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IN THIS ISSUE

BREAK-UP AND CLIMATE CHANGE AT CANADA'S NORTHERN COAST, QUTTINIRPAAQ NATIONAL PARK

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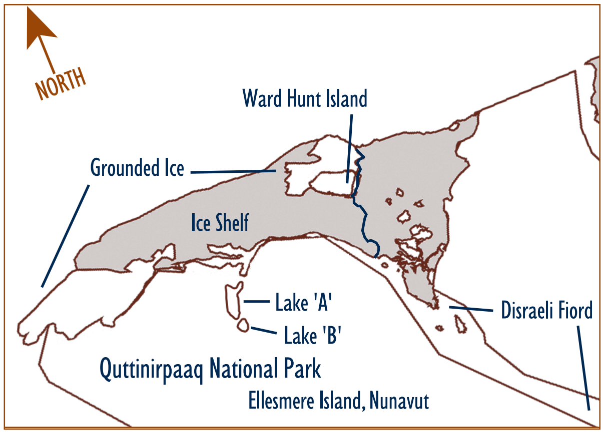
Different climate models vary in their prediction of how fast the world is heating up in different regions, but almost all converge on the conclusion that the north polar region will experience greater temperature increases than elsewhere, and that these changes are likely to become ever faster because of the positive feedback effects of melting snow and ice. This "runaway change" scenario makes northern Canada a particularly important place for monitoring the global climate system. Of course apart from our international responsibilities in this regard, we also have a vital self-interest in knowing how fast the Canadian environment is changing.

One of the remarkable features of Canadian geography is that the landmass spans 41 degrees of latitude, with the northern tip of Ellesmere Island, Nunavut, extending to latitude 83°N, only a few hundred nautical miles from the North Pole (Fig. 1). This northernmost coast includes Quttinirpaaq ("Top of the World" in Inuktitut) National Park, a vast region containing the highest mountains in eastern North America, alpine snowfields, glaciers, rivers, wetlands, striking polar desert landscapes, lakes and deep fiords. These environments and their biological communities are shaped by extreme cold and are likely to be sensitive indicators of climate. Furthermore, they are at the northern limit of North America, at the highest continental latitudes that are likely to experience the strongest impacts of global change.

Our work on Ellesmere Island first began in the mid-1990s on Lake Hazen, the largest waterbody in the park and one of the deepest lakes in the circumpolar Arctic. The frigid, clear waters of this lake were found to be well-mixed to at least 100 m in summer, in sharp contrast to lakes further to the south where a warm surface layer overlies colder water in summer. This deep summer mixing in Lake Hazen is likely to regulate its ecology, but could eventually be dampened and cease under warmer temperatures. Historical studies in northern Finland, for example, have shown that the shift in lakes from summer mixing to a layered structure is accompanied by major changes in biological species composition and in their aquatic food webs. Lake Hazen is readily monitored from space, and future changes in water colour, temperature and duration of ice cover will provide indications of the pace of environmental change.

The northern coast of Ellesmere Island was first explored by Europeans during the British Arctic Expedition in 1875–76. Lieutenant Pelham Aldrich led a sledging party from this expedition along the coastal fringe of undulating ice, and named many of the



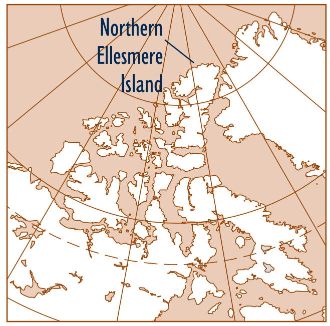
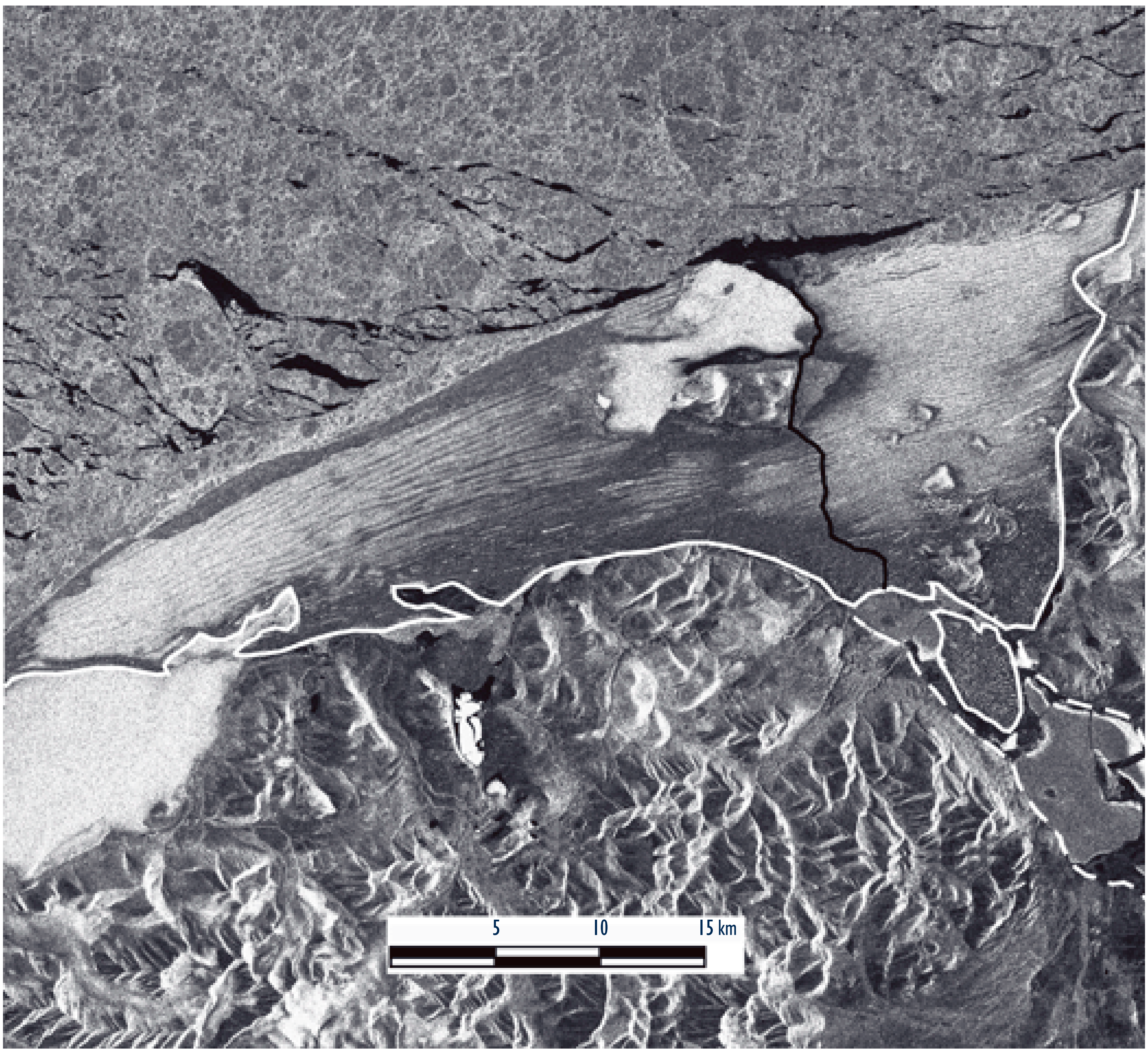


Fig. 1
Fine Beam RADARSAT-1 image of the northern end of Quttinirpaaq National Park, Nunavut (September 27, 2003). The main crack in the Ward Hunt Ice Shelf is traced in black, the southern edge of the ice shelf is traced in white. The dotted line marks the shoreline of Disraeli Fiord which continues for 20 km off the image. Note the ice breaking up in Disraeli Ford and in Lake A (unofficial name). Photo: © Canadian Space Agency/Agence spatiale canadienne 2003, received by the Canada Centre for Remote Sensing, and processed and distributed by RADARSAT International.



features that lie now within the northern boundary of Quttinirpaaq National Park. Ward Hunt Island, just off the northern coast of Ellesmere Island, was named after George Ward Hunt, First Lord of the Admiralty, while Disraeli Fiord was named after the Prime Minister of England at the time, Benjamin Disraeli. Even today, however, several important features of this remote region have yet to be named. For example, the remarkable set of deep, saline lakes along the northern coastline, only discovered a few decades ago, still bear the unofficial codes Lake A, Lake B and Lakes C1, C2 and C3.

Aldrich had some unfavourable comments to make about the undulations in the coastal ice ("large and troublesome hummocks in the snow and ice") and later the American explorer Robert Peary further surveyed this region and confirmed the difficulty of travel. Today these undulations can be made out clearly in the beautiful high resolution images produced by the Canadian satellite RADARSAT (Fig. 1). We first visited this region in 1998 and discovered that these undulations are formed by ridges between parallel, elongate meltwater lakes that contain rich communities of microscopic organisms. The latter occur in such abundance that they produce conspicuous red coloured "ice mats" that on closer inspection have been found to contain viruses, bacteria, algae and even minute animals. These self-contained, microscopic worlds are natural laboratories that are helping us gain insight into how life survived, grew and evolved during major freeze-up events on Earth in the past (Vincent *et al.,* 2004). However, these ice-based ecosystems ("cryo-ecosystems") appear to be dwindling rapidly.

Using RADARSAT data from 1998 and 1999, we estimated the expanse of undulating ice to be about 850 km^2. This ice is several tens of metres thick, and forms a series of ice shelves that float on the sea and that rise fall with the tides, while attached to

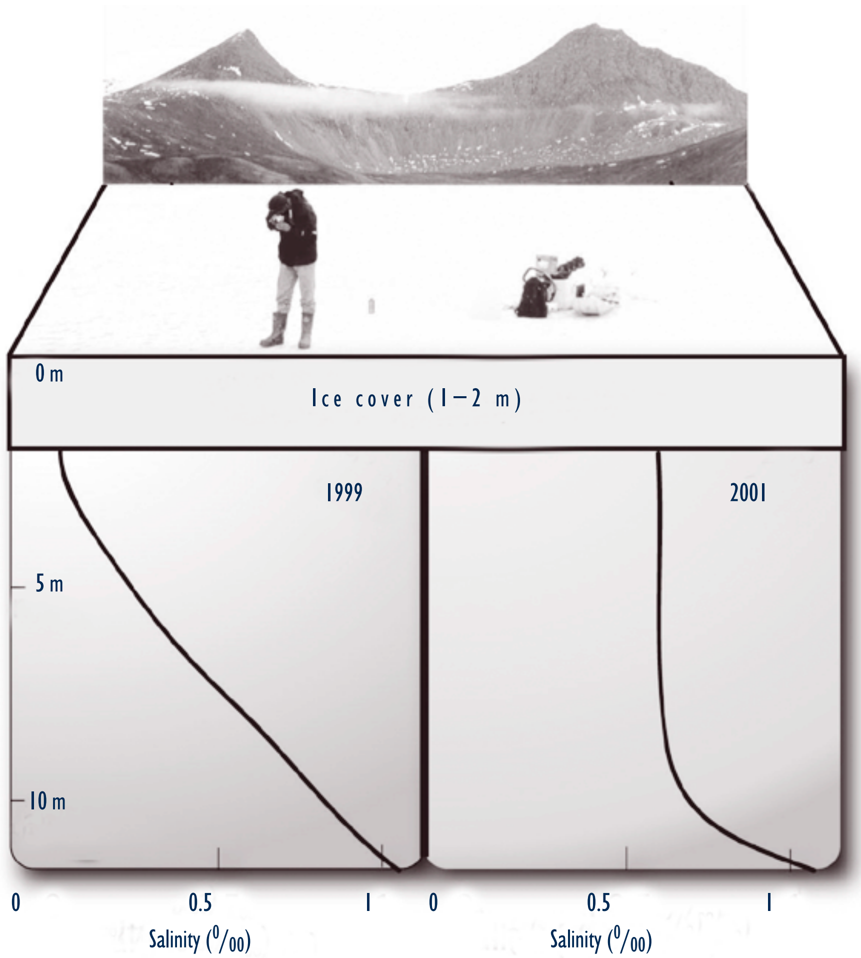


Fig. 2
Salinity changes in the surface waters of Lake A between 1999 and 2001. The unusual ice-out event seen by RADARSAT in late summer 2000 allowed the wind-induced mixing of deeper saline waters into the surface, and eliminated the surface freshwater habitat. Photo: Warwick Vincent.

Ellesmere Island at their southern ends. From Peary's detailed account of his voyage along the coast from Cape Sheridan to Axel Heiberg Island, we estimated a total ice shelf extent of about 8900 km^2. This ice shelf is believed to have started to form about 4500 years ago and to be fully in place (surmised from the carbon 14 dating of driftwood trapped on the landward side of the ice) about 3000 years ago (Jeffries, 2002). Our analyses suggest that there has been a 90% loss of this ancient feature over the course of the 20th century.

Several other components of the northern Ellesmere Island environment provide evidence of substantial change. The saline Lakes A-, B- and C-series are capped by thick ice through most months of the year, and our initial profiling data from Lake A in 1999 bore a close resemblance to earlier measurements decades earlier, suggesting that this lake rarely lost its ice cover. These capped lakes show the effects of hundreds if not thousands of years of slow heating by the solar radiation that penetrates through the surface ice, gradually warming their mid-depth saline waters to surprising temperatures. The absence of mixing means that this heat is not returned to the surface to be lost to the atmosphere, but rather can slowly accumulate. Mean annual air temperatures in this region are around −20°C, yet Lake A reaches a stable 8.5°C in its mid-depth, and Lake C1 attains an astonishing

12°C that is likely to stay fairly constant throughout the year despite winter air temperatures below −40°C. In 2001 we observed for the first time that this unusual layered structure of cold freshwater on warmer salt water was being broken down, and that there was evidence of mixing (Fig. 2). RADARSAT images confirmed the loss of lake ice on all the lakes in the year 2000, and in late summer 2003, Lake A again showed substantial break-up of its surface ice (Fig. 1). This abrupt change in temperature and salinity is likely to completely alter the structure and ecology of these unique ecosystems.

The most dramatic shift we have seen in terms of recent change has taken place in Disraeli Fiord. When we first undertook measurements in this deep, 30 km-long fiord we found that it contained a thick surface layer of freshwater sandwiched between a 2.5 m ice-cap above and the sea beneath. The plankton was composed of an unusual mixture of fresh and brackish water species (Van Hove *et al.,* 2001), and provided another fascinating model system for understanding life processes in the polar environment. This so-called "epishelf lake" was formed because the Ward Hunt Ice Shelf acted as a dam across the mouth of Disraeli Fiord (Fig. 1) and allowed the outflow of freshwater only beneath at the base of its 40–50 m-thick mass of ice. Our observations in 1999 confirmed two earlier records, in 1967 and 1983, of these epishelf conditions. However a comparison of our measurements of the freshwater depths with the earlier data showed a loss of more than 10 m depth of the freshwater layer, suggesting a substantial recent thinning of this ancient ice shelf.

When we flew over the ice shelf in 2001 we noted a central fissure, but were unaware of its extent or significance. In 2002, we returned to the site and immediately saw that the fissure was huge, had widened into a crack that extended 15 km over the full north-south length of the shelf, and was accompanied by multiple east-west fissures extending off for many km. Working with our collaborator Martin Jeffries and the University of Alaska Fairbanks SAR Facility, we were able to obtain high resolution RADARSAT images and to confirm that the ice shelf was in the process of disintegrating (Fig. 1). Most strikingly, salinity-temperature profiles that season in Disraeli Fiord (Fig. 3) showed that brackish water now extended to just beneath the surface ice, and more than 3 billion cubic metres of freshwater contained within the epishelf lake had completely drained away through the central crack of the now-broken Ward Hunt Ice Shelf. Our profiling measurements in 2003 confirmed the complete loss of the surface freshwater ecosystem, which from analyses of RADARSAT, probably took place in 2001.

This dramatic break-up and loss of the ancient ice shelf and its associated epishelf lake was the focus of a great deal of public media interest, with front page stories in newspapers around the world. The previously inconspicuous Ward Hunt Ice Shelf suddenly became known on more than 200 websites. One editorial on the event perhaps captured the reason for this unexpected level of international interest: "There has been no end of scholarly studies confirming the gradual rise in global temperatures over the past century. Yet nothing focuses the mind on global warming and its potential consequences quite so sharply as the occasional news flash from some remote corner of the globe documenting startling changes in landscapes once thought to be immutable" (New York Times, 25 September 2003).

Of course what all the journalists wanted to know was to what extent the ice shelf

Fig. 3
Sampling at the southern end of Disraeli Fiord, from the Disraeli Glacier, August 2003. The insert graph shows the layering of freshwater over saltwater at the northern end of the fiord (an epishelf lake) and the observed loss of the freshwater layer in 2002 caused by the breaking up of the Ward Hunt Ice Shelf (from Mueller *et al.*, 2003). Photo: Derek Mueller.

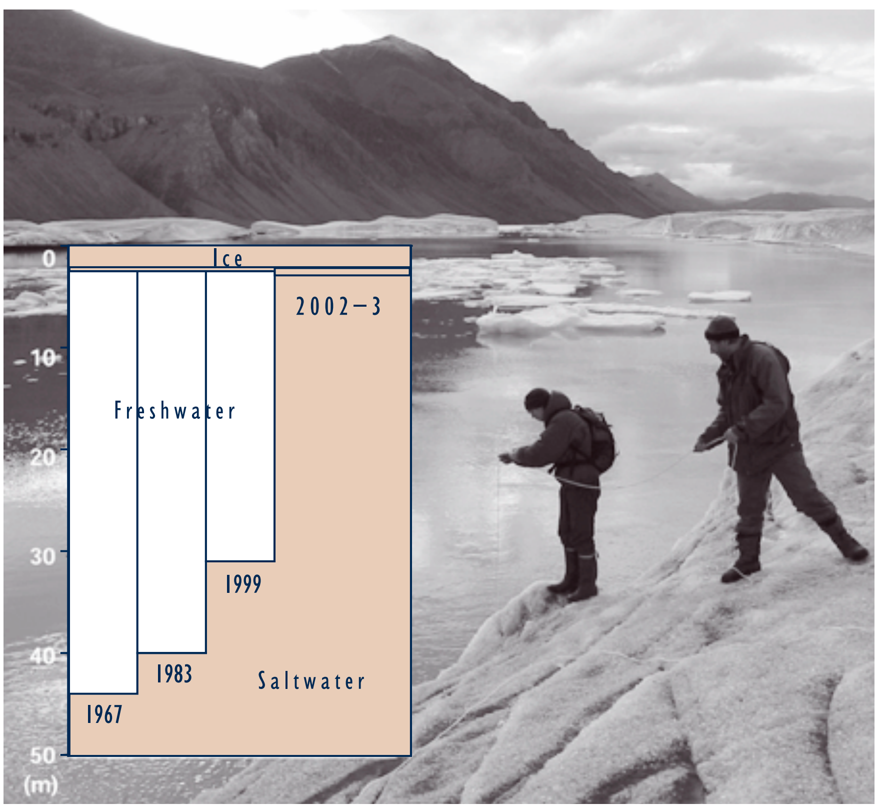
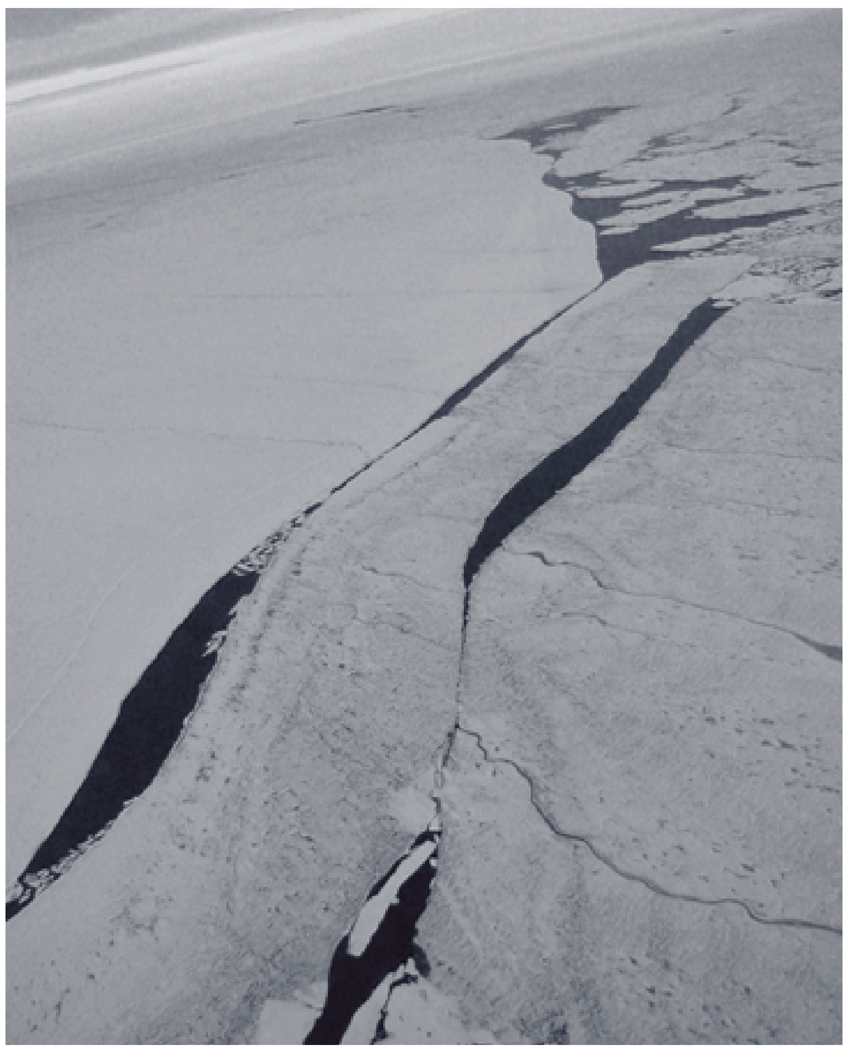


Figure 4
Breakup of the Ward Hunt Ice Shelf. Photo: Warwick Vincent.

break-up and ecosystem loss can be attributed to the increased greenhouse effect caused by human activities. The short answer is we do not know. We do know that Ellesmere Island has been changing for a long time, throughout the 20th century as shown by the ice shelf records, and that the most recent changes correspond to a 30 year period of accelerated warming as indicated by the Environment Canada climate record at Alert (Mueller *et al.,* 2003) and by observations of environmental change throughout the circumpolar Arctic (Serreze *et al.,* 2000). Paleo-ecological work at Cape Herschel, about half-way up Ellesmere Island's eastern coast, showed that there were abrupt changes in diatom fossil indicators of climate in the middle of the 19th century, suggesting the onset of substantial warming at that time (Douglas *et al.,* 1994). Some researchers believe that even this early change may indicate the timing of onset of the effects of industrial society on our global climate. There are important natural sources of variability to consider, including the Arctic Oscillation (AO) which causes swings in climate and oceanic circulation at various timescales. It has been argued that the current increase in greenhouse gases may have forced the AO into an extreme state that accounts for the recent series of anomalously warm years in the high Arctic (Shindell *et al.,* 1999).

The ongoing debate and discussions about how fast our world will heat up in the future, and how much of the present fluctuations in climate can be ascribed to natural versus anthropogenic effects, should not be

Figure 5
Ice islands calving from the ice shelf. Photo: Warwick Vincent.



allowed to obscure the agreed facts: greenhouse gases are accumulating in our global environment at an unprecedented rate, and the circumpolar environment is vulnerable to relatively minor shifts in temperature across the melting point of ice. The cold ice-dependent ecosystems at Canada's northern coast are providing compelling evidence of change. Quttinirpaaq National Park is playing invaluable, multiple roles, not only as a wildlife preserve and recreational wilderness, but also as a global monitoring site that has begun to issue signals of major change ahead.

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References

Douglas, M.S.V., J.P. Smol and W. Blake Jr, 1994. Marked post-18th century environmental change in High-Arctic ecosystems. *Science,* 266: 416–419.

Jeffries, M.O., 2002. Ellesmere Island Ice Shelves and Ice Islands, in *Satellite Image Atlas of Glaciers of the World: Glaciers of North America,* pp. J147–J164. Edited by R.S. Williams and J.G. Ferrigno, United States Geological Survey, Washington D.C.

Mueller, D.R., W.F. Vincent and M.O. Jeffries, 2003. Break-up of the largest Arctic ice shelf and associated loss of an epishelf lake. *Geophys. Res. Lett.* 30: 2031, doi:10.1029/ 2003 GL017931.

Serreze, M.C., J.E. Walsh, F.S. Chapin, T. Osterkamp, M. Dyurgerov, V. Romanovsky, W.C. Oechel, J. Morison, T. Zhang and R.G. Barry, 2000. Observational evidence of recent change in the northern high-latitude environment. *Climatic Change,* 46: 159–207.

Shindell, D.T., R.L. Miller, G.A. Schmidt and L. Pandolfo, 1999. Simulation of recent northern winter climate trends by greenhouse gas forcing. *Nature,* 399: 452–55

Van Hove, P., K. Swadling, J.A.E. Gibson, C. Belzile and W.F Vincent, 2001. Farthest north lake and fjord populations of calanoid copepods in the Canadian High Arctic. *Polar Biology,* 24: 303–307.

Vincent, W.F., J.A.E. Gibson and M.O. Jeffries, 2001. Ice shelf collapse, climate change and habitat loss in the Canadian High Arctic. *Polar Record,* 37: 133–142.

Vincent, W.F., D. Mueller, P. Van Hove and C. Howard-Williams, 2004. Glacial periods on early Earth and implications for the evolution of life. In: Seckbach, J. (Ed.), Origins: Genesis, Evolution and Biodiversity of Life. Kluwer Academic Publishers, Dordrecht, The Netherlands, in press.

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FAT AS AN ECOLOGICAL TOOL: BEARS AND SEALS IN TEMPERATE AND ARCTIC ECOSYSTEMS

Sara Iverson

Most people usually think about fat negatively, as an almost sinister "thing" that we simply have to cope with – a necessary evil. After all, fat is contained in the food we must eat and is readily generated from other nutrients (carbohydrates and proteins) consumed in caloric excess, yet too much of it carried in our bodies can be unhealthy or even life-threatening. Many people abhor the very thought of fat, along with the primary tissue in which it is stored, adipose tissue. However, in the animal kingdom, fat can be one of the most important things in life. Indeed, in many animal species, large fat stores are crucial to survival. Because of its critical place in animal life, understanding aspects of fat and its metabolism can help shed light on a wide range of subjects, from piecing together evolutionary adaptations to providing us with clues as to how some animals make their living in the wild.

For example, we have recently developed a method that uses the basic constituents of fat, fatty acids, to study the diets and foraging strategies of free-ranging animals. Predator-prey relationships and the spatial and temporal scales of foraging in wild animal populations are central issues in the ecology, conservation, and management of animals and the ecosystems on which they depend. Fat is now providing us with some of our first detailed insights into the diet and