SURVEY AND MONITORING OF ICE PATCHES IN THE DENALI HIGHWAY REGION, CENTRAL ALASKA, 2003–2005

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ABSTRACT

The Alaska Office of History and Archaeology conducted three seasons of ice patch survey in the Denali Highway region of central Alaska. Prehistoric organic and lithic hunting and trapping artifacts had emerged from the melting ice patches and were recovered. Alpine ice patches are seen as part of a prehistoric seasonal round, giving hunters a predictable and reliable location to get close enough to prey, usually caribou, to use dart or arrow. Glacial data from interior Alaska document the recent cyclic melting of ice patches and glaciers that has resulted in a net loss of ice. Land management agencies need to perform ice patch surveys *now*, before these important items are lost forever.

Keywords: fossil ice patch, climate change, nivation hollows, mountain geomorphology

INTRODUCTION

In August of 2003, Alaska Office of History and Archaeology (OHA) personnel were surveying the edges of a patch of ice containing caribou (*Rangifer tarandus*) dung in the Amphitheater Mountains in central Alaska (Fig. 1) when parts of an aboriginal hunting arrow were discovered. Further survey recovered additional artifacts and confirmed ice patches in the Amphitheater Mountains as locations with potential for producing prehistoric and protohistoric cultural materials.

Over 240 artifacts have been recovered to date from melting ice patches and glaciers in northwestern North America. These perennial ice and snow patches that contain caribou dung and artifacts have been found on mountains in the Yukon and Northwest Territories in Canada and in the Wrangell and Amphitheater mountains in Alaska (Tom Andrews 2006, personal communication; Dixon et al. 2003, 2004, 2005; Hare et al. 2004a, 2004b; Kuzyk et al. 1999; VanderHoek 2007a, 2007b). Prehistoric hunters used the ice patches and glaciers as ambush locations because they were predictable and reliable locations to find caribou seeking respite from summer heat and insects. In recent years, these ice patches have been melting at a rapid rate, exposing ancient caribou dung and cultural material to the elements. Ice patches are valuable resources to archaeologists because they often preserve organic items used by prehistoric hunters that are rarely found in ice-free

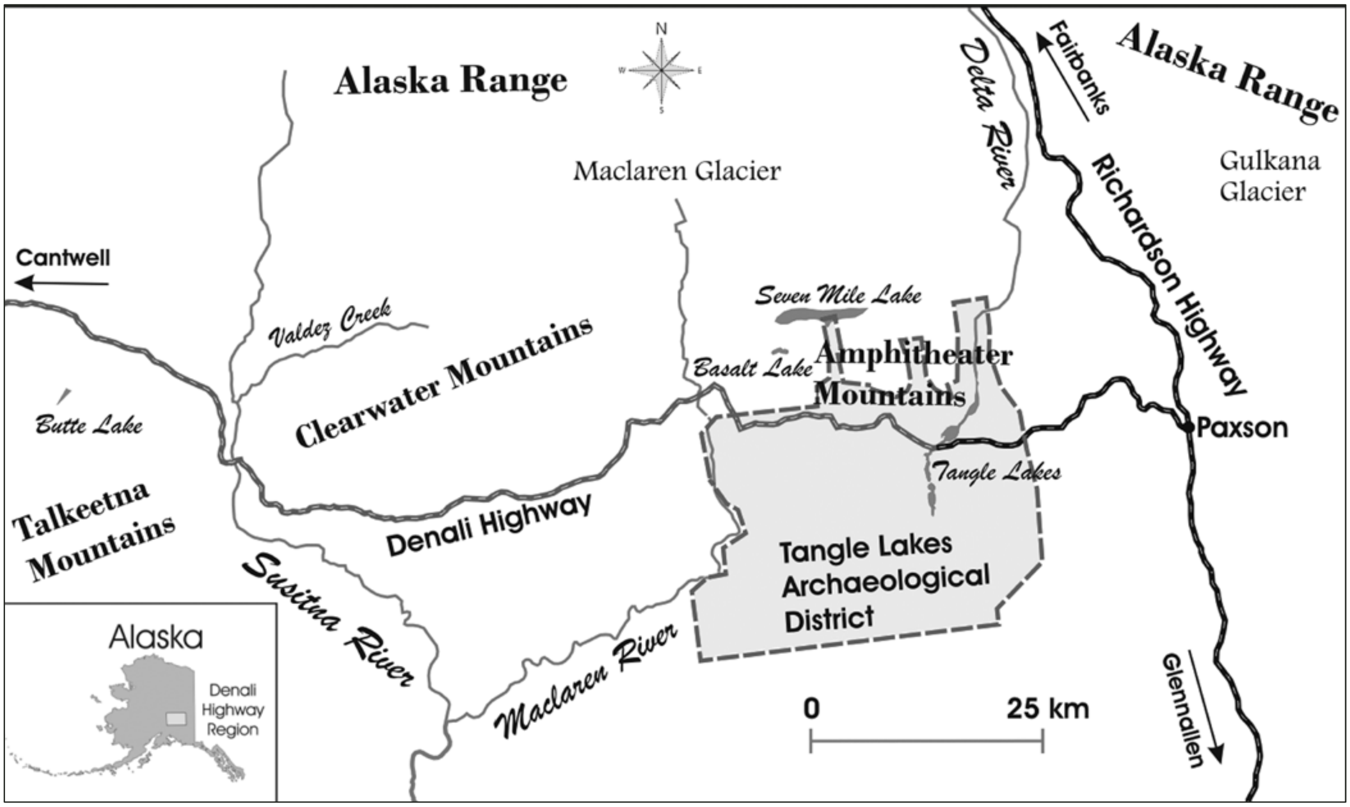

Figure 1. Map of Denali Highway region, central Alaska.

sites. Ice patches have also produced significant biological data: materials recovered from ice patches have provided biologists with an important picture of caribou DNA through time as well as providing data for evaluating regional paleoenvironmental change (Farnell et al. 2004).

The term "ice patch" was coined by Canadian researchers to describe perennial patches of snow and ice (Farnell et al. 2004; Hare et al. 2004b). Ice patches have also been termed *aniuvat* (Dixon et al. 2005), the Inuit term for permanent snow patches (Kusugak 2002). Ice patches form in alpine areas where snow builds up in drifts throughout the winter. Snowdrifts located in shaded areas often form an ice core that lasts through the summer until snow accumulation begins again in late fall.

Snow and ice patches can be divided into three general morphological classes that reflect snow deposition processes and underlying topography (Lewis 1939). The first, transverse ice patches, are those whose major axis lies perpendicular to the line of drainage (Fig. 2, BLIP 1 and 4). These slab-like ice patches generally run parallel to the tops of plateaus or ridges, reflecting the wind deposition of snow on lee slopes. The second class are located in gullies commonly trending down slope and are termed longitudinal ice patches. The third class of snow and ice patches defined by Lewis are circular ice patches. These are generally round in shape and may represent an initial form of cirque glacier.

Ice patches visited in the Amphitheater Mountains in August of 2003 and 2004 were surrounded by large areas of bare gray rock. These areas are believed to be a proxy for the maximum extent of ice patches at the end of the Little Ice Age and mark the former extent of snow and ice cover that prevented lichen (*Umbilicaria* sp.) growth (Blake 2004; Farnell et al. 2004:251–252). Many locations in the alpine areas of the Amphitheater Mountains in 2003 and 2004 showed bare rock patches without any snow, sometimes without noticeable dung as well. Yukon researchers have labeled these zones marking the former extent of ice patches "blond patches" (Blake 2004) or "lichen free zones" (Farnell et al. 2004:252); Dixon uses the term "fossil ice patches" (Dixon et al. 2004). The term "fossil ice patch" is particularly descriptive and is used here to describe the former location of an ice patch that has melted completely away. The term "lichen-free zone" is used here to describe the bare, unvegetated area around an ice patch that has recently been reduced in size.

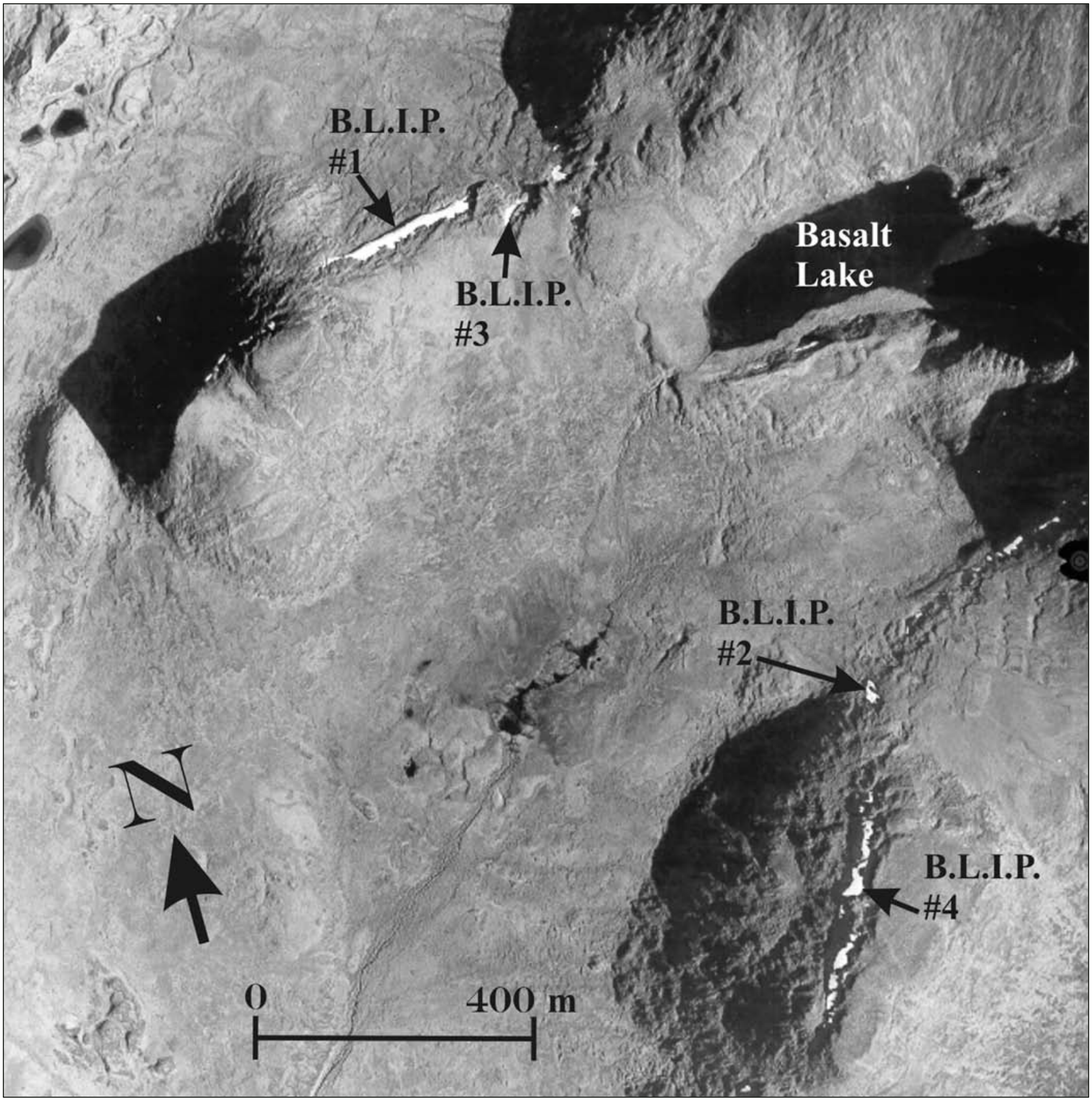

Figure 2. Basalt Lake Ice Patches (BLIPs), western Amphitheater Mountains, September 11, 1984. BLIP 1 and 4 are classic transverse ice patches (Lewis 1939), while BLIP 2 and 3 have melted to reveal underlying longitudinal topography. BLIP 1, 2, and 3 were surveyed in 2003 and then monitored with the survey of BLIP 4 in 2004. Cultural materials were found on all four. Photo courtesy of Aero-Metric, Inc.

CARIBOU AND ICE PATCHES

Caribou move into the high country in the summer months. They feed on a wide variety of plant species in early summer (willow, dwarf birch, grasses, and sedges) but later shift primarily to sedges. Skoog notes "the highly nutritious, early vegetative growth remains are available throughout the summer, because new areas for plant growth are continually being released from lingering snowdrifts and earlier flooded conditions" (Skoog 1968:148–149). In Yukon studies, caribou were found to favor the north side of hills in the summer. This is thought to be because these commonly moist environments provided the excellent growing conditions for the sedges that are the preferred summer diet in the region (Oosenbrug and Theberge 1980). It is in the high country on these northern facing slopes where the ice patches favored by both caribou and prehistoric human hunters are found.

Another motivation for caribou movement into the high country in summer is to seek relief from insect predation. Skoog termed this period of high insect density the "fly-season pause," and noted that "during the height of fly-numbers the caribou spend most of the daylight hours huddled closely together on windswept areas and/or glaciers and lingering snow-drifts" (Skoog 1968:451). Caribou gain some relief from insects on ice patches because of the cooler temperatures and generally higher wind speed found there (Ion and Kershaw 1989). Caribou also seek out ice patches for thermal regulation (both by standing and lying on the ice/snow and by eating snow on the surface), but this may not be as important as the relief provided from insects (Ion and Kershaw 1989:210).

While mosquitoes and black flies are irritating to caribou and can drive them to seek out ice patches, two species of oestrid, or bot fly, are of particular importance to the herds of central Alaska because of their negative impact on caribou vitality (Skoog 1968). Skoog notes that fly harassment of central Alaska caribou herds intimidates and distracts the caribou so much that "the animals are very reluctant to leave their hilltops or their snow-banks, and frequently a person can walk into the midst of the group, with the animals merely milling about" (1968:607).

2003 ICE PATCH MONITORING

In 2003, 95,100 hectares in the Denali Highway region were transferred from federal control to the State of Alaska as part of the Alaska Lands Statehood Act (Fig. 1). A research design was developed at the Alaska Office of History and Archaeology (VanderHoek 2003) to address management issues and management-related research needed to develop a cultural resource management plan for the area (VanderHoek 2007a). Further land transfers in 2004 were covered in an updated research design (VanderHoek 2004). One of the activities called for in the research designs was to survey areas in the Tangle Lakes Archaeological District/Special Use Area and other recently transferred state lands that were previously unsurveyed but that had high potential for the presence of cultural resources. One archaeological resource that had not been previously considered in the Tangle Lakes region was the possible presence of ice patches containing cultural material. With the aid of Bill Kiger, the GIS representative for the Department of Natural Resources, Division of Parks and Outdoor Recreation, Interpretation and Education, Landsat 7 satellite images of the Tangle Lakes region were acquired. These satellite images, taken on August 1, 2002, showed numerous ice patches and glaciers. The most prominent cirque glacier and the largest low-elevation ice patch in the Amphitheater Mountains were chosen to be visited as part of the summer survey. Aerial photographs taken in 1984 were also acquired that included the largest ice patch (Fig. 2).

On August 7–8, 2003, two OHA personnel visited the largest cirque glacier in the Amphitheater Mountains. The cirque is located in the center of the east-west trending ridge north of Seven Mile Lake. Caribou were observed on ice patches near the glacier and on the glacier itself. The face of the glacier was very active, with scattered scree and streams of water across it. No caribou dung or cultural material was observed on the top or face of the glacier. The glacier appeared too active to preserve biological or cultural material. It is limited in extent and steep enough to contain relatively short-lived ice.

BASALT LAKE ICE PATCHES

The largest low-elevation ice patch in the Amphitheater Mountains (Basalt Lake Ice Patch 1, or BLIP 1) was visited by an OHA employee on August 15, 2003. This ice patch is one of a cluster located within approximately a kilometer of Basalt Lake, on the western edge of the Amphitheater Mountains. The ice patch was considerably melted from the images shown on the 1984 aerial and 2002 satellite photographs. Pieces of an almost-complete arrow were recovered (see VanderHoek et al., this volume). The large ice patch was revisited by a larger OHA crew between August 28–30, 2003 (Fig. 3). The crew also surveyed three smaller ice patches to the east of the large ice patch (which includes BLIP 3) and a remnant ice patch approximately 2 km to the southeast (BLIP 2). These were collectively called the Basalt Lake Ice Patches (BLIPs), with those containing artifacts given BLIP and Alaska Heritage Resources Survey (AHRS) numbers.

Basalt Lake Ice Patch 1 (XMH-1081)

Basalt Lake Ice Patch 1 (BLIP 1) is located 650 m northwest of Basalt Lake in the western Amphitheater Mountains.

It is situated on the northern side of a saddle connecting a westward projecting knoll with the main body of the Amphitheater Mountains. BLIP 1 is a transverse ice patch running NNE–SSW across the northern face of the saddle. It was assigned AHRS number XMH-1081.

BLIP 1 has produced the most cultural material of the ice patches visited to date. Artifacts[1] recovered include fragments of two arrow shafts (one complete in three parts), a unilaterally barbed antler point, two pieces of fletching, a sinew lashing, a thick piece of rolled birch bark, and fauna[2] (mostly caribou bones, antler, and antler velvet).

Basalt Lake Ice Patch 2 (XMH-1082)

Basalt Lake Ice Patch 2 (BLIP 2) is located across a valley 1.96 km southeast of BLIP 1. While only 20 m long, BLIP 2 was the largest remnant of a series of transverse ice patches that stretched SSW–NNE across the lower north side of the saddle and promontory landform (Fig. 2). A barbed antler point was discovered on rocks in a melted-out area to the southwest of the remaining ice. The dung under the antler point had begun to revegetate with moss, suggesting the point was exposed for lengthy periods of time during preceding summers. This assessment is supported by the amount of weathering and poor condition of the piece.

Basalt Lake Ice Patch 3 (XMH-1166)

Basalt Lake Ice Patch 3 (BLIP 3) is located approximately 100 m northeast of BLIP 1. Like BLIP 1, BLIP 3 is formed by snow that has been blown from the south and deposited on the saddle's northern face. BLIP 3 is more transverse in shape early in the season, but more longitudinal in nature later as it melts and is left to occupy the gully underneath. In 2003, the outline of this ice patch was clearly defined by a lichen-free zone, with only a thin layer of caribou dung and some small ice fragments remaining. BLIP 3 was initially considered part of BLIP 1. After returning from the field it was noted that BLIP 3 was more than 50 m from BLIP 1, and was therefore assigned its own field and AHRS number. Artifacts found at BLIP 3 include a cut section of antler and a roll of birch bark.

Figure 3. Basalt Lake Ice Patch 1, August 28, 2003. Dark areas on ice and across center of lichen-free zone (lighter gray area around ice patch) are caribou dung. Photo by R. VanderHoek.

1 See Table 3, Cultural Materials from Denali Highway Ice Patches, in VanderHoek et al., Cultural Materials Recovered from Ice Patches, this volume.

2 See Table 2, Fauna from Denali Highway Ice Patches, in VanderHoek et al., Cultural Materials Recovered from Ice Patches, this volume.

2004 ICE PATCH MONITORING

In 2004, OHA personnel visited a cirque glacier in the Clearwater Mountains, and ice patches were monitored in two regions of the Amphitheater Mountains. In early August, OHA personnel visited the remains of a cirque glacier at the head of Surprise Creek valley. Surprise Creek is located in the upper Valdez Creek drainage in the Clearwater Mountains. This site was chosen because the glacier was one of the largest along a historic Native (and later mining) trail that stretched from the Copper River valley to the Valdez Creek region.

All that remained of the glacier were three small patches of ice, the largest less than 15 m long. These glacial remnants were at the eastern head of the valley at the bottom of a rocky headwall. The ice had been regularly covered with layers of scree cascading down from above. Ice patches that form against regularly exfoliating rock walls would appear to have a low probability for finding cultural material, because early historic and prehistoric materials would be destroyed and deeply buried by periodic rock fall.

The Basalt Lake ice patches were revisited and monitored between August 24 and 28, 2004. BLIP 1 had melted from approximately 275 m across in late August 2003 (Fig. 3) to two small fragments, one approximately 13 m long and one less than a meter in length (Fig. 4). Monitoring also included the fossil ice patches along the southern edge of Basalt Lake as well as those along the lower northern edge of the saddle near BLIP 2. BLIP 2 had no visible ice, but excavation through 30 cm of overlying caribou dung in the gully showed an approximately 10 m expanse of ice at the bottom. Gauging from the dung line on the rocks around the edge of the gully, it appeared the ice level in the gully had dropped 1.5 to 2 m in the recent past, possibly within the last year. No new cultural material was recovered at BLIP 1, 2, or 3.

Basalt Lake Ice Patch 4 (XMH-1191)

Basalt Lake ice patch 4 (BLIP 4) is one of several fossil ice patches located along the upper northwestern edge of the promontory south of BLIP 2 (Fig. 2). BLIP 4 was first visited in 2004, when three lithic projectile points and a fragment of wooden shaft were recovered.

Figure 4. Basalt Lake Ice Patch 1, August, 24, 2004. Ice has almost completely melted away, with caribou dung (dark areas) remaining: compare to Figs. 2 and 3. Gulkana Glacier data collected by USGS showed 2004 to have the greatest summer melt since records started in 1966. Grey haze in photo is from summer's forest fires across central Alaska. Photo by R. VanderHoek.

DELTA RIVER ICE PATCHES

A set of ice patches located in the central Amphitheater Mountains west of Lower Tangle Lake, along the northern section of a north-south trending ridge, were identified in 2003 and surveyed in 2004. These were named the Delta River ice patches (DRIPs), due to their location 2.5 to 4 km from the headwaters of the Delta River. As opposed to the Basalt Lake ice patches, where only those with cultural material were given numbers, all significant ice patches visited in the Delta River region were numbered. Faunal materials were collected from DRIP ice patches that contained no cultural material and so identifiers were needed for their location. For this reason, as well as the fact that ice patches may produce no cultural material one year but might the next, it appears prudent when feasible to give a number or other identifier to all ice patches in a region.

Six DRIP ice patches were visited between August 30 and September 2, 2004. Four of the six were longitudinal ice patches, which had formed at the bottom of narrow defiles or gullies. Although the longitudinal ice patches had considerable dung covering them, no cultural materials were found. Two ice patches, DRIP 5 and 6, were transverse patches. A single artifact was recovered from DRIP 5.

Delta River Ice Patch 5 (XMH-1192)

DRIP 5 is located on the northern side of a flat-topped peak 2.5 km west of Lower Tangle Lake. The item recovered from DRIP 5 is a wooden stave-like object 75.5 cm long. It was originally believed to be an atlatl. It was found on a layer of caribou dung on a fossil ice patch at approximately 1,630 m elevation, at a location that was still covered with ice in September 2003 (Fig. 5). The item was later identified as a gopher stick, similar to those used in the Yukon for setting snares for ground squirrels (Johnson and Raup 1964:194).

Figure 5. Delta River Ice Patch 5, late August 2003. By August 30, 2004, this transverse ice patch had completely melted. Arrow shows approximate location of wooden stave found in 2004. Photo by R. VanderHoek.

BUTTE LAKE ICE PATCH MONITORING

A single ice patch near Butte Lake, in the northern Talkeetna Mountains, was chosen for survey after examination of Landsat 7 satellite imagery. The ice patch is located in the middle of the Nelchina caribou herd summer migration path and is the only one available for many kilometers. It is a transverse ice patch and faces north–northwest at approximately 1,310 m elevation. It is 5.7 km from Butte Lake, which is known for its historic burbot and whitefish fisheries (Simeone and Kari 2004:38) and prehistoric/contact period caribou drive camp (Betts 1987).

On July 14, 2004, Bureau of Land Management and OHA cultural resource personnel traveled via helicopter to the small ice patch, located on BLM-managed land southeast of Butte Lake (Jangala 2004). During the initial flyover at least 50 caribou were observed on top of the ice patch, almost completely covering it. A herd of approximately 150 others were visible within a kilometer to the south. Disappointingly, no cultural material was found while surveying the ice patch. John Jangala (2004, personal communication) suggested that this may be explained by a "waterhole effect," where the high use and trampling of the area by caribou causes the destruction and loss of any artifacts that may have melted out.

2005 ICE PATCH MONITORING

The summer of 2005 was a low melt season in central Alaska and northwestern Canada, and proved to be an unproductive one in terms of survey for artifacts emerging from ice patches. BLIP 1 was visited on August 31, 2005. The ice patch measured 510 m long, and nearly covered the lichen-free zone surrounding it (Fig. 6). The edges of the ice patch were surveyed, but no cultural materials were found. BLIP 3, adjacent to BLIP 1, was visited the same day. This ice patch, barely visible in 2003 and completely gone in 2004, nearly filled the depression it rests in. BLIP 2 and 4 were photographed from a ridgetop near Basalt Lake. Both were quite sizeable, with no visible caribou dung. They were not visited. Due to the low melting of the Basalt Lake ice patches and other observable ice across the region, the Delta River ice patches were not visited in 2005.

The single discovery of an ice patch artifact from the Denali Highway region in 2005 was made by James W. Whitney, anthropology curator for the University of Alaska Museum of the North. This discovery was made not in the field but in the UAF museum collections. There he came across a barbed antler arrow point similar to the one discovered at BLIP 2 in 2003 (James W. Whitney 2005, written communication). Museum records show that D. W. Pettyjohn found it in 1957 "on the edge of a

Figure 6. Basalt Lake Ice Patch 1, August 31, 2005. Note how little melting took place in the summer of 2005 in comparison to 2003 and 2004. Photo by R. VanderHoek.

snowfield west of Maclaren Glacier. Elevation 5000 feet." Coincidentally, the Maclaren Glacier lies adjacent to the western edge of the Amphitheater Mountains in the central Alaska Range, approximately 18 km northwest of the cluster of artifact-bearing ice patches at Basalt Lake.

ICE PATCH RECORDING PROCEDURES

Permanent datums were established at BLIP 1 and 2 in 2003 so that these sites could be monitored in subsequent years. These locations were recorded by a Garmin Map 76S GPS unit using NAD 27 Alaska datum. In 2003, BLIP 1 was pedestrian surveyed, with pin flags placed by finds and given field numbers matching the items collected. These items were then recorded with a total station electronic transit. All artifact locations at BLIP 2, 3, 4, and DRIP 5 were recorded by GPS.

The BLIP 1 boundaries were surveyed with a total station (VanderHoek 2007b:Fig. 35) and circumnavigated with a GPS unit in 2003 and 2004. In 2005 the ice patch was again outlined with a GPS (Fig. 7). The use of a GPS unit to lay a trackway trail around the snow and ice extent each fall at BLIP 1 has been found to be a labor-saving way of generating a visual and measurable record of melt on the ice patch from year to year (Farnell et al. 2004:252).

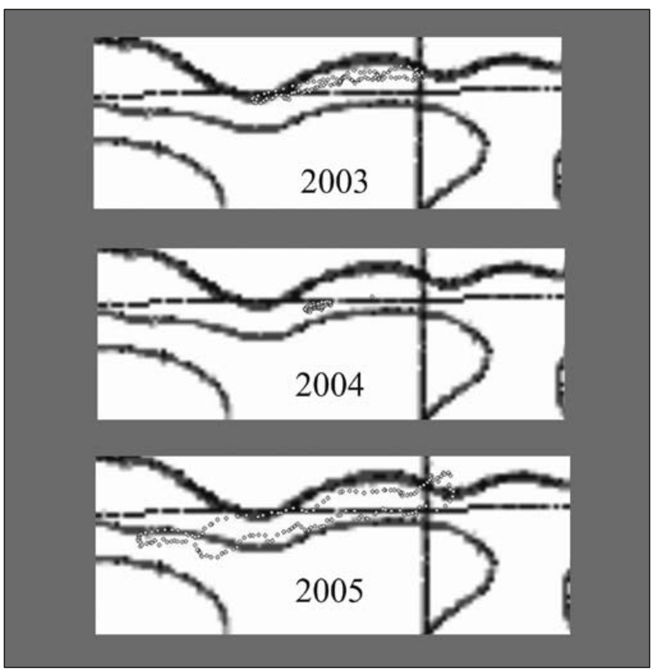

Figure 7. GPS trackways outlining circumference of BLIP 1 in 2003, 2004, and 2005, using Garmin GPSmap 76S. Handheld GPS units provide a rapid, affordable way for monitoring ice patch size/melt year to year. Trackway data from 2004 somewhat overemphasizes size of remaining ice. Ice patch was 510 m long in 2005.

DYNAMICS OF GLACIATION AND ICE PATCH LOCATION

Most ice patches and glaciers in the Northern Hemisphere are rapidly melting. Climate data indicate that the 1990s were the warmest decade on record, with 1998 being the warmest year in the last 1,000 years (World Meteorological Organization 2003). The years 2003 and 2004 were the third and fourth warmest years on record (World Meteorological Organization 2004). Within this overall warming trend, interdecadal climate regime shifts are noted across the North Pacific region, along with shorter frequency interannual El Niño-Southern Oscillation (ENSO) variability (Hodge et al. 1998). Recent work even suggests a connection between ENSO events and warmer and dryer summers in central Alaska (Hess et al. 2001).

The U.S. Geological Survey (USGS) regularly monitors the mass balance[3] of three North American glaciers as part of its Benchmark Glacier Program. These are the Wolverine and Gulkana glaciers in Alaska and the South Cascade Glacier in Washington. Wolverine Glacier is a south-facing valley glacier located on the Kenai Peninsula in southcentral Alaska, with a data record going back to 1965 (Fig. 8). A negative trend of cumulative mass balances for Wolverine Glacier early in its monitoring history was replaced by a growth trend of positive mass balances in the late 1970s and 1980s. This trend is believed to have been driven by warmer winters and increased precipitation during this time (Trabant et al. 1998; Trabant et al. 2003). In the late 1980s the trend reversed, and by the 1990s Wolverine Glacier experienced a strongly negative mass balance (Trabant et al. 2003).

A somewhat different climatic signal is found in the Gulkana Glacier data. The Gulkana Glacier, located on the southern flanks of the Alaska Range, is a south-facing glacier approximately 48 km northeast of BLIP 1. Its mass balance data has been recorded every year since 1966 (Fig. 8). Geologic work on Gulkana Glacier suggests that it has

3 The mass balance is the amount of ice in meters that accumulates over the winter minus the amount of ablation (melting and evaporation) that takes place the next summer.

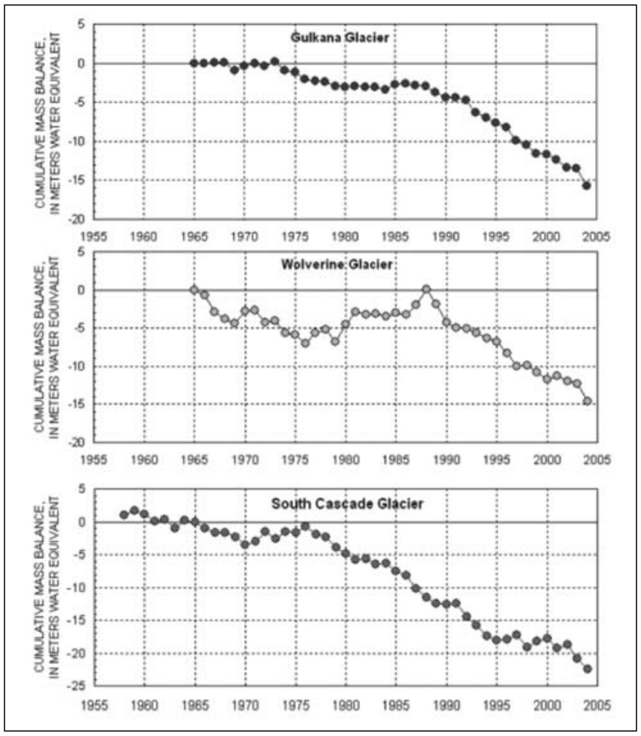

Figure 8. Cumulative mass balance data, Gulkana, Wolverine, and South Cascade glaciers, USGS Benchmark Glacier Program (USGS 2005). Note the steady decline, without replacement, of the Gulkana Glacier.

been actively retreating since 1875 (Reger 1968). The glacier has shown a negative mass balance trend throughout its monitored history, with an average yearly net loss of 0.35 m of ice. The Gulkana Glacier experienced a leveling out of mass balance during the first half of the 1980s (when the Wolverine Glacier went through a period of net ice gain) and then a dramatic period of mass balance loss in the 1990s (Trabant et al. 2003). Between 1966 and 1992, there was only one year where the net mass balance loss for the Gulkana Glacier was over a meter of ice. Between 1993 and 2004, there were five years where net mass balance loss was over a meter. In 2004, the net mass balance loss of the Gulkana Glacier was more than two meters of ice for the first time since recordkeeping began (USGS 2005).

Canadian researchers have noted that satellite and aerial photographs taken between 1960 and 1980 show a period of stabilization for some Yukon ice patches and accumulation for others, with a period of considerable melting during the 1990s (Farnell et al. 2004:252–253). The Gulkana Glacier data suggest that little or no accumulation took place during the earlier period on glaciers in central Alaska. While central Alaska is still influenced by interdecadal climate regime shifts in the North Pacific, like glaciers on the Northwest Coast and the southern coast of Alaska (Trabant et al. 1998; Trabant et al. 2003), periods of snow accumulation on maritime glaciers are not as evident in central Alaska. The interior Alaska glaciers and ice patches are thought by some to be more influenced by local processes or circulation patterns outside the Pacific Ocean basin (Hodge et al. 1998). These ice bodies have experienced rapid melt periods over the last century, interspersed with periods of little or no accumulation or melting. This trend is one of continuing loss without replacement and points to a time in the near future when by late summer there will be no more ancient ice patches to be found in the region. Any cultural materials originally deposited in them will have melted out and will be seasonally exposed to the elements until they decay and disappear.

Ice patch surveys require information about where ice patches are and predictions about those likely to contain cultural material. Satellite imagery[4] and aerial photography are available for locating ice patches, and have been used by OHA and other researchers to find and evaluate ice patches for their cultural potential. Imagery of a region for ice patch location is probably most useful when acquired between mid-June and mid-August, after seasonal snows have melted but before intermittent ice patches have melted away.

The Denali Highway region has numerous snow patches visible in early summer. These are locations where wind-blown snow accumulates through the winter in ravines or on the lee side of ridges or plateaus.[5] During the early summer they are found facing all directions. Those facing in a southerly direction will usually melt completely during the summer. Periodic snow patches like these still provide a location throughout most of the summer for caribou to seek refuge from insects and the heat and may have been excellent ambush locations for prehistoric hunters. Long-term preservation of organic artifacts is expected to be much poorer on seasonal snow patches than on more permanent ice patches. Nevertheless, such places should be surveyed for any artifacts that might remain.

Locations where wind-blown snow accumulates on the lee side of slopes and is shaded from the sun will often

4 Landsat 7, Google Earth (Tom Andrews 2006, personal communication).

5 For an excellent discussion of snow patch formation, see Seppälä (2004:262–275).

survive through the summer. These generally north-facing snow patches melt, compact, and refreeze (Farnell et al. 2004:250) forming a potentially long-lived ice core. As previously noted, these perennially frozen snow patches are what have come to be called ice patches (Farnell et al. 2004; Hare et al. 2004b). Factors involved in the formation of ice patches include latitude, elevation, aspect, geomorphic setting, regional precipitation (particularly winter snowfall), winter wind conditions, catchment basin size, and the warmth and duration of summer temperatures (Christiansen 1998; Lewis 1939; Seppälä 2004). To exist, the ice patches need to gain at least as much snowpack in the winter as they lose to ablation in the summer. This requires enough snowfall throughout the winter, the deposition of wind-drifted snow on the ice patches, and the survival of the ice through the summer. Ice patches form not just in areas of high snowfall, but also in areas of intermediate and low snowfall where ice patches accumulate snow blown in from large catchment basins.

Ice patches commonly occupy depressions called "nivation hollows" (Lewis 1939:153). Nivation is generally considered "the localized erosion of a hillside by frost action, mass-wasting, and the sheetflow or rillwork of meltwater at the edges of, and beneath, lingering snowdrifts" (Washburn 1980:236). The nivation process forms a positive feedback loop, where the formation of a nivation hollow begins to collect snow. This forms a snow patch or cirque, which collects more ice, which deepens the depression, and so on (Locke 2005). This process is poorly understood (Hall 1998), and has been called into question by some authors (French 1996:159).

Ice patches are found near snowline at varying latitudes and elevations across the Arctic. Ice patches on the northern Alaska Peninsula (about 59° north latitude) are found just above 400 m (Dale Vinson 2005, personal communication). Researchers in the Yukon have found ice patches with dung and cultural material at latitudes ranging between approximately 60° and 61° 17' north, at elevations between approximately 1,500 and 2,000 m (Hare et al. 2004b:Table 1). In the Wrangell Mountains (between 61° 15' and 62° 15' north), ice patches begin forming at approximately 1,675 m elevation (Dixon et al. 2005:131, 134, Fig. 2). The ice patches observed in the Amphitheater Mountains (between 63° and 63° 15' North) are between approximately 1,200 and 1,700 m. The Basalt Lake ice patches are between approximately 1,340 and 1,400 m in elevation, while the Delta River ice patches are between 1,450 and 1,650 m. Between 1,500 and 1,700 m, the ice patches with enough volume in the Tangle Lakes region become cirque glaciers. Like ice patches, cirque glaciers in the region have shown a dramatic retreat, with many now half the size shown on USGS maps made from data collected in the 1950s.

Ice patches at high latitudes may be found in areas of low elevation and precipitation, if they are supplied by large enough catchment basins and have short melt seasons. These ice patches exist in cold environments, where temperatures are below freezing for most of the year. An example of this is the large ice patch on the edge of Franklin Bluffs, east of the Sagavanirktok River near the Dalton Highway on Alaska's North Slope. This ice patch, which attracts caribou during the warm season, is located above 69° north latitude,[6] between 150 m and 220 m in elevation, in a region with relatively little snowfall. It appears to owe its existence to cool, short summers, long periods of winter snow accumulation, and a large catchment area.

Canadian researchers have noted that bodies of ice that have the greatest potential for containing artifacts (especially prehistoric artifacts) are those that do not flow (P. Gregory Hare 2003, personal communication). These can be ice patches like those already discussed or larger glaciers, especially those that have sections of stagnant ice. Human remains and cultural materials dating to 500 BP have been recovered from a section of stagnant ice on a glacier in British Columbia (Beattie et al. 2000). Another British Columbia glacier yielded a shaft, presumably an arrow, dating to cal AD 1473–1641 (Keddie and Nelson 2005). Glaciers in the Wrangell Mountains have produced both historic and prehistoric artifacts, including arrow parts and dart sections (Dixon et al. 2004, 2005). Active valley glaciers, like those occupying passes, are relatively short lived and may seldom contain ice more than several centuries old (Dixon et al. 2005:139). These active glaciers are thus less likely to contain prehistoric materials.

While ice patches do not flow like a valley glacier, a Yukon glaciologist has recently noted that large ice patches will slump ("creep flow") over time (Blake 2004). Research has shown that ice patches generally contain relatively few internal layers of dung. When these dung layers are radiocarbon dated, it is found that each layer commonly returns a range of ages (Blake 2004). Major melting periods are believed to cause these thick accumulation layers, termed

6 The Franklin Bluffs ice patch (69° 48' 08" N, 148° 39' 00" W) is visible on Google Earth.

"super layers" (Blake 2004; Farnell et al. 2004:250). Recent visits to several of the largest Canadian ice patches (some over a kilometer long) at the end of high melt summers have revealed "super layers" of caribou dung over the whole surface. These ice patches appear to be quite long-lived and have produced artifacts and caribou skulls dating to more than 8,000 radiocarbon years BP. Smaller ice patches often have more dung deposition around and under the patch than on top of the ice itself. These appear to be shorter-lived and to periodically melt away (P. Gregory Hare 2003, personal communication). It is unclear how often total melting may take place for smaller ice patches, and this may vary from region to region. The ice patches visited or observed from the air in the Amphitheater Mountains generally appear to be relatively short-lived.

Numerous fossil ice patches were observed in the Amphitheater Mountains in 2003 and 2004. These were high melt years for ice patches in the region. Relatively long-lived patches (BLIP 3, with the thousand-year-old chopped antler, and DRIP 5, with the five-hundred-year-old wooden stave) were found to have melted completely away. Some areas inside the lichen-free zone of these ice patches have dung that has been exposed long enough to become vegetated by mosses. The antler point at BLIP 2 was found in one of these areas. Therefore, ice patches, fossil ice patches with caribou dung, the lichen-free zones around existing patches, and even the low-elevation seasonal snow patches are all important locations to examine, because they all may contain cultural material.

ICE PATCH USE BY PREHISTORIC HUNTERS

Prehistoric kill sites are not well known in Alaska. Prehistoric and protohistoric use of caribou fences and drive lanes in Alaska and Canada offer examples of kill sites and communal hunting activities (de Laguna and McClellan 1981:648; Spiess 1979) and are periodically noted in the literature but have seldom been studied (Brink 2005:2). Reasons for this lack of study include the difficulty in finding, interpreting, and (for drive lines) dating these sites, or finding associated cultural material (Brink 2005:2; Fitzhugh 1981:188). With the abundance of overlook and retooling sites documented in the literature, there are many examples of projectile point bases and other implements suggesting the discard and repair of broken hunting implements, but organic technology is lacking or poorly preserved in these sites. With the exception of ice patch and glacial sites of Alaska, the Yukon, and British Columbia, only cave (Ackerman 1996:470; Larsen 1968; Schaaf 1988), permafrost (Geist and Rainey 1976 [1936]; Hall and Fullerton n.d.; Shaw 1983), and wet sites (Knecht 1995) have yielded organic artifacts still hafted to stone tools. Because the ice patch sites were the locus of direct procurement and are reservoirs of well-preserved, dateable organic tools, they offer an unparalleled opportunity to develop an understanding of prehistoric caribou hunting technology.

Though numerous accounts are available of the Athapaskan use of glaciers as travel routes (Cruikshank 2001) and hunting caribou in the high country "near the ice" is a known technique of Inuit hunters (Binford 1978:313), there is a dearth of information on the ethnographic use of ice patches by Athapaskan hunters. Athapaskan hunters with rifles were able to shoot caribou from a greater distance than had been possible with the bow, making it less critical that they hunt caribou in a location amenable for close ambush. Rifles were being imported into the Copper River basin by the Upper Tanana and Upper Ahtna in the 1830s and 1840s, and before the end of the nineteenth century rifles had supplanted the bow and arrow as the chief means of hunting most kinds of game (de Laguna and McClellan 1981:648, 651–652). It is possible that the use of ice patches was discontinued after the regional adoption of the rifle, and they may have fallen from favor as hunting locations.

It is clear that ice patches were used prehistorically by many northern people as part of a seasonal round of resource harvesting sites. Radiocarbon dates on Amphitheater Mountain ice patch material show use of these locations, presumably by ancestors of the modern Athapaskan people, throughout the last millennium. Ethnographic accounts indicate that the Ahtna in the Copper River region used a multiple resource spike camp[7] (VanderHoek 2007a:16) near a lake or stream in the mid-or late summer and fall. A sizeable group of men, women, and children would make this trip into the high country, leaving behind those unable to make the trip to watch the smaller children and to guard the salmon caches. Generally, the women and children would fish, snare ground squirrels and marmots, pick blueberries, and deal with the meat, while the adult men

7 Similar to Binford's (1980:10) "field camp" or the commonly used "base camp," this term is used to denote camping locations centrally located within walking distance of a number of resources.

went into the mountains to hunt caribou and other species. Before snowfall most of the group would return to the permanent winter villages. Hunters left in the mountains would bring the meat back to the villages after freeze-up when lake and river ice was safe for travel (Potter 1997:46; Reckord 1983a:29–30; 1983b:81). A similar pattern was seen ethnographically among the Southern Tutchone of the Yukon Territory. The ice patch hunting sites in the Southern Yukon are within 10 to 15 km or less of known archaeological (multiple resource spike camp) sites in the adjacent valley bottoms, often along lakes (Hare et al. 2004b:262).

Transverse ice patches that form high on the leeward side of saddles, ridges, and plateaus presented an environment that offered prehistoric hunters an opportunity to get relatively close to their prey before being detected. At locations where the ice patch is just below the edge of the hilltop, the break in the slope provides concealment for hunters until they are just above the ice patch and caribou. These hunters, like many modern hunters (especially bow hunters) were aware of the diurnal wind shift and used it in their favor. Summer nights in mountain valleys experience cool down-drafts, while days often have warm updrafts coming up the valley and over the ice patch from below. This allows hunters to stalk the caribou from across the top of the ridge and come down on their quarry from above, both unseen and undetected by smell. The larger bull caribou would probably be found along the top of the ice patches and would have been the most desirable targets because of their greater size, high fat content, and larger antlers (Martin Farris 2005, personal communication). Most of the artifacts found on ice patches in the Amphitheater Mountains have been found along the upper edges, supporting the idea that the caribou were ambushed from above while on the ice.

No rock hunting blinds have been found associated with ice patches in the Amphitheater Mountains, but some have been found in the Yukon (Hare et al. 2004b). The rock blinds in the Yukon are usually located above the ice patches, and it is thought that individuals below the ice patch may have driven the animals up to the hunters in the blinds (Greer et al. 2004), possibly similar to techniques used by the Ahtna for hunting sheep (Reckord 1983b:32).

ICE PATCH ASSESSMENT AND SURVEY

A variety of factors are important in the assessment of an ice patch for the possible presence of cultural materials and prioritization in a survey strategy. Not surprisingly, regions with concentrations of caribou during the summer, or locations that were known to have them in the past, are most likely to have ice patches used by caribou. Researchers should look for the presence of caribou dung, showing regular use by caribou (Dixon et al. 2005; Greer et al. 2004). Ice patches commonly occur in clusters, and when they do it is generally the largest ice patch that produces the most cultural material (Carcross-Tagish First Nation et al. 2005:3). Larger ice patches appear to be more desirable for caribou (giving greater relief from flies) as well as of greater antiquity, increasing the chance for finding older cultural material (Greer et al. 2004). While lower elevation ice patches would have been easier for both caribou and humans to access, higher elevation ice patches may be preferred because of fewer biting insects (Farnell et al. 2004:249). Ice patch proximity to geomorphic features that channel movement of caribou or people may be a significant factor, with those near a pass or other travel route having a higher potential for accumulating cultural material.

The Basalt Lake ice patches are located near both human and caribou travel corridors. An important Ahtna summer trail was located west of Basalt Lake on the eastern edge of the Maclaren River valley. The BLIPs that contained cultural material are on the northern sides of two saddle/promontory complexes on the western edge of the Amphitheater Mountains. These ice patches exist because the southern wind is channeled around the western end of the Amphitheater Mountains and over the saddles and flat-topped promontories, causing snow to accumulate on the north sides. The Basalt Lake saddles also channel caribou movement to and across the ice patches. Deep caribou trails were noted approaching BLIP 2 and 3, and OHA researchers regularly saw caribou approaching the ice patches or crossing the saddles.

Ice patches near areas where resources are concentrated—e.g., lakes and streams, caribou migration corridors, berry patches, ground squirrel and marmot habitat, and lithic sources—would be more likely to have been used by prehistoric hunters. Canadian researchers note that ice patches with cultural material may correlate to the presence of valley-bottom fish lakes (P. Gregory Hare 2003, personal communication), especially those lakes with known archaeological sites around them (Sheila Greer 2006, written communication). Campsites are usually located at these lakes within 10 to 15 km of the ice patches (Hare et al. 2004b:262). The Basalt Lake ice patches (including both existing and fossil patches) form two clusters within a kilometer of Basalt Lake. While Basalt Lake has no significant fish population, Seven Mile Lake, located 2.5 km to the north, is a modern sport fishing destination and may have been a useful prehistoric fishing location.

The Delta River ice patches (DRIPs) appear to be optimally located for use by human hunters. The Tangle Lakes/Delta River corridor in the valley west of the ice patches was a protohistoric travel route and contains many archaeological sites. Lakes with fish are found to the north, southwest, and east (Simeone and Kari 2004:30). A bedrock lithic source is located to the southwest in Landmark Gap. Berries are plentiful in the region, and concentrations of marmots and ground squirrels are available nearby. Sugarloaf Mountain, across the Tangle Lakes valley from the ridge the DRIPs are located on, was called "Ground Squirrel Island" by the Ahtna Athapaskan people who used the area (Kari 1983:62).

Transverse ice patches that form on the leeward sides of saddles, ridges, and plateaus (i.e., BLIP 1 and DRIP 5) have proven to be the most productive type of ice patch for recovering cultural materials, while longitudinal ice patches have been unproductive to date. The OHA's results from the Amphitheater Mountain region match those of other researchers (Tom Andrews 2006, personal communication; E. James Dixon 2006, written communication; P. Gregory Hare 2004, personal communication; John Jangala 2004, personal communication), who also found nothing in longitudinal ice patch surveys. No cultural materials were found on the four longitudinal ice patches examined above the Delta River in 2004, yet each had considerable dung on them, indicating they were repeatedly used by caribou (Fig. 9). Two ice patches found in the bottom of shallow defiles near Basalt Lake (BLIPs 2 and 3; Fig. 2) have lichen-free zones indicating a more transverse history when larger. It may be that the longitudinal ice patches are not as advantageous to hunt caribou on as transverse ice patches. It is also possible that exposed artifacts became buried by alluvial/colluvial deposits along the sides of longitudinal ice patches (Lewis 1939:157) or were washed off by melt water or "slush flows" (Seppälä 2004:276–278) and lost.

Figure 9. Delta River Ice Patch 4 is a longitudinal ice patch, located in the bottom of a ravine. OHA personnel found no cultural material on the longitudinal ice patches surveyed, matching results of other ice patch researchers. Photo by R. VanderHoek.

Modeling the archaeological potential of ice patches can be conducted very explicitly, with variables modeled as layers on a GIS database. This approach was productive when modeling potential survey locations in Alaska's Wrangell-St. Elias National Park and Preserve (Dixon et al. 2005). A series of variables (caribou, sheep, goat, and moose ranges; mineral licks; lithic sources; trails; and archaeological sites) were weighted and combined with land cover classification data from Landsat imagery. These were used to create a map of "site potential values" that highlighted ice patch locations more likely to contain archaeological or paleontological remains (Dixon et al. 2005:135). A qualitative approach was used by OHA (VanderHoek 2003, 2004, 2007b), with variables that included the above as well as fish lakes and multiple resource concentrations. OHA archaeologists used Landsat 7 imagery as a relatively low-cost way to locate potential ice patches. Ahtna and Yukon ethnographic use and archaeological site location patterning were used to prioritize the ice patches for survey. This led to the inspection of two cirque glaciers and approximately 19 existing or fossil ice patches in 2003 and 2004, five of which yielded cultural material.

Ice patch survey would be helped if remote sensing imagery could be used to detect ice patches with caribou dung. The imagery would have to be taken in late summer, in high melt years, when as much caribou dung as possible was exposed. If the spectrographic signature of caribou dung could be determined, this could be used with Landsat 7 multispectral data to highlight those ice patches. OHA personnel contacted Anupma Prakash, an associate professor at the Geophysical Institute, University of Alaska Fairbanks, who agreed to do the spectrographic analysis. Her analysis was performed using the University of Alaska Fairbanks Geophysical Institute high-resolution spectrometer on an approximately one-kilogram sample of thawed caribou dung originally collected in August 2003 from Basalt Lake ice patch 1. The spectrographic readings were taken in Fairbanks in late April 2006 using natural light. Readings were taken at two different heights above the surface of the dung sample, and then again after the dung was "smashed," in an attempt to simulate the natural surface of the dung in the field. Preliminary results were somewhat inconclusive, producing considerable reflectance "noise" in the visible and near-infrared frequencies of the electromagnetic spectrum. A wavelength spike was evident at approximately 1,850 nanometers in all three datasets. No spectrographic search with the 1,850-nanometer signature had been done at the time of publication.

The development of high-potential ice patch models is in its infancy. As such, it runs the risk of eliminating locations that may not fit into a particular model. Yukon researchers caution that the presence of cultural material cannot be verified by a model and must still be groundtruthed (Greer et al. 2004).

Archaeological surveys of ice patches should be done during or after the period of maximum melt, but before the patch is covered with fresh snow in the fall. Canadian ice patches were profitably surveyed starting in late July in high melt years but were otherwise visited in mid-August (Farnell 2004, Sheila Greer 2006, written communication). OHA surveys in the Amphitheater Mountains were usually conducted the last two weeks of August.

CULTURAL RESOURCE MANAGEMENT ISSUES AND RECOMMENDATIONS

Ice patch archaeology is a new concern for land management agencies to deal with on their already full cultural resource management plate. In this regard several points must be kept in mind:

1. **Ice patches are a diminishing resource**. Like an important archaeological site that is being lost to stream erosion, ice patches must be inventoried and surveyed now before they are lost completely. There is no practical way to prevent ice patches from melting.
2. **Ice patch surveys need not be complex or overly expensive**. A sophisticated GIS model, though helpful, is not required. An archaeologist with knowledge of basic anthropological theory, regional ethnographic use patterns, present and past biological resources, and cultural site locations should be able to design and conduct a satisfactory ice patch survey. Remote sensing with Google Earth, Landsat 7, or other imagery is a cost-effective way of discovering and conducting preliminary evaluation of regional ice patches.[8] Expensive airplane or helicopter time should be reserved for examining ice patches for caribou dung and transportation to and from the region. Logistical costs may be moderated by sharing helicopter time with other disciplines or agencies, using fixed-wing aircraft to land researchers on centrally located lakes, and using ground transportation where practical to reach ice patches.
3. **Ice patch surveys must be conducted over multiple years**. While the long-term trend is steady melting, some years may have little or no net loss to ice patches in a particular area. The first three years of ice patch research in the Yukon (1997–99) were high melt years. Researchers were able to survey melting ice patches and find cultural material that had melted out, either from that year, or (if the ice patch had not been surveyed before) in previous years (Carcross-Tagish First Nation et al. 2005:6). The year 2000 was a "zero melt year," and 2001 and 2002 were low melt years where ice patch survey was nonproductive or poorly productive (Greer et al. 2004). The years 2003 and 2004 were high melt years and productive for ice patch surveys, but 2005 again showed little melting.[9] Funding and planning should be flexible enough to shift ice patch surveys to those years where low snow pack and/or high summer melt have exposed more cultural material.[10] Another important reason for planning multiyear ice patch surveys is that as long as ice patches are in existence and melting, they have the potential to produce cultural material. After ice patches with dung

8 See VanderHoek 2007b:Fig. 41 for a Google Earth image of BLIP 1.

9 Compare BLIP 1 in 2003 (Fig. 3) and 2004 (Fig. 4) with 2005 image (Fig. 6).

10 It appears that years with active ENSO events may be higher melt years in central Alaska (Hess et at. 2001). If these events can be noted early they may provide warning of a high-melt summer.

and cultural material have been found, they should be monitored year after year until they melt away, as the potential for additional cultural material is high. Canadian researchers have a 220 cm long, 4,000 year old atlatl dart, the largest complete dart yet found from an ice patch, which was recovered in sections over *four different years* of survey of the same ice patch (Carcross-Tagish First Nation et al. 2005:8; Hare et al. 2004a). Fossil ice patches, with no ice present, still have potential to produce cultural material. Three of the five Amphitheater Mountain ice patches that produced artifacts were fossil ice patches. Artifacts may even be exposed by melt water in the dung of fossil ice patches, years after all ancient ice has melted away (P. Gregory Hare 2004, personal communication).

4. **Thorough ice patch research requires a multidisciplinary approach.** Researchers in the Yukon have set an excellent example for those in Alaska and elsewhere to follow (Hare et al. 2004b; Farnell et al. 2004). The integration of biology, geology, and other disciplines with archaeology not only creates a more detailed picture of the resources and prehistory of a region but also allows the sharing of logistical resources and costs. This can be a critical asset, considering the need to do long-term monitoring of the dung-rich ice patches.
5. **Regional Native communities should be included in ice patch research**. Yukon ice patch researchers have had a close collaboration with Canada's First Nations from the beginning (Carcross-Tagish First Nation et al. 2005:4). Many Native people are interested in regional ice patch research and have valuable ethnographic information to share (Carcross-Tagish First Nation et al. 2005:10; Strand and Greer 2004). Joint Canadian government/First Nations work has demonstrated that a scientific, multidisciplinary approach to studying the past through ice patch research can strengthen traditional values and pride in a people's past (Carcross-Tagish First Nation et al. 2002; Joe 2004).

CONCLUSION

Increased warming across the Arctic and Subarctic is causing ice patches and glaciers in Alaska, the Yukon and Northwest Territories, and British Columbia to melt at an alarming rate. The result of this is that cultural materials, preserved for hundreds or thousands of years in ice, are being exposed to the elements. The artifacts and other materials that have been recovered from melting ice patches and glaciers are unique resources that give us an unprecedented look at how people hunted and lived in the past. It is certain that many prehistorically used ice patches across the Arctic have not been discovered. This is both encouraging and discouraging. It means that northern ice patches hold recoverable materials with tremendous potential to teach more about past human lifeways. Sadly, these artifacts and their potential for elucidating an important part of the prehistoric past will be lost unless immediate action is taken. Land and cultural resource managers alike need to make ice patch survey a priority before these rare, fragile, and irreplaceable items are lost forever.

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