Site Description & Literature Review of Cape Hallett & Surrounding Areas

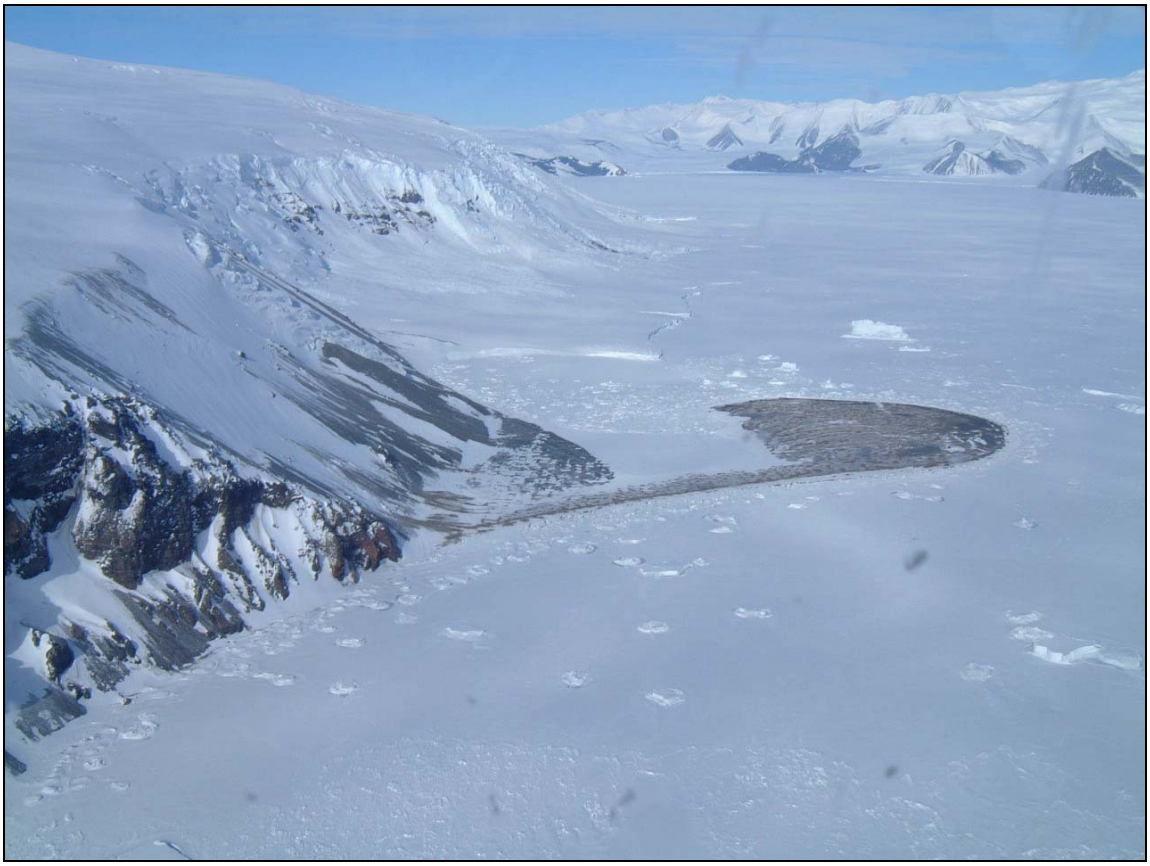

Photo: Antarctica New Zealand Pictorial Collection

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CONTENTS

Contents

SITE DESCRIPTION & LITERATURE REVIEW OF CAPE HALLETT & SURROUNDING AREAS

This section is provided to give a description of the physical characteristics of the Cape Hallett area, especially for those unfamiliar with the location, as well as a review of the research that has been undertaken in the area that pertains to the LGP. The review is by no means comprehensive, but should present the most prominent work that has been carried out in the Cape Hallett area.

Air photos of Cape Hallett can be viewed and downloaded from Gateway Antarctica's website.

A topographic map of Cape Hallett (1970) can be viewed and downloaded from the USGS's Atlas of Antarctic Research website. Antarctica New Zealand does not currently hold maps of Cape Hallett. No detailed topographic maps of Seabee Hook exist.

1. LOCATION

Cape Hallett (72º19´S 170º16´E) is located at the southern end of Moubray Bay, northern Victoria Land, in the western Ross Sea (Figure 1). It forms the northern tip of the 32 km long by 8km wide, north-south aligned Hallett Peninsula which extends south to Cape Wheatstone and is joined to the mainland by a narrow ridge between Tucker Glacier and Edisto Inlet. The low point of this ridge is the broad Football Saddle (700m). Projecting about 1200m west from the high rocky ridge forming Cape Hallett is Seabee Hook (Figure 2) a low (generally less than 5m above sea level), recurved spit composed of coarse volcanic material, of between 130 and 575m wide, with a total area of approximately 41.1 ha. Willett Cove is a small bay enclosed on the south side of Seabee Hook.

2. HALLETT STATION

Hallett Station was established on Seabee Hook at Cape Hallett in 1957 as part of the International Geophysical Year (IGY). The joint New Zealand/US year-round research undertaken at this station was primarily concerned with auroras and airglow, ionospheric physics, geomagnetism, seismology and meteorology. Biological studies became more prominent in the 1960s, especially after 1964 when summer only operations started. The station was also useful for providing weather reports, supporting communication systems and as an emergency landing field as it was located along the flight path between New Zealand and McMurdo and Scott Base stations. Hallett Station was finally abandoned in February 1973.

Between 1984 and 1987 a joint New Zealand/US clean up operation of the station demolished buildings and burnt them on site. Non burnables such as scrap steel, old vehicles and other equipment were hauled out onto the sea ice and allowed to melt through the ice. The site has been gradually cleared up since it closed 29 years ago, but it is still the most significant remaining deactivated station or camp site in the Ross Sea region (Gilmore, 2001). A recent Environmental Impact Assessment of the area (Gilmore, 2001) has suggested further remediation for the site.

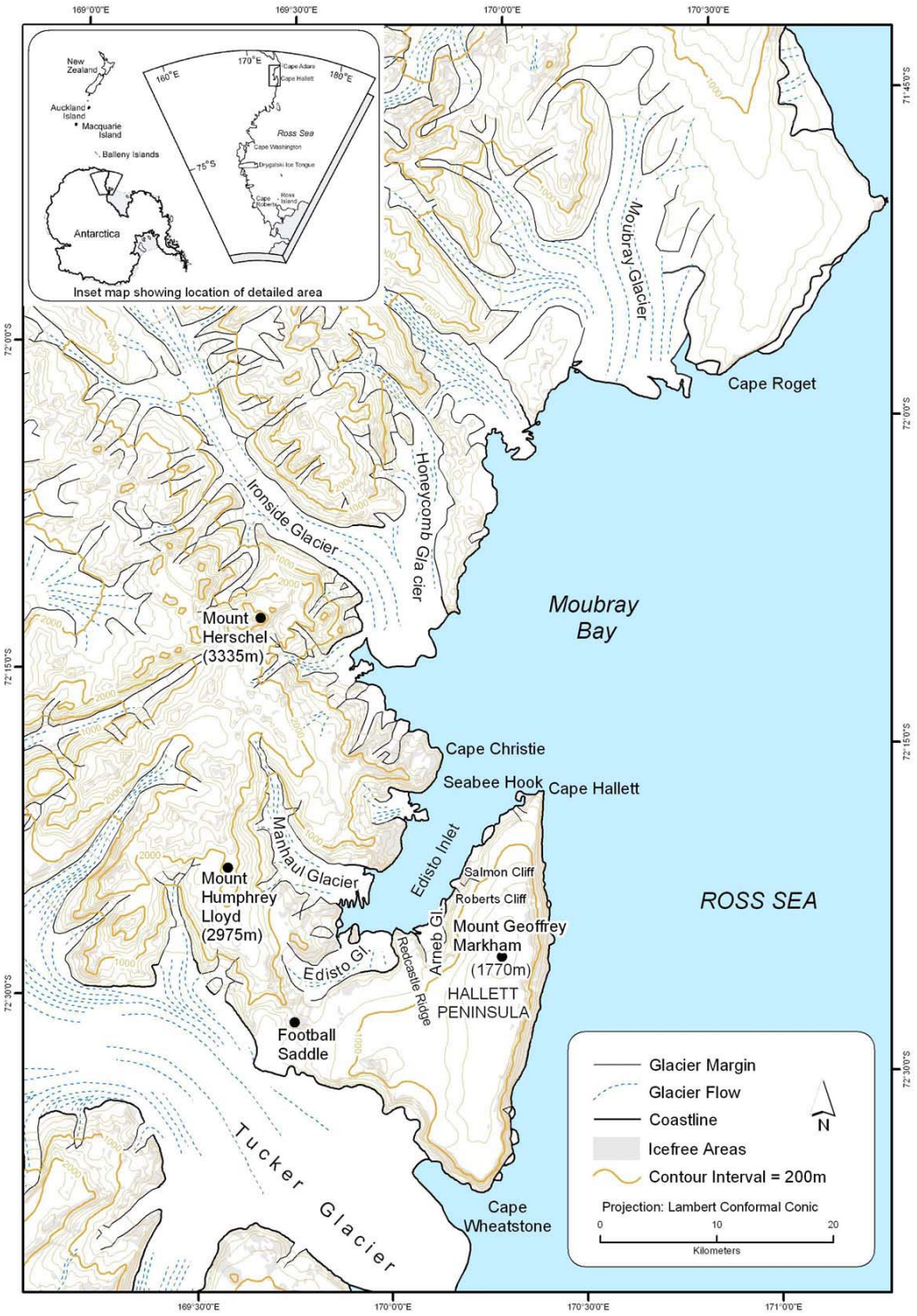

Figure 1. Hallett Peninsula and surrounding areas with the location of features described in the text.

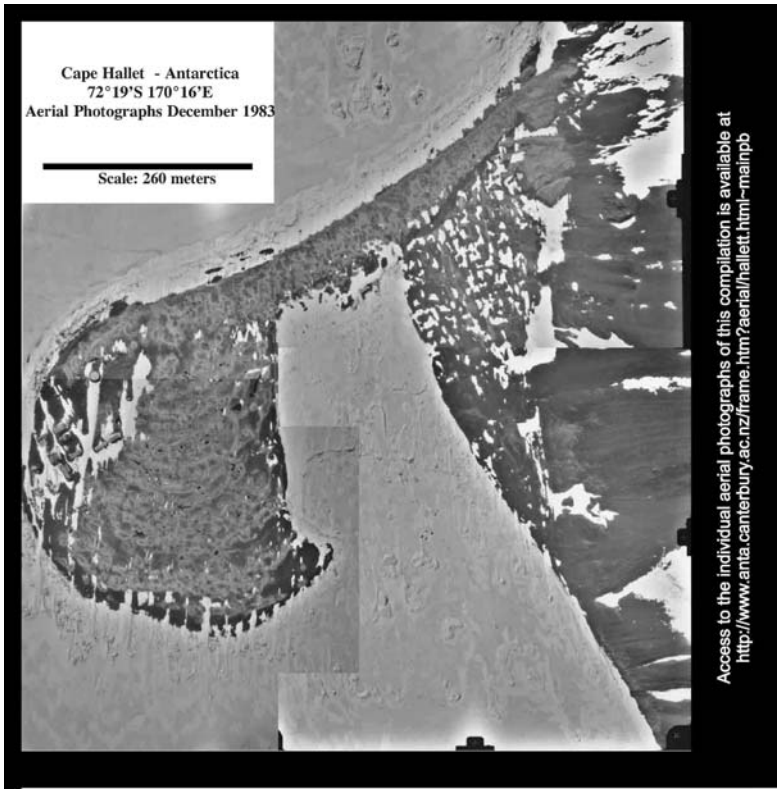

Figure 2. Composite aerial photographs of Seabee Hook. *Courtesy of Gateway Antarctica and Brent Sinclair.*

3. PHYSICAL GEOGRAPHY

3.1 Geology

The Cape Hallett-Tucker Glacier district is characterised by alpine-type ranges to the west rising to heights of 3800m. A linear chain of coastal volcanic mountains up to 1800m is separated from the interior mountains by a topographic corridor extending from Robertson Bay to the north through Edisto Inlet and the Whitehall Glacier to Lady Newnes Ice Shelf in the south (Wood, 1963).

The basaltic, dome-shaped Hallett Peninsula is bound by cliffs of 1500m on its eastern seaboard and 300m on its western side. Its highest point is the extinct 1770m shield volcano, Mt Geoffrey Markham. Volcanic rocks are exposed along the cliff sections of the peninsula, in particular at Salmon Cliff and Roberts Cliff on the eastern face of the peninsula. These are separated by the Bridgeman Glacier.

The most extensive geological and topographical study of the Cape Hallett area is that of Harrington et al. (1967). This study describes the topography and geology of the Cape Hallett District of Victoria Land, extending for 140 km along the coast from Robertson Bay to the Lady Newnes Ice Shelf, and for about 120 km inland along the line of the Tucker Glacier, based on investigations carried out by the New Zealand Geological Survey Antarctic Expedition, 1957-58.

Other geological investigations in the Cape Hallett region include those by Turnbull (1959) who demonstrated that reversals in the direction of magnetisation had occurred in the Cape Hallett lavas, and that these could be representative of the reversals of the main magnetic field of the earth; Hatherton (1960) who measured the electrical resistivity of the frozen ground at Seabee Hook; and Delisle (1983) who demonstrated that Hallett Peninsula lavas are geologically younger than Adare Peninsula basalts from palaeomagnetic measurements on Upper Tertiary volcanics.

3.2 Glaciology

A mantle of undulating ice covers all but a few protruding scoria ridges on Hallett Peninsula. Most of this ice drainage is westward, mainly into Edisto Inlet, where glaciers drape the cliffs on the east side of the bay (Harrington et al., 1967). Much of the drainage from the central part of the peninsula is concentrated into the Arneb Glacier which flows into Edisto Inlet.

The Arneb, Edisto and Manhaul Glaciers are the three main glaciers that flow in to Edisto Inlet and terminate in floating tongues. The only published examples of glaciological studies are from Harrington et al. (1967) who sampled snow pits on the Tucker Glacier and took ablation and velocity measurements on the Edisto Glacier.

Satellite data from 1979 to the present (Falconer and Pyne, 2000) demonstrates that the sea ice at Cape Hallett usually breaks-out on an annual basis. This break-out starts around the end of December to early-January. The sea ice closes back in around the beginning of March.

3.3 Geomorphology

Deposits examined at Redcastle Ridge, a volcanic ridge separating the Edisto and Arneb Glaciers, are considered to be fans and raised beaches. These were correlated with other deposits in Edisto Inlet and it is suggested that two old beach levels are present and that these may be of post-glacial and last interglacial age respectively (Campbell and Claridge, 1966).

The coarse volcanic material of Seabee Hook which extends westwards into Edisto Inlet from Cape Hallett is deposited in a series of beach ridges, with gently undulating terrain of hummocks and depressions and a number of level areas. The depressions are prone to filling with water during the summer melt. The spit is an extension from a slightly earlier, rougher, triangular beach, on the leeward side of Cape Hallett (Harrington and McKellar, 1958) with an apron of scree at the base of the high cliffs of the cape.

Much of Seabee Hook is occupied by an Adèlie penguin rookery. In the area covered by the rookery, the beach is composed of pebbles, guano, flattened hard, permanently frozen bodies of penguins and the general debris of penguin occupation overlying 60cm and more of clean beach gravel devoid of organic remains (Harrington and McKellar, 1958).

Chemical analysis of Cape Hallett soils were undertaken by Boyd et al. (1966). The soil at three Seabee Hook sites have also been described (McCraw, 1967): on the scree slope below Cape Hallett, on the beach gravel of the spit, and on the guano covered part of the spit. Guano soils have been termed ‘ornithogenic soils’ (Campbell and Claridge, 1987) as the organic matter in these soils does not accumulate by biosynthesis in situ but is brought to the rookery during the summer period when the penguins are ashore. The organic matter is contributed in the form of droppings, feathers and bird remains. The organic matter in

these soils (low grade guano) is described as having a reddish brown colour to depths of 10-15cm, grading into darker coloured organic horizons, then into underlying mineral deposits (McCraw, 1967).

4. METEOROLOGY

Year-round meteorological measurements were taken at Hallett Station during its operation from February 1957 to February 1963, and some summer data were collected after 1963 (U.S. Weather Bureau 1962-1965). Data included 3-hourly surface temperature (Figure 2), wind speed and direction (Figure 3), ceiling visibility, number of days with snow or rain, and inches of rain and snowfall. Average values of these observations from 1957 to 1963 are cited in Guthridge (1983) from data published by the US Weather Bureau.

Acknowledgement is due to Lynn Lay from the Byrd Polar Research Center library for supplying copies of Hallett Station meteorological data from the relevant U.S. Weather Bureau publications.

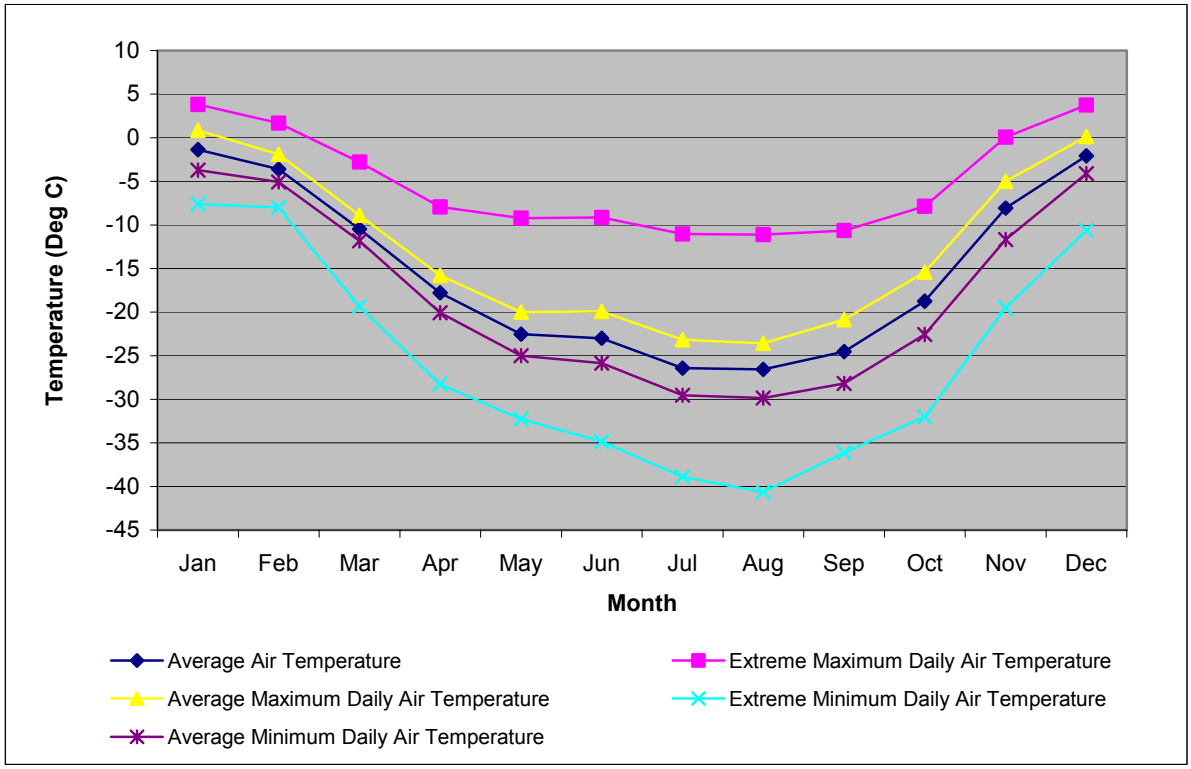

Figure 2. Mean monthly temperatures at Hallett Station 1957-1964.

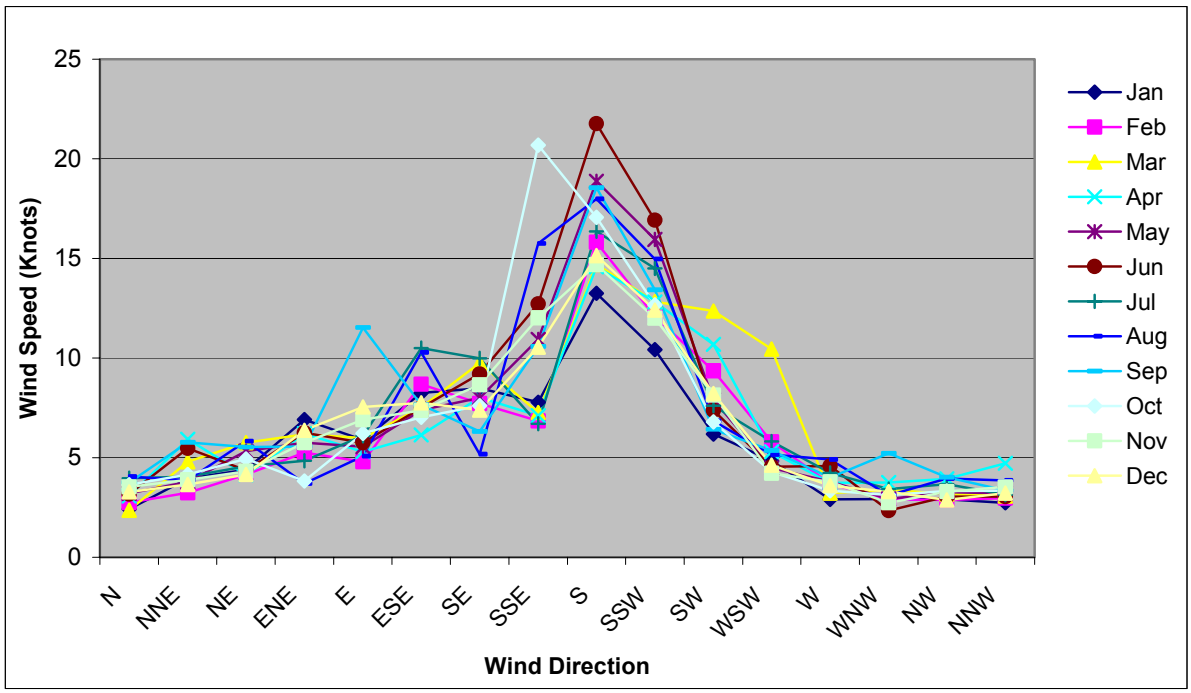

Figure 3. Mean wind speed and direction at Hallett Station 1957-1964.

5. TERRESTRIAL BIOLOGY

5.1 Adèlie penguins

Seabee Hook is the site of an Adèlie penguin colony with a recently estimated population of 39,014 breeding pairs (pers. comm. K. Barton from 1998/99 breeding season). On the spit, penguins nest on well-drained ridges and hummocks where snow does not accumulate. Large subcolonies are also found on scree fans at the base of the cliffs where there is irregular sloping terrain and where neither snow nor meltwater can accumulate (Wilson et al., 1990).

A radiocarbon date from a frozen Adèlie penguin sampled from the base of an accumulation of penguin bodies and guano at Cape Hallett colony was dated at 1210 plus/minus 70 years (Harrington and McKellar, 1958). This indicated that the rookery was probably colonised between about 400-700 AD. No evidence of a break in rookery colonisation was seen in the deposition of penguins and as there did not appear to be empty areas of land with old guano and penguin bodies, it was assumed that the colony had not been larger than the size of the colony observed at the time of the study.

The construction of Hallett Station on part of Seabee Hook in 1957 had a considerable effect on the penguin population. As nesting penguins occupied all suitable building sites, 7580 penguins (including 3318 chicks) were evicted from their nesting sites so that the 0.83 ha required for the station could be fenced off and flattened (Eklund 1959, 1961; Reid, 1964b). Penguin numbers declined from 62 900 pairs in 1959 (Reid, 1964b) to 37 000 pairs in 1968 (Wilson et al., 1990), a decline of 59%. Since this time, the population trend has been one of a general increase (Wilson et al., 1990), although estimates for the 1998/99 breeding season were down to 39,014 breeding pairs (pers. comm. K. Barton). Gilmore (2001, p36) notes that there has only been slow recolonisation of the areas modified by humans.

The Adèlie penguin colony has been the subject of many studies since the establishment of Hallett Station. Most of this work occurred during the station's occupation between 1956 and 1973. Early studies by Reid and his co-workers produced valuable baseline research on population geography (Reid, 1961, 1964a), size, age, composition and structure (Reid, 1960, 1961, 1964b, 1968; Cranfield et al. 1965; Reid et al. 1967), and penguin biology (Reid 1965; Reid and Bailey 1966). These were accompanied by studies of penguin physiology (Douglas, 1963, 1968; Derksen, 1974), behaviour (Thompson and Emlen, 1966; Emlen and Penney, 1964; Müller-Schwarze, 1968; Tenaza, 1971; Derksen, 1975a), and response to both human (Reid, 1968; Choate, 1967) and skua (Maher, 1966) disturbances. Penguins were banded by Reid in the late 50s and early 60s (Reid 1961), and later by an American group from 1969 to 1973 (Baker, 1972, 1973).

Observations of the seasonal behaviour of the Adèlie penguins report that they begin to arrive at Cape Hallett in the second and third weeks of October and occupy territories used in previous years. Two eggs are laid two or three days apart in late October or early November, and incubation by the male begins after the first egg is laid. The female returns to the sea to feed and relieves the male about 30 days later, a few days before the chicks hatch. The adults take turns brooding and feeding the chicks and after four weeks, when the chicks are half-grown, they begin to gather in groups called crèches. They are fed by the adults until fully grown. In early February at nine weeks of age, the chicks attempt to swim, and once proficient enough, they leave the colony not to return for several years when they are ready to breed. The adults leave around the same time as this, with some remaining to undergo their annual molt (Maher, 1966).

There was little work carried out on the penguins at Hallett Station between 1973 and 1983. In 1983 a party conducting work under the auspices of the New Zealand Committee for the International Survey of Antarctic Seabirds (ISAS) spent five weeks at Cape Hallett undertaking, among other responsibilities, a census of the Adèlie penguin and skua populations, and a study of the food intake of the penguins (Wilson, 1983a, 1983b). A main conclusion from this study was that "Man's impact on penguins at Cape Hallett has been long lasting. Even after 10 years without disturbance the population has apparently continued to decline." (Wilson, 1983b). By combining the early population work undertaken at the colony with the results of the ISAS visit and the interpretation of 7 years of aerial photographs of the penguin colony, Wilson et al. (1990) produced a thorough presentation of the impact of man on the Adèlie penguins at Cape Hallett.

The acquisition of aerial photos of the Cape Hallett penguin colony has continued to the present (P. R. Wilson and K. Barton, pers. comm.), but detailed studies of them have been delayed due to the lack of research funding. The most recent assessment of the penguin colony at Cape Hallett was undertaken in 2001 as part of a joint US/NZ remediation effort at the site of the former Hallett Station (Gilmore, 2001). The report highlights potential hazards to penguins and other avifauna and makes recommendations for future work in the rookery.

Other work on the penguins at Cape Hallett includes the attachment of a transmitter to a male penguin to track its winter foraging patterns (Davis, 1997/98), and blood sampling from 30 penguins to determine the genetic evolution in ancient DNA (Lambert, 1998/99; Roeder et al., 2001; Lambert et al., 2002).

5.2 South polar skua

A major skua colony is also present at Cape Hallett. The skuas nest in loosely knit colonies located on the scree slope just above the penguin colony, on adjacent areas of lowland, and in the depressions within the penguin colony (Maher, 1966). Reid (1964a, 1964b) estimated the total area of the skua colonies as 12.2 ha (7.9 ha on the beach, 4.3 ha on the scree section).

As with the Adèlie penguin population, the skua population has declined since the establishment of Hallett Station (see Table 3). A skua census in 1983 (Wilson 1983b; Pascoe, 1984) confirmed this continuing trend 10 years after the closure of Hallett Station, but comments were made that the population may have been affected by a severe snowstorm in December 1982 during the critical skua breeding time. Information about more recent counts of the skua population at Cape Hallett is unknown.

Year	Number of Pairs	Author
1960-61	181	Reid, 1960; Reid 1964b; Maher 1966
1963-64	162	Kinsky cited in Johnston 1971
1965-66	147	Kinsky cited in Johnston 1971
1966-67	113	Choate cited in Johnston 1971
1967-68	105	Johnston 1971
1968-69	98	Johnston 1971
1971-72	98	Trillmich, 1972, 1978
1983	84	Wilson 1983b; Pascoe 1984

Table 3. Numbers of skua pairs at Cape Hallett.

As well as skua population studies, there have been studies on skua growth and development (Reid, 1966), mortality (Choate, 1967), feeding territories and breeding success (Trillmich, 1978), incubation behaviour (Trillmich, 1972) and predatory behaviour (Reid, 1964b; Maher, 1966). In this last category the importance of Adèlie penguin chicks, eggs, adult carcasses and dropped penguin food as a major constituent of the skua diet was demonstrated.

The skuas have been observed to arrive at Cape Hallett in late October after the penguins, where they re-occupy old territories and breed with former partners. Two eggs are usually laid in mid-November, a day or two apart, and both sexes have an equal share in the 28 day incubation period. The eggs hatch in mid-December and the chicks stay near their nest while being fed by their parents for 6-7 weeks until they are strong enough to fly. Fledglings and adults leave in late February and the young do not return to breed until they are 4 or 5 years old (Maher, 1966).

A discussion of skua breeding colonies in the Ross Sea region, including Cape Hallett can be found in Ainley et al. 1986.

5.3 Other avifauna

Although not permanent residents at Cape Hallett, other birds have been observed in the area besides Adèlie penguins and south polar skua. Reid (1961) banded 30 snow petrels in a colony located about 8 km across the sea ice of Edisto Inlet from Cape Hallett nesting on steep, rotten slopes at 9-300 m above sea level. Snow petrels were also observed during other expeditions at Cape Hallett (Harrington, 1958; Reid, 1960, Wilson, 1983b; Gill, unpublished).

Other birds sighted include southern Giant Petrel (Wilson, 1983b; Gill, unpublished); Wilson's storm petrel (Harrington, 1958; Wilson 1983b; Gill, unpublished); Chinstrap penguin (Crawford, 1974; Wilson 1983b; Gill, unpublished); Emperor penguin (Reid, 1960); and the Southern Black-backed gull (Derksen, 1975b).

5.4 Flora

The plant life at Cape Hallett has been the subject of several studies. General observations were made during the IGY with a comment that "the lichen vegetation on the summit of the headland near the joint US-New Zealand IGY Station at Cape Hallett, in East Antarctica, was luxurious out of all proportion to its surroundings" (Llano, 1959). These preliminary observations identified bright orange *Caloplaca* about 60m above the penguin rookery, with light-green *Neuropogon* growing in short grass-like mats above. *Umbilicaria* was the dominant element on the reddish volcanic rubble of the Cape Hallett summit.

Further studies in the 1960s identified the mosses, lichen and algae observed at Cape Hallett (Pryor, 1962; Murray, 1963), linked their distribution to water availability (Rudolph, 1963) and related their ecology to microclimate parameters (Rudolph, 1966a, 1966b). Rudolph (1963) observed that lichen were found in dry areas, mosses in areas with a thin surface water layer, and algae in areas with about 2.5 cm of standing water, thus concluding that the availability of water determined the distribution of the plant types. Rudolph also demonstrated that the moisture content of the plants went from 7-25% of their dry weight in spring to 1000% of their dry weight in summer during the snow melt. The effects of light intensity and temperature on the photosynthesis and respiration of moss and lichen species were also observed (Rastorfer, 1970; Lange and Kappen, 1972).

A more recent expedition to Cape Hallett by a group from Waikato University in collaboration with the Australian Antarctic Division undertook work on three aspects of plant biology (Green, 1998/99). The first was to use moss genetics to determine relationships both within Cape Hallett and between Cape Hallett and distant sites. *Bryum argenteum* (now called *Bryum subrotundifolium*) which was abundant and formed large populations around water channels was mostly used. *Bryum pseudotriquetrum* was also identified and became a novel and useful addition to the study.

Secondly the plant (lichen and moss) distribution at Cape Hallett was recorded. A full plant list was completed which included several unrecorded lichen and moss species (Table 1), and plant distributions were mapped. By comparing sites with those photographed in 1968 by Lange, both the growth and establishment of lichen were demonstrated for the first time in the Ross Sea region. These results showed that the moss species were more dynamic than had been anticipated.

Lichen	Mosses
Acarospora gwynnii	Bryum subrotundifolium
Amandinea petermannii	Bryun pseudotriquetrum
Buellia frigida	Sarconeurum glaciale
Caloplaca athallina	Ceratodon purpureus
Caloplaca citrina	Schistidium (Grimmia) sp.
Candelaria murrayi	
Candelariella flava	
Lecanora chrysoleuca	
Lecanora expectans	
Lecidea cancriformis	
Physcia caesia	
Pleopsidium chlorophanum	
Rhizocarpon geographicum	
Rhizoplaca chrysoleuca	
Rhizoplaca melanophthalma	
Usnea sphacelata	
Xanthoria elegans	
Xanthoria mawsonii	

Table 1. Mosses and lichen identified at Cape Hallett in 1998/99. (Source: Allan Green, University of Waikato, and Rod Seppelt, Australian Antarctic Division.)

Finally, there was a detailed study of how the environmental factors of temperature, light, water content and carbon dioxide concentration affected photosynthesis of the two common mosses *B. subrotundifolium* and *B. pseudotriquetrum*. Results showed an unexpectedly high level of adaptability in the mosses as they became more resistant to low temperatures as the summer proceeded. In addition, microclimate recording stations showed that the mosses rarely fell below freezing point in January and were often several degrees warmer than the air. Publication of these results is in preparation.

5.5 Microbiology

Boyd et al. (1966) identified the mold *Streptomyces* in soil samples from Cape Hallett as well as three different species of yeast each with different morphological and colonial characteristics.

In their experimentation, they cultured three strains of *Escherichia coli* with other species of heterotrophic bacteria using soil from the Cape Hallett skuary in sealed jars and exposed plots. The growth of these organisms were observed and plotted and compared with a simultaneous experiment at an Arctic location of similar latitude to Cape Hallett. Boyd et al. demonstrated that moisture, pH, ionic concentration and temperature are important factors in determining the survival of newly introduced bacteria.

5.6 Terrestrial invertebrates

Descriptions of invertebrates found at Cape Hallett include those by Pryor (1962) and Wise and Shroup (1967a). Wise and Shroup (1967b) also described the distribution of three Collembola species and linked their distribution to the moisture regime of the site. Studies of the low-temperature physiology of Collembola documented their relatively high respiration rates at low temperatures and determined this to be an adaptive strategy (Strong et al., 1970). Gless (1972) undertook a three year intensive study of four species of Antarctic mite found at Cape Hallett and described the morphological changes characterising each growth stage.

5.7 Other

Along slightly different lines, one study found the presence of *Aspergillus fumigatus* Fresenius in the ornithogenic soils of Seabee Hook (Wicklow, 1968). This is characteristically an avian respiratory disease of captivity particularly associated with the removal of penguins from their native habitats to northern latitudes. As this fungus was not found at other ornithogenic soil sites in the region, it was suggested that it's presence at Cape Hallett was the result of human contamination.

There is one instance of a study of the meltwater ponds found at Cape Hallett (Dillon et al., 1969). This compared the pH, temperature and organisms of ponds coloured by penguin guano with clear pools used by skua for bathing.

6. MARINE BIOLOGY

Observed marine fauna either from Cape Hallett or from ships moored in the vicinity of Cape Hallett include: Crabeater seal, Weddell seal, Elephant seal, Leopard seal, Minke whale and Fin whale (Reid, 1960; Wilson, 1983b; Gill, unpublished). Other than the Weddell seal, these animals are visitors to Cape Hallett. A small and scattered Weddell seal colony was observed by Reid (1960), but further mention of such a colony has not been found in the literature.

In February 2001, the *Tangaroa* undertook dredges and videographic transects off Cape Hallett for the Ministry of Fisheries' baseline study of the biodiversity of the Ross Sea (Mitchell, 2001). These enabled descriptions of the sea floor bed along with the benthic and pelagic organisms observed.

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