Management Plan

For Antarctic Specially Protected Area No. 135 NORTH-EAST BAILEY PENINSULA, BUDD COAST, WILKES LAND

Introduction

North-east Bailey Peninsula (66°16'59.9"S, 110°31'59.9"E) is located adjacent to the eastern border of Australia's Casey station in the Windmill Islands region of the Budd Coast, Wilkes Land, East Antarctica. It was designated as Site of Special Scientific Interest (SSSI) No. 16 under Recommendation XIII-8 (1985), following a proposal by Australia. In accordance with Decision 1 (2002), the site was re-designated and renumbered as Antarctic Specially Protected Area (ASPA) No. 135. Revised Management Plans for the Area have been adopted under Measure 2 (2003), Measure 8 (2008) and Measure 6 (2013). The Area was designated primarily as a scientific reference site which, since the early 1980s, has supported a range of studies on the diverse assemblage of vegetation found in the area. Three moss species, 1 liverwort species, 30 lichen species, and over 140 cyanobacterial and algal species have been found in the Area. The immediate proximity of the Area to Casey station allows for ease of access for field research, but subsequently increases the potential for disturbance of sensitive areas so must be managed carefully. The Area is also frequently accessed by Casey station personnel for essential maintenance of communications infrastructure.

1. Description of Values to be Protected

The North-east Bailey Peninsula, ASPA No. 135, is representative of a diverse assemblage of the Windmill Islands region flora. As such, the Area has intrinsic ecological value and scientific importance, particularly to botanists, microbiologists, soil scientists and glacial geomorphologists, and is designated to protect the communities and ecosystem from further human impact.

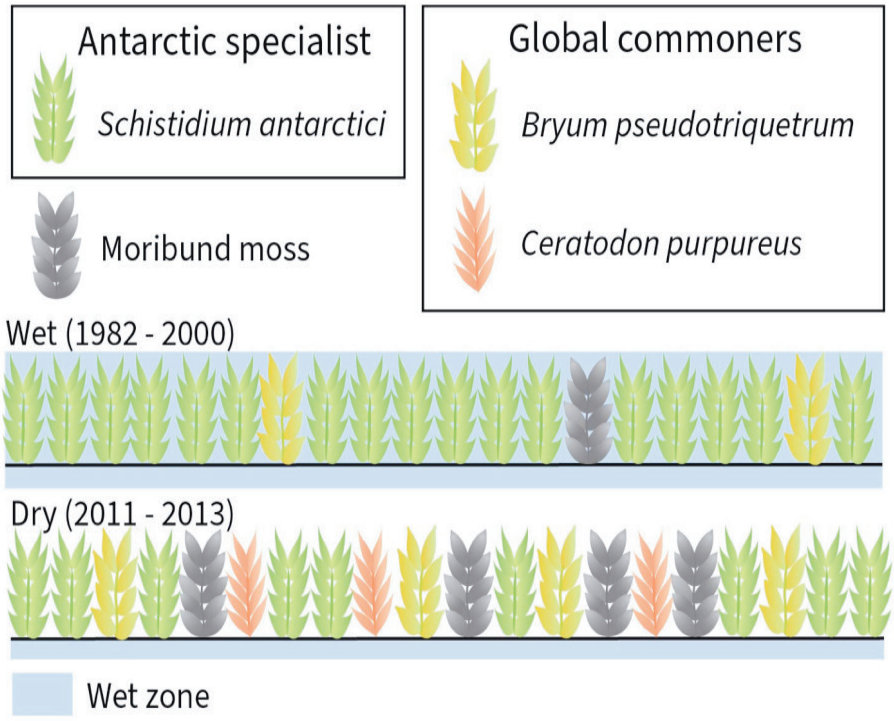
The Area contains several extensive and contrasting moss fields that have been the subject of taxonomic, ecological and physiological studies since the summer of 1982/83 (see Map C). Additional studies have included population ecology of invertebrates associated with the vegetation and soil/water chemistry. Long-term monitoring sites have been established to observe lichen and moss as well as long term vegetation changes (see Map E). Other floral studies have concentrated on the determination of biodiversity, physiological and biochemical attributes, component interactions, impact of anthropogenic pollutants, and effects of global climate change.

Moss and lichen communities are used as indicators of environmental impacts of Casey station. The Area provides baseline data for comparison with changes in similar plant communities in the immediate surroundings of Casey station. The Area also serves as a valuable comparative site for similar plant communities in ASPA 136 Clark Peninsula, which are subject to less environmental stress and disturbance, due to lower human proximity.

Global change studies have included a multi-year investigation into the impact of water and nutrients on various components of the vegetation, associated studies into the tolerance of mosses to both submergence and desiccation, and examination of the tolerance of three moss species to increased UV-B radiation as a result of ozone depletion. Fine-scale analysis of genetic diversity of the cosmopolitan moss species *Ceratodon purpureus* has been compared for this location and others in the region and globally (Biermsa *et al*., 2022). Complex UV-active compounds have also been isolated for Antarctic *C. purpureus* with similarities to populations in Australia. Dating of long cores of mosses using ^{14}C shows that these individual moss plants are up to 100 years old and stable carbon isotopes of moss shoots, which provide a signature for changes in site water availability, indicate that moss beds have become drier since the 1960s (Robinson *et al*., 2018). This study also indicates that mosses in the Area have a higher rate of drying (60% of cores) than the Windmill Islands regional mean (40% of cores), perhaps due to modification of the site prior to ASPA designation.

The Area is included within the geographic coverage of an Australian Antarctic program State of the Environment Indicator 72 "Windmill Islands terrestrial vegetation dynamics", which involves quantitative analysis of a series of long-term transects across selected vegetation since 2003, with the aim of monitoring the effects of climate change on Antarctic cryptogamic communities. This indicator was last updated in 2022. Monitoring indicates that since the 1980s the two cosmopolitan moss species, *Ceratodon purpureus* and *Bryum pseudotriquetrum*, have expanded into locations that were previously dominated by the endemic species *Schistidium antarctici* (see Figure 1).

Figure 1: Moss community change in ASPA 135 since the 1980s (redrawn from Robinson et al., 2018). Replacement of the endemic species Schistidium antarctici, which prefers wetter conditions, with two more generalist native species, Bryum pseudotriquetrum and Ceratodon purpureus, that prefer drier conditions. Samples collected since 2011 also contain more individual plants that appear dead.



However, there is also evidence that vegetation health may have improved since ASPA designation, with moss regrowth on the old station access road and most indicators showing that moss is less stressed (2003-2014) than the other State of the Environment site at Robinson Ridge.

2. Aims and Objectives

Management of the Area aims to:

- avoid degradation of, or substantial risk to, the values of the Area by preventing unnecessary human disturbance in the Area;
- allow scientific research on the ecosystem and elements of the ecosystem in particular on lichen and moss species, algae, invertebrates while ensuring protection from over-sampling;
- preserve a part of the natural ecosystem as a reference for recovery from human impacts, including the direct and indirect effects of Casey station;
- prevent or minimise the introduction of non-native plants, animals and microbes to the Area;
- minimise the possibility of the introduction of pathogens which may cause disease in fauna populations within the Area; and
- allow for the continued maintenance and operation of essential communications infrastructure, including a transmitter mast, antennas, feed lines and associated facilities, without degradation of the Area's values.

3. Management Activities

The following management activities shall be undertaken to protect the values of the Area:

- a copy of this Management Plan made available at Casey station;
- signage installed at the Area boundary illustrating the location, boundaries and restrictions that apply to the Area to prevent inadvertent entry;
- markers, signs and structures erected within the Area for scientific or management purposes, and secured, maintained in good condition and removed when no longer required;
- abandoned equipment or materials removed to the maximum extent possible provided it does not adversely impact on the values of the Area;
- detailed mapping of dense vegetation and ongoing scientific experimental sites to manage human movement and disturbance;
- visitation of the Area as necessary (no less than once every five years) to assess whether the Area continues to serve the purposes for which it is designated and to ensure that management activities are adequate; and
- review of the Management Plan at least every five years with updating as required.

4. Period of Designation

This Area is designated for an indefinite period.

5. Maps

- **Map A:** Antarctic Specially Protected Areas, Windmill Islands, East Antarctica
- **Map B:** Antarctic Specially Protected Areas No 135, North-east Bailey Peninsula: Topography and Bird Distribution
- **Map C:** Antarctic Specially Protected Areas No 135, North-east Bailey Peninsula: Vegetation
- **Map D:** Antarctic Specially Protected Areas No 135, North-east Bailey Peninsula: Geology
- **Map E**: Antarctic Specially Protected Areas No 135, North-east Bailey Peninsula: Long term scientific monitoring sites
- Map specifications:
  - Projection: UTM Zone 49
  - Horizontal Datum: WGS84
- **Figure 1:** Diagram of moss community change in ASPA 135 since the 1980s
- **Figure 2:** Map of moss health within ASPA 135 site

6. Description of the Area

6(i) Geographical co-ordinates, boundary markers and natural features

General description

The Area is located on Bailey Peninsula in the Windmill Islands region of Budd Coast, Wilkes Land, East Antarctica (Map A). Bailey Peninsula is an area of rock exposures and permanent snow and ice fields lying between Newcomb Bay and O'Brien Bay, two kilometres south of Clark Peninsula.

The Area is located in the north-east of Bailey Peninsula, adjacent to Casey station (66°16'59.9"S, 110°31'59.9"E), and covers an area of approximately 0.28 km^2. The boundary is irregular, extending in the north to within approximately 70 m south of Brown Bay. Boundary coordinates for the Area are shown in Appendix 1.

Topographically, Bailey Peninsula comprises low-lying, rounded ice-free rocky outcrops (maximum altitude approximately 40 m), which rise from the coast to the Løken Moraines (altitude approximately 130 m). Intervening valleys are filled with permanent snow or ice, or glacial moraine and exfoliated debris, and contain water catchment areas. The topography of Bailey Peninsula is shown at Map B.

Environmental Domains Analysis

North-east Bailey Peninsula is located within Environment D *East Antarctic coastal geologic* (Resolution 3 (2008)).

Antarctic Conservation Biogeographic Regions

North-east Bailey Peninsula is located within Biogeographic Region 7 *East Antarctica* (Resolution 6 (2012)).

Important Bird Areas in Antarctica

North-east Bailey Peninsula does not represent an *Important Bird Area* (Resolution 5 (2015)).

Vegetation and microbial communities

The vegetation of Bailey Peninsula is exceptionally well developed and diverse and the Area represents one of the most important botanical sites on continental Antarctica. Within the relatively complex plant communities and contrasting habitats found on Bailey Peninsula, at least 30 lichens, three mosses, and a liverwort have been found. There are expansive dense stands of macrolichens and in the more moist and sheltered areas bryophytes form closed stands of 25-50 m^2 with turf up to 11 cm in depth (Waterman *et al*., 2015). Together with the lichens Umbilicaria decussata, Pseudephebe minuscula and Usnea sphacelata mixed bryophytes dominate the vegetation cover of most of the ice-free areas. This is particularly so on the north-east and centre of the Peninsula where there are dense communities similar to those found on Clark Peninsula. The most complex bryophyte communities are restricted to small locally moist hollows adjacent to melt pools and streams in the central north-east and central parts of the Peninsula. Vegetation is absent or poorly developed on the ice-free areas of the Peninsula's southern coast. In many areas mosses appear to be becoming increasingly moribund and are being out-competed or overgrown by lichens (Wasley *et al*., 2012, King *et al*., 2020, Bergstrom *et al*., 2021). Stressed bryophytes have also been noted in the Area, especially for exposed ridges of moss beds, as indicated by shifts in pigmentation from green to red or brown. However, the progression of moss from green to red/brown appears slower at ASPA 135 than at the nearby Robinson Ridge site (King *et al*., 2020). Stable isotopes analysis of moss shoots has shown that growth rates have slowed since the 1980s associated with drying of the moss beds (Robinson *et al*., 2018). Map C provides contemporary spatial data for bryophytes present in the Area and shows *all* areas for which bryophytes have been detected – subsequently bryophyte distributions may appear overrepresented and may be more accurately depicted when further refinement of the spatial data is possible. Appendix 2 provides a list of bryophytes and lichens identified in the Area.

Two principal cryptogamic subformations are recognised; a lichen-dominated association occupying a variety of windswept substrata ranging from bedrock to gravel, and, a short cushion and turf moss subformation comprising four moss dominated groupings. The vegetation of Bailey Peninsula is shown at Maps C and E.

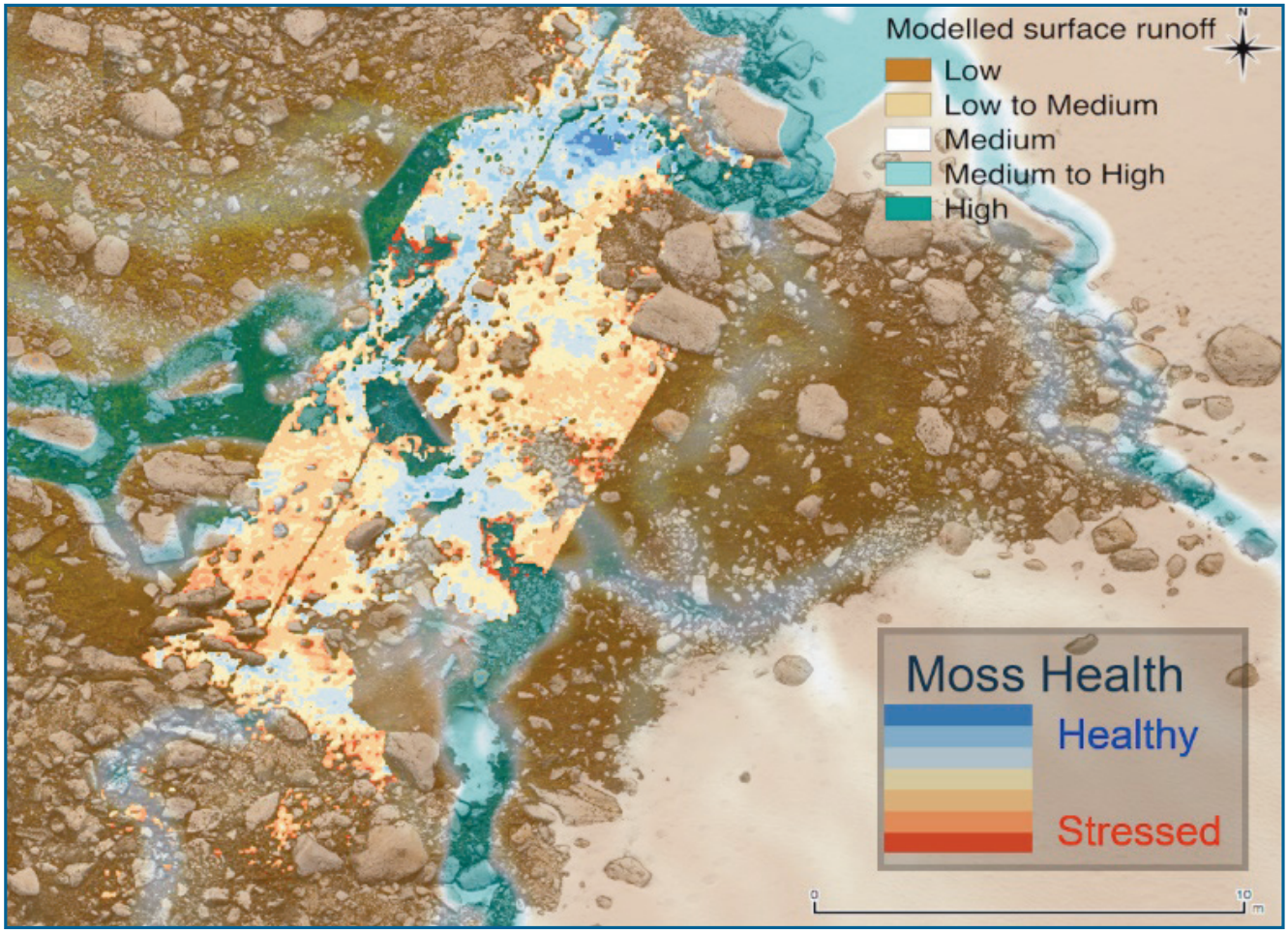
At least 150 taxa of non-marine algae and cyanobacteria have been isolated; these include 50 cyanobacteria, 70 chlorophytes and 23 chromophytes. The taxa have been found in snow and ice, soil, rocks, ephemeral ponds, tarns and lakes; 24 cyanobacterial and algal species occur in the snow. Snow algae are abundant and widespread in the icy corridors between the rocky outcrops and in semi-permanent snow drifts. A list of cyanobacterial and algal species from the Area, Bailey Peninsula, and the Windmill Islands region is shown in Appendix 3. At least 48 species of diatoms have been identified from within Windmill Islands moss turfs (Bishop *et al*., 2020).

The vegetated soils of Bailey Peninsula contain fungal hyphae, yeasts, fungal propagules, an assortment of algae, cyanobacteria, protozoa, and provide a significant habitat for soil microfauna such as nematodes, mites, rotifers and tardigrades. There is relatively low fungal diversity in the Windmill Islands region, with 35 taxa representing 22 genera of fungi being isolated from soils, mosses, algae and lichens. Thirty fungal taxa have been detected in soils in the vicinity of Casey station with 12 of these taxa restricted to anthropogenically influenced soils around the station suggesting that there may be a non-native element in this flora, *Penicillium* species dominate in these sites. Within the Windmill Islands region, 21 fungal taxa have been isolated the mosses, with 12 taxa isolated from algae and 6 from lichens. A number of fungi have also been found associated with animals of the region. Appendix 4 provides detail of the taxa and their source.

Genomic analysis of soil microbial flora is currently under investigation. There have been some genomic analyses of mosses, especially *C. purpureus,* results indicating that the species in the Windmill Islands is distinct from the conspecific found in the Maritime Antarctic (Biersma *et al*., 2020).

Protozoa have been studied at a number of sites on Bailey Peninsula and in the Area ciliates and testate amoebae are active. 27 ciliate species and six testacean species have been found (see Appendix 5). Remotely piloted aerial systems (RPAS) have been deployed in ASPA 135 and a range of vegetation health metrics developed (see Figure 2).

Figure 2: Map of relative moss vigour at the Antarctic Specially Protected Area (ASPA) 135 (redrawn from Malenovsky et al., 2017). Australian Antarctic Program State of the Environment study site. Map derived from RPAS hyperspectral image overlaid onto snowmelt runoff map to illustrate main water drainage pathways observed at ASPA 135 in February 2013.



As full aerial coverage with appropriate sensors is achieved, these will allow for more comprehensive vegetation health assessments to be applied across ASPA 135, whilst maintaining minimal disturbance.

Terrestrial invertebrates

The Antarctic flea *Glaciopsyllus antarcticus* has been found in the nests of southern fulmars in the vicinity of Bailey Peninsula. A number of species of mallophagan lice have also been found on birds, and the anopluran louse *Antarctophthirus ogmorhini* is found on the Weddell seal *Leptonychotes weddellii*.

The free-living mite *Nanorchestes antarcticus* has been found on Bailey Peninsula at sites characterised as having sandy or gravelly soils, free of extensive moss or lichen cover, and moist but not water-logged.

Five species of tardigrades have been collected on Bailey Peninsula: *Pseudechiniscus suillus, Macrobiotus* sp., *Hypsibius antarcticus, Ramajendas frigidus* and *Diphascon chilenense*. Significant positive associations between bryophytes and the most common species of tardigrades *P. suillus, H. antarcticus* and *D. chilenense*, have been found, and strong negative associations between those species and algae and lichens have been established. No systematic or ecological accounts of nematodes have yet been published for the Windmill Islands region.

Birds

Snow petrels *Pagodroma nivea* and Wilson's storm petrels *Oceanites oceanicus* breed throughout the Windmill Islands including close to the Area and may nest within the Area. Snow petrels are seen all year round. Adélie penguin *Pygoscelis adeliae*, are the most abundant bird species breeding at ice free sites throughout the Windmill Islands (Southwell *et al*., 2021). The nearest breeding colony is on Shirley Island about 1.5 km west of Casey station. The Antarctic skua *Catharacta maccormicki* breeds throughout the Windmill Islands region at widely dispersed nests, mostly near Adélie penguin colonies. Skuas use the lake in the Area for bathing.

Climate

The climate of the Windmill Islands region is frigid-Antarctic. Climate records from nearby Casey station (altitude 32 m) show mean temperatures for the warmest and coldest months of 2.2 and -11.4°C respectively, extreme temperatures ranging from 9.2 to -34°C, and mean annual maximum and minimum temperatures of –5.9°C and –12.5°C respectively. The climate is dry with a mean annual snowfall of 219 mm year (rainfall equivalent), precipitation as rain has been recorded in the summer and recently in July 2008 and July 2009.

There is an annual average wind speed of 25 km per hour. Gale winds are predominantly from the east, off the polar ice cap. Blizzards may occur very suddenly and are a frequent occurrence especially during winter. Snowfall is common during the winter, but the extremely strong winds scour the snow off exposed areas of the Peninsula. On most hill crests on Bailey Peninsula snow gathers in the lee of rock outcrops and in depressions in the substratum. Further down the slopes snow forms deeper drifts.

Geology and soils

Bailey Peninsula is part of the northern gradation of a metamorphic grade transition which separates the northern part of the Windmill Islands region from the southern part. The metamorphic grade ranges from amphibolite facies, sillimanite-biotite-orthoclase in the north at Clark Peninsula, through biotite-cordierite-almandine granulite, to hornblende-orthopyroxene granulite at Browning Peninsula in the south. The Ardery Charnockite of the south is prone to deep weathering and crumbles readily because of its mineral assemblage, whereas the metamorphic sequences of the northerly parts of the region have a much more stable mineral assemblage and crystalline structure. This difference has a significant influence on the distribution of vegetation in the Windmill Islands region with the northern rock types providing a more suitable substrate for slow growing lichens.

The leucocratic granite gneiss, which constitutes the main outcrop on Bailey Peninsula, may be subdivided into leucogneiss and two different types of garnet-bearing gneiss. The outcrop on Bailey Peninsula is characterised as a garnet-bearing gneiss type 1 which is white, medium grained and foliated. The foliation is defined by the alignment of an early biotite generation that is tight to openly folded, with a garnet and a later biotite generation that overgrows the fabric. Unmetamorphosed and undeformed dolerite dykes occur over Bailey Peninsula such as at "Penguin Pass" (66°17'18"S, 110°33'16"E), to the south of the Area. Small outcrops of metapelite, metapsammite and leuco- gneisses occur on the Peninsula. Recent geochronology of the rocks of the Windmill Islands region suggest two major phases of metamorphism, the first at c. 1400-1310 Ma, an upper amphibolite facies event, followed by a granulite facies overprint c. 1210-1180 Ma. The geology of Bailey Peninsula is shown at Map D.

The Windmill Islands region was glaciated during the Late Pleistocene. The southern region of the Windmill Islands was deglaciated by 8000 corr. yr B.P., and the northern region, including Bailey Peninsula deglaciated by 5500 corr. yr B.P. Isostatic uplift has occurred at a rate of between 0.5 and 0.6 m/100 yr, with the upper mean marine limit, featured as ice-pushed ridges, being observed on Bailey Peninsula at approximately 30 m where they extend in continuous rows from the present sea- level.

Soils on Bailey Peninsula are derived from weathered gneiss, moraine deposits and outwash gravels stemming from glacial episodes. Seabirds have a large impact on soil formation in the entire landscape. Soils are frozen much of the year during summer, the upper 30-60 cm thaws with the few top centimetres, refreezing at night. Soils are mainly formed by cryoturbation and cryoclastic weathering. In the vicinity of Casey station most soils are classified by Blume, Kuhn and Bölter (2002) as cryosols with lithic, leptic, skeletal, turbic and stagnic subunits. Other soils in the Area are gelic subunits of histosols, podzols, and regosols, boulder and rock outcrops with ecto- and endolithic flora are classified as Lithosols. ASPA 135 was the site of an abandoned penguin colony, isolated due to isostatic uplift between 3-8000 years ago, that provides a rich ancient guano nutrient source for the current vegetation.

Lakes

Cold monomictic lakes and ponds occur throughout the Windmill Islands region in bedrock depressions and are usually ice-free during January and February. Nutrient rich lakes are found near the coast, in close proximity to penguin colonies or abandoned colonies, sterile lakes are located further inland and are fed by meltwater and local precipitation. A number of these lakes and ponds occur across Bailey Peninsula with two large lakes located 500 m to the west of the Area. The distribution of lakes and ponds on Bailey Peninsula is shown at Map B.

6(ii) Access to the Area

The north-west boundary of the Area is located adjacent to the eastern boundary of Casey station limits, and the Area is easily accessible by foot. Vehicle access to and within the Area is covered under section 7(ii) of this plan.

6(iii) Location of structures within and adjacent to the Area

Casey station (Australia) is located immediately west of the Area (the station limits boundary abuts the ASPA boundary). An array of radio transmitters had been progressively established at the site since 1964, until the designation of the Area in 1986, and have since been removed once redundant. A number of structures remain within the Area (see Maps B-E), including the Transmitter hut (which can also be used as an emergency refuge), Transmitter mast – a 45 m high tandem delta antenna mast and a non-directional beacon antenna located in the south-east, – and long-term monitoring markers. A 35 m high mast is located approximately 100 m south of the Area, which together with the Transmitter mast, forms the basis of the Casey High Frequency (HF) Transmit installation.

6(iv) Location of other Protected Areas in the vicinity

Other protected areas in the vicinity include (see Map A):

- ASPA No. 136, Clark Peninsula, (66°15'S, 110°36'E): located 2.5 km to the north-east, across Newcomb Bay;
- ASPA No. 103, Ardery and Odbert Islands (66°22'20"S, 110°29'10"E): located approximately 11 km to the south, west of Robinson Ridge; and
- ASPA No. 160, Frazier Islands (66°14'S, 110°10'E): located in the eastern part of Vincennes Bay approximately 16 km to the west-north-west.

6(v) Special zones within the Area

There are no special zones within the Area.

7. Permit Conditions

7(i) General permit conditions

Entry to the Area is prohibited except in accordance with a permit issued by an appropriate national authority. Conditions for issuing a permit to enter the Area are that:

- the activities permitted give due consideration, via the environmental impact assessment process, to the continued protection of the values of the Area;
- the actions permitted are in accordance with this Management Plan and its objectives and provisions;
- permits shall be issued for a finite period;
- permits shall be carried when in the Area;
- permit holders shall notify the permitting authority of any activities or measures undertaken that were not authorised by the permit;
- a visit report must be supplied to the authority that approved the permit, as soon as practicable after the visit to the Area has been completed (but no later than six months after the visit has been completed); and
- all census and GPS data should be made available to the permitting authority and to the Party responsible for the development of the Management Plan.

Additional conditions, consistent with this Management Plan's objectives and provisions, may be included by the permitting authority.

7(ii) Access to, and movement within or over, the Area

Helicopters are prohibited from landing within the Area.

The operation of Remotely Piloted Aircraft Systems (RPAS) over the Area should be carried out, as a minimum requirement, in compliance with the 'Environmental Guidelines for Operation of Remotely Piloted Aircraft Systems (RPAS) in Antarctica (v 1.1) contained in Resolution 4 (2018).

Vehicles are prohibited from entering the Area, except for the purpose of conducting ongoing maintenance of the transmitter building, associated buildings and antennas, or for the removal of structures/materials. Access to the Transmitter hut near the south-east end of the Area should be via the over-snow access route to Law Dome, several kilometres to the south. Within the Area, vehicles should follow the most direct practicable route between the Area boundary and the communications facilities, avoiding vegetation and cables. Vehicle use in the Area shall be kept to a minimum and only use the route specified in the permit.

The north-west boundary of the Area is located approximately 200 m east of Casey station buildings, and the Area is easily accessible by foot. Due to their fragile and brittle structure, macrolichens (fructose and foliose) are especially sensitive to damage from trampling. Growth rates for continental Antarctic lichens are exceedingly slow, with most growing only a fraction of a mm per year. As a consequence, if damaged, lichens will take hundreds or even thousands of years to recover. Foot traffic should therefore be minimised and remain on solid snow/ice (where there is no risk of punching through) or on bare rock to minimise impact when accessing or transiting through ice-free areas. Rock with crustose lichen cover will likely be more tolerant of occasional foot traffic, where it is practicable and safe, although extreme care should always be exercised.

7(iii) Activities which may be conducted in the Area

Activities which may be conducted within the Area include:

- compelling scientific research which cannot be undertaken elsewhere;
- sampling, but this should be the minimum required for the approved research programs;
- essential management activities, including monitoring, erection of signs, removal of structures/materials, and visits to assess the effectiveness of the Management Plan and management activities; and
- essential operational activities in support of scientific research or management within or beyond the Area, including maintenance and other activities associated with the communications installation including the Transmitter hut, Transmitter mast, antennas, feed lines, storage rack and associated facilities.

7(iv) Installation, modification or removal of structures

Permanent structures and installations are prohibited within the Area. Temporary structures and installations may only be established in the Area for compelling scientific or essential management reasons and for a pre-established period, as specified in a permit.

Any temporary structure or installation established in the Area must be:

- first cleaned of organisms, propagules (e.g. seeds, eggs) and non-sterile soil;
- made of materials that do not impact on the surrounding environment, and can withstand Antarctic conditions;
- installed, maintained, modified and removed in a manner that minimises disturbance (and does not cause more damage than benefit) to the values of the Area;
- clearly identified by country, name of the principal agency/investigator, date of installation and date of expected removal;
- reported to the permitting authority if left *in situ*; and
- removed when they are no longer required, or before the expiry of the permit, whichever is earlier.

7(v) Location of field camps

Camping is prohibited within the Area.

7(vi) Restrictions on materials and organisms which may be brought into the Area

- No living animals, plant material, microorganisms or non-sterile soils shall be deliberately introduced into the Area. Appropriate precautions, such as the thorough cleaning of footwear and equipment, must be taken to prevent accidental introduction.
  - To help maintain the ecological and scientific values of the plant communities found in the Area, persons entering the Area shall take special precautions against unintentional introductions. Of particular concern are microbial or vegetation introductions sourced from soils at other Antarctic sites, including stations, or from regions outside Antarctica. To minimise the risk of introductions footwear and any equipment – such as carry cases, sampling equipment and markers – to be used in the Area shall be thoroughly cleaned before entering the Area.
- No poultry products, including dried food containing egg powder, are to be taken into the Area.
- Chemicals may be introduced for scientific or management purposes specified in a permit, and shall be removed from the Area at or before the conclusion of the permitted activity.
- Permanent or semi-permanent fuel depots are not allowed. Fuel must not to be stored in the Area unless it is required for essential purposes connected with the activity for which the Permit has been granted. All such fuel must be stored in sealed and bunded containers removed from the Area at or before the conclusion of the permitted activity.
- Any materials or supplies introduced for a stated period shall be removed at or before the conclusion of the stated period, and shall be stored and handled so that the risk of dispersal into the environment is minimised.

7(vii) Taking of, or harmful interference with native flora and fauna

The taking of, or harmful interference with, native flora and fauna is prohibited except in accordance with a permit. Where the taking of, or harmful interference with, animals is involved, this action should be conducted in accordance with the *SCAR Code of Conduct for the Use of Animals for Scientific Purposes in Antarctica* as a minimum standard.

7(viii) The collection or removal of material not brought into the Area by the permit holder

Material of human origin likely to compromise the values of the Area, which was not brought into the Area by the permit holder or otherwise authorised, may be removed unless the impact of the removal is likely to be greater than leaving the material *in situ*. If such material is found, the appropriate national authority must be notified. Where possible, photographic documentation should be obtained and included in the site visit report.

7(ix) Disposal of waste

All wastes, including all human wastes, shall be removed from the Area.

7(x) Measures that may be necessary to continue to meet the aims of the Management Plan

Permits may be granted to enter the Area to carry out the following measures, provided they do not adversely impact on the values of the Area:

- the collection of samples for analysis or review;
- the establishment or maintenance of scientific and/or logistical equipment, infrastructure and signposts; and
- other protective measures.

7(xi) Requirements for reports

The principal permit holder for each permit issued shall submit to the permitting authority a report describing the activities undertaken no later than six months after the visit has been completed. Such reports should include, as appropriate, the information identified in the Visit Report form contained in the *Guide to the Preparation of Management Plans for Antarctic Specially Protected Areas*. Parties should maintain a record of such activities and, in the Annual Exchange of Information, should provide summary descriptions of activities conducted by persons subject to their jurisdiction, which should be in sufficient detail to allow evaluation of the effectiveness of the Management Plan. Parties should, wherever possible, deposit originals or copies of such original reports in a publicly accessible archive to maintain a record of usage; to be used both in any review of the Management Plan and in organising the scientific use of the Area.

8. Supporting Documentation

Adamson, E., & Seppelt, R. D. (1990). A comparison of airborne alkaline pollution damage in selected lichens and mosses at Casey Station, Wilkes Land, Antarctica. In K. R. Kerry & G. Hempel (Eds.), *Antarctic Ecosystems: Ecological Change and Conservation* (pp. 347-353). Springer, Berlin.

Ashcroft, M. B., Casanova-Katny, A., Mengersen, K., Rosenstiel, T. N., Turnbull, J. D., Wasley, J., Waterman, M. J., Zuniga, G. E., & Robinson, S. A. (2016). Bayesian methods for comparing species physiological and ecological response curves. *Ecological Informatics* 34, 35-43.

Ashcroft, M. B., King, D. H., Raymond, B., Turnbull, J. D., Wasley, J., & Robinson, S. A. (2017). Moving beyond presence and absence when examining changes in species distributions. *Global Change Biology* 23, 2929-2940.

Australian Government, Australian Antarctic Division. (2021). *Casey: The Daintree of Antarctica*. http://www.antarctica.gov.au/about-antarctica/fact-files/plants/casey-the-daintree-of-antarctica

Azmi, O. R., & Seppelt, R. D. (1997). Fungi in the Windmill Islands, continental Antarctica. Effect of temperature, pH and culture media on the growth of selected microfungi. *Polar Biology* 18, 128-134.

Azmi, O. R., & Seppelt, R. D. (1998). The broad scale distribution of microfungi in the Windmill Islands region, continental Antarctica. *Polar Biology* 19, 92-100.

Bednarek-Ochyra, H., Váòa, J., Ochyra, R., & Lewis Smith, R. I. (2000). *The Liverwort Flora of Antarctica*. Polish Academy of Sciences Institute of Botany, Kraków.

Bergstrom, D.M., Wienecke, B.C., van den Hoff, J., Hughes, L. Lindemayer, D.L., Ainsworth, T.D., Baker, C.M., Bland, L., Bowman, D.M.J.S., Brooks, S.T., Canadell, J., Constable, A., Dafforn, K.A. Depledge, M.H., Dickson, C.R., Duke, N.C., Helmstedt K., Johnson, C.R., McGeoch, M.A., Melbourne-Thomas, J., Morgain, R., Nicholson, E.N., Prober, S.M., Raymond, B., Ritchie, E.G., Robinson, S.A., Ruthrof, K.X., Setterfield, S.A., Sgro, C.M., Stark, J.S., Travers, T., Trebilco, R., Ward, D.F.L., Wardle, G.M., Williams, K.J., Zylstra, P.J. & Shaw, J.D. (2021). Combating ecosystem collapse from the tropics to the Antarctic. *Global Change Biology* 27, 1692-1703.

Beyer, L., & Bölter, M. (2004). *Geoecology of Antarctic Ice-Free Coastal Landscapes*. Springer, Berlin.

Beyer, L., Pingpank, K., Bölter, M., & Seppelt, R. D. Small-distance variation of carbon and nitrogen storage in mineral Antarctic cryosols near Casey Station (Wilkes Land). (1998). *Zeitschrift fur Pflanzenahrung Bodendunde* 161**,** 211-220.

Biersma, E.M., Convey, P., Wyber, R., Robinson, S.A., Dowton, M., van de Vijver, B., Linse, K., Griffiths, H., & Jackson, J.A. (2020). Latitudinal Biogeographic Structuring in the Globally Distributed Moss Ceratodon purpureus. *Frontiers in Plant Science* 11, 2359.

Bishop, J. M., Wasley, J., Waterman, M. J., Kohler, T. J., Van de Vijver, B., Robinson, S. A., & Kopalová, K. (2021). Diatom communities differ among Antarctic moss and lichen vegetation types. *Antarctic Science* 33, 118-132.

Bishop, J.M. Wasley, J., Waterman, M.J., Kohler, T.J. Van de Vijver, B., Robinson, S.A., & Kopalová, K. (2021). Epiphytic diatom communities differ among Antarctic moss and lichen vegetation types. *Antarctic Science* 33, 118-132.

Blight, D. F. (1975). *The Metamorphic Geology of the Windmill Islands Antarctica*. Doctor of Philosophy thesis, University of Adelaide.

Blight, D. F., & Oliver, R. L. (1982). Aspects of the Geological history of the Windmill Islands, Antarctica. In C. Craddock (Ed.), *Antarctic Geoscience* (pp. 445-454). University of Wisconsin Press, Madison.

Blight, D. F., & Oliver, R. L. (1997). The metamorphic geology of the Windmill Islands Antarctica: a preliminary account. *Journal of the Geological Society of Australia* 24, 239-262.

Block, W. (1992). *An Annotated Bibliography of Antarctic Invertebrates (Terrestrial and Freshwater)*. British Antarctic Survey, Natural Environmental Research Council, Cambridge.

Blume, H-P., Kuhn, D., & Bölter, M. (2004). Soils and landscapes. In L. Beyer & M. Bölter, M. (Eds.), *Geoecology of Antarctic Ice-Free Coastal Landscapes* (pp. 94-98, 105-108). Springer, Berlin.

Bramley-Alves, J., King, D.H., Robinson, S.A., & Miller, R.E. (2014). Dominating the Antarctic environment: bryophytes in a time of change. In D.T. Hanson & S.K. Rice (Eds.), *Photosynthesis in bryophytes and early land plants* (pp. 309-324). Springer, The Netherlands.

Bramley-Alves, J., Wanek, W., French, K., & Robinson, S. A. (2015). Moss $\delta^{13}C$: An accurate proxy for past water environments in polar regions. *Global Change Biology* 21, 2454-2464.

Chown, S.L., Leihy, R.I., Naish, T.R., Brooks, C.M., Convey, P., Henley, B.J., Mackintosh, A.N., Phillips, L.M., Kennicutt, M.C. II, & Grant, S.M. (Eds.). (2022). *Antarctic Climate Change and the Environment: A Decadal Synopsis and Recommendations for Action*. Scientific Committee on Antarctic Research, Cambridge, United Kingdom.

Clarke, L.J., & Robinson, S.A. (2008). Cell wall-bound UV-screening pigments explain the high UV tolerance of the Antarctic moss, Ceratodon purpureus. *New Phytologist* 179, 776-783.

Clarke, L.J., Robinson, S.A., & Ayre, D.J. (2009). Genetic structure of Antarctic populations of the moss Ceratodon purpureus. *Antarctic Science* 21, 51-58.

Clarke, L.J., Robinson, S.A., & Ayre, D.J. (2008). Somatic mutation and the Antarctic ozone hole. *Journal of Ecology* 96. 378-385..

Clarke, L.J., Robinson, S.A., Hua, Q., Ayre D.J., & Fink, D. (2012). Radiocarbon bomb spike reveals biological effects of Antarctic climate change. *Global Change Biology* 18, 301-310.

Cowan, A. N. (1979). Giant petrels at Casey, Antarctica. *Australian Bird Watcher* 8, 66-67.

Cowan, A. N. (1981). Size variation in the Snow petrel (Pagodroma nivea). *Notornis* 28, 169-188.

Dunn, J. (2000). *Seasonal variation in the pigment content of three species of Antarctic bryophytes*. Honours thesis, University of Wollongong.

Dunn, J.L., Robinson, S.A. (2006). Ultraviolet B screening potential is higher in two cosmopolitan moss species than in a co-occurring Antarctic endemic moss: implications of continuing ozone depletion. *Global Change Biology* 12, 2282-2296.

Giese, M. (1998). Guidelines for people approaching breeding groups of Adélie penguins (Pygoscelis adeliae). *Polar Record* 34, 287-292.

Goodwin, I. D. (1993). Holocene deglaciation, sea-level change, and the emergence of the Windmill Islands, Budd Coast, Antarctica. *Quaternary Research* 40, 70-80.

Hallingbäck, T., & Hodgetts, N. (2000). *Mosses, Liverworts, and Hornworts: Status Survey and Conservation Action Plan for Bryophytes*. IUCN/SSC Bryophyte Specialist Group.

Heatwole, H., Saenger, P., Spain, A., Kerry, E., & Donelan, J. (1989). Biotic and chemical characteristics of some soils from Wilkes Land Antarctica. *Antarctic Science* 1, 225-234.

Hogg, I. D., & Stevens, M. I. (2004). Soil Fauna of Antarctic Coastal Landscapes. In L. Beyer & M. Bölter, M. (Eds.), *Geoecology of Antarctic Ice-Free Coastal Landscapes* (pp. 265-282). Springer, Berlin.

Hovenden, M. J. and Seppelt, R. D. (1995). Exposure and nutrients as delimiters of lichen communities in continental Antarctica. *Lichenologist* 27, 505-516.

Kennedy, A. D., & Watts, D. J. (2001). *A dataset of Antarctic and sub-Antarctic invertebrates*. Australian Antarctic Data Centre. https://data.aad.gov.au/metadata/records/block_invertebrates

King, D.H., Wasley, J. Ashcroft, M.B., Ryan-Colton, E., Lucieer, A., Chisholm, L.A., & Robinson, S.A. (2020). Semi-automated analysis of digital photographs for monitoring East Antarctic vegetation. *Frontiers in Plant Science* 11, 766.

King, D., Bramley-Alves, J.E., Bergstrom, D.M., Turnbull, J., Robinson, S., Nydahl, A., Malenovsky, Z., Robinson, S., & Wasley, J. (2020). *Windmill Islands Long Term Vegetation Monitoring*. Australian Antarctic Data Centre. https://data.aad.gov.au/metadata/records/AAS_4046_VegetationCoverData

Ling, H. U. (1996). Snow algae of the Windmill Islands region, Antarctica. *Hydrobiologia* 336, 99-106.

Ling, H. U. (2001). Snow Algae of the Windmill Islands, Continental Antarctica: Desmotetraaureospora, sp. nov. and D. antarctica, comb. nov. (Chlorophyta). *Journal of Phycology* 37, 160-174.

Ling, H. U., & Seppelt, R.D. (1998). Non-marine algae and cyanobacteria of the Windmill Islands region, Antarctica, with descriptions of two new species. *Algological Studies* 89, 49-62.

Ling, H. U., & Seppelt, R.D. (1993). Snow algae of the Windmill Islands, continental Antarctica. Chloromonas rubroleosa sp. nov. (Volvocales, Chlorophyta), an alga of red snow. *European Journal of Phycology* 28, 77-84.

Ling, H. U., & Seppelt, R.D. (1990). Snow algae of the Windmill Islands, continental Antarctica. esotaenium berggrenii (Zygnematales, Chlorophyta) the alga of grey snow. *Antarctic Science* 2, 143-148.

Ling, H. U., & Seppelt, R.D. (1998). Snow Algae of the Windmill Islands, continental Antarctica 3. Chloromonas polyptera (Volvocales, Chlorophyta). *Polar Biology* 20, 320-324.

Ling, H. U., & Seppelt, R.D. (2000). Snow Algae of the Windmill Islands Region, Adaptations to the Antarctic Environment. In W. Davison, C. Howard-Williams, & P. Broady (Eds.), *Antarctic Ecosystems: Models for Wider Ecological Understanding* (pp. 171-174). University of Canterbury, New Zealand.

Longton, R. E. (1988). *Biology of polar bryophytes and lichens*. Cambridge University Press, Cambridge.

Lovelock, C.E., & Robinson, S.A. (2002). Surface reflectance properties of Antarctic moss and their relationship to plant species, pigment composition and photosynthetic function. *Plant, Cell and Environment* 25, 1239-1250.

Lucieer, A, Robinson, S., & Bergstrom, D. (2010). Aerial 'OktoKopter' to map Antarctic moss Australian. *Antarctic Magazine* 19, 1-3.

Lucieer A., Robinson S.A., Turner D., Harwin S., & Kelcey J. (2012). Using a micro-UAV for ultra-high resolution multi-sensor observations of Antarctic moss beds. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* Vol. XXXIX-B1, 429–433.

Malenovsky, Z., Lucieer, A., King, D. H., Turnbull, J. D., & Robinson, S. A. (2017). Unmanned aircraft system advances health mapping of fragile polar vegetation. *Methods in Ecology and Evolution* 8, 1842-1857.

Malenovsky, Z., Lucieer, A., Robinson, S., King, D., Turnbull, J., Wasley, J., & King, C. K. (2017). *Airborne, satellite and ground imaging spectroscopy data for estimation of chlorophyll content, leaf density and relative vigour of Antarctic mosses at ASPA 135 and Robinson Ridge study sites*. Australian Antarctic Data Centre. https://data.aad.gov.au/metadata/records/AAS_4046_spectroscopy_chlorophyll/

Malenovsky, Z., Lucieer, A., Robinson S., Turnbull J., & Nydahl, A. (2017). *Ground-based imaging spectroscopy data for estimation of Antarctic moss relative vigour from remotely sensed chlorophyll content and leaf density at ASPA 135*. Australian Antarctic Data Centre. https://data.aad.gov.au/metadata/records/AAS_4046_Spectroscopy_Moss_Vigour

Malenovsky, Z., Turnbull, J. D., Lucieer, A., & Robinson, S. A. (2015). Antarctic moss stress assessment based on chlorophyll content and leaf density retrieved from imaging spectroscopy data. *New Phytologist* 208, 608-624.

Melick, D. R., Hovenden, M. J., & Seppelt, R. D. (1994). Phytogeography of bryophyte and lichen vegetation in the Windmill Islands, Wilkes land, Continental Antarctica. *Vegetation* 111, 71-87.

Melick, D. R., & Seppelt, R. D. (1990). Vegetation patterns in Relation to climatic and endogenous changes in Wilkes Land, continental Antarctica. *Journal of Ecology* 85, 43-56.

Miller, W. R., Miller, J. D., & Heatwole, H. (1996). Tardigrades of the Australian Antarctic Territories: the Windmill Islands, East Antarctica. *Zoological Journal of the Linnean Society* 116, 175-184.

Murray, M. D., & Luders, D. J. (1990). Faunistic studies at the Windmill Islands, Wilkes Land, East Antarctica, 1959-80. *ANARE Research Notes* 73, Australian Antarctic Division.

Ochyra, R., Lewis-Smith R., & Bednarek-Ochyra, H. (2008). *Illustrated Moss Flora of Antarctica*. Cambridge University Press, Cambridge.Orton, M. N. (1963). A Brief Survey of the fauna of the Windmill Islands, Wilkes Land, Antarctica. *The Emu* 63, 14-22.

Øvstedal, D. O., & Lewis Smith, R. I. (2001). *Lichens of Antarctica and South Georgia: A Guide to their Identification and Ecology*. Cambridge University Press, Cambridge.

Paul, E., Stüwe, K., Teasdale, J., & Worley, B. (1995). Structural and metamorpohic geology of the Windmill Islands, East Antarctica: field evidence for repeated tectonothermal activity. *Australian Journal of Earth Sciences* 42, 453-469.

Perera Castro, A.V. Waterman, M.J., Turnbull, J.D., Ashcroft, M.B., McKinley, E. Watling, J.R., Bramley-Alves, J., Casanova-Katny, A., Zuñiga, G.E., Flexas, J., & Robinson, S.A. (2020). It is hot in the sun: Antarctic mosses have high temperature optima for photosynthesis despite cold climate. *Frontiers in Plant Science* 11, 1178

Petz, P. (1997). Ecology of the active microfauna (Protozoa, Metazoa) of Wilkes Land, East Antarctica. *Polar Biology* 18, 33-44.

Petz, P., & Foissner, W. (1997). Morphology and infraciliature of some ciliates (Protozoa, Ciliophora) from continental Antarctica, with notes on the morphogenesis of Sterkiella histriomuscorum. *Polar Record* 33, 307-326.

Raniga, D., Amarasingam. N., Sandino, J., Doshi, A., Barthelemy, J., Randall, K., Robinson, S.A., Gonzalez, F., & Bollard, B. (2024). Monitoring of Antarctica's Fragile Vegetation using Drone-based Remote Sensing, Multispectral Imagery and AI. *Sensors* 24, 1063.

Robinson, S. (2022). Among ancient moss forests - Observing a quarter-century of change. In J. Bradley, J. Blackadder, K. Ellis, J. Chandler, D. Rooke, S. Williams, F. Parrett, N. Webster, & C. Coleman (Eds.), *Griffith Review 77: Real Cool World*. Griffith University Press.

Robinson, S. A., King, D. H., Bramley-Alves, J., Waterman, M. J., Ashcroft, M. B., Wasley, J., Turnbull, J. D., Miller, R. E., Ryan-Colton, E., Benny, T., Mullany, K., Clarke, L., Barry, L. A., & Hua, Q. (2018). Rapid change in East Antarctic terrestrial vegetation in response to regional drying. *Nature Climate Change* 8, 879-884.

Robinson, S., Bramley-Alves, J.E., King, D., Wasley, J., Ashcroft, M., Waterman, M., Turnbull, J., Miller, R., Ryan-Colton, E., Barry, L., Clarke, L., Mullany, K., Benny, T., & Hua, Q. (2020). *Windmill Islands bryophyte communities surveyed 2000-2013 (13 years)*. Australian Antarctic Data Centre. https://data.aad.gov.au/metadata/records/AAS_4046_Transects_2000-2013

Robinson, S.A., Wasley, J., Popp, M., & Lovelock, C.E. (2000). Desiccation tolerance of three moss species from continental Antarctica. *Australian Journal of Plant Physiology* 27, 379-388.

Robinson, S. A., Wasley, J., & Tobin, A. K. (2003). Living on the edge-plants and global change in continental and maritime Antarctica. *Global Change Biology* 9, 1681-1717.

Robinson, S. A., & Waterman, M. (2014). Sunsafe bryophytes: photoprotection from excess and damaging solar radiation. In D. T. Hanson & S. K. Rice (Eds.), *Photosynthesis of Bryophytes and Seedless Vascular Plants* (pp. 113-130). Springer.

Robinson, S. A., Turnbull, J. D., & Lovelock, C. E. (2005). Impact of changes in natural UV radiation on pigment composition, surface reflectance and photosynthetic function of the Antarctic moss, Grimmia antarctici. *Global Change Biology* 11**,** 476-489.

Roser, D. J., Melick, D. R., Ling, H. U., & Seppelt, R. D. (1992). Polyol and sugar content of terrestrial plants from continental Antarctica. *Antarctic Science* 4, 413-420.

Roser, D. J., Seppelt, R. D., & Nordstrom, O. (1994) Soluble carbohydrate and organic content of soils and associated microbiota from the Windmill Islands, Budd Coast, Antarctica. *Antarctic Science* 6, 53-59.

Roser, D. J., Melick, D. R., & Seppelt, R. D. (1992). Reductions in the polyhydric alcohol content of lichens as an indicator of environmental pollution. *Antarctic Science* 4, 185-189.

Sandino, J., Bollard, B., Doshi A., Randall K., Barthelemy J., Robinson S. A., & Gonzalez F. (2023). The Green Fingerprint of Antarctica: Drones, Hyperspectral Imaging and Machine Learning for Moss and Lichen Classification. *Remote Sensing* 15, 5658.

Selkirk, P. M., & Skotnicki, M. L. (2007). Measurement of moss growth in continental Antarctica. *Polar Biology* 30, 407-413.

Seppelt, R. D. (2008). Dr R. Seppelt, Senior Research Scientist, Australian Antarctic Division. Personal communication.

Seppelt, R. D. (2002). Plant Communities at Wilkes Land. In L. Beyer & M. Bölter (Eds.), *Geoecology of Antarctic Ice-Free Coastal Landscapes* (pp. 233-242). Springer, Berlin.

Seppelt, R. D. (2002). Wilkes Land (Casey Station). In L. Beyer & M. Bölter (Eds.), *Geoecology of Antarctic Ice-Free Coastal Landscapes* (pp. 41-46). Springer, Berlin.

Smith, R. I. L. (1980). Plant community dynamics in Wilkes Land, Antarctica. *Proceedings NIPR Symposium of Polar Biology* 3, 229-224.

Smith, R. I. L. (1986). Plant ecological studies in the fellfield ecosystem near Casey Station, Australian Antarctic Territory, 1985-86. *British Antarctic Survey Bulletin* 72, 81-91.

Terauds A., Chown, S. L., Morgan, F., Peat, H. J., Watts, D., Keys, H., Convey, P., & Bergstrom, D. M. (2012). *Conservation biogeography of the Antarctic. Diversity and Distributions* 18, 726–741.

Turnbull, J. D., Leslie, S. J. & Robinson, S. A. (2009). Desiccation protects two Antarctic mosses from ultraviolet–B induced DNA damage. *Functional Plant Biology* 36, 214-221.

Turnbull, J. D., & Robinson, S. A. (2009). Accumulation of DNA damage in Antarctic mosses: correlations with ultraviolet-B radiation, temperature and turf water content vary among species. *Global Change Biology* 15, 319-329.

Turner, D., Cimoli, E., Lucieer, A., Haynes, R., Randall, K., Waterman, M., Lucieer, V., & Robinson, S.A. (2023). Mapping water content in drying Antarctic moss communities using UAS-borne SWIR imaging spectroscopy. *Remote Sensing in Ecology and Conservation* (early view). https://doi.org/10.1002/rse2.371

Turner, D., Lucieer, A., Malenovsky, Z., King, D. H., & Robinson, S. A. (2014). Spatial Co-Registration of Ultra-High Resolution Visible, Multispectral and Thermal Images Acquired with a Micro-UAV over Antarctic Moss Beds. *Remote Sensing* 6, 4003-4024.

Turner, D., Lucieer, A., & Watson, C. (2012). An Automated Technique for Generating Georectified Mosaics from Ultra-High Resolution Unmanned Aerial Vehicle (UAV) Imagery, Based on Structure from Motion (SfM) Point Clouds. *Remote Sens*. 4, 1392-1410.

Turner, D., Malenovsky, Z., Lucieer, A., Turnbull, J. D., & Robinson, S. A. (2019). Optimizing Spectral and Spatial Resolutions of Unmanned Aerial System Imaging Sensors for Monitoring Antarctic Vegetation. *Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 12, 3813-3825.

Wasley, J., Robinson, S. A., Lovelock, C. E., & Popp, M. (2006). Climate change manipulations show Antarctic flora is more strongly affected by elevated nutrients than water. *Global Change Biology* 12, 1800-1812.

Wasley, J., Robinson, S. A., Lovelock, C. E., & Popp, M. (2006). Some like it wet — biological characteristics underpinning tolerance of extreme water stress events in Antarctic bryophytes. *Functional Plant Biology* 33, 443-455.

Wasley, J., & Robinson, S. A. (2011). Changes in Vegetation Communities in Antarctica. Box 7.3. 2011 State of the Environment Report. Australian Government.

Wasley, J., Robinson, S. A., Turnbull, J. D., King D. H., Wanek, W., & Popp, M. (2012). Bryophyte species composition over moisture gradients in the Windmill Islands, East Antarctica: development of a baseline for monitoring climate change impacts. *Biodiversity* 13, 257-264.

Wasley J., Turnbull J., & Robinson, S. (2015). *Field measurements of temperature, moisture and photosynthetic activity in three species of moss at Casey over a two week period in January 2003*. Australian Antarctic Data Centre. https://data.aad.gov.au/metadata/ASAC_1313_Moss_Field_Measurements

Wasley, J., Turnbull, J., & Robinson, S. (2018). *Moss desiccation experiments conducted at Casey 1998-99 and 1999-2000 by Jane Wasley*. Australian Antarctic Data Centre. https://data.aad.gov.au/metadata/ASAC_1087_Desiccation

Waterman, M. J. (2015). *The what and where of ultraviolet protective mechanisms in Antarctic mosses.* Doctor of Philosophy thesis, University of Wollongong.

Waterman, M. J., Bramley-Alves, J., Miller, R. E., Keller P. A., & Robinson, S. A. (2018). Photoprotection enhanced by red cell wall pigments in three East Antarctic mosses. *Biological Research* 51, 49.

Waterman, M. J., Nugraha, A. S., Hendra, R., Ball, G. E., Robinson, S. A., & Keller P. A. (2017). Antarctic moss biflavonoids show high antioxidant and ultraviolet-screening activity. *Journal of Natural Products* 80, 2224-2231.

Waterman, M., Turnbull, J., & Robinson, S. (2018). *Antarctica's 'moss forests' are drying and dying*. The Conversation. https://theconversation.com/antarcticas-moss-forests-are-drying-and-dying-103751

Woehler, E. J., Penney, S. M., Creet, S. M., & Burton, H. R. (1994). Impacts of human visitors on breeding success and long-term population trends in Adélie penguins at Casey, Antarctica. *Polar Biology* 14, 269-274.

Woehler, E. J., Slip, D. J., Robertson, L. M., Fullagar, P. J., & Burton, H. R. (1991). The distribution, abundance and status of Adélie penguins Pygoscelis adeliae at the Windmill Islands, Wilkes Land, Antarctica. *Marine Ornithology* 19, 1-18.

Yin, H., Perera-Castro, A.V., Randall, K. L., Turnbull, J. D., Waterman, M.J., Dunn, J., & Robinson, S.A. (2023). Basking in the sun: how mosses photosynthesise and survive in Antarctica. *Photosynthesis Research* 158, 151–169.

Appendix 1: North-east Bailey Peninsula, Antarctic Specially Protected Area

No 135, boundary coordinates

Boundary Point	Longitude	Latitude	Boundary Point	Longitude	Latitude
1	110°32'56"	66°17'11"	**14**	110°32'12"	66°16'51"
2	110°32'50"	66°17'11"	**15**	110°32'16"	66°16'52"
3	110°32'41"	66°17'10"	**16**	110°32'19"	66°16'53"
4	110°32'22"	66°17'7"	**17**	110°32'19"	66°16'55"
5	110°32'20"	66°17'6"	**18**	110°32'24"	66°16'55"
6	110°32'18"	66°17'2"	**19**	110°32'25"	66°16'53"
7	110°32'18"	66°17'0"	**20**	110°32'29"	66°16'53"
8	110°32'14"	66°17'0"	**21**	110°32'44"	66°16'54"
9	110°32'9"	66°16'56"	**22**	110°33'9"	66°17'5"
10	110°32'8"	66°16'54"	**23**	110°33'11"	66°17'6"
11	110°32'5"	66°16'54"	**24**	110°33'10"	66°17'9"
12	110°32'7"	66°16'52"	**25**	110°33'2"	66°17'11"
13	110°32'7"	66°16'52"			

Appendix 2: Mosses, liverworts and lichens identified from North-east Bailey Peninsula Antarctic Specially Protected Area No 135, (from Melick 1994, Seppelt pers. comm.)

Mosses
Bryum pseudotriquetrum (Hedw.) Gaertn., Meyer et Scherb.
Ceratodon purpureus (Hedw.) Brid.
Schistidium antarctici Card.
Liverworts
Cephaloziella varians Steph.
Lichens
Acarospora gwynii Dodge & Rudolph
Amandinea petermannii (Hue) Matzer, H. Mayrhofer & Scheid.
Buellia cf. cladocarpiza Lamb?
Buellia frigida Darb.
Buellia grimmiae Filson
Buellia cf. lignoides Filson
Buellia papillata Tuck.
Buellia pycnogonoides Darb.
Buellia soredians Filson
Caloplaca athallina Darb.
Caloplaca citrina (Hoffm.) Th. Fr.
Candelariella flava (C.W. Dodge & Baker) Castello & Nimis
Lecanora expectans Darb.
Lecidea spp.
Lecidea cancriformis Dodge & Baker (=*Lecidea phillipsiana* Filson)
Lecidea andersonii Filson
Lepraria sp.
Pleopsidium chlorophanum (Wahlenb.) Zopf
Rhizocarpon geographicum
Rhizoplaca melanophthalma (Ram.) Leuck. & Poelt
Rinodina olivaceobrunnea Dodge & Baker
Physcia caesia (Hoffm.) Hampe
Umbilicaria aprina Nyl.
Umbilicaria decussata (Vill.) Zahlbr.
Umbilicaria cf. propagulifera (Vainio) Llano
Xanthoria elegans (Link) Th. Fr.
Xanthoria mawsonii Dodge.
Pseudephebe minuscula (Nyl ex Arnold) Brodo & Hawksw.
Usnea antarctica Du Rietz
Usnea sphacelata R. Br.

Appendix 3: Fungi isolated from soils, mosses, lichens and algae from ASPA No 135 and from species of wider distribution in the Windmill Islands region (from Azmi 1998 and Seppelt pers. comm. 2008)

Note: This is only a partial list of the taxa isolated from the Windmill Islands

	ASPA No 135	Bailey Peninsula	Bryum pseudotri- quetrum	Ceratodon purpureus	Grimmia antarctici	Algae	Lichens*
Acremonium sp.					9		
Acremonium crotociningenum (Schol-Schwarz) W. Gams		9					9
Alternaria alternata (Fr.) Keissl.		9					
Arthrobotrys			9	9			
Aspergillus nidulans (Eidam) G. Winter		9					
Aspergillus sp.						9	
Botrytis cinerea Pers.		9					
Chrysosporium sp	9		9	9	9		
Chrysosporium pannorum (Link.) S. Hughes	9	9	9	9	9	9	9
Cladosporium sp.		9					
Diplodia sp.		9					
Fusarium oxysporum E.F. Sm., & Swingle		9					
Geomyces sp.		9	9	9		9	9
Geotrichum sp.							
Mortierella sp.		9	9		9	9	9
Mortierella gamsii Milko		9	9				
Mucor pyriformis Scop.		9	9		9		
Mycelia sterilia 1**	9		9	9	9	9	9
Mycelia sterilia 2**	9		9	9	9	9	
Mycelia sterilia 3**	9		9	9	9		
Mycelia sterilia 4**		9					
Nectria peziza Berk.		9	9		9		
Penicillium chrysogenum Thom	9		9		9	9	
P. commune Thom		9					
P. corylophilum Dierckx		9					
P. expansum Link		9	9	9		9	
P. hirsutum Dierckx		9					
P. palitans Westling		9	9	9	9		
P. roqueforti Thom		9					
Penicillium sp.			9	9	9	9	
Penicillium sp. 1							
Penicillium sp. 2							

*Lichens are *Xanthoria mawsonni, Umbilicaria decussata and Usnea sphacelata.*

**Mycelia sterilia is a general term for sterile mycelia. Approximately 45% of all the isolates obtained from the Windmill Islands have not been identified because they remained sterile in culture.

	ASPA No 135	Bailey Peninsula	Bryum pseudotri- quetrum	Ceratodon purpureus	Grimmia antarctici	Algae	Lichens*
Phialophora *malorum* (Kidd & Beaumont) McColloch		9	9	9	9	9	
Phoma herbarum Westend		9	9	9	9		
Phoma sp.	9						
Phoma sp. 1			9	9	9		
Phoma sp. 2				9	9		
Rhizopus stolonifer (Ehrenb.) Vuill.		9				9	
Sclerotinia sclerotiorum (Lib.) de Bary		9					
Thelebolus microsporus Berk. & Broome) Kimbr.	9	9	9	9	9	9	9
Trichoderma harzianum Rifai		9					
T. pseudokoningi Rifai		9					

*Lichens are *Xanthoria mawsonni, Umbilicaria decussata and Usnea sphacelata.*

**Mycelia sterilia is a general term for sterile mycelia. Approximately 45% of all the isolates obtained from the Windmill Islands have not been identified because they remained sterile in culture.

Appendix 4: Cyanobacterial and algal species identified from the Windmill Islands region

The taxa are listed in alphabetical order under each phylum together with their habitats and whether they are maintained in culture. A = Aquatic, T = Terrestrial (from soil),

S = Snow or ice and C = Culture. (from Ling 1998 and Seppelt pers. comm. 2008).

Cyanobacteria	
Aphanothece castagnei (Breb.) Rabenh.	A
Aphanocapsa elachista var. irregularis Boye-Pet.	A
Aphanocapsa muscicola (Menegh.) Wille	A
Aphanothece saxicola Nageli	A
Aphanothece sp.	A
Calothrix parietina Thur.	A
Chamaesiphon subglobosus (Ros-Taf) Lemmerm.	A
Chroococcus dispersus (Keissl.) Lemmerm.	A
Chroococcus minutus (Kutz.) Nageli	A
Chroococcus turgidus (Kutz.) Nageli	A
Dactylococcopsis antarctica F E. Fritsch	A
Dactylococcopsis smithii R. et E.Chodat (= *Rhabdogloea smithii* (R. et E.Chodat)	A
Eucapsis sp.	T
Gloeocapsa dermochroa Nageli	A
G. kuetzingiana Nageli	A
Hammatoidea sp.	A
Homoeothrix sp.	A
Isocystis pallida Woron.	AT
Katagnymene accurata Geitler	AT
Lyngbya attenuata Fritsch	A
Lyngbya martensiana Menegh.	A
Merismopedia tenuissima Lemmerm.	AT
Myxosarcina concinna Printz	A
Nodularia harveyana var. *sphaerocarpa* (Born. et Flah.) Elenkin	A
Nostoc commune Vaucher	ATC
Nostoc sp.	T
Oscillatoria annae Van Gook	A
Oscillatoria fracta Carlson	A
Oscillatoria irrigua Kutz	A
Oscillatoria lemmermannii Wolosz.	A
Oscillatoria proteus Skuja	A
Oscillatoria sp. (Broady 1979a, *Oscillatoria* cf. *limosa* Agardh)	A
Oscillatoria sp. (BROADY 1979a, *Oscillatoria* sp. C)	T
Phormidium autumnale(Agardh) Gomont	T
Phormidium foveolarum Gomont	A
Phormidium frigidum F.E. Fritsch	A
Phormidium subproboscideum (W et G. S. West) Anagnost et Komarek	A
Phormidium sp.	A

Plectonema battersii Gomont	A
Plectonema nostocorum Bornet	A
Pseudanabaena mucicola (Hub.-Pest. et Naum.) Bour.	A
Schizothrix antarctica F E. Fritsch	A
Stigonema mesentericum Geitler f.	T
Stigonema minutum (AGARDH) Hassall	T
Stigonema sp.	T
Synechococcus aeruginosus Nageli	T
Synechococcus maior Schroeter	AT
Tolypothrix byssoidea (Berk.) Kirchner f	A
Tolypothrix distorta var. *penicillata* (Agardh)Lemmerm.(= Tolypothrix penicillata Thuret)	A
Chlorophyta	
Actinotaenium cucurbita (Breb.) Teiling	AC
Apodochloris irregularis Ling et Seppelt	AC
Asterococcus superbus (Cienk.) Scherff.	AC
Binuclearia tatrana Wittr.	AC
Binuclearia tectorum (KÜTZ.) Beger	AC
Chlamydomonas pseudopulsatilla Gerloff	S
Chlamydomonas sphagnicola (F.E. Fritsch) F.E. Fritsch et Takeda	TC
Chlamydomonas subcaudata Wille	A
Chlamydomonas sp. I	A
Chlamydomonas sp. 2	A
Chlorella vulgaris Beij.	AT
Chloromonas brevispina Hoham, Roemer et Mullet	S
Chloromonas polyptera (F.E. Fritsch) Hoham, Mullet et Roemer	SC
Chloromonas rubroleosa Ling et Seppelt	SC
Chloromonas sp. I	SC
Chloromonas sp. 2	A
Coenochloris sp.	T
Desmococcus olivaceus (Pers. ex Ach.) Laundon	ATC
Desmotetra sp. 1	SC
Desmotetra sp. 2	SC
Dictyosphaerium dichotomum Ling et Seppelt	T
Fernandinella alpina Chodat	AC
Geminella terricola Boye-Pet.	T
Gloeocystis polydermatica (Kutz.) Hindak	T
Gloeocystis vesiculosa Nageli	T
Gongrosira terricola Bristol	AC
Gonium sociale (Dujard.) Warm.	AC
Hormotila sp.	SC
Kentrosphaera bristolae G.M.Smith	A
Klebsormidium dissectum var. 1(Broady 1979a, *Chlorhormidium dissectum* var. A)	T
Klebsormidium subtilissimum (Rabenh.) Silva, Mattox et Blackwell	A
Klebsormidium sp. (BROADY 1981, *Klebsormidium* sp. A)	SC

Lobococcus sp.?	T
Lobosphaera tirolensis Reisigl	TC
Macrochloris multinucleate (Reisigl) Ettl et Gartner	ATC
Mesotaenium berggrenii (Wittr.) Lagerh. f.	S
Monoraphidium contortum (Thur.) Komark.-Legn.	A
Monoraphidium sp.	S
Myrmecia bisecta Reisigl	T
Palmella sp. 1	TC
Palmella sp. 2	A
Palmellopsis sp.	SC
Prasiococcus calcarius (Boye-Pet.) Vischer	ATSC
Prasiola calophylla (Carmich.) Menegh.	TC
Prasiola crispa (Lightf.) Menegh.	ATSC
Prasiola sp.?	A
Pseudochlorella subsphaerica Reisigl	T
Pseudococcomyxa simplex (Mainx) Fott	T
Pyramimonas gelidfcola McFadden, Moestrup et Wetherbee	A
Pyramimonas sp.	A
Raphidonema helvetica Kol	S
Raphidonema nivale Lagerh.	S
Raphidonema sempervirens Chodat	TC
Raphidonema tatrae Kol	S
Schizogonium murale Kutz.	ATC
Schizogonium sp.	AT
Staurastrum sp.	A
Stichococcus bacillaris Nageli	TSC
Stichococcus fragilis (A. Braun) Gay	A
Stichococcus minutus Grintzesco et Peterfi	S
Tetracystis sp. 1	TC
Tetracystis sp. 2	TC
Trebouxia sp.	TC
Trichosarcina mucosa (B Broady) Chappell et O'Kelly	TC
Trochiscia sp. (Broady 1979x,	A
Trochiscia sp. A)	
Ulothrix implexa (Kutz.) Kutz. A	
Ulothrix zonata (Weber et Mohr) Kutz	
Ulothrix sp. 1	A
Ulothrix sp. 2	S
Uronema sp.	S
Xanthophyta	
Botrydiopsis sp.	TC
Bumilleriopsis sp.	TC
Ellipsoidion sp.?	S
Fremya sp.	ATC

Gloeobotrys sp.	A
Heterococcus filiformis Pitschm.	TC
Heterococcus sp.	TC
Heterothrix debilis Vischer	TC
Tribonema microchloron Ettl	A
Chrysophyta	
Chrysococcus sp.	S
Chroomonas lacustris Pascher et Ruttner	A
Dinophyta	
Gymnodinium sp.	A
Bacillariophyta	
**Achnanthes coarctata* var. *elliptica* Krasske	S
Amphora veneta Kutz.	A
**Cocconeis imperatrix* A. Schmidt	S
**Diploneis subcincta* (A. Schmidt) Cleve	S
**Eucampia balaustium* Castray	S
Fragilaria sp.	A
Fragilariopsis antarctica (Castray) Hust.	A
Hantzschia amphioxys (Ehrenb.) Grun.	A
Navicula atomus (Nag.) Grun.	A
Navicula murrayi W. et G. S. West	A
Navicula muticopsis Van Heurck	AT
Navicula sp.	A
Nitzschia palea (Kutz.) W. S M.	AT
Pinnularia borealis Ehrenb.	AT
Torpedoes laevissima W et G. S. West	A

*Believed to be marine diatoms from wind-borne sea spray.

Appendix 5: Ciliates and testate amoebae active in the vicinity of Casey

Station on Bailey Peninsula (Modified from Petz and Foissner 1997)

Ciliates
Bryometopus sp
Bryophyllum cf. loxophylliforme
Colpoda cucullus (Mueller, 1773)
Colpoda inflata (Stokes, 1884)
Colpoda maupasi Enriques, 1908
Cyclidium muscicola Kahl, 1931
Cyrtolophosis elongata (Schewiakoff, 1892)
Euplotes sp.
Fuscheria terricola Berger and others, 1983
Gastronauta derouxi Blatterer and Foissner, 1992
Halteria grandinella (Mueller, 1773)
Holosticha sigmoidea Foissner, 1982
Leptopharynx costatus Mermod, 1914
Odontochlamys wisconsinensis (Kahl, 1931)
Oxytricha opisthomuscorum Foissner and others, 1991
Parafurgasonia sp.
Paraholosticha muscicola (Kahl, 1932)
Platyophrya vorax Kahl, 1926
Pseudocohnilembus sp.
Pseudoplatyophrya nana (Kahl, 1926)
Pseudoplatyophrya cf. saltans
Sathrophilus muscorum (Kahl, 1931)
Sterkiella histriomuscorum (Foissner and others, 1991)
Sterkiella thompsoni Foissner, 1996
Trithigmostoma sp.
Vorticella astyliformis Foissner, 1981
Vorticella infusionum Dujardin, 1 841
Testate amoebae
Assulina muscorum Greeff, 1888
Corythion dubium Taranek, 1881
Euglypha rotunda Wailes and Penard, 1911
Pseudodifflugia gracilis var. *terricola* Bonnet and Thomas, 1960
Schoenbornia viscicula Schoenborn, 1964
Trachelocorythion pulchellum (Penard, 1890)

Australian Government
Department of Climate Change, Energy, the Environment and Water
Australian Antarctic Division

Map A: Antarctic Specially Protected Areas, Windmill Islands, East Antarctica

Station
Refuge
Coastline
Contour (50 metre interval)
ASPA boundary
NE Bailey Peninsula ASPA No. 135

0 2 4 6 Kilometres

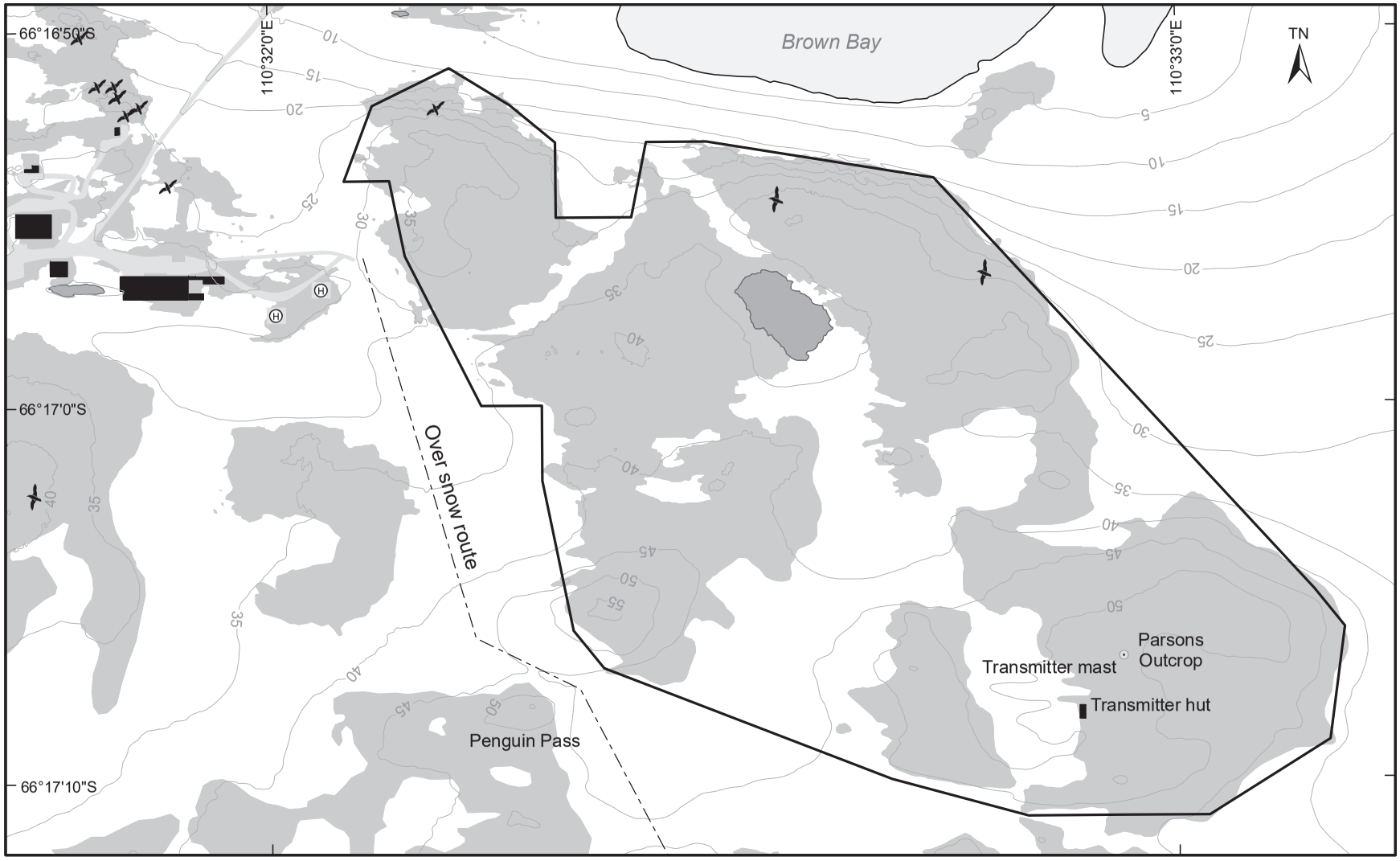
Horizontal Datum: WGS84
Projection: UTM Zone 49

Map available at: *https://data.aad.gov.au/aadc/mapcat/*
Produced by the Australian Antarctic Data Centre
February 2024, Map Catalogue No. 16141

Australian Government
Department of Climate Change, Energy, the Environment and Water
Australian Antarctic Division

Map B: Antarctic Specially Protected Area No. 135, North-east Bailey Peninsula

Topography and Bird Distribution

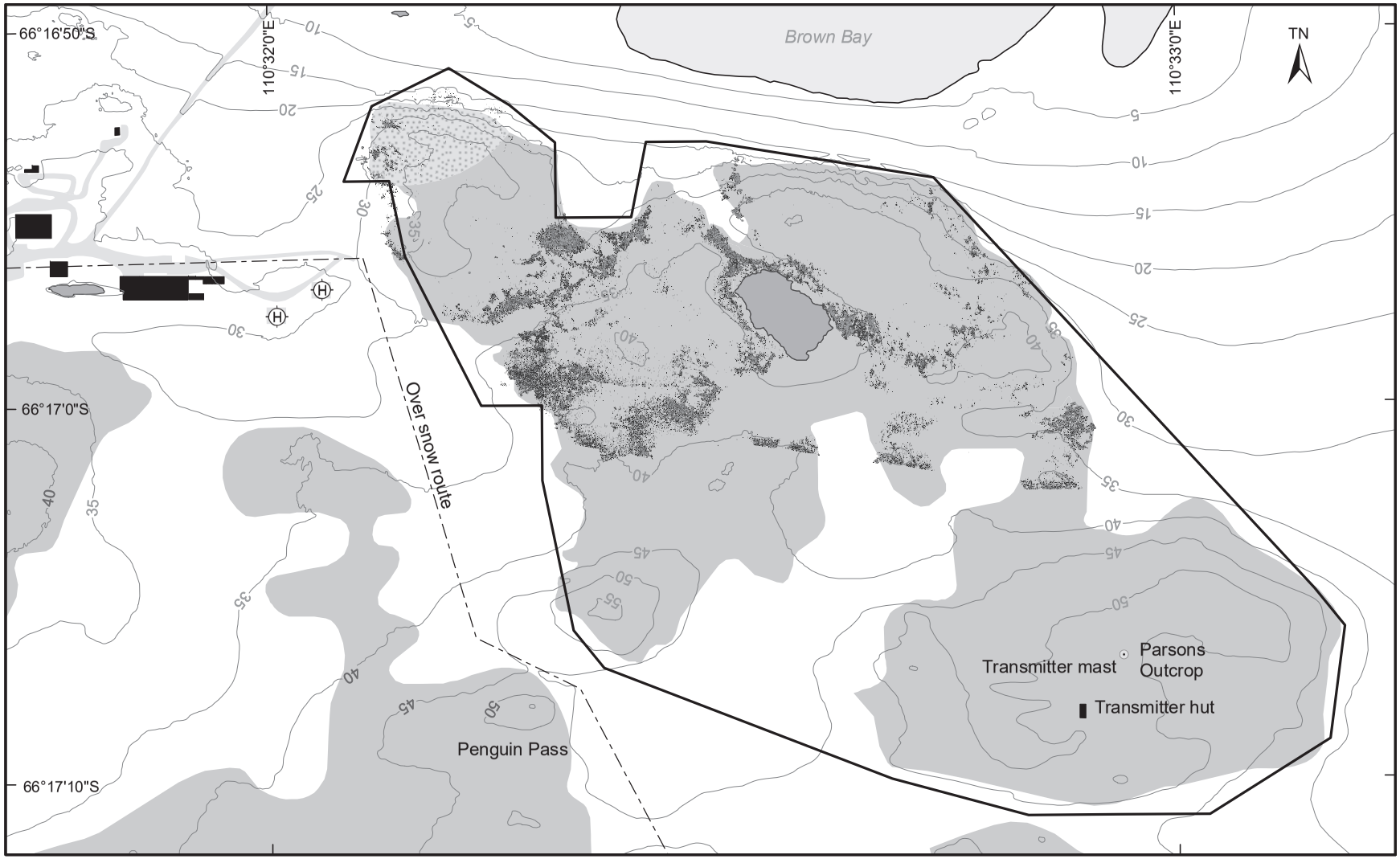


Map available at: *https://data.aad.gov.au/aadc/mapcat/*
Produced by the Australian Antarctic Data Centre
February 2024, Map Catalogue No. 16142

Australian Government
Department of Climate Change, Energy, the Environment and Water
Australian Antarctic Division

Map C: Antarctic Specially Protected Area No. 135, North-east Bailey Peninsula

Vegetation



Vegetation

- *Bryophytes (less dense)**
- *Bryophytes (more dense)**
- *Macrolichens*
- *Crustose lichens*

- Mast
- Helipad
- Building
- Coastline
- Contour (5m interval)
- ASPA boundary
- Lake
- Road

0 25 50 100 150 200 Metres

Horizontal Datum: WGS84
Projection: UTM Zone 49

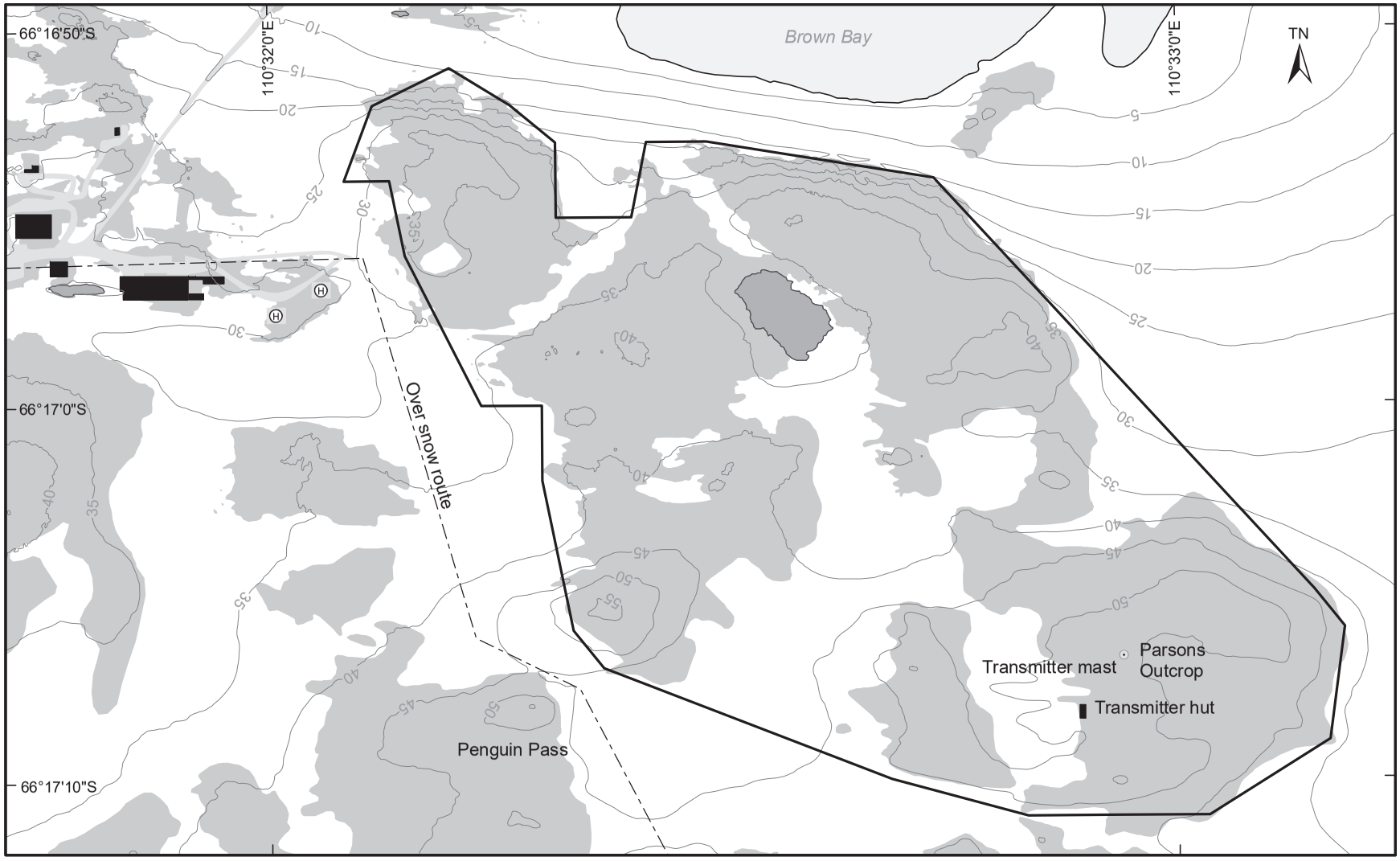
*Note: Bryophytes can occur outside indicated areas. At the date of map publication, south of 66°17'2"S had not been surveyed.

Map available at: *https://data.aad.gov.au/aadc/mapcat/*
Produced by the Australian Antarctic Data Centre
February 2024, Map Catalogue No. 16143

Australian Government
Department of Climate Change, Energy, the Environment and Water
Australian Antarctic Division

Map D: Antarctic Specially Protected Area No. 135, North-east Bailey Peninsula

Geology



Lithology
Late granite gneiss

Mast
Helipad
Building
Coastline

Contour (5m interval)
ASPA boundary
Lake
Road

0 25 50 100 150 200 Metres

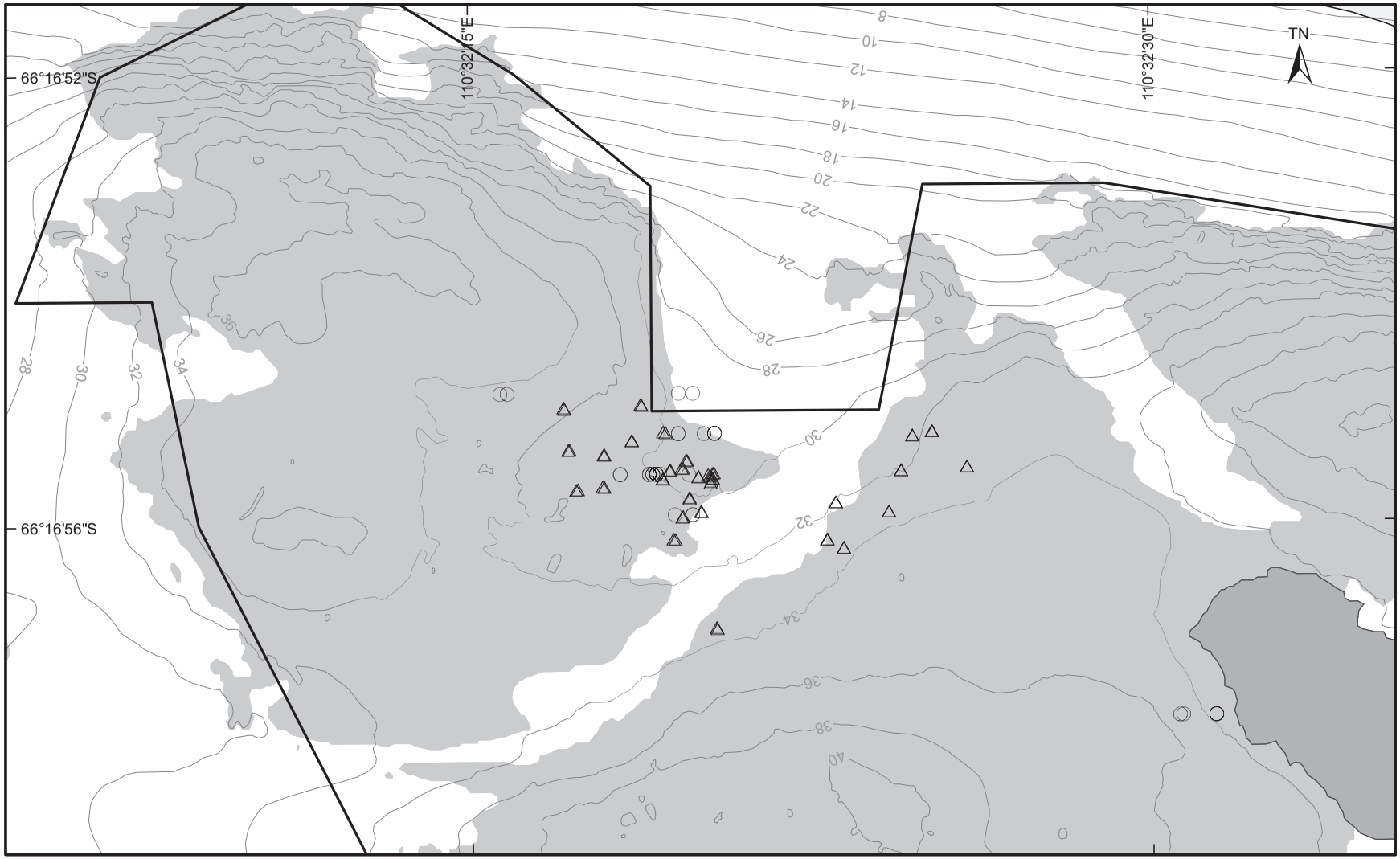
Horizontal Datum: WGS84
Projection: UTM Zone 49

Map available at: *https://data.aad.gov.au/aadc/mapcat/*
Produced by the Australian Antarctic Data Centre
February 2024, Map Catalogue No. 16144

Australian Government
Department of Climate Change, Energy, the Environment and Water
Australian Antarctic Division

Map E: Antarctic Specially Protected Area No. 135, North-east Bailey Peninsula

Long term scientific monitoring sites



AAS Projects

△ 1310, 1313, 2542, 3042, 3129, 3130, 4046

○ 1041, 1104, 2152, 2545

Contour (2m interval)

ASPA boundary

Lake

Ice-free area

0 10 20 40 60 80 Metres

Horizontal Datum: WGS84
Projection: UTM Zone 49

Map available at: *https://data.aad.gov.au/aadc/mapcat/*
Produced by the Australian Antarctic Data Centre
February 2024, Map Catalogue No. 16145