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ARE CONTAMINANTS IN THE ARCTIC OCEAN YESTERDAY'S PROBLEM?

Robie Macdonald

As early as 1967 polychlorinated biphenyls (PCBs) were measured in Arctic seals – a sufficiently surprising finding at that time to be worthy of a paper in *Nature*. Despite the news that Arctic seals harboured PCBs in their fat, there was surprisingly little follow-up by scientists or politicians, and Arctic contaminants attracted little interest until about 1990 when they were rediscovered in the context of risks to northerners whose diets include a large component of marine animal fat. In Canada, the Northern Contaminants Program (NCP) was launched in 1991 and, internationally, the eight Arctic countries established the Arctic Monitoring and Assessment Programme (AMAP) whose task it was to find out where the contaminants came from and what risks they presented to ecosystems and humans. An important lesson here is that news media played a crucial role in raising public and political awareness before sufficient funds were put toward developing a scientific understanding of what was, after all, a 20-year old problem. The NCP had as an ultimate objective the reduction or elimination of contaminant exposure in the Arctic. A dedicated and talented science community set out to find where Arctic contaminants came from and how they managed to attain such high concentrations in animals so far from any sources. During the early stages of research, the surprising became the expected: practically every classic contaminant (Hg, PCB, DDT, chlordane, toxaphene, aromatic hydrocarbons and artificial radionuclides) was found to greater or lesser degree in the Arctic's air, water, soil and biota.

Several first-order scientific discoveries were made. An exquisite story was written on artificial radionuclides, which were disposed under license as nuclear reactor reprocessing waste off the coast of Europe. Rich in ^{137}Cs and ^{129}I, the radionuclide waste provided an incisive tracer that followed ocean currents into the Arctic and then traveled with boundary currents around the margins of the Eurasian and Canadian Basins at time scales of 5–15 years (Smith *et al.,* 1998). HCH (hexachlorocyclohexane; one of its forms is commonly known as the pesticide lindane) provided another elegant story involving air-water exchange and transport by winds and ocean currents. Looked at as an environmental tracer, HCH helped us to understand how surface ocean temperature controls the global distribution of some chemical compounds, and how ocean reservoirs load and unload semi-volatile contaminants over decadal periods (Li *et al.,* 2002). Mercury yielded up an exceptional surprise, which expanded into a vigorous international research effort that continues to this

Canada

day. It was discovered that, at various intervals after polar sunrise, this element disappeared within hours from the lower atmosphere (Schroeder *et al.,* 1998). Behaviour like this is completely out of character for a substance like Hg with an atmospheric residence time of about a year. Canadian pioneering research solved much of the puzzle of why Hg deposits to the ice surface in the Arctic's marginal seas during spring – just preceding the time when biological processes turn on.

Scientists soon focused their attention on contaminant exposure in Arctic ecosystems: in aquatic ecosystems, the highest contaminant burdens were found for chemicals that bioaccumulate or biomagnify within food chains (Muir *et al.,* 1999). Indeed, physical transporting and concentrating processes together with an aquatic food web firmly reliant on the transfer of fat provided the conspiracy that put top predators in the Arctic Ocean at risk from many of these chemicals.

The understanding that came out of the concerted efforts of the first five years of NCP research culminated in the Canadian Arctic Contaminants Assessment Report (CACAR, 1997), and much of the Canadian science was entrained into the AMAP assessment report (1998). In Canada, the NCP scientific research underpinned Canada's position internationally and contributed enormously to getting agreement under the Stockholm Convention to eliminate or reduce the use of many of the bad actors – the so-called dirty dozen organochlorines (PCBs, dioxins, furans, aldrin, dieldrin, DDT, endrin, chlordane, hexachloro benzene, mirex, toxaphene and heptachlor). Having achieved success through a carefully choreographed research and policy plan, the NCP then shifted direction away from studying contaminant pathways and more toward monitoring contaminant trends in selected Arctic media (*e.g.,* air and biota), and investigating the potential role contaminants might play in human health. To the contaminant pathways specialist – and I am one – nothing fails like success. This brings me to the title of this essay. If we have gotten contaminant sources under control, and now are just waiting while the biosphere slowly sheds its historical burden, is there anything left for the Arctic contaminant scientist to do? This question is, perhaps, especially pertinent today as global change has become the pervasive concern of scientists, news media, politicians and, of course, those who reside in the Arctic.

I'm convinced there remain important contaminant science tasks for three reasons: first, time series of contaminants in various Arctic media are confounded to varying degrees by environmental variability and change which, putting it another way, means that the climate system can conspire with contaminant pathways to deliver surprises (Macdonald *et al.,* 2005). Second, environmental change can alter the vulnerability of ecosystems and thereby cause a contaminant effect to "kick in" even though the exposure may have remained constant or even declined (Schiedek *et al.,* 2007). Third, while classical contaminants dwindle globally, new chemicals are invented and distributed, some of which will get to the Arctic (Muir and Howard, 2006). Below, I'm going to discuss these three challenges in a little more detail.

To arrive at a particular location in the Arctic, a contaminant has to navigate a number of pathways (*e.g.,* air, water, foodwebs, migratory animals) and these usually involve a series of steps and transfers, each of which can be altered by climate change (Figure 1). For example, PCBs comprise a family of 209 semi-volatile compounds containing a range from one to ten chlorine atoms. The degree of chlorination affects the physical properties and the biological toxicity. Released as a mixture in temperate industrial regions, PCBs begin to move away from the source by partially volatilizing and traveling on the winds. But this transport is complex, because along the route PCBs will transfer between air, aerosols, soil, vegetation and water, undergoing a sequence of atmospheric hops. Differences in physical properties between PCB compounds will operate so as to separate components in transport. In a way, the Earth behaves as a large, temperature-programmed chromatograph with surfaces acting as the stationary phase, and air and water as the moving phases. Typically, the light PCBs containing few chlorine atoms are more volatile and less attracted to solid phases, so they fan out in the vanguard. Later, the heavy PCB rearguard tries to catch up (*e.g.,* see Wania, 2003). Altering wind pathways, changing soil temperatures, crossing the zero-degree isotherm (solid versus liquid water) and even altering vegetation from, say, tundra to willows, affects the global physical transport.

Once PCBs reach the Arctic, they can enter the ocean through air-sea exchange or deposition (snow, rain, aerosols) and, again, these process are affected by climate variation. In particular, ice cover on the ocean controls air-sea exchange, and of all the physical changes happening within the Arctic, the loss of sea-ice cover is arguably the clearest and most important. Finally, the entry of PCBs into the foodweb and transfer to higher trophic levels can be altered by changing the trophic structure. So, when one examines a time series for PCBs in, for example, a polar bear or a beluga whale, there are quite a few factors in the physical and organic systems that control that final expression of concentration. Many organochlorine compounds that have been banned or restricted in recent years exhibit a characteristic emission history, with emissions commencing about 60 years ago, reaching a maximum, and then declining, sometimes

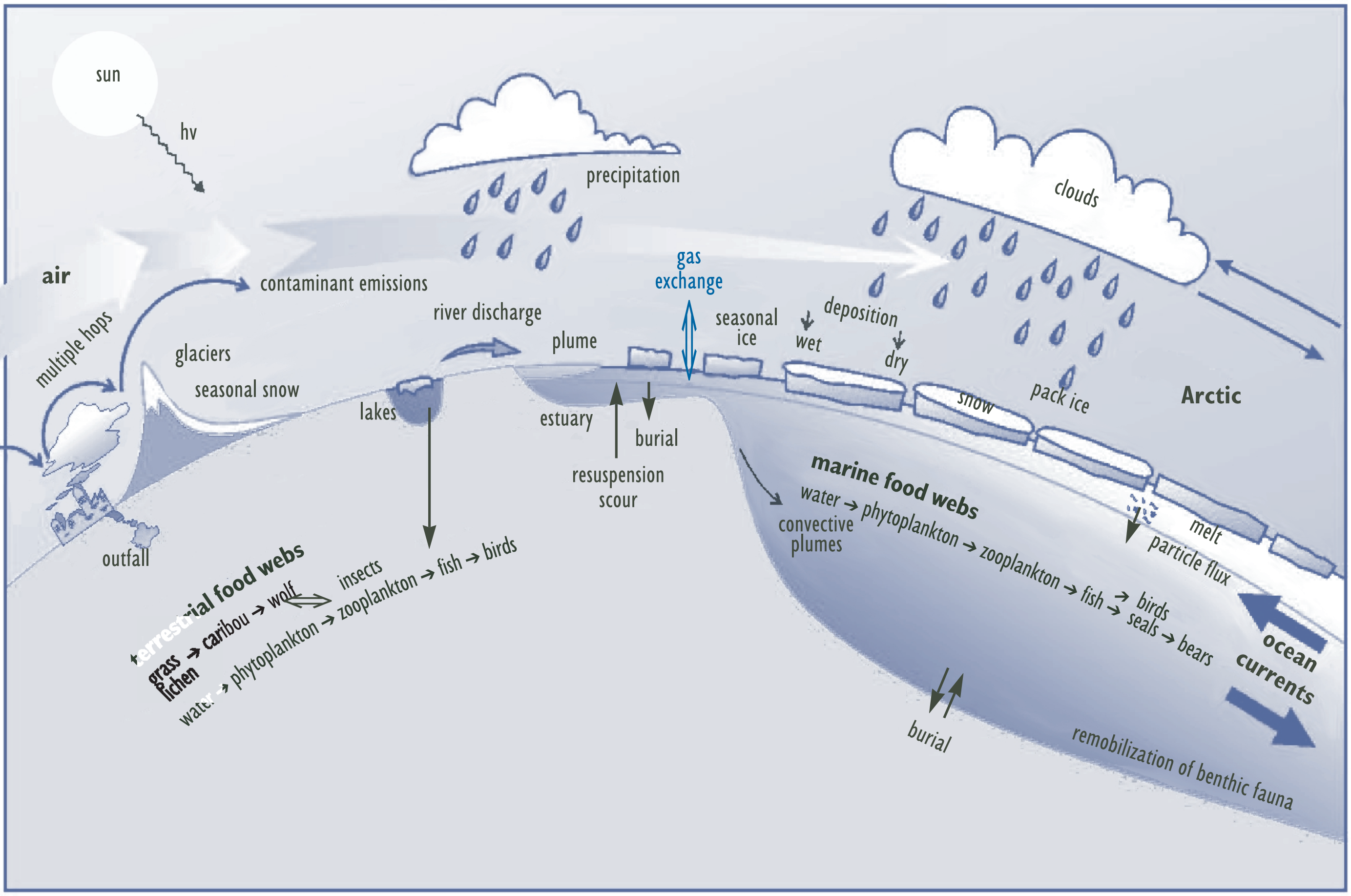

Figure 1
Contaminant pathways to the arctic

precipitously. During the early stages of release, atmospheric transport is a dominant pathway, but as environmental reservoirs become loaded (upper ocean, lakes, soils, vegetation) these then emerge as important secondary sources. After primary emissions are turned off, environmental reservoirs eventually become the dominant supplier of cycling contaminants, and environmental variability has a great opportunity to play its role. To understand the significance of contaminant time series therefore, we must account for variability and change in environmental factors. This is becoming increasingly clear with the recent dramatic demise of Arctic sea ice in summer.

Vulnerability is strongly related to climate change. Although contaminants often turn out to be sophisticated transient tracers, and we've learned much about the connectivity between the Arctic Ocean and the rest of the globe through them, the fundamental question, really, is whether or not contaminants are having effects on the ecosystem or humans. The Arctic is special because these contaminants were not used there and yet, because there is such a strong dependency on lipids (fat) in the food web, top predators including humans can exhibit high exposure especially to the organochlorines. Even though the time series being maintained under the ongoing NCP activities are giving us a reasonable image of chemical exposures with annual resolution at the decadal scale (*e.g.,* Braune *et al.,* 2007), we are far less certain about the effects of those contaminants on biota. One difficulty is that we are dealing with complex mixtures of chemicals and yet we lack epidemiology for most of the species involved even for single chemicals. Furthermore, we are by no means well informed about the exposure variability with season; short-lived, small animals likely respond fairly immediately to environmental exposure whereas long-lived, large animals (whales) may carry a burden accumulated through their lifetimes and this contaminant archive can be released during periods of starvation, migration or fasting (*e.g.,* Hickie *et al.,* 2007). If all this is not difficult enough, chemicals can threaten animal health in different ways, for example by compromising immunity to disease or by impairing reproduction. Under normal circumstances, an animal might tolerate a given chemical exposure, but with the sorts of climate change now occurring in the Arctic and projected to continue to occur or perhaps even accelerate, other stresses (nutrition, invasive species, exposure to viruses) are going to place animals "at the edge." Chemical exposure may provide the final "push." We know far too little about the interactions between change, exposure and vulnerability and we need, at the very minimum, to monitor the health of the more exposed marine predators like toothed whales and bears.

The third task I identified for contaminant scientists, the emission of new chemicals, has been highlighted by Muir and Howard (2006). Two new chemical classes have recently emerged in environmental discussions – brominated diphenyl ethers (flame retardants) and perfluorinated alkyl acids (deriving from widely-used surfactants

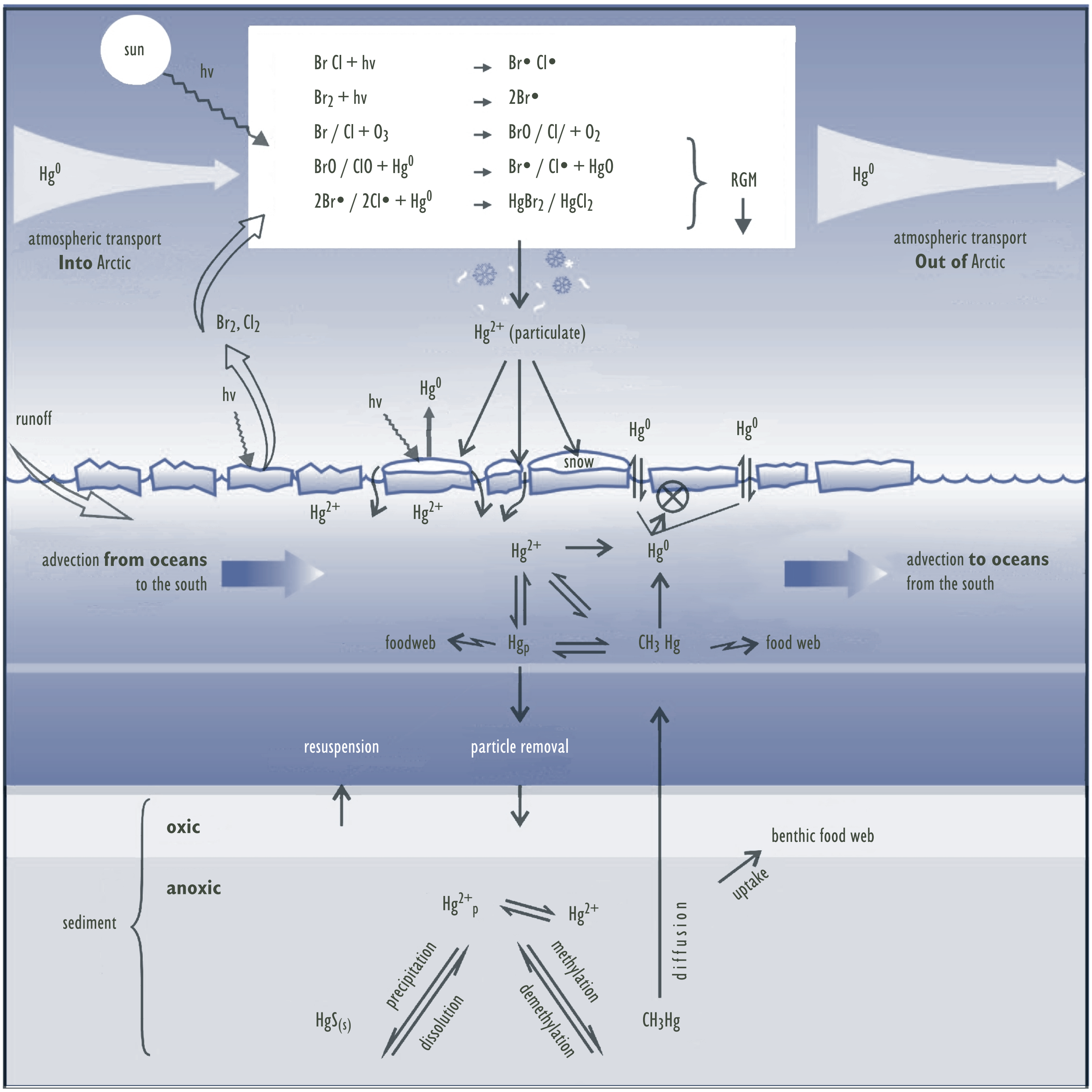

Figure 2
The complexity of the mercury cycle in the Arctic leaves much opportunity for climate change to alter pathways. Although we now understand much about atmospheric processes that convert gaseous Hg to reactive forms after polar sunrise (inset box at top of figure) and deposit it to the surface, we have a much poorer understanding of the transformations occurring in the ocean, especially those that control methylmercury and its entry into foodwebs.

to protect fabric). Their appearance in the Arctic automatically defines them as persistent. Unfortunately, there are about 30,000 chemicals used widely by industry (more than one tonne per year) and most are not monitored in the environment. Out of these, Muir and Howard (2006) have pared the list down to 30 chemicals with high potential for bioaccumulation and 28 with long range atmospheric transport potential. While containing a diverse group of chemicals, this pared-down list is at least manageable in terms of assessing presence and trends in selected Arctic media. Certainly, a task for contaminant chemists is to remain vigilant for new chemicals, something that is helped by a coordinated effort to maintain tissue archives.

Most of the contaminant discussion above refers to selected industrial and agricultural organochlorine compounds, simply because these have been released in large quantities, they transport efficiently in air or water, they associate with organic systems, they undergo magnification in the environment, they are persistent and they are unequivocally identified with human activities. Toxicity varies, but some of these compounds are among the most toxic. This list leaves out one more toxic chemical that especially concerns me – mercury. Mercury is difficult to study in the environment; as its common name, quicksilver, implies, it is an element with "slippery" behaviour that undergoes many chemical transformations and phase changes (Figure 2). Gaseous elemental Hg is volatile, but when oxidized it associates with particulates and water, and under reducing conditions it can be converted to a more toxic, bioaccumulative form – methyl-mercury. The natural Hg cycle complicates the study of Hg as a contaminant. Perhaps two-thirds of the Hg in the atmosphere and upper ocean derives from human activities over the past two centuries, but the other third is part of a global cycle that has endured for eras. Although steps have been taken to curb the release of Hg in North America and Europe from, for example, coal burning, dental technology, soft metal smelting and the chlor-alkali industry, Hg in the large environmental reservoirs (ocean, atmosphere, soil) continues to cycle, and Asia is presently increasing its Hg emissions. Once again, the Arctic is special insofar as Hg is concerned, but for a very different reason than the semi-volatile organochlorines: shortly after polar sunrise Arctic air undergoes unique chemical transformations, initiated by solar radiation and catalyzed by halogens from the ocean, which convert gaseous Hg into reactive forms that subsequently deposit on the surface of the ice or into open leads. A substantial amount of research has confirmed the atmospheric mercury depletion process and revealed it to be widespread around the Arctic Ocean margin.

Figure 3
Trace Hg clean-room trailer on the *CCGS Amundsen*; Joanne Delaronde prepares samples to study Hg in the ocean as part of the Circumpolar Flaw Lead (CFL) study. Photo: Doug Barber.

The complexity of the Hg cycle (Figure 2) and the difficulty of measuring trace Hg concentrations in sea water, which are easily ruined by contamination during sampling, means that clean techniques must be used (Figure 3). Another difficulty, that of accessing the Arctic's coastal oceans between February and May, has left many puzzles still to be resolved in the water side of the Hg cycle. Therefore, the over-wintering of the *CCGS Amundsen* in the Beaufort Sea from November, 2007 through summer of 2008 (Figure 4) provides a rare opportunity to conduct research on the Hg cycle through seasonal transitions in a milieu of other physical, chemical and biological investigations. Much of the Hg deposited on snow and sea ice during depletion events is apparently reduced and emitted back to the atmosphere rather than entering the ocean. The trends that have been assembled during the NCP for atmospheric Hg do not reveal any obvious connection to the sometimes alarming trends and variability of Hg in aquatic predators like beluga. In my view, the answer to this mystery lies in the part of the system that has been most poorly studied – the ocean. Important sources of variation and trends in Hg burdens for biota in the Arctic Ocean can be found in processes such as Hg methylation and demethylation, changes in animal foraging behaviour, and changes in supply of Hg from adjacent drainage basins undergoing melting of the permafrost. It seems clear to me that we need a far more thorough understanding of the Hg cycle in the Arctic Ocean before we can make further progress on how Hg presents risks to Arctic ecosystems and what our opportunities are for mitigation.

In summary, there remains much for the contaminant science community to do.

Figure 4
The *CCGS Amundsen*, here frozen into the ice of Amundsen Gulf, provides a unique opportunity to investigate Hg pathways in air, snow and ocean as the system goes through polar sunrise (mercury deposition), breakup (meltwater production) and biological production. As part of Canada's International Polar Year program, researchers will generate comprehensive data sets for mercury and other system properties. Photo: Doug Barber.

Certainly the maintenance of trend monitoring is important, but this needs to be done in the context of changing pathways. Particularly important as we go through this period of rapid change in the Arctic is to establish what sort of risks contaminants present as additional stresses to aquatic predators facing the loss of summer ice in the Arctic Ocean, the invasion by new species and altered temperature regimes. Chemicals continue to be invented much faster than environmental chemists can develop methods to measure them in the environment. We need to focus some effort on new chemicals that present the greatest risks based on persistence, bioaccumulation potential, toxicity and the capacity to make it to the Arctic. Finally, we require research on ocean processes involving Hg with the objective to catch up with the understanding that has emerged during the past ten years for Arctic atmospheric mercury chemistry (*e.g.,* Steffen *et al.,* 2008).

Robie Macdonald is Head, Marine Environmental Quality, Fisheries and Oceans Canada. At the time of writing he was serving a stint as Chief Scientist aboard the CCGS Amundsen, *which was wintering over in the Beaufort Sea.*

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NEAR-RECORD PRECIPITATION CAUSES RAPID DRAINAGE OF ZELMA LAKE, OLD CROW FLATS, NORTHERN YUKON TERRITORY

Brent B. Wolfe and Kevin W. Turner

While conducting the first phase of hydrological fieldwork in June 2007 for the Government of Canada International Polar Year project, "Environmental change and traditional use of the Old Crow Flats in northern Canada," we observed the rapid overland drainage of Zelma Lake. The Old Crow Flats (OCF), a 5300 km² freshwater ecosystem in the northern Yukon, is internationally recognized for its ecological significance and is closely linked to the cultural identity of the Vuntut Gwitchin community of Old Crow. Zelma Lake stands out among the more than 2000 lakes in the OCF because of its large size, its accessibility by boat, and because local residents have long used it for hunting, trapping and fishing. We used aerial photographs from a later survey in July 2007 as well as water depth measurements to estimate that water loss of approximately 5.8 million cubic metres (the equivalent of about 2300 Olympic-size swimming pools) exposed about 5.2 square kilometres of lake bed, corresponding to 43% reduction in lake area and over 80% reduction in lake volume. Precipitation in the month of May prior to our fieldwork totalled 44.4 mm, the highest recorded since measurements began in 1951; this followed above-average cumulative precipitation during the previous two months. Analysis of lake water isotope composition from Zelma Lake indicates that substantial rainfall likely increased lake levels and ultimately triggered rapid erosion of an outlet leading to the channel network that exports water from the Flats.

INTRODUCTION

Local concerns over declining lake levels in the Old Crow Flats, in the northern Yukon Territory, and resultant consequences to the integrity of the freshwater ecosystem recently led to a multidisciplinary research initiative funded by the Government of Canada International Polar Year (IPY) Program. The project, "Environmental change and traditional use of the Old Crow Flats in northern Canada," brings together a diverse group of researchers from universities and governments, in partnership with the Vuntut Gwitchin First Nation, to address the complexities of climate change impacts on the Old Crow Flats and the neighbouring community of Old Crow. Research expertise spans the disciplines of geology, physical geography, permafrost science, hydrology, limnology, terrestrial ecology, wildlife biology, nutrition, and traditional knowledge of the land and its processes. Over-arching objectives include: 1) documenting the history of environmental change in the Old Crow Flats from a unique assemblage of archives that record natural history from the last interglacial to the present; 2) assessing the distribution and abundance of vegetation and wildlife and identifying the processes that link these to the changing physical environment; 3) evaluating the impact of changes in the physical and biological environment on traditional food sources of the Vuntut Gwitchin; and 4) developing a long-term environmental monitoring program for the Old Crow Flats conducted by the Vuntut Gwitchin through the IPY and into the future.

Hydrological studies within the IPY Project are relying principally on water isotope tracers to determine the relative importance and spatial variability of the processes (*e.g.,* snowmelt, rainfall, melting ground ice, and evaporation) that govern present-day lake water balances and to reveal whether currently declining lake levels represent a unique directional change or instead reflect natural hydrological variability. Fieldwork began in June 2007 and included collecting water samples for analysis of oxygen and hydrogen isotope composition from 56 basins and 13 river locations spanning the area used by the Vuntut Gwitchin. During our first helicopter fly-over we observed that Zelma Lake, a large shallow basin about 12 square kilometres in area and less than a metre deep, had breached its southwestern bank and was rapidly discharging through two smaller basins and into a nearby creek.

Zelma Lake is culturally important to the people of Old Crow, and the event confirmed the prediction of a local resident whose family has hunted, trapped, and fished there for generations. He told us of his concerns about imminent drainage of the lake during a research planning meeting in February 2007. News of the drainage has since attracted national media attention (www.cbc.ca/canada/north/story/2007/08/07/yk-zelma.html). Here we present our field observations and offer climatic and isotopic evidence to suggest near-record precipitation from March through May caused the drainage event.

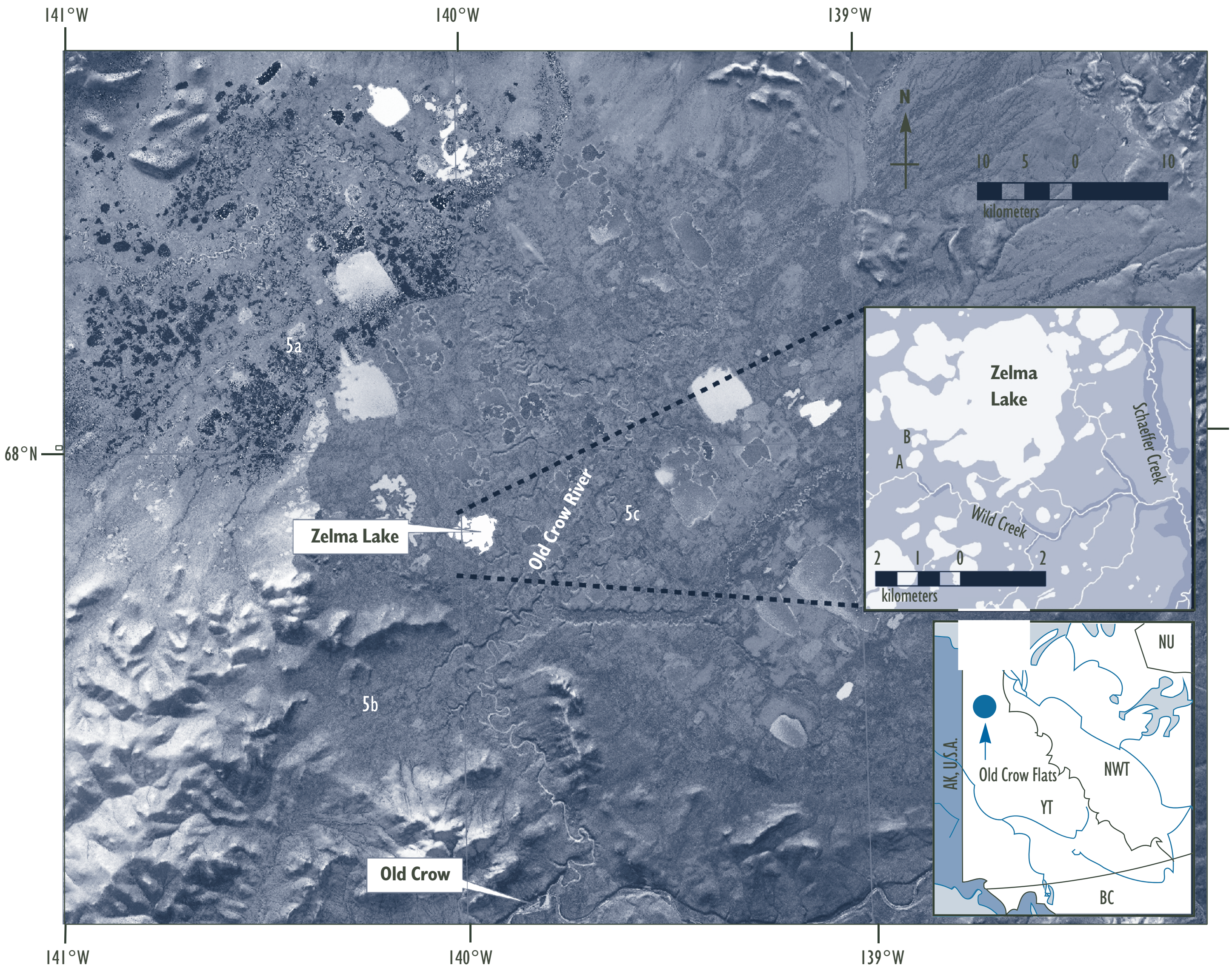


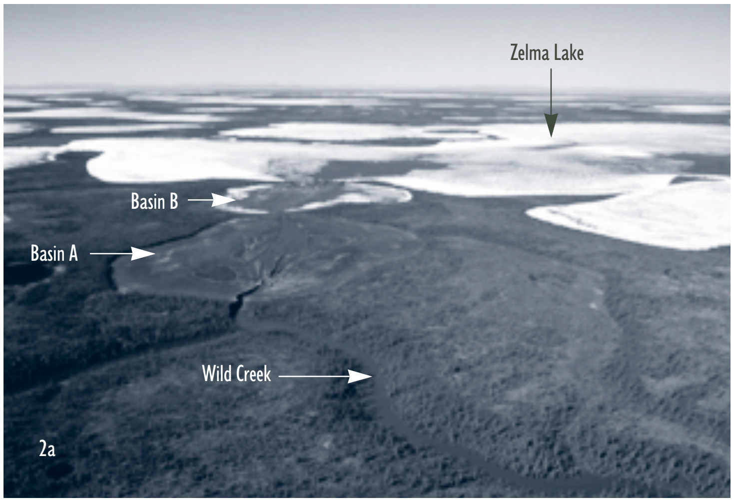
Figure 1
The Old Crow Flats in northern Yukon Territory is the home of the Vuntut Gwitchin First Nation and is a wetland ecosystem of international significance. Zelma Lake is a large basin west of the Old Crow River. Locations 5a–5c refer to photos shown in Figure 5.

FIELD OBSERVATIONS

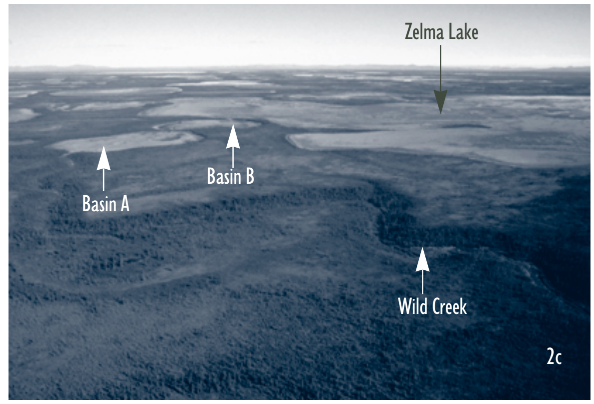
Zelma Lake is one of the largest lakes in the Flats and lies to the north of Wild Creek, a tributary of Schaeffer Creek that empties into the Old Crow River (Figure 1). On 6 June 2007, we observed a small (0.12 km^2) drained lake (Basin A) to the south of the western end of Zelma Lake (Figures 2a and 2b). According to a local resident, Basin A had drained into Wild Creek during the summer of 2006. Most of Basin A was dry except for a central incised channel that was carrying flow from the next similarly sized basin upstream (Basin B). Flow was substantial, as indicated by small sets of white-water rapids evident in the centre and the outlet of Basin A, and had raised the level of Wild Creek well beyond the capacity of its banks, drowning spruce trees on the floodplain. A clear colour distinction marked the point where the lake waters entered Wild Creek. Basin B appeared to be near bankfull, possibly indicating that it had begun to drain only very recently, although its level may have been maintained by Zelma Lake, whose southwestern bank was also breached.

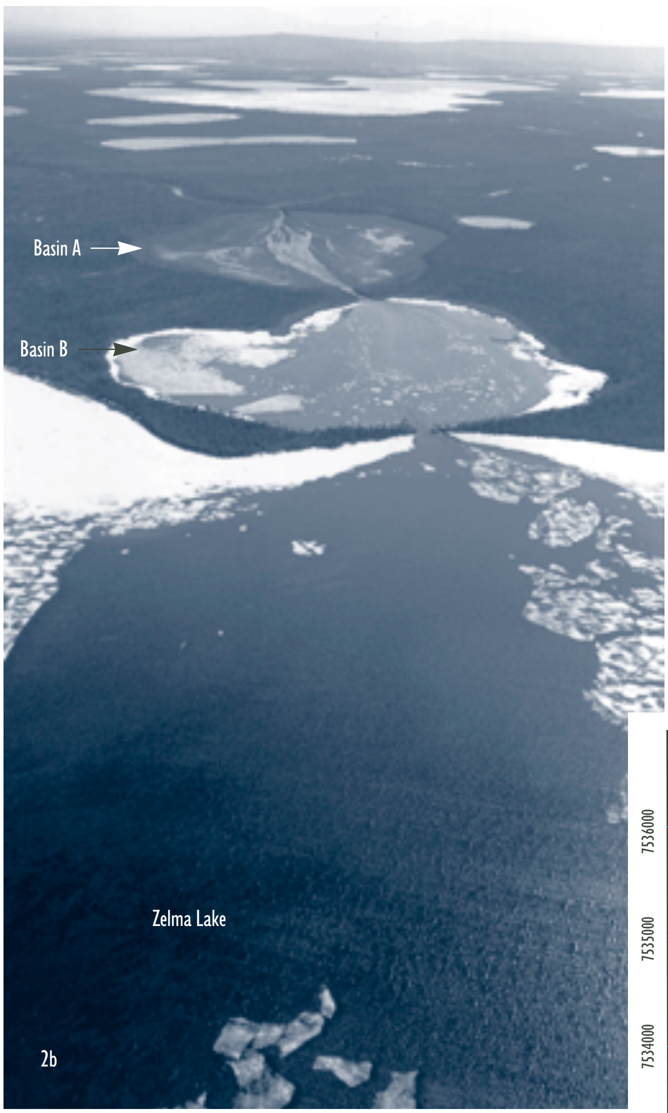
When we returned to the field area on 23 July 2007 we noted that flow had subsided in the incised channel of Basin A, Basin B was dry, and water level had declined substantially in Zelma Lake (Figures 2c and 2d).

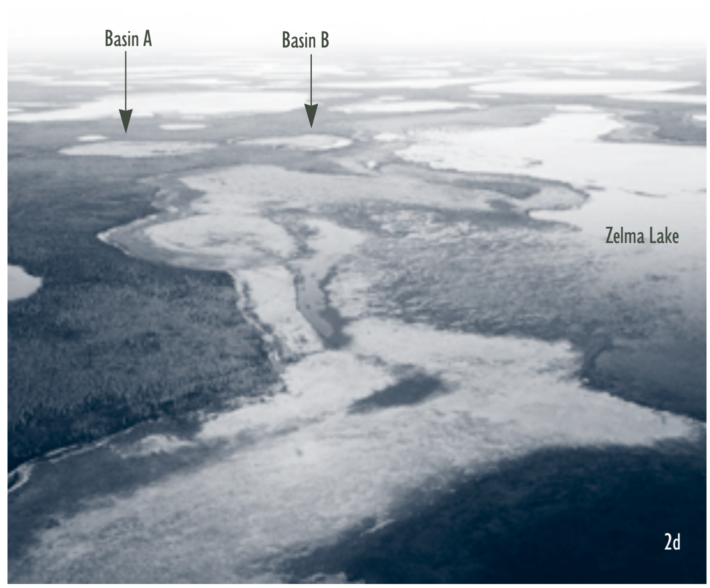
A broad swath of lake bed lay freshly exposed along the shoreline of Zelma Lake. Estimates from oblique aerial photos and measured lake water depths from the June and July surveys suggest ~5.8 million m^3 (~2300 Olympic-size swimming pools) of water loss exposed ~5.2 km^2 of lake bed, corresponding to a reduction in lake area of ~43% (Figure 2e) and of over 80% in lake volume.



Figures 2a and 2b
Photos of Zelma Lake taken on 06 June 2007.







Figures 2c and 2d
Photos of Zelma Lake taken on 23 July 2007.

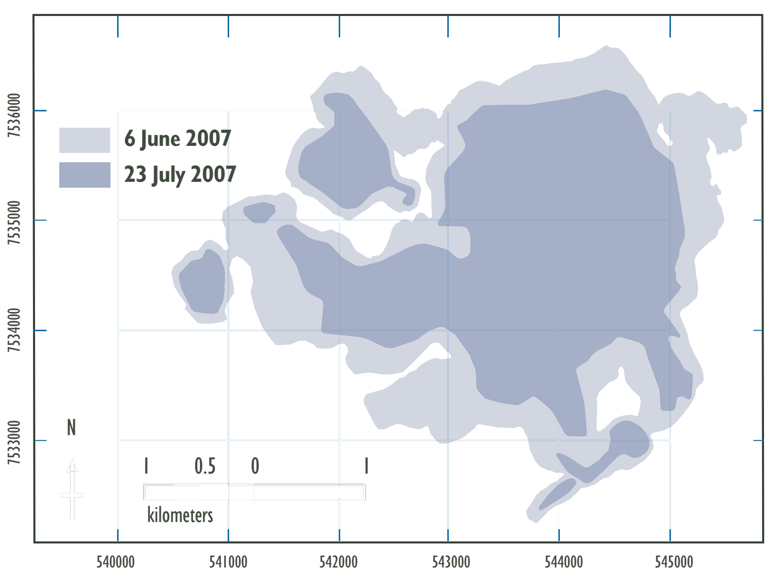


Figure 2e
Estimated spatial extent of Zelma Lake on 06 June 2007

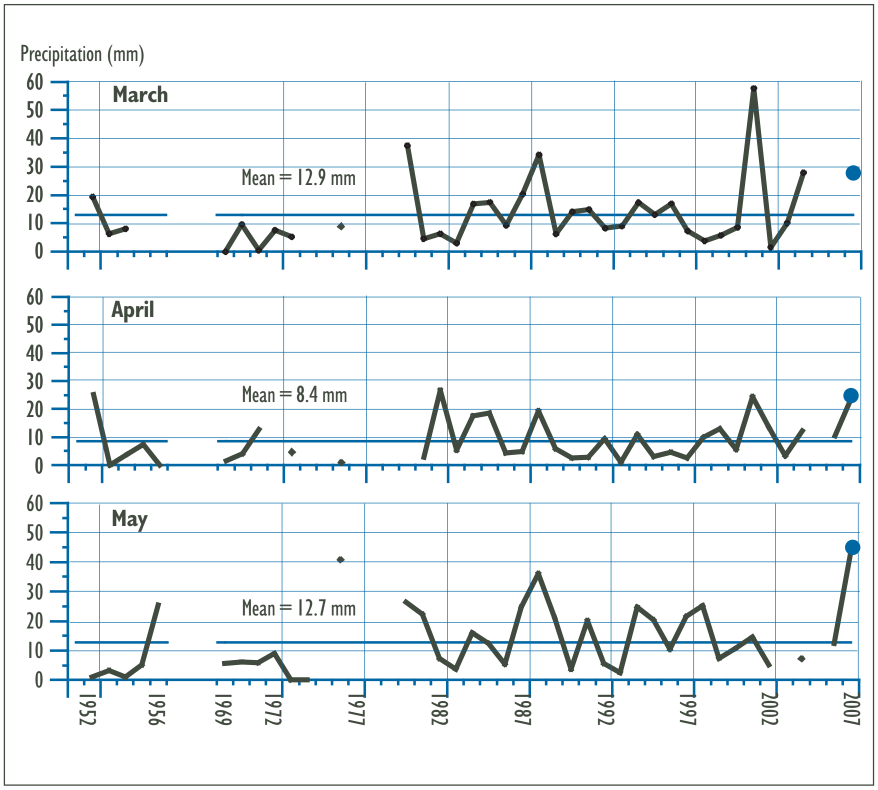
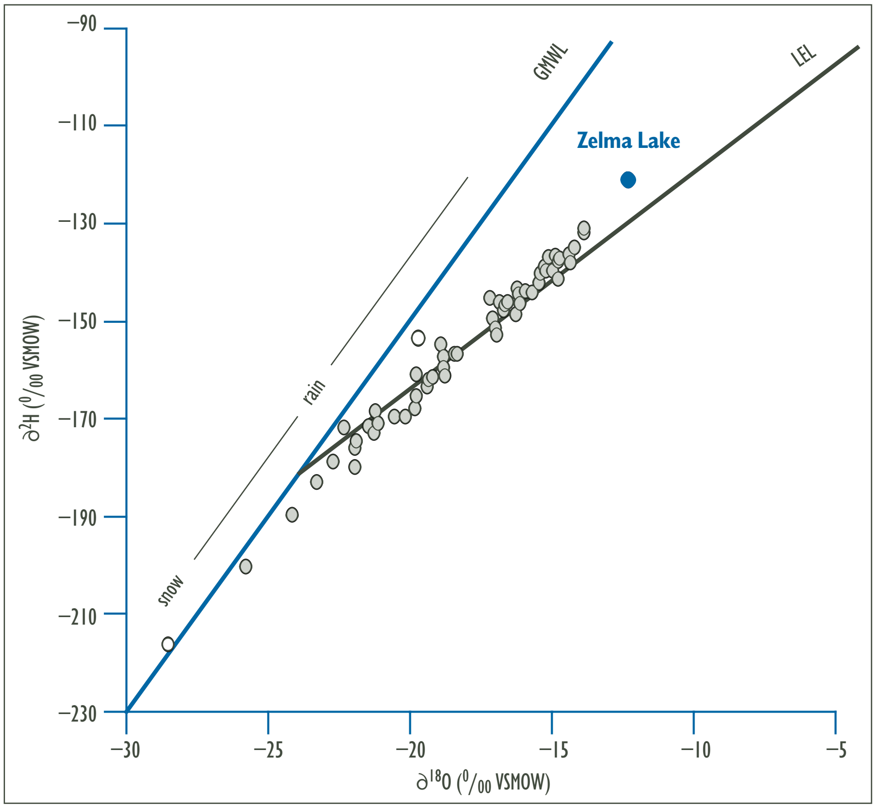


Figure 3
Precipitation for March, April and May (1951–2007) measured at the Old Crow airport (www.climate.weatheroffice.ec.gc.ca/index.html).



CLIMATE AND ISOTOPIC DATA

We examined local climate data to explore potential causes of the drainage of Zelma Lake and discovered that precipitation far exceeded the recorded average during late winter and spring of 2007 (Figure 3). Snowfall accumulation totalled 27.8 mm in March and 24.0 mm in April, well above the 1951–2007 mean values of 12.9 and 8.4 mm, respectively. Precipitation in May of 44.4 mm, comprising 10.0 mm of snow and 34.4 mm of rain, was the highest recorded since 1951 (the mean for 1951–2007 was 12.7 mm). On 31 May, six days before our field visit, 10 mm of rain fell, representing 23% of the monthly total precipitation. Cumulative precipitation over this three-month period (96.2 mm) was almost three times higher than the long-term mean (34.0 mm) and more than any year since 1951 in which complete records exist except for 2001 (96.8 mm).

Results from oxygen and hydrogen isotope analysis of the 56 lakes sampled in the Old Crow Flats in June 2007 are consistent with above-average precipitation in the early thaw season (Figure 4). We draw this conclusion from assessment of the isotopic data relative to the Global Meteoric Water Line (GMWL) and Local Evaporation Line (LEL), two reference lines that characterize precipitation and surface waters in conventional $\partial^{18}O$–$\partial^{2}H$ space, respectively. The

Figure 4
Results from oxygen and hydrogen isotope analysis of 56 lakes (shaded circles) sampled between 6–13 June 2007. Reference lines include the Global Meteoric Water Line (GMWL) and the Local Evaporation Line (LEL), the latter derived from an evaporation pan maintained at the Old Crow airport. Average isotope compositions for local snow and rain (open circles) from samples collected March–July 2007 are also shown. Note that Zelma Lake plots well above the LEL due to the recent input of substantial rainfall.

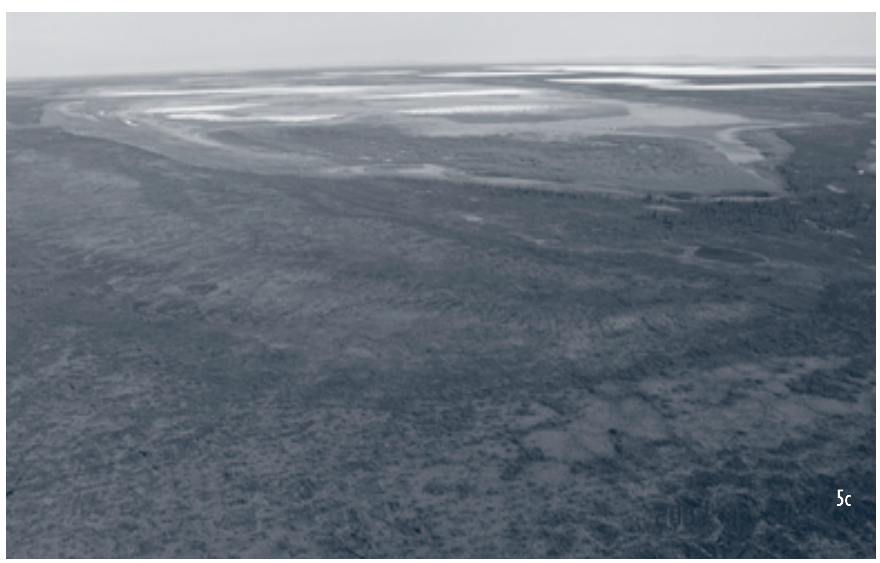
average isotopic composition of local snow and rain, the main sources of input water to lakes in the OCF, are readily distinguished and plot near the GMWL. In contrast, nearly all lakes are distributed along the LEL because of evaporation, although several (including Zelma Lake) plot above the LEL due to the recent input of over 30 mm of rainfall. From this analysis of available climate and isotopic data, we suggest that near-record precipitation during the March–May period capped by an intense rain event on 31 May raised water levels in Zelma Lake, triggering the rapid erosion of an outlet and subsequent drainage into Wild Creek. Other factors, such as melting ground-ice and headwater erosion due to changes in base level, may have also contributed to the drainage of Zelma Lake but their relative importance is difficult to assess at this time.

FUTURE DIRECTIONS

Is the draining of Zelma Lake yet more evidence of climate change impacts in high-latitude regions? Our field observations of the landscape of the Old Crow Flats indicate there are numerous examples of lakes that have contained higher water levels in the past (Figures 5a–5c) and, thus, the draining of Zelma Lake cannot be considered a unique event. However, if extreme precipitation during the late winter and early spring were to become more prevalent, the frequency in the lateral drainage of lakes to the channel network could increase. Water loss may also result from increased evaporation over a longer ice-free season and accelerated permafrost degradation. On the other hand, observations of submerged terrestrial vegetation in some areas of the Flats may be


5a


5b


5c

Figures 5a to 5c
Photos of basins that have had higher water levels in the past. Refer to Figure 1 for locations.

a result of elevated water levels or thermo-erosion of shoreline areas. Clearly, greater understanding of Old Crow Flats hydrology over time is critical to assess the role of climate change on recent drainage events like that of Zelma Lake and will be a primary focus of hydroecological and paleolimnological studies to be conducted over the next few years. It is our hope that findings will contribute to ecosystem management and community plans for adapting to ongoing environmental change.

*Brent B. Wolfe (*bwolfe@wlu.ca*) is an Associate Professor and holds the Natural Sciences and Engineering Research Council of Canada (NSERC) Northern Research Chair in Northern Hydroecology at the Department of Geography and Environmental Studies, Wilfrid Laurier University. Kevin W. Turner is a postgraduate student at the Department of Geography and Environmental Studies, Wilfrid Laurier University.*

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EVALUATING CANADA'S NORTHERN RESEARCH INFRASTRUCTURE AND LOGISTICS

Tom Hutchinson

Over the past year the Canadian Polar Commission has been working with several partners on an evaluation of Canada's northern research infrastructure and logistics support. Tom Hutchinson, Chair of the Commission, discusses the project in this excerpt from a recent interview.

The Polar Commission's infrastructure and logistics evaluation project originates with the recognition by many people over many years that the research infrastructure – field stations and logistics support – for northern science has been woefully degraded for some time, certainly into the 1970s. While we've had a lot of renewal and new opportunities with programs like ArcticNet, the *Amundsen* research icebreaker, the creation of Northern Chairs, and initiatives like the Northern Contaminants Program, none of those have looked at field station infrastructure. The end result is that across the north many of the field stations – which have a long and important historic record going back 40 and 50 years – can no longer fully meet the researchers' needs.

And so the Polar Commission – with partners including the Arctic Institute of North America, Indian and Northern Affairs Canada, the International Polar Year Federal Program Office, the Office of the National Science Advisor, the Natural Sciences and Engineering Research Council (NSERC), and the Territorial governments – has been looking at what research directions are being developed and where we are likely to go over the next 25 or 30 years in terms of research. Then we have been asking what inputs of funding and what changes in resources are needed to actually do the research, based on the present network.

We've proceeded by consulting quite widely across Canada – with northerners, academic researchers, indigenous groups, and government groups. First we developed the framework of the study with the help of a group of northern science leaders. Then we got the managers and operators of all the stations together in at a meeting in Quebec City, and asked them to describe the status of their facilities – the needs and the demands, whether they could meet them, and what changes they felt were necessary. The poor state of the stations was of course confirmed – but particularly interesting was that they found demand had greatly increased. In fact, all but one of the stations across the country are fully booked up. There is a small amount of capacity at one of the High Arctic stations, but the others really can't go any further at the moment. Yet demands are still increasing, because of IPY programs, ArcticNet, and all kinds of other research initiatives. Also, the involvement of northern governments and northern communities has increased.

Next on our agenda was getting the northern perspective. We held a second workshop, in Yellowknife, predominantly with northerners, and we got their take on what is required. Many of the field stations historically have been in isolated locations, doing atmospheric physics or looking at ocean ice and so on. When we got the northerners involved they were very interested and keen to be part of future research; and, not surprisingly, they want a good deal of the research to operate out of their communities. The northern governments have a natural desire to learn a lot more about their own territories and so they want to be involved, with scientific research of their own. I was struck by the depth of the feelings in the north to get facilities built in the northern communities and have them serve as multi-purpose installations. The social problems were discussed frequently. The scientific questions – climate change, atmospheric chemistry, ice, permafrost, and so on – make up one package of infrastructure needs; but the communities are much more concerned with their own social issues and community health. We need to be able to address all of these. Northerners and the northern governments have to be absolutely and completely involved in all that goes on. It's clear that there is a strong need and a desire to have more training facilities in the north at a fairly high level, so that skilled people are available to take advantage of the opportunities that new developments in the north will bring on.

About the time of the Yellowknife workshop the federal government switched a big searchlight onto the north with the Speech from the Throne and its plans to make big investments there. That is helpful: it means that the North is on the radar screen. Included in the speech was the plan to build a "world-class arctic research station". We therefore had a lot of discussion around what models might work, how they could be developed, and how the network that we'd discussed might be involved. There is a very strong, almost unanimous view that because Canada is a huge country geographically, with a lot of variety and a lot of different terrestrial and marine situations, we need to have a network – and that a new "world-class" research station needs to be embedded in this network.

It seems there are several areas where having a research station would be important, and two examples immediately spring to mind. With the increased interest in the Beaufort Sea, with oil and gas development and drilling in deep waters off Banks Island – off the Shelf, in more than one thousand feet of water, which is something new – there was a lot of discussion as to whether the station at Tuktoyaktuk could be redeveloped. Some years ago, the Polar Continental Shelf station there was closed, and so there's some concern that we're not fully servicing the Western Arctic area, especially the Beaufort Sea. The current station in Inuvik focusses on the Mackenzie Delta. Right over on the other side of the country, the new land claims settlement in Labrador has brought a strong desire to develop research stations. The possibility was discussed of having two field stations in Labrador, one on the coast in the Inuit area, and another more inland at Goose Bay serving the Innu.

We recently held a third workshop where we tried to envision where research will be going over the next 25 to 30 years. We looked at climate change scenarios such as changes in wildlife and sea ice conditions – the changes in 25 years may be quite dramatic – and community population dynamics and so on. We then asked what infrastructure would be required for future scientific research, how this fits with the network we presently have, and what plans need to be developed.

That's an overview of what's been happening in the project. The next step is to prepare the report, which we're hoping to publish some time in April. It will be a substantial summary document that will state most of the major findings and recommendations. And then hopefully for the fall we'll produce a more detailed final report.

So that's the game plan. We have had widespread and substantial support for this initiative – it was quite a coalition. A great deal of thought and effort has been put into it by people on the front lines of northern science – those doing and managing the research, and those most affected by it. We are hoping it will have some influence.

Tom Hutchinson is Chairperson of the Canadian Polar Commission and Professor Emeritus in the Environmental & Resource Studies Program at Trent University.

SCIENCE COMMUNICATION 101

Laurie Buckland

> *"The good news is that the rules to communicate (science) effectively are few and simple. The bad news is that it is not easy or natural to apply them."*
>
> – Giovanni Carrada

The Government of Canada is investing $150 million in new funding over six years to support Canada's participation in International Polar Year (IPY) through science and research projects focused on two priority themes – climate change impacts and adaptation and the health and well-being of Northern communities. A total of 44 science and research projects have been funded to date. Additional projects that focus on training, communications and outreach will soon be announced.

IPY projects have a variety of goals and objectives, but they share a common vision, and that is to leave a positive lasting legacy in the form of new knowledge, capacity, and interest in the polar regions. This legacy is meant to benefit not only science and scientists but also northerners, aboriginal communities and all Canadians. While it is important that results from Canadian IPY research projects are published in scientific journals, results must also be publicly accessible. Communicating with the public and engaging them in polar science issues – in a way that is understandable for *all* Canadians – is essential to achieving IPY's vision.

While many scientists are gifted communicators, most of us do not have the talent of David Suzuki or Carl Sagan when it comes to explaining science concepts to a general audience. Most scientists are much more comfortable in the familiar territory of research papers and journal articles; in other words, communicating about their area of science with others who speak their language – their peers. But scientists should be encouraged to take greater responsibility for public understanding of science. The problem is not that we don't know what approach we should take, but that we find it so difficult to step outside the culture of science that we have learned and practiced, and adopt a different and unfamiliar approach, one that seems unnatural to us.

Given the importance of communicating the results of IPY research to a broad sector of Canadians, it is worth looking at some basic principles of science communication. In this article I discuss benefits of engaging the public in science issues, outline current approaches to the public understanding of science, and present some specific communication techniques that can be used by scientists to help engage others in their work and to get their message across.

WHY COMMUNICATE WITH THE PUBLIC?

Why should the average Canadian citizen have an awareness or understanding of science or science issues? Why should he or she know something about the polar regions? Simply put, we live in a knowledge-based society. With knowledge, we are all better equipped to participate in debate and democratic processes such as policy making. In addition to spreading knowledge, communicating science stories helps to convey the value of a rational or scientific way of thinking about problems. Citizens also have a right to know where their tax dollars go. It is the public which often decides what research will be funded and how the results will be used. Decisions about scientists' work are not made by the scientific community alone: such decisions increasingly involve other social groups including private companies, special interest groups, politicians, and others. Interested people should be able to follow research developments and form their own opinion on the basis of sound, science-based information.

Trust has been shown to be more important than knowledge or awareness when it comes to achieving public support for scientific research. Scientists can encourage greater feelings of trust among citizens toward science and scientists by engaging directly in communicating their research, rather than relying on journalists or others to relay information. As individuals, people benefit by being able to make better choices about matters relating to their everyday lives, such as personal health and well-being. Therefore, both individual and societal benefits come from the public understanding of science.

APPROACHES TO SCIENCE COMMUNICATION

The early movement for the public understanding of science that began in the 1980's promoted what is now called the "deficit model" of science communication, whereby scientists adopted a top-down approach to communication. The public was seen as a passive recipient of information: people were empty vessels to be filled with knowledge, and information flowed along a one-way channel, from the source (the scientist) to the receiver (the layperson). Science, presented as fact, was not open to question. The deficit model considered any public controversy over science a result of citizens' lack of understanding about the science in question. Scientists were encouraged to increase the public's understanding of science – if only people understood the science better, they would support research, controversies would disappear, and all would be well. In other words, the problem lay with society.

Science communication as a discipline has come a long way. Since the late 1990's, theories of science communication have evolved to the current view of communication as a process of negotiation. Science communication involves consensus and mutual understanding; it is a process of generating knowledge that is mutually acceptable. We are now more aware that the public is not simply a homogenous mass, but instead consists of many diverse groups. There is not just one public, but many. Even among scientists, increasing areas of specialization often bring difficulties in understanding other disciplines. All scientists are therefore part of the general public when something that lies outside our own field of knowledge is involved.

No longer seen as passive receivers of information, audiences are now considered active creators of meaning, adding new information to the knowledge they already have from previous life experience. A contextual approach to the public understanding of science, in which scientific information is shared in ways that take into account an audience's existing knowledge, beliefs, attitudes, interests and concerns, is much more effective in achieving science communication goals. By establishing a genuinely open dialogue with the public, scientists can help to build a climate of reciprocal knowledge and trust between science and society at large. Scientific knowledge is acknowledged to be cumulative and provisional, and should be presented in this light.

ENGAGING THE AUDIENCE

Understanding your audience is one of the fundamental principles behind effective communication of science. To engage your audience and get your message across, you have to know something about them. Find out as much as you can about their backgrounds, areas of expertise, general interests, probable beliefs and values, prior knowledge and experience of your subject, and attitudes. Knowing your audience helps you decide what to explore in depth and which aspects are less important. It can also help determine which media would be most effective. For example, many science-based publications, such as *Meridian,* have a very diverse but largely adult readership which includes policy makers, public servants, students, and other researchers. New technologies such as podcasts and blogs may be more effective at engaging younger people.

While an audience of other scientists is generally interested in methods, results and other technical details, general audiences are usually more interested in what things do and in what it means for them personally, for instance whether something will be beneficial or detrimental to their safety or health. This emphasis on the practical benefits of a scientific concept or discovery, whether for a particular audience, a society, or humankind, is known as "application appeal." The more a result influences our way of living, the more interest it will arouse. For polar science and climate change issues this means finding a way to connect what is happening in the polar regions to people's everyday lives. Another approach that is effective with a general audience is "wonder appeal," which emphasizes the sense of surprise or awe people often feel in the face of an exciting scientific discovery.

AUDIENCE ADAPTATION

There are many strategies that can be used to help engage an audience in your topic, generate interest, and develop new knowledge. Known as audience adaptation strategies, these generally focus on making the unfamiliar familiar. Adapting scientific information for a general audience may include use of narration, examples, comparisons, graphics and other visual representations, and logic and organization. The idea is to use what the audience is already familiar with – their knowledge, experience and values – as building blocks upon which to construct new knowledge. It is much easier for someone to grasp new concepts and ideas if they can relate them to something they already know or have experienced.

Stories are the oldest form of communication. Narration can make science accessible and acceptable to general audiences by creating a human story through which an audience can identify with a scientific subject. Science can be presented to the general public in the form of a dramatic story, complete with characters, plot, setting, time period, conflict and resolution. Often the story is made more interesting when it is not about the research itself, but about the scientist. For example, how did the scientist become interested in the subject, or what led the scientist to be involved in this area of work? The answers may be surprising.

Comparisons are particularly useful when adapting scientific concepts for a general audience. Bob McDonald, host of the CBC Radio science show "Quirks and Quarks," is master at rephrasing the language of his guest scientists using comparisons to familiar everyday objects and situations. Synonyms, similes, and especially metaphors – like "genetic code" and "biological clock" – are all effective. It is important to find metaphors that relate to the audience's knowledge and experience, and to use the same ones consistently. Effective use of illustrations, photographs and similar material not only adds colour and interest to written text and presentations but also helps make abstract concepts visually concrete.

Logic and organization, in the form of appropriate headings, can provide clues to the content of text rather than the structure. Scientists are taught to follow and use the Scientific Method, a highly structured format for reporting scientific results. Relevant literature is first reviewed, the problem or data gap is stated, a hypothesis is presented, methods are described, results are detailed, and finally conclusions are made. In contrast, non-scientists generally prefer to

NEW CANADIAN COUNCIL MEMBER FOR IASC

The Canadian Polar Commission welcomes Dr. David S. Hik as Canada's representative to the International Arctic Science Committee (IASC) council. Dr. Hik is Professor and Canada Research Chair in Northern Ecology in the Department of Biological Sciences at the University of Alberta, and the Executive Director of the Canadian International Polar Year Secretariat.

get to the bottom line immediately. If they are interested, they will continue to read or explore further. Therefore, begin with the most important idea, then fill in the details, in order of importance. The opening line must capture the audience's attention. Journalists call this the "inverted pyramid."

DEALING WITH THE NEWS MEDIA

Understanding audiences includes choosing the most appropriate medium for your message. Websites, blogs and podcasts can reach niche audiences, particularly younger people, while newspapers, television and radio remain important because they can reach large numbers of people.

Many scientists are reluctant to deal with the news media because it requires them to interact with journalists. Most scientists have no experience or training in this area. There is also a certain amount of distrust between journalists and scientists. Scientists may feel that journalists do not understand the nature and value of science, that they tend to sensationalize science stories, oversimplify, and misinterpret scientific findings. Journalists may see scientists as being unclear or vague, narrowly focused, and fearful of being misquoted. Both parties need to recognize and acknowledge that the journalistic community and the scientific community represent different cultures with divergent purposes and conventions.

Journalists want stories to have an emotional aspect, while scientists aim to be objective and neutral. Journalists expect science to provide answers and certainty, but scientific knowledge is provisional and incremental. Journalists seek controversy while scientists look for consensus. Journalists are trained to give equal weight to opposing viewpoints; science is not about debating, it is about evidence. These differing values and interests may result in misunderstandings and therefore poor relationships between journalists and scientists. Therefore, just as scientists dealing directly with audiences need to understand something about those audiences, scientists who use journalists to translate their messages need to understand something about the culture and norms of journalism to make the most effective use of the news media.

Scientists should be aware of factors that might make a news item valuable to a journalist. A "good" piece of news, according to journalists, is meaningful and relevant to the public. Another factor is frequency or continuity; something that is going to be discussed for a while has news value. Also, if a story can be co-opted, or linked to another one already running, it has a greater chance of getting into the news. The two research priority areas for federally funded IPY science meet these criteria in different ways. Stories relating to health and well-being are generally considered by the public to be pertinent because they are about issues that concern everyone, and of which everyone has some understanding. Many people are beginning to understand climate change in terms of its relevance to their own lives. As it is frequently in the news, a new story can be linked to an existing story. Because climate change is a subject that will likely be around for some time, it is worthwhile for journalists to invest time in researching this topic and in establishing relationships with climate change scientists. Scientists should therefore try to capitalize on these news values, to get IPY science stories into the media.

TOWARD A LASTING LEGACY FOR IPY

This brief overview of science communication is presented in light of the vast amount of polar research currently underway and about to be undertaken as part of IPY 2007–2008. Science journalists and other communication specialists will be key players in the success of IPY in terms of achieving a positive and lasting legacy, but scientists themselves can contribute much to the public understanding of science by making efforts to disseminate their research results outside of scientific journals, conferences, and research papers aimed at the scientific community. Whether this is done directly or through journalists associated with the news media, effective science communication is about establishing a relationship with an audience, and finding a common language and understanding. The more you know about that audience, the more likely you are to be successful in getting your message across, and the more trust you will build in the process.

Laurie Buckland is a biologist with a background in wildlife management and environmental assessment. She is a recent graduate of the Science Communication program at Laurentian University, and interned at the Canadian Polar Commission during her studies. She works as an environmental consultant for Golder Associates Ltd. in Ottawa.

"THE WORLD'S LARGEST MUSKRAT RANCH": THE SUMMERBERRY MUSKRAT REHABILITATION PROJECT, 1935–1965

Frank J. Tough

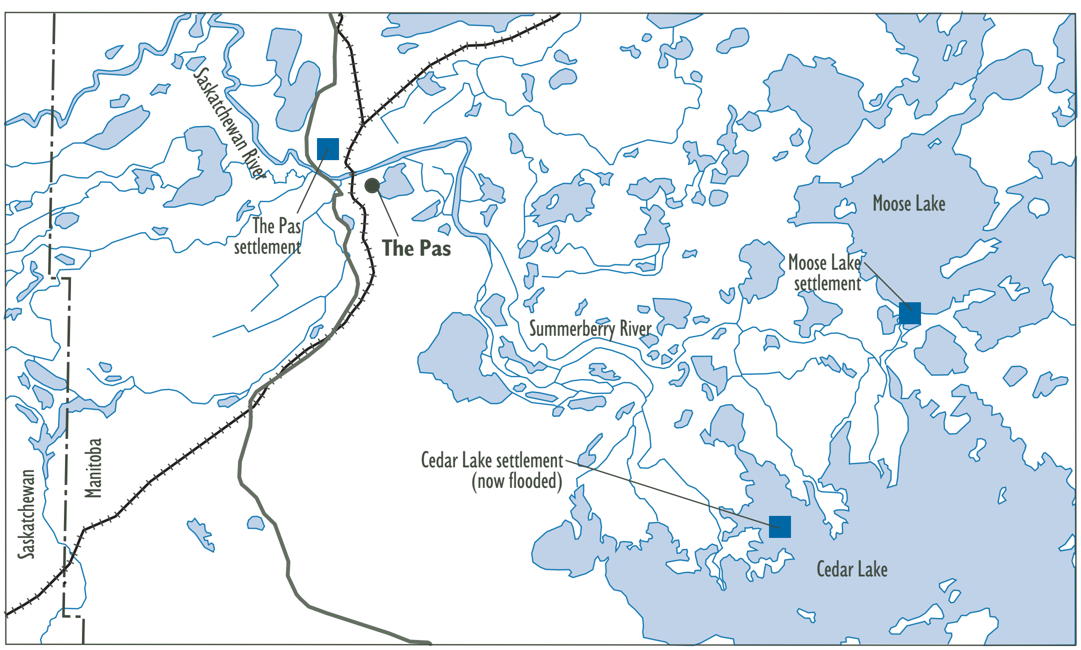
In the 1930s, the Manitoba Game and Fisheries Branch initiated a bold northern development project designed to promote wise resource use and to provide economic assistance to the Native population of The Pas region. This project was based on environmental manipulation, resource and economic planning, income redistribution, and federal and provincial cooperation. D.M. Stephens, Deputy Minister of Manitoba Mines and Natural Resources had good reason for boasting that "the men on this job are not only running a very complicated but also a very large business" and he took pride in "the world's largest muskrat ranch."[1] During an era (*ca.* 1935–1955) when federal and provincial agencies cooperated in northern regions to promote the traditional Native economy, the Summerberry Muskrat Rehabilitation Project provided encouragement for those who believed that conservation principles and techniques could be employed to promote Native well-being. This comprehensive approach to resource management was referred to as a "northern development project," perhaps the very first example of state intervention to be so designated.[2] This article provides only a brief historical précis of a unique process – a planned intervention in the muskrat habitat and Native economy of northern Manitoba – that is relevant to current interests in sustainable development and co-management.

The project took its name from the Summerberry River, a major channel traversing the Saskatchewan River wetland delta region. This vast, swampy region includes many shallow lakes and creeks and a marsh vegetation cover of willows and bulrushes. For the muskrat (*Ondatra zibethicus*), which is well adapted to wetlands, this was an ideal environment. While these rodents can reproduce rapidly, disease, predators, and periodic freeze-outs from low water levels keep their populations in check.[3] The wetland carrying capacity for muskrats is largely determined by a narrow marginal strip of emergent vegetation.[4] Drought severely alters habitat, reducing food and lodging.

FUR RESOURCES HAD BEEN OVER-EXPLOITED

The intense spring muskrat hunt had long been an important traditional source of income for Natives, even though muskrat pelt prices were low compared to beaver and the ten-year population cycle exhibited extreme fluctuations. For the Hudson's Bay Company

The delta of the Saskatchewan River was the site of the muskrat rehabilitation project. In the 1960s the Grand Rapids Hydroelectric project permanently flooded the Cedar Lake basin, turning much of the muskrat habitat into shallow muddy lakes and bogs. This map shows the current lake shoreline.



1 Archives of Manitoba, Department of Mines and Natural Resources, Record Group 17, B1, box 6, file 32.3.1, Department letter for October 1945 (hereafter AM, RG17).

2 AM, RG17, B1, box 96, file 32.1.23 (5 January 1938).

3 Stan Boutin and Dale E. Brikenholz. "Muskrat and Round-Tailed Muskrat," *Wild Furbearer Management and Conservation in North America*, Milan Novak, James A. Baker, Martyn E. Obbard and Bruce Malloch, eds. (Toronto: Ontario Ministry of Natural Resources, 1987) pp. 314–325. The seminal work on muskrats is Paul L. Errington, *Muskrat Populations* (Ames: Iowa State University Press, 1963). Errington visited the project in 1948.

4 J.A. McLeod, "A Consideration of Muskrat Populations and Population Trends in Manitoba," *Transactions of the Royal Society of Canada*, vol. 44, series 3 (June 1950), p. 88.

(HBC), this region, part of the Cumberland House District, was a major source of musk-rat pelts.[5]

By the 1930s, however, the fur resources of this region were virtually non-existent. Significant fur price increases after 1900 had attracted many non-resident White trappers to the subarctic and conservation regulations lacked force. Consequently, fur resources had been over-exploited, severely jeopardizing the ability of Natives to live off the land. Policy-makers understood the magnitude of the decline of the Saskatchewan River Delta muskrat country, where the 1902 harvest of 600,000 had plummeted to half by 1910 and further dwindled to annual yields of 10,000 pelts in the 1930s.[6] The extended drought of that decade dried up the Saskatchewan River Delta wetlands and the muskrat habit at contracted. Moreover, fur prices had dropped, like those of other commodities during the Great Depression.

While the Treaty Indian population received some assistance from the federal Department of Indian Affairs, Manitoba authorities were well aware that The Pas Métis were suffering extreme destitution. A 1938 survey of ten Métis communities in the region indicates average annual family incomes from $35 to $231.[7] L.H. Pinney, Inspector of Game and Fisheries, explained that: "… the relief personnel simply hand the Halfbreed applicant about $3.00 worth of flour, lard and tea and tell him to go out and live off the country"; and consequently, it was "difficult to administer the Game laws fairly and equitably."[8] Authorities could do little to assist except relax hunting regulations.

5 Hudson's Bay Company Archives, B.239/h/1-3, Fur Returns, 1821–1891.

6 D.M. Stephens, "Fur Rehabilitation in Northern Manitoba," *Canadian Geographical Journal*, vol. 30, no. 1 (1945) p. 12.

7 AM, RG17, B1, box 33, file 32.1.1.b, Census of The Pas District Métis (1938).

8 AM, RG17, B1, box 33, file 32.1.1.b (18 February 1938).

NATIVES BECAME ALARMED THAT THEIR TRADITIONAL LANDS WOULD BE LEASED OUT AND CLOSED OFF

It was Tom Lamb, a pilot and businessman from The Pas, who demonstrated the possibility of habitat rehabilitation. By investing in water control features to stabilize levels, he quickly brought muskrats back on 50,000 acres of swampy Crown lands he had leased from the province. Understandably, the Native population of the region became alarmed that their traditional lands would be leased out and closed off. In the spring of 1934, a joint petition from the Treaty Indians and Métis stated:

> *We, the undersigned Indians of The Pas Band, the Members of the Northern-Half-Breed Association, and Residents of The Pas and vicinity do hereby respectfully protest against the further leasing of any lands in The Pas area, that,* [sic] *is, along the Saskatchewan River, The Pas River, or in the vicinity of Moose Lake, for the purpose of fur farming or rat farming, on the grounds that it is vitally interfering with our means of livelihood, and that it will cut us off from the trapping grounds that have been ours from time immemorial …*[9]

Similarly, in 1935, The Pas region Natives requested an exclusive-use area by arguing that "the Treaty Indians were faithfully promised that their means of making a living would not be interfered with, and the Halfbreeds who are born in these parts, are all closely related to the Reserve people, so practically speaking, we are all one."[10]

9 AM, RG17, B1, box 96, file 32.1.10 (ca. February 1934). In this era, the term "Halfbreed" was used by the English-speaking Métis of The Pas region.

10 AM, RG17, B1, box 96, file 32.1.10, Petition to Minister of Mines and Natural Resources from The Pas, Moose Lake, Cedar Lake bands and the Northern Halfbreed Association (18 June 1935).

The question of treaty rights provided an interesting challenge to the province's intended private enclosing of muskrat swamps for private benefit. Natives successfully petitioned provincial authorities to include them in plans for "muskrat ranching"; the government then took on muskrat rehabilitation as a public project and the state became committed to intervention in the fur industry. The request for an exclusive-use area also received federal government support. The federal Minister of Mines and Resources, T.A. Crerar, wrote to Manitoba Minister of Mines and Natural Resource, J.S. McDiarmid in 1938:

> *It is unnecessary to state that the sole purpose I have in mind in seeking to secure long term leases on two or three areas suitable for the propagation of muskrats in the province of Manitoba is to establish the members of certain Indian bands on a partially self-supporting basis. You are aware that these Indians enjoy a number of rights guaranteed to them by the Government. In addition to this, there are certain moral obligations imposed upon the Crown, to which I might attach utmost importance. Perhaps the most important of these is the one relating to the hunting and trapping rights enjoyed by our Indians over a long period of years – rights which are always subject, of course, to the laws governing such activities which may be enacted from time to time.*[11]

McDiarmid's reply indicates that provincial and federal cooperation to promote conservation could be consistent with the spirit and intent of the treaties: "I feel that the Province has and will continue to cooperate with you fully in your desire to live up to the spirit of the Indian treaties."[12] As a result, the federal government negotiated

11 AM, RG17, B1, box 96, file 32.1.23 (14 December 1937).

12 AM, RG17, B1, box 96, file 32.1.23 (5 January 1938).

the Two Island Block lease with Manitoba. The Department of Indian Affairs ensured Treaty Indian participation by paying for further development of the wetlands rehabilitation; however, this portion of the Summerberry Project was set aside exclusively for both Treaty Indians and the Métis.[13]

MAXIMUM ECONOMIC SECURITY FOR TRAPPERS THROUGHOUT THE YEAR

By the late 1930s, the province set aside 137,000 acres as the Summerberry Block, obtained federal funding to build the water control features with local labour, and closed the region off to trapping.[14] Construction of water control features began in 1937. The ensuing employment helped compensate for closing off of the block to trapping. Water levels were raised by dams and dikes that held back the peak water flows and canals diverted water to adjacent marshes and lakes. Very quickly muskrat populations surged (3,951 lodges in 1937 to 32,369 lodges in 1939), and by all accounts the carrying capacity for muskrats of this swampy region had grown. Officials believed that water control was the essential requirement for increasing muskrat populations, thereby making northern wetlands productive and revenue-producing. However, muskrat rehabilitation plans went well beyond scientific conservation and included an income policy, as Deputy Minister Stephens explained: "Fur should be handled and sold in such a manner as to provide the greatest possible financial return to the trapper" and "Funds accruing to the trappers should be distributed in such a fashion as to provide the maximum of economic security throughout the year."[15]

After stabilizing water levels and nursing back the muskrat, orderly harvesting of this fur-bearer began with counting lodges to monitor population changes, restricting access to the block, setting individual trapper quotas, and employing Senior Trappers and Game Guardians to supervise trappers. The project's income objectives required a major reorganization of the traditional, open-access harvest; consequently, trapping effort was controlled and directed. The count of muskrat lodges was spatially detailed in order to determine the annual harvest level. The block had been divided into "sections" composed of "zones." The zone, about 8 square miles in size was the smallest unit, and was used for compiling data and allocating effort. Zone boundaries were established by topographical features, and specific zone conditions (and therefore potential yields), such as water levels and feed, could be considered when directing trapping.

AN ORGANIZED AND EFFICIENT HARVEST

Total harvesting effort varied from year to year according to the number of trappers allowed to participate, and by a pre-set individual quota. The rat census was carried out in mid-October, and by February, after the winter weather effects could be assessed, planners held a meeting to establish individual quotas and the number of trappers permitted onto the block.[16] Provincial officials preferred increased employment (number of trappers) over income (value of quota). Because the count of rat houses provided precise spatial information on potential yields, harvesting could be restricted to particular zones. State management controlled the timing of the trapping season, and so harvesting occurred when the pelts were at their prime and would bring the best price.

The engagement of a large number of trappers and the need to produce the highest quality pelt demanded a well organized and efficient harvest. Along with the regular Game and Fisheries Branch staff, Temporary Game Guardians and Senior Trappers helped organize production. The Temporary Game Guardians were placed in the delta two weeks prior to the harvest to discourage poaching, and received as pay an extra quota of rats over the ordinary limit. From five to ten Ordinary Trappers were assigned to a Senior Trapper. According to Stephens the duties of the Senior Trapper consisted of "supervising the trapping as well as the stretching and drying of pelts, assisting in the enforcement of the regulations and acting as general foreman over the trappers assigned to that particular zone."[17] These foremen kept daily production records and were also rewarded by an extra quota of rats. Under the active direction of Game and Fisheries Branch staff, the harvesting and the management of the muskrat of the Lower Saskatchewan River Delta was therefore closely monitored and clearly structured.

Once the swamps were reopened to trapping, the spring hunt became a major event. Stephens described it: "A few days before the season begins a general exodus takes place and The Pas becomes a hive of activity with trappers purchasing supplies [,] loading up their gear, and generally their families too, on the trucks, tractor or horse sleighs ready to take them down."[18] After being outfitted, trappers entered the rehabilitation block through five control points. Groups of Ordinary Trappers then moved to

13 AM, RG17, B1, box 96, file 32.1.23, Schedule A of the Agreement (15 November 1939).

14 The province obtained funding from the *Unemployment and Agricultural Assistance Act.* Eventually, 565,000 acres were brought under this rehabilitation scheme, Errington, p. 670.

15 Stephens, p. 14.

16 AM, RG17, B1, box 6, file 32.3.1, Department letter (October 1945).

17 Stephens, p. 14.

18 AM, RG17, B1, box 6, file 32.3.1, Department letter (October 1945).

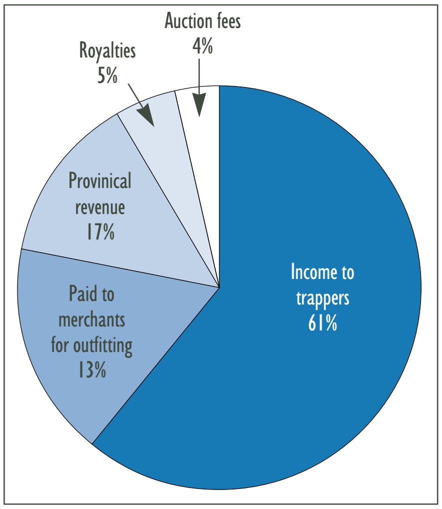


Figure 1
Distribution of the value of Summerberry Project muskrat yields, 1940–1963. Source: Manitoba, Annual Reports for Mines and Natural Resources (1940–1964).

their assigned territory with their Senior Trapper, and once they had harvested their quota, exited through a control point where their pelts were dropped off, counted, rough graded, bagged, and tagged with the trapper's name. Barges moved the bags of rat pelts to The Pas.

Although the direct involvement of Game and Fish Branch staff and the new highly organized and controlled production system significantly changed the traditional work of muskrat trapping, important aspects of the traditional family-based harvesting system remained, as Stephens observed:

> *The individual trapper may take anywhere from a week to a month to complete his quota, but in many cases whole crews will work together until every member has his full complement of pelts. This is quite a matter of pride with many of the senior trappers. While the men are out trapping the women skin and stretch the pelts ready for the market.*[19]

In fact, the organization and mobilization of labour as teams under the direction of Senior Trappers may have allowed for more co-operation than previously. Apparently, this new organization did not foster individual trapping on a competitive basis. Furthermore, the Temporary Game Guardians and Senior Trappers had both harvesting (supervising production) and management responsibilities (enforcement of regulations). The state had involved Natives in the management of this planned system of resource exploitation.

Economic planning sought not only to ensure sustainable muskrat populations but also to maximize employment and secure incomes for trappers. The Game and Fisheries Branch financed the trapper's spring hunting outfit, and by pooling the pelts, secured high prices at Winnipeg auctions. Local fur buyers, such as the HBC, were cut out of the purchasing of muskrat. Figure 1 indicates the distribution of the value of Summerberry muskrats. Between 1940 and 1963, 61% of the market value went directly to the trapper as monthly payments. With the government officials handling the fur, the trapper received a much larger share of the market value of the muskrat pelt than previously.

MONTHLY INCOME AT THE PAS "MADE A NOTICEABLE DIFFERENCE, ESPECIALLY IN THE CHILDREN"

By comparison with the economic realities of the Great Depression, the Summerberry Project had positive income and employment results. Figure 2 indicates participation by trappers. In 1941, The Pas Indian Agent Lovell stated that "practically all of them had been trapping muskrats."[20] In the 1940s, the $20–25 monthly income from spring trapping had a noticeable effect on living standards. Indian Agencies Inspector A.G. Hamilton recorded that at Moose Lake "the steady income of $20.00 per month has greatly improved conditions" and that monthly income at The Pas had "made a noticeable difference, especially in the children."[21] During the project's construction phase, Métis accounted for 90 % of the labour.[22] With no more than one month's labour, Métis family annual incomes had been raised over the 1938 level. Orderly harvesting and product pooling improved incomes.

In revenue terms, the Summerberry Project worked very well for the provincial government. Between 1935 and 1940, development costs for the original Summerberry Block (construction work, survey, cabins, buildings, protection and maintenance) totaled $157,268.84.[23] Much of this expenditure led to employment of local labour and as a result, injected badly needed cash into the region. Evidence of the financial feasibility of muskrat rehabilitation came when the Game and Fish Branch earned $35,986[24] in project revenue and fur royalties from the production (1940–1944), the provincial government's share was $193,757.67 and $27,998.40 was earned as royalties.[25] Stephens pointed out that revenues were "considerably more than the total of all expenditures on the project."[26] Thus, in a few years the government's revenues exceeded the initial project capital costs and state intervention was an unqualified fiscal success.

Along with the successful expansion of wetlands, the fur rehabilitation approach permitted the adoption of new management techniques (over-trapping of rat predators,

19 AM, RG17, B1, box 6, file 32.3.1, Department letter (October 1945).

20 Library and Archives of Canada, Department of Indian Affairs, Record Group 10, vol. 6738, file 420-4 pt. 4 (4 June 1941), (hereafter LAC, RG10).

21 LAC, RG10, vol. 6738, file 420-4 pt. 4 (16 April 1941).

22 AM, RG17, B1, box 96, file 32.1.23 (15 July 1937).

23 PAM, RG17, B1, box 33, file 32.1.1 D (10 February 1941).

24 Manitoba, *Annual Report for the Department of Mines and Natural Resources* (1944), p. 69 (hereafter *ARMNR*).

25 *ARMNR* (1944), p. 69.

26 Stephens, p. 18.

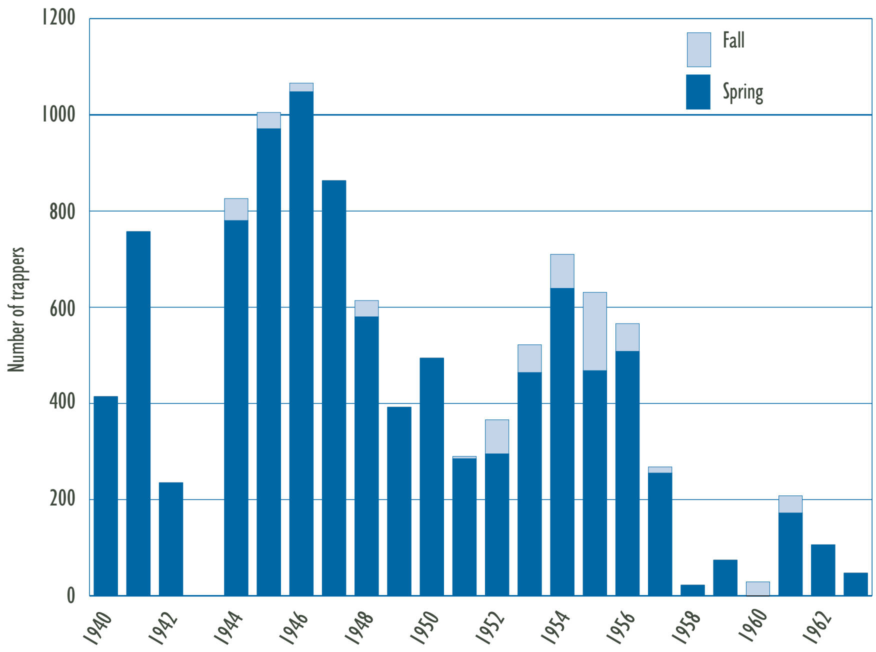


Figure 2
Total number of Summerberry trappers, 1940–1963.
Source: Manitoba, Annual Reports for Mines and Natural Resources (1940–1964).

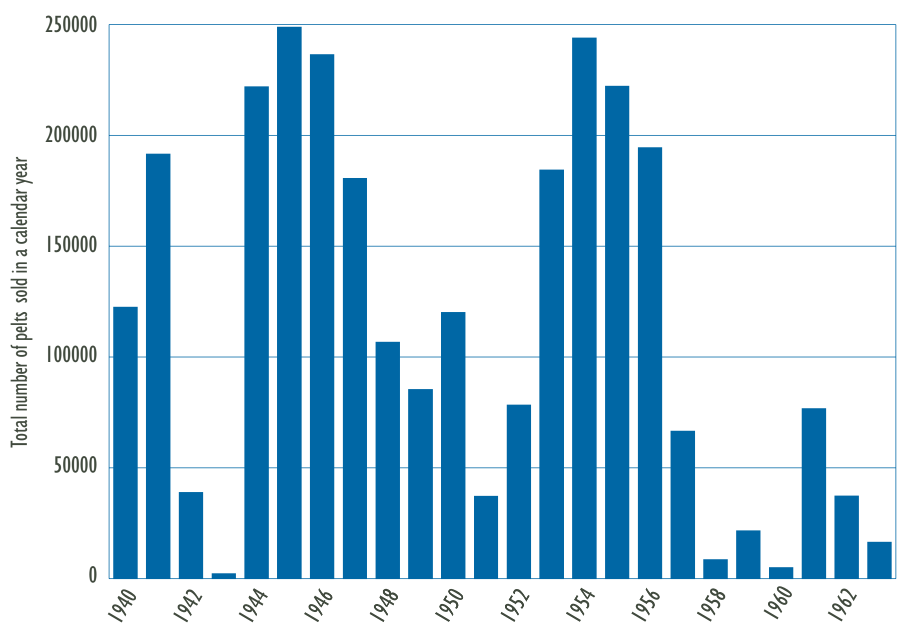
selective trapping of muskrats unlikely to survive winter, and even trapping out diseased rats once detected in particular zones) to enhance production. Regrettably, after a few years, the initial success of the Summerberry Block was tempered by a crash in muskrat populations. Figure 3 indicates the total yields for the duration of the project. The 1942 and 1943 yields were marginal. Stephens discussed a "falling off of both the rate of increase and the quality of pelts produced" when corresponding with University of Alberta zoologist William Rowan.[27] Early investigations indicated that constant water levels had interrupted the marsh nutrient cycle. Vegetation eaten by the rat was depleted of certain nutrients.[28] Stephens explained:

> *Our marsh development programme has been formulated on the premise that constant water levels provided the best environmental conditions for the sustained production of muskrats. In a natural marsh area water levels generally fluctuate considerably over a relatively short period of time. We may find that we have to simulate the fluctuation on our developed areas.*[29]

Yields had been sustained by spatial expansion of the managed muskrat habitat, but similar population dynamics were encountered in the new blocks. Rat population increased rapidly, but within two years of harvesting, yields dropped (see Figure 3).[30]

These problems could not be ignored and in the summer of 1947 scientific research into the changes to wetlands ecology caused by stabilized water levels began. By 1949, it was apparent that prolonged flooding had depleted the soil of nitrogen, which after four or five years caused a deterioration of plant growth. Moreover, plants did not re-seed unless mud banks were exposed.[31] The annual report for Mines and Natural Resources concluded: "Field studies,

FIgure 3
Total annual Summberry Project muskrat yields, 1940–1963.



27 AM, RG17, B1, box 24, file 14.5.6.C (28 February 1947); see also *ARMNR* (1946), p. 75.

28 AM, RG17, B1, box 24, file 14.5.6.C (28 February 1947).

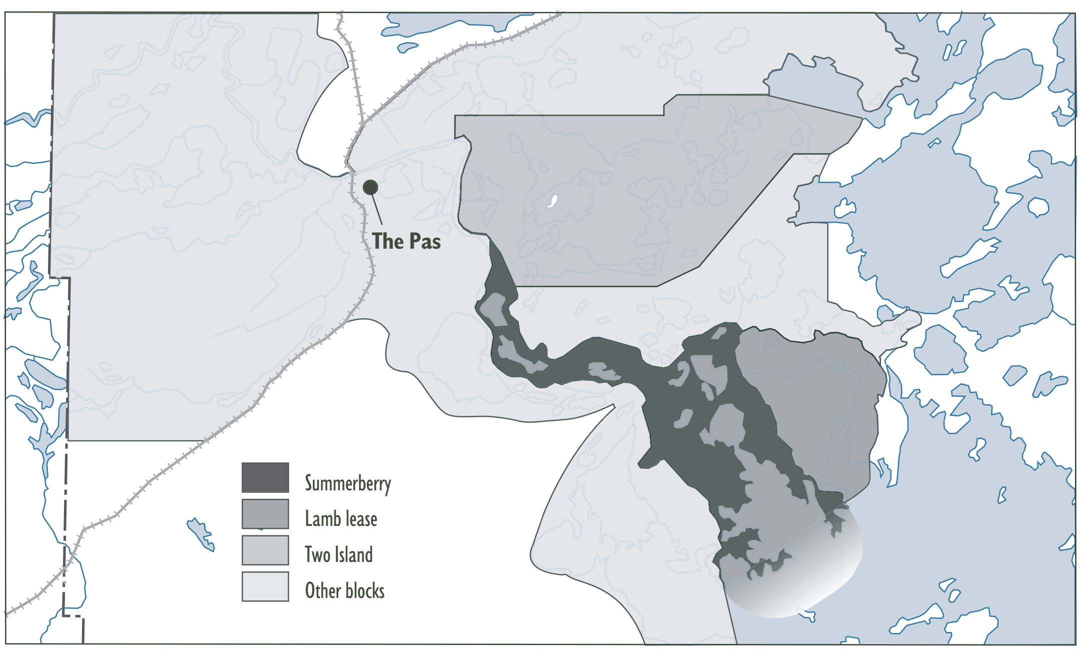
29 AM, RG17, B1, box 24, file 14.5.6.C (28 February 1947).

30 AM, RG17, B1, box 24, file 14.5.6.C (28 February 1947).

31 *ARMNR* (1949), p. 69.

Figure 5
Trappers with their supplies aboard a Department of Mines and Resources tractor train transporting men from The Pas to the trapping grounds. Photo: Jack Long/National Film Board of Canada. Photothèque/ Library and Archives Canada/PA-114382.

particularly of the Summerberry and Netley Marshes, substantiated the contention of earlier reports that an occasional season of low water is necessary in order to have vigorous regeneration of desirable marsh vegetation."[32] Since then, the effects of river impoundment on riparian communities have



Muskrat rehabilitation blocks in The Pas region(map shows current Cedar Lake shoreline) become better known. Stabilized water levels affect the marsh nutrient cycle and the available habitat for regular succession of marsh vegetation. In two respects the feed of the muskrat had been affected: the available vegetation was nutrient-deficient and the volume of the biomass was reduced.

Observations from the 1940s are consistent with contemporary knowledge about impounded streams; Kellerhals and Gill suggested in the 1970s that when "the perturbing effect of spring floods is reduced or eliminated plant succession soon begins to reduce the productivity of the alluvial habitat. Without continued initiation of primary succession, the biological productivity of any northern floodplain or delta soon diminishes."[33] Stabilized water levels were intended to improve the carrying capacity and managed harvesting was designed to prevent over- or under-harvesting; however, stable water levels did not seem to have secured carrying capacity at a high level. Unfortunately, the project's environmental model (stable water = stable muskrats) proved to be too simple. The goal of eliminating the fur cycle through environmental manipulation was unattainable.

As fur prices declined in the 1950s, and the ratio of cost of trapping to revenue increased, interest in muskrat trapping waned, but the project came to an abrupt end with the Grand Rapids hydroelectric project's damming of the Saskatchewan River. The effects of this impoundment had been anticipated. H.E. Wells and E. Daggitt reported in 1958:

> *The survey is informed from reliable sources* [that] *the Big Grand Rapids Power Project will be commenced within a few years. We have had a look at the maps and charts which show what the water levels will be like in the reservoir of Cedar Lake. It will destroy most of the good muskrat habitat in the Summerberry. If and whn* [when] *the power project is completed the Summerberry program will have to be completely revised and it appears impossible to imagine what program for the remaining marsh could be.*[34]

The last official reference to the Summerberry Project was a mention in the annual report that only some 28,160 pelts had been harvested in 1964.[35] The flooding caused by this megaproject severely disrupted the muskrat habitat, and it had a number of other impacts on the livelihood of nearby Native communities.[36]

SUCCESSFUL PROMOTION OF A SUSTAINABLE NORTHERN NATIVE ECONOMY THROUGH CONSERVATION PLANNING

While muskrat ranching encountered a more complex wetlands ecology than anticipated, economic planning based on orderly, structured harvesting had allocated labour rationally and successfully obtained a fairer share of the market value for trappers. In

Figure 4
Muskrat trapper and his daughter travelling down river to The Pas, May 1945. Photo: Jack Long/National Film Board of Canada. Photothèque/Library and Archives Canada/PA-144823.

32 *ARMNR* (1951), p. 75.

33 Rolf Kellerhals and Don Gill, "Observed and Potential Downstream Effects of Large Storage Projects in Northern Canada", *Transactions of the Eleventh International Congress on Large Dams*, vol. 1 (Paris: International Commission on Large Dams, 1973), p. 745; and see Geoffrey E. Petts, *Impounded Rivers: Perspectives For Ecological Management* (Chichester: John Wiley and Sons, 1984).

34 AM, RG17, B1, Box 42, Interim Report Registered Trapline Survey (4 February 1958), p. 14; see also *ARMNR* (1960), pp. 108, 110.

35 *ARMNR* (1964).

36 James B. Waldram, *As Long as the Rivers Run: Hydroelectric Development and Native Communities in Western Canada* (Winnipeg: University of Manitoba Press, 1988), pp. 81–114.

contrast to some depression-era projects, this initiative's revenues exceeded its development costs and the investments in water control were recouped. The Summerberry Project was thus a very successful instance of Depression-era inspired public sector intervention. This Manitoba project was also instructive to other joint federal and provincial efforts promoting the sustainability of northern Native economies through conservation planning. In common with US President Roosevelt's New Deal responses to the economic crisis of the 1930s, the Summerberry Muskrat Rehabilitation Project was designed to promote resource conservation, economic planning, and income redistribution. Of special note is the fact that this project involved Native communities: these are often assumed to be marginal and irrelevant to world trends, and yet this population had not been left unaffected by the global downturn of the 1930s.

The goal of eliminating the fur cycle by stabilizing water levels was not achieved; but significantly, state involvement in this industry had transcended typical regulatory policies that limited harvesting effort (licenses and closed seasons). Moreover, conservation was not used as a guise to reallocate Native resources to sportsmen, as it sometimes has been. In this project many decades ago, Native people and federal and provincial officials clearly demonstrated the benefits of economic planning and income redistribution.

Frank J. Tough is a Professor in the Faculty of Native Studies at the University of Alberta.

BOOK REVIEW

Peter Suedfeld

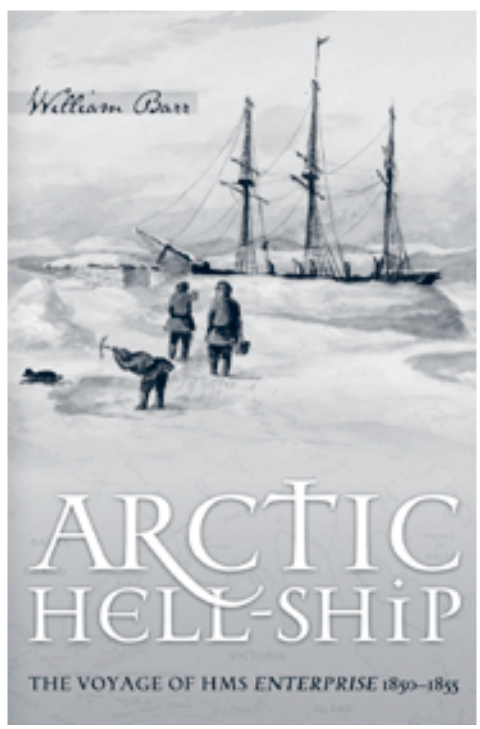
Arctic Hell-Ship: The Voyage of HMS Enterprise 1850–1855, by William Barr. Edmonton, University of Alberta Press, 2007. ISBN: 0-88864-472-8. Paperback, 318 pp., $34.95 CDN.

The exploration of the polar regions and, specifically, the search for the Northwest Passage and the lost expedition of Sir John Franklin, produced some of the most dramatic, harrowing, and tragic episodes in the history of human endeavour. The story of Captain Richard Collinson and the voyage of *HMS Enterprise* was not one of these.

Collinson, an experienced and respected navigator and surveyor, sailed to the Arctic in 1850 to look for the Northwest Passage and for traces of the lost expedition. His ship and crew spent three winters frozen into the ice, not a unique or even remarkably unusual experience in those days. They suffered no disasters or unusual hazards: no starvation, no epidemics, no shipwreck, no rash of fatal accidents, no mutiny … only the normal discomforts and deprivations of that time, place, and activity.

Why, then, the title of this book, which forebodes some or all of the dire events that other polar explorers suffered? The explanation lies in the almost constant friction between Collinson and his officers, which William Barr, the author, attributes almost exclusively to the faults of the Captain. To summarize the story, Collinson seems to have been a somewhat irascible man, not very decisive (and not uniformly successful in the decisions he did make), considerate of his crew but overbearing and dictatorial toward his officers. In turn, his officers indulged in disrespect, criticism, and quibbling.

One of the most critical was Second Master Francis Skead, the ship's navigator, who ran afoul of Collinson early and had nothing good to say about him ever after. Barr relies extensively on Skead's journal and his later annotations on Collinson's account of the journey, generally blaming Col-



llinson for misjudgments, excessive caution, and petty tyranny, to a great extent based on Skead. But Skead is a highly biased witness, whose accusations deserve much more skepticism than they get in this book.

There is no doubt that Collinson was a petty martinet toward his officers, almost all of whom (including all of the commissioned line officers) ended the three-year expedition under arrest. Their offenses were minor by civilian standards, but one can understand that criticizing and contradicting the Captain would not be overlooked in a naval vessel.

Actually, Collinson's brother, Major-General Thomas Collinson, got it right: "There appears to be something in that particular [*i.e.*, Arctic] service – either the intense cold, or the poor feeding, or the close confinement between decks for several months without regular employment, or in all these together – that stirs up the bile and promotes bitter feelings …" (quoted on pp. 237–238). Modern research has amply demonstrated the increase in interpersonal friction, irritability, and general stress caused by long periods of isolation and confinement, and reading this account one can sympathize with both the Captain and the officers who suffered the results.

One telling point is that Collinson's problems were only with those in close contact with him; toward the crew, he was thoughtful and foresighted (too lenient, according to Skead). He made sure that there were opportunities for recreation, having a skittle alley and billiard room constructed on the ice, supporting theatrical performances, sending men out to hunt and fish, trying to relieve the boredom of being iced in. He even reproved and punished the Assistant Surgeon for calling one of the men a bloody fool.

Aside from the running story line of the conflict, the tale of the expedition is fairly routine. *Enterprise* did not discover the Northwest Passage, found no useful clue about Franklin's fate (Collinson ignored what might have turned into one), and explored very little previously unknown territory. Barr gives detailed descriptions of such topics as the subsidiary sledging and boating expeditions sent out from the ship and its provisioning both in port and in the Arctic, the latter down to how many ptarmigans, ducks, and other game were shot by hunting parties. Repeated encounters with Inuit make for interesting reading; relations were generally amicable, but the crew never trusted the Inuit not to attempt to steal desirable items, and the Inuit often justified those suspicions.

The story of the voyage would have been easier to follow if Barr had provided one large-scale map showing all of it, and if all of the maps had incorporated a track chart. In addition, given that this was a three-year trip, occasional references to the year (not only the month and day) when various events occurred would have been helpful.

All in all, the voyage was quite mundane by the standards of exploration stories. The dramatization of the conflicts between Collinson and his officers, which resulted in bitterness but no courts-martial or punishments after returning, does not elevate it into anything very special. Still, the book is a useful reminder of the special importance of good leadership under extreme conditions, and – because Barr's sources include unpublished journals and other materials scattered around libraries and private collections – fills a gap in the history of polar exploration and the search for Franklin.

Peter Suedfeld is Professor Emeritus, Department of Psychology, University of British Columbia. His research interests include the effects of challenging and stressful environments such as spacecraft and polar stations on psychological processes and behaviour. He is former Chair of the Canadian Committee on Antarctic Research.

NEW BOOKS

The Arctic Promise: Legal and Political Autonomy of Greenland and Nunavut **,** by Natalia Loukacheva. Toronto, University of Toronto Press, 2007. ISBN: 0802092950.

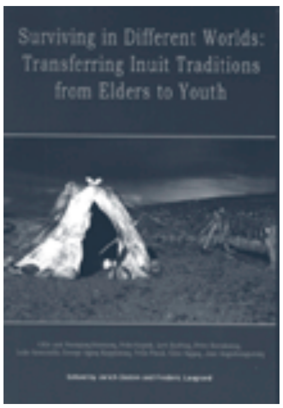
In Canada's Eastern Arctic and Greenland, the Inuit have been the majority for centuries. In recent years, they have been given a promise from Canadian and Danish governments that offers them more responsibility for their lands and thus control over their lives without fear of being outnumbered by outsiders. *The Arctic Promise* looks at how much the Inuit vision of self-governance relates to the existing public governance systems of Greenland and Nunavut, and how much autonomy there can be for territories that remain subordinate units of larger states.

The Return of Caribou to Ungava, by A.T. Bergerud, Stuart N. Luttich and Lodewijk Camps. Montreal, McGill-Queens University Press, 2007. ISBN: 9780773532335.

In one of the great natural marvels of hoofed mammal demography, the George River caribou herd increased from 15,000 animals in 1958 to 700,000 in 1988 – the largest herd in the world at the time. The authors trace the fluctuations in this caribou population back to the 1700s, detail how the herd escaped extinction in the 1950s, and consider current environmental threats to its survival.

Surviving in Different Worlds: Transferring Inuit Traditions from Elders to Youth, edited by J. Oosten and F. Laugrand. Iqaluit, Nunavut Arctic College, 2007. ISBN: 1896204708.

This book presents information from two workshops that brought Nunavut elders and young people together to discuss Inuit traditional knowledge. Inuit elders discuss a variety of topics including survival, marriage, shamanism, and legends.



HORIZON

After the Melt (IPY)
An International Conference on Ecological Responses to Arctic Climate Change
5–7 May 2008
University of Aarhus, Denmark
http://ipy.dmu.dk

3rd Annual International Polar and Alpine Microbiology Conference
11–15 May 2008
Banff, Alberta
www.polaralpinemicrobiology.com

Aboriginal and Northern Studies Research Conference
12–14 May 2008
University College of the North, Thompson, Manitoba
sbarber@ucn.ca

Polar Tourism: a Tool for Regional Development
21–25 August 2008
Kangiqsujuaq, Nunavik, Quebec
www.polartourismnetwork.uqam.ca

The Northern Community in the 21st Century: Seeking Balance in a Changing North – Fifth Northern Research Forum (NRF)
24–27 September 2008
Anchorage, Alaska, U.S.A.
www.nrf.is

16th Inuit Studies Conference
23–25 October 2008
Winnipeg, Canada
Chris Trott, trottcg@cc.umanitoba.ca
Peter Kulchyski, kulchysk@cc.umanitoba.ca

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Canadian Polar Commission
Suite 1710, Constitution Square
360 Albert Street
Ottawa, Ontario
K1R 7X7

Tel.: (613) 943-8605
Toll-free: 1-888-765-2701
Fax: (613) 943-8607
E-mail: mail@polarcom.gc.ca
www.polarcom.gc.ca