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RESEARCH ARTICLE

Documenting an isolated and high-priority Arctic cultural heritage site: case study from Kapp Pettersen, Svenskøya, Svalbard

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Abstract

With a warming climate, changing weather patterns and increased erosion from various permafrost- and marine-related processes, the cultural heritage (CH) sites in Svalbard are increasingly vulnerable to destruction. Documentation of CH sites in the Arctic can be very difficult on account of the harsh environment, remoteness (and associated costs), limited access time windows and—in Svalbard—the need to obtain permits from local authorities. The main objectives of this study are: (1) to document an isolated and prioritized CH site in Svalbard—the hut at Kapp Pettersen, Svenskøya—using an uncrewed aerial vehicle and ground photography; (2) to identify the effects of coastal erosion and permafrost-related processes on the cabin; and (3) to gain a better understanding of the landscape surrounding the site. We found that the shoreline had retreated, on average, by 0.42 m/yr between 2010 and 2024. This is significantly more than has been documented at other CH sites in Svalbard. The limited number of photographs of the hut meant that a three-dimensional representation could not be made. However, a detailed auditory description of the hut was made during the visit. This study highlights the challenges and limitations of Arctic CH documentation.

Keywords

UAV; permafrost; coastal erosion; polar history; contemporary archaeology

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Abbreviations

3D: three-dimensional
CH: cultural heritage
DEM: digital elevation model
GCP: ground control point
GIS: geographic information system
GPS: global positioning system
NPI: Norwegian Polar Institute
UAV: uncrewed aerial vehicle

Introduction

Documenting CH sites has significantly advanced in recent decades. The development of high-resolution sensors and sophisticated software solutions has facilitated the creation of detailed 3D models, which are essential for comprehensively documenting CH sites that are increasingly vulnerable to environmental and human-induced risks (Soler et al. 2017; Buragohain et al. 2024). Documentation of CH is limited in many polar regions, which are warming two to three times faster than the global average (Rantanen et al. 2022). Research in this regard began in 2010 in Antarctica and Svalbard using repeat photography (Roura 2009) and has been further explored with 3D laser scanning for the conservation of Fort Conger, Arctic Canada (Bertulli et al. 2013; Dawson et al. 2013; Dawson & Levy 2016) and Inuit architecture (Dawson et al. 2009; Dawson & Levy 2013). The management of Alaskan heritage has made use of UAVs (Lim et al. 2022). In Svalbard, 3D laser scanning has been used to virtually reconstruct a mining building at Camp Asbestos (Lewińska & Zagórski 2018), to document small-scale industrial heritage threatened by coastal erosion (Nicu, Rubensdotter et al. 2021) and to document large-scale industrial heritage in the settlement of Svea (NRK 2023). The harsh conditions of the cold regions limit the time available for data collection to a few months per year, while the remote locations impose enormous costs in terms of coordination and field planning. In addition, the Arctic CH is subject to the effects of cryospheric hazards (Nicu & Fatorić 2023), such as biological degradation (Flyen & Thuestad 2023; Hollesen et al. 2024), coastal erosion (Darwent et al. 2019; Nicu et al. 2020; Tanguy et al. 2024), thaw slumps (Walls et al. 2020; Nicu, Lombardo et al. 2021), solifluction (Rubensdotter et al. 2025) and thermo-erosion gullying (Nicu et al. 2022; Nicu et al. 2024). Arctic (cruise) tourism is also increasing (Flyen et al. 2023; Tømmervik et al. 2025).

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As indicated by Hollesen et al. (2018), of the nearly 180 000 registered CH sites across the Arctic, 4590 are in Svalbard. The history of Svalbard has been shaped by whaling during the 17th century, hunting, trapping and scientific exploration in the 18th century and industrialization during the last two centuries. The remnants of these eras and activities hold the status of protected CH sites. The Svalbard Environmental Protection Act states that all cultural remains from before 1946 are automatically protected. Furthermore, all remains of animal and human bones and bone fragments discovered on or beneath the surface of the ground, along with any evidence of human graves, including crosses and other grave markers, are automatically protected, regardless of their age. The protected CH sites are buffered by a 100-m protected area surrounding them; these zones are protected by the same regulations as the cultural remains themselves (Governor of Svalbard 2019). This buffer area is of equal importance to the site itself. Ninety-nine priority sites have been designated as urgent for preservation because of their extreme vulnerability to a combination of environmental and human threats (Albrethsen 1989; Arlov 2005; Sandodden 2013a; Tavakoli et al. 2023).

In 1936, the Norwegian state built four huts, using the state's crisis funds, to assert Norwegian authority in Svalbard (Rossness 1993). During mining director Hans Merckoll's expedition to the eastern regions of the archipelago, the huts were set up for use as emergency shelters—in the case of shipwreck, for example—and for hunting. Svalbard's northernmost hut, in the bay of Isflakbukta on the island of Phippsøya, is among these. Two huts are in the group of small islands that make up Kong Karls Land: one at Kapp Pettersen on the island of Svenskøya and one at Kapp Koburg on the island of Kongsøya. The fourth is at Heimland on the island of Barentsøya. The Phippsøya, Kapp Koburg and Kapp Pettersen huts were designed by Anders Orvin from Norway's Svalbard and Arctic Ocean Survey, which later became the Norwegian Polar Institute (Rossnes 1993). The four huts that were erected during Merckoll's expedition were described as being in relatively good condition in 2011 (Sandodden & Yri 2011).

According to the Governor of Svalbard, the huts should be maintained so that they continue to serve as emergency shelters (Sandodden 2013b). Moreover, the four huts are worthy of preservation as rare, well-preserved and well-documented symbols of Norway's sovereignty in Svalbard and as technical and architectural artefacts of interwar polar strategy (Sandodden 2013b). Of the four huts, only the hut at Kapp Pettersen is in the *Catalogue of the cultural heritage sites with high priority in Svalbard*, where it is listed as entry 32 (cultural heritage identification number 92704-1; Sandodden 2013b).

Here, we document the hut at Kapp Pettersen, an isolated and prioritized CH site, using UAV and ground photography. We also identify the effects of coastal erosion and permafrost-related processes on the cabin, improving our understanding of the landscape surrounding the site.

Study site

An archipelago of significant ecological and geopolitical importance, Svalbard has an area of approximately 61 020 km^2 (Zwoliński et al. 2013) and is about halfway between the northern coast of continental Norway and the North Pole. Spitsbergen is the largest island in Svalbard and the only one with a permanent population. Our study area is in the eastern part of the Svalbard, on the island of Svenskøya ("the Swedish island"), which is the westernmost and second largest of the islands of Kong Karls Land (Fig. 1). The hut is at Kapp Pettersen, in the north-eastern part of Svenskøya (Fig. 1c). The place is named after Karl Johan Pettersen (1826–1890), the Norwegian geologist who published an account of the discovery of Kong Karls Land (NPI 1942). Svenskøya is about 21 km long and 6 km wide. A large part of the island is low-lying and formed of well-preserved beach deposits (Fig. 1d) dissected by a distinctive drainage pattern. Salvigsen (1981) documented uplifted beaches up to 120 m a.s.l., with the highest dated Holocene age beach at 70 m a.s.l. (8940 ± 110 years in age). An axial ridge runs the length of the island, with altitudes ranging from 260 m in the north to 180 m to the south. The north–south ridge forming the backbone of Svenskøya rises to its highest point in the north at Mohnhøgda (283 m a.s.l.; Fig. 1e; Smith et al. 1976).

Eastern Svalbard has a High-Arctic climate, with average temperatures about −13°C in winter and 5°C in summer (Førland et al. 2020). The island undergoes polar night from mid-October to mid-February and polar day from mid-April to mid-August. The area is influenced by the cold East Spitsbergen Current, which contributes to colder sea temperatures and persistent ice cover in winter. Sea ice does not persist around Svenskøya during the summer months (Førland et al. 2020). Svenskøya is an important denning site for polar bears; potential appearances by polar bears must be taken into account throughout the year by any expeditions to the island (Siegel & Cummings 2005). Svenskøya is one of the most isolated areas in Svalbard. It falls under the direct protection of the Governor of Svalbard as part of the Nordaust-Svalbard Nature Reserve. Human access to the island is significantly restricted to protect its flora and fauna.

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Fig. 1 (a) The location of Kong Karls Land in Svalbard (base map from Esri 2024). (b) The location of Svenskøya and the study site in Kong Karls Land (base map: NPI no date). (c) Satellite image of the site at Kapp Pettersen, with the hut marked with a yellow dot and the hatching indicating the surrounding zone of legal protection around it. (d) View—from the south-east toward the north-west—of the area around the hut from the UAV flight. (e) Photograph of the hut (from the south-east toward the north-west), with the background topographical features labelled.

Fieldwork

In August 2024, as part of the HarSval project (HarSval 2024), an expedition to the eastern part of Svalbard investigated and documented CH sites in the *Catalogue of cultural heritage sites with high priority in Svalbard*. The Kapp Pettersen cabin was one of the CH sites selected, partly because a boat could be landed near it. At the time of the survey, the sky was clear, and the temperature was about 10°C. As prescribed by the research permit obtained from the office of the Governor of Svalbard, the number of personnel was limited to three and only a single landing took place.

UAV survey

During the UAV survey, on 18 August 2024, the DJI Phantom 4 Pro drone took 349 timelapse photographs at 3 second intervals during a single manual flight at an average height of 21 m above ground. Eight GCPs were distributed across the flight area, and their GPS coordinates were taken using a handheld Garmin Montana 700. The images were processed using Agisoft Professional software (version 2.0.3). The images were aligned at the highest accuracy and generic preselection. GCPs were identified in ≥ three photographs for precise georeferencing. The horizontal GCP error was 2.31 m. A point cloud was produced at high quality and mild depth filtering. Points with confidence < 3 were filtered out. A mesh model, an orthophoto mosaic and a DEM were generated. The DEM and an orthophotomap were exported at 10 cm resolution. These were then integrated into a GIS, and the elevation was matched to the 2020 orthophotomap.

Ground photographic documentation

The interior and exterior of the hut were photographed with the camera (108 megapixels) built into a rugged mobile phone (iHunt Titan Metal 22000 Projector PRO). To make the best use of the approximately 30 minutes that we could be at the site, an auditory description of the hut and its state of conservation was recorded during the visit.

GIS analysis: coastal erosion and geomorphological observations

The remote location of Svenskøya relative to Spitsbergen results in a comparatively limited database of high-resolution remote sensing data, such as UAV and aerial imagery. Moreover, the small size of the site poses a challenge for utilizing publicly available satellite imagery. The orthophotomap created from the UAV photographs in 2024 (10-cm resolution) and the 2010 orthophotos (5 × 5 m resolution) available online through the NPI's Map and Data Services were used to quantitatively assess the coastal erosion. Coastal retreat was then projected into the future using a simple linear extrapolation as an indicator of upcoming change.

Results and discussion

Erosion and other geomorphological observations

The hut is in the central part of a small cape that has been shaped by the accumulation of pebble and gravel-dominated beaches around bedrock ridges. Two main marine terraces mapped above the present storm ridges are covered with periglacial sorted marine sediments and a well-developed ice wedge polygon network, which suggests the presence of permafrost beneath the raised beaches (Fig. 2d).

The distance from the hut to driftwood near the shore to the west of the structure is 88 m (Fig. 3). The western shore of the cape exhibits intense erosion and undercutting of cliffs that are about 2 m high and comprise pebble and gravel. On that western shore, erosion has advanced by 8 m between 2010 and 2024. There is thermo-erosion gullying (Fig. 2b) on this shore, about 100 m west of the hut, which is too far away to pose an immediate threat to the structure.

The distance from the hut to the eastern shore is 28 m. This shore is much less steep than that to the west, but it is marked by massive storm ridges (Fig. 2c), and storm waves have carried drift logs tens of metres inland. The eastern shore has receded by about 6 m from 2010 to 2024, which works out to an average shoreline retreat of 0.42 m/yr. At this rate, erosion will reach the hut in about 65 years.

This rate of 0.42 m/yr exceeds rates calculated in other studies in Svalbard assessing shoreline retreat in the vicinity of CH sites. Shoreline retreat rates between 0.14 and 0.21 m/yr were documented near another high-priority CH site, the cable car from Hiorthhamn (Nicu et al. 2020; Nicu, Rubensdotter et al. 2021). The retreat rate around Calypsostranda was assessed at 0.07 m/yr (Zagórski et al. 2020). In Isbjørnhamna, where the infrastructure of the Polish Polar Station Hornsund and CH are frequently damaged by storms, the mean shoreline retreat rates from 1960 to 2011 were ca. 0.26 m/yr (Zagórski et al. 2015). The significantly higher rate of shoreline retreat observed at Svenskøya compared with the Isbjørnhamna area can be attributed to the location of the former in the open Arctic Ocean. Unlike sheltered Isbjørnhamna, Svenskøya's coast is directly exposed to the full force of ocean waves and currents and, hence, more intense erosion processes, such as wave undercutting.

The condition of the hut

Because of a rotten plank blocking the door, we had to remove the door to enter the hut (Fig. 4). (The door was put back in place upon our departure.) As seen from the entrance, some of the floorboards are rotten. A large pile of firewood occupies the first of the hut's two rooms. Birch bark, waxed paper and coal—for making a fire—are stored in a wooden box. On the left, lying on a piece of wood, there is a small knife for making kindling. Three rusty hacksaws—only one of which still has a blade—hang from the ceiling. An inscription on the right wall of the room dates from the building's construction: "1936 BYGGET AV DEN NORSKE STAT" (1936 BUILT BY THE NORWEGIAN STATE). Above this, someone has commemorated a visit in less formal lettering with the words "BIG BOB STEVENS ANCHORAGE, ALASKA SEPT. 20, 1965, KILROY WUZ HERE!", illustrated by the graffiti character that was popular among US soldiers during World War II.

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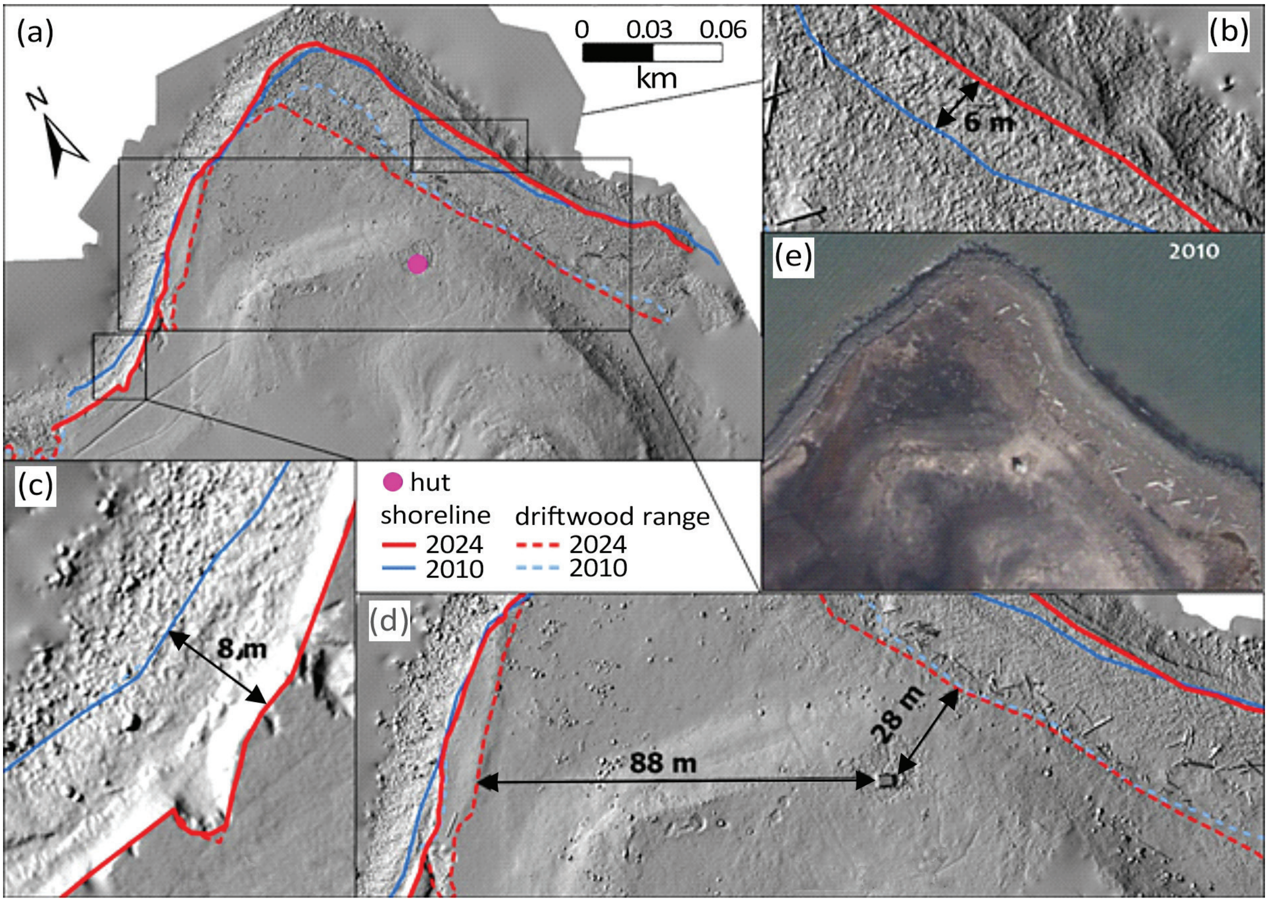

Fig. 2 Orthomap images showing (a) the small cape where the hut (pink dot) is located, the retreat of the shorelines to the (b) east and (c) west of the structure and (d) the distances between the hut and the nearest storm-deposited driftwood in each direction. (e) The NPI orthophoto from which the 2010 shoreline and driftwood range was interpreted (NPI 2010).

Two bunk beds are on the left as one enters the second (main) room. There is an axe on the lower bed. Under the lower bed, there is a rusty scoop, firewood and what appear to be the remains of a foam sleeping mattress. The floor in this area is rotten, and care must be taken to avoid further damage. In the right corner, on top of a wooden box, is a woodstove with a rusty pipe. A small green paraffin lantern hangs on the wall, and a larger white lantern—"Made in W. Germany" by Feur, with a Jenaer glass shade—stands on the floor. A small wooden bench and a metal container for paraffin are next to the woodstove. Above the bench, there is a small window; it appears that the entire original window has been replaced. A postcard at the end of the upper bed is dated to 1992.

The cabin is 3.2 m by 2.2 m. Its slightly sloping roof is 2.5 m high at the front and 2.05 m at the back. Bitumen sheeting completely covers the roof and the western side of the hut and partially covers the rest of the hut, where it is torn in places; pieces can be seen on the ground. Driftwood and pieces of cut wood are scattered outside of the hut; on the south side of the hut, the wood has been heaped up. Stones are piled against the back (south), west and part of the north sides of the hut, probably to reduce drafts. The small number of photographs taken at the site was not sufficient to produce a 3D representation of the hut.

Material degradation in the Arctic context

The wooden floor absorbs moisture from the (frozen) ground and the atmosphere. During the brief summer thaw, meltwater or condensation may form under the floor, where restricted airflow slows drying and fosters rot. Salt spray and nearby salty driftwood may accelerate wood decomposition, potentially affecting the whole structure. Inside, the wooden bunk beds have limited contact with the floor and the moisture, microbes and fungi that may be under it. Air circulates more freely around the beds, limiting dampness.

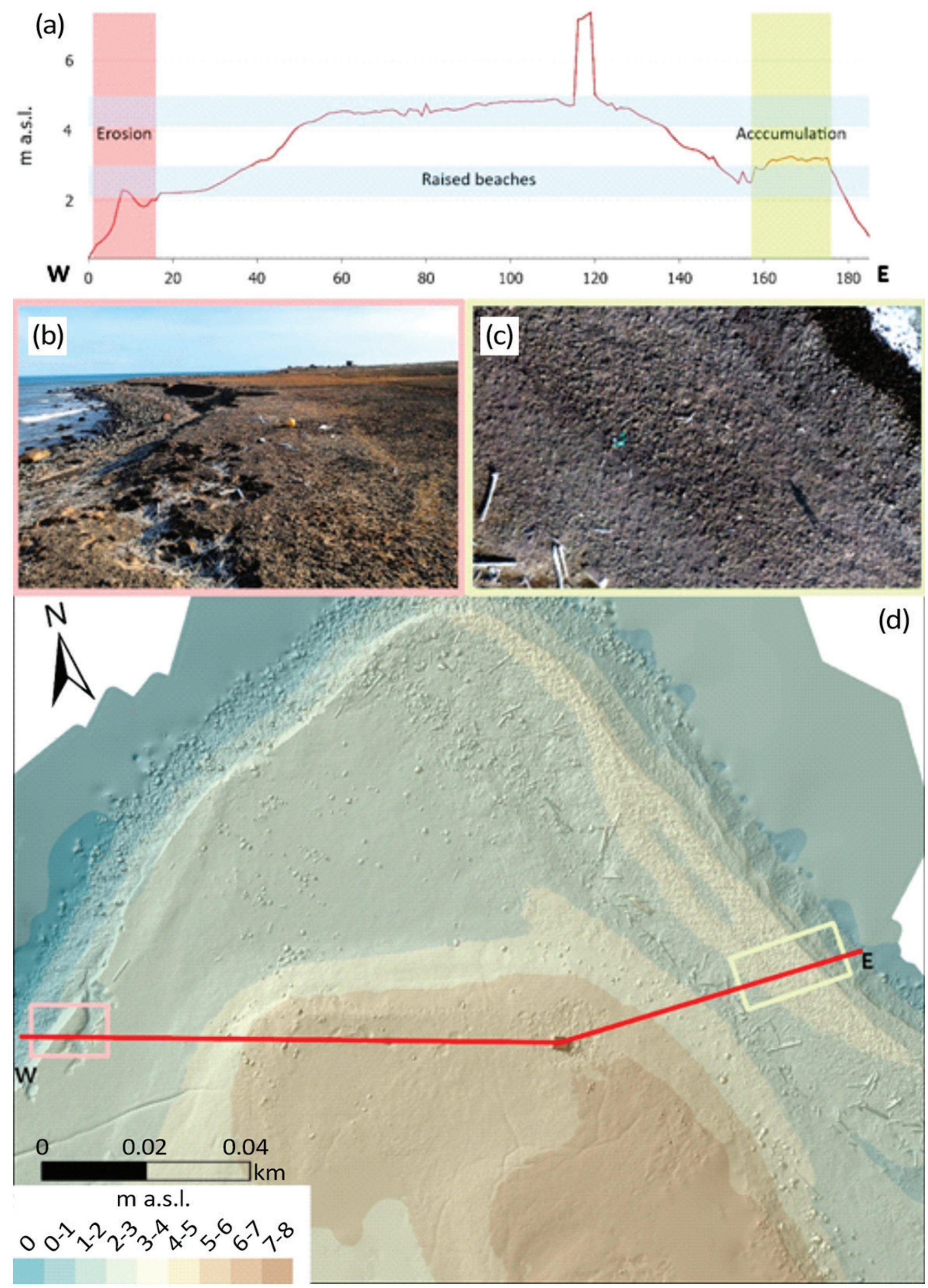

Fig. 3 (a) Cross-section of the DEM of the area around the hut, highlighting the erosion zone in the west (pink) and the accumulation zone in the east (yellow), as well as two raised beaches (blue). (b) Ground photograph of the erosion zone. (c) Drone photograph of the accumulation zone. (d) Details of the DEM of the area around the hut.

Used to insulate and waterproof, bitumen sheeting is subject to mechanical damage from winds, snow and thawing and refreezing meltwater. Ultraviolet light exposure—limited in winter but intense during the summer months—contributes to breaking down the bitumen. The resulting gaps let moisture infiltrate the structure. Bitumen is more resistant to rot and biological degradation than many other organic materials, but its failure often sets off accelerated internal decay.

Metal objects, such as the lanterns and saws, are prone to rust caused by humidity, condensation (especially inside small, infrequently heated huts like this one) and salty air.

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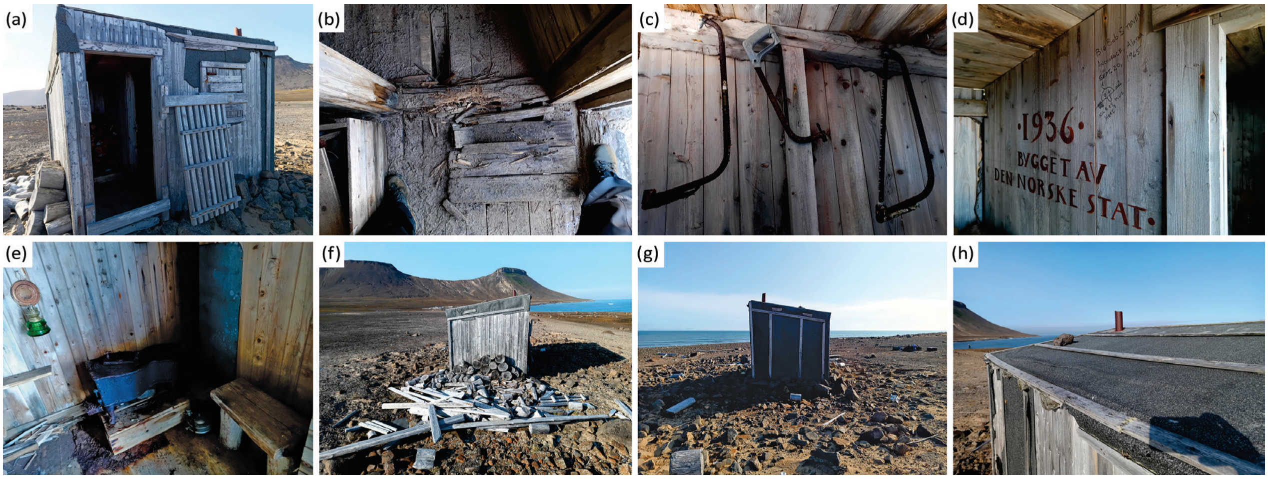

Fig. 4 (a) The front of the hut with the door cover placed to the right of the doorway (the door itself is inside the hut). (b) Just inside the entrance. (c) The hacksaws hanging on the left of the main entrance. (d) The inscriptions. (e) The woodstove, bench, lanterns and metal paraffin container. The cabin exterior (f) looking from the south-east toward the north-west and (g) from the north-west toward the south-east. (h) The roof and stovepipe.

Conclusions

The documentation of CH sites in the Arctic and Antarctica has made remarkable progress in recent decades, driven by advances in high-resolution sensors, 3D modelling technologies and UAV-based surveys. However, the harsh environmental conditions, remote locations and accelerating impacts of climate change pose significant challenges to the preservation and documentation of these sites.

Our study of the Kapp Pettersen hut, a high-priority CH site in Svalbard, reveals that it has remained in relatively good condition despite its exposure to harsh Arctic conditions. The study also highlights the threat of coastal erosion as the shoreline is receding toward the hut at a rate of 0.42 m/yr, calculated on the basis of measurements in 2010 and 2024. This rate is significantly higher than those documented at other CH sites in the archipelago.

The methodological approach employed in this study, which combines UAV surveys, photographic documentation on the ground and GIS analysis, proved effective in capturing spatial detail despite the logistical challenges of working in a remote and extreme environment. However, the limited time available for fieldwork and the reliance on a small number of photographs meant that a comprehensive 3D model of the hut could not be made. Another limitation of our study is that we did not undertake a comprehensive assessment of cryospheric hazards that may affect the hut and the area around it. There have been a few recent studies addressing this issue (Walls et al. 2020; Rubensdotter et al. 2025). The limitations and challenges of our work provide lessons for future researchers who can adapt the CH documentation protocol (Parrinello et al. 2019) in the cold regions of the globe, including Antarctica (Pearson et al. 2009).

Future efforts should prioritize longer fieldwork and more advanced documentation techniques, such as a portable 3D laser scanner, to enhance the accuracy of CH site documentation and assessment. Further studies should undertake more comprehensive evaluations of potential cryospheric hazards, thereby establishing a solid foundation for effective preservation strategies. The insights derived from this study can inform similar initiatives in other cold regions, contributing to the global effort to protect CH in the face of climate change.

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Disclosure statement

The authors report no conflict of interest.

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