

Life in the Arctic Ocean

A unique, complex food web fashioned by distinctive species and environmental factors

By Carin Ashjian, Associate Scientist
Biology Department
Woods Hole Oceanographic Institution

Capped with a formidable ice and snow cover, plunged into total darkness during the winter, buffeted by blizzard winds, and bitterly cold, the Arctic Ocean is one of the most inaccessible and yet beautiful environments on Earth. Life here endures some of the greatest extremes in light and temperature known to our planet. Yet despite these inhospitable conditions, the Arctic Ocean is teeming with life.

Great polar bears roam the Arctic ice

and swim the Arctic seas. Supporting these top predators is a complex ecosystem that includes plankton, fish, birds, seals, walruses, and even whales. At the center of this food web, supporting all of this life, are phytoplankton and algae that produce organic material using energy from the sun.

The Arctic's extreme environmental conditions have limited our opportunities to study this complex food web. Expeditions to the remote Arctic are difficult and expensive. When we can get there at all, it is usually only in summer. Such gaps in our observations have compro-

mised our ability to understand the food web's intricacies and vulnerabilities—at a time when the ecosystem appears to be increasingly vulnerable.

Scientists now know that warming temperatures are affecting the Arctic Ocean, producing changes that may have cascading effects on the Arctic's interlinked and delicately balanced food web. Changes in the food web not only threaten life in the Arctic region, they also could have impacts on Earth's climate. Populations of Arctic plankton for example, not only provide food at the base of the food web, they also convert carbon dioxide



In October of 1997, pastel Arctic sky illuminates the tiny, isolated town composed of the Canadian icebreaker Des Groseilliers, frozen into the ice for the year, and outlying laboratory structures. Inset: Drifting within the ice, the ship traveled over 1,739 miles (2,800 kilometers) during the year.

from the atmosphere into organic matter that eventually sinks to the ocean bottom—effectively extracting a heat-trapping greenhouse gas from the atmosphere.

Life and light springs eternal

Every spring, after the long dark night of Arctic winter, the sun reappears over the horizon. Then, a cumulative sequence of events begins, and life in the Arctic springs into action.

With each day longer than the previous one, light begins to penetrate through the thick cover of snow and ice to the under-surface of the ice, where ice algae begin to grow, like mold on a damp ceiling. One green, string-like form, *Melosira*, grows long, hanging under the ice like Spanish moss. It eventually detaches from the under-ice surface and sinks to the seafloor where it is consumed by the animals living there.

As days lengthen, light and warmth increase, and the winter snow cover that accumulated over the ice begins to melt. Once the snow melts, enough light can penetrate through the ice to spur the growth of phytoplankton—very small, drifting, plantlike organisms that live in the water. They become available as food for higher organisms in the food web, the zooplankton—tiny marine animals that, in turn, are eaten by larger animals, from fish to jellyfish to whales.

A rich and vulnerable ecosystem

Nowhere is the plankton ecosystem less well-understood than in the Arctic Ocean. Without more detailed knowledge about the workings of these ecosystems and the life histories of the individual life forms in them, we cannot predict how they will be affected by climate changes. But those changes already appear to be happening.

Scientists have documented dramatic shifts in Arctic ice cover, water temperature in the Arctic Ocean, and the atmosphere above it—all potentially due to the effects of a warming climate. Such changes are likely to affect, and may alter, the Arctic food web and ecosystem. They may



Carin Ashjian, WHOI

The four major species of copepods in the Beaufort Sea all have different sizes, different life cycles, and different prey. L to R: Metridia longa (~2.5 millimeters), Calanus glacialis (~4mm), Calanus hyperboreus (~7mm). The smallest, Oithona similis (0.5mm) is below the center. The largest species, Calanus hyperboreus, is a critical link in the Arctic food web, eating phytoplankton and microzooplankton when the returning spring light triggers their growth. They are eaten in turn by many larger animals.

change the amounts of water, nutrients, and plankton coming into the Arctic Basin, or change the timing of spring growth.

The great bowhead whale, for example, depends on plankton patches found along the northern coast of Alaska for food during its migrations between the summer feeding grounds off of Arctic Canada and its overwintering grounds in the Pacific. Climate-induced changes in the availability of these plankton patches may have dramatic impacts on the whales, with either more or less food available along their migration route.

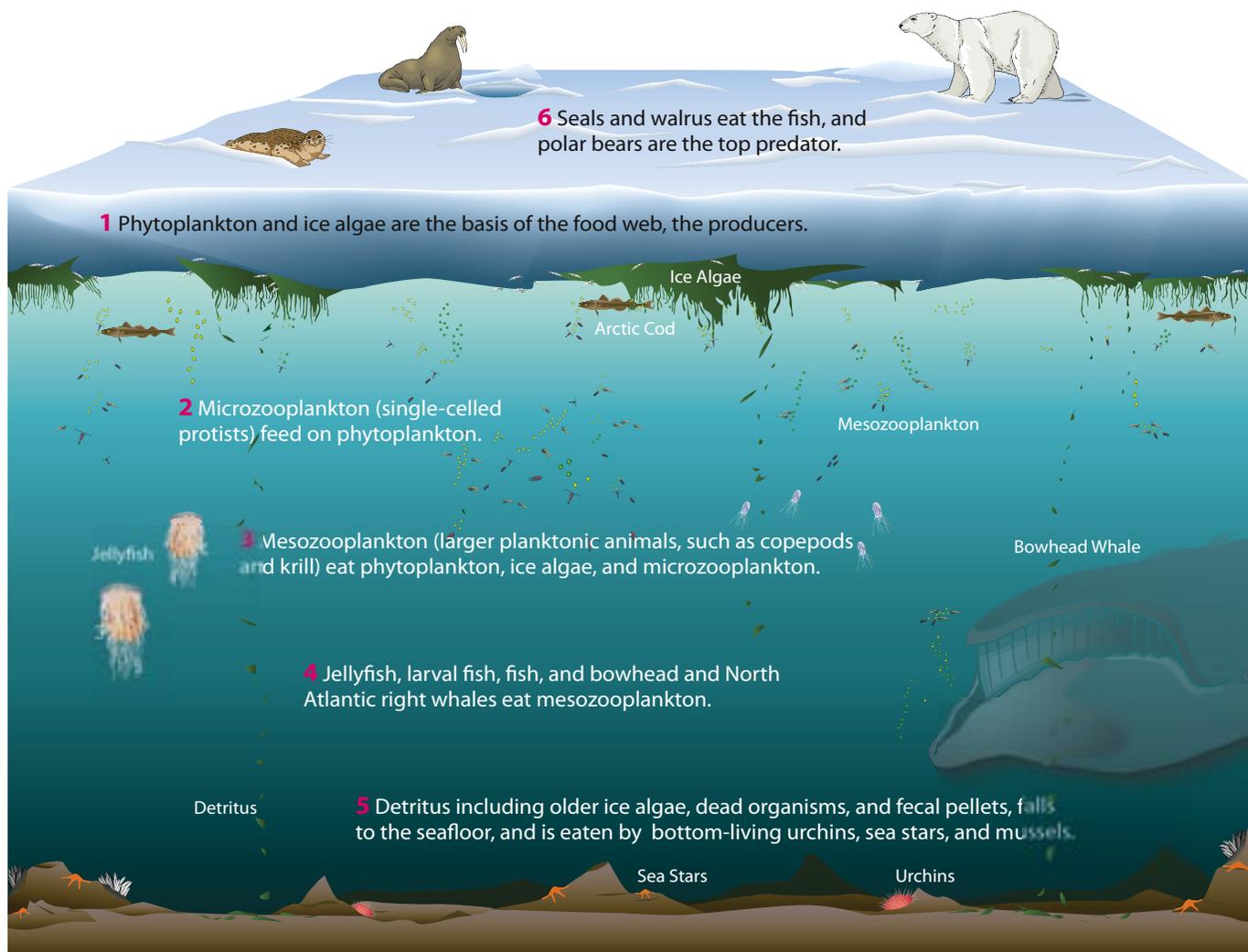
Populations of Arctic plankton are a conduit for the uptake, processing, and transformation of carbon dioxide. Warming related changes in the Arctic environment, such as ice cover, may have impacts on this planktonic conduit. Changes in the amount of carbon

that flows and cycles through this food web will change the amount of carbon retained in the ocean or respired back into the atmosphere. These changes may fundamentally alter the structure of Arctic ecosystems.

The SHEBA ice camp

To begin to shed light on the dimly understood Arctic ecosystems and food webs, I lived during parts of 1997 and 1998 at the SHEBA (Surface HEat Budget of the Arctic) ice camp, a major science encampment both on and in the ice in the part of the Arctic Ocean known as the Beaufort Sea, where I studied seasonal and life cycles of the Arctic plankton ecosystem. The heart of the camp was the Canadian Coast Guard icebreaker *Des Groseilliers*—a big, bright red ship conspicuously and intentionally frozen into the ice for

The Arctic Ocean Ecosystem



Jayne Doucette, WHOI Graphic, 2010

CARBON ALSO FLOWS THROUGH IT—The Arctic ecosystem has a unique, complex food web that is fashioned by its distinctive plankton, animal species, and environmental factors. Carbon also cycles through the web from atmosphere to seawater and back. Phytoplankton and algae take up carbon dioxide from seawater and transform it into the organic carbon of their tissue. Then it flows through successive levels of eating animals that convert their prey's carbon into their own tissues or into sinking fecal pellets. Along the way, some carbon dioxide escapes back to the atmosphere through the organisms' respiration.

the entire year. It served as a comfortable and opulent (for ice camps!) hotel and laboratory base. Separate labs were scattered on the ice surrounding the ship, housed in structures ranging from small tents to a 20-foot blue metal, bear-proof container, affectionately named the "Blue Bio," because it supported biological studies.

Leaving the ship for the labs held risks for the unwary. During summer months, we observed firsthand the effects of a warmer climate, as our stable ice platform melted into an impressive resemblance of

Swiss cheese. Life jackets were required equipment when venturing off the ship onto the ice—in case we made a false step between the holes on our way to the labs. In addition, the threat of polar bears was very real, and all eyes were on watch at all times. Often, the tracks of visiting polar bears were visible in the snow in the morning. We had several opportunities to watch these fascinating creatures from the safety of our warm, red ship.

My studies focused on copepods—small (1 to 7 millimeters-long) crustaceans

that are a critically important link between phytoplankton and larger animals. I concentrated on four species of copepods that dominate the zooplankton community both in terms of numbers and biomass (weight). Each has a different size, different life cycle strategies, and different roles in the food web marked by the quantity and type of prey that they consume.

Two of the species are fairly large and are members of the genus *Calanus*, which are believed to be omnivores (eating both plant-like phytoplankton and tiny animal-

like microzooplankton). One medium-sized species, *Metridia*, is an omnivore and a voracious consumer of *Calanus* copepod eggs and juveniles. The fourth is the extremely abundant and very small *Oithona*, also an omnivore.

An abundance of diverse life

At the SHEBA ice camp in 1997 and 1998, I studied the abundance, reproduction, growth and development rates, and sizes of these four copepod species over their seasonal cycles with my colleague Bob Campbell from the University of Rhode Island. We verified that previous studies dating back to the 1950s through 1970s underestimated the biomass of zooplankton in the Arctic Basin. It may be as much as 10 times greater than we previously believed.

We confirmed that *Calanus* copepods live to be three years old, reproducing during the summer when food is plentiful. Two species (*Oithona* and *Metridia*) have more prolonged reproduction that extends over much of the year. The fourth species (*C. glacialis*) cannot successfully reproduce in the central Arctic, we think, so *C. glacialis* populations there must be brought in by currents from the surrounding Arctic shelves.

These different life histories may have important consequences for the species, and they give scientists new insights into understanding the species' chances to survive changing seasonal cycles or food availability that might occur with climate change.

Tracking who eats whom

In an ongoing project, Campbell, Evelyn and Barry Sherr of Oregon State University, and I are exploring planktonic food webs in western Arctic shelves and basins. We are measuring the rates at which the tiniest animal plankton, called microzooplankton, consume Arctic phytoplankton. We then measure the rates at which the copepods (which are middle-sized plankton, or mesozooplankton) consume phytoplankton and microzooplankton. We also are finding out the food



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A view from the ship *Des Grosielliers* during Arctic spring, showing the blue biology lab ("Blue Bio"). The long straight line is a newly opened crack, or lead, in the melting ice, coated with a skin of freshly frozen ice.

preferences of the different groups. Do copepods prefer a phytoplankton or a microzooplankton diet, for example? Do they eat ice algae?

To do this, we conducted feeding experiments during two six-week-long cruises to the Arctic in the summer of 2002, on the U.S.C.G. *Healy*, the United States' newest icebreaker—a ship not frozen into the ice! First, we collected plankton by towing plankton nets to catch the copepods and determine their abundance in the water. In feeding experiments, we collect animals and seawater, select a known number of copepods, and incubate them with their prey to measure how much they eat in 24 hours.

Then we couple the grazing (feeding) rates of individuals with their abundances in the water to calculate the flow of carbon through the food web. This fundamental information is critical to our basic under-

standing of Arctic food webs, and it gives biological modelers the data they need to predict more accurately the potential impact of environmental and climate change on the fate of carbon in this ecosystem.

Summering in the ice

In the summer of 2004, we will embark on two more cruises on *Healy* to continue this work. We plan to concentrate on investigating the potential of ice algae as a food source for copepods. We also want to document whether one of the *Calanus* copepods (*C. glacialis*) can reproduce using its stored fat alone, or whether it requires available food.

Every trip to the largely unexplored Arctic seas brings new challenges, surprises, and insights for researchers. Every trip also contributes to our understanding of this remote, severe, but very active ocean and its role in sustaining life on Earth.



Peter Lane, University of Miami

Growing up in Massachusetts, Carin Ashjian became interested in the ocean during summer vacations spent on Buzzards Bay. She studied biology at Cornell University and then specialized in oceanography, receiving a Ph.D. from the University of Rhode Island. Her interest in polar regions was sparked by two cruises to the Arctic during postdoctoral positions at Brookhaven National Laboratory and the University of Miami. She moved to WHOI in 1995, and has pursued her interest in polar research since then, working first at the SHEBA ice camp in the Beaufort Sea. More recently, she has divided her research time between the Antarctic continental shelf, and the shelf-basin boundary of the Chukchi and Beaufort Seas in the Arctic, studying the ecology of polar zooplankton. On average, she spends three months per year at sea. On those occasions when she gets tired of the ocean, she spends time inland picking apples or making maple syrup. Shortly she will begin a new significant project in the Arctic, to investigate the cascading impacts of climate variability on oceanography, plankton distributions, bowhead whale migrations, and Inupiat subsistence whaling.