



Management Plan

For Antarctic Specially Protected Area No. 105 BEAUFORT ISLAND, McMURDO SOUND, ROSS SEA

1. Description of Values to be Protected

Beaufort Island was originally designated as Specially Protected Area No. 5 in Recommendation IV-5 (1966) on the grounds that it “contains substantial and varied avifauna, that it is one of the most important breeding grounds in the region, and that it should be protected to preserve the natural ecological system as a reference area.” The Area was re-designated by Decision 1 (2002) as Antarctic Specially Protected Area (ASPA) No. 105 and a revised Management Plan was adopted through Measure 2 (2003), Measure 4 (2010), and Measure 5 (2015)). The Area is an island relatively untouched by human activity, set aside primarily to protect the ecological values of the site from human interference.

Beaufort Island is the northern-most feature of the Ross Archipelago, lying approximately 30 kilometres north of Cape Bird, Ross Island. It is a portion of the rim of a volcanic cone, the remainder of which was eroded away and is now submerged to the east of the island. The island, and the remains of the submerged caldera, block the predominantly westward drift of pack ice and icebergs calving from the nearby Ross Ice Shelf. Icebergs ground on these peaks which in turn facilitate fast ice growth. Beaufort Island is predominantly rock but portions are ice and snow covered. On the south west side of the island there is a broad ice-free shelf with raised beaches behind which summer ponds form, fed by small meltwater streams draining to the coast. Sloping ice fields (about 12° to 15°) cover much of the west and north side of the island. An extensive flat area of less than 50 m elevation is at the north end of the island, where the ice cap of the island drains to a boulder beach, fringing that portion of the shore. Near vertical cliffs compose the eastern side of the island facing the centre of the caldera.

The avifauna is the most varied in the southern Ross Sea. There exists a large Adélie penguin (*Pygoscelis adeliae*) colony on the broad shelf of the southwest side of the island, and a smaller newly formed subcolony, established in 1995, on the beach along the northwest coast. The dating of Adélie penguin remains goes back 45,000 years. A breeding colony of Emperor penguins (*Aptenodytes forsteri*) exists in variable locations on the fast ice to the north and east of the island where grounded icebergs facilitate fast ice establishment. There is a colony of South polar skua (*Catharacta maccormicki*) on both the north and south coasts and Snow petrels (*Pagodroma nivea*) have been seen nesting in cavities on the cliffs at the south of the island. The boundaries of the Area, which previously excluded the Emperor colony, have been extended to include the fast-ice that could potentially be occupied by breeding birds. Weddell seals (*Leptonychotes weddellii*) haul out and pup on the fast ice adjacent to the various grounded icebergs and Leopard seals (*Hydrurga leptonyx*) and Ross sea killer whales (Type C) but also the form known as Type B, occur in the vicinity. The Ross sea killer whales are attracted by fish, and the Leopard seals and Type B killer whales are attracted by the penguins and seals. Crabeater seals (*Lobodon carcinophagus*), Minke whales (*Balaenoptera acutorostrata*) and Arnoux’s beaked whales (*Berardius arnuxii*) have also been seen in the surrounding waters.

Beaufort Island is situated in Environment S – McMurdo South Victoria Land geologic based on the Environmental Domains Analysis for Antarctica (Resolution 3 (2008)) and in Region 9 – South Victoria Land based on the Antarctic Conservation Biogeographic Regions (Resolution 6 (2012)).

Important Bird Area (IBA) 188, Beaufort Island, is found within the Area.

Open water and pack ice around the island early in the summer season make access difficult so most of the Area is known to have been visited only infrequently. Other than the penguins, Beaufort Island has not been comprehensively studied and is largely undisturbed by direct human activity. However, recent observations indicate that the snow and ice fields are receding. The ecological, scientific and aesthetic values derived from the isolation and relatively low levels of human impact are important reasons for special protection at Beaufort Island.



2. Aims and Objectives

The aim of the Management Plan is to provide protection for the Area and its features so that its values can be preserved. The objectives of the Management Plan are to:

- Avoid degradation of, or substantial risk to, the values of the Area by preventing unnecessary human disturbance to the Area;
- Preserve the natural ecosystem as a reference area largely undisturbed by direct human activities;
- Allow scientific research on the natural ecosystems, plant communities, avifauna, invertebrate communities and soils in the Area provided it is for compelling reasons which cannot be served elsewhere;
- Minimise human disturbance to these communities by preventing unnecessary sampling;
- Minimise the possibility of introduction of alien plants, animals and microbes to the Area;
- Allow visits for management purposes in support of the aims of the Management Plan.

3. Management Activities

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

- Copies of this Management Plan (stating the special restrictions that apply), including maps of the Area, shall be made available at adjacent operational research/field stations.
- Markers, signs or structures erected within the Area for scientific or management purposes shall be secured and maintained in good condition, and removed when no longer necessary.
- Visits shall be made as necessary to assess whether the Area continues to serve the purposes for which it was designated and to ensure management and maintenance measures are adequate.
- National Antarctic Programmes operating in the region shall consult together with a view to ensuring these steps are carried out.

4. Period of Designation

Designated for an indefinite period.

5. Maps and Photographs

- **Map 1:** Beaufort Island topography and air access map. Specifications: Projection: Lambert Conformal Conic; Spheroid and horizontal datum: WGS8; Data sources: ASPA boundary, topography & infrastructure data supplied by Antarctica New Zealand (2019).
 - Inset 1: Ross Sea region showing the location of Beaufort Island near Ross Island
 - Inset 2: Beaufort Island in relation to Ross Island, showing the locations of McMurdo Station (USA) and Scott Base (NZ).

- **Map 2:** Beaufort Island wildlife and vegetation on northern coast. Specifications as for Map 1; ice-free ground from NZ Aerial Mapping imagery (22 Nov 1993).
- **Map 3:** Beaufort Island - Cadwalader Beach Adélie penguin colony. Specifications as for Map 1.
 - Photograph 1: Beaufort Island, Northern Coast, aerial, C.M. Harris January 1995
 - Photograph 2: Beaufort Island, North Coast, South polar Skua and Vegetation, C.M. Harris January 1995.
 - Photograph 3: Beaufort Island, Cadwalader Beach, aerial, C.M. Harris January 1995.

6. Description of the Area

6(i) Geographical coordinates, boundary markers and natural features

The designated Area encompasses the whole of Beaufort Island (76° 56'S, 166° 56'E) above the mean high water mark, and includes adjacent fast-ice occupied by breeding Emperor penguins (Map 1). The coordinates include:

- From the northern coast of Beaufort Island at 76 ° 55' 44" S, 166° 52' 42" E north to 76° 55' 30" S, 166° 52' 49" E;
- From 76° 55' 30" S, 166° 52' 49" E east to 76° 55' 30" S, 167° 00' E;
- From 76° 55' 30" S, 167° 00' E south along the 167° longitude parallel to where it intersects with the coastline of Beaufort Island at 76° 55' 30"S, 167° E (Map 1).

The island is part of the late Tertiary volcanic vents that developed in a series along a line of weakness in the Ross Sea floor. The island is the remains of a basaltic cone of about the Last Interglacial age, and is one portion of the caldera. More than three quarters of the cone now comprises a circular series of submerged peaks to the east of Beaufort Island. These submerged peaks, along with the island, block the predominant westward drift of pack ice and cause icebergs to ground here which in turn allows fast ice to establish in this area. It is upon this fast ice that the Emperor penguins breed. The location of the breeding colony varies with the fast ice distribution and therefore the protected area boundary has been extended to account for the location of the colony in any given season.

The geology of the island is typical of an eroded, sub-aerially produced basaltic complex, with lava flows and explosion breccias and tuffs evident. Many of the volcanic rocks have been intruded by a series of late stage basaltic dikes, and there is evidence of layered ash-fall tuffs and welded spatter flows from local subsidiary cinder and spatter cones. The island is roughly 7 km long and 3.2 km wide rising to a highest point of 771 m at Paton Peak. The west and northwest side of the island is predominantly an ice field with ice cliffs along the northwest edge of about 20 m on the coast, while the east and south sides of the island are largely ice-free, with almost vertical, inaccessible cliffs rising straight from the sea. On the south west shore is Cadwalader Beach which comprises a beach foreland and cusped spit, backed by steep basaltic cliffs and several talus cones. A series of beach ridges, which are generally occupied by the breeding Adélie penguins, have trapped meltwater ponds and mark the growth of the beach face



away from the cliffs with time and isostatic uplift. A series of raised beaches is evident at the northern side of the island, some with evidence (quills and guano) of former and apparently substantial penguin occupation (to 45,000 years). Sub-tidal (abrasion) platforms and massive boulders are found below the highly weathered southern cliffs. The eastern cliffs descend directly into the sea. Beaufort Island is relatively inaccessible by sea, except on the south and north shores, due to the steep cliff nature of the island and owing to the submerged peaks and grounded icebergs. Shipping, therefore, gives the island a wide berth. In view of the isolation of Beaufort Island and the current low levels of shipping activity in the region, boundary markers and signs have not been installed to mark the Area.

There is one main Adélie penguin colony and one newly formed subcolony on Beaufort Island. The main colony of 70,468 breeding pairs (2013/14) occupies the flat area at Cadwalader Beach (Maps 1 and 3). Between 1981 and 2000 there was a general decreasing trend in the number of breeding pairs at the main colony, then an increasing trend from 2001-2012. The 2013/14 count is the highest number of breeding pairs recorded at this site since counts began in 1981 and is nearly twice the 30 years average (39,391 breeding pairs) for this site (Lyver et al., 2014). In 1995 a sub-colony established at the west end of the ice-free beach on the northern coast (76° 55' S, 166° 52'E) comprising 2 pairs with 3 chicks and approximately 10-15 non breeders. The sub-colony has continued to grow with 525 breeding pairs in the 2005-06 breeding season, 677 breeding pairs in the 2008-09 season and 989 breeding pairs in the 2013/14 season. Since 1996, scientists from the USA and NZ programmes have been banding a sample of 400 near-to-fledging Adélie penguin chicks at the Cadwalader Beach area. A few hundred banded adults, survivors of their juvenile years, now reside in the colony. Penguins banded at Cape Royds, Cape Bird and Cape Crozier have been sighted especially at the sub-colony on the north beach. Beaufort Island not long ago provided many emigrants to Ross Island colonies, but with recession of the ice fields and increased availability of nesting space, this is no longer the case. Above the beach, a raised ice-cored moraine terrace (5–20 m elevation, ranging from 2-3 metres wide over most of its length but broadening to 50 metres at its eastern end) extends for 550 m before rising more steeply toward the unstable basaltic cliffs which persist around the entire eastern side of the island. At least three sub-fossil penguin colony deposits have been identified within the moraine terrace, each layer vertically separated by around 50–100 cm of gravels and sand, suggesting this part of the island had been occupied by a sizable breeding penguin colony.

South polar skuas nest (roughly 150 pairs, but not specifically known) on the steep talus accumulating below the cliffs that rise behind the Adélie penguin colony at Cadwalader beach. Another population of approximately 50 pairs of skuas (1995 count) breed on the terrace and ice-free slopes on the northern shore. The proportion of breeders to non-breeders in this population is not known, but approximately 25 and 50 chicks were counted in January 1995 and 1997 respectively. Several snow petrels have also been seen in the cliffs above the Adélie colony at Cadwalader Beach.

On the fast-ice extending out from the northern and eastern coasts of Beaufort Island, a small colony of Emperor penguins (live chick counts from 1962 to 2012 range from 131 to 2,038 individuals; aerial photo of adult abundance was 812 in 2012 and 462 in 2018) is present annually between the months of approximately April to January. Chick counts minimally represent the number of breeding pairs. Chick counts at Beaufort Island declined between 2000 and 2004 when the giant iceberg B15A collided with the north-west tongue of the Ross Ice Shelf at Cape Crozier, Ross Island (Kooyman et al., 2007). In 2012 aerial photo of chick abundance was 705 and 417 in 2018.

Between 2000 and 2012 chick and adult counts have been variable. The size of the colony is limited by the areal extent and condition of the fast-ice, which affects the availability of breeding sites in the lee of the northern slopes of Beaufort Island. The precise location of the colony varies from year to year and the colony moves within a breeding season, but the general area of occupation is on the fast ice at the foot of the cliffs off the north-eastern corner of the island, indicated on Maps 1 and 2. A higher coefficient of variation in chick abundance found at this small colony suggests that it occupies a marginal habitat and may be susceptible to environmental change.

The ice-cored moraine terrace above the beach on the north end of the island (Maps 1 and 3) supports the growth of vegetation. Little can grow in the thick guano covering the Cadwalader beach area and all other areas of the island are either cliffs or ice covered. An area of vegetation, 50 meters wide and 5-7 meters above the beach on the north of the island, was described from site visits in January 1995 and 1997, consisting of an extensive (approximately 2.9 ha), continuous area of a single moss species *Bryum argenteum*. A second species of moss, *Hennediella heimii*, is also found among the *B. argenteum*. The moss community is known to support significant populations of mites (Acari) and springtails (Collembola). Although a detailed survey of invertebrates has not been conducted, *Gomphiocephalus hodgsoni* (Collembola) and *Stereotydeus mollis* (Acari) were found to be very abundant in moss samples taken from Beaufort Island. Recent genetic analysis of these populations has found unique genetic mitochondrial DNA haplotypes at Beaufort Island not found in other invertebrate populations in the Ross Sea region.

A diverse community of algae, also prolific on the south-shore shelf, is found at this site and while a detailed algal survey has not yet been undertaken, several species of algae have been found including the red snow algae *Chlamydomonas* sp., *Chloromonas* sp., and *Chlamydomonas nivalis*, representing one of the most southerly locations where red snow algae have been observed and *Prasiola crispa* is particularly abundant at the north beach site. A number of unicellular chlorophytes and xanthophytes (including *Botrydiopsis* and *Pseudococcomyxa* species) and cyanobacteria (particularly scillatorians) were found mixed with *P. crispa*. Green snow algae, noticeable as a green band at the lower levels of snow banks above the beach and below the ice cliffs, contained a mixture of *Chloromonas* and *Klebsormidium* species.

6(ii) Restricted zones within the Area

None.



6(iii) Structures within and near the Area

The only structure known to exist on the island is a signpost on a prominent rock in the Adélie penguin colony at Cadwalader Beach (Map 3). The sign, erected in 1959–60, bears the names and home towns of the seamen and the Captain of the HMNZS *Endeavour*. The sign is set in concrete and was in good condition in November 2008. The sign is of potential historic value and should remain *in situ* unless there are compelling reasons for its removal, which should be kept under review.

An astronomical survey station is recorded on a map of the island compiled in 1960, but it is unknown whether any associated permanent marker exists. The station is recorded as located at the south end of the main island ridge-line divide at an altitude of 549 m (Map 3).

6(iv) Location of other protected areas within close proximity of the Area

The nearest protected area to Beaufort Island is New College Valley, Caughley Beach, Cape Bird (ASPAs 116) located approximately 30 km to the south at Cape Bird, Ross Island. Cape Royds and Backdoor Bay (ASPAs 121 and 157) are a further 35 km to the south on Ross Island. Cape Crozier (ASPAs 124) is about 40 km to the east. (Refer to the inset: Map 1).

7. Terms and Conditions for Entry Permits

Entry into the Area is prohibited except in accordance with a Permit issued by appropriate national authorities. Conditions for issuing a Permit to enter the Area include:

- It is issued only for essential management purposes or compelling scientific reasons that cannot be served elsewhere;
- The actions permitted will not jeopardise the ecological or scientific values of the Area;
- Any management activities are in support of the aims of the Management Plan;
- The actions permitted are in accordance with the Management Plan;
- The Permit, or an authorized copy, shall be carried within the Area;
- A visit report shall be supplied to the authority named in the Permit;
- Permits shall be issued for a stated period.

7(i) Access to and movement within the Area

- Land vehicles are prohibited within the Area and access shall be by small boat or by aircraft.
- There are no special restrictions on where access can be gained to the island by small boat. Pilots, air or boat crew, or other people on aircraft or boats, are prohibited from moving on foot beyond the immediate vicinity of the landing site unless specifically authorised by a Permit.
- The operation of aircraft over the Area should be carried out, as a minimum requirement, in compliance with the 'Guidelines for the operation of aircraft near concentrations of birds' contained in Resolution 2 (2004).
- Over flight of bird breeding areas lower than 610 m (or 2000 ft) is normally prohibited. The areas where these special restrictions apply are shown on Maps 1 and 3. When required for essential scientific or management purposes (e.g. aerial photography to assess colony size), transient over flights down to a minimum altitude of 300 m (1000 ft) may be allowed over these areas. Conduct of such over flights must be specifically authorised by a Permit.

- Aircraft should land on the island only at the designated site (166° 52' 05" E, 76° 55' 09" S: Maps 1 and 3) on the large flat toe of ice on the north end of the island.
- Should snow conditions at the designated landing site at the time of visit prevent a safe aircraft landing, a suitable mid- to late-season alternative to the designated landing site may be found at the nominated northern camp site at the western end of the northern beach on Beaufort Island. It is preferred that aircraft approach and depart from the designated landing site from the south or west (Map 1). When it is found necessary to use the alternative site at the northern beach campsite, practical considerations may dictate a northern approach. When this is the case, aircraft shall avoid over flight of the area east of this site indicated on Maps 1 and 3.
- Use of smoke grenades when landing within the Area is prohibited unless absolutely necessary for safety and all grenades should be retrieved.
- The operation of Remotely Piloted Aircraft Systems (RPAS) in the area should be carried out, as a minimum, in compliance with the 'Environmental Guidelines for operation of Remotely Piloted Aircraft Systems (RPAS)1 in Antarctica' contained in Resolution 4 (2018). Visitors should avoid unnecessary disturbance to birds, or walking on visible vegetation. Pedestrian traffic should be kept to the minimum consistent with the objectives of any permitted activities and every reasonable effort should be made to minimise effects.

7(ii) Activities that are or may be conducted in the Area, including restrictions on time or place

- Compelling scientific research that will not jeopardise the ecosystem of the Area and which cannot be served elsewhere;
- Essential management activities, including monitoring.



7(iii) Installation, modification or removal of structures

No scientific equipment or structures are to be erected within the Area except as specified in a Permit. All markers, structures or scientific equipment installed in the Area must be approved by Permit and clearly identified by country, name of the principal investigator and year of installation. All such items should be made of materials that pose minimal risk of contamination of the Area. Removal of specific equipment for which the Permit has expired shall be a condition of the Permit.

7(iv) Location of field camps

Camping is permitted only at two designated sites (Maps 1, 2 and 3). The north camping site is located on the flat area north of the designated landing site, on a more sheltered location at the NW end of the beach, 200 m from where several pair of Adélie penguins and skuas nest (if present). The second site is located 100 m from the northern edge of the large Adélie penguin colony at Cadwalader Beach.

7(v) Restrictions on materials and organisms which can be brought into the Area

- No living animals, plant material or microorganisms shall be deliberately introduced into the Area and the precautions listed in 7(ix) below shall be taken against accidental introductions.
- No herbicides or pesticides shall be brought into the Area. Any other chemicals, including radio-nuclides or stable isotopes, which may be introduced for scientific or management purposes specified in the Permit, shall be removed from the Area at or before the conclusion of the activity for which the Permit was granted.
- No poultry products, including food products containing uncooked dried eggs, shall be taken into the Area.
- Fuel is not to be stored in the Area, unless required for essential purposes connected with the activity for which the Permit has been granted.
- All materials introduced shall be for a stated period only, shall be removed at or before the conclusion of that stated period, and shall be stored and handled so that risk of their introduction into the environment is minimised. Permanent depots are not permitted.

7(vi) Taking or harmful interference with native flora or fauna

Taking or interfering with native flora or fauna is prohibited, except in accordance with a separate Permit issued under Article 3 of Annex II by the appropriate national authority specifically for that purpose. Where animal taking or harmful interference is involved, this should, as a minimum standard, be in accordance with the SCAR Code of Conduct for the Use of Animals for Scientific Purposes in Antarctica.

7(vii) Collection or removal of anything not brought into the Area by the Permit holder

Material may be collected or removed from the Area only in accordance with a Permit and should be limited to the minimum necessary to meet scientific or management needs. 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 removal is likely to be greater than leaving the material in situ. If this is the case the appropriate authority should be notified.

7(viii) Disposal of waste

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

7(ix) Measures that are necessary to ensure that the aims and objectives of the Management Plan can continue to be met

- Permits may be granted to enter the Area to carry out biological monitoring and site inspection activities, which may involve the collection of small samples for analysis or review, or for protective measures.
- Any specific sites of long-term monitoring shall be appropriately marked.
- To help maintain the ecological and scientific values of the isolation and historically low level of human impact at Beaufort Island visitors shall take special precautions against introductions. Of particular concern are microbial or vegetation introductions sourced from soils at other Antarctic sites, including stations, or from regions outside Antarctica. Visitors shall take the following measures to minimise the risk of introductions:
- Any sampling equipment or markers brought into the Area shall be sterilised and, to the maximum extent practicable, maintained in a sterile condition before being used within the Area. To the maximum extent practicable, footwear and other equipment used or brought into the Area (including backpacks, carry-bags, tent pegs, tarps and any other camping equipment) shall be thoroughly cleaned or sterilised and maintained in this condition before entering the Area;
- Sterilisation should be by an acceptable method, such as by UV light, autoclave or by washing exposed surfaces in 70% ethanol solution in water.

7(x) Requirements for reports

Parties should ensure that the principal holder for each Permit issued, submit to the appropriate authority a report describing the activities undertaken. Such reports should include, as appropriate, the information identified in the Visit Report form suggested by SCAR. 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.



Bibliography

- Ainley, D.G., Ballard, G., Barton, K.J., Karl, B.J., Rau, G.H., Ribic, C.A. and Wilson, P.R. 2003. Spatial and temporal variation of diet within a presumed metapopulation of Adélie penguins. *Condor*, 105, 95-106.
- Barber-Meyer, S.M., Kooyman, G.L. and Ponganis, P.J. 2007. Estimating the relative abundance of emperor penguins at inaccessible colonies using satellite imagery. *Polar Biology*, 30, 1565-1570.
- Barber-Meyer, S.M., Kooyman, G.L. and Ponganis, P.J. 2008. Trends in western Ross Sea emperor penguin chick abundances and their relationships to climate. *Antarctic Science*, 20 (1), 3-11.
- Barry, J.P., Grebmeier, J.M., Smith, J. and Dunbar, R.B. 2003. Oceanographic versus seafloor-habitat control of benthic megafaunal communities in the S.W. Ross Sea, Antarctica. *Antarctic Research Series*, 76, 335-347.
- Caughley, G. 1960. The Adélie penguins of Ross and Beaufort Islands. *Records of Dominion Museum*, 3 (4), 263-282.
- Centro Ricera e Documetazione Polare, Rome, 1998. *Polar News*, 13 (2), 8-14.
- Denton, G.H., Borns, H.W. Jr., Grosval's, M.G., Stuiver, M., Nichols, R.L. 1975. Glacial history of the Ross Sea. *Antarctic journal of the United States*, 10 (4), 160-164.
- Emslie, S.D., Berkman, P.A., Ainley, D.G., Coats, L. and Polito, M. 2003. Late-Holocene initiation of ice-free ecosystems in the southern Ross Sea, Antarctica. *Marine Ecology Progress Series*, 262, 19-25.
- Emslie, S.D., Coats, L., Licht, K. 2007. A 45,000 yr record of Adélie penguins and climate change in the Ross Sea, Antarctica. *Geology*, 35 (1), 61-64.
- Harrington, H.J. 1958. Beaufort Island, remnant of Quaternary volcano in the Ross Sea, Antarctica. *New Zealand journal of geology and geophysics*, 1 (4), 595-603.
- Kooyman, G.L., Ainley, D.G., Ballard, G. and Ponganis, P.J. 2007. Effects of giant icebergs on two emperor penguin colonies in the Ross Sea, Antarctica. *Antarctic Science* 19 (1), 31-38.
- LaRue, M., a. Unpublished aerial counts via USAP event B-243-M. 2018.
- LaRue, M.A., Ainley, D.G., Swanson, M., Dugger, K.M., Lyver, P.O., Barton, K. and Ballard, G. 2013. Climate change winners: Receding ice fields facilitate colony expansion and altered dynamics in an Adélie penguin metapopulation. *PLoS ONE* 8(4): e60568. doi:10.1371/journal.pone.0060568.
- Lyver, P. O., Barron, M., Barton, K.J., Ainley, D.G., Pollard, A., Gordon, S., McNeill, S., Ballard, G. and Wilson, P.R. 2014. Trends in the breeding population of Adélie penguins in the Ross Sea, 1981-2012: A coincidence of climate and resource extraction effects. *PLoS ONE* 9(3): e91188. doi:10.1371/journal.pone.0091188.
- McGaughran, A., Torricelli, G., Carapelli, A., Frati, F., Stevens, M.I., Convey, P. and Hogg, I.D. 2009. Contrasting phylogenetic patterns for spring tails reflect different evolutionary histories between the Antarctic Peninsula and continental Antarctica. *Journal of Biogeography*, doi:10.1111/j.1365-2699.2009.02178.x
- McGaughran, A., Hogg, I.D. and Stevens, M.I. 2008. Phylogeographic patterns for springtails and mites in southern Victoria Land, Antarctica suggests a Pleistocene and Holocene legacy of glacial refugia and range expansion. *Molecular Phylogenetics and Evolution*, 46, 606-618.
- Schwaller, M.R. Olson, C.E. Jr., Ma, Z., Zhu, Z., Dahmer, P. 1989. Remote sensing analysis of Adélie penguin rookeries. *Remote sensing of environment*, 28, 199-206.
- Seppelt, R.D., Green, T.G.A., Skotnicki, M.L. 1999. Notes on the flora, vertebrate fauna and biological significance of Beaufort Island, Ross Sea, Antarctica. *Polarforschung*, 66, 53-59.
- Stevens, M.I. and Hogg, I.D. 2002. Expanded distributional records of Collembola and Acari in southern Victoria Land, Antarctica. *Pedobiologia*, 46, 485-495.
- Stonehouse, B. 1966. Emperor penguin colony at Beaufort Island, Ross Sea, Antarctica. *Nature*, 210 (5039), 925-926.
- Todd, F.S. 1980. Factors influencing Emperor Penguin mortality at Cape Crozier and Beaufort Island, Antarctica. *Biological Sciences*, 70 (1), 37



Appendix A





