Comment

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The iconic swordfish (*Xiphias gladius*) is projected to move its range farther north as waters warm owing to climate change.

To save the high seas, plan for climate change

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Species are already on the move as waters warm. Conservation plans need to take this into account.

Corals frying in Florida, billions of snow crabs dead in the Arctic — climate change is wreaking havoc in the world's oceans[1,2]. The race is on to protect marine areas amounting to 30% of global seas by 2030 under the Convention on Biological Diversity. Controlling uses of the high seas — waters that are beyond national control, comprising around two-thirds of the surface area of the planet's oceans — is crucial, because there is currently no international policy mechanism for biodiversity conservation in these areas.

That is set to change in the next year, following the adoption in June 2023 of the High Seas Treaty, a new agreement that forms part of the United Nations Convention on the Law of the Sea. When it enters into force — probably in 2025, after 60 nations have ratified it — the treaty will enable implementation of new marine conservation tools in parts of the ocean that are beyond national jurisdictions.

The treaty provides new tools that will help protect the high seas from human industrial activities. Broadly, it recognizes climate change as a threat to the success of these measures. But specific actions remain to be taken to mitigate that threat[3].

The pace and scale of climate change raises questions about how best to define areas of marine protection[4]. In particular, how can species that move be conserved as their distributions change because of warming waters? Tunas cross the Pacific Ocean to breed and hunt. Whales migrate from polar regions to the subtropics to feed and give birth. As water temperatures and ocean currents change, so too will these routes and timings. Other climate-change effects, including ocean acidification and disruptions to food webs, could accentuate species shifts.

For instance, North Atlantic right whales (*Eubalaena glacialis*) have altered their migrations, moving farther north and into new regions off the coast of Canada in response to warming waters and changes in food availability[5]. There, these endangered animals have come into additional conflict with fisheries and shipping, resulting in deaths. Consequently, new conservation measures are needed in the areas to which the whales are moving, in addition to those in their original habitats.

Protecting biodiversity in the high seas in the face of climate change is an ongoing chess game. Coordination across jurisdictions — including national and international boundaries and the high seas — will be crucial. Strategic planning at a global scale will be needed[3]. It will require a mix of conservation areas that serve as reference points and others to be placed in anticipation of climate-related changes.

As nations gather at the first preparatory meeting on implementing the High Seas Treaty this month in New York City, we share here our experiences of working on such issues in the North Atlantic. We propose three steps that will allow the High Seas Treaty to address climate-change impacts on species effectively: collaborating across sectors; simulating movements of species and developing strategic plans for conservation; and building capacity and mechanisms in the treaty for implementing dynamic marine protections.

Learn from the North Atlantic

The North Atlantic hosts globally important ocean currents, including the Gulf Stream, which moves warm subtropical waters northwards, and the Labrador Current, which moves cold waters southwards around Greenland and down the eastern coast of Canada. These currents and the nutrients they carry meet in a complex whirl of eddies, forming an area of tremendous productivity that is important to wildlife and the source of one of the world's most productive cod and lobster fisheries.

> **"The changing strengths and interactions of currents will profoundly reorganize species' distributions."**

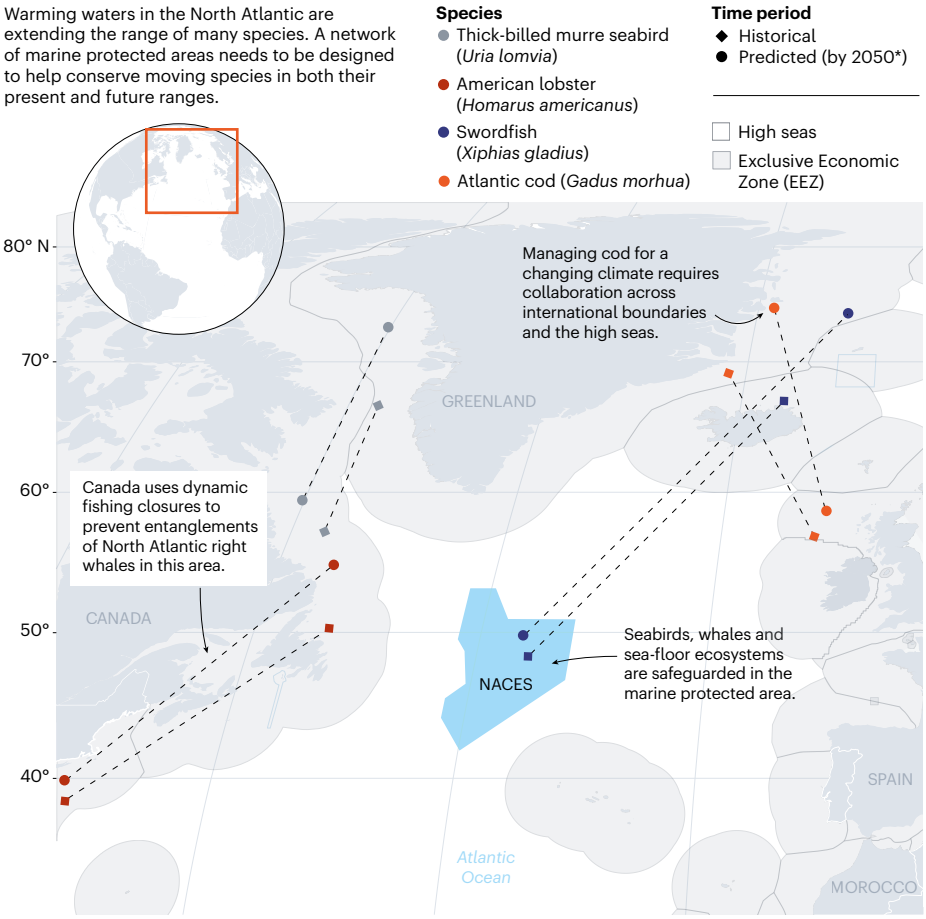
Governance of these rich fishing grounds and their conservation areas are equally complex. As well as spanning Canadian waters, areas crossed by these two currents come under the jurisdiction of the Northwest Atlantic Fisheries Organization (NAFO). The currents also influence an area governed by the Oslo–Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) and by the North-East Atlantic Fisheries Commission, among others.

Canadian conservation measures include closures that prevent fishing methods that come into contact with the sea bottom, and marine protected areas that can cover the full water column. In an adjacent patch, NAFO maintains bottom-fishing closures to protect vulnerable marine ecosystems, including concentrations of deep-water corals and sponges. To the east, OSPAR has designated a marine protected area to conserve seabirds, whales and seafloor ecosystems (called the North Atlantic Current and Evlanov Sea Basin Marine Protected Area, or NACES; see 'Species on the move')[6].

None of these conservation measures can be fully effective in isolation. Regional ecosystems are interconnected — seabirds that nest in Canada fly out to feed south of Greenland when nesting is finished; whales use the entire region; and the rich invertebrate

SPECIES ON THE MOVE

Warming waters in the North Atlantic are extending the range of many species. A network of marine protected areas needs to be designed to help conserve moving species in both their present and future ranges.



*2060 for thick-billed murre. Lines represent distance between range-limit centroids. For swordfish and cod, range centroids are used in place of southern limits because southern ranges extend beyond the map limits. Data for Atlantic cod and swordfish are for Eastern Atlantic populations. NACES, North Atlantic Current and Evlanov Sea-Basin Marine Protected Area.

L. HANNAH *ET AL.* SOURCES: RANGES: AQUAMAPS.ORG; THICK-BILLED MURRE DATA: A. PATTERSON *ET AL.* MARINE ECOLOGY PROGRESS SERIES MEPS-2023-10-023 (IN REVIEW).

sea-bed communities of the Flemish Cap, an isolated bank some 500 kilometres east of Newfoundland are likely to be genetically connected to the sea floor communities of the NACES Evlanov Seamount.

Climate change will broaden these connections, with species potentially entering Canadian waters from the northeast on the Labrador Current. The changing strengths and interactions of currents will profoundly reorganize species' distributions and affect fisheries, requiring even greater coordination of management across the region.

OSPAR has started to address these shifts by planning an ecologically coherent network of marine protected areas from south of Greenland eastwards to European national waters. This network is designed to protect all species that are endemic to the area, as well as representing other native species multiple times. This aims to insure against catastrophic loss of populations to disease, marine heatwaves or other events. None of these protections is formally coordinated with Canada or NAFO.

More cross-jurisdictional approaches will be needed. But, without an impetus, these could take decades. For example, OSPAR's plans for NACES took around five years to develop, from the first proposal of the marine protected area in 2016 to its final approval in 2021. With climate change accelerating, the High Seas Treaty cannot wait so long. It needs to streamline the process for designating marine protected areas and put in place a strategy for a changing future. It can make a start through these three steps.

Thick-billed murre, among other seabirds, are sensitive to changes in temperature and sea ice.

Coordinate among existing science and governance bodies

Many of the bodies for fisheries management, science and governance are central partners to the treaty and are already trying to incorporate climate change into their plans. Coordination of existing data and trends and effective communication of this information will allow for efficient management responses, which can then be integrated into more-comprehensive regional plans as the treaty comes into force. One practical step that could be taken immediately would be to start providing collated information on movements of seabirds and whales that can help shipping companies to minimize ship strikes and fisheries bodies to reduce the impacts on non-target species.

Examples of bodies working in this space include NAFO, OSPAR, the International Commission for the Conservation of Atlantic Tunas and the Western and Central Pacific Fisheries Commission. The Inter-American Tropical Tuna Commission and partners have developed a toolkit to provide scientific advice on shifts in species ranges related to fishing activity. The International Council for the Exploration of the Sea, which engages a network of 700 marine institutes across 20 member countries, is increasingly addressing climate-related impacts on marine species, fisheries and conservation areas in the Arctic, Atlantic and Mediterranean. These organizations, and others, need to accelerate and coordinate their efforts in anticipation of the Treaty coming into force.

Create regional climate conservation plans

Systematic plans for managing conservation across the high seas and national waters need to be developed. These can build on existing measures and knowledge of climate impacts on marine species. The High Seas Treaty includes provision for a science and technical body to advise its secretariat. Species movements and changing oceanographic dynamics due to climate change should be a key focus for that advisory body.

Scientists and managers should ensure that habitats and ecosystems are represented across multiple sites, to promote resilience in the face of climate change. And they should consider 'whole ocean networks' that capture the scale of species movements and population dynamics[7].

Scientists and conservationists can start now by using computer modelling to simulate species shifts. On the basis of these results, together with understanding of key biodiversity areas and existing protections in national waters[8], they can propose priorities for high-seas conservation.

Conservation plans incorporating climate change have been completed for several ocean regions[9], including OSPAR, which can act as an exemplar. Frontiers include considering extreme events such as marine heatwaves, as well as planning for species movements in three dimensions — latitude, longitude and depth[10].

Researchers should adopt a 'reference, core and flexible' approach to marine protection plans[11]. This involves three key steps. First, establish a core set of fully protected areas, with protections extending throughout the water column. These can serve as reference points to understand how biodiversity responds to climate change in the absence of complex human uses such as fishing. Second, design a complementary system of fixed conservation areas that represent key habitats and species, using current areas and simulated future ranges. Third, supplement the network of core areas with extra measures

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that are flexible in time and space to account for unexpected species movements, new data and improved climate models.

For example, in Canada, the St. Anns Bank Marine Protected Area provides a permanent core element that protects a key migratory pathway for many whale species. Across a wider region, lobster and crab fishing closures to prevent entanglement go into effect when whales are detected in an area, providing a more flexible element tailored for North Atlantic right whales.

"National research-funding agencies and foundations can take key roles as partners to the treaty."

Similar systems can now be planned across national waters and the high seas, for species whose ranges often cross jurisdictional boundaries and will move as a result of climate change. For example, some fish species are likely to shift with surface currents, which will affect where fisheries are located and which species are represented in conservation areas[12]. Recent proposals[13] to trade commitments between nations for meeting the goal of protecting 30% of the world's oceans by 2030 hinge on biodiversity targets that are verifiable across boundaries, further emphasizing the importance of systematic conservation planning for climate change. Done well, systematic planning can minimize costs while efficiently conserving moving species and ecosystems and benefiting fisheries and other ocean users.

Set up governance mechanisms and build capacity

Countries and other invited parties can begin to develop such strategies at the series of preparatory meetings that will take place in the run-up to ratification. At the first preparatory meeting this month, treaty planners can start to develop structures and procedures for planning conservation under climate change. They can mandate the treaty's science and technical body to address climate change and foster regional climate conservation plans. Mechanisms for addressing species shifts and interactions with other governance entities will also need to be proposed, debated and approved by the ratifying countries, with support from non-governmental organizations and scientists.

The treaty has a strong emphasis on capacity building. Developing equitable, shared scientific understanding of how species shift their ranges under climate change is imperative to ensure that conservation measures under the treaty are effective in the long term. Yet models that simulate species' movements and ocean change are complex[14], are based mostly in high-income countries and have varying degrees of availability.

For instance, models of range movements for all known marine species across dozens of future climate scenarios are now freely available online (for example, aquamaps.org). By contrast, regional ocean models that enable high-resolution simulations of physical changes, such as those in the North Atlantic, are region-specific and might be less readily available in low- or middle-income countries (see, for example, go.nature.com/3vu7qi8).

The High Seas Treaty includes a provision for a committee to promote capacity building and marine-technology transfer, supported by a fund to finance these activities. National research-funding agencies and foundations can provide extra finance and take key roles as partners to the treaty. For example, the Belmont Forum is a consortium of national research-funding agencies from various countries worldwide that builds multinational teams to address global environmental problems[15].

As the number of countries ratifying the High Seas Treaty grows, there is still time to lay the groundwork before the agreement enters into force — but the clock is ticking. Planning for protection of the high seas is a one-time opportunity. Only by engaging in each of the three solutions we discuss will the treaty be enabled to stand the stark test of climate change.

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