

Management Plan for

Antarctic Specially Protected Area No. 113

LITCHFIELD ISLAND, ARTHUR HARBOR

ANVERS ISLAND, PALMER ARCHIPELAGO

Introduction

Litchfield Island lies within Arthur Harbor, SW Anvers Island, at 64°46' S, 64°06' W. Approximate area: 0.34 km². Designation on the grounds that Litchfield Island, together with its littoral zone, possesses an unusually high collection of marine and terrestrial life, is unique amongst the neighboring islands as a breeding place for six species of native birds and provides an outstanding example of the natural ecological system of the Antarctic Peninsula area. In addition, Litchfield Island possesses rich growths of vegetation and has the most varied topography and the greatest diversity of terrestrial habitats of the islands in Arthur Harbor.

The Area was originally designated as Specially Protected Area (SPA) No. 17 through Recommendation VIII-1 (1975) after a proposal by the United States of America. The site was renamed and renumbered as Antarctic Specially Protected Area (ASP) No. 113 by Decision 1 (2002). The original Management Plan was adopted through Measure 2 (2004) and revised through Measure 4 (2009).

The Area is situated within Environment E – Antarctic Peninsula, Alexander and other islands based on the Environmental Domains Analysis for Antarctica and within Region 3 – Northwest Antarctic Peninsula based on the Antarctic Conservation Biogeographic Regions. Litchfield Island lies within Antarctic Specially Managed Area No.7 Southwest Anvers Island and Palmer Basin.

1. Description of values to be protected

Litchfield Island (Latitude 64°46' S, Longitude 64°06' W, 0.34 km²), Arthur Harbor, Anvers Island, Antarctic Peninsula was originally designated on the grounds that “Litchfield Island, together with its littoral, possesses an unusually high collection of marine and terrestrial life, is unique amongst the neighboring islands as a breeding place for six species of native birds and provides an outstanding example of the natural ecological system of the Antarctic Peninsula area”.

The current management plan reaffirms the original reasons for designation associated with the bird communities. The island supports a diverse assemblage of bird species that is representative of the mid-western Antarctic Peninsula region. The number of bird species recorded as breeding on Litchfield Island is currently six, following the recent local extinction of Adélie penguins (*Pygoscelis adeliae*) on the island. Population decline has been attributed to the negative impact of increased snow accumulation and reduced sea ice extent on both food availability and survival of young (McClintock *et al.* 2008). The species continuing to breed on Litchfield Island are southern giant petrels (*Macronectes giganteus*), Wilson’s storm petrels (*Oceanites oceanicus*), kelp gulls (*Larus dominicanus*), south polar skuas (*Stercorarius maccormicki*), brown skuas (*S. lonnbergi*), and Antarctic terns (*Sterna vittata*). The status of these bird colonies as being relatively undisturbed by human activities is also an important value of the Area.

In 1964 Litchfield Island supported one of the most extensive moss carpets known in the Antarctic Peninsula region, dominated by *Warnstorfia laculosa* which was then considered near its southern limit (Corner 1964a). *W. laculosa* is now known to occur at a number of sites further south, including Green Island (ASP No. 108, in the Berthelot Islands) and Avian Island (ASP No. 118, in Marguerite Bay). Accordingly, the value originally cited that this species is near its southern limit at Litchfield Island is no longer valid. Nevertheless, at the time Litchfield Island represented one of the best examples of maritime Antarctic vegetation off the western coast of Graham Land. Furthermore, several banks of *Chorisodontium aciphyllum* and *Polytrichum strictum* of up to 1.2 m in depth were described in 1982, which were considered to be some

of the best examples of their kind in the Antarctic Peninsula area (Fenton and Lewis Smith 1982). In February 2001 it was observed that these values have been severely compromised by the impact of Antarctic fur seals (*Arctocephalus gazella*), which have damaged and destroyed large areas of vegetation on the lower accessible slopes of the island by trampling and nutrient enrichment. Southern elephant seals (*Mirounga leonina*) have also had a severe, although more localized, impact. Some areas previously richly carpeted by mosses have been completely destroyed, while others have suffered moderate-to-severe damage. Slopes of *Deschampsia antarctica* are more resilient and have persisted even where fur seals have been numerous, although here signs of damage are also obvious. However, on the steeper and higher parts of the island, and other areas that are inaccessible to seals, the vegetation remains undamaged. Furthermore, observations suggest that a recent local decline in Antarctic fur seal numbers has led to the recovery of previously damaged vegetation on Litchfield Island (Fraser and Patterson-Fraser pers. comms. 2014). While the vegetation is less extensive and some of the moss carpets have been compromised, the remaining vegetation continues to be of value and an important reason for special protection of the island. Litchfield Island also has the most varied topography and the greatest diversity of terrestrial habitats of the islands in Arthur Harbor.

The Antarctic Peninsula is currently experiencing regional warming at a rate that exceeds any other observed globally. The marine ecosystem surrounding Litchfield Island is undergoing substantial and rapid change in response to this climatic warming, which has included a decline in local Adélie penguin and Antarctic fur seal populations and changes in vegetation patterns. As such, maintenance of the relatively undisturbed state of Litchfield Island has potential value for long-term studies of this ecosystem.

Litchfield Island has been afforded special protection for most of the modern era of scientific activity in the region, with entry permits having been issued only for compelling scientific reasons. Litchfield Island has therefore never been subjected to intensive visitation, research or sampling and has value as a terrestrial area that has been relatively undisturbed by human activities. The Area is thus valuable as a reference site for some types of comparative studies with higher use areas, and where longer-term changes in the abundance of certain species and in the micro-climate can be monitored. The island is easily accessible by small boat from nearby Palmer Station (US), and Arthur Harbor is visited frequently by tourist ships. Continued special protection is therefore important to ensure the Area remains relatively undisturbed by human activities.

The designated Area is defined as including all of Litchfield Island above the low tide water level, excluding all offshore islets and rocks.

2. Aims and objectives

Management of Litchfield Island aims to:

- Avoid degradation of, or substantial risk to, the values of the Area by preventing unnecessary human disturbance and sampling in the Area;
- Allow scientific research on the ecosystem and physical environment in the Area provided it is for compelling reasons which cannot be served elsewhere and that will not compromise the values for which the Area is protected;
- Allow visits for educational and outreach purposes (such as documentary reporting (visual, audio or written) or the production of educational resources or services) provided such activities are for compelling reasons that cannot be served elsewhere and will not compromise the values for which the Area is protected;
- Minimize the possibility of introduction of alien plants, animals and microbes to the Area;
- Minimise the possibility of the introduction of pathogens that may cause disease in faunal populations within the Area; and
- Allow visits for management purposes in support of the aims of the management plan.

3. Management activities

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

- Signs showing the location of the Area (stating the special restrictions that apply) shall be displayed prominently, and copies of this management plan, including maps of the Area, shall be made available at Palmer Station (US);
- Copies of this management plan shall be made available to all vessels and aircraft visiting the Area and/or operating in the vicinity of Palmer Station, and all personnel (national program staff, field expeditions, tourist expedition leaders, pilots and ship captains) operating in the vicinity of, accessing or flying over the Area, shall be informed by their national program, tour operator or appropriate national authority of the location, boundaries and restrictions applying to entry and overflight within the Area;
- National programs shall take steps to ensure the boundaries of the Area and the restrictions that apply within are marked on relevant maps and nautical / aeronautical charts;
- Markers, signs or other structures erected within the Area for scientific or management purposes shall be secured and maintained in good condition, and removed when no longer required;
- Visits shall be made as necessary (at least once every five years) to assess whether the Area continues to serve the purposes for which it was designated and to ensure management and maintenance measures are adequate.

4. Period of designation

Designated for an indefinite period.

5. Maps and photographs

Map 1: ASPA No. 113 Litchfield Island – Arthur Harbor, Anvers Island, showing the location of nearby stations (Palmer Station, US; Yelcho Station, Chile; Port Lockroy Historic Site and Monument No. 61, UK), the boundary of Antarctic Specially Managed Area No. 7 Southwest Anvers Island and Palmer Basin, and the location of nearby protected areas.

Projection: Lambert Conformal Conic; Central Meridian: 64° 00' W; Standard parallels: 64° 40' S, 65° 00' S; Latitude of Origin: 66° 00' S; Spheroid and horizontal datum: WGS84; Contour interval: Land – 250 m, Marine – 200 m.

Data sources: coastline & topography SCAR Antarctic Digital Database v4.1 (2005); Bathymetry: IBCSO v.1 (2013); Protected areas: ERA (Jul 2013); Stations: COMNAP (May 2013).

Inset: the location of Anvers Island and the Palmer Archipelago in relation to the Antarctic Peninsula.

Map 2: ASPA No. 113 Litchfield Island: Physical features and selected wildlife.

Projection: Lambert Conformal Conic; Central Meridian: 64°06'W; Standard parallels: 64°46'S, 64°48'S; Latitude of Origin: 65°00'S; Spheroid and horizontal datum: WGS84; Vertical datum: mean sea level; Contour interval: Land – 5 m; Marine – 20 m; Coastline, topography, vegetation & southern elephant seal wallow derived from orthophoto (Feb 2009, ERA 2014) with a horizontal accuracy of $\sim \pm 2$ m and a vertical accuracy of $\sim \pm 3$ m; Bathymetry derived from Asper & Gallagher PRIMO survey (2004); Skuas: W. Fraser (2001-09); Former penguin colony: USGS Orthophoto (1998); Survey mark: USGS; Camp site, Boat landing site: RPSC; Protected area and zones: ERA (Jan 2014).

6. Description of the Area

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

General description

Litchfield Island (64°46'15" S, 64°05'40" W, 0.34 km²) is situated in Arthur Harbor approximately 1500 m west of Palmer Station (US), Gamage Point, Anvers Island, in the region west of the Antarctic Peninsula known as the Palmer Archipelago (Map 1). Litchfield Island is one of the largest islands in Arthur Harbor, measuring approximately 1000 m northwest to southeast and 700 m from northeast to southwest. Litchfield Island has the most varied topography and the greatest diversity of terrestrial habitats of the islands in Arthur Harbor (Bonner and Lewis Smith 1985). Several hills rise to between 30-40 m, with the maximum elevation

of 48 m being in the central western part of the island (Map 2). Rocky outcrops are common both on these slopes and on the coast. The island is predominantly ice-free in summer, apart from small snow patches occurring mainly on the southern slopes and in valleys. Cliffs of up to 10 m form the northeastern and southeastern coasts, with pebble beaches found in bays in the north and south.

The designated Area is defined as all of Litchfield Island above the low tide water level, excluding all offshore islets and rocks. The coast itself is a clearly defined and visually obvious boundary feature, so boundary markers have not been installed. Several signs drawing attention to the protected status of the island are in place and legible, although deteriorating (Fraser pers. comm. 2009).

Climate

Few meteorological data are available for Litchfield Island, although temperature data were collected at two north- and south-facing sites on Litchfield Island from January – March 1983 (Komárková 1983). The north-facing site was the warmer of the two, with January temperatures generally ranging between 2° to 9°C, February between -2° to 6°C, and March -2° to 4°C in 1983. A maximum temperature of 13°C and a minimum of -3°C were recorded at this site over this period. The south-facing site was generally about 2°C cooler, with January temperatures generally ranging between 2° to 6°C, February between -2° to 4°C, and March -3° to 2°C. A maximum temperature of 9°C and a minimum of -4.2°C were recorded at the south-facing site.

Longer-term data available for Palmer Station show regional temperatures to be relatively mild because of local oceanographic conditions and because of the frequent and persistent cloud cover in the Arthur Harbor region (Lowry 1975). Yearly air temperature averages recorded at Palmer Station during the period 1974 to 2012 show a distinct warming trend but also demonstrate significant inter-annual variability (Figure 1). The maximum temperature recorded during the period was 11.6° C in March 2010, whilst the minimum was -26° C in August 1995. Previous studies have identified August as the coldest month and January as the warmest (Baker 1996). Storms and precipitation at Palmer Station are frequent, with winds being persistent but generally light to moderate in strength, prevailing from the northeast.

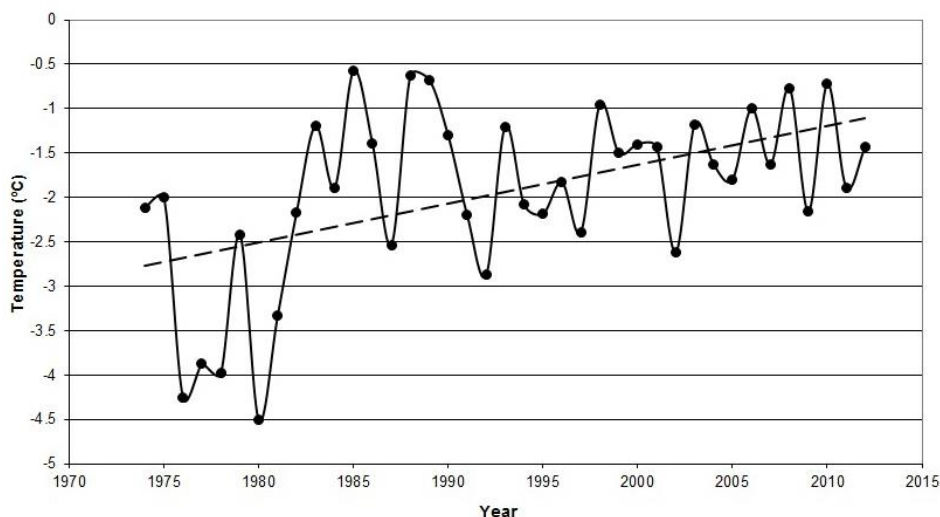


Figure 1. Mean annual surface air temperature at Palmer Station 1974 – 2012.

Data source: Palmer LTER (<http://oceaninformatics.ucsd.edu/datazoo/data/pallter/datasets?action=summary&id=189>).

Geology, geomorphology and soils

Litchfield Island is one of numerous small islands and rocky peninsulas along the southwestern coast of Anvers Island which are composed of an unusual assemblage of late Cretaceous to early Tertiary age rock types called the Altered Assemblage (Hooper 1962). The primary rock types of the Altered Assemblage are tonalite, a form of quartz diorite, and trondhjemite, a light-colored plutonic rock. Also common are granite and volcanic rocks rich in minerals such as plagioclase, biotite, quartz and hornblende. Litchfield Island is characterized by a central band of medium-dark gray, fine-grained diorites which separate the predominantly

light gray medium-grained tonalites and trondhjemites of the east and west (Willan 1985). The eastern part is characterized by paler dykes up to 40 m across and trending north-south and east-west. Minor quartz, epidote, chlorite, pyrite and chalcopyrite veins of up to 8 cm thick strike SSE, cutting the tonalite. Dark gray fine-grained plagioclase-phyric dykes with traces of magnetite strike ENE to ESE. Numerous dark gray feldspar-phyric dykes are present in the west, up to 3 m thick and trending north-south and ESE. Some cut, or are cut by, sparse quartz, epidote, chlorite, pyrite, chalcopyrite and bornite veins of up to 20 cm thick.

The soils of Litchfield Island have not been described, although peaty soils of up to one meter in depth may be found in areas where there is, or once was, rich moss growth.

Freshwater habitat

There are a few small ponds on Litchfield Island: one small pond on a hill in the central, northeastern part of the island has been described as containing the algae *Heterohormogonium* sp. and *Oscillatoria brevis*. Another pond 50 m further south has been described as containing *Gonium* sp., *Prasiola crispa*, *P. tessellata* and *Navicula* sp (Parker *et al.* 1972).

Vegetation

The plant communities at Litchfield Island were surveyed in detail in 1964 (Corner 1964a). At that time, vegetation on Litchfield Island was well-developed and comprised several distinct communities with a diverse flora (Lewis Smith and Corner 1973; Lewis Smith 1982). Both species of Antarctic vascular plant, Antarctic hairgrass (*Deschampsia antarctica*) and Antarctic pearlwort (*Colobanthus quitensis*) were present on Litchfield Island (Corner 1964a; Greene and Holtom 1971; Lewis Smith and Corner 1973). Corner (1964a) noted that *D. antarctica* was common along the northern and northwestern coast of the island, with more localized patches growing further inland on ledges with deposits of mineral material and forms closed swards (Greene and Holtom 1971; Lewis Smith 1982). *C. quitensis* was present in two localities: a patch on the northeastern coast measuring approximately 9x2 m and a series of about six cushions scattered over a steep, flushed cliff above the northwestern coast. Commonly associated with the two vascular plants was a moss carpet assemblage comprising *Bryum pseudotriquetrum*, *Sanionia uncinata*, *Syntrichia princeps* and *Warnstorfia laculosa* (Corner 1964a). Factors controlling the distribution of *C. quitensis* and *D. antarctica* area include the availability of suitable substrate and air temperature (Komarkova *et al.* 1985). In conjunction with recent warming, existing populations of *C. quitensis* have expanded and new colonies have been established within the Arthur Harbor area, although this has not been studied specifically at Litchfield Island (Grobe *et al.* 1997; Lewis Smith 1994).

On well-drained rocky slopes, several banks of *Chorisodontium aciphyllum* and *Polytrichum strictum* were described in 1982 as up to 1.2 m in depth, and were considered to be some of the best examples of their kind in the Antarctic Peninsula area (Fenton and Lewis Smith 1982; Lewis Smith 1982). The more exposed areas of moss turf were covered by crustose lichens, species of *Cladonia* spp. and *Sphaerophorus globosus* and *Coelocaulon aculeatum*. In deep, sheltered gullies there was often a dense lichen cover comprising *Usnea antarctica*, *U. aurantiaco-atra* and *Umbilicaria antarctica*. Raised areas of *P. strictum* turf of approximately 0.5 m high occurred at the bottom of a narrow, east to west trending, valley. The hepatics *Barbilophozia hatcheri* and *Cephaloziella varians* were associated with the turf communities, particularly in frost heave channels and often occurred as stunted specimens on exposed humus.

There were a number of permanently wet areas on the island, an outstanding feature of which was one of the most extensive moss carpets known in the Antarctic Peninsula region, dominated by *W. laculosa* (Fenton and Lewis Smith 1982). Elsewhere, *S. uncinata* and *Brachythecium austro-salebrosum* formed smaller stands. *Pohlia nutans* lined the drier areas where the moss carpet communities merged with the moss turf communities.

Rock surfaces supported a variety of lichen-dominated communities in addition to the numerous epiphytic species that occurred on the moss banks. An open lichen and bryophyte community covered rocks and cliffs around the coast and in the center of the island. The southern coast of the island consisted of primarily crustose species of lichen, predominantly *Usnea antarctica* along with the mosses *Andreaea depressinervis*

and *A. regularis*. The foliose alga *Prasiola crispa* forms small stands associated with the penguin colonies and other seabird habitats.

Other species recorded as present within the Area are: the hepatic *Lophozia excisa*; the lichens *Buellia* spp., *Caloplaca* spp., *Cetraria aculeata*, *Coelopogon epiphorellus*, *Lecanora* spp., *Lecidia* spp., *Lecidella* spp., *Lepraria* sp., *Mastodia tessellata*, *Ochrolechia frigida*, *Parmelia saxatilis*, *Physcia caesia*, *Rhizocarpon geographicum*, *Rhizocarpon* sp., *Stereocaulon glabrum*, *Umbilicaria decussata*, *Xanthoria candelaria* and *X. elegans*; and the mosses *Andreaea gainii* var. *gainii*, *Bartramia patens*, *Dicranoweisia grimmiaea*, *Pohlia cruda*, *Polytrichastrum alpinum*, *Sarconeuron glaciale* and *Schistidium antarctici* (BAS Plant Database 2009).

Previously, increasing populations of Antarctic fur seals (*Arctocephalus gazella*) have caused significant damage to the moss banks and carpets at lower elevations (Lewis Smith 1996; Harris 2001). However, observations suggest previously damaged vegetation is recovering at some sites following a recent decline in fur seal populations on Litchfield Island, although recent increases in southern elephant seals (*Mirounga leonina*) hauling out on the island has resulted in severe damage in their wallow locality (Map 2) and on access routes (Fraser and Patterson-Fraser, pers comms. 2014). South polar skuas (*Stercorarius maccormicki*) nest in the moss banks and cause some local damage.

Invertebrates, bacteria and fungi

The invertebrate fauna of Litchfield Island has not been studied in detail. Observations made in 1966 recorded the presence of large populations of invertebrates, particularly in areas colonised by plants, including *Cyrtolaelaps*, *Protereunetes*, *Stereotydeus*, *Rhagidia*, *Tydeus*, *Alaskozetes* and *Opisa*, in addition to *Cryptopygus*, *Parisotoma* and *Belgica*. Larvae of *Belgica* were numerous under grass and moss, numbering approximately 10,000 per m². Large numbers of *Nanorchestes* and some *Cryptopygus* were observed on the green algae *Pandorina*. The intertidal mite *Rhombognathus gressitti* was observed, although very scarce, on a rocky beach and mudflat of the island (Gressitt 1967). The tardigrades *Macrobiotus furciger*, *Hypsibius alpinus* and *H. pinguis* have been observed in moss patches, predominantly on north-facing slopes (Jennings 1976).

Breeding birds

Six bird species breed on Litchfield Island, making it one of the most diverse avifauna breeding habitats within the Arthur Harbor region. A small Adélie penguin (*Pygoscelis adeliae*) colony was previously situated on the eastern side of the island and has been censused regularly since 1971 (Table 1, Map 2). Following the substantial decline in the numbers of breeding pairs over a 30-year period, Adélie penguins are presently extinct on Litchfield Island (Fraser pers. comm. 2014). Population decline has been attributed to changes in both sea ice distribution and snow accumulation (McClintock *et al.* 2008). Adélie penguins are sensitive to changes in sea ice concentration, which has an influence on penguin access to feeding areas and on the abundance of Antarctic krill, which is their primary prey (Fraser and Hofmann 2003; Ducklow *et al.* 2007). The recent substantial extension of ice-free conditions within the Palmer LTER study area occurred concurrently with an 80 percent decrease in krill abundance along the northern half of the western Antarctic Peninsula and as a result may have significantly reduced the food supply of Adélie penguins inhabiting Litchfield Island (Fraser and Hofmann 2003; Forcada *et al.* 2008). In recent years, spring blizzards in the Arthur Harbor area have become more frequent and more intense, which coupled with widespread precipitation increases, is thought to have substantially increased mortality rates of Adélie chicks and eggs (McClintock *et al.* 2008; Patterson *et al.* 2003). The Litchfield Island colony receives the most snowfall of the seven penguin colonies studied in the Palmer area and has shown the most rapid decline, strongly implicating increased snowfall as a contributing factor in Adélie penguin losses (Fraser, in Stokstad 2007).

Table 1. Numbers of breeding Adélie penguins (*Pygoscelis adeliae*) on Litchfield Island 1971-2009

Year	BP	Count	Source	Year	BP	Count	Source	Year	BP	Count	Source
		Type ¹				Type ¹				Type ¹	
1971-72	890	N3	2	1986-87	577	N1	3	2000-01	274	N1	3

1972-73				1987-88	430	N1	3	2001-02	166	N1	3
1973-74				1988-89				2002-03	143	N1	3
1974-75	1000	N4	2	1989-90	606	N1	3	2003-04	52		4
1975-76	884	N1	3	1990-91	448	N1	3	2004-05	33		4
1977-78	650	N1	2	1991-92	497	N1	3	2005-06	15		4
1978-79	519	N1	2	1992-93	496	N1	3	2006-07	4		4
1979-80	564	N1	2	1993-94	485	N1	3	2007-08	0		4
1980-81	650	N1	2	1994-95	425	N1	3	2008-09	0		4
1981-82				1995-96	410	N1	3	2009-10	0		5
1982-83				1996-97	346	N1	3	2010-11	0		5
1983-84	635	N1	2	1997-98	365	N1	3	2011-12	0		5
1984-85	549	N1	2	1998-99	338	N1	3	2012-13	0		5
1985-86	586	N1	2	1999-2000	322	N1	3				

1. BP = Breeding pairs, N = Nest, C = Chick, A = Adults; 1 = $< \pm 5\%$, 2 = $\pm 5-10\%$, 3 = $\pm 10-15\%$, 4 = $\pm 25-50\%$ (classification after Woehler, 1993)
2. Parmelee and Parmelee, 1987 (N1 and December counts are shown where several counts were made in one season).
3. W.R. Fraser data supplied February 2003, based on multiple published and unpublished sources.
4. W.R. Fraser data supplied January 2009.
5. W.R. Fraser data supplied February 2014.

Southern giant petrels (*Macronectes giganteus*) breed in small numbers on Litchfield Island. Approximately 20 pairs were recorded in 1978-79, including an incubating adult that had been banded in Australia (Bonner and Lewis Smith 1985). More recent data on numbers of breeding pairs are given in Table 2 and show a continuing upward trend in breeding pairs, followed by a stabilization in recent seasons. An increasing, and now stable, breeding population on Litchfield Island and in the vicinity of Palmer Station provide a notable exception to more widespread decline of southern giant petrels in the Antarctic Peninsula region, and have been attributed to the close proximity of prey-rich feeding grounds and the relatively low level of commercial fishing activity within the region (Patterson and Fraser 2003). In austral summer 2004, six southern giant petrel chicks from four colonies located close to the Palmer Station were found to have poxviral infection (Bochsler *et al.* 2008). While the reasons for the emergence of the virus and its potential impacts on southern giant petrel populations are currently unknown, it has been suggested that Adélie penguins may be equally vulnerable to infection.

Table 2. Numbers of breeding southern giant petrels (*Macronectes giganteus*) on Litchfield Island 1993-2012 (nest counts accurate $< \pm 5\%$)

Year	Breeding pairs	Year	Breeding pairs	Year	Breeding pairs
1993-94	26	2000-01	39	2007-08	45
1994-95	32	2001-02	46	2008-09	57
1995-96	37	2002-03	42	2009-10	52
1996-97	36	2003-04	47	2010-11	60
1997-98	20	2004-05	48	2011-12	54
1998-99	44	2005-06	43	2012-13	54
1999-2000	41	2006-07	50		

Source: Unpublished data supplied by W.R. Fraser, February 2003, January 2009, February 2014.

Wilson's storm petrels (*Oceanites oceanicus*) breed within the Area, although numbers have not been determined. Up to 50 pairs of south polar skuas (*Stercorarius maccormicki*) occur on the island, although the number of breeding pairs fluctuates widely from year to year. Brown skuas (*S. lonnbergi*) have in the past been closely associated with the Adélie penguin colony (Map 2), with the number of breeding pairs having ranged from two to eight. The low count of two pairs in 1980-81 followed an outbreak of fowl cholera, which killed many of the brown skuas on Litchfield Island in 1979. Hybrid breeding pairs also occur. Although 12-20 kelp gulls (*Larus dominicanus*) are seen regularly on the island, there are only two or three nests each season. A small number of Antarctic terns (*Sterna vittata*) regularly breed on Litchfield Island, usually less than a dozen pairs (approximately eight pairs in 2002-03) (Fraser pers. comm. 2003). They are most commonly found on the NE coast although their breeding sites change from year to year, and in 1964 they occupied a site on the NW coast (Corner 1964a). A recent visit to Litchfield Island indicates that the number of Wilson's storm petrels, south polar skuas, brown skuas, kelp gulls and Antarctic terns breeding on the island has undergone minimal change in recent years (Fraser pers. comm. 2009).

Among the non-breeding birds commonly seen around Litchfield Island, the Antarctic shag (*Phalacrocorax [atriceps] bransfieldensis*) breeds on Cormorant Island several kilometers to the east; chinstrap penguins (*Pygoscelis antarctica*) and gentoo penguins (*P. papua*) are both regular summer visitors in small numbers. Snow petrels (*Pagodroma nivea*), cape petrels (*Daption capense*), Antarctic petrels (*Thalassoica antarctica*) and southern fulmars (*Fulmarus glacialisoides*), are irregular visitors in small numbers, while two gray-headed albatross (*Diomedea chrysotoma*) were sighted near the island in 1975 (Parmelee *et al.* 1977).

Marine mammals

Antarctic fur seals (*Arctocephalus gazella*) started to appear in Arthur Harbor in the mid-1970s and are now common on Litchfield Island from around February each year. Regular censuses conducted in February and March over the period 1988-2003 recorded on average 160 and 340 animals on the island in these months respectively (Fraser pers. comm. 2003), with a peak of 874 on 19 March 1994 (Fraser pers. comm. 2014). In recent years, however, Antarctic fur seal numbers have decreased within the Arthur Harbor area (Siniff *et al.* 2008). Population decline has been tentatively attributed to reduced Antarctic krill availability within the area, which represents a key component of the diet of Antarctic fur seals, particularly during pupping (Clarke *et al.* 2007; Siniff *et al.* 2008). Diminished Antarctic krill abundance is thought to be a result of reduced sea ice extent and persistence within the Arthur Harbor area (Fraser and Hoffman 2003; Atkinson *et al.* 2004).

Southern elephant seals (*Mirounga leonina*) haul out on accessible beaches from October to June, numbering on average 43 animals throughout these months since 1988 (Fraser pers. comm. 2003), with numbers remaining relatively stable or perhaps increasing slightly (Fraser and Patterson-Fraser, pers. comms. 2014). A group of a dozen or more is found on the northeastern side of the island, having moved in recent years from the low-lying valley to more elevated ground ~150 m northwest of the former haul-out site (Map 2). A few Weddell seals (*Leptonychotes weddellii*) occasionally haul out on beaches. Long term census data (1974-2005) indicate that elephant seal populations within the Arthur Harbor area have recently expanded, as larger ice-free areas have become available for breeding. In contrast, data indicate that Weddell seal numbers have declined as a consequence of reduced fast-ice extent, which is necessary for breeding (Siniff *et al.* 2008). Both crabeater seals (*Lobodon carcinophagus*) and leopard seals (*Hydrurga leptonyx*) may also commonly be seen on ice floes near Litchfield Island. Minke whales (*Balaenoptera acutorostrata*) have been sighted in the Arthur Harbor area during both the austral summer (Dec-Feb) and autumn (Mar-May) (Scheidat *et al.* 2008).

Littoral and benthic communities

Strong tidal currents occur between the islands within Arthur Harbor, although there are numerous sheltered coves along the coast (Richardson and Hedgpeth 1977). Subtidal rocky cliffs grade into soft substrate at an average depth of 15 m and numerous rock outcrops are found within the deeper soft substrate. Sediments in Arthur Harbor are generally poorly sorted and consist primarily of silt sized particles with an organic content of approximately 6.75 % (Troncoso *et al.* 2008). Significant areas of the seabed within Arthur Harbor are covered by macroalgae, including *Desmarestia anceps* and *D. menziesii*, and sessile invertebrates such as sponges and corals are also present (McClintock *et al.* 2008; Fairhead *et al.* 2006). The predominantly soft mud substrate approximately 200 m off the northeastern coast of Litchfield Island has been described as

supporting a rich macrobenthic community, characterized by a high diversity and biomass of non-attached, deposit-feeding polychaetes, arthropods, molluscs and crustaceans (Lowry 1975). Analysis of molluscan assemblages within Arthur Harbor, conducted as part of an integrated study of the benthic ecosystem in the austral summers 2003 and 2006, indicates that species richness and abundance are relatively low (Troncoso *et al.* 2008). The fish species *Notothenia neglecta*, *N. nudifrons* and *Trematomus newnesi* have been recorded between 3 and 15 meters depth (De Witt and Hureau 1979; McDonald *et al.* 1995). The Antarctic limpet (*Nacella concinna*) is common in the marine area around Litchfield Island and is widespread within shallow water areas of the western Antarctic Peninsula (Kennicutt *et al.* 1992b; Clarke *et al.* 2004). Monitoring of zooplankton distribution within the marine area surrounding Litchfield Island indicates that the abundance of *Euphausia superba* and *Salpa thompsoni* decreased significantly between 1993 and 2004 (Ross *et al.* 2008).

Human activities and impact

In January 1989 the vessel *Bahia Paraíso* ran aground 750 m south of Litchfield Island, releasing more than 600,000 liters (150,000 gallons) of petroleum into the surrounding environment (Kennicutt 1990; Penhale *et al.* 1997). The intertidal communities were most affected, and hydrocarbon contaminants were found in both sediments and inter- and sub-tidal limpets (*Nacella concinna*), with an estimated mortality of up to 50% (Kennicutt *et al.* 1992a&b; Kennicutt and Sweet 1992; Penhale *et al.* 1997). However, numbers recovered soon after the spill (Kennicutt 1992a&b). Levels of petroleum contaminants found in intertidal sample sites on Litchfield Island were among some of the highest recorded (Kennicutt *et al.* 1992b; Kennicutt and Sweet 1992). It was estimated that 80% of Adélie penguins nesting in the vicinity of the spill were exposed to hydrocarbon pollution, and exposed colonies were estimated to have lost an additional 16% of their numbers in that season as a direct result (Penhale *et al.* 1997). However, few dead adult birds were observed. Samples collected in April 2002 detected hydrocarbons within the waters surrounding the *Bahia Paraíso* wreck, suggesting some leakage of Antarctic gas oil (Janiot *et al.* 2003) and fuel occasionally reaches beach areas on south-western Anvers Island (Fraser pers. comm. 2009). However, hydrocarbons were not found within sediment or biota samples collected in 2002 and high sea energy within the area is thought to significantly limit the impact of fuel leaks on local biota and the persistence of contaminants on beaches. In addition, marine debris, including fishing hooks, lines and floats are occasionally observed on Litchfield Island.

US permit records show that between 1978-92 only about 35 people visited Litchfield Island, with possibly around three visits being made per season (Fraser and Patterson 1997). This suggests a total of approximately 40 visits over this 12-year period, although given that a total of 24 landings were made at the island over two seasons in 1991-93 (Fraser and Patterson 1997), this would seem likely to represent an underestimate. Nevertheless, visitation at Litchfield Island was undoubtedly low over this period, and has remained at a minimal level. Visits have been primarily related to bird and seal censuses and work on terrestrial ecology.

Plant studies carried out on Litchfield Island in 1982 (Komárková 1983) used welding rods inserted into the soil to mark study sites. At nearby Biscoe Point (ASPA No. 139), where similar studies were conducted, numerous rods left *in situ* killed surrounding vegetation (Harris 2001). It is unknown how many of the rods were used to mark sites on Litchfield Island, or whether most were subsequently removed. However, one was found and removed from a vegetated site in a small valley approximately 100 m west of the summit of the island after a brief search in February 2001 (Harris 2001) and welding rods are still occasionally found (Fraser pers. comm. 2009). A more comprehensive search would be required to determine whether further welding rods remain within the Area. No other impacts on the terrestrial environment that could be attributed to human visitation were observed on 28 February 2001, although one of the two protected area signs was in poor condition and insecurely placed. The impact of human activities upon the terrestrial ecology, birds and seals on Litchfield Island from direct visits may thus be considered to have been minor (Bonner and Lewis Smith 1985; Fraser and Patterson 1997; Harris 2001).

6(ii) Access to the Area

The Area may be accessed over sea ice or by sea. Particular routes have not been designated for access to the Area, although the preferred small boat landing site is located in a small cove on the eastern coast of the island (Map 2). Overflight and aircraft landing restrictions apply within the Area, the specific conditions for which are set out in Section 7(ii) below.

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

With the exception of a cairn on the summit of the island, there are no structures present within the Area. A permanent survey marker, consisting of a 5/8" stainless steel threaded rod, was installed on Litchfield Island by the USGS on 9 February 1999. The marker is located near the summit of the island at 64°46'13.97"S, 64°05'38.85"W at an elevation of 48 m, about 8 m west of the cairn (Map 2). The marker is set in bedrock and marked by a red plastic survey cap. A survival cache is located near the crest of a small hill overlooking the former Adélie penguin colony, approximately 100 m south of the small boat landing site.

6(iv) Location of other protected areas in the vicinity

Litchfield Island lies within Antarctic Specially Managed Area (ASMA) No.7 Southwest Anvers Island and Palmer Basin (Map 1). The nearest Antarctic Specially Protected Areas (ASPAs) to Litchfield Island are: Biscoe Point (ASPA No. 139) which is 16 km east of the Area adjacent to Anvers Island and South Bay (ASPA No. 146), which is approximately 27 km to the southeast at Doumer Island (Inset, Map 1).

7. Permit conditions

7(i) General Permit conditions

Entry into 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:

- it is issued only for compelling scientific reasons that cannot be served elsewhere, and in particular for research on the terrestrial ecosystem or fauna in the Area;
- it is issued for compelling educational or outreach reasons that cannot be served elsewhere, or for reasons essential to the management of the Area;
- the actions permitted will not jeopardize the ecological or scientific values of the Area or the value of the Area as a terrestrial reference site;
- any management activities are in support of the objectives of the Management Plan;
- the actions permitted are in accordance with the Management Plan;
- the activities permitted will give due consideration via the environmental impact assessment process to the continued protection of the environmental and scientific values of the Area;
- the Permit shall be issued for a finite period;
- the Permit, or a copy, shall be carried when in the Area.

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

Access to the Area shall be by small boat, or over sea ice by vehicle or on foot. Vehicles are prohibited and all movement within the Area shall be on foot. When access over sea ice is viable, there are no special restrictions on the locations where vehicle or foot access may be made, although vehicles are prohibited from being taken on land.

Foot access and movement within the Area

Persons on foot should at all times avoid disturbance to birds and seals, and damage to vegetation. Boat crew, or other people in boats or vehicles, are prohibited from moving on foot beyond the immediate vicinity of the landing site unless specifically authorised by Permit.

Pedestrians should maintain the following minimum approach distances from wildlife, unless it is necessary to approach closer for purposes allowed for by the permit:

- Southern giant petrels (*Macronectes giganteus*) – 50 m
- Antarctic fur seals (for personal safety) – 15 m
- other birds and seals – 5 m.

Visitors should move carefully so as to minimize disturbance to flora, fauna, and soils, and should walk on snow or rocky terrain if practical, but taking care not to damage lichens. Pedestrian traffic should be kept to the minimum consistent with the objectives of any permitted activities and every reasonable effort should be made to minimize effects.

Small boat access

The recommended landing site for small boats is on the beach in the small cove mid-way along the eastern coast of the island (Map 2). Access by small boat at other locations around the coast is allowed, provided this is consistent with the purposes for which a Permit has been granted.

Aircraft access and overflight

Landing by aircraft within the Area is prohibited and landings within 930 m (~1/2 nautical mile) of the Area should be avoided wherever possible. Overflight below 610 m (~2000 ft) Above Ground Level is prohibited except when operationally necessary for scientific purposes.

7(iii) Activities that may be conducted within the Area

- Scientific research that will not jeopardize the ecosystem values of the Area or the value of the Area as a reference site, and which cannot be served elsewhere;
- Activities with compelling educational and / or outreach purposes that cannot be served elsewhere;
- Essential management activities, including monitoring and inspection.

7(iv) Installation, modification or removal of structures

- No structures are to be erected within the Area except as specified in a permit and, with the exception of permanent survey markers and the existing cairn at the summit of the island, permanent structures or installations are prohibited;
- All structures, scientific equipment or markers installed in the Area must be authorized by permit and clearly identified by country, name of the principal investigator, year of installation and date of expected removal. All such items should be free of organisms, propagules (e.g. seeds, eggs) and non-sterile soil, and be made of materials that can withstand the environmental conditions and pose minimal risk of contamination or damage to the values of the Area;
- Installation (including site selection), maintenance, modification or removal of structures or equipment shall be undertaken in a manner that minimizes disturbance to flora and fauna.
- Removal of specific structures / equipment for which the permit has expired shall be the responsibility of the authority which granted the original Permit, and shall be a condition of the permit.

7(v) Location of field camps

Camping should be avoided within the Area. However, when necessary for essential purposes specified in the Permit, temporary camping is allowed at the designated site on the terrace above the former penguin colony. The campsite is located at the foot of a small hill (~35 m), on its eastern side, approximately 100 m south-west of the small boat landing beach (Map 2). Camping on surfaces with significant vegetation cover is prohibited.

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

In addition to the requirements of the Protocol on Environmental Protection to the Antarctic Treaty, restrictions on materials and organisms which may be brought into the Area are:

- Deliberate introduction of animals, plant material, micro-organisms and non-sterile soil into the Area is prohibited. Precautions shall be taken to prevent the accidental introduction of animals, plant material, micro-organisms and non-sterile soil from other biologically distinct regions (within or beyond the Antarctic Treaty area);

- Visitors shall ensure that sampling equipment and markers brought into the Area are clean. To the maximum extent practicable, footwear and other equipment used or brought into the area (including backpacks, carry-bags and other equipment) shall be thoroughly cleaned at Palmer Station before entering the Area. Visitors should also consult and follow as appropriate recommendations contained in the Committee for Environmental Protection Non-native Species Manual (CEP 2011), and in the Environmental Code of Conduct for terrestrial scientific field research in Antarctica (SCAR 2009);
- All poultry brought into and not consumed or used within the Area, including all parts, products and / or wastes of poultry, shall be removed from the Area or disposed of by incineration or equivalent means that eliminates risks to native flora and fauna;
- 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;
- Fuel, food, chemicals and other materials are not to be stored in the Area, unless specifically authorized by permit or are contained within an emergency cache authorized by an appropriate authority, and shall be stored and handled in a way that minimises the risk of their accidental introduction into the environment;
- 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 minimized;
- If release occurs which is likely to compromise the values of the Area, removal is encouraged only where the impact of removal is not likely to be greater than that of leaving the material *in situ*.

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

Taking or harmful interference of native flora and fauna is prohibited, except in accordance with a permit issued under Article 3 of Annex II of the Protocol on Environmental Protection to the Antarctic Treaty. 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(viii) Collection or removal of materials 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. This includes biological samples and rock specimens.
- 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 authorized, may be removed from any part of the Area, 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(ix) Disposal of waste

All wastes shall be removed from the Area. Human wastes may be disposed of into the sea.

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:

- 1) carry out monitoring and Area inspection activities, which may involve the collection of a small number of samples or data for analysis or review;
- 2) install or maintain signposts, markers, structures or scientific or essential logistic equipment;
- 3) carry out protective measures;
- 4) carry out research or management in a manner that avoids interference with long-term research and monitoring activities or possible duplication of effort. Persons planning new projects within the Area

should consult with established programs working within the Area, such as those of the US, before initiating the work.

7(xi) *Requirements for reports*

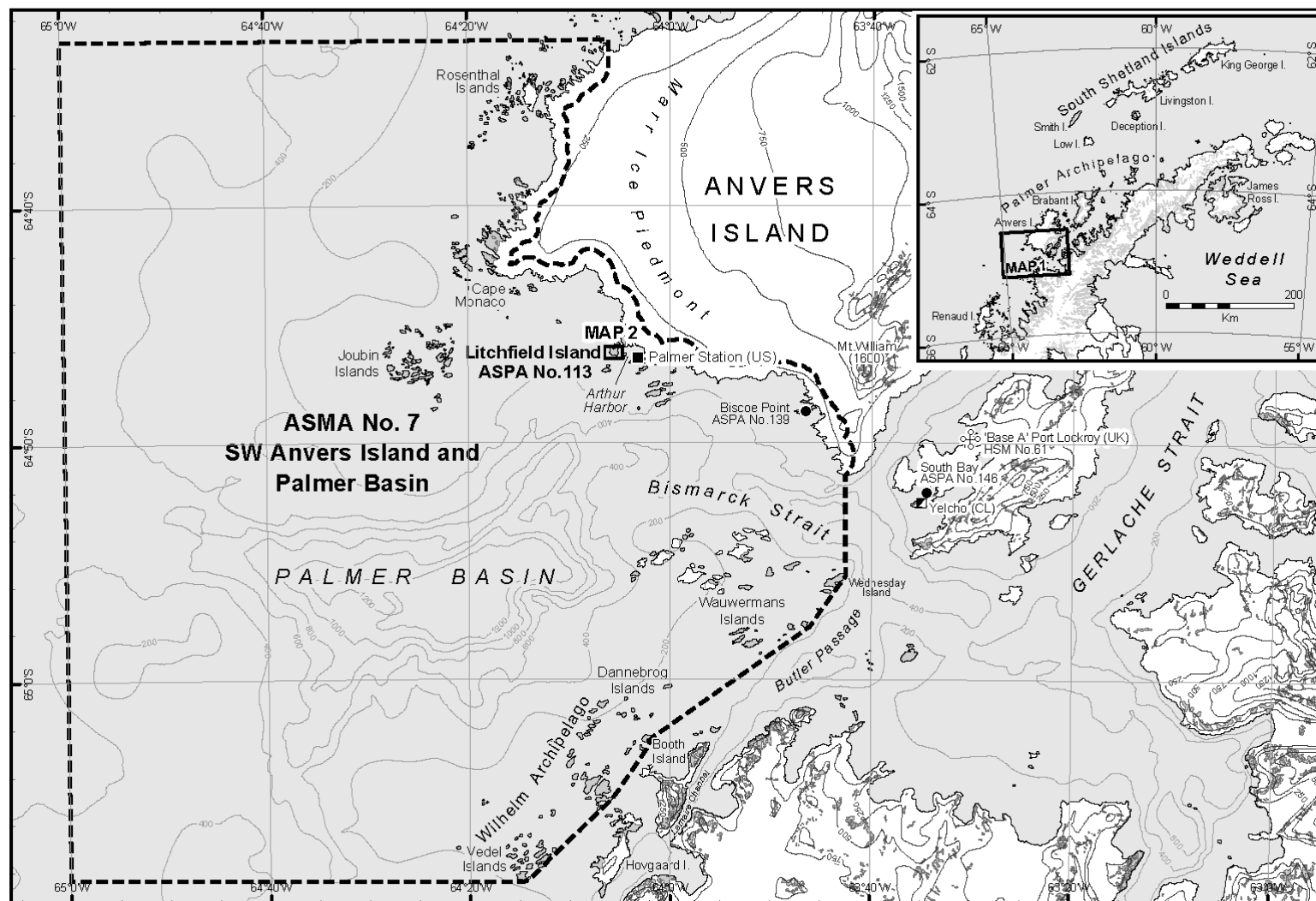
- The principal permit holder for each visit to the Area shall submit a report to the appropriate national authority as soon as practicable, and no later than six months after the visit has been completed.
- Such reports should include, as appropriate, the information identified in the visit report form contained in the Guide to the Preparation of Management Plans for Antarctic Specially Protected Areas. If appropriate, the national authority should also forward a copy of the visit report to the Parties that proposed the Management Plan, to assist in managing the Area and reviewing the Management Plan.
- Parties should, wherever possible, deposit originals or copies of such original visit reports in a publicly accessible archive to maintain a record of usage, for the purpose of any review of the Management Plan and in organising the scientific use of the Area.
- The appropriate authority should be notified of any activities/measures undertaken, and / or of any materials released and not removed, that were not included in the authorized permit.

References

- Atkinson, A., Siegel, V., Pakhomov, E. & Rothery, P. 2004. Long-term decline in krill stock and increase in salps within the Southern Ocean. *Nature* **432**: 100–03.
- Bonner, W.N. & Lewis Smith, R.I. (eds) 1985. *Conservation areas in the Antarctic*. SCAR, Cambridge: 73–84.
- Baker, K.S. 1996. Palmer LTER: Palmer Station air temperature 1974 to 1996. *Antarctic Journal of the United States* **31** (2): 162–64.
- Clarke, A., Murphy, E.J., Meredith, M.P., King, J.C., Peck, L.S., Barnes, D.K.A. & Smith, R.C. 2007. Climate change and the marine ecosystem of the western Antarctic Peninsula. *Philosophical Transactions of the Royal Society B* **362**: 149–166 [doi:10.1098/rstb.2006.1958]
- Clarke, A., Prothero-Thomas, E., Beaumont, J.C., Chapman, A.L. & Brey, T. 2004. Growth in the limpet *Nacella concinna* from contrasting sites in Antarctica. *Polar Biology* **28**: 62–71. [doi 10.1007/s00300-004-0647-8]
- Corner, R.W.M. 1964a. Notes on the vegetation of Litchfield Island, Arthur Harbour, Anvers Island. Unpublished report, British Antarctic Survey Archives Ref AD6/2F/1964/N3.
- Corner, R.W.M. 1964b. Catalogue of bryophytes and lichens collected from Litchfield Island, West Graham Land, Antarctica. Unpublished report, British Antarctic Survey Archives Ref LS2/4/3/11.
- Domack E., Amblàs, D., Gilbert, R., Brachfeld, S., Camerlenghi, A., Rebesco, M., Canals M. & Urgeles, R. 2006. Subglacial morphology and glacial evolution of the Palmer deep outlet system, Antarctic Peninsula. *Geomorphology* **75**(1-2): 125–42.
- Ducklow, H.W., Baker, K., Martinson, D.G., Quentin, L.B., Ross, R.M., Smith, R.C. Stammerjohn, S.E. Vernet, M. & Fraser, W. 2007. Marine pelagic ecosystems: the West Antarctic Peninsula. *Philosophical Transactions of the Royal Society B* **362**: 67–94. [doi:10.1098/rstb.2006.1955]
- Fairhead, V.A., Amsler, C.D. & McClintock, J.B. 2006. Lack of defense or phlorotannin induction by UV radiation or mesograzers in *Desmarestia anceps* and *D. menziesii* (phaeophyceae). *Journal of Phycology* **42**: 1174–83.
- Fenton, J.H.C & Lewis Smith, R.I. 1982. Distribution, composition and general characteristics of the moss banks of the maritime Antarctic. *British Antarctic Survey Bulletin* **51**: 215–36.
- Forcada, J., Trathan, P.N., Reid, K., Murphy, E.J. & Croxall, J.P. 2006. Contrasting population changes in sympatric penguin species in association with climate warming. *Global Change Biology* **12**: 411–23. [doi: 10.1111/j.1365-2486.2006.01108.x]
- Fraser, W.R. in: Stokstad, 2007. Boom and bust in a polar hot zone. *Science* **315**: 1522–23.
- Fraser, W.R. & Hofmann, E.E. 2003 A predator's perspective on causal links between climate change, physical forcing and ecosystem response. *Marine Ecological Progress Series* **265**: 1–15.
- Fraser, W.R. & Patterson, D.L. 1997. Human disturbance and long-term changes in Adélie penguin populations: a natural experiment at Palmer Station, Antarctic Peninsula. In Battaglia, B., Valencia, J. & Walton, D.W.H. (eds) *Antarctic Communities: species, structure and survival*. Cambridge University Press, Cambridge: 445–52.

- Greene, D.M. & Holtom, A. 1971. Studies in *Colobanthus quitensis* (Kunth) Bartl. and *Deschampsia antarctica* Desv.: III. Distribution, habitats and performance in the Antarctic botanical zone. *British Antarctic Survey Bulletin* **26**: 1-29.
- Gressitt, J.L. 1967. Notes on Arthropod populations in the Antarctic Peninsula - South Shetland Islands - South Orkney Islands area. In *Entomology of Antarctica*, J.L. Gressitt (ed) Antarctic Research Series **10**. AGU, Washington DC.
- Grobe, C.W., Ruhland, C.T. & Day, T.A. 1997. A new population of *Colobanthus quitensis* near Arthur Harbor, Antarctica: correlating recruitment with warmer summer temperatures. *Arctic and Alpine Research* **29**(2): 217-21.
- Harris, C.M. 2001. Revision of management plans for Antarctic protected areas originally proposed by the United States of America and the United Kingdom: Field visit report. Internal report for the National Science Foundation, US, and the Foreign and Commonwealth Office, UK. Environmental Research & Assessment, Cambridge.
- Holdgate, M.W. 1963. Observations of birds and seals at Anvers Island, Palmer Archipelago, in 1956-57. *British Antarctic Survey Bulletin* **2**: 45-51.
- Hooper, P.R. 1958. Progress report on the geology of Anvers Island. Unpublished report, British Antarctic Survey Archives Ref AD6/2/1957/G3.
- Hooper, P.R. 1962. The petrology of Anvers Island and adjacent islands. *FIDS Scientific Reports* **34**.
- Janiot, L.J., Sericano, J.L. & Marcucci, O. 2003. Evidence of oil leakage from the *Bahia Paraíso* wreck in Arthur Harbour, Antarctica. *Marine Pollution Bulletin* **46**: 1615-29.
- Jennings, P.G. 1976. Tardigrada from the Antarctic Peninsula and Scotia Ridge region. *BAS Bulletin* **44**: 77-95.
- Kennicutt II, M.C. 1990. Oil spillage in Antarctica: initial report of the National Science Foundation-sponsored quick response team on the grounding of the *Bahia Paraíso*. *Environmental Science and Technology* **24**: 620-24.
- Kennicutt II, M.C., McDonald, T.J., Denoux, G.J. & McDonald, S.J. 1992a. Hydrocarbon contamination on the Antarctic Peninsula I. Arthur Harbour – subtidal sediments. *Marine Pollution Bulletin* **24** (10): 499-506.
- Kennicutt II, M.C., McDonald, T.J., Denoux, G.J. & McDonald, S.J. 1992b. Hydrocarbon contamination on the Antarctic Peninsula I. Arthur Harbour – inter- and subtidal limpets (*Nacella concinna*). *Marine Pollution Bulletin* **24** (10): 506-11.
- Kennicutt II, M.C. & Sweet, S.T. 1992. Hydrocarbon contamination on the Antarctic Peninsula III. The *Bahia Paraíso* – two years after the spill. *Marine Pollution Bulletin* **25** (9-12): 303-06.
- Komárková, V. 1983. Plant communities of the Antarctic Peninsula near Palmer Station. *Antarctic Journal of the United States* **18**: 216-18.
- Komárková, V. 1984. Studies of plant communities of the Antarctic Peninsula near Palmer Station. *Antarctic Journal of the United States* **19**: 180-82.
- Lewis Smith, R.I. 1982. Plant succession and re-exposed moss banks on a deglaciated headland in Arthur Harbour, Anvers Island. *British Antarctic Survey Bulletin* **51**: 193-99.
- Lewis Smith, R.I. 1994. Vascular plants as bioindicators of regional warming in Antarctica. *Oecologia* **99**: 322-28.
- Lewis Smith, R.I. 1996. Terrestrial and freshwater biotic components of the western Antarctic Peninsula. In Ross, R.M., Hofmann, E.E. and Quetin, L.B. (eds) *Foundations for ecological research west of the Antarctic Peninsula*. Antarctic Research Series **70**: 15-59.
- Lewis Smith, R.I. & Corner, R.W.M. 1973. Vegetation of the Arthur Harbour – Argentine Islands region of the Antarctic Peninsula. *British Antarctic Survey Bulletin* **33 & 34**: 89-122.
- Lowry, J.K. 1975. Soft bottom macrobenthic community of Arthur Harbor, Antarctica. In Pawson, D.L. (ed.). *Biology of the Antarctic Seas V*. Antarctic Research Series **23** (1): 1-19.
- McClintock, J., Ducklow, H. & Fraser, W. 2008. Ecological responses to climate change on the Antarctic Peninsula. *American Scientist* **96**: 302.
- McDonald, S.J., Kennicutt II, M.C., Liu, H. & Safe S.H. 1995. Assessing aromatic hydrocarbon exposure in Antarctic fish captured near Palmer and McMurdo Stations, Antarctica. *Archives of Environmental Contamination and Toxicology* **29**: 232-40.
- Parker, B.C., Samsel, G.L. & Prescott, G.W. 1972. Freshwater algae of the Antarctic Peninsula. 1. Systematics and ecology in the U.S. Palmer Station area. In Llano, G.A. (ed) *Antarctic terrestrial biology*. Antarctic Research Series **20**: 69-81.

- Parmelee, D.F., Fraser, W.R. & Neilson, D.R. 1977. Birds of the Palmer Station area. *Antarctic Journal of the United States* **12** (1-2): 15-21.
- Parmelee, D.F. & Parmelee, J.M. 1987. Revised penguin numbers and distribution for Anvers Island, Antarctica. *British Antarctic Survey Bulletin* **76**: 65-73.
- Patterson, D.L., Easter-Pilcher, A. & Fraser, W.R. 2003. The effects of human activity and environmental variability on long-term changes in Adelie penguin populations at Palmer Station, Antarctica. In A. H. L. Huiskes, W. W. C. Gieskes, J. Rozema, R. M. L. Schorno, S. M. van der Vies & W. J. Wolff (eds) *Antarctic biology in a global context*. Backhuys, Leiden, The Netherlands: 301–07.
- Patterson, D.L. & Fraser, W. 2003. *Satellite tracking southern giant petrels at Palmer Station, Antarctica*. Feature Article 8, Microwave Telemetry Inc.
- Penhale, P.A., Coosen, J. & Marschoff, E.R. 1997. The *Bahia Paraíso*: a case study in environmental impact, remediation and monitoring. In Battaglia, B. Valencia, J. & Walton, D.W.H. (eds) *Antarctic Communities: species, structure and survival*. Cambridge University Press, Cambridge: 437-44.
- Richardson, M.D. & Hedgpeth, J.W. 1977. Antarctic soft-bottom, macrobenthic community adaptations to a cold, stable, highly productive, glacially affected environment. In Llano, G.A. (ed.). *Adaptations within Antarctic ecosystems: proceedings of the third SCAR symposium on Antarctic biology*: 181-96.
- Ross, R.M., Quetin, L.B., Martinson, D.G., Iannuzzi, R.A., Stammerjohn, S.E. & Smith, R.C. 2008. Palmer LTER: patterns of distribution of major zooplankton species west of the Antarctic Peninsula over a twelve year span. *Deep-Sea Research II* **55**: 2086–2105.
- Sanchez, R. & Fraser, W. 2001. *Litchfield Island Orthobase*. Digital orthophotograph of Litchfield Island, 6 cm pixel resolution and horizontal / vertical accuracy of ± 2 m. Geoid heights, 3 m² DTM, derived contour interval: 5 m. Data on CD-ROM and accompanied by USGS Open File Report 99-402 “GPS and GIS-based data collection and image mapping in the Antarctic Peninsula”. Science and Applications Center, Mapping Applications Center. USGS, Reston.
- Scheidat, M., Bornemann, H., Burkhardt, E., Flores, H., Friedlaender, A. Kock, K.-H, Lehnert, L., van Franekar, J. & Williams, R. 2008. Antarctic sea ice habitat and minke whales. Annual Science Conference in Halifax, 2008.
- Shearn-Bochsler, V. Green, D.E., Converse, K.A., Docherty, D.E., Thiel, T., Geisz, H. N., Fraser, W.R. & Patterson-Fraser, D.L. 2008. Cutaneous and diphtheritic avian poxvirus infection in a nestling Southern giant petrel (*Macronectes giganteus*) from Antarctica. *Polar Biology* **31**: 569–73. [doi 10.1007/s00300-007-0390-z]
- Siniff, D.B., Garrot, R.A. & Rotella, J.J. 2008. Opinion: Projecting the effects of environmental change on Antarctic seals. *Antarctic Science* **20**: 425-35.
- Stammerjohn, S.E., Martinson, D.G., Smith, R.C. & Iannuzzi, R.A. 2008. Sea ice in the Western Antarctic Peninsula region: spatio-temporal variability from ecological and climate change perspectives. *Deep-Sea Research II* **55**: 2041–58. [doi:10.1016/j.dsr2.2008.04.026]
- Troncoso, J.S. & Aldea, C. 2008. Macrobenthic mollusc assemblages and diversity in the West Antarctica from the South Shetland Islands to the Bellingshausen Sea. *Polar Biology* **31**(10): 1253–65. [doi 10.1007/s00300-008-0464-6]
- Vaughan, D.G., Marshall, G.J., Connolley, W.M., Parkinson, C., Mulvaney, R., Hodgson, D.A., King, J.C., Pudsey, C.J., & Turner, J. 2003. Recent rapid regional climate warming on the Antarctic Peninsula. *Climatic Change* **60**: 243–74.
- Willan, R.C.R. 1985. Hydrothermal quartz+magnetite+pyrite+chalcopyrite and quartz+polymetallic veins in a tonalite-diorite complex, Arthur Harbour, Anvers Island and miscellaneous observations in the southwestern Anvers Island area. Unpublished report, British Antarctic Survey Archives Ref AD6/2R/1985/G14.
- Woehler, E.J. (ed) 1993. *The distribution and abundance of Antarctic and sub-Antarctic penguins*. SCAR, Cambridge.

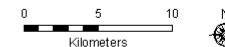


Map 1: ASPA No. 113 Litchfield Island - Arthur Harbor, Anvers Island

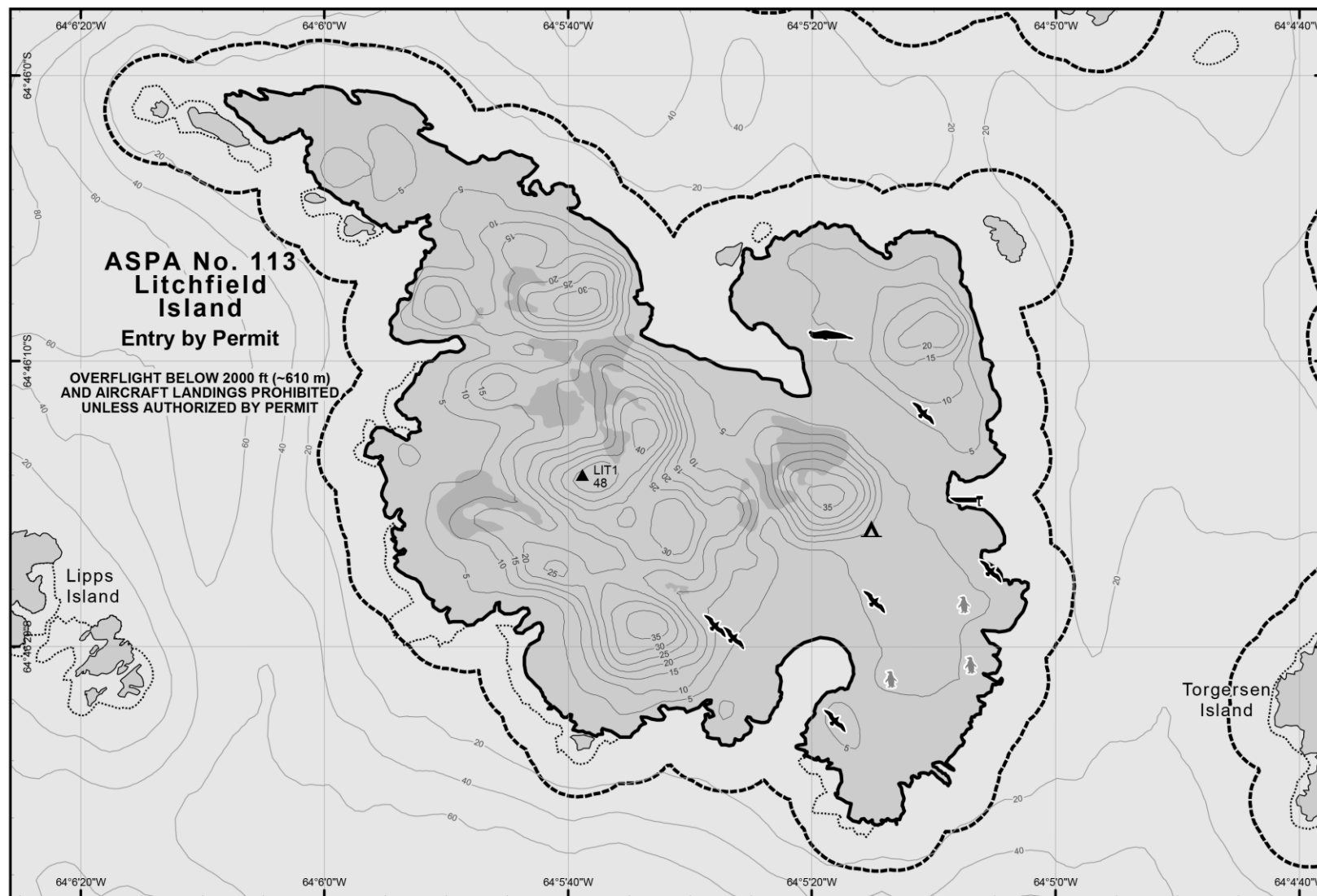
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- Coastline
- Contour (250 m)
- Isobath (200 m)
- Ice free ground
- Permanent ice
- Ocean
- Antarctic Specially Managed Area (ASMA) boundary
- Antarctic Specially Protected Area (ASPA)
- Station (year round)
- Station (seasonal)
- Historic Site & Monument (HSM)



Projection: Lambert Conic Conformal,
Spheroid and horizontal datum: WGS 84;
Data sources: Bathymetry: IBCSO v.1 (2013) (<http://www.ibcso.org/>);
Topography: SCAR ADD v4.1 SQ19-20 (2005);
Protected areas: ERA (Jul 2013); Stations: COMNAP (May 2013).



Map 2: ASPA No. 113 Litchfield Island - Physical features and selected wildlife

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- | | | | |
|----------------|-----------------|---|----------------------------|
| Coastline | Ice free ground | Principal areas of vegetation (approx.) | ▲ Survey mark (monumented) |
| Contour (5 m) | Ocean | <i>Mirounga leonina</i> | Small boat landing site |
| Isobath (20 m) | ASPA boundary | <i>Stercorarius lonnbergii</i> | ▲ Designated camp site |
| Offshore rocks | Restricted Zone | Former penguin colony | |

0 50 100 150 200
Meters



Projection: Lambert Conic Conformal,
Spheroid and horizontal datum: WGS 84;
Data sources: Bathymetry: PRIMO survey (2004);
Topography, vegetation, seals: from orthophoto (Feb 2009);
Former penguin colony: USGS Orthophoto (1998);
Protected areas / zones: ERA (Jan 2014); Survey mark: USGS;
Camp site, Boat landing site: RPSC; Skuas: W.Fraser (2001-09).