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InfoNorth

A Year on the Ice: The SHEBA/JOIS Project

By Harold E. Welch

HOME is an icebreaker—at least for a few of us frozen into the Arctic Ocean aboard the Canadian Coast Guard ship *Des Groseilliers*. We are here as an ancillary part of SHEBA (Surface Heat Budget of the Arctic Ocean), the largest project that the United States National Science Foundation has funded in the Arctic to date. Associated with this primary driving force is JOIS (Joint Ocean Ice Study), an integrated science project working on the biology of the Arctic Ocean.

The SHEBA head office is in the Applied Physics Lab at the University of Washington in Seattle. Meteorologists and climatologists came together several years ago to initiate a project that would provide better arctic data for climate modelling. Although important to global climate, physical parameters over the Arctic polar pack are poorly known. The investigators decided to freeze a Canadian icebreaker into the Beaufort Sea in the vicinity of 75˚N, 142˚W, expecting that the ship would drift west and northwest in the Beaufort gyre. Accordingly, the icebreakers *Des Groseilliers* and *Louis S. St-Laurent* moved through the Northwest Passage in September, arriving on site on 2 October 1997. After assisting with camp set-up, the *Louis S. St-Laurent* departed on 10 October, leaving our ship in place until October 1998.

SHEBA has been busy collecting data on phenomena such as cloud physics and the atmosphere, solar radiation, and turbulent heat flux through the air/snow/ice/water boundaries. Many unique, state-of-the-art instruments are being used to collect the data. Certainly not everything has been working at any one time, but the data-gathering is still remarkably successful: an excellent example of collaborative work by dozens of principal investigators, nearly all American.

JOIS has taken advantage of this "ship of opportunity" to measure the carbon flux in and out of the ocean, the plant photosynthesis driving this flux, and the productivity of the food web supported by this production. JOIS is also a collaborative effort, primarily between Canadian and American marine biologists and physical oceanographers. Because I know most about JOIS and nothing about air turbulence, and because the Canadian science effort is concentrated on the biology, I will describe our biological efforts in more detail. But first, let's look at the logistical and daily-life aspects of the project.

The Canadian Coast Guard ships the Louis S. St-Laurent *and* Des Groseilliers *(front) with some of the ice camp in the foreground. Photo by Andries Blouw, Fisheries and Oceans Canada.*

The *Des Groseilliers* is a Canadian Coast Guard vessel based in the Laurentian Region of the Department of Fisheries and Oceans, although for the SHEBA project it is controlled from the Central and Arctic Region. Two minimal crews of 14 run the vessel along with a National Health and Welfare nurse, and they are doing a marvelous job supporting science. Meals are gourmet-quality, based on food loaded last summer and supplemented with fresh produce flown in from Alaska every six weeks during crew rotation. The crew assists the scientific effort whenever possible. The captain is in overall charge, followed by the chief officer, who oversees the day-to-day running of the ship. A third officer takes the night shift. Thus, the bridge is manned continually to keep track of personnel moving off and on the ship and their location on the ice, maintain communications with the mainland, and watch for polar bears. The logistics officer oversees the "hotel" aspects, assigning rooms, working with the chefs and steward to plan meals and provisioning, and maintaining stores. Two deck hands work at practically everything, from burning trash to maintaining skidoos, in addition to normal ship duties like operating the cranes and keeping the decks organized. The electronics technician keeps the ship's computer and communication systems running and is very often asked to troubleshoot various instrumentation

The ship's crew and scientific personnel in front of the CCGS Des Groseilliers*, autumn 1997. Photo by Andries Blouw, Fisheries and Oceans Canada.*

The Blue Bio lab being moved into position on the ice. Photo by Andries Blouw, Fisheries and Oceans Canada.

problems for the scientists. Two engineers and two oilers keep the electrical and mechanical systems operational. The engineers are skilled machinists, knowledgeable about everything from refrigeration to electrical systems and they have a good machine shop on board. They have been especially helpful to the biologists, who seem to have a never-ending demand for equipment fabrication, modification, and repair.

As a floating hotel, the *Des Groseilliers* is great: the only thing missing is abundant lab space on board a ship not designed as a science-support vessel. The SHEBA project office also provides a three-person logistical support team on site. They maintain the runway with a D4 Caterpillar tractor that was loaded aboard the *Louis* last fall in Resolute (courtesy of the Polar Continental Shelf Project), keep science huts, etc. on the ice operational, and organize the supply flights. Because of this tremendous support infrastructure, science personnel can devote all their time and energy to data acquisition, maximizing their efficiency.

We are often asked what we do with our spare time, and our usual reply is "What spare time?" Most of us science types welcome the opportunity to work every day and most evenings at what we do best. The bar is open three nights a week for a couple of hours and is well-attended as a source of relaxation and social interaction. The exercise room is popular with some, although use has decreased since the motor burned out on the treadmill. Movies are played on the ship's network every night, and a variety of music is piped over the public address system. A couple of hundred paperbacks are available and well-read. There must be fifty or more computers on board and on the ice. The officers' lounge and dining room have been converted to computer rooms and at any time of the day, there are people staring at the screens, downloading and analyzing their latest data.

Back east, at the beginning of the drift, the ship received both the Msat and Inmarsat satellites, and the former was relatively cheap at one dollar per minute. Now, however, we are in range only of the Inmarsat, at a much higher rate, so phone calls, at least for personal use, are avoided as much as possible. E-mail, which comes in and out twice daily, is the primary means of communication with the south. My wife Cathy and I have been on board since August and will remain until next October, so e-mail is the social high point of our day, a marvelous and inexpensive way to keep up contacts with family, friends, and colleagues, all of whom now fall into two categories: e-mail (= regular correspondence) and snail mail. We didn't get our Christmas presents and cards until February or March.

Now on to the science. We biologists have several labs on the ice about 100 m from the ship. Three are modified shipping containers painted bright blue, so the whole thing is called Blue Bio. One 2.5 × 5 m container holds a large electric-hydraulic winch spooled with 4 km of kevlar cable deployed through a 1.25 × 1.25 m hole in the floor. With that cable, we drop salinity profilers, 1 m^2 plankton nets, water sampling bottles, and even baited long-lines. Nestled against the winch room is Big Blue, a 12 m container housing water baths with pumped fresh seawater and various instruments. A small container nearby serves as a photosynthesis lab for radioactive carbon tracer work. A Parcol hut for cold storage completes the setup. Everything is powered by two 440 V electrical lines from the ship.

Our efforts to quantify the productivity and its controlling factors start with light transmission through ice and snow, because that is what drives the marine system. A critical advantage for us is the opportunity to extrapolate our data over a wide area of the Arctic Ocean using the information provided by our SHEBA colleagues. We then monitor the biomass of microalgae floating in the water column (phytoplankton) and growing on the underside of the ice (ice algae), and measure growth rates as a function of light flux in lab experiments, using radioactive carbon as a tracer label. Micronutrients (N, P, Si) are also potential controlling factors for plant growth, so every eighth

Buster Welch being readied for a dive through the Blue Bio Hydrohole. Photo by Andries Blouw, Fisheries and Oceans Canada.

day is "chem day," when we measure nutrient concentrations, oxygen, organic carbon, and chlorophyll at 21 depths down to 240 m. Chemical measurements are followed by a salinity/temperature profile because the water mass structure (layering) has a lot to do with nutrient availability, as well as being of interest to physical oceanographers working on the project. The fate of organic carbon in the water column begins with the "microbial loop" (all the critters too small to see), which we study with a variety of tracer, oxygen consumption, and counting experiments. Next come the visible animals living in the water column (zooplankton). We quantify the zooplankton from top to bottom with net hauls, measure their respiration and growth rates, and estimate their energy demand and productivity.

In addition to ice algae, fingernail-sized crustacea called amphipods live against the ice surface, as well as arctic cod, which spend most of their time hiding in crevices in the ice keels beneath pressure ridges (they also occur in the water column). To quantify ice algae, we use a sub-ice suction device on an arm (familiarily called the Drill Sucker) to reach under the ice, drill a hole of known area, and suck the sample back to the surface for subsequent analysis. For amphipods and ice algae on pressure ridges, we use divers and a system that returns exhaust air to the surface to avoid disturbance by bubbles, and permits good communication between divers and surface. For amphipods, the surface support team notifies the diver when ready; the diver vacuums a known sub-ice area with a vacuum hose; and the sample is collected at the surface—a procedure that sounds deceptively simple. Murphy does indeed lurk beneath the ship, and hoses freeze, pumps fail, flasks break, regulators freeze, the litany goes on and on. But then, no one said Arctic field work was easy!

Of course it is the top predators that are of most interest to the average person: in this case, they are ringed seals, permanent pack ice residents, who feed on arctic cod and amphipods, and in turn support polar bears. Unfortunately, the helicopter that was to support the bear and ringed seal work this spring was cancelled, and with it went our chance to quantify production of seals and bears, the fourth and fifth levels in the food chain. We have had about ten bears near the ship since October and have seen a few seals in the leads. Last week a large bear excavated a ringed seal birth lair in sight of people watching from the bridge, but it did not catch the young seal. This water is less productive than the seasonal ice zone around Hudson Bay and the islands, so seals and bears are less abundant than in those areas.

Associated with this work, sediment traps have been suspended from the ice to collect particles falling out of the upper ocean. This will give us one measure of the flux of carbon, nutrients, and contaminants to the deep ocean. We also measure contaminants coming in with air, accumulating on the snow, and running into the sea with spring melt, as well as their concentration changes up the food chain. Stable isotopes of carbon and nitrogen give us information on the trophic level (or place in the food chain) for each species, even though we may not know precisely what a given species eats. This trophic level estimate closely parallels the concentration of biomagnified contaminants, such as PCB and mercury. The well-known "arctic haze" phenomenon results from aerosol transport of contaminants from Eurasia over the polar basin into the Canadian Arctic, and here we should be right in its path. We also collect snow samples to measure the chemical changes and fractionation that occur as the return of the sun in late winter brings complex ozone and other chemistry. Measurements of O^{18} trace the origin and fate of rain, snow, ice, and meltwater in the upper ocean, and also support the contaminant studies.

So what have we found so far? There is always the public perception on projects such as this that we must have made some astounding breakthrough, made some observation that allows us to say something like "Yes, global warming has done thus and such to the arctic marine food web." But science isn't usually that simple, and JOIS is no exception. We are acquiring the best set of data on the

Dr. Harold "Buster" Welch of the Freshwater Institute, Winnipeg, Manitoba. Photo by Andries Blouw, Fisheries and Oceans Canada.

productivity of the Arctic Ocean made to date, from which we can measure changes, extrapolate, and pretty much speculate at will (was it Mark Twain who said that science was wonderful—where else could so little data generate so much speculation?). But there have been some interesting preliminary results.

First, the only previous estimates of productivity in this area were made many years ago with cruder techniques, and they indicated a carbon fixation (photosynthesis) rate of 1–5 g C/m^2/yr. But our zooplankton respiration rates require a minimum of 15–20 g C; if we combine them with microbial demand, the requirement must be at least 25–50 g C, or ten times as much as first thought. Although this is still low compared with, say, the requirement for the east or west coast of Canada, it is not much lower than the production in the seasonal ice zone of Lancaster Sound.

Second, there is a persistent, low-salinity surface mixed layer about 35 m thick floating on a remarkably abrupt density gradient, where salinity increases nearly two parts per thousand (ppt) over less than two metres. This layer appears to be a quasi-permanent feature in this region, and it appears not to circulate freely with deeper water even in late winter when salt rejection from new ice growth (on the order of 0.5–0.7 m thick) has increased surface salinity. As a result, plant growth depletes nutrients, carrying them downward from the upper 40–50 m, and vertical circulation in winter does not replenish them. The stratification is enhanced every summer with melt, and the permanent ice cover protects the surface water from wind-driven vertical circulation. This situation is in sharp contrast to the seasonal ice zone, where about 1.7 m of new annual ice injects a lot of salt into the surface water. Combined with mixing from the interaction of tidal currents and topography, and wind-driven summer mixing, nutrients in the surface layer are completely replenished by spring and are available once again to support a brief but productive summer bloom. We don't know what will happen here, but we hypothesize that the low nutrient concentration will seriously limit photosynthesis. One piece of evidence supporting this hypothesis is an oxygen maximum around 50 m where the nutrients begin, which suggests high phytoplankton production last summer down where nutrients were available and light still could penetrate. Of course, if the plants are unable to utilize light efficiently in the upper 50 m, total production decreases accordingly.

Third, there is evidence that climate warming has occurred in this part of the Arctic Ocean. When we drove in with the ship, we were surprised that we couldn't find multiyear floes of more than about 1.7 m mean thickness. The low-salinity surface mixed layer discussed above is about 2 ppt fresher than it was 22 years ago. The edge of the pack ice was farther north than usual. It appears that long-term warming is in fact happening. Can water skiing to the North Pole be far behind?

Our drift to the west has been surprisingly rapid, with Russia and the International Dateline looming ahead. Unfortunately, the drift took us over the shallow water of the Northwind ridge and Chukchi shelf, so that now the ocean is relatively more productive. Nutrients are increasing in the upper mixed layer, and zooplankton biomass per unit area has doubled despite the shorter water column. We are anxious to test our hypothesis that there has been no injection of nutrient-rich deep water into the surface mixed layer where we were in December, so next week we plan to fly eastward to 152°W, over water that is 3800 m deep, and sample for salinity, nutrients, zooplankton, and algal growth.

We have wondered what occurs on the bottom in such deep water. Small, baited amphipod traps yielded hundreds of large amphipods (up to 8 cm long), scavengers living nearly 4 km down that are able to survive for a year on a single meal. When we reached shallower water, that particular species disappeared. We also fished long-lines several times when we were in water over a few hundred metres deep, catching skates and Greenland halibut (the infamous turbot of fish wars fame), and losing several hooks to what might have been Greenland sharks. But we have no dredges and no way of quantifying benthic animals. Because we are constantly drifting, and because pressure differentials are so great, we can't even drop landers to the bottom to measure sediment respiration rates, a measure of organic carbon export to the deeps.

Finally we must consider the ice: our friend and foe. Were it not for ice, the sea here would be little different from the sea elsewhere in the world. We travel and work on the ice constantly, just as if it were solid land, and we tend to forget that 2 m beneath us is a 4 km void. But this is the polar pack, and it is constantly in motion. Since late January, the pack has been especially active near the ship. The science camp was separated by a lead which opened 50 m, then crushed together to form a pressure ridge and a keel 10 m deep. The main camp was moved north half a kilometre and now has to generate its own power rather than be hooked to the ship. Blue Bio remains unscathed (the Parcol went under and had to be moved) although it is no longer 120 m off starboard, but 56 m off the bow! It's a good thing it's still close, because otherwise we wouldn't be able to generate enough power to run the 15 hp winch motor. Sometimes we are awakened by a lurch as the ice snaps and the ship moves, or we hear the ice grinding against the side. No matter the time of day or night, the bridge immediately fills with people anxious to see where the action is, and whether their huts and instruments are in the water or crushed in the ice.

It is a wonderful experience, and we are all trying our best to make SHEBA/JOIS a landmark (or is that seamark?) science expedition. For more information, check the SHEBA web site at http://sheba.apl.washington.edu/.

Harold "Buster" Welch is a biological oceanographer with the Freshwater Institute, Department of Fisheries and Oceans in Winnipeg, Manitoba. He wrote this in early May while aboard the Canadian Coast Guard ship Des Groseilliers *at 76˚02'N, 165˚15'W.*