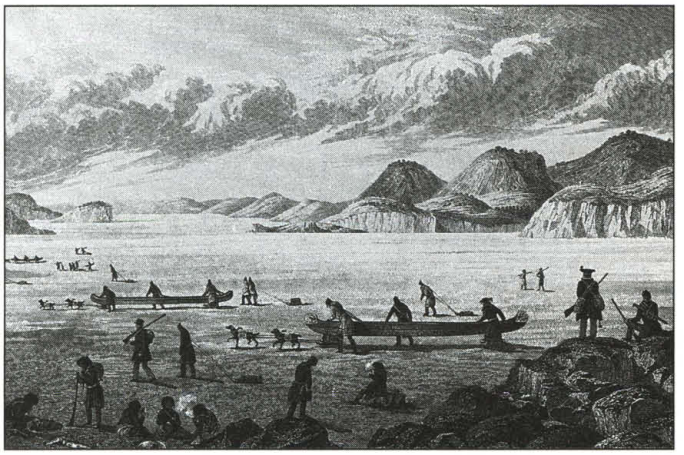
A Warmer Arctic Means Change for All

The seeming inevitability of shrinking ice on the Arctic Ocean means hard times for polar bears, a threat to an indigenous way of life, and an age-old dream come true for sailors

When John Franklin set out in 1845 to find a sea route to the Orient over the top of North America, he knew full well that he faced "warfare with ocean and ice, with storms and toils," as a predecessor put it. He proved to be no match for the elements: The Arctic ice doomed Franklin and his 128 men to a horrific end, foiling yet another search for a Northwest Passage. Despite dozens of rescue missions in the following years, none of Franklin's crew was seen alive again. Yet it was those missions that finally led to the mapping of a water route to the Orient—albeit an ice-clogged one.



Hardscrabble life. During John Franklin's second Arctic expedition (1819–1822), his party ran out of food but made it home alive. He and his crew weren't so lucky when they went searching for the Northwest Passage 2 decades later.

The centuries-long quest for the fabled Northwest Passage proved quixotic for generations of explorers, but what eluded those brave if sometimes foolhardy adventurers will come to pass, probably in this century. By simply staying home and burning billions of tons of fossil fuels, humans will melt an ice-free path through the Arctic seas, at least in summer, that will finally link Europe and eastern North America to the Orient by the shortest possible seaway. Shipping will pass freely, and petroleum and mineral riches of the high Arctic will flow out. For oil exploration alone, the Arctic "is *the* frontier in the world," says geologist Thomas Ahlbrandt of the U.S. Geological Survey. And the polar frontier might well set the stage for conflict, as naval powers stake out competing claims in the newly open waters of a new "global commons."

But a frustrating barrier to navigators is an essential platform for life. As the summer's ice retreats farther and farther northward, the open water so alluring to commercial interests will confound polar bears looking for solid footing in their hunt for seals. Inuits and other indigenous peoples likewise depend on the ice for access to whales and walruses. And algae at the base of the food pyramid cling to the underside of the ice. A hundred years from now, life around the Arctic Ocean will go on—but it will not be the same.

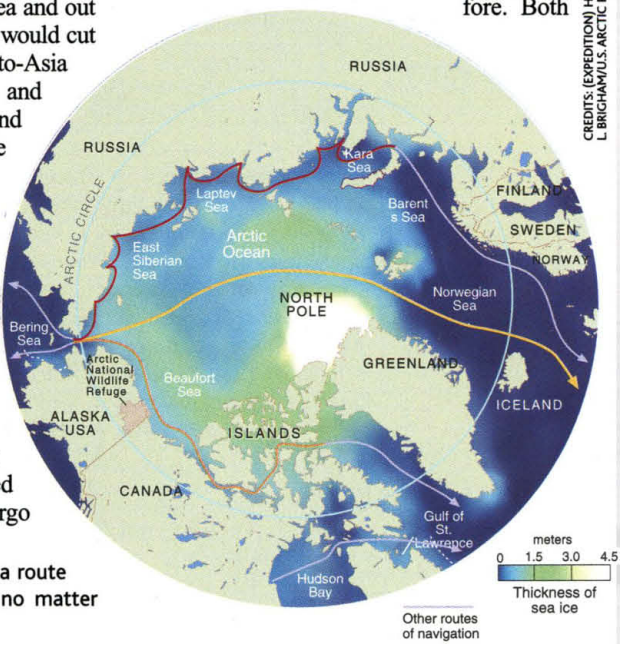
Breaking through

From the surface, the Arctic would appear to have changed little since Martin Frobisher first probed these ice-clogged waters for a route to the Orient in the 1500s. The ice proved impenetrable to him and a parade of adventurers who followed, although great explorers such as Robert McClure in his hunt for Franklin established that there is indeed a water route west of Greenland through a maze of Canadian islands and Alaska's Beaufort Sea and out the Bering Strait. If navigable, that would cut 11,000 kilometers off the Europe-to-Asia route through the Panama Canal and 19,000 kilometers off the trip around Cape Horn for supertankers unable to squeeze through the canal.

No single ship sailed the Northwest Passage until Roald Amundsen and six companions succeeded in 1906 in a tiny cutter, the Gjöa, taking 3 years to thread their way through islands and ice floes. The first deep-draft ship didn't complete the passage until 1954. And the route remains a commercial nonentity. During the shipping season, limited to a 3- to 5-month window, cargo reaches Arctic communities, grain ships out of Churchill on Hudson Bay, and ecotourists flock in, but pack ice drifting under wind and ocean currents presents a constant threat. And rarely do ships venture northwest of Hudson Bay, through the Canadian archipelago, where assistance from icebreakers is essential. The Northeast Passage or Northern Sea Route up around Scandinavia and along Russian's Arctic coast has seen more traffic, but completing a trip from Europe to Asia along that path requires an icebreaker as well.

Now the Arctic ice is poised to offer a reprieve from 4 centuries of nautical frustration. The extent of Arctic ice has shrunk 5% in the past 20 years, its thickness is down, and climate models forecast continued shrinkage as global temperatures climb (see facing page). In a report released earlier this year, Gary Brass, director of the U.S. Arctic Research Commission (USARC) in Arlington, Virginia, predicted that within a decade, both the Northwest Passage and the Northern Sea Route could be open to vessels lacking reinforcement against the ice for at least a month in the summer, assuming recent trends in ice coverage continue. A conservative scenario in the report has both routes open every summer by 2050 (wintertime remaining ice-covered indefinitely). The very latest runs of leading climate models have, on average, both routes opening in summer before about 2080.

However, as soon as passages open up, less tangible but no less imposing obstacles will come to the fore. Both



On top of the world. A northern sea route is likely to trigger border disputes no matter where it opens up.

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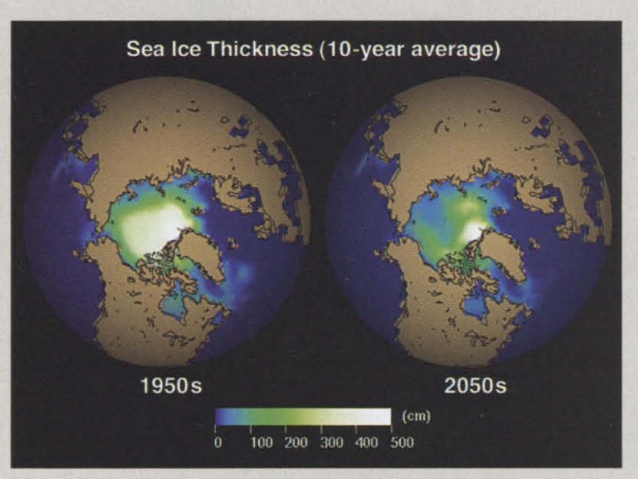
Whither Arctic Ice? Less of It, for Sure

Just a few years ago, the Arctic Ocean seemed to be skating on dangerously thin ice. In 1998, scientists working nearly 500 kilometers north of the Alaskan coast found the meters-thick sea ice there to be melting, thinning, and breaking up when it's usually rock solid. The next year, stunning submarine data revealed that Arctic sea ice had thinned by almost half since the 1950s.

With greenhouse warming declared official by a panel of experts early in 2001, the prospect of an ice-free Arctic looked all too real. But in the last couple of years, nature has hinted that the torrid pace seen in the 1990s will not be sustained. Computer models of the ice's fate under a growing greenhouse now concur that it will continue to shrink markedly, but it won't likely disappear in this century. The shrinkage should, however, be enough to open the Northwest Passage in summer and play havoc with Arctic life (see main text). All the scientific uncertainties aside, notes John Falkingham of the Canadian Ice Service in Ottawa, "the predominant scientific opinion is that there will be much less ice in the Arctic in future than we have seen in the past."

Only lately has Arctic ice come under close scrutiny. Never the stuff of deep-keeled, far-ranging icebergs, it mostly lay unwatched within the Arctic Ocean's bounds: the northernmost fringes of Russia, Alaska, the Canadian Archipelago, Greenland, and Scandinavia. Sailors' stories suggest that the far reaches of the North Atlantic were "an icier place in the first half of the 19th century," says polar researcher John Walsh of the University of Illinois, Urbana-Champaign. That was the tail end of the Little Ice Age, from which the world had emerged by the early 20th century. The trend that followed was frustratingly anecdotal and ill defined until a few years ago, when satellite monitoring revealed a 5% decrease in the extent of the ice between 1978 and 1998 (*Science*, 3 December 1999, p. 1828). That loss hardly represents a threat to the existence of Arctic ice in this century. But the thickness, gauged by nuclear submarine sonar, decreased 43% from the late 1950s to the mid-1990s. At that rate of decline, Walsh observed in 1999, the ice would disappear in a few decades. "It looked like [the ice loss] could be a harbinger of global warming," says physical oceanographer Humfrey Melling of the Institute of Ocean Sciences (IOS) in Sidney, British Columbia.



On thin ice. Current models suggest that the Arctic Ocean's sea ice could lose more than half of its 1955 volume by midcentury.

From the vantage point of 2002, the demise of Arctic ice looks less imminent: It has bounced back, or at least much of the way back, since 1998. "Every 10 years or so, for reasons we don't understand, there's a dramatic loss of ocean ice" over the top of North America, says Melling. Deciphering a long-term trend against a background of natural ups and downs in ice volume is tricky, he notes, especially when the reliable record goes back only a few decades. What would help, he and others agree, is a better understanding of what drives the variability of Arctic ice.

Recent computer models point to changing atmospheric circulation as the culprit in the abrupt ice thinning in the 1990s. "If we take into account everything we know about the Arctic," says physical oceanographer Gregory Holloway of IOS, "we see the ice readily moves sideways, piles up in some places, and thins in others" under the influence of shifting winds.

When the wind data of the past 20 years are put in a model that includes Arctic ice, the ice indeed thins over much of the Arctic in the 1990s. Coincidentally, it thins especially where the ice-monitoring submarines happened to have passed and thickens elsewhere or is blown right out of the Arctic Ocean. In light of such results from a number of modeling groups, the 43% decrease in ice thickness is an overestimate, says Holloway: "The real number is in the 10% to 15% range."

But if wind shifts were behind most of the thinning, what caused the wind shifts? For that, researchers look to the Arctic Oscillation, or AO (*Science*, 9 April 1999, p. 241). The AO is an erratic seesaw of atmospheric pressure that alternately raises pressure over the North Pole and then in a ring passing over southern Alaska and central Europe. The pressure shifts drive circulation changes, boosting westerly winds swirling around the pole when the AO kicks into its so-called positive phase. That's just what happened starting in 1989 as the AO pumped up winds in the vortex ringing the pole and swept unusual warmth over high latitudes. The ice responded, culminating in the lean ice year of 1998. Since then, "it looks like things are shifting back again," says Melling. The AO has backed off from its extreme positive phase, and the ice has been coming back, although both the AO and the ice volume remain far from their long-term averages.

So the AO could be driving variations in Arctic ice, but what drives the AO? Just about everything, it seems. It's a natural mode of the atmosphere, just as a drum has a natural mode of vibration. Hit a drum almost anywhere with almost anything, and much the same sound comes out; hit the atmosphere—with random jostlings, sunlight-reflecting volcanic ash in the stratosphere, variations in solar brightness, or added greenhouse gases—and it will oscillate with the pattern of the AO. An oscillation's duration can vary depending on what is doing the hitting, however. A random, natural swing in the AO lasting a decade might account for the ice loss of the '90s, and scientists are increasingly suspicious that the slowly building greenhouse is driving the observed decades-long swing toward the positive AO phase on which decadal swings are superimposed.

Researchers are using their climate models to take the AO, warming, and ocean circulation changes into account and divine the future of Arctic ice in the coming greenhouse. "You can come up with a wide range [of outcomes]," says Walsh, who's chairing a chapter on ice for a report due out next year as part of the Arctic Climate Impact Assessment. One model wipes out all Arctic ice in summer by 2050, but three out of the five models only open summertime passages in the second half of the century, retaining some ice year-round in 2100.

Even in an ice-diminished Arctic, winter will remain frozen solid. But thanks to global warming, summers will likely see more frequent early springtime meltback of the ice from the shore and farther retreat toward the pole, Walsh says. And that will gradually expose new frontiers—and new perils—for those who venture there.

–R.A.K.

CREDIT: NOAA

Canada and Russia claim, under international maritime law, that the island-strewn straits along their Arctic coasts are internal waters and in their exclusive control. Under the United Nations Convention on the Law of the Sea, they argue, they can draw boundaries encompassing their island groupings to define internal waters. The United States, which has yet to sign the convention, has argued that Canada and Russia are stretching their lines beyond the legal limit, and, besides, there has already been international traffic through these passages. The United States "is worried about setting precedents elsewhere in the world" where free passage might be restricted, says oceanographer Lawson Brigham of USARC. "It's one of the most intractable issues in the Arctic."

Passable straits in either route could become political hot spots. To illustrate the possibilities, the USARC report offers a fictional "vignette" of a naval operation that might be mounted in an ice-free Arctic. In it, three U.S. Navy warships and a nuclear submarine are sent through the Northern Sea Route to show the flag and head off the European Union's imminent concession of transit control to Russia. The vignette does not hazard a guess as to Russia's response. In another scenario, the USARC report assumes the creation of a major fishing industry in the now largely inaccessible Beaufort and Chukchi seas, where fishing wars among Russia, Japan, and the United States could break out.

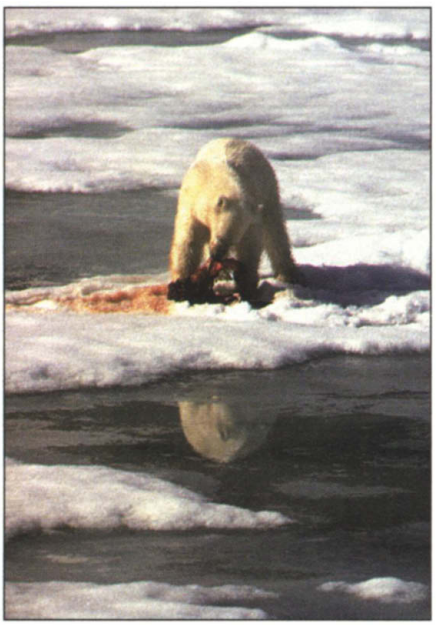
Such concerns might not be so farfetched considering that the ice-covered Arctic was the Cold War province of Soviet and allied nuclear attack submarines playing cat-and-mouse games and ballistic missile subs trying to avoid detection. In the coming greenhouse world, "melting of sea ice in the Arctic will turn it into a conventional open-ocean [antisubmarine warfare] environment," states the USARC report, "with none of the advantages it now affords" to submarines. Everyone will be able to get in the game.

Naval powers are likely to have more than just patches of water to fight for. Even under current climatic conditions, grains, minerals, and oil are dispatched from the Arctic. According to a recent assessment by the U.S. Geological Survey, the Arctic holds an estimated 130 billion barrels of undiscovered oil, or a quarter of the petroleum resources yet to be discovered in the world.

After the *Exxon Valdez* spill off the coast of Alaska in 1989, the prospect of large amounts of oil moving around the Arctic can be disturbing. "The environmental issues are the biggest ones," says Brigham. "The [Arctic] marine environment is reasonably pristine, and you could have problems."

Snags in the web of life

Less ice alone will spell trouble for some Arctic denizens. Mats of diatoms—microscopic, silica-encased algae—that hang from the bottom of the ice would perforce become less common in seasonally ice-free regions such as the Chukchi and Beaufort seas. Dead diatoms rain down from the ice onto the sea floor, where they feed worms and crustaceans that in turn sustain bottom-feeding whales such as the gray whale. How all this would fall out ecologically under diminished-ice conditions is anyone's guess, says marine biologist Patricia Wheeler of Oregon State University in Corvallis, who notes that such questions are being addressed in the 10-year Western Arctic Shelf-Basin Interactions project now under way. She adds that an ice-free Arctic might even benefit some critters: For example, removal of summer ice cover could boost production of phytoplankton. Working up the food chain, these floating algae are consumed by zooplankton, which are eaten by Arctic cod—dinner for seals and humans alike.



Polar feast. Earlier spring breakups could make seal dinners in the Arctic harder to come by.

For one Arctic inhabitant, however, receding ice presents a clear danger. The polar bear, the world's biggest land carnivore, spends most of its life on the ice. From late spring to midsummer, polar bears hunt seals from the ice to store up energy reserves for leaner days. Where receding ice strands bears on land for part of this feasting season, they fast, possibly for months.

In western Hudson Bay, where warmer temperatures in the 1990s made for earlier ice melting in the spring and later formation in the fall, polar bears suffered. For every week that the ice broke up earlier, bears came ashore 10 kilograms lighter, says zoologist Ian Stirling of the Canadian Wildlife Service in Edmonton. Cub survival depends on well-fed nursing females and, after weaning, a reliable food supply. Thus, as temperatures climb and the ice breaks up earlier, Stirling would expect more of the Arctic's 22,000 polar bears to suffer, especially toward the southern edge of their range.

Walruses would be in the same boat. They use the ice as a platform to rest between dives to the bottom to feed on clams, worms, and crabs. In 1998 the ice retreated to waters too deep for walruses to reach bottom in the Beaufort and Chukchi seas and forced them to swim long distances to feed, says social scientist Henry Huntington, a consultant in Eagle River, Alaska. Not surprisingly, the walruses ended up leaner than average that year, although it's unclear how that influenced their odds of making it through the winter.

Ill omens?

The indigenous peoples of the Arctic are wary of the changes they have witnessed over the past decade. From generations of experience on the ice, "they know you have to be prepared to hunt early or late, or to hunt geese rather than whales," depending on what they can divine about conditions in the coming days and weeks, says Huntington. "To the extent things stay within some broad limits," he says, "that's a good strategy. The question is, what happens when conditions move out of that broad range of expectations? It can make life significantly more dangerous"—even more dangerous than life on the ice already is.

For instance, Huntington says, after a recent whale hunt, no one was sure the ice was thick enough to bear hauling the catch out for butchering. And, a couple of years ago, two older, experienced natives ventured out in unusual ice conditions and never came back. The presumption, says Huntington, was that the ice got the better of them because they had no experience with such conditions and no traditional knowledge of it.

The strange environment wrought by changing Arctic ice isn't the only concern for the indigenous communities. The prospect of heightened activity in the region also threatens to encroach on their isolated way of life. And with more ships of every sort passing along the coast, including traffic booming through the Northwest Passage and Northern Sea Route, "what happens when something goes wrong?" asks Huntington. When things went wrong for the early explorers, they suffered, while the locals and the environment were unperturbed. That is about to change.

–RICHARD A. KERR

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