently observed spectacular decrease in the area and thickness of Arctic sea ice suggests that climate change has entered a new phase. The Arctic pack ice, i.e. the floating cover of sea ice accumulated over many years, has been recognized as one of the cornerstones of the Earth's climate, and changes here can have a global impact.

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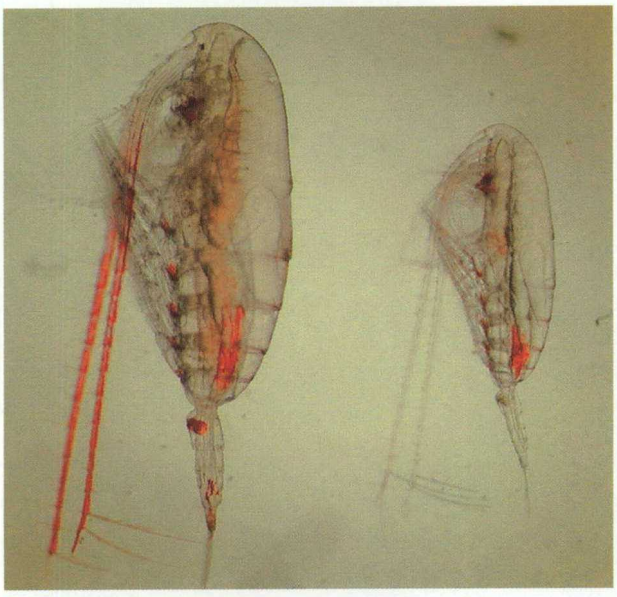

The Polish team involved in the ATP project has focused on the reproduction and development of two copepods (planktonic crustaceans) that are key to the marine ecosystem: the Arctic species *Calanus glacialis* and the Atlantic species *C. finmarchicus*, which both constitute lipid-rich sources of food for planktivorous fish and birds

Moreover, in the Atlantic sector of the Arctic, warm Atlantic waters have recently been reaching further and further to the north, augmenting the consequences of the observed climate changes.

The food chain in the Arctic Ocean is based on an intensive springtime bloom of sea-ice algae and phytoplankton, which compensates for a nearly complete lack of productivity during the polar night. The organic matter generated during spring drives the trophic food web, through zooplankton and fish to birds and marine mammals such as seals and polar bears.

Ecosystem change

The replacement of Arctic waters, dominated by large Arctic species of zooplankton, by warmer Atlantic waters carrying smaller Atlantic plankton organisms will have consequences that extend far beyond the marine ecosystem itself. Increased numbers of Atlantic zooplankton will attract fish and fry from the Boreal zone, which will cause piscivorous (fish-eating) birds inhabiting coasts to be favored relative to the little auk - an arctic bird species that mainly feeds on Arctic zooplankton. Such changes in the proportions of bird fauna will trigger further changes in land ecosystems, because the composition of guano (which affects tundra flora) depends on the type of bird diet and because the range of tundra fertilization differs depending on whether a region is dominated by cliff-inhabiting piscivorous species or by planktivorous auks, which nest further away from the coast. Smaller amounts of sea ice bring changes in physicochemical characteristics and processes in the Arctic Ocean itself as well as in other, interlinked parts of the atmosphere and geosphere. The shrinking pack ice also causes many ice-associated species to lose their habitats, including key groups of sea ice and planktonic autotrophs responsible for primary production. Moreover, the warming of Arctic regions leads to the influx of invasive, non indigenous species, further disrupting the ecological balance.

Points of no return

There is more and more evidence that when ecosystems are exposed to external or internal factors related to human activity, climate warming, or the introduction of new species, they respond in nonlinear, sudden ways. Such reactions frequently trigger considerable changes in an ecosystem's properties and processes, called *regime shifts*. These shifts take place when an ecosystem responds to such stimuli by taking on significantly different characteristics, or when processes formerly typical of it change course or cease to occur at all. A regime shift comes when a critical "point of no return" is crossed (known as a *tipping point*). The momentum of ecosystem change is then so great that the ecosys-

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Polar bears, whose lives are inextricably linked to the Arctic pack ice, are losing the ground beneath their feet

tem will not revert to its initial state even if the crucial stimulus returns to its previous levels.

Given the observed rapid rate of warming in the Arctic, there is a high probability that the Arctic ecosystems will become exposed to first crossing such tipping points as a consequence of global climate change. It is also likely that once the Arctic does cross its critical point, changes in the characteristics and processes typical for Arctic ecosystems will begin to occur significantly faster than in other regions of the world.

Arctic Tipping Points

Polish scientists from the Institute of Oceanology, Polish Academy of Sciences, in Sopot have been involved in the Arctic Tipping Points (ATP) project, a major international research initiative implemented under the 7th EU Framework Programme. Its most important objective is to identify elements of the Arctic marine ecosystem that may be the first to undergo significant change in response to ongoing climate warming. Another goal of the project is to identify the wider impact of crossing the tipping points on the functioning of Arctic marine ecosystems and on economic activity that exploits Arctic marine resources. As the project is implemented, the results of the latest research voyages and laboratory experiments will be supplemented with forecasts generated by state-of-the-art oceanographic, ecological, fishing, and socioeconomic models based on the analysis of historical data. Yet another important part of the ATP project is to draw the attention of politicians to the likelihood that Arctic ecosystems will soon reach - and cross - such critical tipping points, and to the regional and global impact thereof. ■

Further reading:

Strona internetowa projektu ATP: http://www.eu-atp.org