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Community Monitoring of Environmental Change: College-Based Limnological Studies at Crazy Lake (Tasirluk), Nunavut

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ABSTRACT. In light of the difficult logistics and high cost of polar research into climate change, involvement of local people can contribute immensely to important data collection. One can use the knowledge and skills of human resources that are already present—teachers, students, and community members. An example is the long-term Arctic monitoring program established at Crazy Lake (63˚51′ N, 68˚28′ W) near Iqaluit, Nunavut, to monitor snow and ice thickness, biological components, and water chemistry. Nunavut Arctic College students collected basic limnological data at Crazy Lake during spring field camps held between 10 and 16 April in 2005 and 2006. Mean snow depth ± SD for Crazy Lake was 0.46 ± 0.13 m (n = 24). White ice averaged 0.13 ± 0.12 m and black ice 1.38 ± 0.28 m. Total ice thickness (white ice + black ice) ranged between 0.91 and 1.91 m (mean = 1.51 ± 0.22 m). The total lake cover (snow + ice) averaged 1.97 ± 0.20 m. Water depth ranged from 1.48 to 18.58 m (mean = 10.10 ± 4.99 m).

Key words: Arctic, Baffin Island, college project, community monitoring, freshwater, ice cover, lake, limnology, snow

RÉSUMÉ. À la lumière de la complexité de la logistique et du coût élevé de la recherche polaire en matière de changement climatique, la participation des gens de la collectivité de la région à la collecte des données peut jouer un rôle très important en ce sens qu'il est possible de recourir aux connaissances et aux compétences des ressources humaines déjà en place, comme les enseignants, les élèves et les membres de la collectivité. Le programme de surveillance de l'Arctique de longue date établi au lac Crazy (63˚51′ N, 68˚28′ O) près d'Iqaluit, au Nunavut, en constitue un exemple. Ce programme vise à surveiller l'épaisseur de la neige et de la glace, de même que leurs composantes biologiques et la composition chimique de l'eau. Les élèves du collège Nunavut Arctic ont recueilli des données limnologiques de base au lac Crazy à l'occasion d'études sur le terrain réalisées au printemps 2005 et 2006, du 10 au 16 avril. Au lac Crazy, l'épaisseur moyenne de neige ± DS était de 0,46 ± 0,13 m (n = 24). La glace blanche atteignait en moyenne 0,13 ± 0,12 m et la glace noire, 1,38 ± 0,28 m. L'épaisseur totale de glace (glace blanche + glace noire) variait entre 0,91 et 1,91 m (moyenne = 1,51 ± 0,22 m). La couche du lac (neige + glace) atteignait en moyenne 1,97 ± 0,20 m, tandis que l'épaisseur de l'eau variait entre 1,48 et 18,58 m (moyenne = 10,10 ± 4,99 m).

Mots clés : Arctique, île de Baffin, projet du collège, surveillance par la collectivité, eau douce, couche de glace, limnologie, neige

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INTRODUCTION

The importance of High Arctic inland water bodies, such as lakes and ponds, has been well recognized in the past, and interest in these water bodies is now increasing in light of climate change. If ambient temperatures increase as predicted and freeze-thaw cycles change, then lake water levels, ice thickness, and snow cover could decrease in future years, possibly affecting lake ecosystems (Doran et al., 1996; Intergovernmental Panel on Climate Change, 2001; Schindler, 2001; ACIA, 2005). Global warming could also change the chemical parameters (i.e., pH, alkalinity) of lakes, making it more difficult for local fish species to adapt, or even to survive (Schindler, 2001; Quayle et al., 2002; Wolfe, 2002).

Many lakes are important to nearby communities as sources of fresh water supply or for subsistence and commercial fishing. Therefore, major environmental changes could have cultural and social implications detrimental to the local population. Monitoring these important lakes could aid in preparing for these human impacts, as well as improving our understanding of how climatic change may affect these high-latitude freshwater bodies (e.g., Vincent and Hobbie, 2000; American Fisheries Society, 2002).

However, despite the importance of these high-latitude lakes and ponds, and despite the recent increase in scientific investigations, data collection at such locations is rare, especially in winter and spring (e.g., Hamilton et al., 2000, 2001; Joynt and Wolfe, 2001; Lim and Douglas, 2003; Van Hove et al., 2006), and basic limnological data are still sparse. Long-term Arctic monitoring programs, especially those related to climate change (e.g., Rouse et al., 1997), are usually challenging because of high costs and logistical constraints. Moreover, researchers conducting these investigations are

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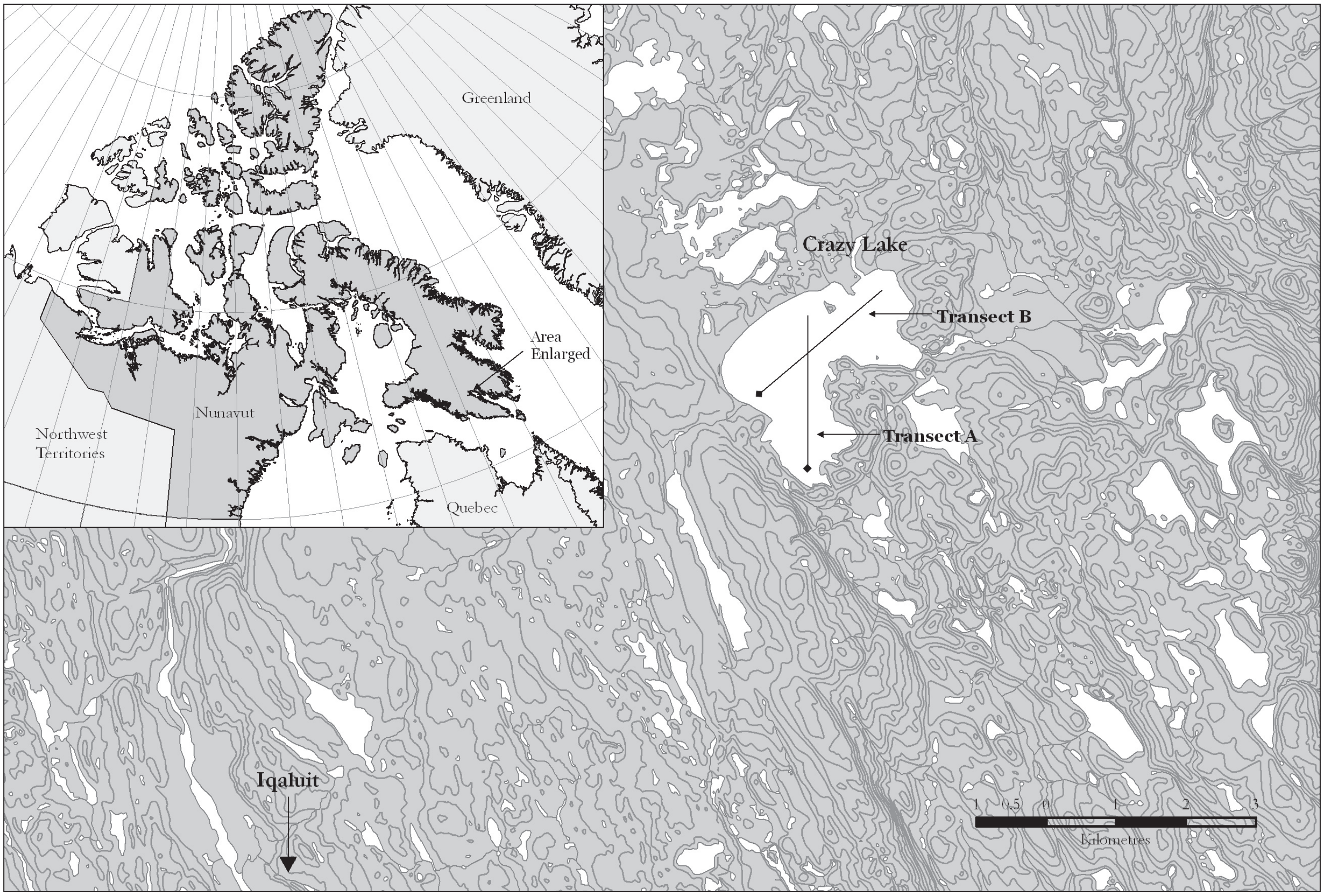

FIG. 1. Location of study area in relation to Nunavut (insert) and Iqaluit (larger map). The squares on lines A and B indicate transect starting points.

almost exclusively from southern latitudes. They spend short periods in the Arctic only for the duration of their projects, and once they return to their own institutions, the collected data generally go south as well.

Making use of the high schools and colleges in larger communities spread throughout the Arctic could help to meet these challenges. Both management agencies and southern universities could benefit from partnerships with these northern educational institutions because most government organizations in the North lack the manpower and resources needed to develop and implement comprehensive, long-term monitoring programs.

An example of using local human resources is the project reported in this paper, which presents baseline limnological data from Crazy Lake (near Iqaluit, Nunavut) that were collected by students of Nunavut Arctic College's Environmental Technology Program as part of limnology field camps in April 2005 and 2006. The Environmental Technology Program is Nunavut's only post-secondary educational program particularly aimed at training northern students (i.e., mostly Inuit) as environmental practitioners, preparing them for employment (e.g., as conservation and fisheries officers or environmental land and water inspectors) in governmental and non-governmental positions across Nunavut. Other goals of this project for students included gaining practical experience in data collection and understanding the purpose and value of repetitive tasks (including the requirements for data accuracy and precision) in scientific investigation.

Given the importance of snow and ice in climate change studies, and the fact that most limnology work is conducted during June and August (e.g., Pienitz et al., 1997a, b; Hamilton et al., 2001; Michelutti et al., 2002; Antoniades et al., 2003), the primary goals of this college project were a) to establish a long-term monitoring program; b) to collect baseline spring (April) limnology data for an important local lake; c) to expose students to simple and practical research techniques; and d) to establish and foster relationships between Nunavut Arctic College and southern academic institutions.

STUDY AREA AND METHODS

The lake selected to be established as the long-term monitoring site had to fulfill two important requirements: a) it had to be relatively close to the college so that long-term monitoring could be ensured without major logistical constraints, and b) it had to have some local importance. Crazy Lake (63˚51′ N, 68˚28′ W; Fig. 1) near Iqaluit, Nunavut, was the perfect choice because land-locked Arctic charr (*Salvelinus alpinus*) are present there and local residents engage in subsistence fishing activities throughout the year. However, information about the fish and the simple physical and chemical parameters of the lake is non-existent. The lake is approximately 11 km north of Iqaluit, which would allow for easy monitoring.

Fieldwork was conducted between 10 and 16 April in 2005 and 2006. In April, average temperatures are still far below freezing (mean = -14.8˚C), average wind speeds are about 15.8 km/h, and snowfall (mean = 32.4 cm) is greater than in any month of the year except October and November (Fig. 2). These conditions make spring limnology work in the Arctic very challenging.

In April 2005, a satellite image and ArcView® software were used to determine shoreline length, surface area, and maximum length and breadth of Crazy Lake. A transect was then selected that approximated the maximum length of the lake (i.e., Transect A in Fig. 1). Twenty-four drill-hole locations were selected along Transect A at intervals of ca. 150 m and recorded with a global positioning system (GPS) to allow future replication of the measurements. At each drill-hole location, a snow pit (ca. 1 m × 1 m) was excavated down to the lake surface to facilitate snow measurement readings (when snow was present) and the use of a 10-inch (ca. 25 cm) ice auger. Snow depth was measured with a ruler along a vertical surface of the snow pit and the measurements recorded to the nearest cm. For consistency, all snow measurements were taken from a west bearing when possible. After the hole was drilled, white ice was measured using a ruler and recorded (to nearest cm). Black ice was measured using a wooden pole with a nail attached perpendicularly to one end. The pole was lowered into the hole and pulled upward so that the nail caught the bottom of the ice. The measurement (in cm) recorded for black ice was the distance from the nail to the top of the ice, minus the white ice. Total ice was the sum of black and white ice, whereas total lake cover was the sum of total ice and snow thickness. (For a brief discussion on white and black ice, see Woo and Heron, 1989.) Water depth (to nearest cm) was determined by lowering a weight attached to a rope to the bottom of the hole, reading the value at the top of the ice, and subtracting the total ice measurement.

In 2006, we determined locations for holes along Transect A by using established GPS locations. In addition, Transect B (with 13 holes at 150 m intervals) was established (Fig. 1), and measurements were obtained from both transects, as outlined previously. The college was also fortunate to fuel interest in this project at a southern university. As a result, a university biologist visited the project site during the 2006 field season and provided a Hydrolab Surveyor probe, which was used to measure pH, dissolved oxygen (DO; mg/L), water temperature (T_w), Total Dissolved Solids (TDS; ppm), and conductivity (SpC; mS/cm). To ensure the probe would not freeze, a dome tent with a cut-out bottom was placed over a selected hole and heated with a camping stove. This procedure allowed us to obtain an oxygen, temperature, and pH profile of Crazy Lake from hole C of Transect B at 2 m depth intervals. The probe was calibrated before use. Statistical tests were considered significant at $\alpha = 0.05$.

RESULTS

Physical Parameters

Crazy Lake has an approximate surface area of 4.5 km^2, a shoreline length of 12.2 km, and a maximum length and width of about 3.2 km and 2.2 km, respectively. Arithmetic mean water depth is about 10 m, however, depths along transects ranged from less than 1 m to over 20 m (Fig. 3). No significant differences between transects were detected for 2006 snow and ice values (unpaired t-test, $p > 0.05$); however, significant differences between years were detected for Transect A (paired t-test; Fig. 4). In 2006 (n = 36), mean snow depth ± SD was 0.34 ± 0.11 m (range: 0.13 – 0.57 m). White ice averaged 0.04 ± 0.06 m (range: 0 – 0.23 m) and black ice, 1.30 ± 0.12 m (range: 1.04 – 1.62 m). Comparisons between sampling years for Transect A indicated significant decreases in total lake cover (paired t-test; $p < 0.0001$, n = 23), total ice ($p = 0.003$), white ice ($p = 0.006$), and snow depth ($p = 0.0004$; Fig. 4). Total lake cover (snow + ice) decreased from 1.97 m in 2005 to 1.68 m in 2006.

Chemical Parameters

Mean water temperature was 0.75˚C (range: -0.12 – 1.37˚C); dissolved oxygen ranged between 8.7 and 14.4 mg/L (mean DO = 12.3 mg/L), depending on water depth; and mean pH was 8.4 (Fig. 5). No total dissolved solids were detected, and conductivity was nearly constant at all depths (SpC = 0.03 mS/cm).

DISCUSSION

Lake Parameters

Judged by its measured depth and surface area, Crazy Lake is a relatively small and shallow lake. However, a complete bathymetric map of the lake basin has not yet been completed and may still reveal greater depths. Nevertheless, Crazy Lake fills one more gap in the limnological examination of northern freshwater bodies of similar size (e.g., Pienitz et al., 1997a, b).

The snow/ice depths recorded at Crazy Lake fall within the approximate 2 m thickness found at other Arctic lakes (e.g., Woo and Heron, 1989; Stefan and Fang, 1997; Belzile et al., 2001). Ice thickness and snow cover are inversely related: as the snow depth increases, ice thickness usually decreases (Woo and Heron, 1989). When

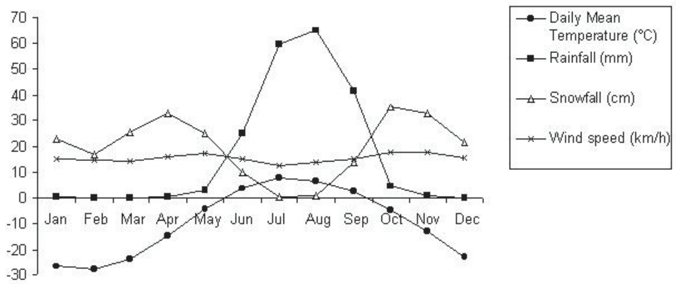

FIG. 2. Annual means of climatic variables for the study area, from data collected at the Iqaluit airport (Environment Canada, 2004).

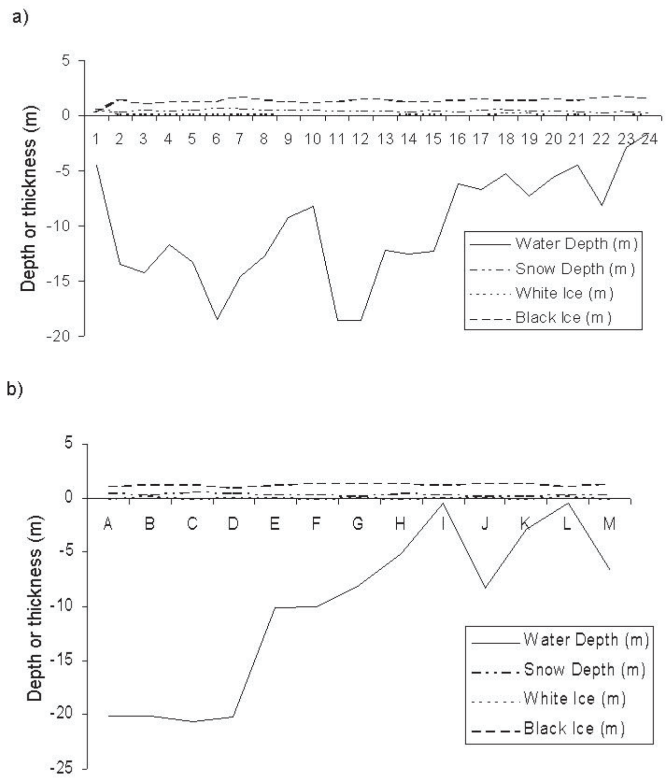

FIG. 3. Profiles of water depth and snow and ice cover along (a) Transect A and (b) Transect B at Crazy Lake. Letters and numbers along the horizontal axes represent drill holes.

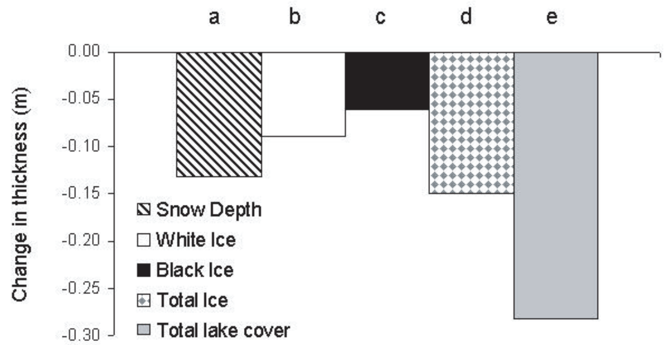

FIG. 4. Change between the two sampling periods in depth or thickness of (a) snow, (b) white ice, (c) black ice, (d) total ice, and (e) total lake cover for Transect A on Crazy Lake, Nunavut (NB: a: $p = 0.0004$; b: $p = 0.006$; c: not significant; d: $p = 0.003$; e: $p < 0.0001$).

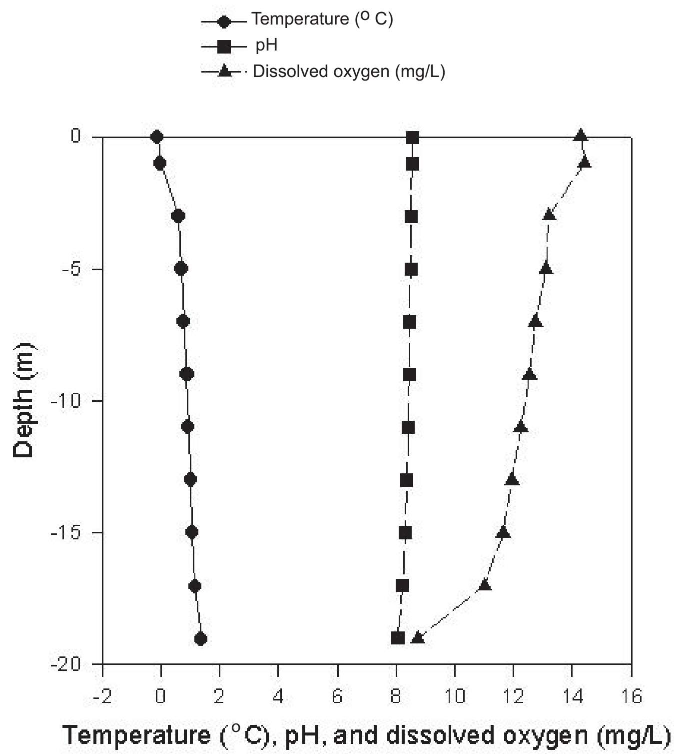

FIG. 5. Temperature, pH, and dissolved oxygen profiles of Crazy Lake, from measurements taken in hole C along Transect B in April 2006.

monitoring the effects of climate change, investigators should record snow depths together with ice thickness in order to be fully aware of the snow-ice interactions. One could falsely conclude, over the long term, that changes in ice thickness were related to some other factor, when in fact snow depths were also changing and affecting ice thickness. At this point, it is too early to determine whether climatic change or annual variation in snow and ice accumulation is responsible for the changes in snow and ice thickness at Crazy Lake observed between 2005 and 2006. Continued monitoring of these data will help in the examination of long-term trends.

The dissolved oxygen concentrations in Crazy Lake were relatively high, even at greater depths and even with a snow and ice cover that prevents the light penetration needed for photosynthesis to occur. Comparable spring data from other lakes are unknown, but summer DO values of lakes in the Northwest Territories were similar in range (Pienitz et al., 1997b), suggesting that summer DO levels of Crazy Lake are likely to be higher because of wind action and increased photosynthesis throughout the water column. The profile indicates greater oxygen depletion near the benthic zone, which is possibly caused by decomposition of organic material. The colder water temperatures throughout the lake also support greater oxygen concentrations (Wetzel, 1983). It is currently not clear how these high DO values at Crazy Lake are maintained into spring. In late winter and early spring, lakes usually experience oxygen deficits because of oxygen consumption by living organisms, decomposition, and reduced photosynthesis. During open-water season, shallow tundra lakes are usually saturated with oxygen (Hobbie, 1984; Welch, 1991). Strong wind action usually provides good mixing of the lake water and also results in the absence of a thermocline (Fee et al., 1988). Perhaps a combination of good fall mixing, constant cold water temperatures, and phytoplankton photosynthesis during the open-water season all contribute to these high spring DO values.

Measurements of pH indicated that Crazy Lake is alkaline, which is in general consistent with values recorded across other Arctic regions (Douglas and Smol, 1994; Pienitz et al., 1997a, b; Bloom et al., 2000; Antoniades et al., 2000, 2003; Hamilton et al., 2001; Lim et al., 2001). The alkalinity of Arctic lakes and ponds is predominantly caused by carbonate bedrock and glacial material. However, bedrock in the Crazy Lake area is Cumberland batholith monzogranite (Hodgson, 2005), which usually should result in acidic water (Wetzel, 1983). Perhaps some of the till in the area contributes to the alkaline nature of the lake, but confirmation must await further examination.

Community Monitoring and Partnerships

Research in the Arctic is costly. One way to minimize these costs is to make use of the knowledge and skills of people who are already present: teachers, students, and community members. Most northern communities have well-established high schools or colleges that educate Northerners. Investigators should consider these resources when planning long-term projects and attempt to establish long-lasting, mutually beneficial relationships.

Southern universities, government, and non-governmental organizations are not always aware of the presence of northern skills and human resources. How then can these partnerships be established? One method is by advertising local college and high school skills through the media, e.g., in newspapers (Dyck, 2006). The other option is to search on the Internet for researchers who visit communities and ask directly whether they are interested in nurturing partnerships for research projects. The Environmental Technology Program was fortunate to establish several partnerships in such ways.

Northerners are even more “under the magnifying glass” because of climate change issues revolving around Arctic regions. Scientists come and go, and the local people are rarely aware of what research was conducted in their region. Involving local people responsibly in data collection can build trust in academia and in research results. My students initially were scared of the intensive work before them, but when I mentioned how we contribute locally to such a project, students felt proud of what they were going to accomplish.

The Environmental Technology Program has relationships with several universities through which researchers visit our college, give lectures, and present research project overviews. Students have intense and active interactions with these researchers. Ideas are exchanged and stimulated, as academic research is brought into the community and students offer their traditional skills and knowledge to stimulate the researcher. Some students are motivated to continue education in a southern institution so they can address local resource issues once they return to the North. Possibilities for summer field assistantships are also discussed.

Science can be very abstract for people who are not brought up in a Western science-based environment. Being involved in community projects and working on a team of local residents and researchers means being elevated to the same contributing level. For example, everyone (researchers and students) drilled holes, froze hands, and was hungry and tired, but the team also shared a sense of accomplishment.

Projects like the long-term monitoring program at Crazy Lake do not require much equipment. Sophisticated gear can be secured through relationships with academic, government, or non-governmental institutions. These relationships may also increase the scope of such projects. For example, more detailed water analyses (e.g., of major ions, nutrients, carbon, and chlorophyll) and a complete bathymetric examination of Crazy Lake are planned for future field camps.

CONCLUSIONS

The importance of ice and snow thickness is known, especially with respect to climate change (e.g., Rouse et al., 1997; Stefan and Fang, 1997). Ice cover has been declining on northern lakes and rivers since about the mid-19th century (Magnuson et al., 2000), and I therefore encourage other investigators to measure variables such as snow and ice thickness during spring limnology studies. If climate is progressively changing, ice cover thickness and freeze-thaw dates will also change over time, and thus should be part of a monitoring program.

The Crazy Lake project demonstrated that baseline scientific data for long-term monitoring programs can be collected by local educational institutions. Similar approaches are used in Alaska, where K-12 students collect lake ice observations for the Alaska Lake Ice and Snow Observatory Network (ARCUS, 2005). An international network of circumpolar countries and partnerships between northern and southern educational institutions should be envisaged, through which students can contribute a vast amount of data needed by academic or other institutions for modeling and monitoring of climate change. Such a network will also enhance northern participation in science, education, and decision making and reduce the financial and logistical constraints on researchers planning fieldwork excursions to High Arctic latitudes.

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