NOAA's Arctic Ocean Exploration Program

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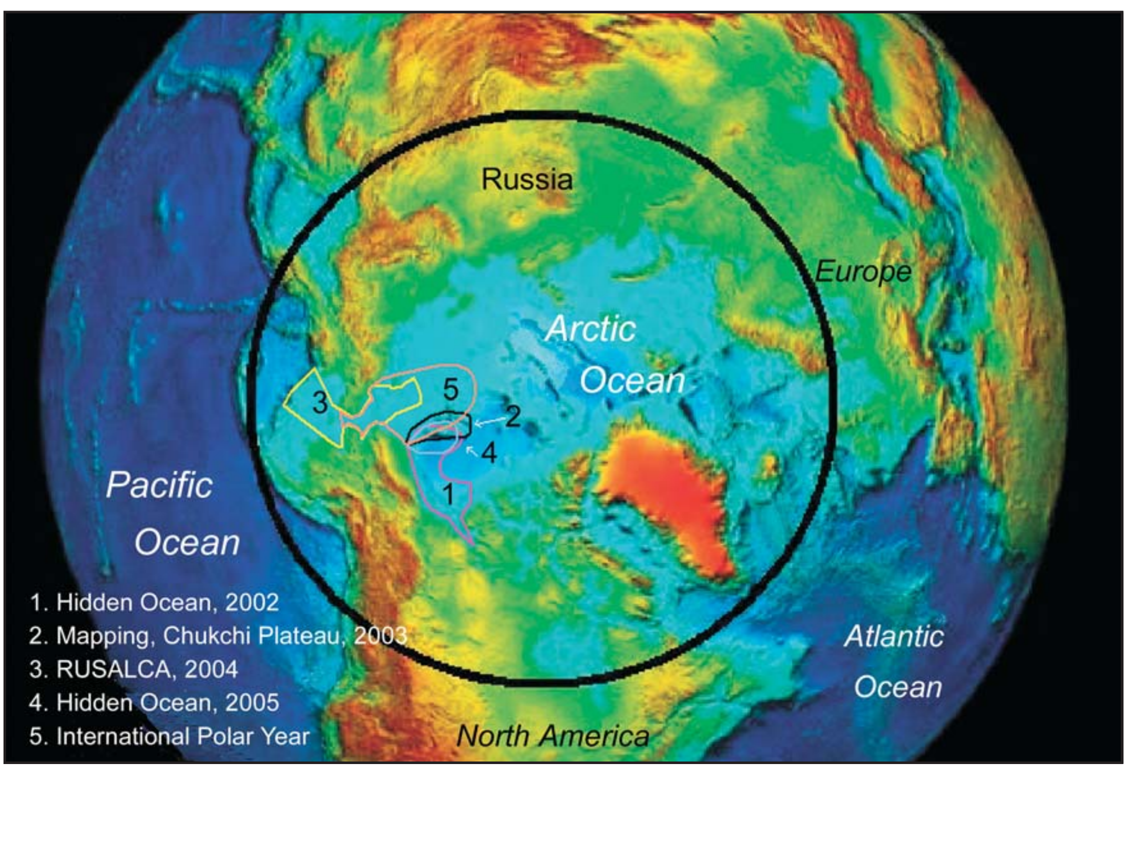
The Arctic Ocean is largely unexplored, especially those aspects not visible to the human eye from a surface ship or to a satellite sensor. Some data collected for national defense purposes are now available, and they provide a better picture of the bathymetry and circulation of the Arctic Ocean. In addition, the International Arctic Buoy Programme contributes data on ice drift trajectories and surface meteorology. While there have been intensive research campaigns, such as the Surface Heat Budget of the Arctic (SHEBA) program that lasted about a year, the deeper portions of the Arctic Ocean and areas far from land-based facilities remain mostly unmapped, from the seafloor to the life and the currents within the sea.

Exploration Approach

NOAA and its domestic and international partners decided in 2001 to undertake expeditions of exploration and discovery in the Arctic Ocean, with initial emphasis on missions of discovery near the Pacific Gateway to the Arctic, the Canada Basin, and the Mendeleev Basin. Additional emphasis has grown to include a census of marine life plus the mapping and imaging of previously unmapped seafloor, including the continental shelves, major ridges, and deeper basins.

The original exploration plan set forth in 2001 stated that the most appropriate autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), and acoustic technologies would

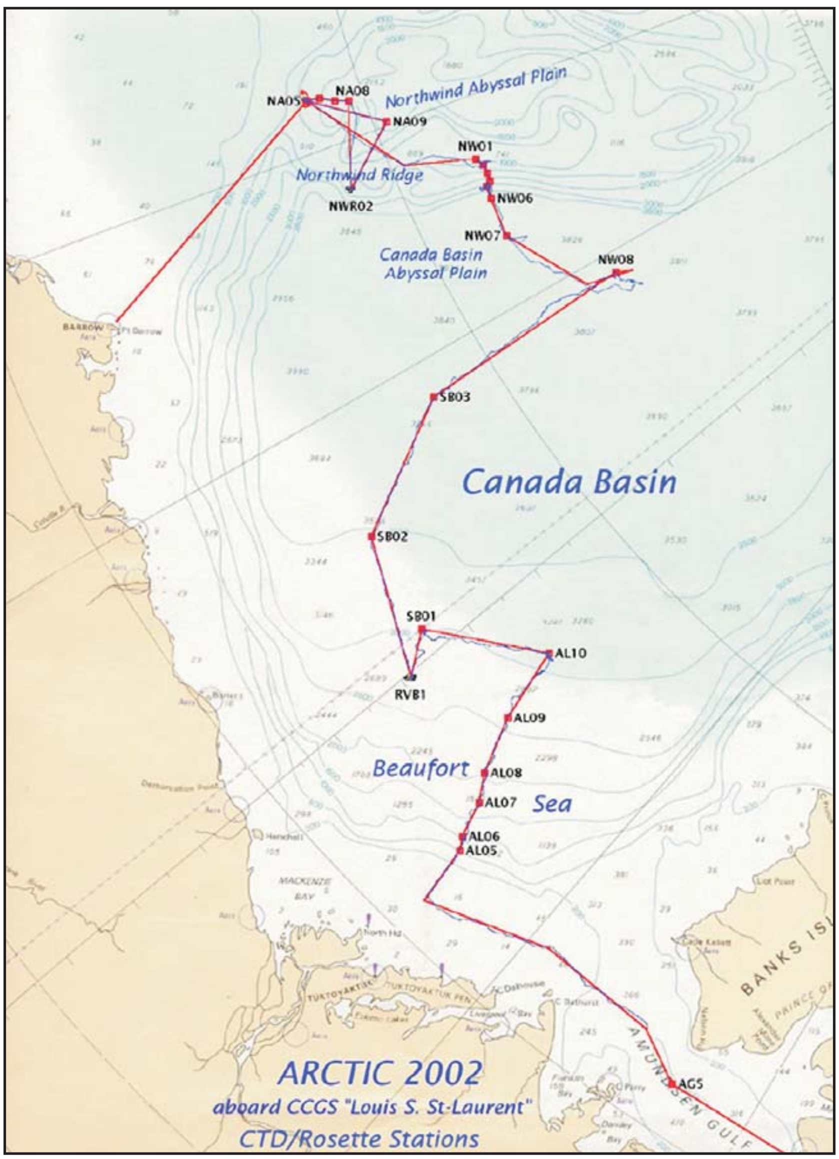


Locations of NOAA's past, present, and proposed Arctic Ocean Exploration Missions, 2002–2008.

be employed to complement more traditional wireline sampling of the seafloor and water column. The use of aircraft and buoys was also proposed to extend the spatial and temporal range of the expeditions. Steps were also planned that would contribute to the search for new products from the sea. Since the summer of 2002, four Arctic Ocean exploration expeditions have taken place under the guidance of NOAA's Ocean Exploration Program.

The Hidden Ocean: Canada Basin

In 2002 the first of these expeditions focused on exploring the deep Canada Basin, located in the Arctic Ocean, together with the Department of Fisheries and Oceans, Canada, on the *Louis St. Laurent*, a Canadian Coast Guard icebreaker. In addition, both China and Japan carried out significant programs onboard the vessel.



Ship track of the Arctic 2002 expedition, with station numbers superimposed.

This international team of 50 scientists from the U.S., Canada, China, and Japan participated in a collaborative effort to explore the frigid surface to the depths of the Canada Basin. Because of the region's heavy year-round ice cover, research in this region had been extremely limited. This expedition was the first of its kind. With the aid of an ROV called the *Ocean Explorer* (specially designed to operate under ice and at great depth), scientists examined the hidden world of life in the extreme Arctic conditions.

The Canada Basin may be geologically isolated from all the other deep-sea basins in the world's oceans because there *may* be no deep pathways connecting it to other regions of the Arctic. This lack of connectivity could severely limit the exchange of biota from the Atlantic and the other parts of the Arctic deep sea into the Canada Basin. What are the consequences of this biological isolation? Perhaps relict species of life still thrive in this remote basin. Perhaps new species have evolved here, isolated by the millennia. The expedition's scientists were eager to bring back samples and image the life in this ocean, from within the ice to the deep seafloor below.

From intricate microscopic organisms found in the brine channels that run through the ice to the creatures that make the sea bottom their home, the science team studied the relationships between sympagic (ice-associated), pelagic (water-column), and benthic (bottom-dwelling) communities. They investigated the manner in which food energy is transferred from the surface of the ice, through the water column, and to the bottom of this harsh environment. In addition, they analyzed bottom sediments to determine their chemical makeup, as well as help reconstruct the climatic history and paleo-environmental events that formed the region.

Ice cores were taken at a total of ten stations (on the *Louis St. Laurent* and the *Xue Long*, a Chinese research vessel) and analyzed for ice temperature, salinity, chlorophyll, and ice faunal abundances. Ice fauna were mainly located in the bottom 10 cm of the sea ice. These life forms included turbellarians, copepods, and nematodes. The abundances of these in-ice fauna in the Canada Basin were about two orders of magnitude below estimates for coastal fast, first-year ice.

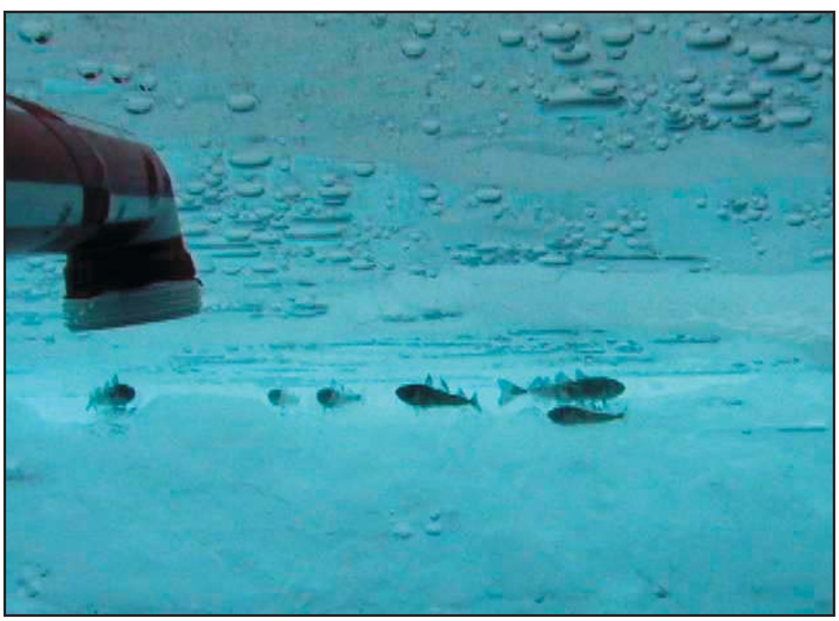
Carbon and nitrogen productivity of the water column was measured at 13 locations, including

R. Hopcroft examining a freshwater melt pond on the sea ice of the Canada Basin, 2002.

three ice stations. A chlorophyll maximum was observed at many stations at 50–60 m. Primary production under the ice is about an order of magnitude lower than in open water. The occurrence of amphipods and Arctic cod was also studied. Amphipods were less abundant than reported from other parts of the Arctic, occurring at mean abundances between 1 and 23 per m^2 at each station. Small schools of Arctic cod were discovered in narrow wedges along the ice edges, which were

Qing Zhang, a member of the Chinese science team, removing a long cylindrical core of ice from the thick Arctic icepack. After the core had been drilled and extracted, scientists with the Primary Productivity Group could begin their sampling procedures.

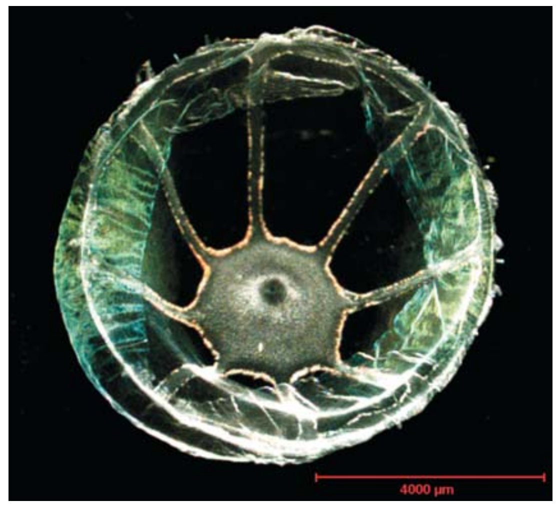
Arctic cod under the ice.



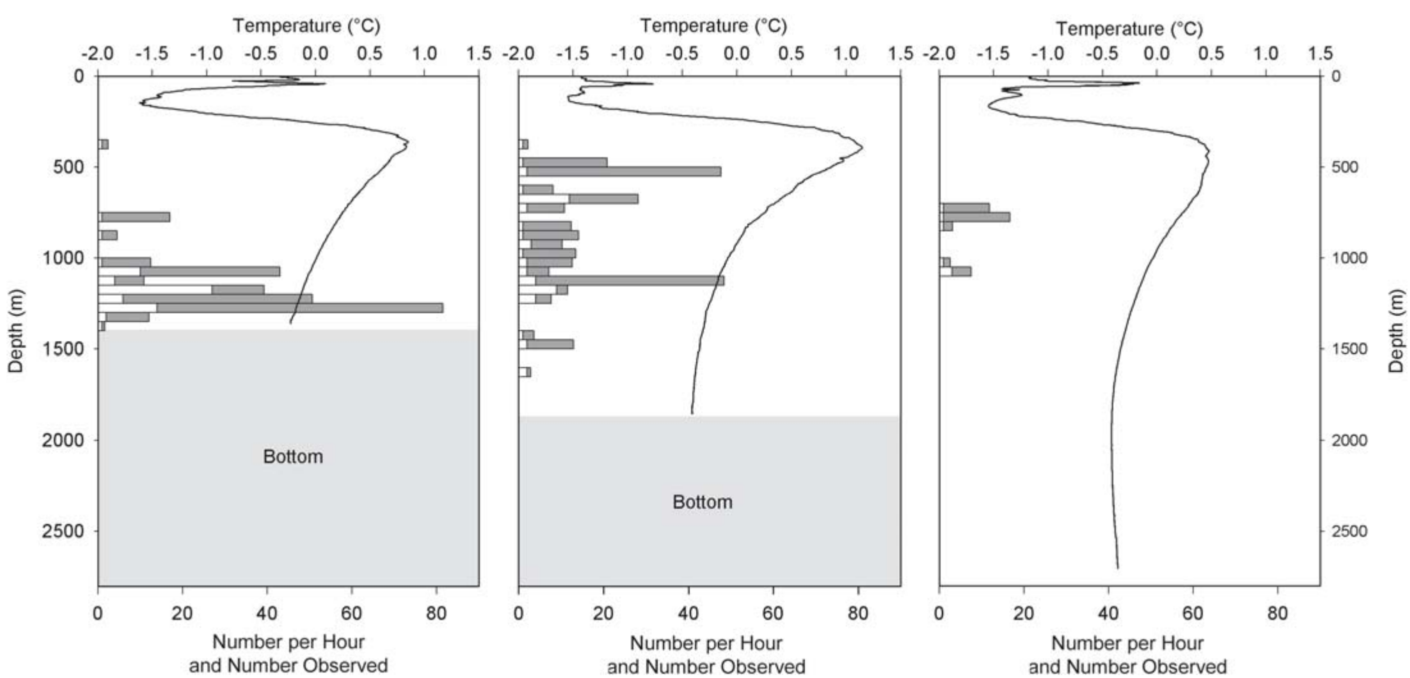
documented for the first time as important fish habitat. In addition, an unexpectedly high abundance of small-bodied copepod species was found in the water column under the ice, the importance of which has not yet been pursued in the Arctic.

Water column observations suggested a more abundant assemblage of gelatinous taxa than expected, with many species having distinct depth ranges, some extending to the bottom of the basin. The gelatinous zooplankton of the Canada Basin observed with the ROV fell into four main groups: cnidarians, ctenophores, chaetognaths, and pelagic tunicates. The vertical distributions of these gelatinous zooplankton showed several trends related to the physical properties of the water and the geographic locations within the basin. The most common gelatinous organisms in the surface waters were the ctenophores *Mertensia ovum* and *Bolinopsis infundibulum*. These two species were found in very large numbers in the near-surface mixed layer, immediately above a layer characterized by the large jellyfish *Chrysaora melanaster.* In the mesopelagic zone, siphonophores were common at the top of the Atlantic water layer, while below the transition between the Pacific water layer and the Atlantic water layer, the most common species was *Sminthea arctica.* Surprising numbers of the scyphomedusa *Atolla tenella* were found in the deep waters of the basin, along with an undescribed species of narcomedusa. Larvaceans were common in surface waters, were broadly distributed throughout the water column, and represent the most abundant holoplanktonic taxa below 2000 m. Chaetognaths were observed primarily in the upper 500 m, where plankton net collections revealed that the biomass of the most abundant chaetognath, *Eukrohnia hamata,* was exceeded only by the two species of *Calanus* copepods that classically dominate Arctic zooplankton collections.

The benthic infauna were sampled using box cores between 640 and 3250 m. A total of 90 benthic invertebrate taxa were identified from four biogeographic regions in the Canada Basin. At least three



The small medusa Sminthia arctica*, the most common species identified by video in the mesopelagic realm during the 2002 Canada Basin expedition.*

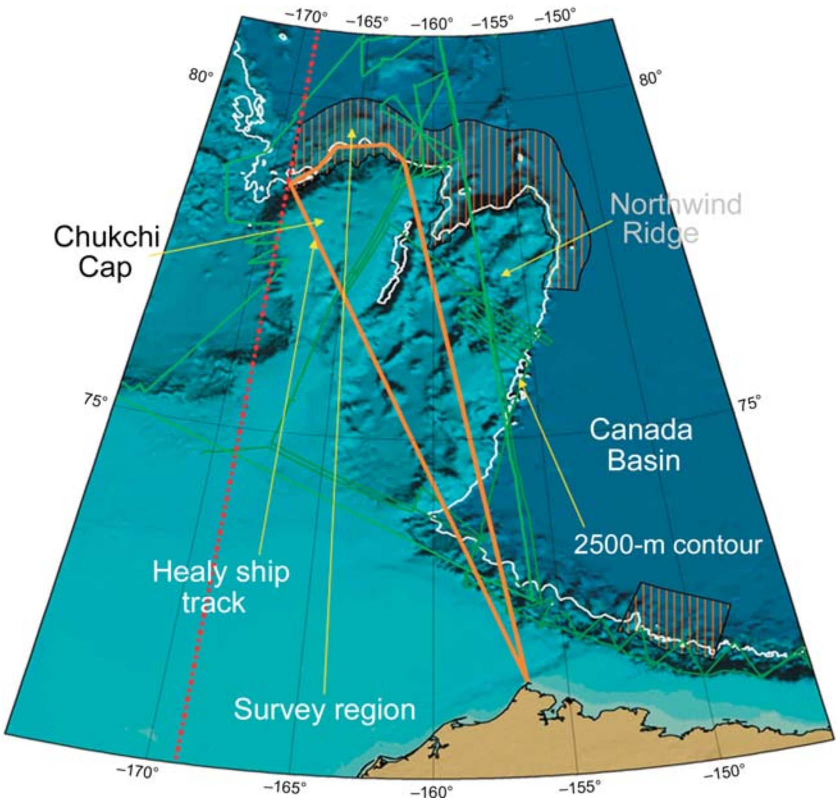


Vertical distribution of observed Sminthea arctica *in the water column from the top of the Chukchi Plateau (left), the edge of the Northwind Ridge (center), and the central part of the Canada Basin (right). Temperature profiles are superimposed. Because the time spent at each depth varied (all stations were less than one hour), the number of total observed specimens are indicated in light bars and the numbers of specimens standardized to one hour are indicated in dark bars.*

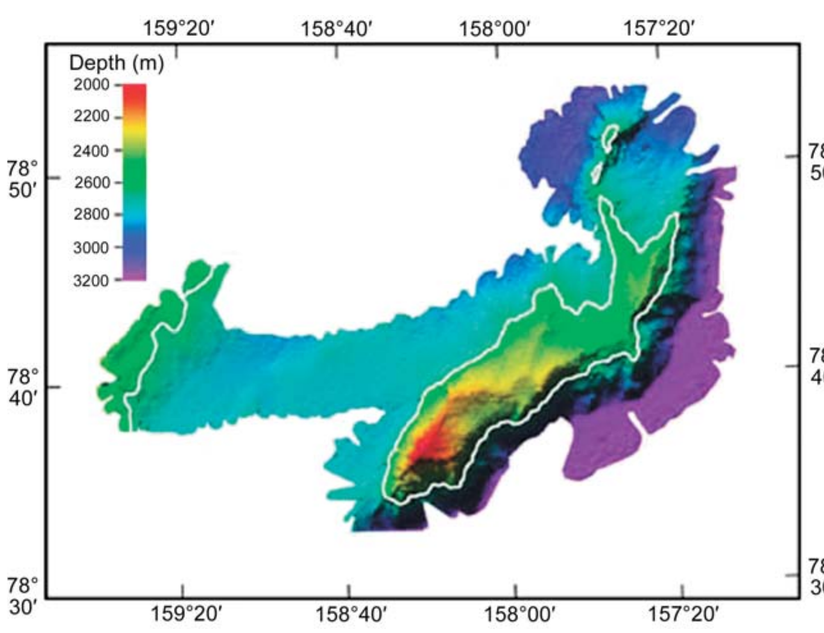
new species of isopods were discovered. However, the benthic abundance of life and the biomass are very low in the Canada Basin. Total abundances and biomass were highest in the shallow Amundsen Gulf and lowest in the deep basin. Polychaetes and crustaceans were most abundant in the samples, while polychaetes and mollusks dominated the biomass. ROV surveys revealed epifauna (life on the seafloor) where hard substrate was available for attachment.

Abyssal and midslope Arctic benthic fishes were sampled by still photography and videography using the ROV *Global Explorer*. The species diversity of the observed fishes was very low, with only six species; the diversity varied among stations sampled. Qualitative ROV video analysis suggests that demersal fish may be selecting habitats based on the presence or absence (or density) of other benthic animals. Stable isotope analysis suggests that most of the primary production is consumed by water column grazers and that the benthos primarily relies on food taken from sinking grazers and their products. This information suggests that there is a long food web of four trophic levels, which suggests low food availability.

Overall, the 2002 Canada Basin exploration revealed fundamental discoveries about the distribution and types of life that inhabit this ocean.



High-priority multibeam mapping sites on the Chukchi Cap and Northwind Ridge, 2003.



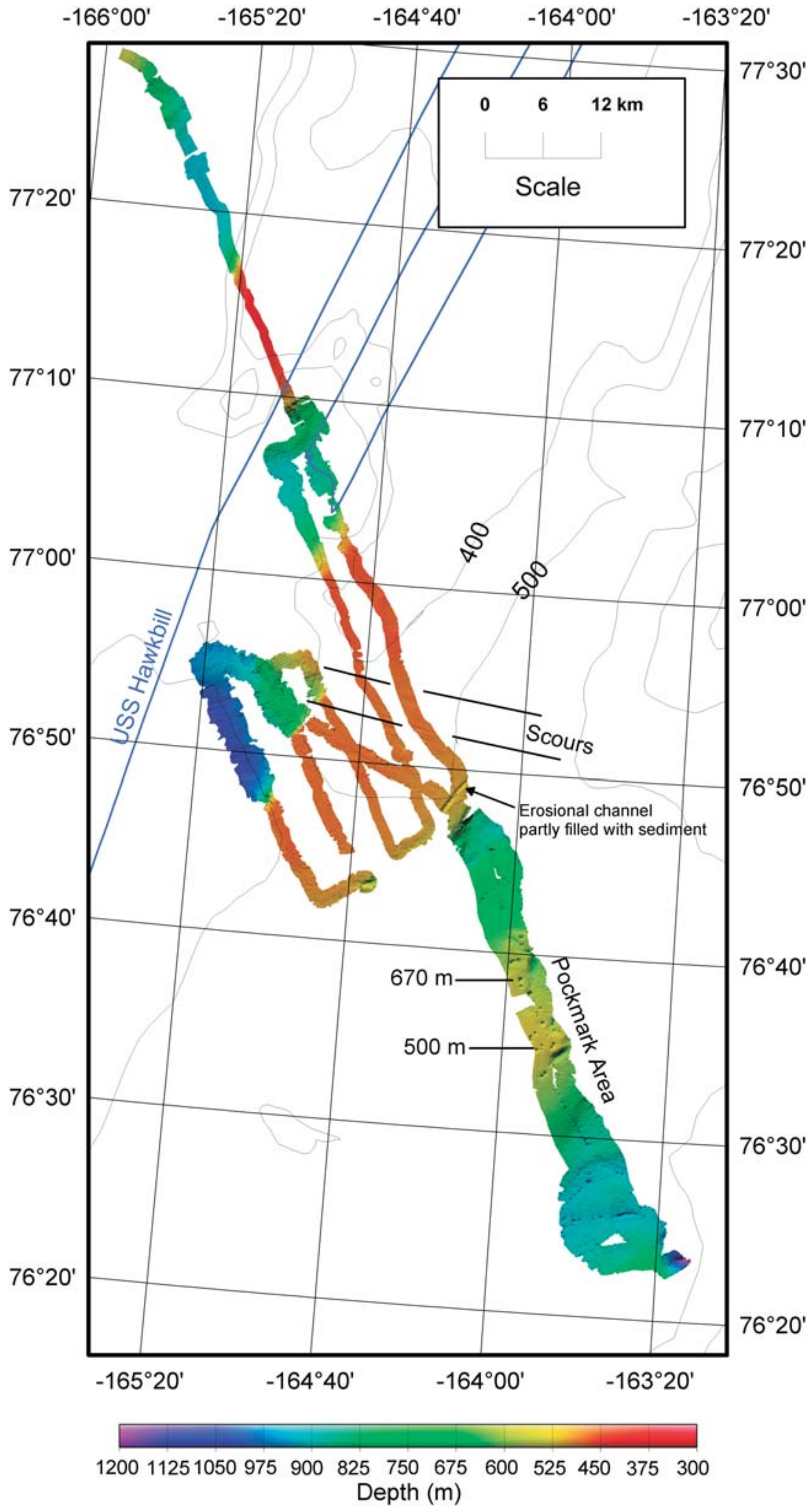
Seamount discovered on the northern boundary of the Chukchi Plateau, 2003.

Mapping the Arctic: Exploring the Chukchi Plateau

In September 2003, Arctic and hydrographic researchers, led by Dr. Larry Mayer from the Center for Coastal and Ocean Mapping at the University of New Hampshire, embarked on a 10-day Arctic Ocean mapping expedition along the Chukchi Plateau and Northwind Ridge. This mission focused on creating detailed bathymetric maps in a unique area located in the U.S. Exclusive Economic Zone (EEZ) north of Alaska.

The team sailed aboard the U.S. Coast Guard icebreaker *Healy*. The vessel was equipped with a hull-mounted Seabeam multibeam sonar capable of sensing the ocean floor at great depths. The bathymetric and backscatter imagery data created by the multibeam sonar provided important information about the tectonic processes affecting the ocean basin.

In particular, the research team addressed questions regarding the extent of grounded ice on the Chukchi Plateau. Confirmation of the extent of ice grounding in this region is of great importance for understanding the history of Pleistocene glaciation in the Northern Hemisphere.



Multibeam bathymetry of a section of the Chukchi Plateau, revealing a field of pockmarks and deep iceberg plow marks. The data were collected during the 2003 USCG icebreaker expedition.

In addition to mapping the 2500-m contour surrounding the Chukchi Plateau, the team discovered a seamount taller than Mount Rainier and uncovered evidence suggesting the outgassing of methane from the top of the Chukchi Plateau.

Russian–American Long-term Census of the Arctic

On July 23, 2004, a Russian research ship, the *Professor Khromov*, left Vladivostok, Russia, packed with U.S.- and Russian-funded scientists. It marked the beginning of a 45-day collaborative journey of exploration and research in the Russian Arctic. It was also a historic day for Russian–U.S. relations.

Stemming from a 2003 Memorandum of Understanding for World Ocean and Polar Regions Studies between NOAA and the Russian Academy of Sciences, this cruise was the first activity under the Russian–American Long-term Census of the Arctic (RUSALCA).

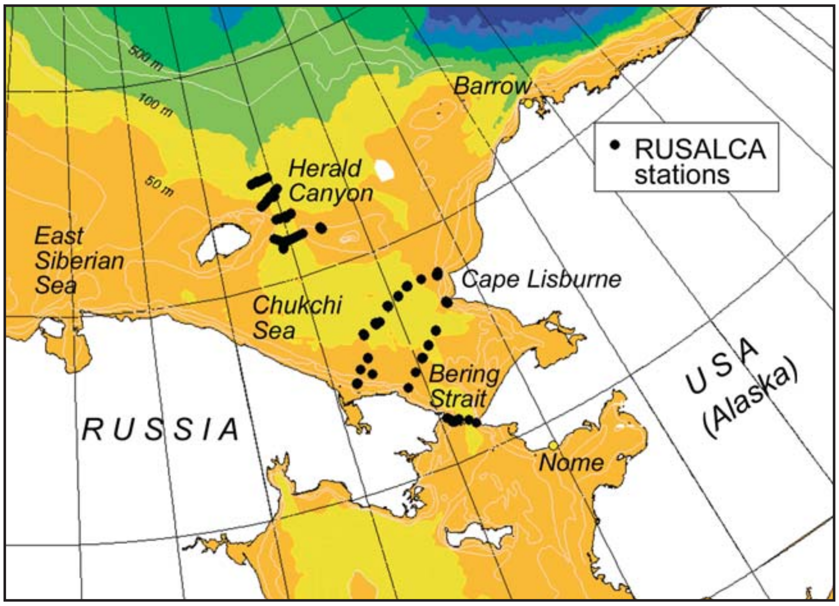
The expedition took place in the Bering and Chukchi Seas. These seas, and the life within, are thought to be particularly sensitive to global climate change, because they are centers where steep thermohaline and nutrient gradients in the ocean coincide with steep thermal gradients in the atmosphere. The Bering Strait acts as the only Pacific gateway into and out of the Arctic Ocean. As such, it is critical to the flux of heat between the Arctic and the rest of the world.

Monitoring the flux of fresh and salt water, as well as establishing benchmark information about the distribution and migration patterns of the sea life, is particularly important prior to the installation of an Arctic climate-monitoring network.

The cruise was divided into two integrated legs. Both included sampling and instrument deployment in U.S. and Russian territorial waters. The cruise objectives supported the U.S. interagency Study of Environmental Arctic Change (SEARCH) program and the NOAA Ocean Exploration Program.

The Hidden Ocean II: Canada Basin

In June–July 2005 a second exploration expedition to the Canada Basin took place, building on the exploration of the deep Canada Basin in 2002. This program also included collaboration with



Location of the RUSALCA leg 2 stations in the Bering and Chukchi Seas, 2004.

Russian and Chinese scientists. Like the previous expedition, it utilized an ROV, the *Ocean Explorer*, and sub-ice divers in conjunction with a deep-ocean camera package and more traditional sampling tools.

Education and Outreach

Educators, media specialists, and data managers have been involved from the beginning of the Arctic Ocean Exploration Initiative. *National Geographic* magazine participated during the 2002 Canada Basin Expedition and was an integral part of the ROV development and operations. In 2004 a reporter from Reuters participated onboard the RUSALCA expedition. Data management for the 2004 RUSALCA expedition will be coordinated with the National Oceanographic Data Center, the National Climate Data Center, the National Geological Data Center, the National Snow and Ice Data Center, and the World Data Center at Obninsk, Russia, along with universities and other relevant institutions.

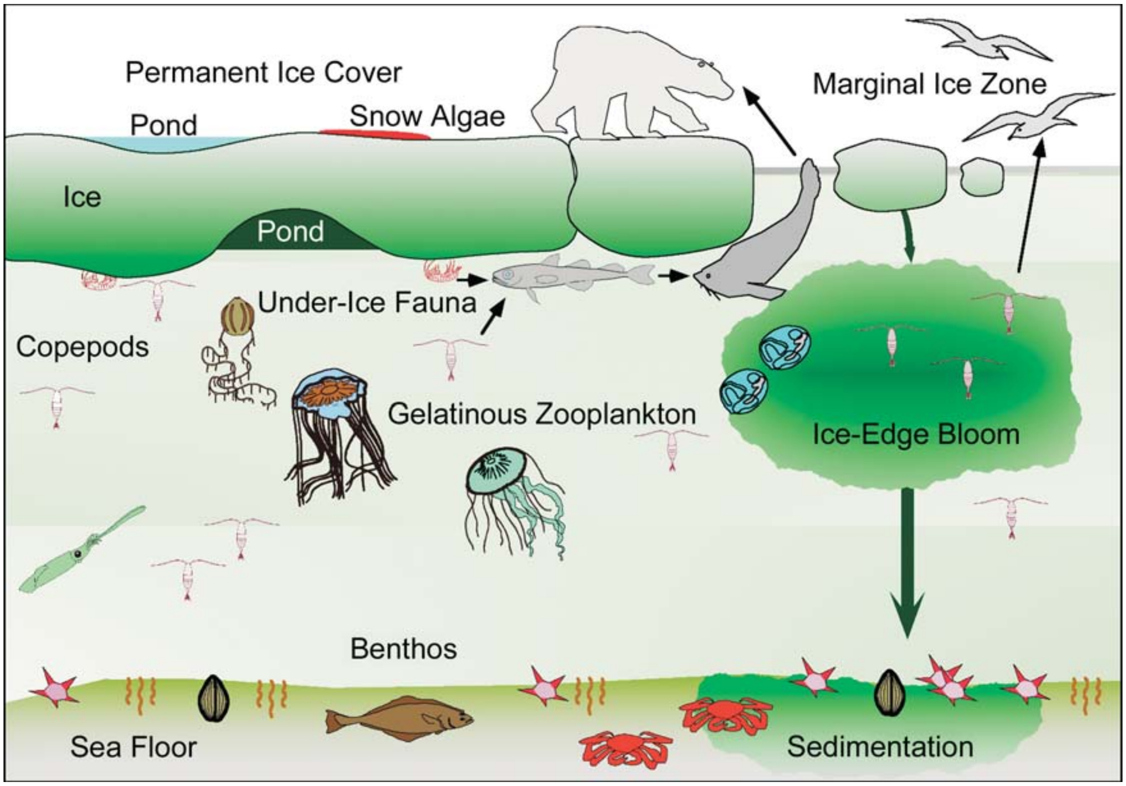
Partners

NOAA has involved partners from other Federal agencies (such as NSF, DOD, DOI, and Homeland Security), universities, its joint institutes, and the National Ice Center in the Arctic Ocean Exploration expeditions. NOAA also cooperates with appropriate international Arctic research institutions, such as those in Canada, Germany, Norway, Sweden, China, Korea, Japan, and the Russian Federation. In addition, private sector organizations were invited to participate, especially to facilitate international collaboration and the public outreach aspects of the Ocean Exploration Office.

Arctic Ocean Diversity

At the same time as NOAA was developing its plans for an Arctic Exploration Program, the international Census of Marine Life (CoML) program was also in development. Officially launched in 2003, the program established an Arctic project in 2004. The Arctic Ocean Diversity (ArcOD) project aims to increase our basic knowledge of biodiversity in the three major biological realms by consolidating existing biological information, filling gaps in our knowledge by new sampling efforts, and synthesizing what is known by 2010. The steering group contains representatives from Canada, Denmark, Germany, Norway, Russia, and the U.S. to foster international collaboration and a pan-Arctic perspective on marine biodiversity. Within the U.S., NOAA's Offices of Arctic Research and Ocean Exploration have been the primary supporters of this initiative because of their overlapping and complementary interests. ArcOD-associated scientists have been major participants on the 2002 and 2004 NOAA expeditions, as they will be on the upcoming 2005 expedition as well. Their attention to ecosystem-wide biodiversity will help lay the foundation for assessing the impacts of climate change on biological communities within all Arctic marine realms.

A copepod, Paracuchaeta*, with its late summer egg mass. This species is abundant in the Canada Basin.*



The Arctic food web.

International Polar Year

During 2007 and 2008, the Ocean Exploration Program plans to support multiple projects in both the Arctic and the Antarctic in conjunction with the International Polar Year. The type and level of support provided will be project-specific. The Office of Ocean Exploration may coordinate ship and submersible time for multiple Ocean Exploration-funded projects, as part of one or more larger explorations.

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