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Fifty Years of Science at the Kluane Lake Research Station

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INTRODUCTION

> Touched down on the Kluane strip with the Helio Courier 4153D June 24, 1961. First landed 53D on the Kaskawulsh glacier at what we later called Glacier Camp (ca. 8500 ft) with Dr. Wood and Ralph Lenton to eat snow. Four more landings with tents and all comfort items including food June 30. Two more trips with essentials to start research July 1. Got caught at the camp because of whiteout. A snowstorm followed the whiteout and the time was spent setting up a comfortable camp. Finally, on July 8, I was able to stagger 53D in the air and return to Kluane base camp. IRRP was in business.
>
> Richard H. (Dick) Ragle,
> IRRP field leader and pilot, 1960–74 (Ragle, 2011)

Dick Ragle's account describes the very first days of the Arctic Institute of North America's (AINA) Icefield Ranges Research Project (IRRP), an international, multidisciplinary scientific research program focused on the study of the physical and biological environments of the Icefield Ranges of the St. Elias Mountains. The base of operations for IRRP was built around an airstrip located at the south end of Kluane Lake, and soon this unique site adjacent to this remote stretch of the Alaska Highway would be become known as the Kluane Lake Research Station (KLRS) (Fig. 1). KLRS has since become a venerable cornerstone of science in the Canadian North, facilitating research in a diverse range of fields, including glaciology, geomorphology, geology, geography, biology, botany, zoology, hydrology, limnology, climatology, human physiology, anthropology, and archaeology. In addition to substantial information on the regional environment of southwest Yukon, significant new scientific knowledge with global implications has emerged from research conducted from KLRS. Perhaps most notable is knowledge of the geophysics of glaciers, impacts of global environmental change in mountain environments, the physiological responses of humans to the stress of high altitude, and ecosystem dynamics in boreal forests and alpine meadows. Over the past 50 years, there has been a complementary emphasis on the training of well over 1000 students—most of whom have gone on to work in the private sector, government, and academia, in fields as diverse as engineering, natural resource management, education, business, the arts, public policy, and scientific research. By any metrics, the significance of KLRS to Yukon, to Canada, and to the world is clearly evident.

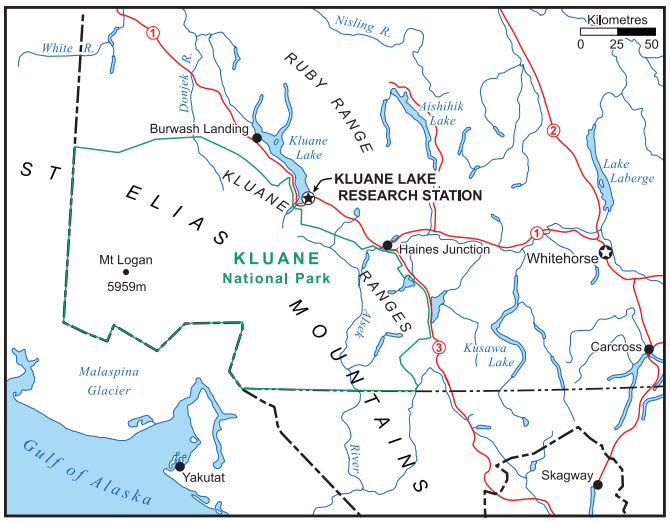

FIG. 1. Location of the Kluane Lake Research Station in southwest Yukon, Canada.

The year 2011 marked the 50th anniversary of KLRS. Managers and users of the station felt that this occasion was too important to pass unheralded, and a celebratory weekend was organized for 5–7 August, which included a public open house, a science symposium, a workshop, presentations, and much camaraderie over fine northern cuisine, campfires, and music. It was a reunion and homecoming for many of the people who have worked at the station over the years, as well as a time to reflect on the past and imagine the future, ensuring the station's continued success.

One of the directions that emerged from the anniversary weekend was an idea to assemble a collection of papers that would highlight some of the ongoing research being conducted at KLRS. Despite hundreds of individual technical publications, few collected volumes on research conducted at KLRS have been published (Bushnell and Ragle, 1969; Houston, 1980; and Krebs et al., 2001 are exceptions) and none that span multiple research programs. The consensus was that it would be advantageous to produce a single publication that could act as a contemporary introduction to KLRS. To this end, KLRS researchers were invited to submit papers that would summarize results of their research programs. Papers would be written as reviews, intended not to present new technical results, but to synthesize various research themes, present results to date, and identify gaps

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in knowledge to help guide further investigation. Difficulties in funding ensued, as the money initially earmarked for publication was lost when funding programs that had long supported KLRS were cut in 2012. But, with the Arctic Institute's help, we are able to publish these papers in the form of this special issue of *Arctic*.

CONTRIBUTED PAPERS

The papers in this issue cover some of the more salient research themes at KLRS, but numerous other topics and research programs—some larger, some smaller—are not represented here. Moreover, many more research projects in southwest Yukon are not conducted from KLRS, including those led by government agencies, such as Parks Canada and Yukon Environment, and by the Kluane First Nation or Champagne and Aishihik First Nations. Nevertheless, this collection provides a glimpse into the diversity and significance of research being conducted in the region.

Three papers in this issue describe research conducted on the glaciers of the St. Elias Mountains, which collectively constitute the largest non-polar icefield in the world. Garry Clarke, who has been conducting research in Kluane since 1963, documents the progression of glaciology in the region during the 20th century and provides an overview of findings from his research program over four decades. Gwenn Flowers and colleagues report results of recent glaciological research that indicates significant ongoing changes to the area, volume, and dynamics of glaciers located in the Donjek Range and of the Kaskawulsh Glacier. Christian Zdanowicz and colleagues synthesize the analytical results obtained to date from a suite of ice cores obtained from the Mount Logan area in 2001 and 2002. Their results provide evidence of changes in climate and atmospheric composition in the late Holocene, but also demonstrate the complex nature of atmospheric circulation in the North Pacific region.

Three more papers in this issue report on research conducted in the region's boreal forest ecosystem. Charles Krebs and colleagues summarize nearly 40 years of research investigating trophic dynamics, the central objective of which has been to determine the causes of the decadal-scale cycling of snowshoe hares and other mammals. Rudy Boonstra and colleagues provide a synthesis of their work supporting the hypothesis that stress is a driving mechanism for these population cycles. Roy Turkington and colleagues report on their research on the plant community ecology of grasslands and boreal forest understories. Each of these three papers demonstrates the importance of long-term studies and experimental approaches for understanding how these northern ecosystems are structured.

A seventh paper by Konrad Gajewski and colleagues bridges the physical and biological sciences by examining long-term environmental change in the region as inferred through proxies such as tree rings and lake bed pollen, fossil, and sediment stratigraphies. They provide a rich overview of the nature of Holocene-scale changes in southwest Yukon, which is of particular relevance to the large amount of research currently focused on recent climate-driven environmental change.

A BRIEF HISTORY OF KLRS

The massive St. Elias Mountains, which include North America's largest concentration of high peaks, their associated glaciers, and adjacent montane areas, have attracted explorers and scientists for more than 100 years (see Danby et al., 2003, for a detailed review). Early scientific work in the Kluane region was predominantly exploratory, but the transition toward scientific research began in 1935 with two different expeditions into the Icefield Ranges. One, led by Bradford Washburn and sponsored by the National Geographic Society, surveyed the mountains and glaciers in the southern part of the region between the Lowell Glacier and Nunatak Fiord. The other, led by American alpinist and explorer Walter Abbott Wood and sponsored by the American Geographical Society, explored the northern part of the region in an area around Mt. Steele. In addition to conducting the first detailed survey of this high alpine region in 1935, Wood's goal was to experiment with and refine techniques for aerial photogrammetry and mapping in remote mountain landscapes (Wood, 1936). Wood returned to the region again in 1936, 1939, and 1941 to continue this work.

These early expeditions were based at Burwash Landing on the west shore of Kluane Lake, relying on a small community of Southern Tutchone people who provided guidance and logistical support. Many remarkable and wise elders have contributed to the scientific work conducted at KLRS. For example, Josephine (Josie) Jacquot-Sias (1927–2012) and her family were associated with scientific exploration of the St. Elias from the very beginning. Josie supported the early expeditions led by Walter Wood, and her guidance and support for science and education in the Kluane region and northern Canada continued throughout her life.

Wood was to become a principal of AINA, which was created by an Act of Parliament in 1945. In 1948, when Wood was the director of AINA's New York office, the Institute mounted Project Snow Cornice to survey and investigate the physics and dynamics of the Seward Glacier on the south side of Mount Logan and to carry out studies of the meteorology and biology of the area (Wood, 1948). The operation was based at Yakutat on the southeast Alaska coast, with a seasonal base camp on the Seward, and used the first of several AINA aircraft: a ski-equipped Norseman. The effort ran for four years and was highly productive, but the Norseman tragically vanished in 1951 en route from Seward Station to Yakutat with Wood's wife and daughter aboard. This tragedy marked the end of Snow Cornice, but ultimately provided valuable experience in the region and laid the foundation for subsequent studies.

Wood returned to Yukon in 1961 when AINA, in collaboration with the American Geographical Society, established the Icefield Ranges Research Project (IRRP). The goal of IRRP was twofold: (1) to study and describe the "total environment" of a high mountain area, and (2) to provide field research and training opportunities for graduate and undergraduate students working alongside senior scientists (Bushnell and Ragle, 1969). Locating this endeavour in the mountains of the southwestern Yukon allowed for scientific research and training in a severe northern environment without incurring the enormous costs of travelling to the High Arctic.

The base of operations for IRRP was established on the south shore of Kluane Lake near the small settlement of Silver City. An airstrip had been constructed there in the early 1950s as part of a cooperative training exercise of the Canadian and U.S. military known as "Exercise Eager Beaver," but it had subsequently been abandoned. These were then termed "Commissioners Lands," under the jurisdiction of the federal government, and AINA received permission to occupy the site "for as long as required." The existence of an airstrip was critical in selection of the location. Initially, IRRP emphasized glaciology, and field camps on the icefields would require air support. AINA acquired another aircraft, a ski-equipped Helio Courier, for this purpose. Additional advantages of this location for AINA were related to accessibility: it was adjacent to the Alaska Highway and close (about a four-hour drive at the time) to Whitehorse, the largest city in the Yukon and a centre for supplies, logistics, and technical support. Further, the location enabled easy access to boreal and alpine tundra environments, which would be necessary for making IRRP attractive to other disciplines.

The base at Silver City was initially a tent camp. A couple of Jamesway huts, ubiquitous in the North, provided mess and work facilities, while researchers camped in canvas tents along the lakeshore. The dismantling of the Alaska Highway construction camp at Mile 1056 provided an opportunity to upgrade the base camp. Two of the wooden frame buildings were purchased for a dollar each, dismantled, transported to the site, and re-erected. A number of plywood cabins were constructed along the airstrip, and a well was dug for fresh water (Fig. 2).

With their experience supporting IRRP, AINA pilots had determined that, given an aircraft with enough power, they might possibly land on the Mount Logan plateau. Although it was an unprecedented notion, in a large leap of faith, AINA purchased a turbo-charged Helio Courier and Chief Pilot Philip Upton conducted a successful landing (and subsequent take-off!) at 5400 m, proving the concept possible. The capacity for this aerial support led to the establishment of the High Altitude Physiology Project (HAPS) in 1967. HAPS was an international project supported by the U.S. National Institute of Health and what was then the Defense and Civil Institute of Environmental Medicine in Canada. A camp was established on Mount Logan for the purpose of conducting clinical studies to investigate the physiological responses of humans to the stress of high altitudes. It was led by Dr. Charles Houston, a medical doctor, professor, and noted mountaineer. There followed some 14 years of high risk and high adventure that were to sustain KLRS throughout the 1970s until opportunities for external financing diminished (Houston, 1980).

FIG. 2. An early photograph of the Kluane Lake Research Station (top) (from AINA files), and a photograph from the same perspective in 2014 (bottom) (courtesy Lance Goodwin).

In 1973, AINA hired Andy Williams to manage operations at Kluane. A second Helio Courier had been purchased, and Williams soon began flying with Upton in support of HAPS and other scientific projects. By the 1970s, it was obvious that AINA's concept of "build it and they will come" had proven fortuitous. Researchers not previously part of IRRP or HAPS were starting to use the station regularly, attracted by the relative ease of access to other landscapes and the variety of environments and biota. By the time HAPS and IRRP had finished, the station was able to continue operations under its own head of steam. But this result was also due in part to the able direction of Williams and his wife Carole, who would continue in that role until their daughter, Sian Williams, and her husband, Lance Goodwin, took over in 2012.

During the 1980s and 1990s the station supported several new and continuing research programs in parallel. The largest of these was the Kluane Boreal Forest Ecosystem Project—initiated and supervised by Dr. Charles Krebs (University of British Columbia), and supported by the Natural Sciences and Engineering Research Council of Canada (NSERC)—which would engage a dozen principal investigators and several hundred students throughout the course of the study. The project explored many aspects of boreal ecology but is best known for its novel experimental assessment of the cyclical nature of snowshoe hares and other wildlife populations, which was achieved through long-term predator exclusion, food additions, and forest fertilization experiments (Krebs et al., 2001, 2014). Studies of the

region's glacial history and dynamics also continued during this time. Notable are the Mount Logan ice core drilling projects: the pioneering project in 1980 led by AINA's Dr. Gerald Holdsworth; a second project led by the Geological Survey of Canada in 2001 and 2002; and the long-term research program of Dr. Garry Clarke on Trapridge Glacier investigating subglacial physical processes (Clarke, 2014). Over the last decade, projects led by a single principal investigator, usually supported by NSERC, have been the most common mode of research conducted from KLRS. Some of these are summarized in this special issue.

In addition to the staging and facilitation of scientific research, KLRS has served as a base of operations for dozens of university and college field courses, as well as multiple science symposia and workshops. The longest standing of these is the field course on the physical geography of northern environments run by the Department of Geography, University of Ottawa. This course was first established and taught by Dr. Peter Johnson in 1973 and has continued annually since, employing a model of "learning by doing" and introducing students to various field methods and techniques in glaciology, geomorphology, meteorology, hydrology, and limnology (Johnson, 2006). Not surprisingly, many of these students subsequently returned to KLRS to conduct graduate research projects.

While AINA provides support and access to KLRS, it does not design or supervise the research or teaching activities, and facility users are required to pay a fee for use. Nevertheless, AINA has been able to acquire various funding sources to help keep user fees at a manageable level. For many years the station benefited from a Major Resources Support infrastructure grant from NSERC; however, this program was terminated in 2012. The University of Calgary, through AINA, has continued to provide some financial and administrative support, and modest annual contributions have also been provided by the Universities of British Columbia, Alberta, Ottawa, and Toronto, and by Simon Fraser University. Throughout the years, private and government financing have provided for the construction of several buildings to a standard that could support operations during the winter. In 2009, the Government of Canada provided $2.4 million for upgrading infrastructure through the one-time Arctic Research Infrastructure Fund. This grant funded construction of a new kitchen and dining hall and allowed for improvements of several existing buildings to a higher standard (Fig. 3), which included critical upgrades to water, power, and sewage services.

FIG. 3. A photograph of the building that served as the KLRS dining hall for nearly 40 years (top) (courtesy Gwenn Flowers), and a photograph of the new dining hall from the same perspective in 2014 (bottom) (courtesy Lance Goodwin). The old dining hall dates to the construction of the Alaska Highway and is still in use at KLRS as a teaching building, though in a different location. The new dining hall was completed in 2011 as part of the $2.4 million infrastructure upgrade.

THE FUTURE

Since KLRS opened in 1961, the way that science is conducted and funded in northern Canada has changed dramatically. From the early days of the Icefield Ranges Research Project to the Boreal Forest Research Project, KLRS has always supported ambitious, integrated and interdisciplinary research programs, and even projects conducted by individual researchers have been connected within a larger, collective understanding of the physical, biological, and social dynamics of the region. However, the norm for successful research in the North is increasingly an integrated approach, which brings together scientists from many disciplines and a variety of partners, including representatives from indigenous peoples, industry, colleges, and institutes, as well as municipal, territorial, provincial, First Nation and federal governments (Hik and Boonstra, 2004). The KLRS research community has continued to explore new initiatives and opportunities to strengthen these partnerships.

As an example, in 2009 KLRS was one of the first Canadian research facilities to join INTERACT, the International Network for Terrestrial Research and Monitoring in the Arctic. INTERACT (http://www.eu-interact.org/) links more than 60 terrestrial field bases in northern Europe, Russia, the United States, Canada, Greenland, Iceland, the Faroe Islands, and Scotland to support programs that increase capacity for research and monitoring across the circumarctic region. Nationally, KLRS has also

been active in the Canadian Network of Northern Research Operators (CNNRO; http://www.cnnro.ca/), which links diverse research facilities scattered across northern Canada. Regionally there has also been a robust and growing investment in research infrastructure, capacity, and supporting policies within Yukon College, the Yukon government, Parks Canada, and First Nations organizations.

As Danby et al. (2003) noted previously, management of the Kluane region has become less sectoral and more cooperative in nature, partly through the implementation of co-management agreements, regional land-use planning, and settlement of land claims. Incorporating both science and traditional knowledge into this process through collaborative endeavours such as long-term and community-based ecological monitoring, adaptive management, and information integration and sharing will contribute to sustainable, ecosystem-based management of the southwestern Yukon and ensure that all perspectives play an integral role in sustainable development of the region (Hik et al., 2012). At the same time, gaps within existing research capacity can be identified and addressed through new activities such as the Kluane Lake Watershed Initiative. This initiative involves a new set of research and monitoring projects that are being co-designed with Kluane First Nation and Yukon agencies. Their objective is to study the physical, biological, and human dimensions of Kluane Lake (or Łù'àn Män, 'big fish lake'), which at 400 km^2 and 70 km long is the largest lake entirely within Yukon.

CONCLUSION

The most obvious and accessible products resulting from 50 years of KLRS-supported research have been the prolific and diverse output of scientific publications. A search of the Kluane Lake Research Station Bibliography (http://www.aina.ucalgary.ca/scripts/minisa.dll/144/klrs?DIRECTSEARCH) yields more than 1500 entries, largely in the form of learned papers and graduate theses, all of which contribute to the intellectual benefit of Yukon, Canada, and the world. An equal contribution of KLRS has been its role in education and training. Exposed to working in a harsh environment and designing highly technical equipment, many graduates and field assistants are now employed by resource industries and government, and many others are self-employed and, in turn, employers—a contribution to society that cannot be assigned a monetary value. Nevertheless, over 50 years there have also been direct benefits to the local economy since equipment, supplies, and services all require local sourcing and people.

Perhaps less obvious is the legacy of research at KLRS handed down from one scientific generation to the next (Williams, 1991). There are direct lineages, and numerous long-term relationships that have been essential in facilitating the scientific contributions of KLRS. For example, when Garry Clarke (UBC) first came to KLRS in 1963, he probably did not imagine that one day a PhD student of his, Gwenn Flowers, now at SFU, would establish a thriving glaciological research program in the Kaskawulsh drainage. Similarly, when Charley Krebs, Tony Sinclair, and Jamie Smith (UBC) began to design their grand boreal forest experiment in the late 1970s, it would have been hard to predict that one of us (Hik) would complete a PhD with them and then establish a decades-long alpine ecology project in the Ruby Range. Or that two of Hik's PhD students would subsequently continue their own research programs at KLRS: Ryan Danby, now at Queen's University, and Isla Myers-Smith (Jamie Smith's daughter!), now at the University of Edinburgh. Such are the ties that bind all of us to KLRS across generations and time.

Of course KLRS continues to attract new researchers who are both building on the legacy and accomplishments of those who have preceded them and bringing bold new ideas to the station. But in addition to the research endeavor, it is also the beauty of the Kluane landscape and the welcoming and friendly atmosphere of the station that keeps many researchers returning year after year to continue their scientific pursuits. In this context, it is fitting to end with the following words from Sam Collins (2011), who worked for 20 years (1965 to 1984) on a host of projects staged from KLRS:

> Commitment to science can't claim first place as my attraction to the St. Elias: mostly it was a more generalized curiosity, maybe wanderlust, the sort of urge to look elsewhere that curses some, drives them as far as possible from their perfectly comfortable home town. Maybe it's in the genome. Most, more fortunate *H. sapiens* don't suffer it. But the company of those who do, who congregate in places like KLRS, is a prize and cherished treasure to me. The people I worked and ventured with were every one the exceptional folks who can't stay home, have to hunt for something more. Their memory I value more than all the rest. And those of you I'll never meet: Welcome! To a very select company!

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