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Text S1. General Information

This table provides detailed information about the 27 East Antarctic emperor penguin colonies examined for the paper (Fig. S1). It summarises the current knowledge of these colonies, and for some, provides updates on population estimates. The historical information may be incomplete as a number of early field reports could not be accessed. A broad summary is provided in Table S1. Antarctic lands and key geographical names used in the table are shown in Fig. S2.

Text S2. Description of the variables in Table S2:

- **Region:** General information on the land/coast where a colony occurs.
- **Recent location:** The most recently published location, or location obtained during field work.
- **Date:** Date when the colony location was recorded.
- **Interannual movement:** approximate distance (km) the main wintering area moved from one season to the next. Some historical locations were included, and distances were estimated from previously known locations to present day ones.
- **Size:** As far as available, an estimate of the number of adults present when the colony location was recorded.
- **Colony description:** A general description of the local features of a colony. The colonies are listed from west to east.
- **Fast ice extent:** Information on the regional maximum recorded in October in the period 2018–2023.
- **Ice breakout/formation:** A general description of the timing of these events to indicate variability.
- **Maximal distance to fast ice edge:** Recorded in October in the period 2018–2023 (date provided).
- **Minimal distance to fast ice edge:** Recorded in October in the period 2018–2023 (date provided).
- **Average distance to fast ice edge \pm SD:** Estimated from September to December in the period 2018–2023.
- **Early fast ice breakout:** Date when the ice broke out before the end of the breeding season.
- **Distance from coast:** Distance from continent recorded in October in the period 2018–2023 (date provided).
- **History:** As far they are known, dates of discoveries, events and changes in position are included here.
- **Population estimates/counts:** Ground estimates and counts differ in accuracy due to variations in time and methods used. It is important not to treat them equally. They are presented as they were reported. Population estimates in italics are based on satellite surveys. All available data are listed chronologically from the oldest to the newest date.
- **References:** list of references referred to. These include unpublished field reports.
- **Images:** Satellite images are modified Copernicus Sentinel data (2021), processed by Sentinel Hub. We also acknowledge the use of imagery from the NASA Worldview application (<https://worldview.earthdata.nasa.gov>), part of the NASA Earth Observing System Data and Information System (EOSDIS).

Text S3. Notes:

- The nomenclature of features and locations is based on the *SCAR Composite Gazetteer* hosted by the Australian Antarctic Data Centre (<https://data.aad.gov.au/aadc/gaz/scar/>)
- All distances are approximate as they change frequently.
- NASA Worldview images are labelled as such. All other images are from Sentinel2.
- NASA Worldview images were rotated so that the view is to the North.
- Image dates are provided in the image captions.
- Colony names are shown in blue font in the images.
- Some changes in colony locations are due to movement of icebergs/ice shelves.

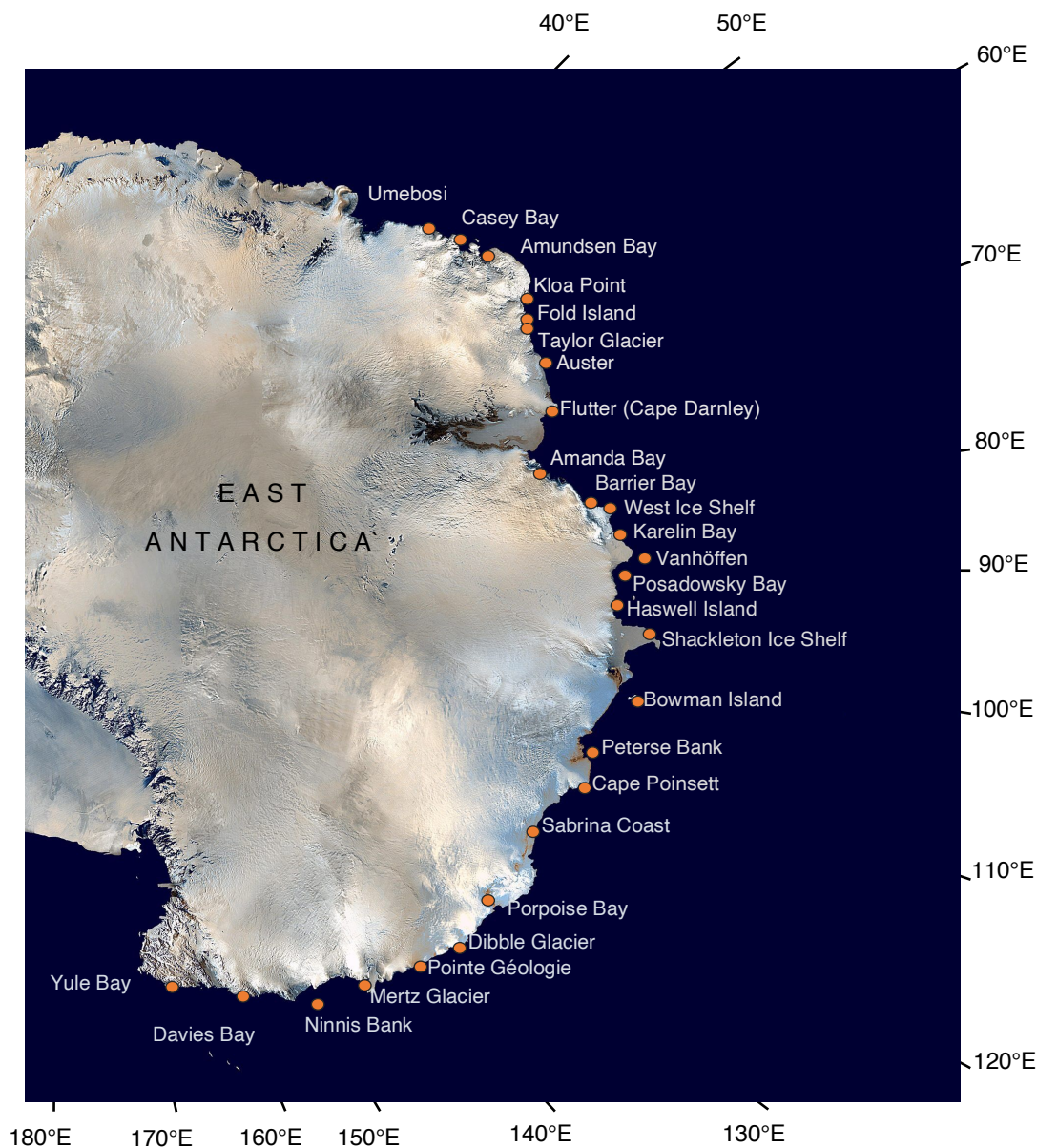


Fig. S1 Map of locations of the 27 study colonies in East Antarctica. Background image: orthographic projection of Antarctica generated by Dave Pape, NASA, using NASA's Blue Marble data set. https://en.wikipedia.org/wiki/File:Antarctica_6400px_from_Blue_Marble.jpg



Fig. S2 Map of East Antarctic lands and important locations mentioned in Table 2. Background image: orthographic projection of Antarctica generated by Dave Pape, NASA, using NASA's Blue Marble data set. https://en.wikipedia.org/wiki/File:Antarctica_6400px_from_Blue_Marble.jpg

Table S1. Overview of colonies described in detail in Table S2. Names in bold indicate Antarctic Specially Protected Areas. For details of dates for population estimates, see Table S2. (n/a = not applicable)

Colony	Latitude	Longitude	Date of observation	Habitat type	Approximate number of breeding pairs	Interannual movement (km)	Mean distance (km) fast ice edge	Breakout event recorded	Historical background (pre-2000)
1. Umebosi	68.05°S	43.08°E	17/12/23	coastal	200–600	0–3	51.0 ± 5.0	no	yes
2. Casey Bay	67.31°S	46.96°E	7/12/23	coastal	>1,000	<1	41.1 ± 9.5	no	no
3. Amundsen Bay	66.79°S	50.55°E	17/12/23	land-based	unknown	<1	48.6 ± 12.5	n/a	no
4. Kloa	66.64°S	57.28°E	26/10/23	coastal	3,470	0–2	53.0 ± 5.4	no	yes
5. Fold Island	67.30°S	59.26°E	21/11/23	coastal	<1,000	1–5	66.3 ± 11.2	no	yes
6. Taylor Glacier	67.45°S	60.88°E	20/11/23	land-based	<3,000	0	54.8 ± 15.1	n/a	yes
7. Auster	67.40°S	63.98°E	19/11/23	fast ice sheet	11,000	0–5	46.4 ± 8.7	Dec 2023	yes
8. Flutter	67.88°S	69.70°E	24/10/23	coastal	9,000	0–2	6.0 ± 2.2	Jan 2024	yes
9. Amanda Bay	69.27°S	76.83°E	15/11/23	coastal	10,000	<1	27.7 ± 11.9	no	yes
10. West Ice Shelf	66.26°S	81.44°E	1/11/23	ice tongue/glacier	3,500–7,800	1–6	6.5 ± 4.7	Dec 2023	yes
11. Barrier Bay*	67.17°S	81.95°E	3/09/21	ice tongue/glacier	400	1–6	3.9 ± 1.9	Sep 2020, 2021	yes
12. Karlin Bay	66.39°S	85.38°E	20/10/23	ice tongue/glacier	unknown	1–3	3.1 ± 2.5	Oct 2021, Nov 2022	yes
13. Vanhöffen	66.07°S	86.49°E	26/09/23	fast ice sheet	unknown	0–3	11.9 ± 4.2	no	no
14. Posadowsky Bay	66.14°S	89.78°E	19/11/23	fast ice sheet	<200	0–5	12.0 ± 10.2	no	yes
15. Haswell Island	66.54°S	93.05°E	12/11/23	coastal	6,000	0–2	25.7 ± 6.9	no	yes
16. Shackleton Ice Shelf	64.92°S	95.95°E	13/11/23	ice tongue/glacier	6,000–10,000	1–13	5.8 ± 3.2	no	yes
17. Bowman Island	65.28°S	103.18°E	1/11/23	coastal	3,000	2–3	23.0 ± 6.9	no	yes
18. Petersen Bank	65.87°S	110.22°E	10/11/23	fast ice sheet	<1,000	1–6	7.0 ± 3.7	Dec 2020, 2022, 2023	yes
19. Cape Poinsett	65.79°S	113.57°E	10/10/23	coastal	unknown	1–5	3.1 ± 2.8	Dec 2020, Oct 2021, 2022	no
20. Sabrina Coast	66.17°S	121.13°E	27/11/23	fast ice sheet	4,000	1–6	4.4 ± 2.0	Dec 2022, 2023	no
21. Porpoise Bay	66.27°S	130.04°E	12/10/23	fast ice sheet	>1000	5–13	45.7 ± 30.0	Nov 2022	no
22. Dibble Glacier	65.96°S	134.70°E	16/10/23	ice tongue/glacier	12,500	0–5	13.7 ± 9.8	no	no
23. Pointe Géologie	66.67°S	140.02°E	24/10/23	coastal	4,500	0–1	11.3 ± 13.1	no	yes
24. Mertz Glacier	67.26°S	146.01°E	13/10/23	ice tongue/glacier	4,800	2–7	8.8 ± 6.1	Nov 18	no
25. Ninnis Bank	66.71°S	149.67°E	13/11/23	ice tongue/glacier	unknown	1–2	9.6 ± 7.0	Dec 2020, Nov 2022	no
26. Davies Bay	69.34°S	158.41°E	26/10/23	coastal	unknown	0–4	4.6 ± 4.5	Dec 2020, Oct 2022, Nov 2023	no
27. Yule Bay	70.72°S	166.48°E	9/11/23	coastal	unknown	0–1	56.3 ± 12.2	no	yes

* colony not seen since 2021

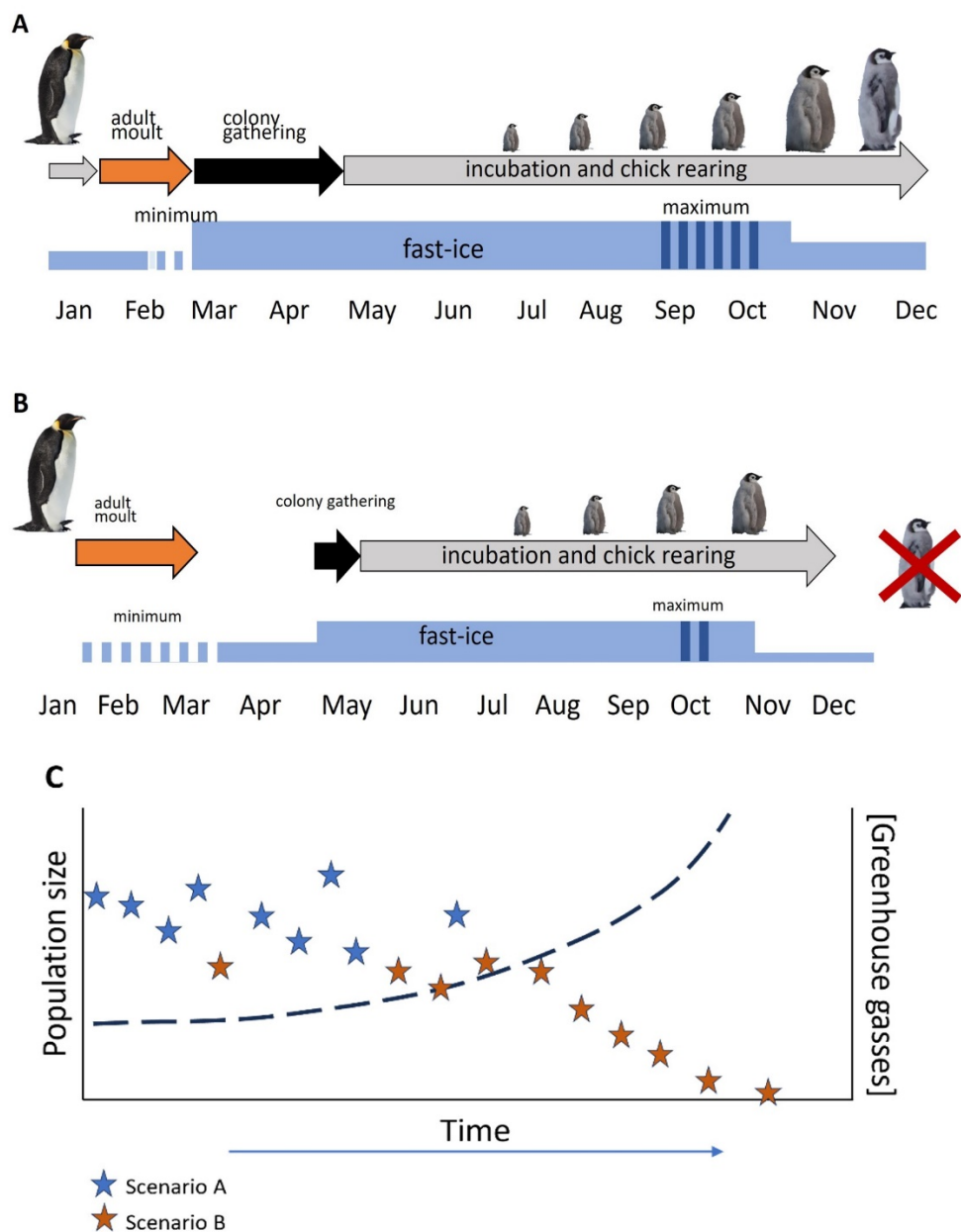


Fig. S3 Two scenarios of fast ice conditions encountered by emperor penguins at their colonies. **A.** Usual conditions where the fast ice lasts for at least 10 months, long enough to rear chicks to fledging. **B.** Shorter fast ice duration due to early ice breakout limits the penguins' ability to rear chicks and causes increases in chick mortality. Colony populations can recover from scenario B in the long-term provided it does not occur frequently. **C.** Changes in population size when concentrations of greenhouse gasses continue to increase show that should scenario B become the norm, populations (local and global) will become quasi-extinct.

Table S2. Detailed description and history of 27 emperor penguin colonies in East Antarctica (40°E–170°E)

Colony	1. Umebosi
Region	Prince Olav Coast, Queen Maud Land (25°W – 45°E), East Antarctica
Recent location	68.05°S, 43.08°E
Date	17 November 2023
Interannual movement	0–3 km
Size	200–600 breeding pairs ⁽¹⁾
Colony description	A small colony located on fast ice at the northern edge of an ice tongue (~1 x 1.5 km) of a small, unnamed glacier ~500 m west of Umebosi Rock (68.05°S, 43.12°E). At the northern side of the ice tongue are small icebergs. In 2018, 2020 and 2021–2023, the penguins gathered on the eastern side of a small iceberg immediately north of the glacier tongue, but in 2019, the colony was west of the ice tongue. The colony is usually <3 km from the coast.
Fast ice extent	The fast ice can extend from the Stanjukovicha Ice Shelf (~27.5°E), past the Riiser-Larsen Peninsula (34.33°E) into Amundsen Bay (50.22°E); in some years, it nearly reaches Cape Batterbee (53.80°E), Enderby Land. It can cover >64,000 km ² along ~1,200 km of coastline (Image A). The most extensive section is in Lützow-Holm Bay (69.2°S, 37.5°E) where the fast ice can be >120 km wide. The narrowest section is in front of the Stanjukovicha Ice Shelf where the fast ice tends to break out in February. In the eastern part, ice persists until April, then reforms (multi-year), especially in the southern parts of Lützow-Holm Bay, Casey Bay and Amundsen Bay.
Ice break out/formation	The fast ice tends to break out any time from late February to early April, and re-forms in late April/May, but regional differences exist. It often disintegrates first around 42°E, in the region of the Ichime (68.38°S, 42.13°E) and Kasumi (68.30°S, 42.35°E) glaciers, and on the western side of the Tange Promontory (67.45°S, 46.75°E), but may remain in Lützow-Holm Bay and Casey Bay (Image B).
Maximal distance to fast ice edge	57.5 km (1 October 2021)
Minimal distance to fast ice edge	24.2 km (28 December 2022)
Average distance to ice edge ± SD	51.0 ± 5.0 km
Early fast ice breakout	None observed
Distance from coast	<3 km
History	<p>We could not determine when this small colony was discovered. In 1961, the sighting of some young emperor penguins near Ongul Island (68.67°S, 39.50°E) indicated the possible presence of a colony somewhere along the Prince Olav Coast ⁽¹⁾. It was only in 1984 that Japanese researchers estimated the population size on 28 September 1984, possibly from the air. Four more counts were conducted from 1994 to 2000. The highest estimate (~600 breeding pairs) was acquired on 22 August 1994 ⁽²⁾. In August, both males and females are present in the colony, and the number of adults is higher than during incubation. Thus, the number of adults in the colony is no longer equal to the number of breeding pairs.</p> <p>During a satellite survey of emperor penguins, 146 adults were estimated to be attending the colony on 14 October 2009 ⁽³⁾.</p> <p>The colony location does not appear to have changed much since the early days. Kato et al. (2004) placed it at 68.05°S, 43.08°E, <1 km south of its current position. Based on satellite imagery, its location was 68.05°S, 43.01°E ⁽³⁾, ~2.7 km west of its current position in 2009.</p> <p>From 2018 to 2023, the colony was situated near the northern end of the ice tongue of a small, unnamed glacier just west of Umebosi Rock. The penguins usually gathered on the eastern side (Image C), but in 2019, they moved to the west of the ice tongue, an area they already occupied in 2009. Here, the penguins were on an open ice plain some 700 m west of the ice tongue.</p>

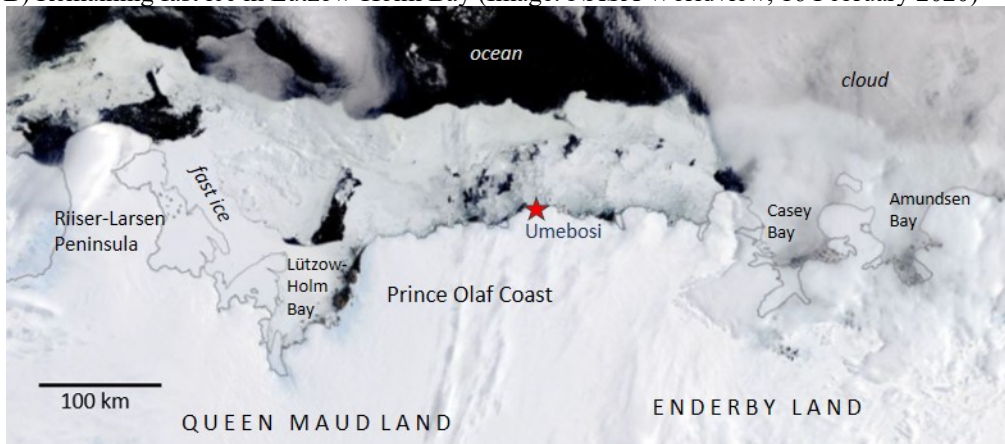
History	<p>The following year, 2020, the penguins occupied again an area east of the ice tongue, and in 2021, they were only ~300 m south of the 2018 colony area, and ~560 m north of the position recorded in September 2000 ⁽²⁾.</p> <p>The colony shifted only over short distances (0–3 km) between years, partly due to the movement of the ice tongue of a small unnamed glacier.</p> <p>The distance from this coastal colony to the fast ice edge usually exceeds 50 km. During the breeding seasons 2018–2023, the penguins had to traverse 48–57 km of fast ice to reach the ice edge (e.g. Image D). Due to the extensive fast ice sheet and the location of the colony near the coast, the distance from the colony to the ice edge averaged 51 ± 5 km.</p> <p>In 2023, the colony established itself in a small area (~1 ha) among three small, closely positioned icebergs that had calved the unnamed glacier. Two narrow gaps between the bergs allowed access. The colony was within ~600 m of the previous position due to shifts in iceberg positions (Image E).</p> <p>In 2023, the fast ice extent was similar to that in previous years, but from 25 to 28 December, some 700 km² of fast ice broke out west of the colony across the fast ice sheet reaching the coast. The distance between colony and fast ice edge was greatly reduced but did not endanger the colony.</p>
Population estimates/counts	<p>~200 adults (28 September 1984) ⁽²⁾; ~600 adults (22 August 1994) ⁽²⁾; ~450 adults (11 September 1996) ⁽²⁾; ~500 adults (9 September 1997) ⁽²⁾; ~200 adults (13 September 2000) ⁽²⁾; 146 adults (14 October 2009) ⁽³⁾</p>
References	<p>⁽¹⁾ Haga R (1961) Birds and seals around Japanese Syowa Base on Prince Harald Coast, Antarctica (preliminary). <i>Antarctic Record of JARE</i> 2, 146–148</p> <p>⁽²⁾ Kato A, Watanabe K, Naito Y (2004) Population changes of Adélie and emperor penguins along the Prince Olav Coast and on the Riiser-Larsen Peninsula. <i>Polar Bioscience</i> 17, 117–122</p> <p>⁽³⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p>

Images

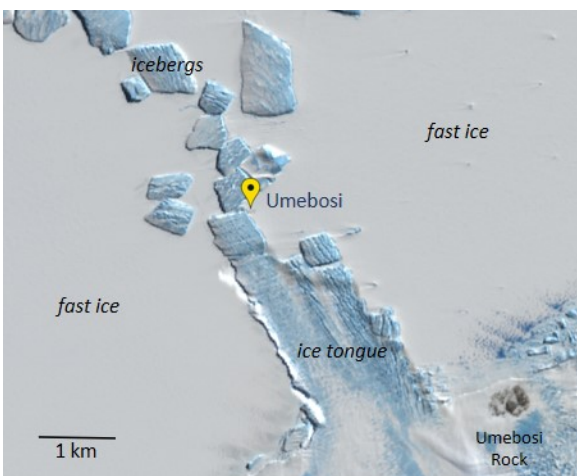
A) Regional fast ice extent along the Prince Olaf Coast (Image: NASA Worldview, 17 September 2021)



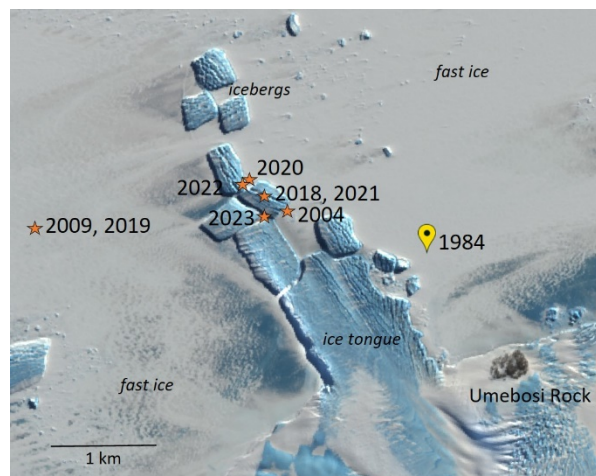
B) Remaining fast ice in Lützw-Holm Bay (Image: NASA Worldview, 16 February 2020)



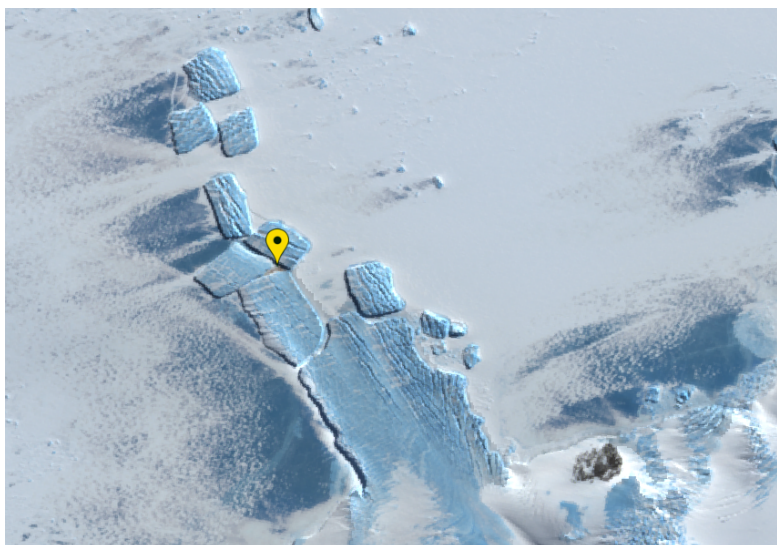
C) Colony location (yellow marker) on 9 November 2018



D) Known colony positions (Background image from 24 September 2023)



E) Colony location (yellow marker) on 7 November 2023

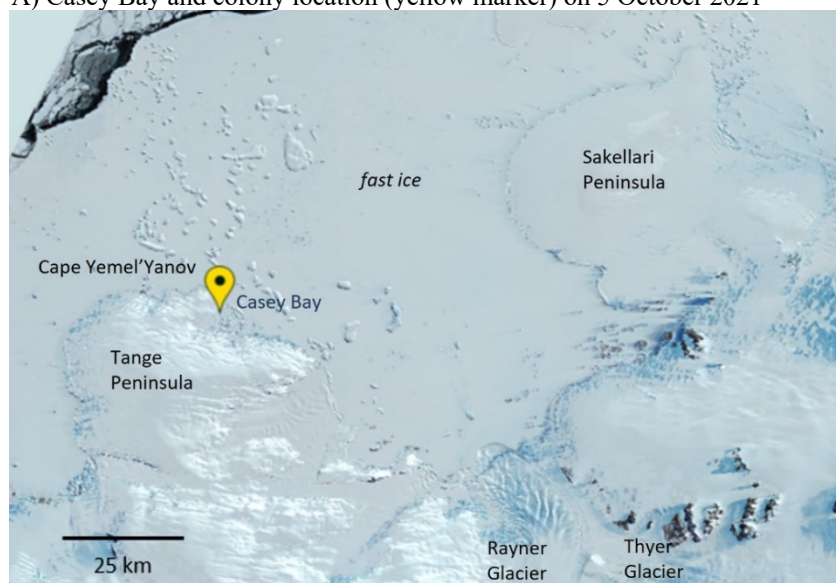


Colony	2. Casey Bay
Region	Tange Peninsula, Casey Bay, Enderby Land (45°E–55°E), East Antarctica
Recent location	67.31°S, 46.96°E
Date	7 November 2023
Interannual movement	<1 km
Size	>1,000 (late 2019) ⁽¹⁾
Colony description	The colony establishes on the fast ice at the northwestern side of Casey Bay in a small, sheltered embayment on the eastern side of Tange Promontory (67.45°S, 46.75°E), ~3.3 km SSW of Felton Head (67.28°S, 46.98°E), near ice cliff in the western part of a small (~1.5 x 1 km). The colony is only 300–500 m from the ice cliffs. Several small icebergs are inside the bay and at its entrance.
Fast ice extent	In this area, the fast ice is extensive stretching ~50 km north during the breeding season. The fast ice in bay often persists even in March/April. The regional fast ice can extend from the Stanjukovicha Ice Shelf (~27.5°E) past the Riiser-Larsen Peninsula (34.33°E) to Amundsen Bay (50.22°E), and in some years to roughly Cape Batterbee (53.80°E), Enderby Land. It may cover >64,000 km ² along ~1,200 km of coastline. The deepest section is in Lützow-Holm Bay where fast ice can be >120 km wide. The narrowest section is in front of the Stanjukovicha Ice Shelf where the fast ice tends to break out in February. In the eastern part, fast ice persists until April, then reforms (multi-year), especially in the southern parts of Lützow-Holm, Casey and Amundsen bays. Small breakouts occur near Casey Bay, occasionally north of the Tange Peninsula (2000, 2003), but mainly near White Island (2003, 2005, 2007, 2008, 2009, 2010 and 2012). The most extensive ice loss occurred in 2009.
Ice break out/formation	The fast ice tends to break out in late February/early April and re-forms in late April/May, but regional differences exist. It often disintegrates first around 42°E, in the region of the Ichime (68.38°S, 42.13°E) and Kasumi (68.30°S, 42.35°E) glaciers, and on the western side of the Tange Promontory, but may remain in Lützow-Holm Bay and Casey Bay.
Maximal distance to fast ice edge	57.0 km (29 September 2018)
Minimal distance to fast ice edge	15.9 km (29 December 2023)
Average distance to fast ice edge	41.1 ± 9.5 km
Early fast ice breakout	None observed
Distance from coast	<0.5 km
History	In 1961, Russian scientists reported large groups of emperor penguins in Casey Bay (Lena Bay in Russian) near their field camp in February/March, and suspected that a breeding colony existed here somewhere in winter. No locations or numbers were provided ⁽²⁾ . A Russian Atlas, published in 2005 ⁽³⁾ , shows penguin “colonies” in three locations in Casey Bay, and a fourth on the fast ice at the western side of the Tange Peninsula in Spooner Bay (67.62°S, 46.25°E), just west of the Assender Glacier tongue (67.60°S, 46.42°E) ⁽³⁾ . However, the symbols indicate aggregations of Adélie penguins and since they were located on the fast ice, these were not colonies. Currently, there are definitely no colonies at the positions indicated in the atlas. The locations in the atlas were possibly derived from sightings made by Russian scientists who investigated Enderby Land in February and March 1961 ⁽²⁾ . A satellite survey in 2009 did not detect a colony in Casey Bay ⁽⁴⁾ . However, on 17 October 2018, a satellite image showed a colony here in a small embayment at the eastern side of the Tange Peninsula ⁽¹⁾ (Image A). The fast ice tends to remain in the bay throughout summer (Image C). In 2023, it started to break out in early March, and by April, the bay was ice-free.

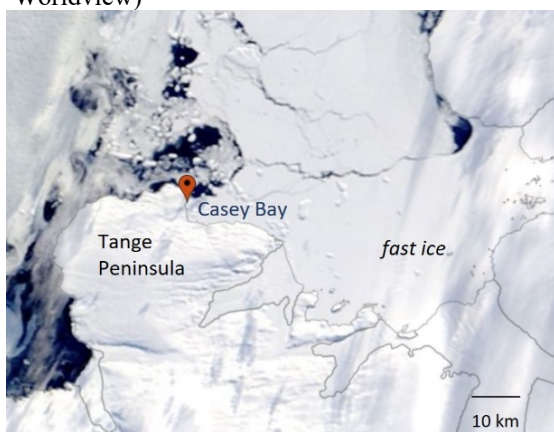
History	From 2018 to 2023, the colony location barely changed. The penguins remained in the small bay at the eastern side of the Tange Promontory where the colony usually forms on multi-year fast ice. Large areas of Casey Bay often retain fast ice, especially on the western side, but it can be ice-free in autumn (Images B & C). To date (January 2024), a direct count of this colony has not been attempted.
Population estimates/counts	>1,000 (late 2019) ⁽¹⁾
References	⁽¹⁾ Fretwell P, Trathan PN (2021) Discovery of new colonies by Sentinel2 reveals good and bad news for emperor penguins. <i>Remote Sensing in Ecology and Conservation</i> 7, 139–153 ⁽²⁾ Korotkevich YS, Ledenev VG (1962) Investigations in Enderby Land. <i>Information Bulletin of the Soviet Antarctic Expeditions</i> 33, 65–72 ⁽³⁾ Ministry of Defense, Federation of the Russian Navy (2005) Atlas of the Southern Oceans, Antarctica. State Research Centre of the Russian Federation, Arctic and Antarctic Research Institute, Saint Petersburg ⁽⁴⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751.

Images

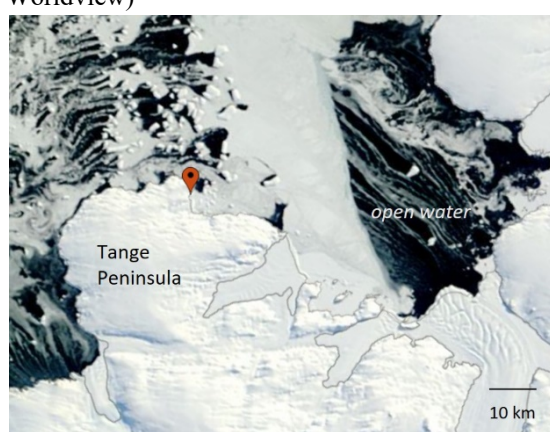
A) Casey Bay and colony location (yellow marker) on 5 October 2021



B) Casey Bay on 3 April 2021 (Image: NASA Worldview)



C) Casey Bay on 1 April 2023 (Image: NASA Worldview)



Colony	3. Amundsen Bay
Region	Mt Riiser-Larsen, Amundsen Bay, Enderby Land (45°E–55°E), East Antarctica
Recent location	66.79°S, 50.55°E
Date	17 November 2023
Interannual movement	<1 km
Size	Unknown; possibly a few hundred pairs (<1000 breeding pairs)
Colony description	The land-based colony is located ~1 km inland on snow or ice-covered ground at the western side of Mount Riiser-Larsen, and north of a small melt lake. During the breeding season, the penguins occasionally move onto a small compression zone (1 x 0.3 km) of an unnamed glacier. The ice ridges in this compression zone provide very rough terrain. Emperor penguins were present on or near the Richardson Lakes ^{(1),(2)} which appear to remain frozen due to snow cover. Ice algae blooms occur in summer.
Fast ice extent	The fast ice can extend from the Stanjukovicha Ice Shelf (~27.5°E) past the Riiser-Larsen Peninsula (34.33°E) to Amundsen Bay (50.22°E), and in some years to roughly Cape Batterbee (53.80°E), Enderby Land. It can cover >64,000 km ² along ~1,200 km of coastline. The deepest section is in Lützw-Holm Bay where fast ice can be >120 km wide. The narrowest section is in front of the Stanjukovicha Ice Shelf where the fast ice tends to break out in February. In the eastern part, ice persists until April, then reforms (multi-year), especially in the southern parts of Lützw-Holm, Casey and Amundsen bays. However, it may remain in Lützw-Holm and Casey bays.
Ice break out/formation	The fast ice tends to break out in late February/early April and re-forms in late April/May, but regional differences exist. It often disintegrates first around 42°E, in the region of the Ichime (68.38°S, 42.13°E) and Kasumi (68.30°S, 42.35°E) glaciers, and on the western side of the Tange Promontory. In Amundsen Bay, the fast ice may start to retreat in December; by late January, the bay is largely ice-free.
Maximal distance to fast ice edge	67.0 km (18 September 2018)
Minimal distance to fast ice edge	12.3 km (11 December 2021)
Average distance to fast ice edge	48.6 ± 12.5 km
Early fast ice breakout	Not applicable as colony is land-based
Distance from coast	Up to 1 km inland
History	In February 1988, a Japanese field party conducted some geological and geomorphological work near Mt Riiser-Larsen and estimated several thousand Adélie penguins <i>Pygoscelis adeliae</i> (adults and chicks?) that occupied a small, raised beach area ⁽¹⁾ west of some small melt lakes (~66.47°S, 50.33°E), but emperor penguins were not recorded. On 25 February 1995, the Adélie penguin colony (66.79°S, 50.67°E) was visited near Mount Riiser-Larsen ⁽²⁾ . Again, no emperor penguins were sighted. Any emperor penguins present here over winter probably had left by then. Ten months later, in December 1996, adult and chick emperor penguins were present. The penguins occupied an area near a small, frozen lake several 100 m inland, and about 200 m from the northern limit of an Adélie penguin colony. A precise location was not provided. Most chicks were in an advanced state of moult ⁽²⁾ . A Russian atlas, published in 2005, indicates a penguin location on the fast ice in southern Amundsen Bay, west of the Beaver Glacier Ice Tongue (67.03°S, 50.67°E), but the symbol indicates Adélie penguins; no emperor penguins were depicted ⁽³⁾ . Russian expeditioners mapped the area using aerial photographs taken in 1962, but no Adélie penguin colony was noted in the atlas near Mount Riiser-Larsen, although one exists there today.

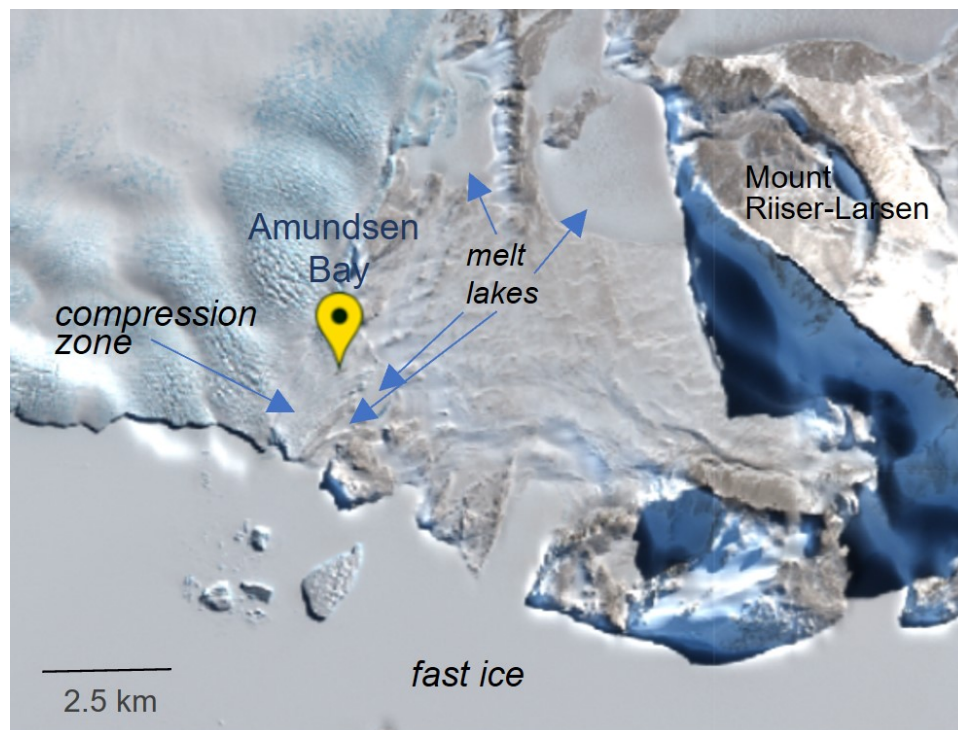
History	<p>On 6 January 2007, 22 emperor penguin fledglings were seen at ~66.79°S, 50.57°E. In addition, another four fledglings were at 66.75°S, 50.62°E⁽⁴⁾. Since this visit occurred very late in the breeding season, the numbers are not indicative of the colony size, nor are these coordinates a precise indication of the winter location.</p> <p>An estimate based on a satellite image from 20 October 2009 suggested the presence of 88 adults. However, the image quality was poor⁽⁵⁾.</p> <p>From 2018–2021, the colony was within ~1 km from its 2009 position⁽⁶⁾. The penguins tended to gather on the slopes of the Tula Moraine⁽¹⁾, west of Mt. Riiser-Larsen, near the edge of the continental ice.</p> <p>In 2022 and 2023, the colony shifted in part or entirely onto the ice in the compression zone (Image B). In satellite images, the surface here appears to be very rugged and uneven, and it is unclear why the penguins would use it for months on end. It is also unclear whether the group nearest the water could descend from the compression zone into the Adélie penguin colony and reach the fast ice from there, or whether the penguins had to traverse back over the heavily ridged, compressed ice.</p>
Population estimates/counts	<p>25 adults (3 moulting), 2 immatures, 250 chicks (17 December 1996)⁽²⁾; 26 fledglings plus 2 emperor penguins (adults?) (7 January 2007)⁽⁴⁾; 88 adults (20 October 2009)⁽⁵⁾</p>
References	<p>⁽¹⁾ Hayashi M (1990) Glacial history with special reference to the past lacustrine deposits in the Mt. Riiser-Larsen area, Enderby Land, East Antarctica. <i>Proceedings of the NIPR Symposium on Antarctic Geosciences</i> 4, 119–134</p> <p>⁽²⁾ Kato A, Ichikawa H (1999) Breeding status of Adélie and emperor penguins in the Mt Riiser-Larsen area, Amundsen Bay. <i>Polar Bioscience</i> 12, 36–39</p> <p>⁽³⁾ Atlas of the Oceans — Antarctic (2005) Head Department of Navigation and Oceanography, Ministry of Defense, Federation of Russia, State Research Centre of the Russian Federation — Arctic and Antarctic Research Institute, Saint Petersburg.</p> <p>⁽⁴⁾ Dan Colborne, pers. comm., 12 January 2007</p> <p>⁽⁵⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p> <p>⁽⁶⁾ This study</p>

Images

A) Amundsen Bay and colony location (yellow marker) on 5 October 2021



B) Colony location at Amundsen Bay on 5 October 2021



Colony	4. Kloa (IBA 118)
Region	Edward VIII Plateau, Kemp Land (55°E–60°E), East Antarctica
Recent location	66.64°S, 57.28°E
Date	26 October 2023
Interannual movement	0–2 km Note: from 2009 to 2023, the colony location did not change. The 2 km shift is based on data from 1956 and 1957.
Size	~3,470 adults (22 September 2022) ⁽¹⁾
Colony description	The colony occupies the fast ice right next to coast in small embayment south of Bagliani Point (immediately south of Kloa Point). The local fast ice here is highly persistent, and the colony appears to have occupied this area since its discovery.
Fast ice extent	Regionally, the fast ice stretches along ~520 km of coastline from Flåodden (~66.01°S, 55.54°E), a cape in northern Enderby Land, in the west to the Cape Darnley Polynya in the east (~68.25°E), and covers an area of >31,000 km ² (Image A). In October, its width varies locally from 50–90 km. The widest stretch occurs in the Mawson area, generally to ~62.6°E. Compared to the western section of fast ice, the eastern section is quite variable. In October 2009, it reached 68.9°E, and in October 2010 and 2014, the ice connected to the “ice tongue” of Cape Darnley, but retracted to 67.8°E and 65.6°E in November 2010 and 2014, respectively. In November, the fast ice often reaches into Shallow Bay (67.4°E), about 20 km east of Murray Monolith (67.78°S, 66.89°E).
Ice break out/formation	Mid-March but embayment still frozen. In March 2019, the fast ice reached <500 m from the coast preserving the colony area (Image B). The fast ice forms from ~April onwards.
Maximal distance to fast ice edge	60.6 km (16 September 2023)
Minimal distance to fast ice edge	20.8 km (25 December 2032)
Average distance to fast ice edge	53.0 ± 5.4 km
Early fast ice breakout	None observed
Distance from coast	<0.5 km
History	<p><i>Note on name:</i> Kloa Point was named by members of the Lars Christensen expedition (1936–1937) from the Norwegian “kloen” – the claw – because of the two distinct protruding capes. In 1978, the Australian Antarctic Names Committee called the smaller, southern point “Bagliani Point”, after the geophysicist Fulvio Bagliani, who wintered at Mawson station in 1975 and 1977. The emperor penguin colony is thus actually located south of Bagliani Point. The colony has retained the by 1978 well-established name “Kloa Point colony”, after the northern more prominent cape.</p> <p style="text-align: center;">---</p> <p>The colony is located on exceptionally stable, usually multi-year fast ice. The penguins move along the southern side of the rocky outcrop during the breeding season. The overall location has remained remarkably consistent since the colony was discovered.</p> <p>The colony occupied the same location since 1957 when it was discovered from an Australian National Antarctic Research Expeditions (ANARE) Beaver aircraft by Squadron Leader P.H. Clemence, Commanding Officer of the Royal Australian Air Force (RAAF) who wintered at Mawson in 1957⁽²⁾. On 25 September 1957, he estimated 5,000 penguins at ~66.62°S, 57.18°E⁽²⁾. The longitude is incorrect as it would place the colony >3 km inland, but the pilots commented that the penguins were situated “seaward of Kloa Point, among small islands”⁽²⁾. The only group of small islands in the vicinity are the Jagar Islands (66.58°S, 57.33°E), about 6 km north of Kloa Point. The colony location was estimated from the air during a flight, which may explain the inaccuracy. Thus, the precise location in 1957 is unknown.</p> <p>Since the discovery, the colony was visited multiple times to census the penguins. The travel distance from Mawson to Kloa Point is nearly 300 km. In the early years, expeditioners oftentimes employed dog teams to undertake this journey. Thus, visits often occurred during</p>

History	<p>September. For census work, September is not ideal as many chicks are still being brooded and may be invisible, and parent birds are moving in and out of the colony. However, the counts were useful for a relative comparison and for information on an approximate size of the colony.</p> <p>Budd (1961) notes that, in 1956, the colony was located “close under a rocky bluff on the southern side of Kloa Point”, the current position, and mentions that the colony was virtually land locked ⁽³⁾. But the coordinates he provides (66.63°S, 57.32°E) put the colony into an area of open fast ice ~2 km from the point. Thus, the site description and coordinates do not agree.</p> <p>Three expeditioners from Mawson, Sandercock, Armstrong and Sawert, were the first to visit the Kloa colony on 21 November 1959 ⁽⁴⁾, and counted 840 adults plus 1,600 chicks. The count method is not further described.</p> <p>An Australian supply ship approached Kloa Point on 21 February 1960; personnel noted 40 moulting adults and a further 7 non-moulting emperor penguins at the ice edge ⁽⁵⁾. Budd (1962) stated that 4,660 adults occupied the colony on 10 April 1960 ⁽⁴⁾, but it is unclear how this number was derived.</p> <p>The colony was visited on 29 August 1965. Of the estimated 4,550 birds, 90% possibly had chicks. About 40 dead chicks were sighted ⁽⁶⁾.</p> <p>On 30 September 1975, the colony was next to the southern ice cliff of Kloa Point (current location, Images C & D). To enable the census, the colony was counted in 11 sections; only chicks were counted ⁽⁷⁾.</p> <p>On 17 September 1976, the colony was visited again. The penguins stretched along the southern cliffs of the point as in 1975 forming one large and one small group. The team members agreed on an estimate of 2,500 adults and approximately twice this number of chicks; they noted though that due to the many chicks present, it was difficult to estimate their numbers ⁽⁸⁾.</p> <p>In September 1977, a field party camped near Kloa Point for two nights. The colony was again located next to the ice cliffs. To enable a count, the chicks were divided into 10 different groups and counted separately ⁽⁹⁾.</p> <p>The team visiting Kloa Point in September 1981 reported that the colony had split into two groups. The main group “featured a very extensive and mobile area of birds and some difficulty was found in counting” ⁽⁶⁾. The colony occurred in the same area as in previous years ⁽¹⁰⁾.</p> <p>In September 1982, the colony occupied the same area as previously. Personnel from Mawson observed that the colony looked “healthy” as they hardly saw any dead chicks. However, they also noted that perished chicks probably had been covered by a recent blizzard ⁽¹¹⁾.</p> <p>The Kloa Point region had also received a lot of snow in September 1985. Team members reported the difficulties of walking through the freshly fallen snow. They noted ~200 dead chicks and 10 lost eggs. The chicks were counted in 5 separate groups. All were again located in the same area as in previous years ⁽¹²⁾.</p> <p>Personnel of Mawson station travelled to Kloa Point sometime in 1989 ⁽¹³⁾, but no records or population estimates could be found.</p> <p>On 8 December 1992, a tourist vessel visited Kloa Point. Extrapolation from grid counts, staff estimated that 4,000–5,000 chicks that outnumbered adults by at least three to one ⁽¹⁴⁾.</p> <p>The same vessel visited again on 16 December 1996. Some 2,625 chicks were counted, and ~20% of the total were estimated to be adults ⁽¹⁴⁾.</p> <p>Based on satellite data, 3,283 adults attended the colony on 13 November 2009 ⁽¹⁵⁾.</p> <p>In September 2022, for the first time in 33 years a team from Mawson station travelled to Kloa Point to photograph the colony. As before, the colony was on the fast ice south of the cliffs. Most penguins formed one large group; two smaller groups occurred a short distance east of the main group (Image E).</p> <p>On this occasion, only the adults were counted (n = 3,740), because many still brooded or guarded their offspring, and chicks were largely invisible. The size of this population appears</p>
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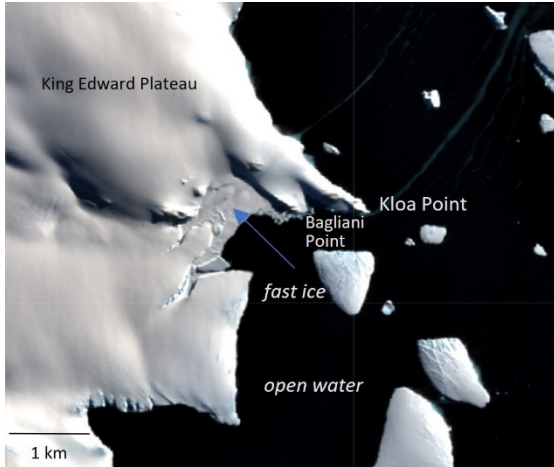
History	<p>to have remained relatively stable since its discovery. However, significant data gaps exist. In December 2023, the usually extensive fast ice started to break out sooner than in previous years. By mid-January 2024, the fast ice edge was only ~10 km from the colony. However, the quality of the fast ice at the colony had deteriorated, and open water holes had appeared (very unusual for this colony). However, this is unlikely to have affected the colony significantly. By 13 February 2024, some of the multi-year fast ice of the colony area had disappeared. Regionally, most fast ice had disappeared markedly sooner than in years prior to 2022.</p>
Population estimates/counts	<p>~5,000 birds (25 September 1957)⁽²⁾; 840 adults and 1660 chicks (21 November 1959)⁽⁴⁾; 40 adults (21 February 1960)⁽³⁾; 4,660 adults (10 April 1960)⁽⁴⁾; ~4,550 birds (29 August 1965)⁽⁶⁾; 4,332 chicks (30 September 1975)⁽⁷⁾; ~2,500 adults (17 September 1976)⁽⁸⁾; 3,087 chicks (12 September 1977)⁽⁹⁾; 3,238 chicks (c. 28 September 1981)⁽¹⁰⁾; 2,500 adults and 4,000 chicks (30 September 1982)⁽¹¹⁾; ~4,310 adults (21 September 1985)⁽¹²⁾; 4,000–5,000 chicks (8 December 1992)⁽¹³⁾; 2,625 chicks (16 December 1996)⁽¹⁴⁾; 3,283 adults (13 November 2009)⁽¹⁵⁾; 3,491 adults in main group plus ~250 farther east (24 September 2022)⁽¹⁾</p>
References	<p>⁽¹⁾ This study ⁽²⁾ Willing RL (1958) Australian discoveries of emperor penguin rookeries in Antarctica during 1954–57. <i>Nature</i> 182, 1393–1394 ⁽³⁾ Budd GM (1961) The biotopes of emperor penguin rookeries. <i>The Emu</i> 61, 171–189 ⁽⁴⁾ Budd GM (1962) Population studies in rookeries of the emperor penguin <i>Aptenodytes forsteri</i>. <i>Proceedings of the Zoological Society of London</i> 139, 365–388 ⁽⁵⁾ Ingham S (nd) Unpublished data from Mawson Biology logs collated by Sue Ingham, Australian Antarctic Division ⁽⁶⁾ Cameron A (1965) Biology log Mawson 1965. Unpublished report ⁽⁷⁾ Moonie P (1975) Field report Kloa Point-Fold-Taylor, emperor penguin rookeries, spring 1975. Unpublished report, Australian Antarctic Division ⁽⁸⁾ Larsen LS (1976) Fieldtrip to Kloa Point and Fold, spring 1976. Unpublished report ⁽⁹⁾ Nash R (1977) Field report Taylor – Fold – Kloa Point emperor penguin rookeries, spring 1977. Unpublished report, Australian Antarctic Division ⁽¹⁰⁾ Butler P (1981) Field journey to Taylor Glacier, Fold Island and Kloa Point, 23rd September – 12th October, 1981. Unpublished report, Australian Antarctic Division ⁽¹¹⁾ Werner O (1982) Kloa Point fieldtrip 16/9 to 13/10 – 1982. Unpublished report ⁽¹²⁾ Pottage D (1985) Trip report – 8/85 Mawson. Unpublished report, Australian Antarctic Division ⁽¹³⁾ Paterson D (2019) Mawson remembered. <i>Aurora Journal</i>, Spring 2019, p 25 ⁽¹⁴⁾ Todd FS, Spletstoesser JF, Ledingham R, Gavrillo M (1999) Observations in some emperor penguin <i>Aptenodytes forsteri</i> colonies in East Antarctica. <i>The Emu</i> 99, 142–145 ⁽¹⁵⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p>

Images

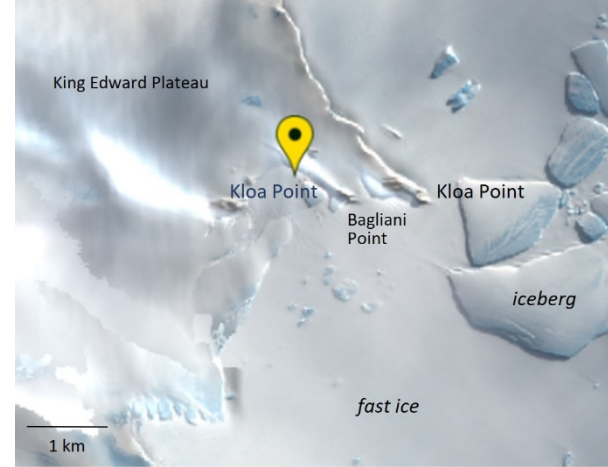
A) Regional fast ice extent along the Mawson Coast (Image: NASA Worldview, 17 October 2021)



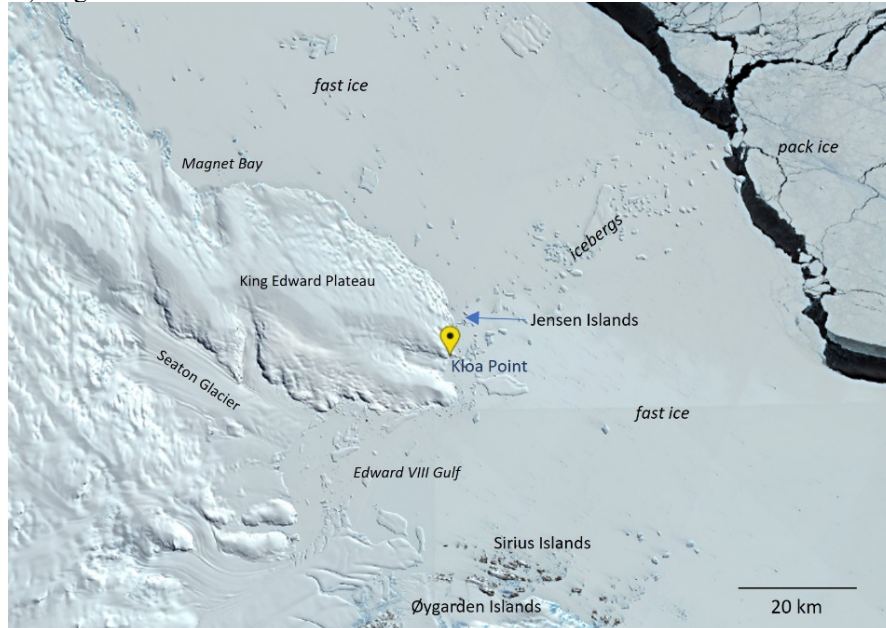
B) Persisten fast ice in colony area, 18 March 2019



C) Colony location (yellow marker) on 23 September 2021



D) Regional fast ice extent on 7 October 2019



Colony	5. Fold Island
Region	Stefansson Bay, Mawson Coast, Kemp Land (55°E–60°E), East Antarctica
Recent location	67.30°S, 59.26°E
Date	21 October 2022
Interannual movement	1–5 km
Size	<1,000 adults
Colony description	<p>The colony is located on the fast ice at the eastern side of Stefansson Bay (67.3°S, 59.2°E), southwest of Fold Island and northwest of Transverse Island (67.31°S, 59.32°E). It is closest to the southern coast of Fold Island (Image A). At times the colony settles between the Dovers Glacier (67.47°S, 59.35°E) and Fold Island (<1 km wide gap). Over time, the position of the northern edge of the ice tongue has changed. In the 1950s–60s, it butted against the western side of Transverse Island. By 1999, the eastern edge was about 5 km south of Transverse Island at ~67.38°S. It then started to expand north again. By 2018, the ice tongue had reached Keel Island (67.35°S, 59.33°E) at ~67.34°S. From 2018–2021, it was ~800 m farther north than the northern coast of Transverse Island at ~67.32°S. In 2022, the colony occurred ~5 km west of the 2021 position, and was in front of the ice tongue of the Dovers Glacier.</p> <p>Fold Island is >200 m high and shields the colony from the sun, making this area very cold ⁽¹⁾. Due to these circumstances, the fast ice east of Transverse Island and south of Fold Island is multi-year fast ice and very thick as it rarely breaks out.</p>
Fast ice extent	<p>The fast ice stretches along approximately 520 km of coastline from Flåodden (~66.24°S, 56.01°E), a cape in Enderby Land, in the west to the Cape Darnley Polynya in the east (~68.25°E), and covers an area of >31,000 km². In October, its width varies locally from 50–90 km. The widest stretch occurs in the Mawson area generally to ~62.6°E. Compared to the western end of this stretch of fast ice, the eastern extent is quite variable. In October 2009, it reached 68.9°E, and in October 2010 and 2014, the ice connected to the “ice tongue” of Cape Darnley, but retracted to 67.8°E and 65.6°E in November 2010 and 2014, respectively. In November, the fast ice often reaches into Shallow Bay (67.4°E), about 20 km east of Murray Monolith (67.78°S, 66.89°E).</p> <p>Measured from Fold Island, the width of the fast ice averaged 71.7 ± 5.8 km from 2028 to 2022.</p>
Ice break out/formation	In Stefansson Bay, the fast ice can persist into early March (~48 km north of island) but the bay tends to be ice-free in late March. The fast ice re-forms in late April/May. Occasionally it persists throughout the summer and does not breakout (e.g. 2021) (Image B).
Maximal distance to fast ice edge	78.2 km (11 October 2022)
Minimal distance to fast ice edge	16.9 km (25 December 2023)
Average distance to fast ice edge	66.3 ± 11.2 km
Early fast ice breakout	None observed
Distance from coast	~6 km, but <0.5 km from Fold Island
History	<p>R. Dovers, Officer-in-Charge at Mawson station in 1954, first suspected that a colony existed in the region. He noted about 20 adults feeding in tide cracks near Fold Island in October 1954 ⁽¹⁾. Since then, the colony was located and visited numerous times to census the penguins, if possible, in winter as well as in spring. In the early years, the ~165 km distance from Mawson station was covered by dog sledges and, depending on the weather, could take more than a week. Since the Mawson coast lies south of the Antarctic circle, the winter travel usually occurred in darkness.</p> <p>On 12 May 1956, the colony was sighted from the air at ~67.32°S, 59.38°E (south of the island); some 300–500 birds were estimated to be present. The colony was located between</p>

History	<p>Fold and Transverse islands and a third unnamed island ⁽¹⁾. The penguins still occupy this general area today. In 1956, the colony was visited on five more occasions; the largest number of adults (~1,250) was recorded on 18–24 May. On 27 October, only about 60 chicks were present ⁽¹⁾.</p> <p>In 1957, the colony was visited on 14 May and ~1,250 ($\pm 10\%$) adults were estimate to be present ⁽¹⁾. Departing penguins moved eastwards into William Scoreby Bay (67.40°S, 59.62°E) and then turned northeast towards the sea ⁽¹⁾.</p> <p>The field report from 1959 could not be recovered, but Moonie et al. (1971) mentioned a visit to Fold Island on 9 June 1959 and stated that 1,030 adults appeared to be present. On 22 October 1959, ~230 chicks were counted. There is no further information about colony location or conditions ⁽²⁾.</p> <p>Chicks were counted on 4 September 1961. The colony was approximately 100 m northeast of Transverse Island and 690 chicks were estimated to be present. Twenty-five dead chicks were found of which 8 seemed to be recently hatched ⁽³⁾.</p> <p>The spring count in 1962 occurred on 9 October. Adults numbered $248 \pm 5\%$ and chicks $563 \pm 10\text{--}15\%$. Some 18 dead chicks were found, but snow may have covered other chicks and eggs ⁽⁴⁾.</p> <p>Some inconsistencies and data gaps exist. For example, the breeding success for 1961 and 1962 was estimated at about 60% in these years ⁽²⁾. However, since winter counts of adults were not available, these numbers were obtained by applying the so-called <i>one-third rule</i> that assumed that the number of adults present in 11–18 weeks after hatching represents about one-third of the adults that had attempted to breed (suggested range 26–40%) ⁽⁵⁾. This is highly inaccurate and provides at best a crude estimate of the population size.</p> <p>In September 1965, vehicles rather than dog sledges were used to travel to the colony. On 3 September, 450 adults were counted of which an estimated 95% had chicks. Some 20 dead chicks and 35 abandoned eggs were noted ⁽⁶⁾.</p> <p>In 1969, the emperor penguins were counted on 12 June. The average of three counts gave 1,006 individuals (range 994–1,019) of which an estimated 6% did not carry an egg ⁽⁷⁾.</p> <p>On 8 June 1970, a team from Mawson station initially had difficulties finding the colony due to darkness. When they eventually found it, they counted the penguins in the dark and estimated that ~1,200 adults were present, ~95% with eggs ⁽⁸⁾.</p> <p>Five weeks later, on 14 August 1970, the colony still occupied the same location in the bay formed by Fold and Transverse islands and the ice bridge. An estimated $1,000 \pm 50$ adults were counted and ~95% (based on a sample of 70 birds) had chicks ⁽⁹⁾.</p> <p>The winter count in 1971 occurred on 5 June. The penguins were in their usual location south of Fold Island, and three counts gave an average of 1,151 adults present ⁽¹⁰⁾.</p> <p>In September 1971, 201 chicks were counted. The trip report mentioned that this was a low number given that there had been 1,036 eggs in June of this year ⁽¹¹⁾. The discrepancy between the two figures (1,151 adults and 1,036 eggs) possibly indicates that the total number of adults had been reported, and of those only 1,036 were carrying eggs.</p> <p>On 14 July 1975, the colony was found just east of an ice bridge that connected Fold and Transverse islands ⁽¹²⁾ in roughly the same location as in previous years.</p> <p>During a second visit in 1975, on 3 October, only 550 chicks were estimated to be present ⁽¹³⁾, noticeably fewer than the 1,038 adults counted earlier in July.</p> <p>On 22 September 1976, a team from Mawson found the colony widely dispersed making the census work easy. Only adults were counted ($n = 258$); the number of chicks was guessed to be about double this number ⁽¹⁴⁾.</p> <p>The colony was visited twice in 1977. During winter, ~1,500 adults were estimated to be present ⁽¹⁵⁾, and in October, 468 chicks were counted ⁽¹⁶⁾. Since winter, the colony had shifted about 1 km to the east.</p> <p>In 1981, the emperor census work took place from 23 September to 12 October. Precise dates for the colony visits were not recorded. Probably in early October, 631 chicks were counted at</p>
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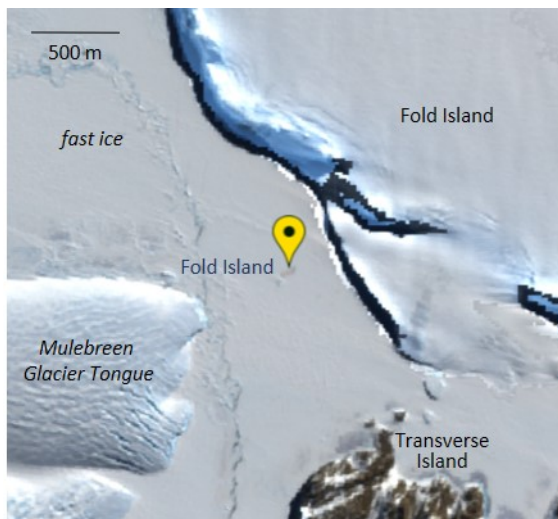
<p>History</p>	<p>Fold Island. Since the colony had spread out, the census was straight forward⁽¹⁷⁾.</p> <p>On 24 September 1982, the chick census took place. The team reported that all chicks were still rather small and that no dead chicks or eggs were found. During 21 and 22 September, heavy snow had probably buried them⁽¹⁸⁾.</p> <p>The next spring count occurred on 3 October 1984. The colony was next to Transverse Island (probably eastern side since the ice bridge still existed). The penguins had assembled in two groups ~70 m apart. There were nearly twice as many chicks as adults⁽¹⁹⁾.</p> <p>In 1985, only chicks ($n = 341 \pm 49$) were counted on 19 September. Only a few dead chicks were noticed; the clean look of the colony indicated recent snow fall⁽²⁰⁾.</p> <p>Since 1985, visits to Fold Island were undertaken less frequently. Since 2009, six visits occurred, and the colony was photographed. In September 2009, August 2010, September 2016, 2018 and 2020, adults were counted with great accuracy. However, September is too early in the season to obtain reliable chick numbers. At this time of year, many chicks are still being brooded and are not visible, particularly when an adult is seen from behind. Thus, only visible chicks could be counted⁽²¹⁾.</p> <p>In September 2021, the colony was located near an ice ridge that partially obscured the colony. A count from ground photographs was attempted but was incomplete⁽²¹⁾. However, on 20 September 2022, photos covered the entire colony; 361 adults were counted, and 234 chicks were visible.</p> <p>For as long as it has been visited, this colony has been at south of Fold Island, and its positions had shifted ~3 km from 1956 to 2009. From 2018 to 2021, the location moved by <1 km. In 2022, the penguins shifted ~5 km west from the location in 2021, and were situated north of the ice tongue of the Mulebreen (Dovers) Glacier.</p> <p>2023 was unusual in that the fast ice receded unusually quickly (~34 km from 15–25 December) and earlier than previously, but the colony appeared not to be endangered.</p>
<p>Population estimates/counts</p>	<p>~1,000 adults (18–24 May 1956)⁽¹⁾; 1,250 adults (14 May 1957)⁽¹⁾; 220 chicks (13 October 1957)⁽²⁾; 1,030 adults (9 June 1959)⁽²⁾; 230 chicks (22 October 1959)⁽²⁾; ~690 chicks (4 September 1961)⁽³⁾; 248 adults and 563 chicks (9 October 1962)⁽⁴⁾; 450 adults (3 September 1965)⁽⁶⁾; 1,006 adults (12 June 1969)⁽⁷⁾; ~1,200 adults (8 June 1970)⁽⁸⁾; 1,000 (994–1019) adults (14 August 1970)⁽⁹⁾; 1,151 (1124–1185) adults (5 June 1971)⁽¹⁰⁾; 201 chicks (27 September 1971)^{(2), (11)}; 1,038 adults (14 July 1975)⁽¹²⁾; ~550 chicks (3 October 1975)⁽¹³⁾; 258 adults (22 September 1976)⁽¹⁴⁾; ~1,500 (2 June 1977)⁽¹⁵⁾; 468 chicks (20 September 1977)⁽¹⁶⁾; 631 chicks (early October 1981)⁽¹⁷⁾; 260 adults and 550 chicks (24 September 1982)⁽¹⁸⁾; 234 adults and 410–440 chicks (3 October 1984)⁽¹⁹⁾; 341 chicks (19 September 1985)⁽²⁰⁾; 398 adults and 238 chicks (23 September 2009)⁽²¹⁾; 213 adults (14 October 2009)⁽²²⁾; 502 adults and 185 chicks (10 September 2010)^(21 *); 794 adults (22 August 2016)⁽²¹⁾;</p>

<p>Population estimates and counts</p>	<p>496 adults and 336 chicks visible (7 September 2018) ⁽²¹⁾ *; 160 adults and 290 chicks visible (27 September 2020) ⁽²¹⁾ *; 192 adults and 140 chicks visible (23 September 2021) ⁽²¹⁾ *; 361 adults and 234 chicks visible 20 September 2022) ⁽²¹⁾ *</p> <p>* Note: <i>In September, chick counts are incomplete as many chicks are still being brooded and are therefore not visible. Some were probably also obscured by adults. In September 2020 and September 2021, the counts of adults were also incomplete as some penguins were hidden behind an ice ridge.</i></p>
<p>References</p>	<p>⁽¹⁾ Ingham S (nd) Unpublished data from Mawson Biology logs collated by Sue Ingham, Australian Antarctic Division</p> <p>⁽²⁾ Moonie P, Hogg J, Budd GN (1972). Population size and breeding success over 14 years in two colonies of the emperor penguin <i>Aptenodytes forsteri</i>. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽³⁾ Pardoe R (1961) Biology log 1961/62 Mawson. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽⁴⁾ Wigg D (1962) ANARE Mawson field report – 8/62: vehicle journey to Taylor Glacier & Fold Island, 3–12 October, 1962. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽⁵⁾ Budd GM (1962) Population studies in rookeries of the emperor penguin <i>Aptenodytes forsteri</i>. Proceedings of the Zoological Society of London 139, 365–388</p> <p>⁽⁶⁾ Cameron AS (1965) Biology log Mawson 1965. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽⁷⁾ Moonie P (1969) Field report – Mawson 1969, Fold Island & Taylor Glacier dog sledge journey, June 1969. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽⁸⁾ Watson KD (1970) Foldoya snow cruiser trip – June 1970. Unpublished report, Antarctic Division</p> <p>⁽⁹⁾ Foster AL (1970) Report on dog trip from Mawson to Foldoya penguin rookery and return, August 1970. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁰⁾ Moonie P (1971) Field report Fold Island emperor penguin rookery, June 1971. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹¹⁾ Moonie P (1971) Field report Fold/Taylor emperor penguin rookery, September 1971. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹²⁾ Moonie P (1975) Field report Fold Island emperor penguin rookery, July 1975. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹³⁾ Moonie P (1975) Field report Taylor – Fold – Kloa Point emperor penguin rookeries, spring 1975. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁴⁾ Larsen LS (1976) Fieldtrip to Kloa Point and Fold, spring 1976. Unpublished report.</p> <p>⁽¹⁵⁾ Nash R (1977) Field report Taylor – Fold – Kloa Point emperor penguin rookeries, winter 1977. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁶⁾ Nash R (1977) Field report Taylor – Fold – Kloa Point emperor penguin rookeries, spring 1977. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁷⁾ Butler P (1981) Field journey to Taylor Glacier, Fold Island and Kloa Point, 23rd September – 12th October, 1981. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁸⁾ Werner O (1982) Kloa Point fieldtrip 16/9 to 13/10 – Williams 1982. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁹⁾ Sheridan K (?) (1984) Fold Island trip, 29/9/84 to 6/10/84. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽²⁰⁾ Pottage D (1985) Field trip report 8/85. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽²¹⁾ This study</p>

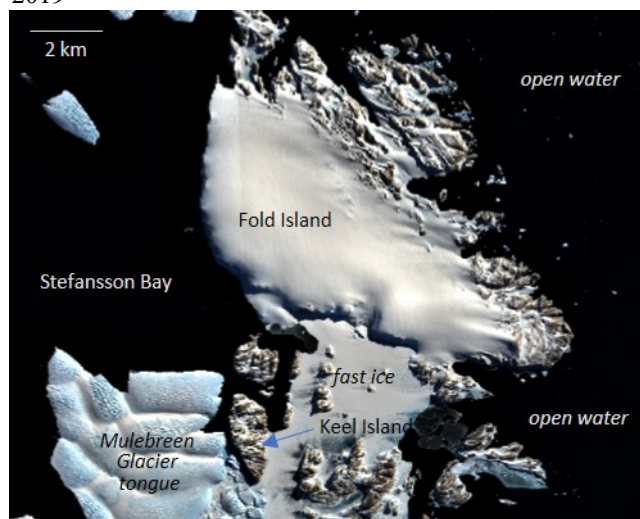
⁽²²⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. *PLoS ONE* 7, e33751

Images

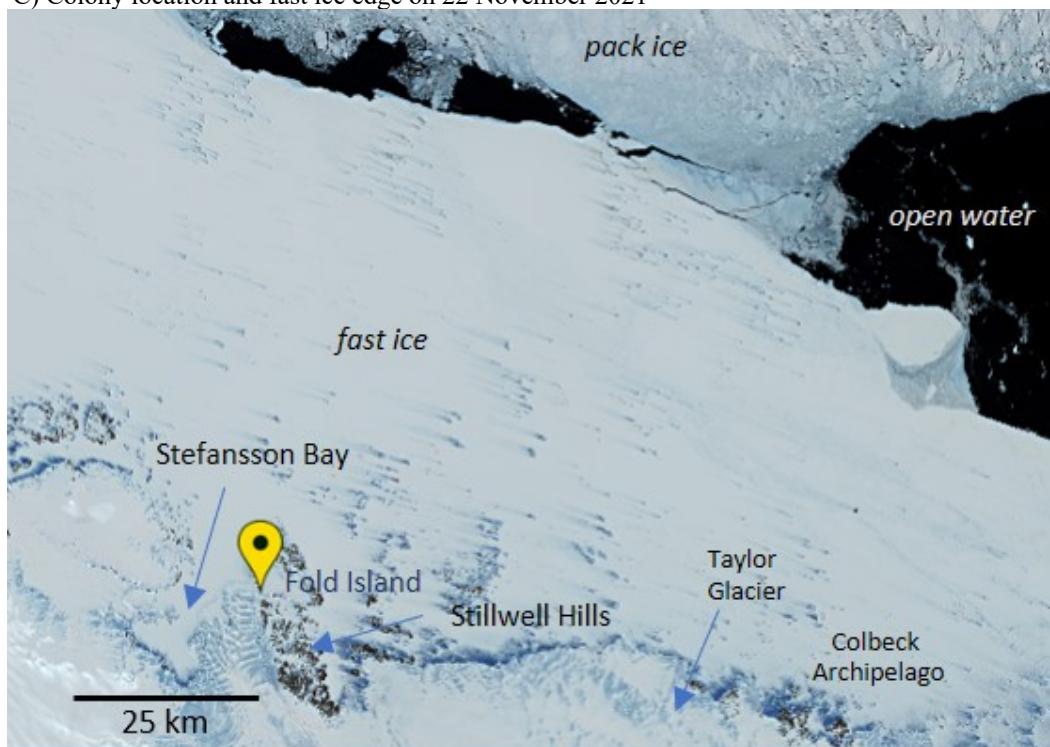
A) Colony location on 13 October 2021



B) Remaining fast ice east of the colony area, 18 March 2019



C) Colony location and fast ice edge on 22 November 2021



Colony	6. Taylor Glacier (ASPA 101, IBA 119)
Region	Mawson Coast, Mac.Robertson Land (60°E–73°E), East Antarctica
Recent location	67.45°S, 60.88°E
Date	20 October 2023
Interannual movement	0 km
Size	<3,000 pairs ⁽¹⁾
Colony description	The entire colony occupies a rocky outcrop east of Taylor Glacier (67.45°S, 60.85°E). The flat central area is ~200 m long and ~60 m wide. In the northern part is a low rocky rise while to the east and south the hills are quite steep. In the west is the sheer ice cliff of the glacier, about 30 m high. A small melt lake occurs at approximately 67.45°S, 60.88°E.
Fast ice extent	The fast ice stretches along approximately 520 km of coastline from Flåodden (~66.24°S, 56.01°E), a cape in Enderby Land, in the west to the Cape Darnley Polynya in the east (~68.25°E), and covers an area of >31,000 km ² . In October, its width varies locally from 50–90 km. The widest stretch occurs in the Mawson area generally to ~62.6°E. Compared to the western end of this stretch of fast ice, the eastern extent is quite variable. In October 2009, it reached 68.9°E, and in October 2010 and 2014, the ice connected to the “ice tongue” of Cape Darnley, but retracted to 67.8°E and 65.6°E in November 2010 and 2014, respectively. In November, the fast ice often reaches into Shallow Bay (67.4°E), ~20 km east of Murray Monolith (67.78°S, 66.89°E).
Ice break out/formation	Locally, open water tends to exist in March and the fast ice reforms in April. The coast can be ice free in mid-February. Extensive fast ice occurred along coast in the summers of 2020 (to 61.6°E) and 2021 (to 65.5°E).
Maximal distance to fast ice edge	70.0 km (12 October 2020)
Minimal distance to fast ice edge	1.4 km (29 December 2032)
Average distance to fast ice edge	54.8 ± 15.1 km
Early fast ice breakout	Not applicable as colony is land-based.
Distance from coast	0 km
History	<p>This colony is one of the best known and most studied colonies in East Antarctica. R. Dovers and G. Schwartz discovered it on 21 October 1954 on a sledging trip ⁽²⁾. The men followed a stream of penguins marching towards the continent, and reported a land-based colony on the eastern side of “Brettangen Glacier” (named by Douglas Mawson in 1931; now Taylor Glacier). The colony was located in a snow-filled depression, sheltered from the wind but exposed to the sun. The two men estimated 2,200 chicks, and found 103 dead chicks and 20 abandoned eggs ⁽³⁾.</p> <p>On 25 September 1955, 1,800 chicks were estimated in the colony, but the count method was not recorded ⁽⁴⁾.</p> <p>Three counts (early winter, winter and spring) were first undertaken in 1957. On 4 May, 4,500 (± 10%) were estimated. On 12 June, of 2,940 adults present, 89% were estimated to carry an egg. Forty abandoned eggs were also found. On 30 October, ~1,000 adults were thought to be present and 1,870 chicks were counted. In addition, about 400 dead chicks were recorded ⁽⁵⁾. It is unclear whether they had all died in this season.</p> <p>In 1958, the first counts were made on 6 May when 2,000 ± 20% adults were estimated, and again on 13 and 14 May, when 3,000 ± 20% adults were thought to be in the colony ⁽²⁾. There is no information about the count method. On 24 May 1958, apparently 2,700 eggs were incubated ⁽²⁾. There is no information on how the count method. Two weeks later, on 6 July, evidently 2,400 adults were counted of whom 92% were incubating. Again, no details of the methods employed were recorded ⁽²⁾. Although not impossible, it seems to be highly</p>

History	<p>unlikely that 500 eggs (~20%) should have been lost in two weeks in a colony as sheltered as Taylor Glacier. These numbers may simply reflect the absence of the female birds in June or differences among observers.</p> <p>On 11 June 1959, the highest number of adults ($n = 4,180$) was recorded at Taylor Glacier. Since the count method employed was the “droving” method (see ⁽⁴⁾), it was probably a very accurate count. Note though that this invasive method led to egg abandonment and, hence, is no longer applied. The presence of only some 1,200 chicks on 20 October ⁽⁴⁾ indicates that this was a poor breeding year for the penguins.</p> <p>On 29 May 1960, an estimated 4,080 adults attended the colony, of which 3,220 had an egg ⁽⁴⁾. Given the time of year, females were probably still present. On 27 July, 3,390 adults were counted, 3,160 with egg ⁽⁴⁾. Again, it appeared to have been a year with low breeding success; on 4 October, some 1,070 adults were counted but only 840 chicks ⁽⁴⁾. In October, generally the chicks should outnumber adults in the colony.</p> <p>For reasons unknown, the winter counts in 1961 and 1962 were deemed to be dissatisfactory ⁽⁶⁾. The earliest count in 1961 occurred on 24 August and averaged 2,500 adults (lowest estimate = 1,700, highest estimate = 3,000) ⁽⁷⁾. Some 15 counts were carried out of smaller groups to determine the number of penguins with chicks. On average, 88% of adults had chicks (median 7% without offspring). Adults constantly moved to and from the colony all day ⁽⁷⁾. Thus, the females had returned and the parent birds had started to take turns brooding their chick.</p> <p>In 1962, the spring count took place on 6 October. About 1,160 adults were present and roughly 3,800 chicks were counted. In addition, 48 frozen eggs and 110 dead chicks were recorded. Again, the constant coming and going of adults was noted ⁽⁸⁾.</p> <p>In 1965, the main aim of the trip west appears to have been the resupply of the depot at Taylor Glacier for the next trip to Kloa Point. However, the count of emperors at Taylor Glacier was also to be undertaken. On 8 August, of the estimated 3,500 adults approximately 70% had chicks ⁽⁹⁾. On 5 September, ~3,600 adults were estimated in the colony ⁽¹⁰⁾.</p> <p>The colony was visited by helicopter on 21 February 1967 to ascertain whether the penguins were still there in summer. Only four penguins were present. No further information was provided. The birds seen were probably adults that moulted there ⁽¹¹⁾.</p> <p>In 1968, only the spring count was carried out. On 25 September, the estimate was ~3,000 adults and 4,950 chicks ⁽¹²⁾. Both estimates appear to be very much on the high side. Only one person counted and did not repeat the count.</p> <p>The following year, only the winter count took place. On 12 June 1969, two people counted the colony twice each; the counts averaged $3,554 \pm 206$ adults (lowest count = 3,337, highest count = 3,758). Five percent of adults present were estimated to be without egg ⁽¹³⁾.</p> <p>In 1970, Taylor Glacier was visited in winter by snow cruiser after a visit to Fold Island. On 9 June, a very rough estimate gave 3,000 adults of whom 75% had eggs. Apparently, technical difficulties with the radio equipment required an urgent return to station and did not allow time for a detailed ground count ⁽¹⁴⁾.</p> <p>On 9 June 1971, the colony had separated into two distinct groups. Thus, the penguins were counted in two parts. A triple count gave an average of 3,643 adults (lowest count = 3,573, highest count = 3,705) ⁽¹⁵⁾.</p> <p>Chicks were counted sometime in September 1971; the average of three counts was 2,179 chicks. The field report from 1971 indicated that during the winter count about 9% of birds did not have eggs ⁽¹⁶⁾. If that were the case, about 66% of chicks were still alive in spring.</p> <p>In 1972, Taylor Glacier was visited only once on 18 July. Again, only a “rough estimate” was made ($n = \sim 3,500$ adults), the majority of adults carried eggs and some had chicks ⁽¹⁷⁾.</p> <p>In the following year, adults were counted on 3 July 1973. Of the 3,866 adults present 116 did not carry an egg ⁽¹⁸⁾. Apparently, 2,584 chicks were found on 10 October 1973, but the original reference could not be retrieved.</p> <p>There were two visits in 1974. In mid-June, the total number of adults present was 4,451 (average of two counts: 4,469 and 4,433) ⁽¹⁹⁾. On 16 September 1974, $3,408 \pm 250$ chicks</p>
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History	<p>were reported. Only one person counted but it is unclear how many counts were made ⁽²⁰⁾. The winter count in 1975, on 5 June, included only penguins with eggs. Three counts gave an average of 3,963 adults (lowest count = 3,795, highest count = 4,153) ⁽²¹⁾. The chicks were counted on 5 October. With 2,794 chicks surviving ⁽²²⁾, the penguins probably had a successful season.</p> <p>On 27 May 1976, the colony was visited and panoramic images were taken. It is unknown what happened to these images. The report indicated that running the dogs and testing the gear were the main purposes of this trip ⁽²³⁾. It seems that the penguins were not counted on the ground. In September 1976, the dogs were taken for a run to Kloa Point, but the party did not stop at Taylor (or Fold) for any census work ⁽²⁴⁾.</p> <p>The following year, two counts were achieved. On 30 May 1977, the colony was photographed, but again the fate of the images is unknown. Only a general estimate of ~4,000 birds was reported ⁽²⁵⁾. For the chick count on 20 September 1977, the chicks were divided into four groups; each group was counted four times and the results averaged ($n = 1,745 \pm 136$ chicks, range 1017–2320). Again, the colony was photographed, but the images could not be retrieved ⁽²⁶⁾.</p> <p>On 22 August 1978, a very rough estimate of adults gave $2,000 \pm 20\%$ ⁽²⁷⁾.</p> <p>A year later, on 10 August 1979, ~3,500 adults were estimated, the majority of which appeared to have chicks ⁽²⁸⁾.</p> <p>Similarly, on 10 August 1980, an estimated 3,450 adults were present; 50% were thought to have eggs and another 30% seem to have chicks. There is no detail on the method of estimating numbers ⁽²⁹⁾. The report also mentions that < 200 eggs and < 100 dead chicks were sighted ⁽²⁹⁾.</p> <p>The only information found for 1981 was a report of a trip west that included a visit to Taylor Glacier in late September/early October. The four men in the field party counted only chicks but did so several times. Precise details are not available, but they noted “quite marked differences in counts”. Since the penguins were spread out in a long line, they were relatively easy to count. The average came to 3,149 chicks (lowest count = 2,687, highest count = 3,600) ⁽³⁰⁾.</p> <p>We could not find any evidence for a winter count in 1982. In spring, a field trip was undertaken to Kloa Point during which Taylor Glacier was also visited. On 20 September, some 1,800 adults and 2,100 chicks were counted. These numbers were derived by averaging counts by the four team members. Details of the counts were not provided. However, the report noted that >100 dead chicks and many more eggs were found ⁽³¹⁾.</p> <p>The details are sketchy about the visit on 3 August 1983. Only parts of the trip report could be retrieved. The major aim of this trip was checking and replenishing of depots along the dog route. The penguin census is mentioned but the only statement is that “2,000 penguins were agreed upon” ⁽³²⁾.</p> <p>In August 1984, apparently two parties visited the colony again. The report about the first trip (31 July–3 August 1984) mentioned that black and white photographs were taken of the whole colony to allow an accurate count. However, the fate of the images is unknown. It is also uncertain that a count was made ⁽³³⁾. A second trip was made shortly after (7–12 August 1984). The report indicated that about 2,000 adults were estimated to be present of whom approximately 80% had small chicks ⁽³⁴⁾.</p> <p>In 1985, only a spring census was conducted on 5 October. The number of adults averaged 1,177 (lowest count = 1,050, highest count = 1,400) ⁽³⁵⁾. Chicks were not counted; about 80% of adults were thought to have chicks. Around 200 dead chicks and about 20 eggs were noted ⁽³⁵⁾.</p> <p>The date of the spring count was not recorded in 1986; the report indicates it occurred sometime in September/October. Four men counted both adults and chicks and averaged the results: 1,360 adults (lowest count = 1,230, highest count = 1,550), 1,022 chicks (lowest count = 910, highest count = 1,100). These numbers are based on the data of the individual counts; they differ from the averages provided in the report (adults = 1,500, chicks = 1,150) ⁽³⁶⁾. As in previous year, black and white photographs were taken, but they could not be</p>
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<p>History</p>	<p>retrieved nor was it possible to find any indication that counts were made based on the images.</p> <p>On 27 July 1987, it was estimated that the colony comprised about 4,500 adults. The author of the report noted that the estimate appeared to be “a bit high”, and also mentioned that “more birds were heading out across the ice today”⁽³⁷⁾.</p> <p>From 1988 onwards, each year two counts were conducted at Taylor Glacier, fast ice conditions permitting. The winter count was made as soon as possible after midwinter (21 June) to estimate the number of males attending the colony. A second count was made as late as possible in the chick-rearing season to estimate the number of surviving chicks, providing some indication of breeding success for the season. Photographic images were the basis for the counts. The advantage is that they tend to be more accurate than ground counts, especially when penguins are moving around. Photographs also provide archival records that can be rechecked. The count details and trends until 2010 were published in⁽³⁸⁾.</p> <p>For comparative purposes, the spring count from 2009 is mentioned. Some 937 adults attended to colony on 28 October; some 1,443 chicks were also counted. However, the penguins were relatively densely grouped and a number of chicks were assumed to have been shielded by their parents. On 1 December 2009, some 1,971 chicks were counted indicating that about one quarter of chicks had indeed been hidden in the colony.</p> <p>Incidentally, on 21 October 2009, a satellite image captured the colony, and the count indicated the presence of 519 adults. The image quality was described as “fair”⁽³⁹⁾. The image was not entirely clean (thin cloud?), but given that about 45% more adults were present than indicated by the satellite image, emperor penguins on rocks may be more difficult to count than on ice.</p> <p>In the past, the fast ice edge tended to be ~20–60 km from the colony around the time when chicks started to leave the colony. In December 2023, the fast ice extent diminished rapidly (~20 km in 10 days) bringing the fast ice edge to within <1.5 km of the colony. This shortened markedly the distance fledglings had to travel on their way to the ocean.</p>
<p>Population estimates/counts</p>	<p>Note: <i>Bold numbers indicated reliable, systematic counts</i></p> <p>2,200 chicks (21 October 1954)⁽³⁾; 1,800 chicks (25 September 1955)⁽⁴⁾; 4,500 ± 20% adults (4 May 1957)⁽⁵⁾; 2,940 adults (12 June 1957)⁽⁵⁾; ~1,000 adults and 1,870 chicks (30 October 1957)⁽⁴⁾; 3,000 ± 20% adults (13 and 14 May 1958)⁽⁴⁾; 2,400 adults (6 July 1958)⁽⁴⁾; 4,180 adults (11 June 1959)⁽⁴⁾; 1,220 adults and 1,200 chicks (20 October 1959)⁽⁴⁾; 4,080 adults* (29 May 1960)⁽⁴⁾; 3,390 adults (27 July 1960)⁽⁴⁾; 1,070 adults and 840 chicks (4 October 1960)⁽⁴⁾; 2,500 adults (25 August 1961)⁽⁷⁾; 1,500 chicks (9 October 1961)⁽⁷⁾; 3,294 adults (20 June 1962)⁽⁸⁾; 1,160 ± 100 adults and 3,800 ± 200 chicks (6 October 1962)⁽⁸⁾; 3,500 adults (8 August 1965)⁽⁹⁾; 3,600 adults (5 September 1965)⁽⁹⁾; ~3,000 adults and 4,950 chicks (25 September 1968)⁽¹²⁾; 3,554 adults (12 June 1969)⁽¹³⁾; ~3000 adults (9 June 1970)⁽¹⁴⁾; 3,643 adults (9 June 1971)⁽¹⁵⁾; 2,179 chicks (29 September 1971)⁽¹⁶⁾; ~3,500 adults (17 July 1972)⁽¹⁷⁾; 3,866 adults (3 July 1973)⁽¹⁸⁾; 4,451 adults (7 June 1974)⁽¹⁹⁾; 3,408 chicks (16 September 1974)⁽²⁰⁾;</p>

<p>Population estimates/counts</p>	<p>3,963 adults (5 June 1975)⁽²¹⁾; 2,794 chicks (5 October 1975)⁽²²⁾; ~4,000 adults (30 May 1977)⁽²⁵⁾; 1,746 chicks (20 September 1977)⁽²⁶⁾; ~2,000 ± 20% adults (22 August 1978)⁽²⁷⁾; ~3,500 adults (10 August 1979)⁽²⁸⁾; 3,450 adults (10 August 1980)⁽²⁹⁾; 3,149 chicks (late September/early October 1981)⁽³⁰⁾; 1,800 adults and 2,100 chicks (20 September 1982)⁽³¹⁾; ~2,000 adults (? August 1984)⁽³⁴⁾; 1,177 adults (5 October 1985)⁽³⁵⁾; 1,360 adults and 1,022 chicks (ground count, 28 September 1986)⁽³⁶⁾; ~4,500 adults (27 July 1987)⁽³⁷⁾; 3,215 adults (13 July 1988)⁽¹⁾; 2,460 adults (June 1994)⁽³⁸⁾; a annual photographic counts (winter and spring) 1988–2010 summarised in⁽³⁹⁾; 519 adults (21 October 2009)⁽⁴⁰⁾; 2,698 adults (26 June 2022)⁽⁴¹⁾</p>
<p>References</p>	<p>⁽¹⁾ Robertson G (1992) Population-size and breeding success of emperor penguins <i>Aptenodytes forsteri</i> at Auster and Taylor Glacier colonies, Mawson Coast, Antarctica. <i>The Emu</i> 92, 65–71</p> <p>⁽²⁾ Ingham S (nd) Unpublished data from Mawson Biology logs collated by Sue Ingham, Australian Antarctic Division, Melbourne</p> <p>⁽³⁾ Dovers R (1954) Trip report. Western coastal journey. Unpublished report, Australian Antarctic Division, Melbourne</p> <p>⁽⁴⁾ Budd G (1962) Population studies in rookeries of the emperor penguin <i>Aptenodytes forsteri</i>. <i>Proceedings of the Zoological Society of London</i> 139, 365–388</p> <p>⁽⁵⁾ Willing RL (1958) Biological research in emperor penguin rookeries, Mawson 1957. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽⁶⁾ Moonie P, Hogg J, Budd GN (1972). Population size and breeding success over 14 years in two colonies of the emperor penguin <i>Aptenodytes forsteri</i>. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽⁷⁾ Pardoe R (1961) Biology log 1961/62 Mawson. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽⁸⁾ Wigg D (1962) ANARE Mawson field report – 8/62: vehicle journey to Taylor Glacier & Fold Island, 3–12 October 1962. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽⁹⁾ Cameron AS (1965) Field trip Nr 7. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁰⁾ Cameron AS (1965) Biology log Mawson 1965. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹¹⁾ Erskine J (1967) Field trip to Taylor rookery by helicopter, 21 February 1967. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽¹²⁾ McKenzie D (1968) Taylor rookery trip 19th – 17th September 1968. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽¹³⁾ Moonie P (1969) Field report – Mawson 1969, Fold Island & Taylor Glacier dog sledge journey, June 1969. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁴⁾ Watson KD (1970) Foldoya snow cruiser trip – June 1970. Unpublished report</p> <p>⁽¹⁵⁾ Moonie P (1971) Field report Fold Island emperor penguin rookery, June 1971. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁶⁾ Moonie P (1971) Field report Fold/Taylor emperor penguin rookery, September 1971.</p>

References	<p>Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁷⁾ Parker D (1972) Field trip to Taylor rookery, 14th – 21st July. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽¹⁸⁾ Moonie P (1973) Field report Fold/Taylor emperor penguin rookery, July 1973. Unpublished report, Antarctic Division, Department of Supply, Melbourne</p> <p>⁽¹⁹⁾ Luders D (1974) Field report. Snow cruiser trip to Taylor rookery, 4th – 19th June 1974. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽²⁰⁾ Luders D (1974) Field report. Dog trip to Taylor rookery, 12th – 19 September 1974. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽²¹⁾ Moonie P (1975) Field report Taylor Glacier June 1975. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽²²⁾ Moonie P (1975) Field report Kloa Point – Fold – Taylor emperor penguin rookeries, spring 1975. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽²³⁾ Larsen L (1976) Field trip report Taylor 1976. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽²⁴⁾ Larsen L (1976) Field trip to Kloa Point and Fold, spring 1976. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽²⁵⁾ Nash R (1977) Field Report Taylor – Fold emperor penguin rookeries, winter 1977. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽⁶⁴⁾ Nash R (1977) Field Report Taylor – Fold – Kloa Point emperor penguin rookeries, spring 1977. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽²⁷⁾ Randall J (1978) Taylor Fold dog trip log. Field trip 7/78. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽²⁸⁾ Higgins SJ (1979) Field report on trip to Taylor rookery. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽²⁹⁾ McIntosh C (1980) Taylor rookery 7-08-80 to 14-08-90. Unpublished report, Antarctic Division, Melbourne</p> <p>⁽³⁰⁾ Butler P (1981) Field journey to Taylor Glacier, Fold Island and Kloa Point, 23rd September – 12th October 1981. Unpublished report, Antarctic Division, Hobart</p> <p>⁽³¹⁾ Pottage D (1982) Kloa Point fieldtrip 16/9 to 13/10 – 1982. Unpublished report, Antarctic Division, Hobart</p> <p>⁽³²⁾ Anon (1983) Taylor trip July/August 1983. Unpublished report, Antarctic Division.</p> <p>⁽³³⁾ Anon (1984) Report on field trip to Taylor hug, 31/7/84 to 3/8/84. Unpublished report, Antarctic Division, Hobart</p> <p>⁽³⁴⁾ Mitchell R (1984) Filed trip report 1984, Taylor Glacier – Cape Bruce 7th to 12th August. Unpublished report, Antarctic Division, Hobart</p> <p>⁽³⁵⁾ Pottage D (1985) Emperor penguin census (Fold Island, Kloa Point and Taylor rookeries). Unpublished report, Antarctic Division, Hobart</p> <p>⁽³⁶⁾ Dietrich M (1986) Field trip report Taylor rookery spring count, September/October 1986. Unpublished report, Antarctic Division, Hobart</p> <p>⁽³⁷⁾ Upton T (1987) Field trip report [July/August 1987]. Unpublished report, Antarctic Division, Hobart</p> <p>⁽³⁸⁾ Kirkwood R, Robertson G (1997) The foraging ecology of female emperor penguins in winter. <i>Ecological Monographs</i> 67, 155–176</p> <p>⁽³⁹⁾ Robertson G, Wienecke B, Emmerson L, Fraser AD (2014) Long-term trends in the population size and breeding success of emperor penguins at the Taylor Glacier colony,</p>
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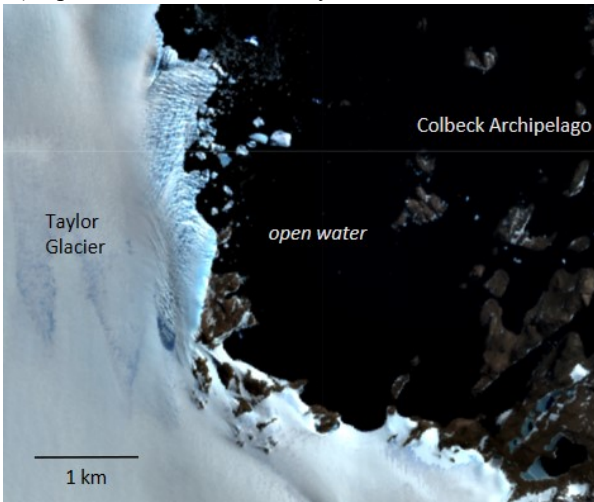
Antarctica. *Polar Biology* 37, 251–259

⁽⁴⁰⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. *PLoS ONE* 7, e33751

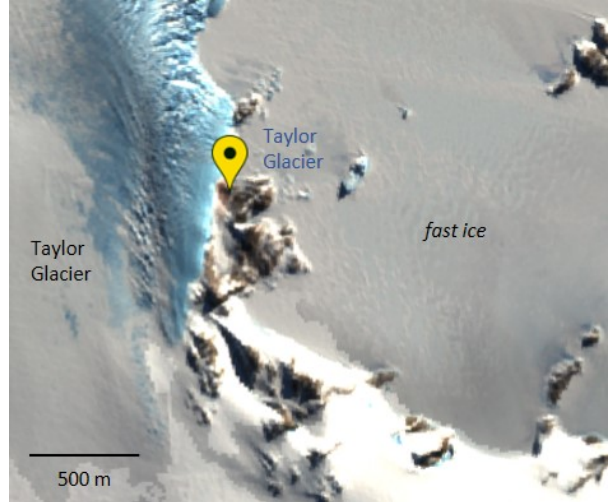
⁽⁴¹⁾ This study

Images

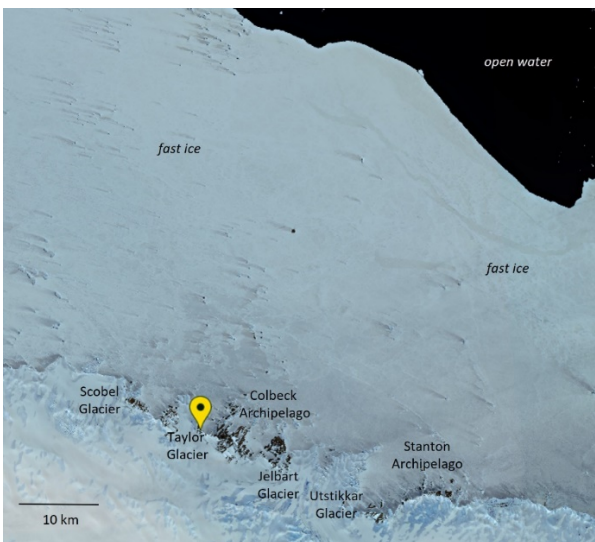
A) Open water on 26 February 2019



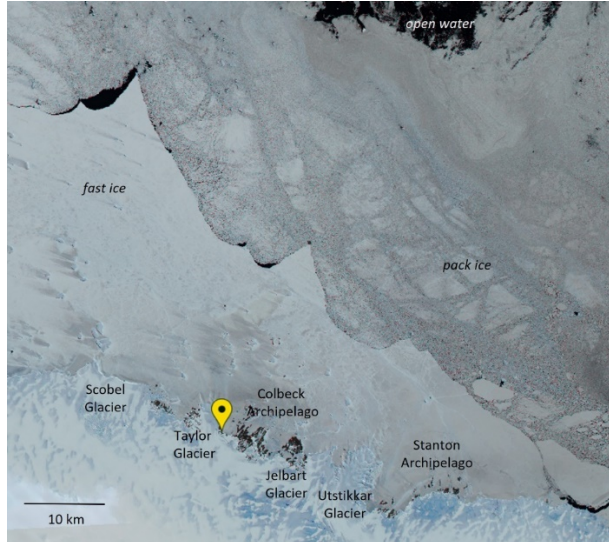
B) Colony location on 14 September 2019



C) Colony location and fast ice edge on 29 December 2019



D) Colony location and fast ice edge on 9 December 2023

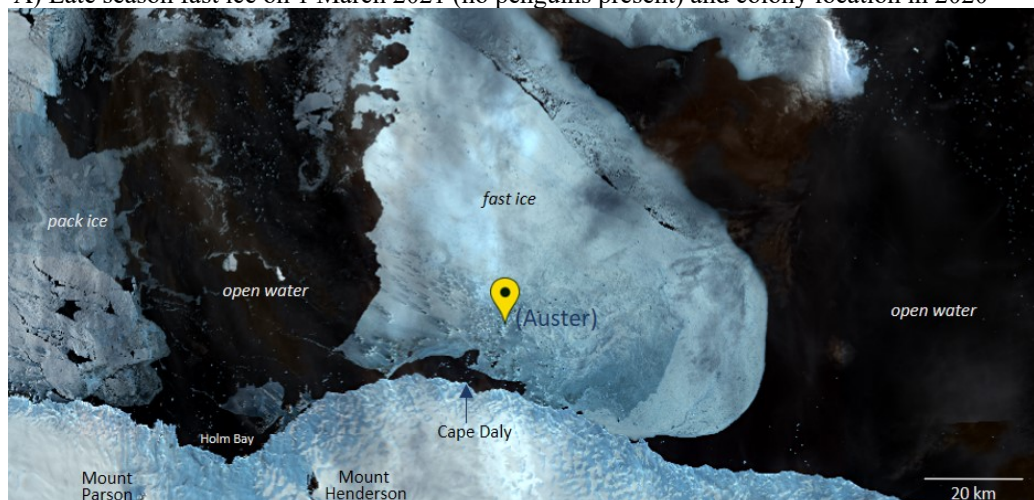


Colony	7. Auster (IBA 125)
Region	Mawson Coast, Mac.Robertson Land (60°E–73°E), East Antarctica
Recent location	67.40°S, 63.98°E
Date	19 November 2023
Interannual movement	0–5 km
Size	~11,000 breeding pairs ⁽¹⁾
Colony description	The Auster colony is located on the fast ice among a concentration of icebergs (“Iceberg Ally”), 12–13 km from coast. The colony used to form on the vast ice plain east of the icebergs. However, since 2018, it has moved into the space among grounded icebergs. When the fast ice breaks out in summer, the bergs may drift apart and rearrange themselves before the fast ice reforms. The breeding location of a season may thus no longer exist in the following year, and the penguins relocate slightly. They tend to occupy the eastern, windward side of the bergs.
Fast ice extent	The fast ice stretches along ~520 km of coastline from Flåodden (~66.24°S, 56.01°E), a cape in Enderby Land, in the west to the Cape Darnley Polynya in the east (~68.25°E), and covers an area of >31,000 km ² . In October, its width varies locally from 50–90 km. The widest stretch occurs in the Mawson area generally to ~62.6°E. Compared to the western end of this stretch of fast ice, the eastern extent is quite variable. In October 2009, it reached 68.9°E, and in October 2010 and 2014, the fast ice connected to the “ice tongue” of Cape Darnley, but retracted to 67.8°E and 65.6°E in November 2010 and 2014, respectively. In November, the fast ice often reaches into Shallow Bay (67.4°E), ~20 km east of Murray Monolith (67.78°S, 66.89°E).
Ice break out/formation	The fast ice, or sections thereof, can persist over summer to form multi-year ice (e.g. 2020, 2021) (Image A). It may break out nearly completely in March (e.g. 2019), starts to reform in April and tends to be fully formed in May.
Maximal distance to fast ice edge	68.7 km (8 October 2019) (Image B)
Minimal distance to fast ice edge	0 km (29 December 2023)
Average distance to fast ice edge	46.4 ± 8.7 km
Early fast ice breakout	None observed
Distance from coast	~13 km
History	<p>The colony was discovered during a flight along the Mawson Coast in August 1956 at 67.42°S, 64.00°E ⁽²⁾. The colony was ~12 km north of the coast, and ~5 km east of the Auster Islands (67.7°S, 63.38°E) in an area with clusters of grounded icebergs. In the late 1950s, population estimates were only rough approximations. Ground counts, especially in large colonies, are notoriously problematic, because of the movement of the penguins and the difficulty to separate individuals, especially in huddles. In addition, various methods with different levels of errors and accuracy were applied to estimate the penguin numbers. Available figures are thus difficult to interpret.</p> <p>In 1959, ground estimates (~18,000 birds) far exceeded the estimates based on images taken from an aircraft (10,000 ± 5% on 23 July) ⁽³⁾. Also in 1959, a second group of penguins (~1,900 birds) was found several kilometres south-west of the main group; but this group was not present in 1960 ⁽³⁾. In later years, a group different to the main colony was also occasionally observed. These groups often separate from the main colony by an iceberg and can be >1 km away (Image C).</p> <p>In 1959 and 1960, personnel from Mawson station visited the colony and set its location at 67.38°S, 64.03°E ⁽²⁾. In 1993, it was located at 67.38°S, 64.07°E ⁽³⁾, ~1 km from the position in the late 1950s. The colony is visited regularly recreationally by station personnel. Recorded colony positions indicate that the colony moved maximally 4 km in consecutive years. Among the grounded icebergs, the fast ice tends to be stable although the surface can be rough (rafted ice), particularly early in the season.</p> <p>In 1988, the Auster colony was studied over the winter ⁽¹⁾. From laying until 21 November, 397</p>

History	<p>lost eggs and 2,154 dead chicks were collected, giving a total of 2,551 unsuccessful pairs. On 21 November, 8,412 surviving chicks were counted. Thus, the breeding population at Auster comprised 10,963 pairs in 1988 ⁽¹⁾.</p> <p>In the 1993 and 1994 winters, two satellite tracking studies were conducted to determine foraging areas of females in winter ^{(3),(4)}. In the 1990s, the penguins occupied large, open areas of fast ice usually on the eastern side of the local icebergs. In recent years, they have moved right among some grounded icebergs (Image C). Sub-colonies still occur. For example, in 2018 a group established itself in an open fast ice area ~2.2 km north northwest of the main colony (Image C). It is unknown how much traffic there is between these groups.</p> <p>Auster is the largest colony at the Mawson Coast and has occupied the same general area since it was discovered in 1957 (Image D). From 1957 to 2007, the colony position shifted <5 km southwest, adapting to fast ice conditions and the distribution of local iceberg, and from 2020–2023 <1 km interannually.</p> <p>The expansive fast ice in the region was considered particularly stable ⁽⁵⁾. During the 1990s, the fast ice tended to persist well into March. Since at least 2000, the fast ice season appears to have shortened. In most years, the ice was solid and extensive throughout December, except in 2001 and 2002 when it was greatly reduced by the end of the month. In January, fast ice quality appears to have degenerated. In 2002, 2009, 2010, 2012, 2015, 2016 and 2020, the regional fast ice extent reduced quickly bringing the edge close to the colony. Furthermore, areas of open water appeared in the colony area, possibly indicative of a thinning of the ice. Where guano accumulates over winter, heat is absorbed melting the ice. For most years, high resolution satellite imagery was not available so that effect on the colony cannot be assessed.</p> <p>From early September to 27 November 2023, fast ice conditions appeared to be good at Auster; the nearest fast ice edge was ~47 km east of the colony. On 28 November, the distanced measure only 37 km, and ~27 km on 8 December. From then on, the fast ice disintegrated rapidly along ~120 km of coast. By 29 December, the colony area had broken up near the peak of fledging (Image E). Not all chicks would have perished, but some most likely did not survive this event. Given the marked changes in fast ice conditions at Auster, updated population data are urgently needed.</p>
Population estimates/counts	<p>~11,000 adults (7 August 1957) ⁽³⁾; ~10,500 birds (10 May 1958) ⁽³⁾; ~18,000 birds (6 July 1959) ⁽³⁾; 3,960 adults and 5,220 chicks (10 November 1959) ⁽³⁾; 11,500 adults (1 June 1960) ⁽³⁾; 3,500 adults and 6,500 chicks (3 November 1960) ⁽³⁾; 12,400 adults (13 June 1988) ⁽¹⁾; ~13,300 adults (June 1993) ⁽³⁾; 7,855 adults (25 October 2009) ⁽⁶⁾</p>
References	<p>⁽¹⁾ Robertson G (1992) Population-size and breeding success of emperor penguins <i>Aptenodytes forsteri</i> at Auster and Taylor Glacier colonies, Mawson Coast, Antarctica. <i>The Emu</i> 92, 65–71.</p> <p>⁽¹⁾ Willing RL (1958) Australian discoveries of emperor penguin rookeries in Antarctica during 1954–57. <i>Nature</i> 182, 1393–1394</p> <p>⁽²⁾ Budd G (1962) Population studies in rookeries of the emperor penguin <i>Aptenodytes forsteri</i>. <i>Proceedings of the Zoological Society of London</i> 139, 365–388</p> <p>⁽³⁾ Kirkwood R, Robertson G (1997) The foraging ecology of female emperor penguins in winter. <i>Ecological Monographs</i> 67, 155–176</p> <p>⁽⁴⁾ Wienecke BC, Robertson G (1997) Foraging space of emperor penguins <i>Aptenodytes forsteri</i> in Antarctic shelf waters in winter. <i>Marine Ecology Progress Series</i> 159, 249–263</p> <p>⁽⁵⁾ Robertson G (1992) Population-size and breeding success of emperor penguins <i>Aptenodytes forsteri</i> at Auster and Taylor Glacier colonies, Mawson Coast, Antarctica. <i>The Emu</i> 92, 65–71</p> <p>⁽⁶⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p>

Images

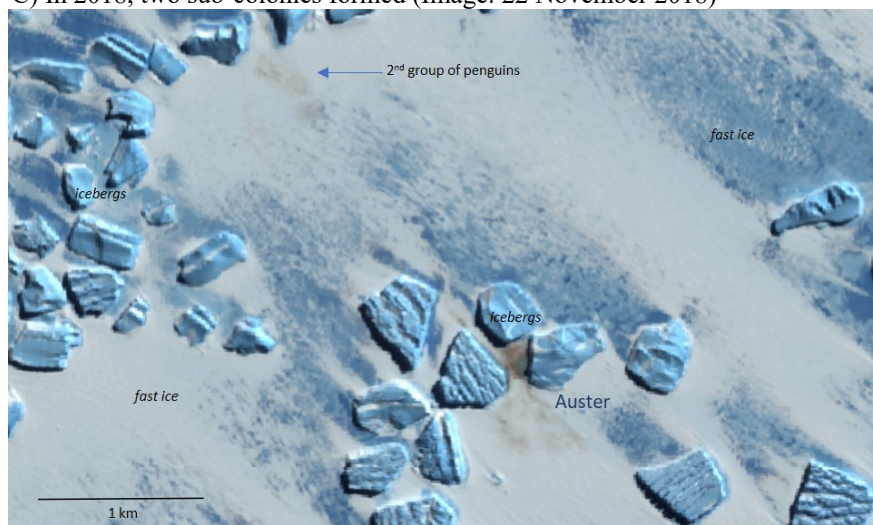
A) Late season fast ice on 1 March 2021 (no penguins present) and colony location in 2020



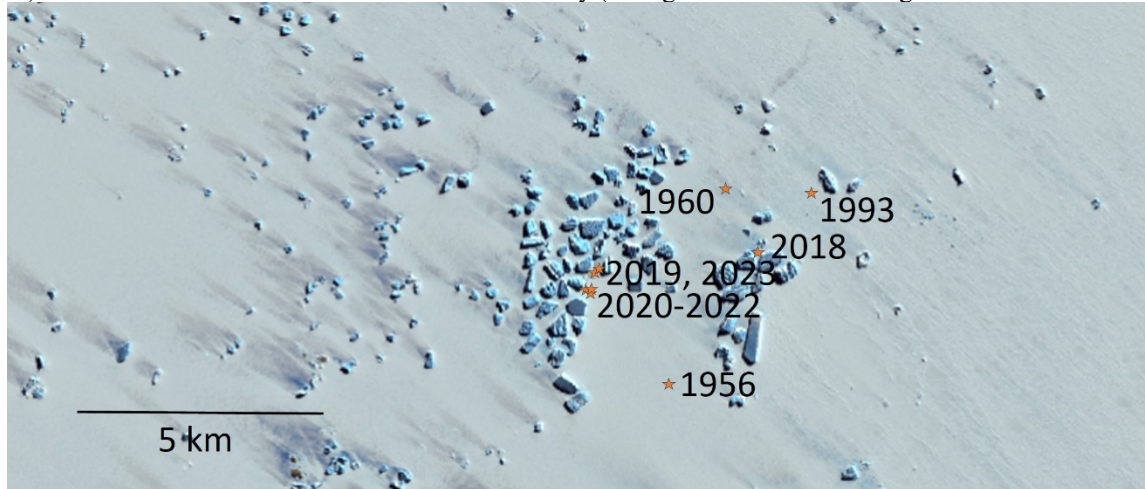
B) Extent of regional fast ice and colony location on 8 October 2019



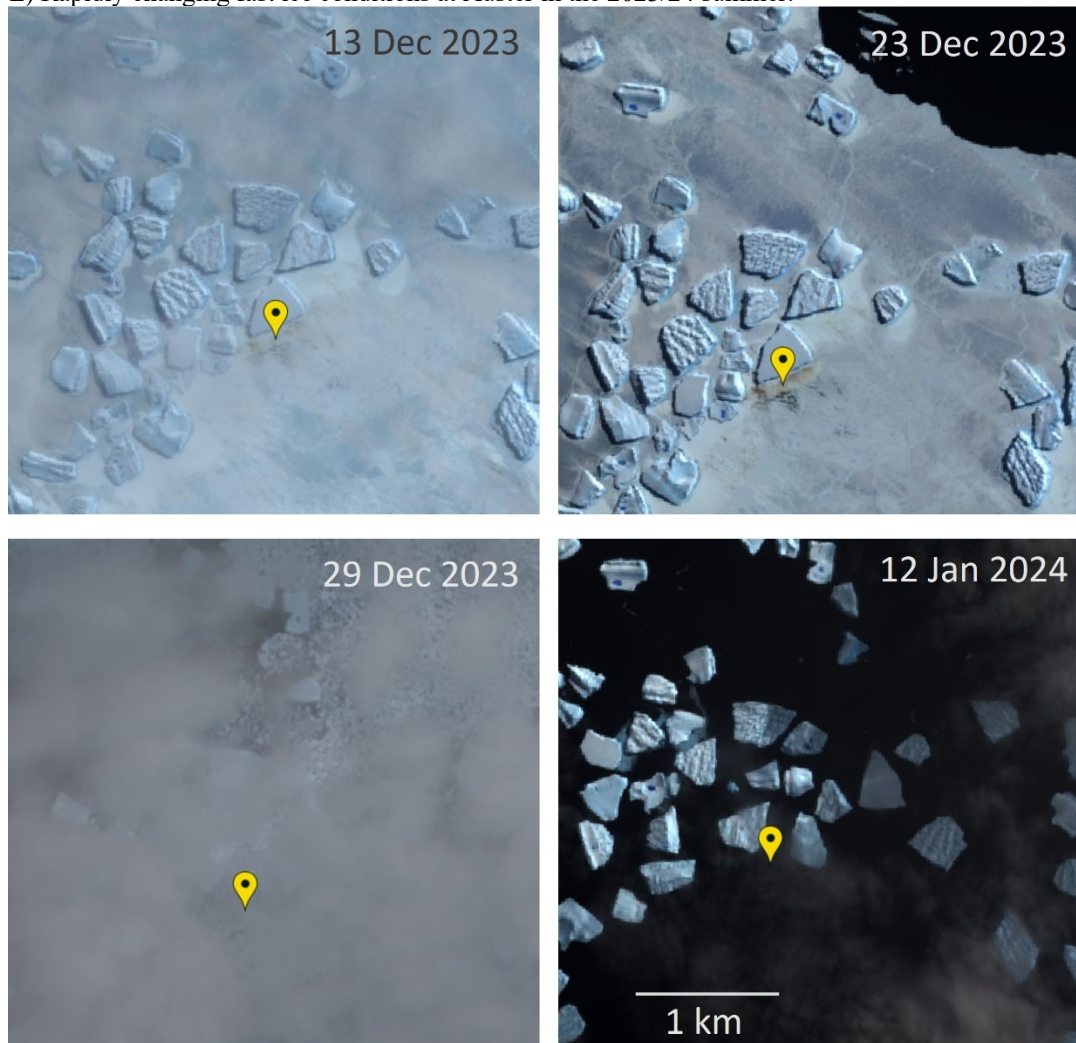
C) In 2018, two sub-colonies formed (Image: 22 November 2018)



D) Previous and current locations of the Auster colony (Background: Sentinel2 image from 8 October 2019)



E) Rapidly changing fast ice conditions at Auster in the 2023/24 summer.

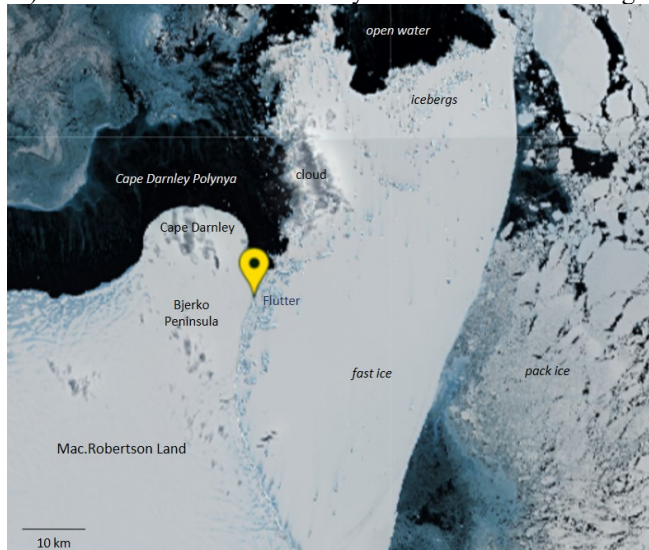


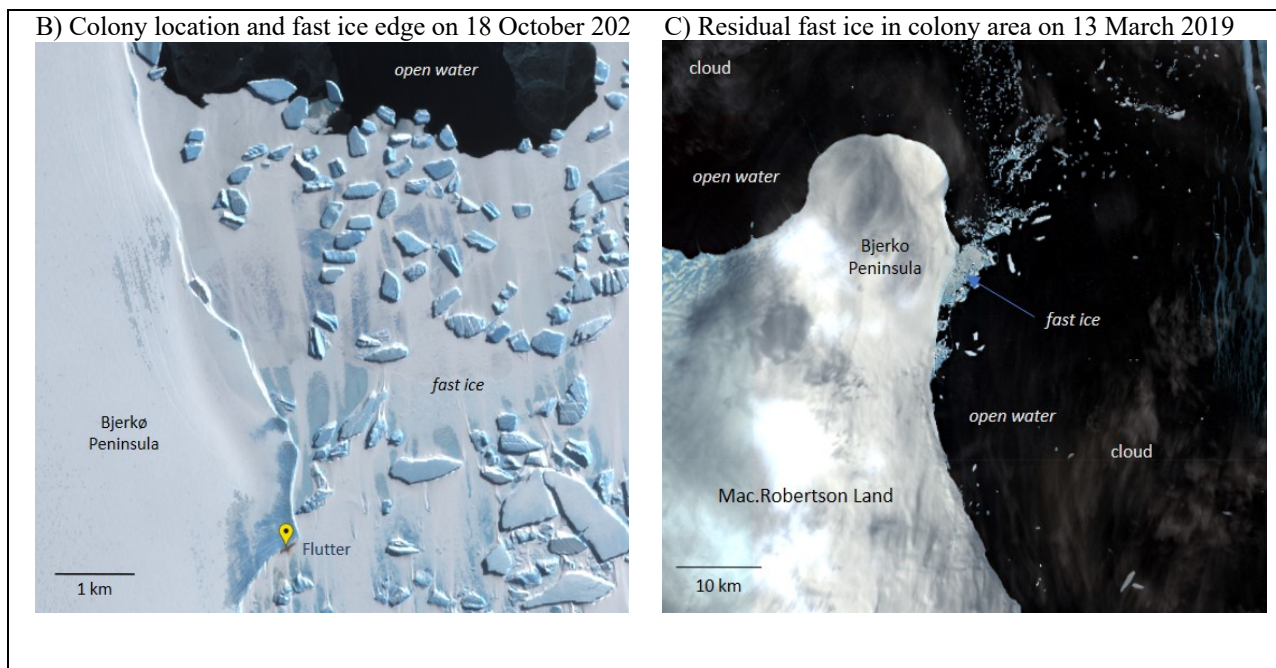
Colony	8. Flutter (Cape Darnley) (IBA 127)
Region	Bjerkø Peninsula, Lars Christensen Coast, Mac.Robertson Land (60°E–73°E), East Antarctica
Recent location	67.88°S, 69.70°E
Date	24 October 2023
Interannual movement	0–2 km
Size	~9,000 breeding pairs ⁽¹⁾
Colony description	The colony is located on the fast ice at the eastern side of Bjerkø Peninsula (67.83°S, 69.50°E) right next to the ice cliff, and at the northern edge of a vast, keel-shaped fast ice area. The ice surface is rather uneven. The penguins have easy access to Cape Darnley Polynya (Image A). The colony location has not moved much over the years. Like other colonies of similar size, it divides into a number of suburbs that moved around a relatively small area. However, the colony location has remained almost the same since its discovery.
Fast ice extent	The fast ice forms a large (~3,790 km ² in 2021), wedge-shaped “tongue” that forms under the influence of currents and katabatic winds. Grounded icebergs at northern side hold the fast ice in place. At times, there is multi-year fast ice (e.g. 2021) when the ice tongue does not break up entirely.
Ice break out/formation	Parts of the fast ice can be multi-year; reforms usually in March/April
Early fast ice breakout	around 2–6 January 2024
Maximal distance to fast ice edge	12.5 km (3 October 2020)
Minimal distance to fast ice edge	3.3 km (13 December 2018)
Average distance to fast ice edge	6.0 ± 2.2 km
Distance from coast	~0.1 km
History	<p>During the British, Australian and New Zealand Antarctic Research Expedition (BANARE) 1929–1931, apparently ~50 moulting emperor penguins had been recorded near Cape Darnley ⁽²⁾. On 3 August 1958, whilst on a flight from Mawson to Davis, Flight Lieutenant H.O. Wilson, RAAF, discovered the colony that was named after M.J. Flutter, Officer-in-Charge at Davis in 1958 ⁽³⁾.</p> <p>Australian expeditioners photographed the colony from the air in October 1956 ⁽³⁾ and on 22 May 1960 ⁽⁴⁾.</p> <p>On 27 November 1960, members of the Fifth Soviet Antarctic Expeditions noted a colony near Cape Darnley at 67.83°S, 69.75°E, and estimated ~10,000 adults to be present ⁽⁵⁾.</p> <p>A tourist vessel visited the colony on 11 December 1992 ⁽⁶⁾. The colony comprised several groups; at least 5,000 individuals were thought to be present, but it is unclear how many of them were adults or chicks. Tourists visited the colony again on 19 December 1996 and it was estimated that ~90% of penguins were chicks, but their numbers were not estimated ⁽⁶⁾.</p> <p>On 1 December 2013, the colony was visited and photographed from the air for the first systematic census ⁽¹⁾. The colony had separated into four distinct suburbs of varying size. The variation in the shading of faecal stains indicated that the penguins had left their wintering area, where the staining was darkest, and had moved to outer areas where fresh snow was freely available. The wintering area was on a gentle slope of solidified snow on the eastern side of an iceberg that, judging by the amount of snow build-up, wind scouring around it and ablation, appeared to have broken off Cape Darnley a long time ago.</p> <p>A penguin highway was clearly visible between two icebergs at the northern side of the colony area; the adults moving in and out of the colony along this route (n = 118) were not included in the count, but the few penguins marching between the groups were because they were still in the colony area. Since no fledglings were sighted on this highway, we assumed that they had not yet started to leave the colony. About half the chicks had started to moult with varying</p>

History	<p>degrees of plumage change. While most chicks had only just commenced shedding their down and had only small patches of black and white feathers on their flippers, others had already lost the down on their lower abdomens, and some were nearly at the end of this process. Some 1,797 adults and 8,619 chicks were present ⁽¹⁾.</p> <p>Eight years later, on 30 November 2021, the colony was again photographed from the air, and counts indicated that 1,768 adults and 8,207 chicks were in the colony ⁽¹⁾. Some chicks appeared to have started to moult, but no fledglings were seen departing the colony.</p> <p>On 3 November 2022, counts from aerial photographs showed that 1,378 adults and 7,707 chicks attended the colony ⁽¹⁾. This count was made nearly 4 weeks earlier than in the previous season. Chicks had definitely not yet commenced their moult. The reduction of about 6% in chick numbers compared to 2021 is within the expected range of variations in breeding success. After several low ice years in recent years, the very low sea ice extent in 2022 ⁽⁷⁾ appeared not to have affected this colony. By the end of January 2023, the fast ice edge was only ~1 km from the colony location, but the area appeared to have been vacated by then.</p> <p>Fast ice conditions were worse in December 2023 than in 2022. By 27 December, the fast ice edge was only ~1km from the colony next to which a large tide crack had formed. By 6 January 2024, the colony area had turned into pack ice. Faecal stains were visible on three small ice floes. Whether chicks were still present is unknown.</p>
Population estimates/counts	<p>~10,000 adults (27 November 1960) ⁽⁵⁾; <2,000 adults and >5,000 chicks (11 December 1992) ⁽⁶⁾; 1,797 adults and 8,619 chicks (1 December 2013) ⁽¹⁾; 1,768 adults and 8,207 chicks (30 November 2021) ⁽¹⁾; 1,378 adults and 7,707 chicks (3 November 2022) ⁽¹⁾</p>
References	<p>⁽¹⁾ This study ⁽²⁾ Falla RA (1937) Birds. Vol II, BANZ Antarctic Research Expedition 1929–1931 Reports – Series B, BANZAR Expedition Committee, Adelaide ⁽³⁾ Budd GM (1961) The biotopes of emperor penguin rookeries. <i>The Emu</i> 61, 171–189 ⁽⁴⁾ Korotkevich YS (1964) The distribution of Emperor penguins. <i>Soviet Antarctic Expedition Information Bulletin</i> 4, 371–375 ⁽⁵⁾ Newton G (1960) Biology log, Mawson 1960. Kingston: Australian Antarctic Division archives (unpublished log), Hobart ⁽⁶⁾ Todd FS, Splettstoesser JF, Ledingham R, Gavrillo M (1999) Observations in some emperor penguin <i>Aptenodytes forsteri</i> colonies in East Antarctica. <i>The Emu</i> 99, 142–145 ⁽⁷⁾ National Snow and Ice Data Centre (7 February 2023) Antarctic sea ice settles on record low extent, again. https://nsidc.org/arcticseaicenews/ (accessed 2 March 2023)</p>

Images

A) Location of the Flutter colony and extent of the iceberg tongue on 18 October 2021





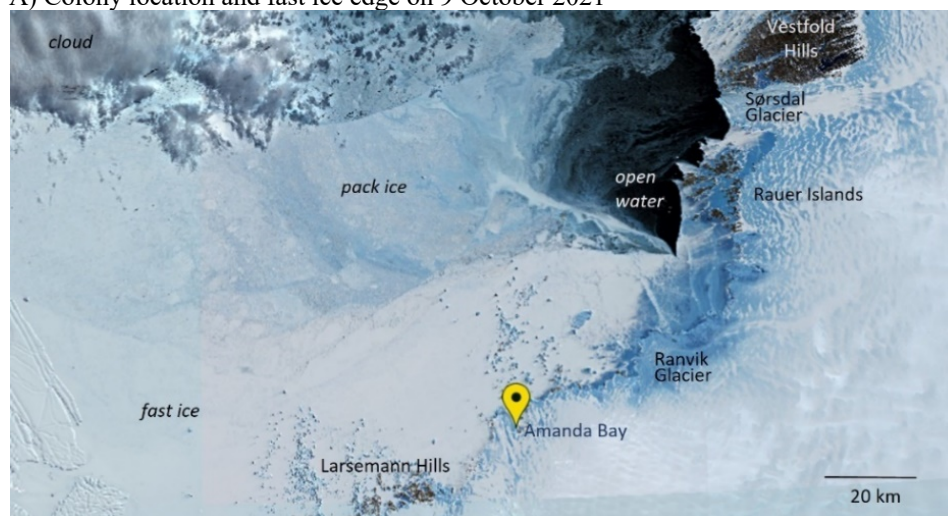
Colony	9. Amanda Bay (ASPA 169, IBA 128)
Region	Ingrid Christensen Coast, Princess Elizabeth Land (72.6°E–81.4°E), East Antarctica
Recent location	69.27°S, 76.83°E
Date	25 November 2023
Interannual movement	<1 km
Size	Up to ~10,000 breeding pairs
Colony description	<p>Amanda Bay is located between the Flatnes Ice Tongue (69.27°S, 76.73°E) in the west and the Hovde Glacier (69.26°S, 76.83°E) in the east. The bay is ~3.4 km wide and 5 km deep, and opens north west into southern Prydz Bay (69°S, 76°E). On the eastern side of the entrance is Hovde Island (69.23°S, 76.95°E; ~0.8 x 0.9 km), a steep, largely ice-free island. In the south western part of the bay is Reel Island (69.27°S, 76.84°E), a small, relatively flat, ice-free island. At the southern side of the bay, three steep continental rock outcrops extend through continental ice cliffs into the bay.</p> <p>In winter, the colony tends to occupy the fast ice between Reel Island and the eastern side of the Flatnes Ice Tongue.</p> <p>The maximal distance from the colony to the edge of the fast ice is remarkably consistent from year to year. On average, it is 32 ± 3 km; fast ice extent ranged from 29 km (2019, 2020) to 38 km (2018).</p> <p>The area was designated an Antarctic Specially Protected Area (ASPA) in 2008 ⁽¹⁾ and an Important Bird Area (IBA) in 2015 ⁽²⁾.</p>
Fast ice extent	In October, the fast ice stretches nearly 500 km from the northern end of the Amery Ice Shelf (69.75°S, 71.00°E) along the coast to the western side of the Sørsdal Glacier (68.70°S, 78.25°E). The width of the fast ice varies; the widest section (~57 km) extends north from the region of the Hargreaves Glacier, west of the Publications Ice Shelf; the narrowest fast ice occurs on western side of the Sørsdal Glacier where it is usually not more than 9 km wide.
Ice break out/formation	From 2010 to 2021, the bay was ice-free usually in the period from 24 January (2010, 2016, 2018) to 8 March (2021). The ice reformed in the bay anytime from 10 March (2012, 2013) to mid-April (2015). The fast ice tends to reform in the southern part of the bay from which it then extends north. By ~23 December 2023, 2/3 of the bay were ice-free and by the end of the year all fast ice had gone.
Early fast ice breakout	None observed that affected colony, but open water occurred in the bay in December 2023
Maximal distance to fast ice edge	39.8 km (8 November 2021)
Minimal distance to fast ice edge	0.6 km (25 December 2023)
Average distance to fast ice edge	27.7 ± 11.9 km
Distance from coast	<1 km
History	<p>Members of the First Soviet Antarctic Expeditions discovered the Amanda Bay colony on a survey flight on 30 November 1956 ⁽³⁾. According to the coordinates provided the penguins were at Amanda Bay, but the landmark provided was “Sturnes Island”, probably the island now known as Hovde Island. The colony was “investigated” on 16 December 1956 by members of the First Soviet Antarctic Expeditions ⁽³⁾; it is unclear whether they landed and whether the population estimate was derived in November and December. Unless the colony suffered substantial losses since the 1950s, it seems unlikely that 5,000 adults were still present in November or December. If the estimate was made in December, it is possible that fledglings were included.</p> <p>On 26 August 1957, an Australian party noted the colony when flying from the Larsemann Hills (69.39°S, 76.14°E) to Davis station (68.58°S, 77.97°E). The Australians, unaware of the Russian discovery, named the colony Amanda Bay. Roughly 3,000–5,000 penguins (both</p>

History	<p>adults and chicks) were estimated to be present in August 1957⁽⁴⁾.</p> <p>Since then, the colony has been visited numerous times at various times of year. The first ground visit occurred on 21 May 1960. A detailed count of the colony was not made; based on a “snap estimate”, 3,500–4,000 adults were thought to be in attendance⁽⁴⁾.</p> <p>We could not find any records of visits to Amanda Bay in the 1970s.</p> <p>In 1981, the colony was visited three times in December (3, 14, 16 December). At least on one occasion, the colony was photographed. A few adults and many chicks occupied the area but no count data are available. The images were not suitable for a count.</p> <p>In 1983, a private expedition visited the area on 29–30 September undertaking the first attempt of a systematic count of the colony⁽⁶⁾. Two observers performed two counts of each group. One issue was that two different counting methods were employed (indirect counts and <i>en masse</i> counts) to count chicks rendering the results unreliable. Adults were counted on two occasions (30 September and 18 October)⁽⁶⁾. The distances between penguins and observers were about 200–500 m. This distance avoids disturbance of the birds, but is too large for an accurate count and may explain, at least in part, the relatively small number of chicks.</p> <p>In 1986⁽⁷⁾, Amanda Bay was visited three times. The purpose was to collect data on the penguins’ diet. No counts were made on these occasions. However, in August 1987, a broad estimate was made of about 9,000 adults (possible with an error margin of 30%; M Whitehead, pers. comms., September 2008).</p> <p>Tourists spent some hours at the colony on 13 December 1992, and again on 21 December 1996⁽⁸⁾. In 1992, the chicks had split into five distinct groups; in total 5,500–6,000 chicks were conservatively estimated⁽⁸⁾. On 21 December 1996, the colony was only seen from the air; the estimate was 1,000–5,000 total birds were present⁽⁸⁾. Adults and chicks were not distinguished.</p> <p>About a year later, researchers carried out a study on the disturbance of the birds by helicopters. No counts were made; the only observation reported was that the penguins had split into six groups of 900–2,000 birds⁽⁹⁾.</p> <p>The next visit by Australians was made on 29 October 2006⁽¹⁰⁾ who photographed the entire colony from Reel Island. The colony had divided into several suburbs, and some were ~1 km from the observers. The distance together with the shallow angle at which the images were taken made a complete count impossible⁽¹⁰⁾.</p> <p>The first count of the colony during incubation was based on photographs taken on 2 July 2008⁽¹⁰⁾. Two counts gave 6,351 and 6,534 adults, or an average of 6,443 individuals. The standard deviation was 29. Since the counts differed by <3%, they were deemed sufficiently accurate.</p> <p>On 29 November 2009, the entire colony was photographed to conduct a complete census. On a warm, still day, the penguins had spread out near Reel Island forming four separate suburbs. In total, there were 2,128 adults and 9,738 chicks. The plumage of some chicks showed the first signs of moult, but no chick was advanced in its moult. No chick was seen leaving the colony giving confidence that the count provided a reliable estimate of the number of surviving chicks⁽¹¹⁾.</p> <p>The colony has inhabited Amanda Bay continuously since its discovery in 1957. The main wintering area is usually located on the fast ice between the Flatnes Ice Tongue in the west and Reel Island in the east. The bay (~17.3 km²) used to offer reliable fast ice of good quality (thick, flat and persistent). Throughout the breeding season, the colony separates into several suburbs that usually move around in the southern part of the bay. Late in the chick rearing season, the penguins also haul out onto Reel Island, particularly when the ice in the heavily stained wintering area turns to water.</p> <p>In 2023, the winter fast ice was the lowest since 2000. By November, the colony was only ~6 km from the ice edge. By 10 December, open water occurred at the northern boundary of the ASPA, and by 23 December about two thirds of Amanda Bay were ice-free (Image C). It is unclear whether any chicks were lost; some appeared to have relocated onto Reel Island.</p> <p>Since Worlview images became available in 2000, this is the first time that Amanda Bay lost its fast ice in December. In 2002 and 2009, most fast ice broke out west of the Flatness Ice Tongue, but the bay had remained frozen.</p>
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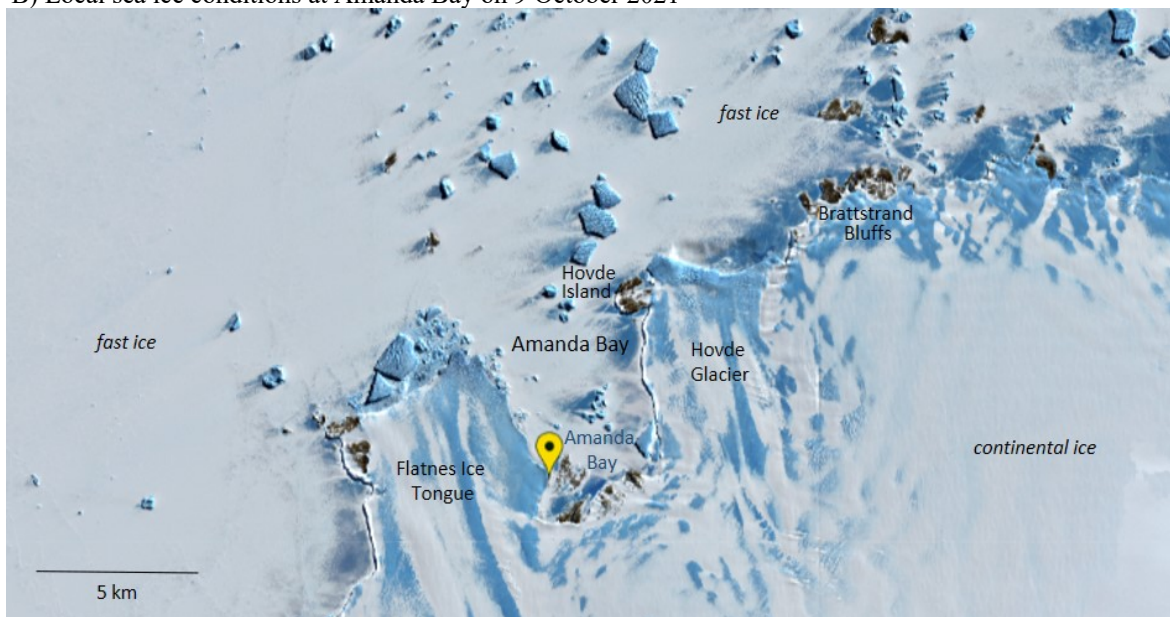
<p>Population estimates/counts</p>	<p>5,000 adults (30 November or 16 December 1956)⁽³⁾; 3,000–5,000 birds (adults) (26 August 1957)⁽⁴⁾; 3,500–4,000 adults (21 May 1960)⁽⁴⁾; 2,339 ± 69 chicks (29 September 1983)⁽⁶⁾; 2,448 ± 23 adults (30 September 1983)⁽⁶⁾; 2,188 ± 21 adults (18 October 1983)⁽⁶⁾; 5,500–6,000 chicks (21 December 1992)⁽⁸⁾; 1,000–5,000 total birds (21 December 1996)⁽⁸⁾; ~8,000 chicks (November 1997)⁽⁹⁾; 6,443 ± 129 adults (2 July 2008)⁽¹⁰⁾; 2,128 adults and 9,738 chicks (29 November 2009)⁽¹¹⁾; 1,836 adults and 8,852 chicks (13 December 2014)⁽¹¹⁾; 1,002 adults and 6,517 chicks (8 December 2018)⁽¹¹⁾; 1,424 adults and 10,485 chicks (23 November 2022)⁽¹¹⁾</p>
<p>References</p>	<p>⁽¹⁾ Secretariat of the Antarctic Treaty (2008) Measure 3 (2008) – ATCM XXXI – CEP XI, Kyiev. https://www.ats.aq/devAS/Meetings/Measure/393 ⁽²⁾ Harris CM, Lorenz K, Fishpool LDC, Lascelles B, Cooper J, Coria NR, Croxall JP, Emmerson LM, Fijn RC, Fraser WL, Jouventin P, LaRue MA, Le Maho Y, Lynch HJ, Naveen R, Patterson-Fraser DL, Peter H-U, Poncet S, Phillips RA, Southwell CJ, van Franeker JA, Weimerskirch H, Wienecke B, Woehler EJ (2015) Important Bird Areas in Antarctica 2015 Birdlife International and Environmental Research & Assessment Ltd., Cambridge ⁽³⁾ Korotkevich YS (1964) The distribution of emperor penguins. Soviet Antarctic Expedition Information Bulletin 4, 371–375 ⁽⁴⁾ Newton G (1960) Biology diary Davis 1960. Unpublished report, Australian Antarctic Division, Melbourne ⁽⁵⁾ Johnstone G (1981) Australian Antarctic Division, Hobart ⁽⁶⁾ Cracknell GS (1986) Population counts and observations at the emperor penguin <i>Aptenodytes forsteri</i> colony at Amanda Bay, Antarctica. The Emu 86, 113–117 ⁽⁷⁾ Gales NJ, Klages NTW, Williams R, Woehler EJ (1990) The diet of the emperor penguin, <i>Aptenodytes forsteri</i>, in Amanda Bay, Princess Elizabeth Land, Antarctica. Antarctic Science 2, 23–28 ⁽⁸⁾ Todd FS, Splettstoesser JF, Ledingham R, Gavrillo M (1999) Observations in some emperor penguin <i>Aptenodytes forsteri</i> colonies in East Antarctica. The Emu 99, 142–145 ⁽⁹⁾ Giese M, Riddle M (1999) Disturbance of Emperor penguin <i>Aptenodytes forsteri</i> chicks by helicopters. Polar Biology 22, 366–371 ⁽¹⁰⁾ Wienecke B, Pedersen P (2009) Population estimates of emperor penguins at Amanda Bay, Ingrid Christensen Coast, Antarctica. Polar Record 45, 207–217 ⁽¹¹⁾ This study</p>

Images

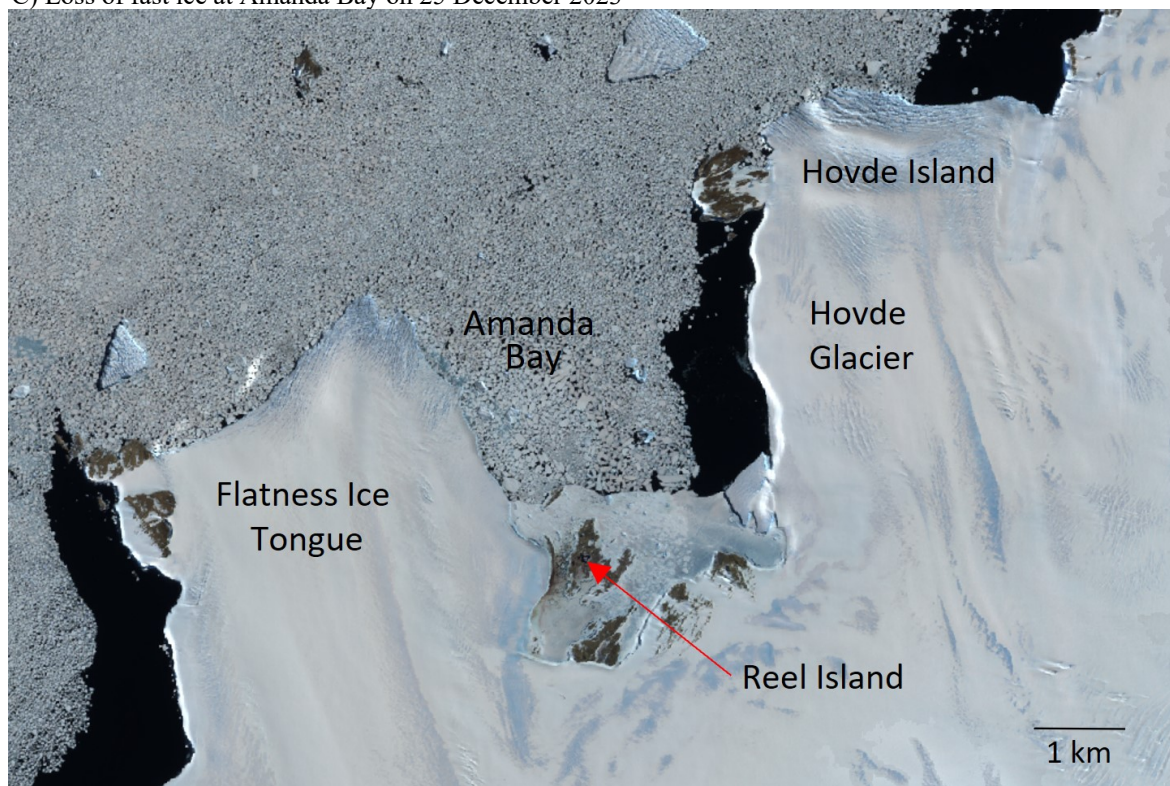
A) Colony location and fast ice edge on 9 October 2021



B) Local sea ice conditions at Amanda Bay on 9 October 2021



C) Loss of fast ice at Amanda Bay on 25 December 2023



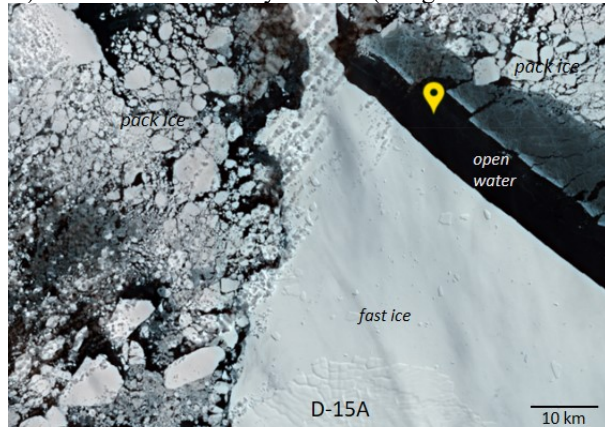
Colony	10. West Ice Shelf (IBA 140)
Region	King Leopold and Astrid Coast, Princess Elizabeth Land (81.4°E–87.8°E), East Antarctica
Recent location	66.26°S, 81.44°E
Date	1 November 2023
Interannual movement	1956–2011: 49 km 2018–2023: 3.9 ± 1.9 km (range 1–6 km)
Size	~5,500 breeding pairs
Colony description	The colony is located at the northern edge of the iceberg D-15A and ~110 km north of the northern edge of the West Ice Shelf (67°S, 85°E). The penguins are usually situated on the fast ice. However, snow accumulated in front of the ice cliff forms snow ramps that in some places allow access to the top of the iceberg. The fast ice is quite uneven and comprises ice floes that are frozen together.
Fast ice extent	The fast ice extent in the region is highly variable interannually and inter-seasonally. At the western side of the West Ice Shelf and D-15 tends to be free of fast ice due to the Barrier Bay Polynya (67°S, 81°E) which generally reaches its maximal size any time from June to October. On average it covers an area of >5,400 km ² ⁽¹⁾ . On the eastern side of D-15A, the fast ice extends about 50–80 km from the coast and covers >4,600 km ² , including Nikolaeva Bay (66.47°S, 83.58°E). At times, a narrow band of fast ice reaches into southern Karelin Bay (66.53°S, 85.01°E) and the western side of the West Ice Shelf Polynya. In September 2014, fast ice covered over 13,700 km ² west (as far as 77.8°E) and north of iceberg D-15. From 2018–2022, fast ice formed mainly at the northern edge of D-15 and tends to extend east of 81.3°E and into Nikolaeva Bay, but in 2023, >20,000 km ² extended west from the ice shelf.
Ice break out/formation	Highly variable within and between years
Maximal distance to fast ice edge	19.5 km (2 September 2023)
Minimal distance to fast ice edge	1 km (24 November 2023)
Average distance to fast ice edge	6.5 ± 4.7 km
Early fast ice breakout	Early to mid-December 2023
Distance from coast	~160 km
History	The West Ice Shelf has experienced extensive changes over time. Already in 1974 Russian scientists described the West Ice Shelf as one of the most dynamic in Antarctica ⁽³⁾ . Massive ice tongues appear to have formed several times in the modern era, and when they broke off, huge amounts of ice were lost from the ice shelf. Prior to 1992, the very large Chelyuskintsy Ice Tongue existed at ~82°E, and may have extended to ~65.7°S ⁽⁴⁾ . The Chelyuskintsy Ice Tongue appeared to have split off the West Ice Shelf in the 1964/65 summer ⁽⁵⁾ , possibly sometime before March 1965, and moved some 29 km (18 mi) to the west ⁽⁵⁾ . Sometime in the 1970s, it disappeared completely ⁽⁵⁾ , probably decreasing the total area of the West Ice Shelf by 5,200 km ² ⁽⁵⁾ . A satellite image from 7 July 1991 showed that another giant piece of ice (~4,700 km ²) had broken off the northwestern section of the West Ice Shelf ⁽⁶⁾ . In 1992, another huge iceberg, D-15 (~95 x 55 km, area >4,500 km ²), calved off the West Ice Shelf, and shortly thereafter got stuck on uncharted seamounts at the western side of the ice shelf. A narrow strip of fast ice connects the berg to the West Ice Shelf. D-15 occupies about the same area as the Chelyuskintsy Ice Tongue at 81.9°E, but the earlier ice tongue had reached >60 km farther north than D-15. Until 2015, D-15 was the largest grounded iceberg in Antarctica ⁽⁷⁾ . In March 2015, a ~32 km long rift became visible on the western side of D-15, and the following year D-15 had split into two. The larger, eastern berg, D-15A, was ~96 km long and

History	<p>42 km wide, while the smaller, western berg (D-15B) measured roughly 60 x 20 km (Image B).</p> <p>Emperor penguins have occupied the general area for many years. Members of the First Soviet Antarctic Expeditions discovered emperor penguins the region on 30 November 1956 during a flight. They estimated that ~15,000 adults were present at 65.92°S, 81.92°E ⁽²⁾. In the 1960 winter, they returned and thought some 30,000 adults occupied the colony ⁽²⁾. These are clearly very broad, inaccurate estimates, but they confirmed the presence of a possibly large colony (males incubating in winter). In 1960, the colony was ~49 km northeast of the current position (Image A).</p> <p>For many years, the area was not visited. Dense pack ice makes it difficult to access the area by ship, and extensive cloud cover and strong winds provide few opportunities for flights. But on 17 November 2011, the colony was sighted from the air. The penguins had spread out and formed two groups. The larger group was situated next to the ice cliff of D-15 (66.33°S, 81.54°E), the other ~1.3 km east (66.32°S, 81.53°E), and farther away from the ice cliff. The penguins were photographed and counted from the images. There were 1,498 adults and 3,436 chicks. The image of one very small group (several tens of penguins) was too blurred to be counted ⁽⁸⁾.</p> <p>In late March 2013, a small iceberg (~77 km²) attached to the northern edge of D-15 and remained there. It gradually decreased in size until it moved away in early March 2019, its area measuring only ~25 km². The colony established itself near this berg.</p> <p>In October 2018, the penguins occupied a small area (~0.03 km²) on the sloping ice of D-15 at its northern edge where D-15 and the small berg had formed a very narrow canyon (Image C). The slope of D-15 probably provided a more stable platform than the fast ice between the two bergs.</p> <p>By September 2019, the small berg had vanished and D-15 had moved ~1.5 km farther north. The penguins gathered on the fast ice just over 5 km north west of the previous year's location (Image D).</p> <p>On 4 November 2019, the colony was again photographed from the air ⁽⁹⁾ (Image E). Six groups of penguins had spread out over ~1 km. The largest group was close to the ice cliff. In total, 2,053 adults and 5,296 chicks were counted ⁽⁹⁾.</p> <p>In 2020, a small group of penguins congregated again near the 2019 position (~300 m north), but a large group assembled about 2.5 km north northwest of the 2018 position. D-15 had moved about another kilometre north. The penguins here also occupied the fast ice east of some small icebergs. The eastern and western groups were 4.4 km apart (Image F).</p> <p>The same division occurred in 2021. In November, two groups of penguins were approximately in the same locations as in 2020 ~4.1 km apart. Whether the individuals moved between the groups is unknown.</p> <p>In November 2022, five suburbs of different sizes had formed, and adults were moving among the groups. All were situated on the fast ice near the ice cliffs. Chick numbers were 44% and 68% higher than in 2011 and 2019, respectively. It is unknown where the additional penguins came from.</p> <p>In 2023, fast ice covered >20,000 km² including the Four Ladies Bank west of the ice shelf reaching west as far as the Vestfold Hills (Image E). In early September 2023, two groups that assembled in the same general area as in previous years were just over 20 km from the fast ice edge. The two sub-colonies were about 5 km apart. Cloud cover made it difficult to observe the colony, but in mid-November, most of the fast ice west of the penguins disappeared quickly, reducing the distances to 2 km and 6 km for the western and eastern sub-colony, respectively. By 6 December, the western group had lost its breeding platform, followed by the eastern group about 2 weeks later (Image F).</p> <p>The changes of position of this colony are shown in Image G.</p> <p>This colony may be threatened with losing its breeding space in the near future. After having been quite stable for nearly 30 years, D-15 slowly changing. In 2022, the rift between its two parts was up to 6 km wide, but fast ice still connects the two sections (Image B). D-15-A is likely to persist for some time yet. It will be changes in fast ice conditions that will challenge</p>
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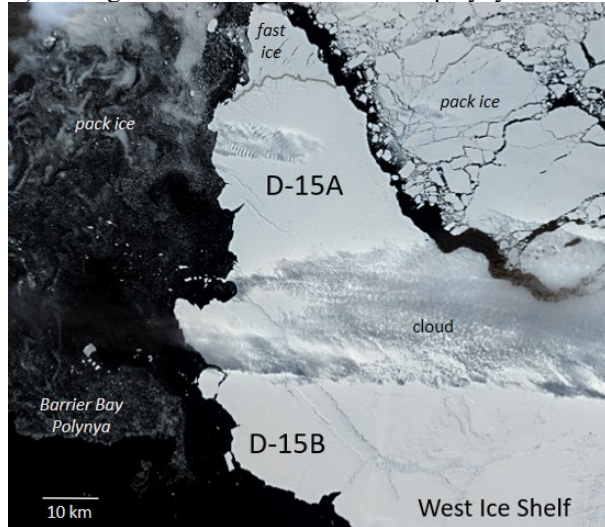
	the penguins.
Population estimates/counts	1,526 adults and 3,449 chicks (17 November 2011) ⁽⁸⁾ ; 2,053 adults and 5,296 chicks (4 November 2019) ⁽⁹⁾ ; 2,480 adults and 7,786 chicks (3 November 2022) ⁽⁹⁾
References	⁽¹⁾ Massom RA, Harris PT, Michael KJ, Potter MJ (1998) The distribution and formative processes of latent-heat Polynyas in East Antarctica. <i>Annals of Glaciology</i> 27, 420–426 ⁽²⁾ Korotkevich YS (1964) The distribution of emperor penguins. <i>Soviet Antarctic Expeditions Information Bulletin</i> 4, 371–375 ⁽³⁾ Sayatiugin LM (1974) ‘Self-destruction’ of ice shelves in Antarctica. <i>Soviet Antarctic Information Bulletin</i> 89 ⁽⁴⁾ Holdsworth G (1985) Some effects of ocean currents and wave motion on the dynamics of floating glacier tongues. In “Oceanology of the Antarctic Continental Shelf” (SS Jacobs, ed), Antarctic Research Series 43, 253–271 ⁽⁵⁾ Ledenev VG, Evdokimov AP (1967) Changes in the West and Amery ice shelves. <i>Soviet Antarctic Expedition Information Bulletin</i> 6, 4–7 ⁽⁶⁾ Korotkov AI, Podmorin VG, Ponomarev VA (1993) Periodic calving from the West Ice Shelf. <i>Russian Antarctic Expedition Information Bulletin</i> 117, 98 ⁽⁷⁾ Walker CC et al (2021) On the brink of change: Observations reveal coastal oceanographic impacts and inland glacier response associated with the ongoing collapse of West Ice Shelf, East Antarctica. AGU Conference, 17 December 2021 ⁽⁸⁾ Wienecke B (2012) Emperor penguins at the West Ice Shelf. <i>Polar Biology</i> 35, 1289–1296 ⁽⁹⁾ This study

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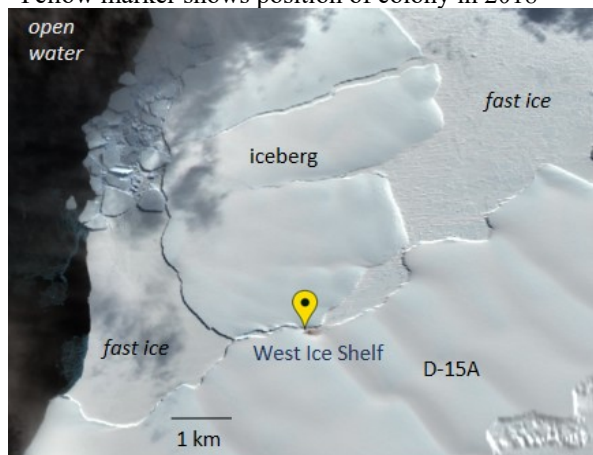
A) Position of the colony in 1960 (Image: 8 November 2021)



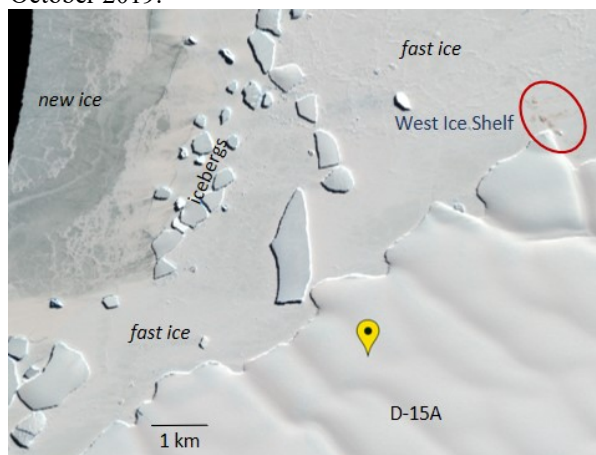
B) Icebergs D-15A and D-15 B and the polynya on 22 January 2021



C) Colony location on D-15A on 15 October 2018
Yellow marker shows position of colony in 2018



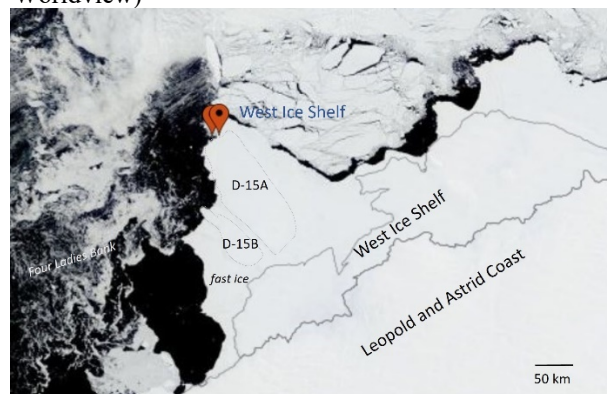
D) Colony location (red circle) on fast ice on 20 October 2019.



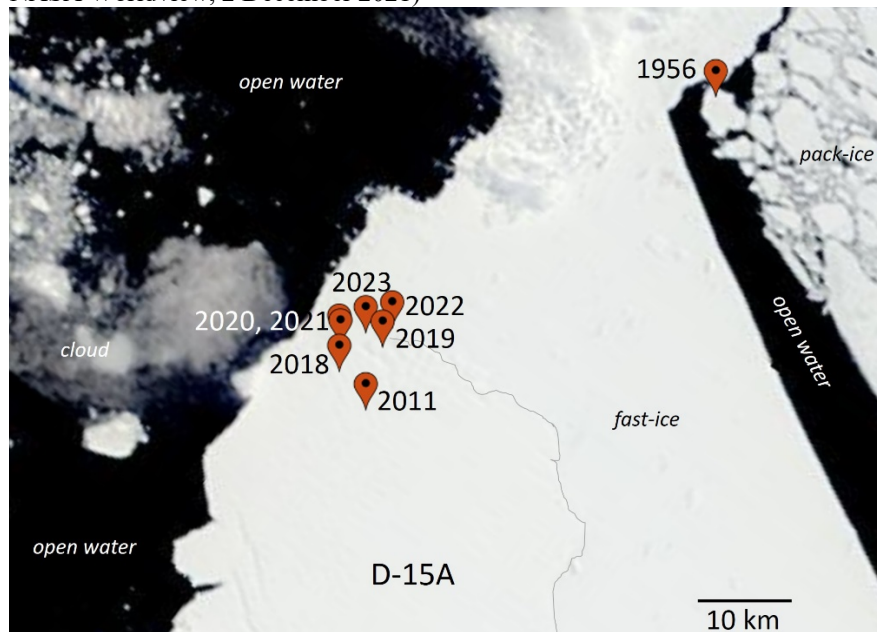
E) West Ice Shelf on 27 September 2023 (Image: NASA Worldview)



F) West Ice Shelf on 12 December 2023 (Image: NASA Worldview)



G) Historic and recent locations of the West Ice Shelf colony (Background image: NASA Worldview, 2 December 2021)



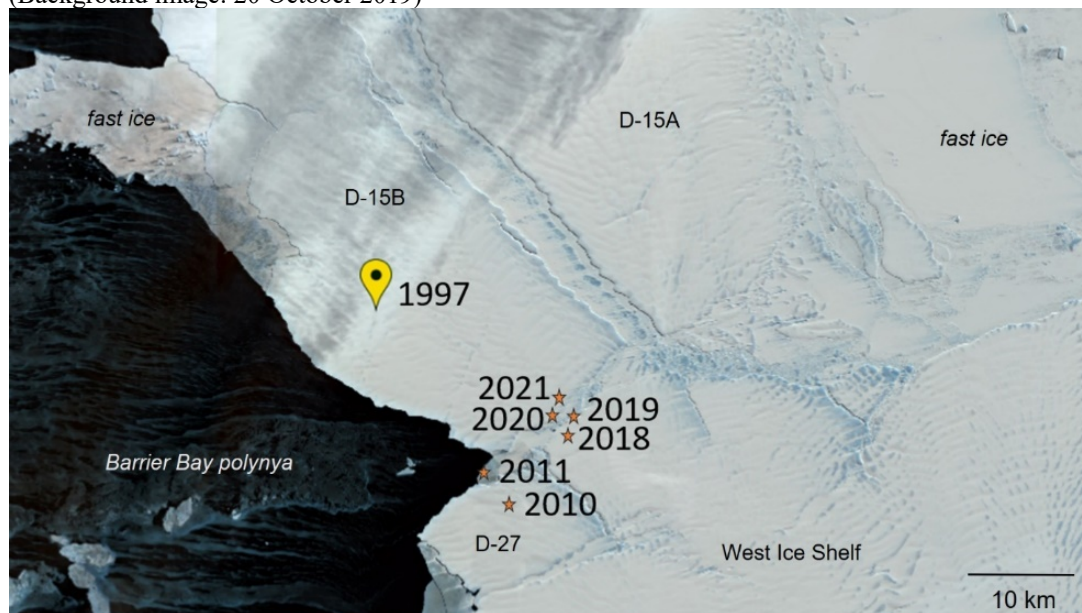
Colony	11. Barrier Bay
Region	King Leopold and Astrid Coast, Princess Elizabeth Land (81.4°E–87.8°E), East Antarctica
Recent location	67.17°S, 81.95°E
Date	3 September 2021
Interannual movement	1997–2009: 21 km 2009–2021: 1–6 km <i>Note: some of the movement is due to the movement of the ice shelf.</i>
Size	~400 breeding pairs
Fast ice extent	West of the colony is the Barrier Bay Polynya. There is very little fast ice. In 2022, iceberg D-15B formed the eastern limit of the Barrier Bay Polynya.
Ice break out/formation	The Barrier Bay Polynya occurs annually. Since a calving event in mid-May 2020, the fast ice is more vulnerable to early breakouts (see History).
Maximal distance to fast ice edge	~6.3 km (20 October 2019)
Minimal distance to fast ice edge	0.3 km 21 (September 2021)
Average distance to fast ice edge	3.9 ± 1.9 km
Early fast ice breakout	September 2020, 19 September 2021; not seen in 2022 and 2023
Distance from coast	~54 km
Colony description	<p>On 5 December 2009, the colony was situated on top of the iceberg D-15. The area was heavily crevassed. Sheer ice cliffs reached about 40 m above the ocean surface. The penguins accessed the colony area from the sea ice via a snow bridge. The distance from the bottom of the snow bridge to open water was ~9 km.</p> <p>This snow bridge collapsed sometime after December 2011. By 2018, the colony had relocated onto the fast ice between the iceberg and the West Ice Shelf (~67.23°S, 81.8°E). Due to the movement of the iceberg, a small bay had formed. At its opening, it was ~10 km wide and it was ~15 km deep. The colony was at deep inside the bay where it was <400 m wide. The fast ice extent measure ~7 km from the eastern side to open water.</p>
History	<p>This colony occupies the same dynamic environment as the West Ice Shelf colony ~100 km farther north, and had to reposition its location several times (Image A). In recent years, it experienced changes that may have had major effects on the colony size and breeding success.</p> <p>During a tourist visit on 12 December 1997, 11 adult emperor penguins and 108 chicks were seen at 67.08°S, 81.57°E on the fast ice in a small bay at the western edge of the West Ice Shelf⁽¹⁾.</p> <p>Based on satellite imagery (Sentinel2), the small bay still exists but has moved ~9 km north-westwards since. It is unknown for how long the penguins may have utilized this small bay, but penguins have not been seen there in recent years. At least since 2018, the fast ice in this bay has broken out any time from mid-September to mid-November, too early for the penguins to breed successfully. This may have forced the birds to relocate into another embayment on the western side of the West Ice Shelf, ~21 km farther south. Another small bay (40 km²) had formed between D-15 and the West Ice Shelf. Its opening was ~8 km wide and ~17 km deep; the fast ice in the bay extended ~11 km. When first sighted on 5 December 2009⁽²⁾, the colony comprised several groups of chicks 1–3 km apart, and was situated on top to the iceberg D-15 (Image B). The penguins were counted from aerial photographs; some 295 chicks and 5 adults were present at ~67.22°S, 81.85°E. The stained ice indicated that the penguins had been there for some time⁽²⁾.</p> <p>On 30 December 2010, the area was overflowed a second time. The faecal staining on top of the iceberg was still clearly visible, and 62 adults were slowly tobogganing on top of the berg in an eastward direction. Only one chick was there⁽²⁾.</p> <p>In 2011, the fast ice in the bay extended over <5 km. The area was photographed from the air on 17 November. Three groups of penguins were again on top of the iceberg in the same</p>

History	<p>position as in 2010 comprising an estimated 473 adults and 1,084 chicks ⁽²⁾.</p> <p>Adults (n = 150) and chicks (n = 185) were also sighted on 6 December 2011. The penguins were in three small groups on fresh snow on top of the iceberg but some distance from where they had been seen previously. No old faecal stains were visible ⁽²⁾.</p> <p>Due to the movement of the ice shelf, the snow bridge has collapsed sometime from 2011 to 2018. The precise time is unknown as the feature is too small to be visible in satellite images. If it happened before the chicks fledged, the young birds would have been stuck on top of the iceberg and would have perished. In all likelihood, the event occurred in summer, i.e., post-breeding.</p> <p>D-15 also changed. In December 2013, a 13 km long crack became visible in D-15; by mid-January 2015, this crack was ~20 km long, and by the end of April 2015, it measured 43 km. By September 2015, D15 had split into two. In November 2021, D-15B detached from the ice shelf and D-15A; the distance between the two bergs was at least 3.8 km. Several small icebergs calved off D-15B. Before the calving of a small iceberg off the West Ice Shelf, the small area of fast ice where the colony was located tended to persist until December.</p> <p>By April 2018, the colony had moved onto the sea ice between the iceberg and the ice shelf (67.18°S, 81.98°E), and established itself deep in the small bay between D-15 and the West Ice Shelf, next to two small bergs wedged between the iceberg and the shelf.</p> <p>In 2019, the colony was visible in satellite images. The last image was taken on 19 December 2019. In September, the penguins were at 67.18°S, 81.97°E, east of a water hole ~0.15 km² in size. The distance between D-15B and the ice shelf was ~250 m. On 4 November 2019, the area was photographed from an aircraft; the still images showed 194 adults and 512 chicks ⁽³⁾. Considering the timing of the censuses, the counts in 2010, 2011 and 2019 appear to indicate that the colony size had not changed dramatically. Thus, the snow bridge possible vanished when the penguins were absent, rather than at a time when penguins may have become stranded on top of the berg.</p> <p>The following year, the ice berg had shifted ~0.78 km north, but the colony formed in the same spot in relation to the ice features. On 14 September 2020, it was at 67.17°S, 81.96°E, again east of a 1 km wide area of open water covering ~0.37 km² and south of a small iceberg wedged between D-15B and the ice shelf (Image C). By 4 October 2020, D-15B had shifted north by ~630 m north west. This may have released the small iceberg which by this date had drifted ~50 km west into Barrier Bay. The fast ice appeared to have lost its integrity; it is unclear whether the penguins were still present. By 23 November 2020, D-15B had moved another 115 m north west, and the embayment was entirely ice-free (Image D).</p> <p>On 23 March 2021, a very small stain was visible in the bay at 67.17°S, 81.97°E ⁽³⁾. Thus, at least some penguins may have attempted to breed. On 3 September 2021, the penguins were ~0.88 km farther north than in March. Water holes had formed in the bay, and the fast ice extended only ~1.1 km. By 19 September 2021, the entire area was ice-free again. In September, chicks start crêching and are not yet able to survive in the water. If any chicks were present in September 2021, they would not have survived.</p> <p>After the penguins moved into the southern bay, the area changed markedly. From October 2018 until March 2022, the colony area had moved ~3.4 km north due to the movement of the ice shelf and iceberg. In March 2018, the bay was ~7.5 km deep with an area of ~13.6 km². Around 9–12 May 2020, a 10 x 14 km iceberg, D-27, calved off the north western edge of the West Ice Shelf. D-27 was first reported on 26 February 2018 (https://usicecenter.gov/Products/AntarcIcebergs). The loss of this berg from the ice shelf increased the width of the entrance to the colony area from 2 to 13 km (Image C), exposing the area to more wind and swell from the polynya.</p> <p>In mid-June 2022, the former colony area appeared to be still ice-free (Image F), and thin ice formed only in October 2022.</p> <p>The western area of the West Ice Shelf and the two icebergs has become rather unstable. A channel of open water exists between D-15A and D-15B in summer that is ~25 km long and up to 7 km wide.</p>
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History	<p>D-15B is slowly disintegrating. In March 2022, D-15B was 62 km long; ~22 km from its northern edge, a large crack was visible. In March 2023, the western side of this crack was 230 m wide with a 1 km deep channel of open water. The two sections of D-15B have been held together by an ice bridge <2.5 km long. The northern section is exposed to open water in the eastern, northern and western side and will eventually calve off the berg. South of the former colony area, large cracks have also appeared in the ice shelf proper and eventually bergs will calve here.</p> <p>The presence of the polynya appears to delayed or prevent the formation of fast ice in the colony area. However, in 2023, the fast ice covered >20,000 km² west of the ice shelf (see 10. West Ice Shelf, Image D). Had the colony been in its previous position, it would have been ~90 km from the fast ice edge for most of the winter. By 19 December, <1,800 km² remained, but by 21 December, the previous colony area was open water.</p> <p>From 2000 to 2023, the area was extensively covered by fast ice only in 2008, when ~25,400 km² of fast ice from west of D-15, covering the Four Ladies Bank (67.50°S, 77.22°E), to Cape Rundingen (68.03°S, 79.83°E); from here, a narrow bank of fast ice stretched west along the coast to the Amery Ice Shelf. Assuming the Barrier Bay colony was approximately in the position where emperor penguins were seen in 2009⁽²⁾, the distance from there to the fast ice edge was ~128 km. In mid-January 2009, the fast ice still reached ~80 km west.</p> <p>The Barrier Bay colony has experienced several extreme events since 2000, and not been seen since September 2021. It remains to be seen to where this colony will move to next.</p>
Population estimates/counts	<p>[11 adults and 108 chicks (12 December 1997)]⁽⁷⁾; 5 adults and 295 chicks (5 December 2010)⁽²⁾; 257 adults and 315 chicks (17 November 2011)⁽²⁾; 15 adults and 185 chicks (7 December 2011)⁽³⁾; 194 adults and 512 chicks (4 November 2019)⁽³⁾</p>
References	<p>⁽¹⁾ Splettstoesser JF, Gavriilo M, Field C, Field C, Harrison P, Messick M, Oxford P, Todd FS (2000) Notes on Antarctic wildlife: Ross seals <i>Ommatophoca rossii</i> and emperor penguins <i>Aptenodytes forsteri</i>. <i>New Zealand Journal for Zoology</i> 27, 137–142 ⁽²⁾ Wienecke B (2012) Emperor penguins at the West Ice Shelf. <i>Polar Biology</i> 35, 1289–1296 ⁽³⁾ This study</p>

Images

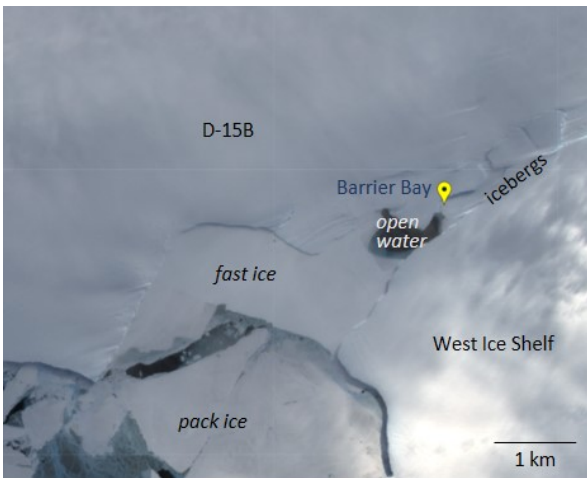
A) Historic locations of the Barrier Bay colony. Colony location reflect the dynamic ice environment (Background image: 20 October 2019)



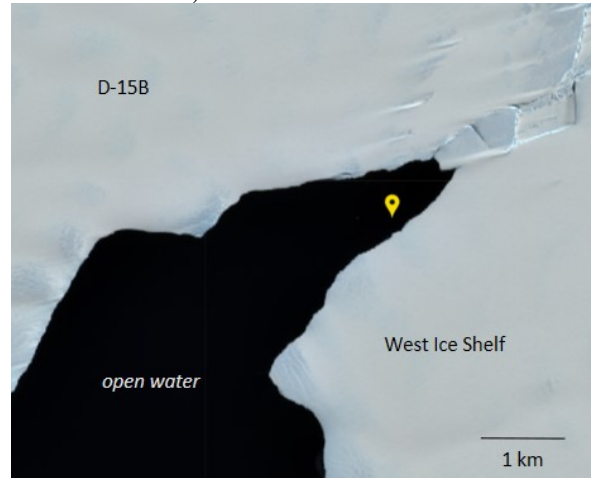
B) Location of colony on top of iceberg D-15A, 26 November 2009 (Image: NASA Worldview)



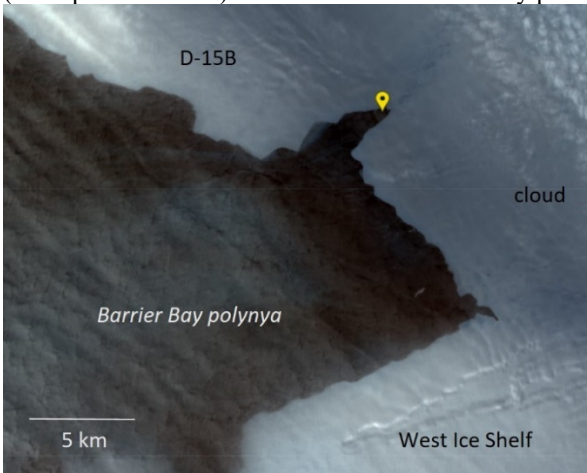
C) Colony location on 14 September 2020



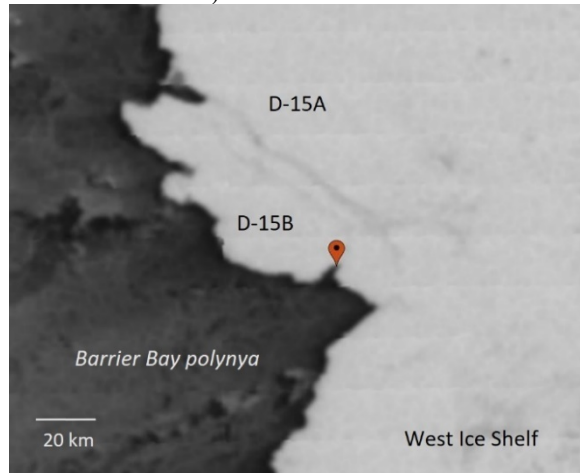
D) Loss of fast ice in colony area (Image: 23 November 2020)



E) Early fast ice breakout destroys colony area (19 September 2021). Yellow marker: old colony position



F) Former colony area on 17 June 2022 (Image: NASA Worldview)

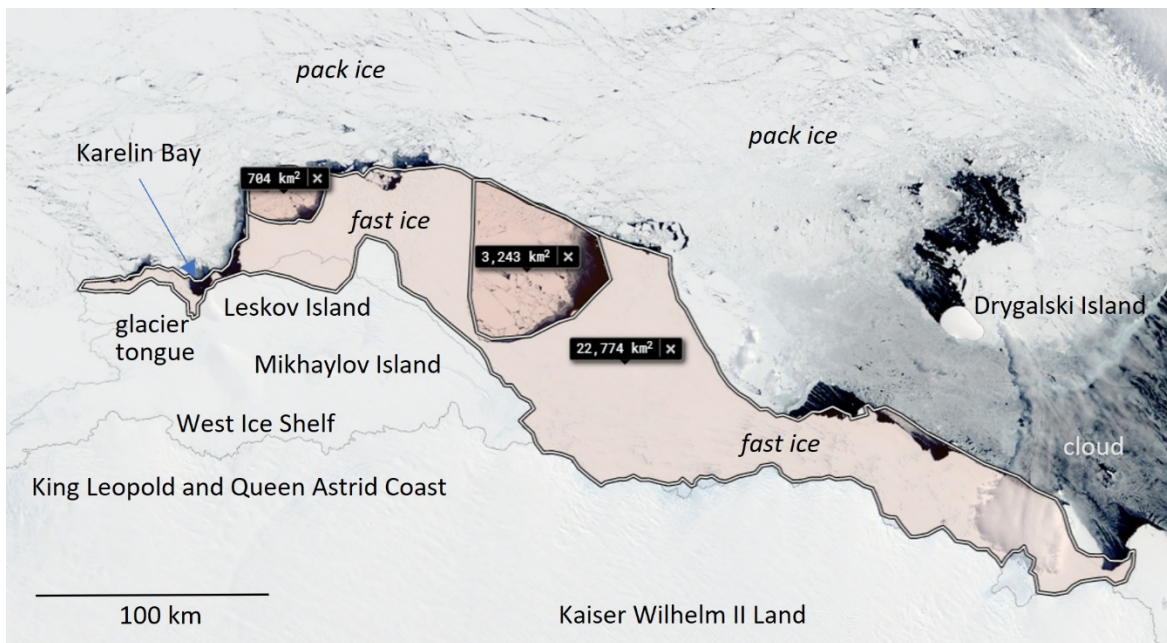


Colony	12. Karelin Bay
Region	King Leopold and Astrid Coast, Princess Elizabeth Land (81.4°E–87.8°E), East Antarctica
Recent location	66.39°S, 85.38°E
Date	20 October 2023
Interannual movement	1–3 km <i>Note: historically, the colony moved ~10 km (Image B)</i>
Size	Unknown
Fast ice extent	The fast ice extends over approximately 420 km from the eastern side of Karelin Bay (66.53°S, 85.01°E) across the eastern part of the West Ice Shelf to Farr Bay (66.58°S, 94.33°E). In years when the polynya west of the Shackleton Ice Shelf does not form, this section of fast ice can reach the ice tongue of the Roscoe Glacier (66.5°S, 95.4°E) and covers >23,000 km ² (e.g. in 2019). However, large areas can suddenly break out (Image A). The narrowest part can be <10 km wide; in Posadowsky Bay (66.78°S, 89.45°E), the fast ice can extend to ~100 km. In some years, vast areas of fast ice can break out in October.
Ice break out/formation	By January, the ice is generally breaking up until it is entirely gone in March. In April, it gradually starts to reform.
Maximal distance to fast ice edge	8.5 km (25 September 2022)
Minimal distance to fast ice edge	0 km (20 September 2021, November 2022)
Average distance to fast ice edge	3.1 ± 2.5 km
Early fast ice breakout	10 October 2021; 4 November 2022
Distance from coast	~51 km
Colony description	The colony is located on the fast ice at the eastern side of Karelin Bay. It is usually <5 km from the fast ice edge and quite unprotected in an open area of fast ice at the southern end of a row of possibly grounded icebergs.
History	<p>This colony has only been seen from the air and in satellite images. Members of the Third Soviet Antarctic Expeditions discovered the colony in August 1958 on a flight over the West Ice Shelf. Its position was ~66.5°S, 85.5°E ⁽¹⁾, ~13 km east of Leskov Island (66.6°S, 85.17°E) which is 184 m elevated above the surface of the West Ice Shelf. Since the ice shelves moves, the 1958 colony area is now underneath the shelf ice, ~8 km south of the edge of the ice shelf.</p> <p>A Landsat8 image from 17 October 2014 shows the colony in its new position at 66.42°S, 85.40°E, 10 km north of its position in 1958 ⁽²⁾. At least since 2014, the colony has only moved 1–2 km interannually (Image B).</p> <p>On 9 October 2018, the colony was again in nearly the same location as in 2014, at 66.41°S, 85.38°E ⁽³⁾. In the following year, cloud obscured the colony location for most of the season. The colony was seen in only one Sentinel2 image on 1 October 2019 at 66.42°S, 85.42°E, only 1 km from its 2018 position ⁽³⁾.</p> <p>By 2020, the colony location had moved ~2 km from the previous years. Only four clear images were available from September to November. From mid-November onwards, the staining was very faint, and it is uncertain whether penguins were still present. By then the distance to the ice edge was <1 km ⁽³⁾.</p> <p>In 2021, the colony was noted in a satellite image from 31 August (Image C). The penguins were only 2.7 km from the fast ice edge. Six weeks later (10 October), the fast ice edge had retreated eastwards, and the location recorded in August was now open water (Image D). The fate of the penguins is unknown, but since no stains were visible on the residual ice for the remaining season, it is likely that the colony sustained losses, especially among the chicks ⁽³⁾.</p> <p>On 19 November 2021, a very small and very faint stain was visible right at the fast ice edge at 66.40°S, 85.40°E ⁽³⁾. In aerial photographs taken on the same day, two small groups of</p>

History	<p>penguins were visible; one was located near fast ice edge and comprised 11 adults. Another one was near a small iceberg stuck in the fast ice ~500 m from its edge. Here, three adult emperor penguins were present, joined by 12 Adélie penguins. The emperor penguins were only a small portion of the colony and the numbers are not representative of the colony size. When the fast ice broke out in early October, the chicks were too young to survive in the water. Since no chicks were seen during the aerial survey, it is unlikely that any managed to rescue themselves ⁽³⁾.</p> <p>In 2023, the colony occupied approximately the same area as in previous years. From September to December, the distance to the fast ice edge averaged 4.0 ± 0.5 km, and the fast ice persisted through January 2024. Thus, after two consecutive years of complete breeding failure, this colony may have had a successful season.</p> <p>Many days with dense cloud cover make it difficult to observe this colony. The short distance to the fast ice edge puts it at risk when the fast ice breaks out before the chicks are ready to go to sea.</p>
Population estimates/counts	<p>1,000 adults (1 August 1958) ⁽¹⁾; 14 adults (19 November 2021) ⁽³⁾ <i>Note: incomplete count due to early fast ice breakout.</i></p>
References	<p>⁽¹⁾ Korotkevich YS (1964) The distribution of Emperor penguins. Soviet Antarctic Expedition Information Bulletin 4, 371–375</p> <p>⁽²⁾ Fretwell PT, Trathan PN (2020) Discovery of new colonies by Sentinel2 reveals good and bad news for emperor penguins. <i>Remote Sensing in Ecology and Conservation</i> 7, 139–153</p> <p>⁽³⁾ This study</p>

Images

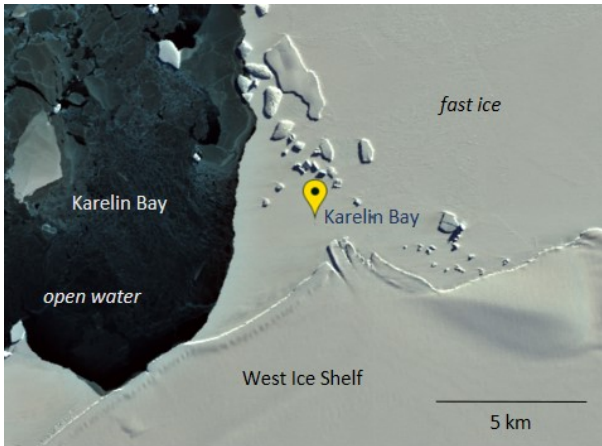
A) Around 21 October 2020, >3,000 km² of fast ice broke out (shaded area) (Image: NASA Worldview, 25 October 2020)



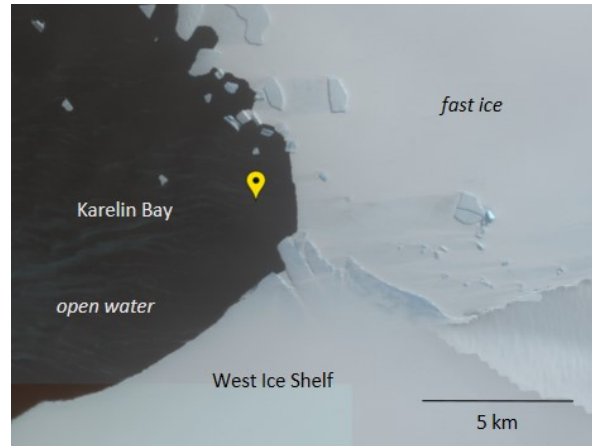
B) Locations of the colony in Karelin Bay (Image: Worldview, 13 December 2023)



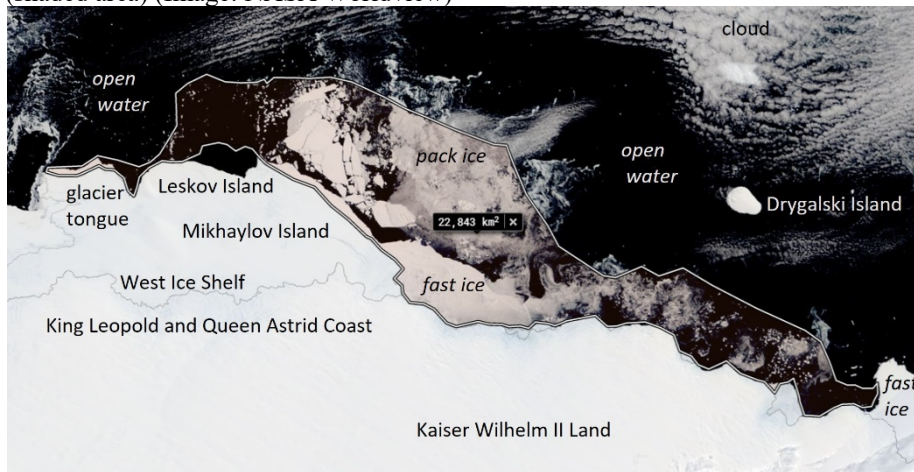
C) Colony location and fast ice edge on 31 August 2021



D) By 10 October 2021, the fast ice had retreated eastwards



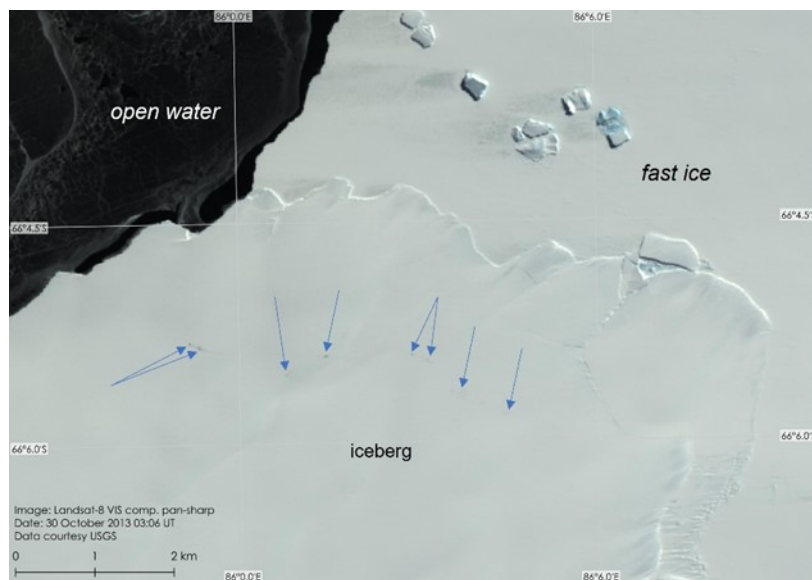
E) Breaking fast ice on 29 January 2019 compared to fast ice extent on 20 October 2019 (shaded area) (Image: NASA Worldview)



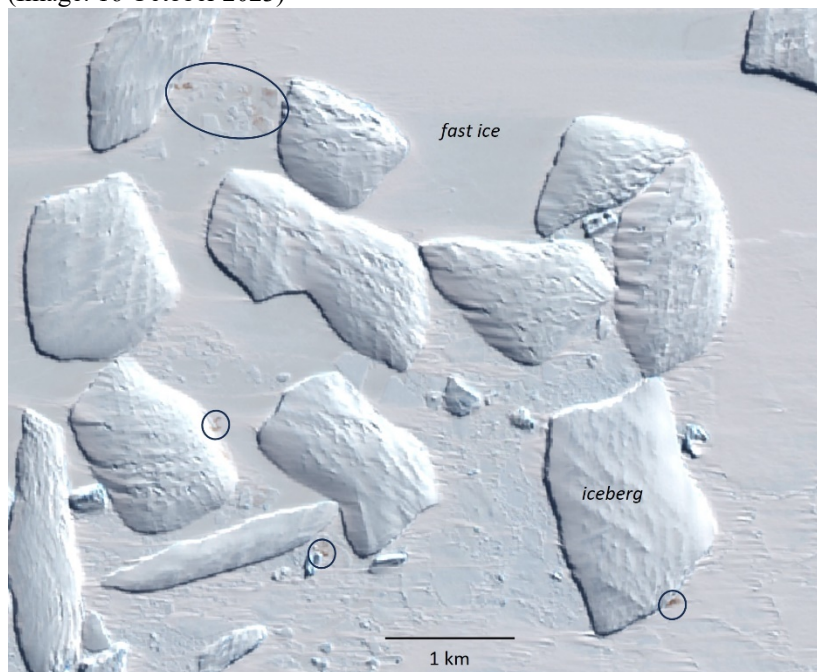
Colony	13. Vanhöffen
Region	King Leopold and Astrid Coast, Wilhelm II Land (80.9°E–92°E), East Antarctica
Recent location	66.07°S, 86.49°E
Date	26 September 2023
Interannual movement	0–3 km
Size	Unknown; possibly several thousand pairs ⁽¹⁾
Fast ice extent	The fast ice extends over ~420 km from the eastern side of Karelin Bay (66.53°S, 85.01°E) across the eastern part of the West Ice Shelf to Farr Bay (66.58°S, 94.33°E). In years when the polynya west of the Shackleton Ice Shelf does not form, this section of fast ice can reach the ice tongue of the Roscoe Glacier (66.5°S, 95.4°E, e.g. in 2019). It covers an area of >23,000 km ² . The narrowest part can be <10 km wide; in Posadowsky Bay (66.78°S, 89.45°E), the fast ice can extend to ~100 km.
Ice break out/formation	Break out and formation of the fast ice vary interannually. Generally, the ice remains in the region well into January. In some years, the ice breaks out first west of a 37 km long, northwards running row of icebergs at ~86°E. In March, the fast ice is largely lost, but small sections can remain well into April, when fast ice area starts to expand again.
Maximal distance to fast ice edge	20.6 km (1 October 2019)
Minimal distance to fast ice edge	6.0 km (30 December 2022)
Average distance to fast ice edge	11.9 ± 4.2 km
Early fast ice breakout	None observed
Distance from coast	~97 km
Colony description	The colony is located on the fast ice ~26 km north of the eastern West Ice Shelf among grounded icebergs.
History	<p>In October 2013, several small groups of stains were visible on an iceberg at the eastern side of West Ice Shelf (Image A)⁽²⁾. They were spread out over a distance of 4 km, and probably had accessed the top of the iceberg from the east. The western side of the berg was exposed to open water. Sometime during the following summer, the berg was set adrift and the penguins were not seen again in this location.</p> <p>The penguins on top of the berg were ~169 km west of the recent locations of the Posadowsky Bay colony, and ~47 km northeast of the Karelin Bay colony.</p> <p>In 2024, a colony was reported at 66.75°S, 88.30°E⁽¹⁾, 21 km east of the location occupied by emperor penguins in 2013. Since 2018, the colony occurred in generally the same area; interannually, it moved 0.4–2.4 km depending on how local icebergs rearranged during the summer months. The changes in breeding location may also indicate variations in local fast ice conditions. The emperor penguins have to adjust to these changes constantly.</p> <p>The largest stain was sighted in 2021 which may indicate an increase in the number of penguins present as the stain was very dark.</p> <p>In 2023, the colony has separated into four sub-colonies that were out of visual range of each other as small icebergs blocked the direct line of sight (Image B). The distances between the groups were 1.2–2.5 km. Movement between the groups was unlikely and the sub-colonies remained separated throughout the season.</p>
Population estimates/counts	unknown
References	<p>⁽¹⁾ Fretwell P (2024) Four unreported emperor penguin colonies discovered by satellite. <i>Antarctic Science</i>, published online, 1–3. Doi: 10.1017/SO954102023000329</p> <p>⁽²⁾ This study</p>

Images

A) Several groups of emperor penguins on top of a small iceberg at the eastern side of the West Ice Shelf on 30 October 2013 (Image: Landsat-8, USGS).



B) The Vanhöffen colony split into four sub-colonies in 2023 (Image: 16 October 2023)

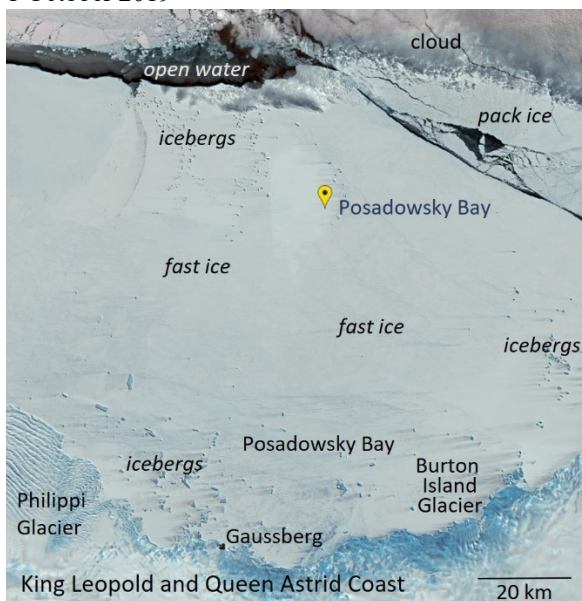


Colony	14. Posadowsky Bay (“Gaussberg”)
Region	King Leopold and Astrid Coast, Wilhelm II Land (80.9°E–92°E), East Antarctica
Recent location	66.14°S, 89.78°E
Date	19 November 2023
Interannual movement	0–5 km Note: <i>historically, the colony moved 7–17 km (Image D)</i>
Size	<200 pairs
Fast ice extent	The fast ice extends over ~420 km from the eastern side of Karelin Bay (66.53°S, 85.01°E) across the eastern part of the West Ice Shelf to Farr Bay (66.58°S, 94.33°E). In years when the polynya west of the Shackleton Ice Shelf does not form, this section of fast ice can reach the ice tongue of the Roscoe Glacier (66.5°S, 95.4°E, e.g. in 2019). It covers an area of >23,000 km ² . The narrowest part can be <10 km wide; in Posadowsky Bay (66.78°S, 89.45°E), the fast ice can extend ~100 km. In some years, vast areas of fast ice can break out in October. For example, the fast ice extended just over 21 km east of the colony on 1 October 2019 (Image A). On 15 October 2019, a large piece of fast ice (~1,900 km ²) broke off reducing the distance between the colony and the ice edge to <5 km (Image B). Similarly, in October 2020, a chunk of near equal size broke off east of the colony. At the same time, some 45 km west of the colony, another large area of fast ice also broke up (Image C).
Ice break out/formation	Break out and formation of the fast ice vary interannually. Generally, the ice starts to break up in January, and in some years, it had disappeared entirely in March (e.g. 2019). In most years though, an area of fast ice remains and extends ~86°E some 40–55 km to the east and even to the Philippi Glacier (66.75°S, 88.30°E) at the western side of the fast ice sheet. In April, it gradually starts to reform and expand.
Maximal distance to fast ice edge	27.9 km (15 September 2022)
Minimal distance to fast ice edge	0.6 km (19 November 2021 & 15 October 2022)
Average distance to fast ice edge	12.0 ± 10.2 km
Early fast ice breakout	None observed
Distance from coast	~72 km
Colony description	It is difficult to observe this colony via satellite imagery due to the frequent, dense cloud cover. This small colony is located ~70 km north of the coastline on the fast ice eastern side of a vast fast ice sheet extending north of Posadowsky Bay. It has relocated several times since its discovery (see History), but since 2018 has been in the same area (~66.2°S, 89.8°E).
History	This colony was found — but not recognized as such — in 1902 during the First German South Polar Expedition ⁽¹⁾ . Its precise location was not recorded. The only reference made by E. von Drygalski, leader of this expedition, was that the colony was ~10 km south of the ship’s position ⁽²⁾ . No attempt was made to investigate the colony and estimate the number of penguins present. Subsequent expeditions attempted to find this colony with varying degrees of success. On 21 June 1960, Soviet expeditioners sighted the colony during a flight but were unable to land ⁽³⁾ . A location was not recorded. A month later, on 22 August 1960, during a ground visit the colony was reported at 66.22°S, 89.58°E comprising 2,500–3,000 adults ⁽⁴⁾ . In 2014, the colony was spotted in a satellite image (location recorded as “Burton Ice Shelf”) at 66.272°S, 89.695°E ⁽⁵⁾ , some 8 km farther south than in 1960. <i>Note: a “Burton Ice Shelf” does not exist, but the Burton Island Glacier (~66.8°S, 90.4°E) is ~40 km south of the indicated location. The 2014 position is 14.7 km south of the area where the penguins have been sighted in this study.</i> On 6 September 2018, the colony occurred at 66.130°S, 89.815°E, ~14 km farther north than in 2014 year ⁽⁶⁾ . Historically the colony location has shifted noticeably over the years. However, from 2018–2023, it was located every year in generally the same area ^(1,6) (Image

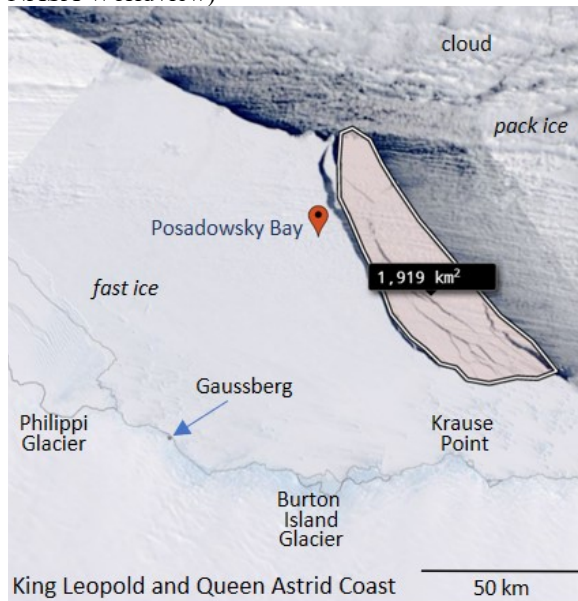
History	<p>D) on the eastern side of a vast fast ice sheet that extends up to ~110 km from the coast. To the east of the colony, the sea ice is highly dynamic. Consolidated pack-ice can significantly increase the distance the penguins have to walk to reach open water. Alternatively, the dense pack can quickly disappear, greatly reducing the distance between colony and fast ice edge. Such changes can occur within the same season and can repeat. For example, on 9 November 2023, the ice edge was 27 km from the colony but only 1.7 km on 9 December 2023.</p> <p>The historic changes in breeding location likely indicate variations in local fast ice conditions. Emperor penguins have to adjust to these changes constantly.</p> <p>The first aerial survey of this colony in November 2022 indicated that this is the smallest colony in the study area, and perhaps in Antarctica.</p>
Population estimates/counts	<p>4,000 adults (21 June 1960)⁽³⁾; 2,500–3,000 adults (20 August 1960)⁽⁴⁾; 123 adults and 155 chicks (3 November 2022)⁽⁶⁾</p>
References	<p>⁽¹⁾ Wienecke B (2021) Emperor penguins and the First German South Polar Expedition, 1901–1903: The elusive colony in Posadowsky Bay. <i>Polar Record</i> 57, e15, doi: 10.1017/S0032247421000115</p> <p>⁽²⁾ Drygalski, E von (1904). <i>Zum Kontinent des eisigen Südens—Deutsche Südpolarexpedition. Fahrten und Forschungen des “Gauss” 1901–1903 (To the continent of the icy south—German south polar expedition. Trips and research of the “Gauss” 1901–1903)</i>. Georg Reimer, Berlin</p> <p>⁽³⁾ Korotkevich YS (1964) The distribution of Emperor penguins. <i>Soviet Antarctic Expedition Information Bulletin</i> 4, 371–375</p> <p>⁽⁴⁾ Nudel’Man AV (1962) <i>Soviet Antarctic Expeditions 1955–1959</i>. Izdatel’stvo Akademii Nauk SSSR, Moskva (translated from the Russian by the Israel Program for Scientific Translations, Jerusalem, 1966)</p> <p>⁽⁵⁾ Fretwell PT, Trathan PN (2020) Discovery of new colonies by Sentinel2 reveals good and bad news for emperor penguins. <i>Remote Sensing in Ecology and Conservation</i> 7, 139–153</p> <p>⁽⁶⁾ This study</p>

Images

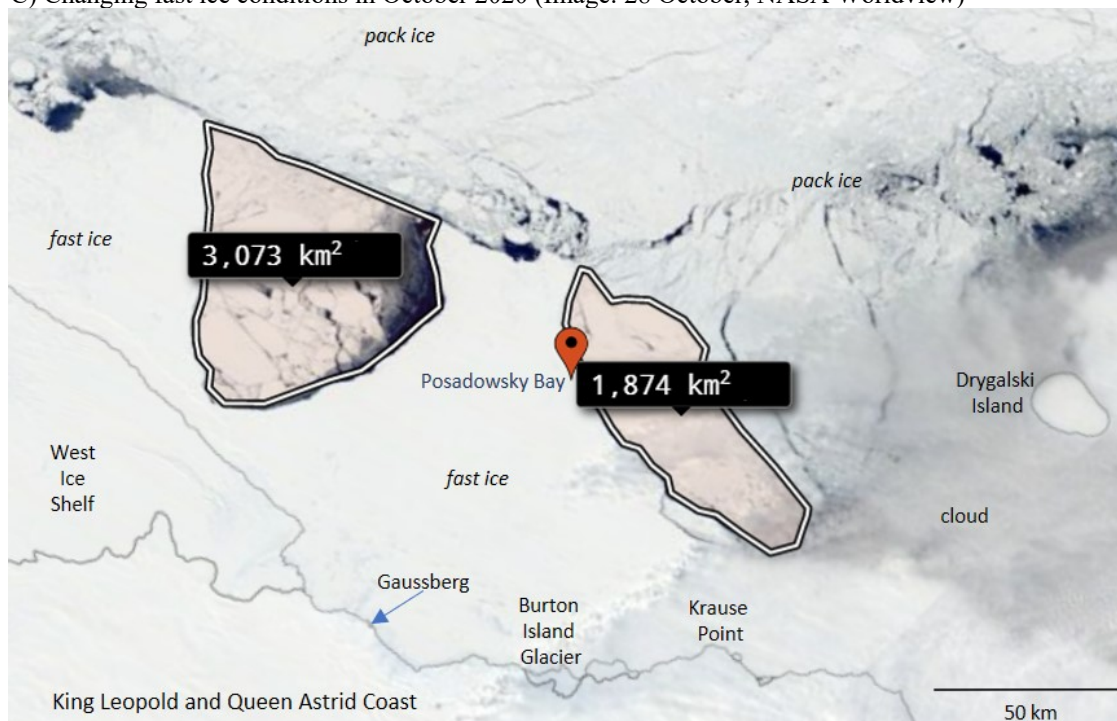
A) Colony location and regional fast ice on 1 October 2019



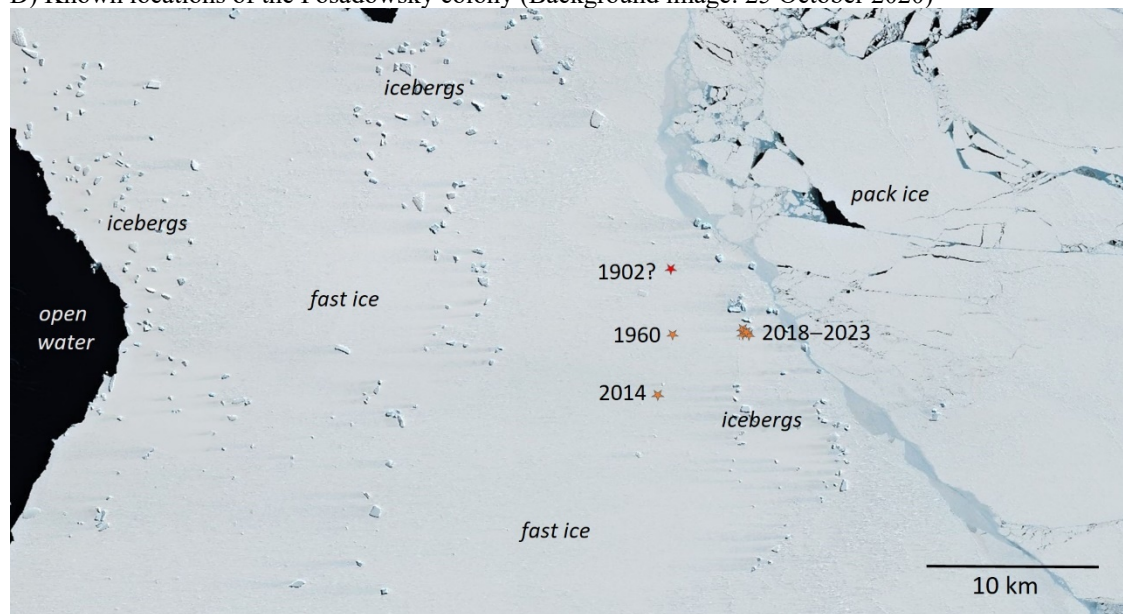
B) Fast ice loss on 15 October 2019 (Image: NASA Worldview)



C) Changing fast ice conditions in October 2020 (Image: 28 October, NASA Worldview)



D) Known locations of the Posadowsky colony (Background image: 25 October 2020)



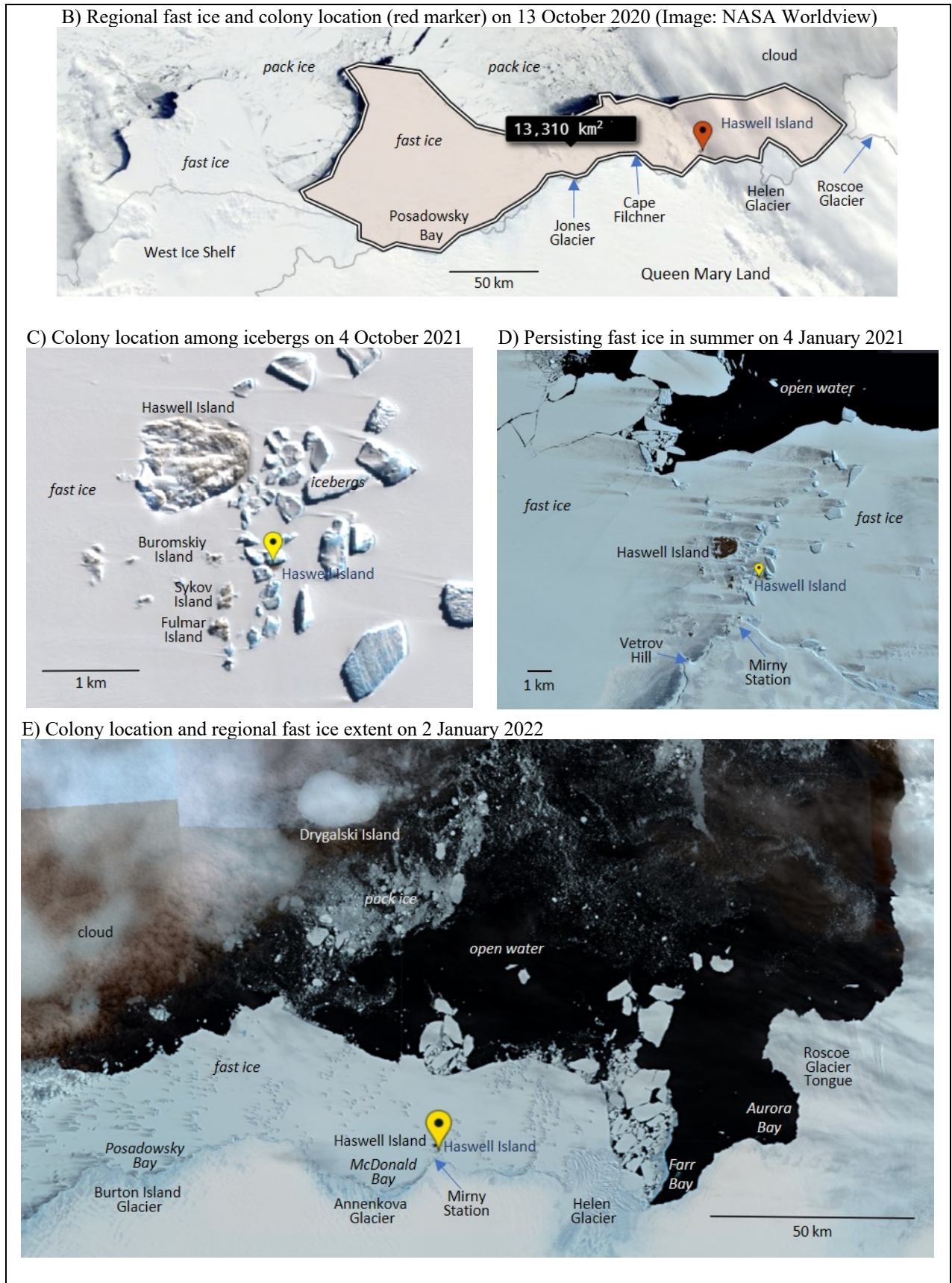
Colony	15. Haswell Island (ASPA 127, IBA 141)
Region	Southern Davis Sea, Queen Mary Land (92°E–100.5°E), East Antarctica
Recent location	66.54°S, 93.05°E
Date	13 November 2023
Interannual colony movement	0–2 km
Size	Several thousand breeding pairs
Fast ice extent	<p>The fast ice extends over approximately 420 km from the eastern side of Karelina Bay (66.53°S, 85.01°E) across the eastern part of the West Ice Shelf to Farr Bay (66.58°S, 94.33°E). In years when the Polynya west of the Shackleton Ice Shelf does not form, this section of fast ice can reach the ice tongue of the Roscoe Glacier (66.5°S, 95.4°E, e.g. in 2018). It covers an area of >21,000 km² (Image A). The narrowest part can be <10 km wide; in Posadowsky Bay (66.78°S, 89.45°E), the fast ice can extend to ~100 km. In October 2020, the fast ice was also extensive but covered ~8,000 km² less than in 2018 (Image B).</p> <p>Regionally, the fast ice extent from the Jones Glacier (91.47°E) to the Roscoe Glacier varied by as much as 25% from 2010–2021. For example, on 15 October 2016, the fast ice area in this region was ~6,250 km², compared to ~4,640 km² on 15 October 2021. Open water occurred in Aurora Bay (west of the Roscoe Ice Tongue) in 4 out of 12 years already in October.</p>
Ice break out/formation	The fast ice starts to reduce in December, and virtually disappears in February. In April, it starts to reform.
Maximal distance to fast ice edge	43.2 km (4 September 2023)
Minimal distance to fast ice edge	7.0 km (31 December 2020)
Average distance to fast ice edge	25.7 ± 6.9 km
Early fast ice breakout	None observed
Distance from coast	<2 km
Colony description	The colony is located on the fast ice just east of the Haswell Island (66.52°S, 93.00°E), the largest island in the Haswell Island archipelago (Image C). The colony is among icebergs about 1 km southwest of Haswell Island. The Russian research station Mirny is <2 km south-west of the colony. The fast ice can persist over the summer (Images D & E).
History	<p>The men of the western party of Mawson’s Australasian Antarctic Expedition (1911–1914) discovered this colony on 25 November 1912. S.E. Jones, medical officer and leader of the western party, estimated that ~7,500 birds were present, the majority of which were chicks ⁽¹⁾. D.T. Harrison, biologist, who never had the chance to visit this colony, noted that ~7,000 of the birds sighted were chicks and concluded that — due to an apparently high mortality among the chicks — the colony must comprise ~20,000 adults ⁽²⁾.</p> <p>In 1956, the Russian research station Mirny was established at Mabus Point (66.5°S, 93.0°E), 2.7 km south of Haswell Island. On several occasions, attempts were made to estimate the size of the emperor penguin population. Russian scientists have carried out biological studies at various times (1956–1962; late 1960s to early 1970s; 1999–2011), but the results are difficult to find in the English literature. Particularly annual count data or estimates are hard to obtain.</p> <p>On 5 May 1962, 18,000 ± 500 birds (both males and females) were thought to be present ⁽³⁾. From 1956–1970, the average number of breeding pairs over four counts was 6,374 ± 487 ⁽⁴⁾. Details about the actual counts, methods and timing could not be found. Apparently, estimates of population size were not attempted from 1970 to the early 1990s.</p> <p>On 6 January 1993, a tourist vessel visited the Haswell Island archipelago and the remaining emperor penguin chicks (n = 160) and “all emperor penguins within several kilometers of the island” were counted ⁽⁵⁾. These counts were made very late in the breeding season and are difficult to interpret. The majority of chicks would have fledged by then; 10 young birds</p>

History	<p>were seen near the fast ice edge. It is unclear how many of the 222 adult penguins⁽⁵⁾ still occupied the colony area or whether a portion of the adults were pre-moulters or non-breeders.</p> <p>Sometime in the period of missing observations, the colony at Haswell Island had declined by just over 30%⁽⁴⁾. Counts/estimates (n = 6) from ~1994–2010 indicated a small increase since ~2,000; the numbers averaged $4,356 \pm 579$ over this period⁽⁴⁾.</p> <p>The most recent population estimate (~6,000 males in June 2020) was provided in the latest management plan for this Antarctic Specially Protected Area⁽⁷⁾.</p>
Population estimates/counts	<p>~7,500 birds (adults and chicks) (25 November 1912)⁽¹⁾; 18,000 ± 500 birds (adults) (9 May 1962)⁽²⁾; 222 adults and 160 chicks (6 January 1993)⁽⁵⁾; 3,247 adults (27 August 2008)⁽⁶⁾; ~6,000 males (June 2020)⁽⁷⁾</p>
References	<p>⁽¹⁾ Falla RA (1937) Birds. Vol II, BANZ Antarctic Research Expedition 1929–1931 Reports – Series B, BANZAR Expedition Committee, Adelaide</p> <p>⁽²⁾ Mawson D (1914) Australasian Antarctic Expedition, 1911–1914. <i>The Geographical Journal</i> 37, 256–284</p> <p>⁽³⁾ Pryor M (1968) The avifauna of Haswell Island. In (Austin OL, ed) <i>Antarctic Bird Studies</i>. Antarctic Research Series 12, 57–82</p> <p>⁽⁴⁾ Barbraud C, Gavrilov M, Mizin Y, Weimerskirch H (2011) Comparison of emperor penguin declines between Pointe Géologie and Haswell Island over the past 50 years. <i>Antarctic Science</i> 23, 461–468</p> <p>⁽⁵⁾ Todd FS, Spletstoesser JF, Ledingham R, Gavrilov M (1999) Observations in some emperor penguin <i>Aptenodytes forsteri</i> colonies in East Antarctica. <i>The Emu</i> 99, 142–145</p> <p>⁽⁶⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p> <p>⁽⁷⁾ Antarctic Treaty System (2022) Management plan for Antarctic Specially Protected Area No. 127 “Haswell Island”. https://documents.ats.aq/recatt/att721_e.pdf</p>

Images

A) Regional fast ice and colony location (red marker) on 20 October 2018 (Image: NASA Worldview)





Colony	16. Shackleton Ice Shelf
Region	Queen Mary Coast/Knox Coast, Queen Mary Land (92°E–100.5°E)/Wilkes Land (100.5°E–136°E), East Antarctica
Recent location	64.92°S, 95.95°E
Date	13 November 2023
Interannual colony movement	1–13 km <i>Note: historically, the colony may have moved ~73 km from 1960 to 2008 (Image B)</i>
Size	6,000–10,000 breeding pairs
Fast ice extent	The fast ice extent is highly variable. In mid-October 2014, it reaches from 94.83°E ~45 km west of the northwestern part of the ice shelf eastwards into Vincennes Bay (66.5°S 109.5°E) covering >53,000 km ² (Image A). In September 2014, an additional 11,700 km ² had existed north of the ice shelf but started to disintegrate in early October. In comparison, in October 2015, an area nearly twice as large (20,200 km ²) disintegrated in the same region, east of the ice tongue of the Denman Glacier (66.75°S, 99.42°E) and Mill Island (65.52°S, 100.67°E). The fast ice cover in the area of the penguin colony measured only ~9,300 km ² . This scenario repeated itself in the following years until 2020, when the fast ice reached a little farther east (~100.34°E).
Ice break out/formation	The fast ice north of the iceberg occupied by the penguins may break up in January, and reform in mid-April.
Maximal distance to fast ice edge	12.5 km (29 September 2022)
Minimal distance to fast ice edge	3.2 km (16 December 2020)
Average distance to fast ice edge	5.8 ± 3.2 km
Early fast ice breakout	None observed
Distance from coast	~195 km
Colony description	The colony is located near or on top of a small, grounded iceberg C-31B (19 x 20 km) on the northwestern side of the ice shelf. It is ~190 km north of the Antarctic continent. The colony (or colonies?) appears to be rather mobile, having shifted its location several times in recent years. The penguins are often divided into two main groups that move independently from each other.
History	<p>On 26 October 1960, Russian scientists spotted emperor penguins at 65.53°S, 97.5°E from an aircraft near a large iceberg known at the time as “Pobeda [Victory] Island”; a crude estimate gave ~10,000 adults ⁽¹⁾. A landing was not attempted. The 1960 location was about 41 km northeast of the current location (Image B).</p> <p>A satellite survey in 2002 did not find this colony ⁽²⁾. However, on 10 October 2009, faecal stains occurred on the fast ice north of the northwestern Shackleton Ice Shelf, and 6,471 adults were estimated to be at 64.86°S, 96.02°E ⁽³⁾, roughly 74 km southwest of the 1960 location ⁽¹⁾. To date, this remains the only estimate of the size of this colony.</p> <p>On 2 January 2010, emperor penguins were noted at the northwestern side of the ice shelf during a survey flight (Images C & D). A large guano stain was visible, and four adults and 12 chicks were seen at 65.874°S, 96.016°E (Dan Colborne, pers. comm.).</p> <p>The penguins utilized the same area in the following year ⁽³⁾, but in 2011 and 2012, the colony shifted 15 km south onto a small iceberg ⁽³⁾, a remnant of a 47 km long iceberg (C-31) that had broken off the western side of the ice shelf in 2003 (Image E). Initially, the berg remained near the ice shelf, but broke into two pieces in late December 2004. The southern chunk (C-31A) drifted south and disappeared while the northern piece, C-31B (~320 km²), drifted slightly north and collided with the ice shelf. It has been in this position ever since and does not appear to have changed much in size (Image F).</p> <p>In 2011 and 2012, the penguins accessed the top of C-31B via a gully on its eastern side, 3.4 km from the colony location ⁽⁴⁾. The penguins may have stayed on top of the iceberg since; from 2018 to 2021, the faecal stains occurred in various locations on top of the iceberg. In 2018, the penguins occupied the northern side of the berg, ~13 km north west</p>

History	<p>from the 2012 site (Image E). In October 2018, the colony had split into several small suburbs, all ~100 to <700 m from the edge of the berg. Stains were visible over a stretch of roughly 4.2 km.</p> <p>In October 2019, the colony had split into two. One part was now ~8.7 km southeast of the previous year's location, and the other was ~7.2 km farther west. It appeared that these two groups did not re-unit in this season. The eastern group was ~2.7 km away from the 2012 location, and may have used the former access route. The western group was very close to the edge of the berg. It is likely that these penguins found another ramp off the berg and onto the fast ice.</p> <p>In October 2020, the eastern group had moved nearly 12 km west, and the western group had shifted ~3 km south compared to the previous year. The two groups were ~2.1 km apart.</p> <p>A year later, on 21 October 2021, two groups again occupied areas on the northwestern side of the berg; they were within <700 m of each other. Another two very small groups were sighted. One had established itself at the western edge, apparently still on top of berg (64.91°S, 95.68°E). The other seemed to have moved onto the sea ice (64.91°S, 95.84°E).</p> <p>This colony is quite dynamic; historically, its location shifted >70 km west from the fast ice onto the western edge of the Shackleton Ice Shelf (Image B). By 2018, it had also split into two distinct groups, several kilometres apart. It is unknown whether the penguins moved between the groups. Between years, the colony locations shifted ~7–13 km. Even within a season, the penguins at the Shackleton Ice Shelf moved 3–9 km. Although the katabatic winds do not reach the colony so far from the coast, the penguins are exposed to winds as there is not shelter on top of the iceberg. This exposure may contribute to the intra-seasonal movement of the colony.</p> <p>The penguins continue to find new locations to set up their colonies. Note that from 2018–2019, the entire berg had moved ~500 m west. In 2020, the iceberg had shifted about 330 m northwest, and another 220 m north in 2021. Shifting and slightly turning movements are common for icebergs loosely attached to an ice shelf. However, they are likely to affect the penguins' access from the northern edge of the iceberg as any movement may lead to the collapse of snow bridges and access routes.</p> <p>Such an event was reported by Russian scientists who camped at the Salyut summer camp in 1978 ⁽⁵⁾, then 47 km south of the northern edge of the ice shelf (currently, the northern edge is ~20 km farther north than then). On 19 April 1978, 32 emperor penguins approached the camp from the north and remained overnight (Image G). The following day, another 150 penguins were observed, also coming from the north and continuing southwest towards Masson Island. Two days later, the penguins returned and went north again. The scientists assumed that the penguins tried to reach the Haswell Island colony, and noted that this would have been impossible since the western edge of the shelf had experienced significant losses in January-February destroying any access route that may have existed ⁽⁵⁾. It is unlikely that the penguins would have tried to access the Haswell Island colony via the ice shelf. They were probably looking for the colony that had been reported in 1960.</p> <p>In 2022, the colony was first seen in a satellite image on 2 April; it had relocated back onto the fast ice north of iceberg C-31B. It is unknown whether access ramps had changed. As the season progressed, the colony split into three groups ~3.2–3.5 km apart. On 6 December 2022, the Shackleton Ice Shelf colony was photographed from the air. The first chicks had already started to fledge; some small groups of fledglings were seen among adults near the ice edge. The colony count probably presents a slight underestimate of the colony size. It is unknown how many chicks had already departed by then.</p> <p>As in 2022, the colony occupied the fast ice again in 2023 right next to the cliffs of C-31B. The first satellite image showing a small group of penguins was taken on 28 March 2023. Much of the fast ice north of C-31B had not yet formed, and the fast ice edge was only 0.4 km from the birds. By 13 December 2023, the penguins had moved 7 km to the west.</p>
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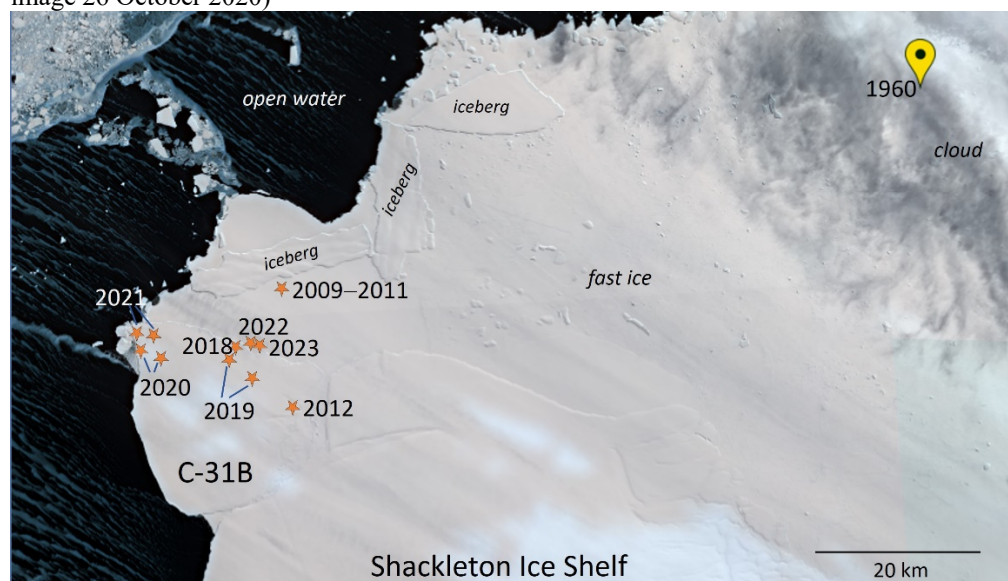
Population estimates/counts	~10,000 adults (26 October 1960) ⁽¹⁾ ; 6,471 adults (10 October 2009) ⁽³⁾ ; 1,339 adults and 10,738 chicks (6 December 2022) ⁽⁶⁾
References	⁽¹⁾ Korotkevich YS (1964) The distribution of emperor penguins. Soviet Antarctic Expedition Information Bulletin 4, 371–375 ⁽²⁾ Fretwell P, Trathan PN (2009) Penguins from space: faecal stains reveal the location of emperor penguin colonies. <i>Global Ecology and Biogeography</i> 18, 543–552 ⁽³⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751 ⁽⁴⁾ Fretwell P, Trathan PN, Wienecke B, Kooyman GL (2014) Emperor penguins breeding on iceshelves. <i>PLoS ONE</i> 9, e85285 ⁽⁵⁾ Kamenev VM, Savatyugin LM (1980) Emperor penguins on the Shackleton Ice Shelf. Soviet Antarctic Expedition Information Bulletin (Russian) 100:133 ⁽⁶⁾ This study

Images

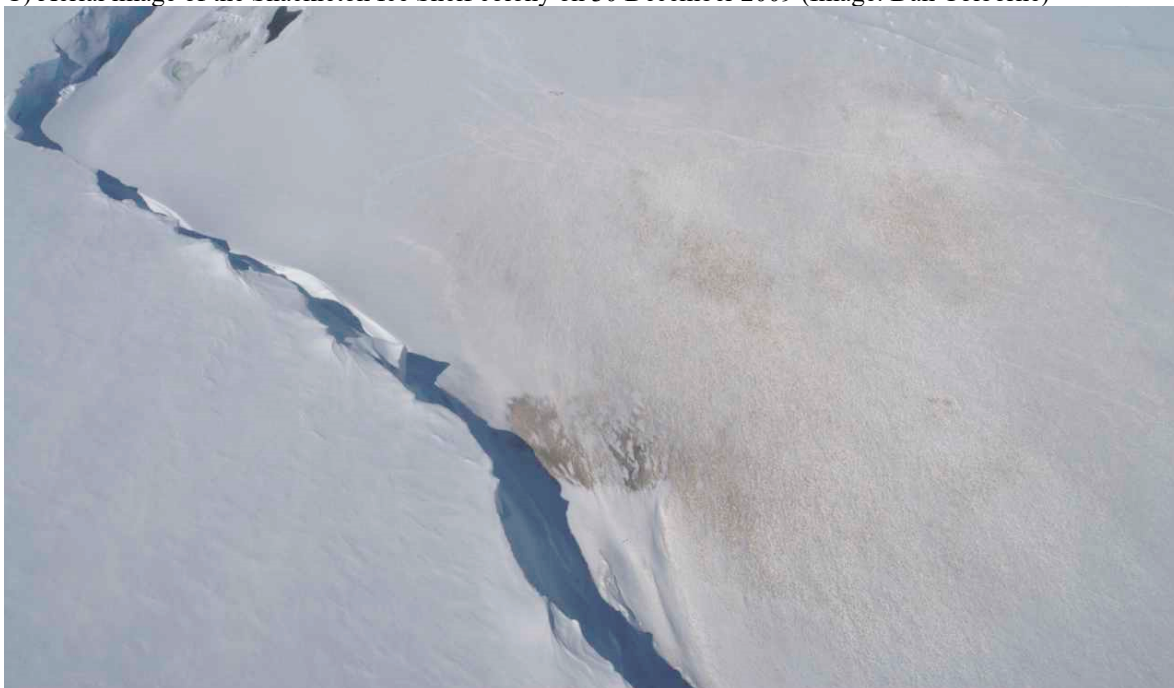
A) Fast ice from Shackleton Ice Shelf to Vincennes Bay; the red marker indicates colony location on 22 October 2014 (Image: NASA Worldview)



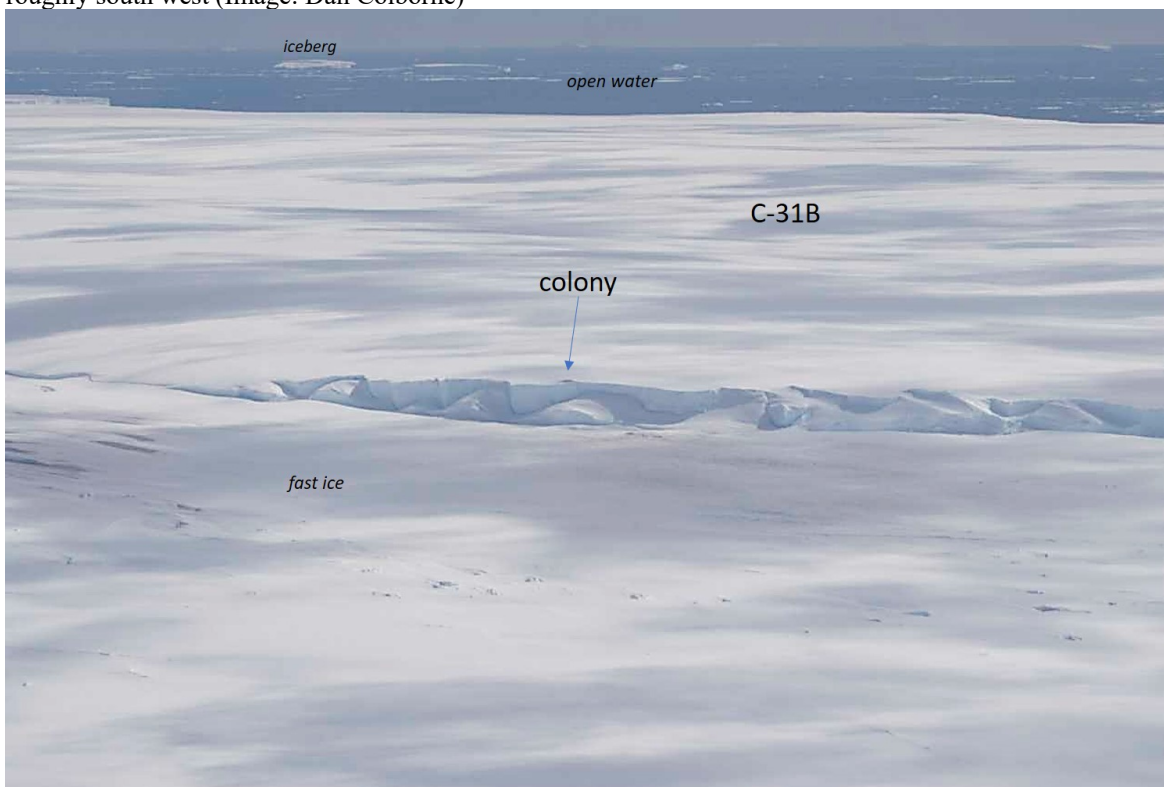
B) Historical locations of emperor penguins at the Shackleton Ice Shelf (Background image 26 October 2020)



C) Aerial image of the Shackleton Ice Shelf colony on 30 December 2009 (Image: Dan Colborne)



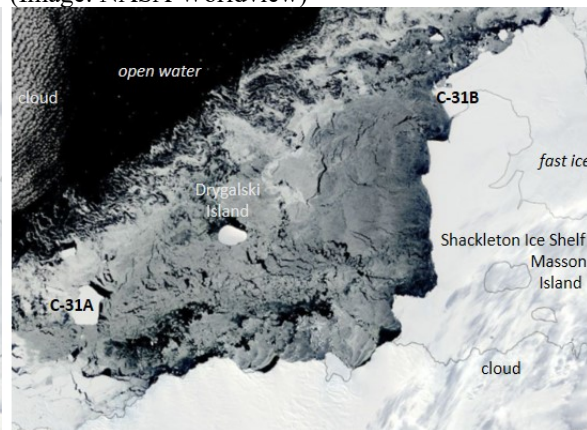
D) Aerial image of the Shackleton Ice Shelf colony on top of iceberg C-21B on 2 January 2010, looking roughly south west (Image: Dan Colborne)



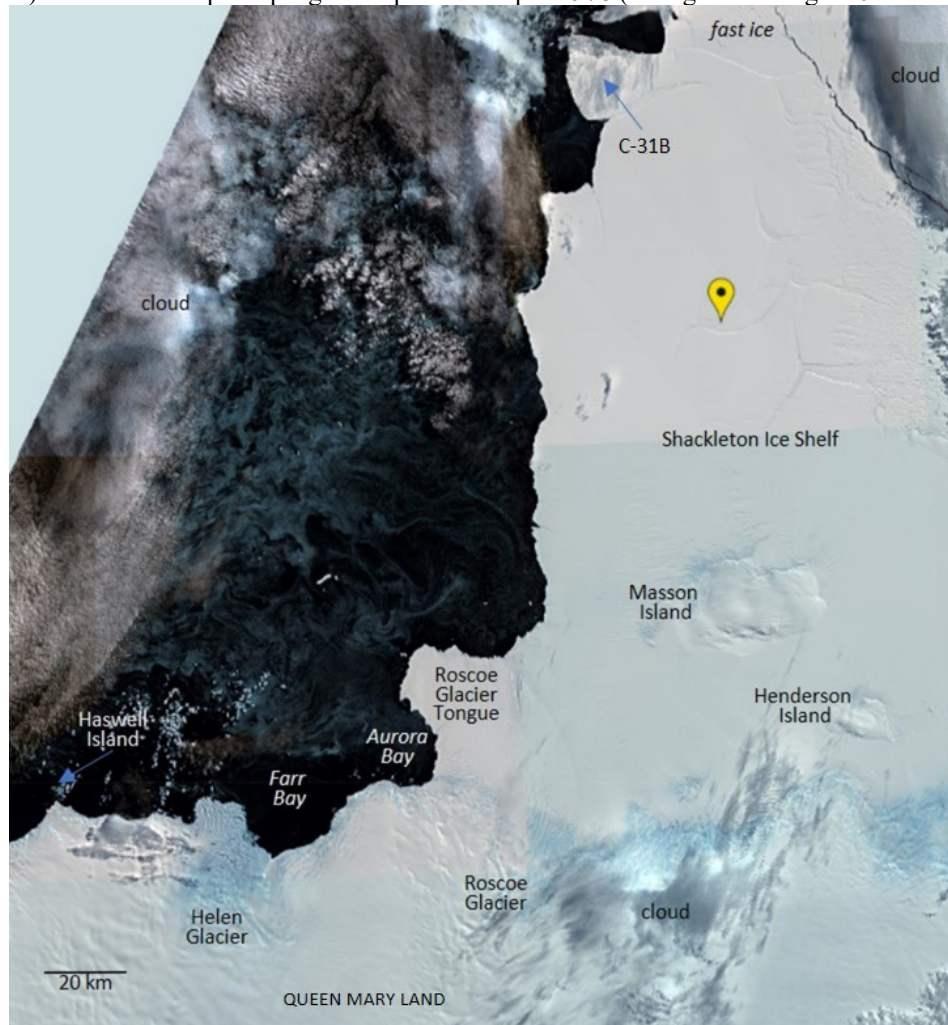
E) Iceberg C-31 on 14 February 2003 (Image: NASA Worldview)



F) C-31 has split into two bergs, 21 March 2005 (Image: NASA Worldview)



G) Location of emperor penguins reported in April 1978 (Background image: 10 March 2020)



Colony	17. Bowman Island
Region	Knox Coast, Wilkes Land (100.5°E–136°E), East Antarctica
Recent location	65.28°S, 103.18°E
Date	1 November 2023
Interannual colony movement	2–3 km <i>Note: historically, the colony moved ~14 km east (Image C)</i>
Size	~3,000 breeding pairs
Fast ice extent	<p>The fast ice can extend from the northern side of Mill Island (65.52°S, 100.67°E), ~30 km north and 60–75 km east of Bowman Island (65.20°S, 103.00°E) to 105.05°E. From here, fast ice occurs as a narrow band (~7–20 km) along the coast past the Underwood Glacier (107.93°E) until it reaches Brooks Point (66.76°S, 108.42°E) in southern Vincennes Bay (66.5°S, 109.5°E). Here, it broadens again to a width of ~40 km. It may cover <20,200 km² (Image A).</p> <p>The fast ice on the western side of the Bowman appears less stable than on its eastern side. In some years, it can break out early (Image B).</p> <p>Connecting Bowman Island to the continent is the small Conger Ice Shelf that is fed by four glaciers (from west to east: Kiselëva, Glenzer, Conger and Angarskij glaciers). The ice shelf tended to hold in place the sea ice on its eastern side.</p>
Ice break out/formation	The fast ice tends to break out first in Vincennes Bay and along the narrow strip of ice off the coast. This can occur as early as late November; some ice is also lost on the eastern side of the large western part. In some years (e.g. 2010–2013), the western ice part persists over summer. In April 2014, most of the ice had disappeared. In 2016, a large area of fast ice persisted east of Bowman Island but the penguin area had become ice free in February, and started to reform in early April.
Maximal distance to fast ice edge	31 km (7 October 2020)
Minimal distance to fast ice edge	0.8 km (16 December 2020)
Average distance to fast ice edge	23.0 ± 6.9 km
Early fast ice breakout	None observed
Distance from coast	<0.5 km
Colony description	<p>The colony sits right next to the eastern side of Bowman Island, ~70 km north of the Antarctic continent. The island is ~44 km long, roughly shaped like a figure eight, and covered in ice. The Glenzer and Conger Ice Shelf (~1,200 km²) used to connect the island to the continent and formed a barrier to pack-ice drifting from the east. The ice shelf collapsed around 15 March 2022.</p> <p>West of Bowman Island is Milozovora Bay (65.7°S, 102.7°E) where the sea ice concentration is high in winter, but the ice is unstable. A dense cluster of icebergs occurs to the north of Bowman Island, and east of the area previously taken up by Glenzer and Conger Ice Shelf. At longitude 104.3°E, a band of icebergs extends >80 km from the continent to the edge of the fast ice until it collapsed in March 2022 (see History).</p>
History	<p>Bowman Island was discovered on 28 January 1931 during the British, Australian and New Zealand Antarctic Research Expedition (BANZARE) led by Douglas Mawson ⁽¹⁾, but emperor penguins were not sighted ⁽²⁾. It was very late in the season, and the ship was a good distance (~35 km) from the island ⁽¹⁾.</p> <p>Members of the Fifth Soviet Antarctic Expeditions sighted a colony on a survey flight at 65.08°S, 102.83°E on 26 October 1960. The colony was located ~5 km north of the island at its western side (Image C). The Russians estimated some 3,000 adults in the colony at the time ⁽³⁾.</p> <p>On 4 January 1993, the colony was visited by a tourist vessel, and 28 chicks and 30–35 adults were counted ⁽⁴⁾. A precise location was not provided, only the comment that the</p>

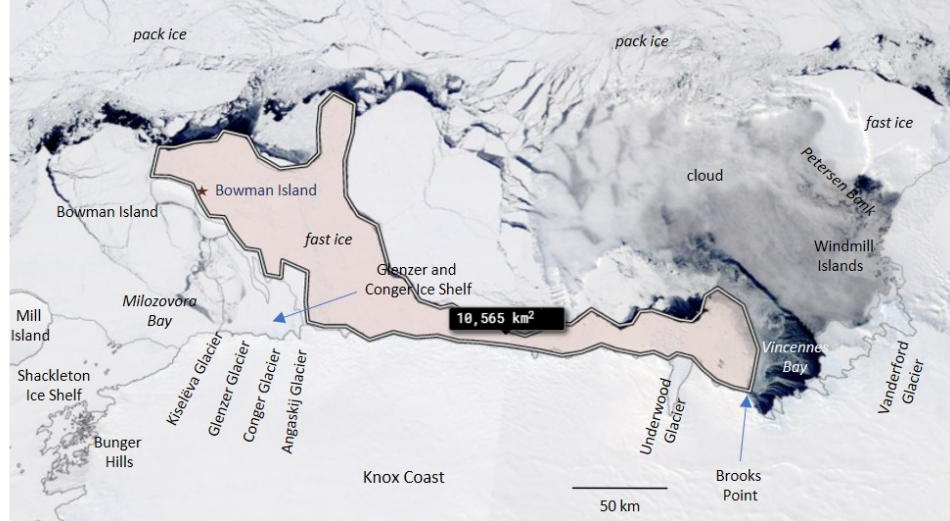
History	<p>penguins were ~2 km east of the island ⁽⁴⁾. They would have been part of the colony, which would largely have been abandoned so late in the breeding season.</p> <p>The satellite survey provided a population estimate of 1,609 adults on 26 October 2009 ⁽⁵⁾.</p> <p>If fast ice conditions in 1960 were similar to today's, the colony would have been situated on the fast ice extending east from the Shackleton Ice Shelf and Mill Island (Image C). Since at least 2018, the colony has moved ~20 km farther south and ~27 km southeast to the eastern side of Bowman Island (Image C).</p> <p>The colony location has also shifted in recent years by ~10 km along the northeastern coast of Bowman Island. The fast ice in Milozovora Bay is comparatively unstable (Image D). It is thus not surprising that the penguins avoid the western side of the island. However, in December 2020, the fast ice remained in Milozovora Bay but broke out in the northeast of Bowman Island. This reduced the distance from the colony to the fast ice edge to <1 km.</p> <p>In 2022, the ice conditions east of the island were generally similar to those in previous years. The distance to the fast ice edge decreased more rapidly than in other years in November reducing from 21.4 km on 16 November to 12.1 km by 6 December. However, the colony was not at threat.</p> <p>In 2023, the fast ice conditions were again more stable. On 31 December 2023, the colony was still 21 km from the fast ice edge. By 23 March 2023, the residual fast ice south of the island had disintegrated. In April, fast ice developed on the southern and eastern sides of the island, including in the colony area.</p> <p>The small ice shelf formed by the Glenzer and Conger glaciers used to cover ~1,200 km², and connected Bowman Island to the continent. It formed a barrier to the pack-ice drifting in from the east. By February 2019, it had lost ~125 km² on its western side, and by February 2020 had contracted east by 1.4 km with an associated ice loss of ~33 km². A year later, a further 215 km² were lost at its western margin halving the width of its northern neck from 10 km to 5 km (Image E). It collapsed entirely within a few days in March 2022 ⁽⁶⁾ (Image F).</p> <p>The loss of this small ice shelf appeared to have had no effect on the colony in 2022 or 2023; the fast ice had formed on time, and its extent was similar to that in previous years. It remains to be seen whether the loss of the small ice shelf will affect sea ice dynamics and the breeding platform of the Bowman Island colony in future.</p>
Population estimates/counts	<p>~3,000 adults (26 October 1960) ⁽³⁾;</p> <p>30–35 adults and 28 chicks (4 January 1993) ⁽⁴⁾;</p> <p>1,609 adults (26 October 2009) ⁽⁵⁾;</p> <p>399 adults and 2,372 chicks (6 December 2022) ⁽⁷⁾ <i>Note: chicks had already started to fledge</i></p>
References	<p>⁽¹⁾ Jacka F, Jacka E (editors) (1988) <i>Mawson's Antarctic diaries</i>. Sydney: Allen and Unwin Australia</p> <p>⁽²⁾ Falla RA (1937) <i>Birds</i>. Vol II, BANZ Antarctic Research Expedition 1929–1931 Reports – Series B, BANZAR Expedition Committee, Adelaide</p> <p>⁽³⁾ Korotkevich YS (1964) The distribution of emperor penguins. <i>Soviet Antarctic Expedition Information Bulletin</i> 4, 371–375</p> <p>⁽⁴⁾ Todd FS, Splettstoesser JF, Ledingham R, Gavrillo M (1999) Observations in some emperor penguin <i>Aptenodytes forsteri</i> colonies in East Antarctica. <i>The Emu</i> 99, 142–145</p> <p>⁽⁵⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p> <p>⁽⁶⁾ Lu D (2022) Satellite data shows entire Conger Ice Shelf collapsed in Antarctica. <i>The Guardian</i>, 25 March 2022; https://www.theguardian.com/world/2022/mar/25/satellite-data-shows-entire-conger-ice-shelf-has-collapsed-in-antarctica</p> <p>⁽⁷⁾ This study</p>

Images

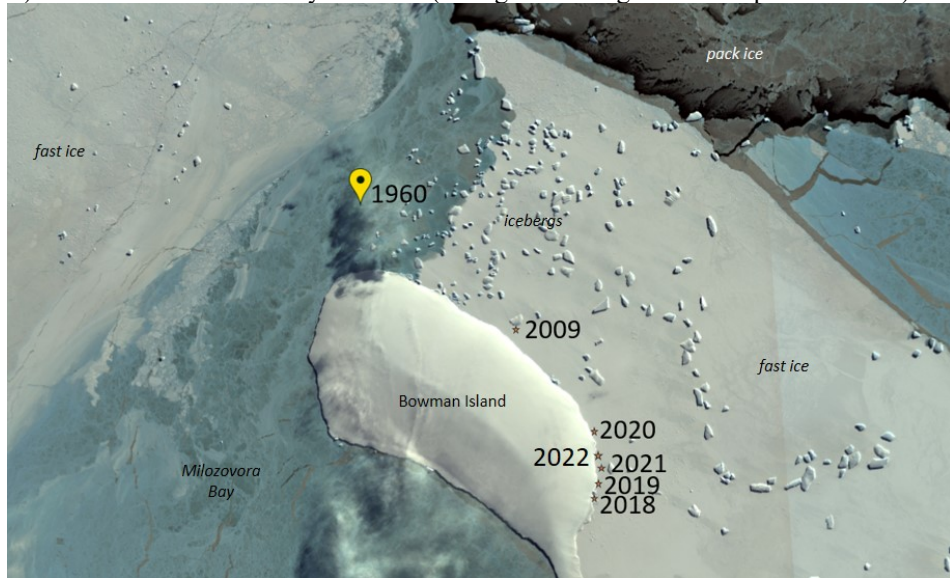
A) Regional fast ice along the Knox Coast on 20 September 2018 (Image: NASA Worldview)



B) Regional fast ice along the Knox Coast on 16 October 2021 (Image: NASA Worldview)



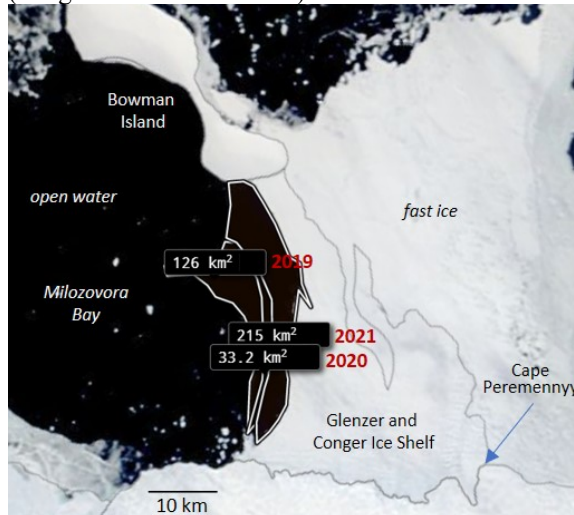
C) Historic and recent colony locations (Background image from 3 September 2019)



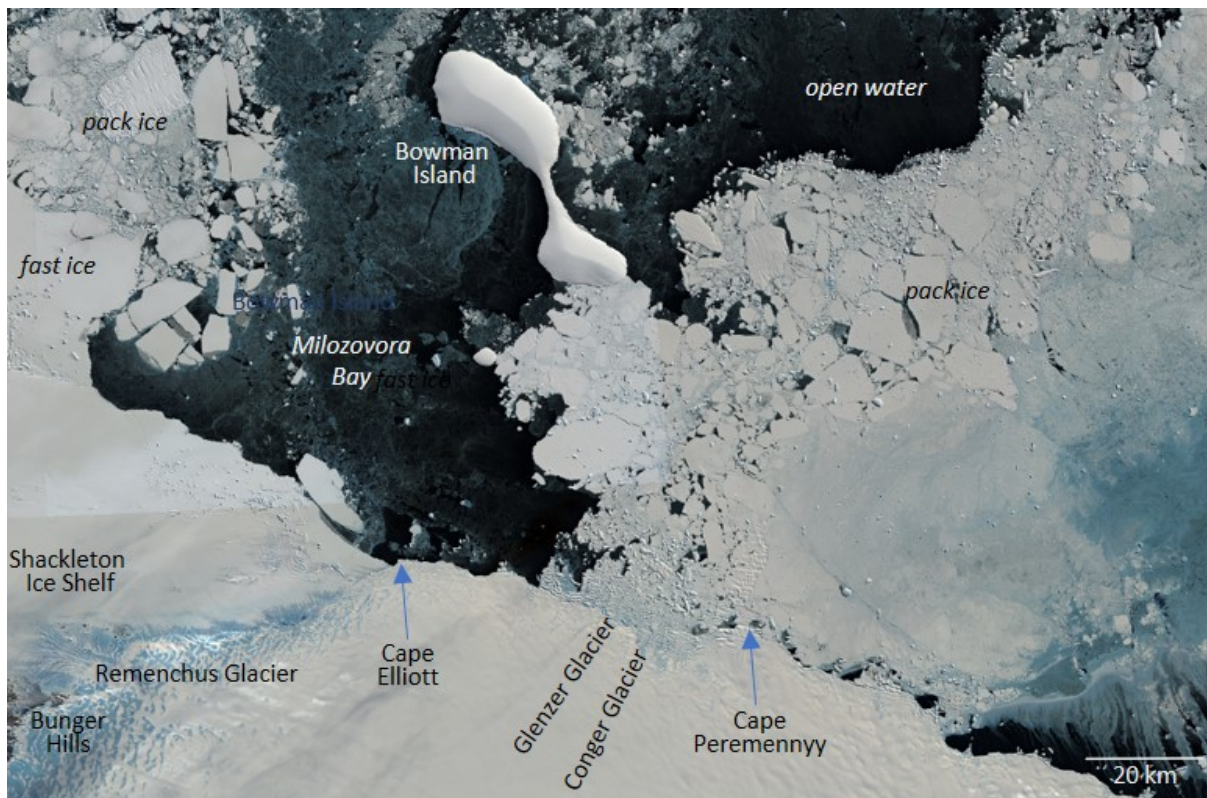
D) Ice breakout in Milozovora Bay, 25 October 2021 (Image: NASA Worldview)



E) Area largely ice-free in summer, 27 February 2021 (Image: NASA Worldview)



F) The Glenzer and Conger Ice Shelf finally collapsed in March 2022



Colony	18. Petersen Bank
Region	Budd Coast, Wilkes Land (100.5°E–136°E), East Antarctica
Recent location	65.87°S, 110.22°E
Date	10 November 2023
Size	<1,000 breeding pairs
Interannual colony movement	1–6 km
Fast ice extent	In October, the fast ice usually stretches from Cape Folger (66.12°S, 110.75°E) along roughly 110 km of coast towards Cape Poinsett (65.75°S, 113.19°E). The edge of the fast ice exposed to the sea is about three times (>330 km) longer than the edge attached to the coast. It covers around 6,000 km ² , and extends nearly 80 km north at the western side, and >50 km at the eastern side. The narrowest part is approximately in the middle of this ice sheet and measures only ~20 km (Image A).
Ice break out/formation	The eastern side of this stretch of fast ice can start to break up in early November and may disappear entirely by early March. Local fast ice losses may occur early in the vicinity of the colony. In summer, the fast ice usually disappears completely (Image B).
Maximal distance to fast ice edge	13.9 km (21 October 2020)
Minimal distance to fast ice edge	0.6 (18 November 2018)
Average distance to fast ice edge	7.0 ± 3.7 km
Early fast ice breakout	possibly 23 November 2019, 16 December 2020, 15 December 2022, 15 December 2023
Distance from coast	~34 km
Colony description	The colony is situated on the fast ice in the Mawson Sea. Petersen Bank, a shallow (~200 m) submarine bank is the most distinct geographical feature in the area. The penguins occupy an area at the western side of this fast ice, ~40 km off the coast, and are usually <8 km off the fast ice edge. At the western side, the fast ice is prone to breaking off during storm events. This reduces the distance the penguins have to walk to the water's edge. For example, on 12 October 2018, the colony was 7 km from the ice edge. Ten days later, the distance was only 1.8 km.
History	<p>Emperor penguins are occasionally encountered in the Windmill Islands during summer. For many years, they were described as “a regular summer visitor”⁽¹⁾.</p> <p>On 3 November 1994, during a helicopter flight during the station's resupply, an emperor penguin colony was noted on Petersen Bank at 65.93°S, 110.20°E⁽²⁾. A population estimate was attempted on the ground; ~2,000 chicks and at least 1,000 adults were thought to be present. The colony location among loosely grouped icebergs was quite unsheltered from the easterly winds. At the time of the visit, the penguins were only about 5 km from open water. The fast ice was heavily compacted and apparently several meters thick⁽²⁾. Emperor penguins were in the area again on 24 April 1995.</p> <p>Although Casey station has been occupied year-round since 1959, it took nearly four decades to discover this colony. The fast ice is difficult to access from the station even in winter. East of Casey, the ice is unreliable and access via the plateau is not possible. Had it not been for an ice-bound resupply vessel, the discovery of this colony may have occurred even later.</p> <p>The colony was not found during the 2009 satellite survey. It was assumed that the image had been taken too late in the season and the penguins had already left the area⁽³⁾. Based on our observations, in 2018–2021 the colony has been in the same area as in 1994, and was visible in late November/early December in 2019–2021⁽⁴⁾. It is unknown whether the penguins had indeed left early, whether snow may have obscured the faecal stains, or whether the ice in the colony area broke out prematurely.</p> <p>On 16 December 2014, the colony was photographed from the air; 110 adults and 635 chicks were counted. However, given the time of year and the presence of fledglings, an unknown number of young penguins must have already departed by then.</p> <p>In 2018, only six cloud-free Sentinel2 images were available for this colony. The fast ice</p>

History	<p>over Petersen Bank tends to consist of ice floes that freeze together. This makes for a rough and uneven surface. On 30 August 2018, the colony was at the edge of this rough fast ice; new, smooth, thin ice stretched over 10 km to the west (Image C). A month later, the distance from the colony to open water had reduced to ~8.5 km, and by 16 October distance from the August position of the colony to the edge of the fast ice was <1 km. The smooth ice had disintegrated. The penguins had moved ~560 m southeast where they were only ~570 m from open water. A large tide crack had formed only ~130 m west of the colony. By 11 November, the ice on the western side of the tide crack had broken out. The stains of the colony were faint, and it is unclear how many penguins were still in the area. It seems that at least some had moved northeastwards and away from the water's edge. Remaining close the edge is a high-risk strategy as a storm can quickly destroy the fast ice.</p> <p>In 2019, the colony was near the same grounded icebergs as in 2018, and <3.5 km from the fast ice edge. In September, nearly 4 km of relatively thin, new ice occurred west of the colony. Towards the end of October, the fast ice retreated west of the colony which was now only ~3.1 km from the fast ice edge (Image D). About a month later, the colony area was open water (Image E). It is difficult to know whether this break-out affected the colony. Given the short distance to the ice edge, it is possible that the penguins had raised (most of) their chicks to fledging by then.</p> <p>The following year, 2020, the colony split into three groups. The largest one had gathered on an ice floe (~540 x 400 m) by 11 April. At this time, the sea ice comprised a jumble of large floes, and had not yet connected to the coast. It became fast ice only in early May.</p> <p>In late August, the largest group was ~4 km farther east than in April. This movement may have at least in part been due to the movement of the ice floe. Two small groups were ~4.4 km southwest and ~7 km south of the large group. At least one of those may have also occupied an ice floe in mid-April. The three groups appear to have remained separated from each other throughout the season. All occurred in open areas of ice where they were exposed to the easterly winds.</p> <p>By 27 November 2020, the colony spread out over ~3 km, and the nearest penguins were only about 2.5 km from the fast ice edge. By 16 December, the ice at the colony area was gone and the edge of the fast ice was ~2.2 km east of the penguins' location. Whether the penguins were still present or not was difficult to determine.</p> <p>In April 2021, two groups about 1 km apart formed about 2 km from the 2021 position, and remained in the general area throughout the season. As in previous years, the colony was within a few kilometres of the edge of the fast ice. In November, the penguins moved eastwards away from the edge. Throughout November/December, the fast ice edge appeared to be unchanged in 2021.</p> <p>From April to November 2022, the colony moved ~6 km east. The fast ice edge was east of its November 2021 position, and the regional fast ice extent was greatly reduced. In October 2021, the fast ice covered nearly 6,000 km² and extended from 110.9°E to 112.9°E (Image A), compared to around an area of 3,000 km² in October 2022 (reaching from 110.8°E to 111.5°E). By the end of November, only some 1,300 km² of fast ice were left; the colony was < 1.5 km from the ice edge. Aerial images take on 28 December 2021 showed no chicks and only a handful of adults were present.</p> <p>On 2 December 2022, the colony was overflowed and photographed. Adults, fledglings and large chicks occurred in several groups, but since fledglings appeared to have left the colony already, the count was incomplete.</p> <p>In 2023, the colony lost its breeding platform in mid-December. Extensive cloud cover made observations difficult, but the ice edge was <3 km from the nearest penguins from September to ~13 December when the ice suddenly broke out. It is unknown to what extent these events affect breeding success in this colony, but some chicks are likely to have perished because of these breakout events.</p>
Population estimates/counts	<p>~1,000 adults and ~2,000 chicks (3 November 1994) ⁽²⁾; <i>0 birds</i> (24 November 2009) ⁽³⁾; 110 adults and 635 chicks (16 December 2014) ⁽⁴⁾</p>

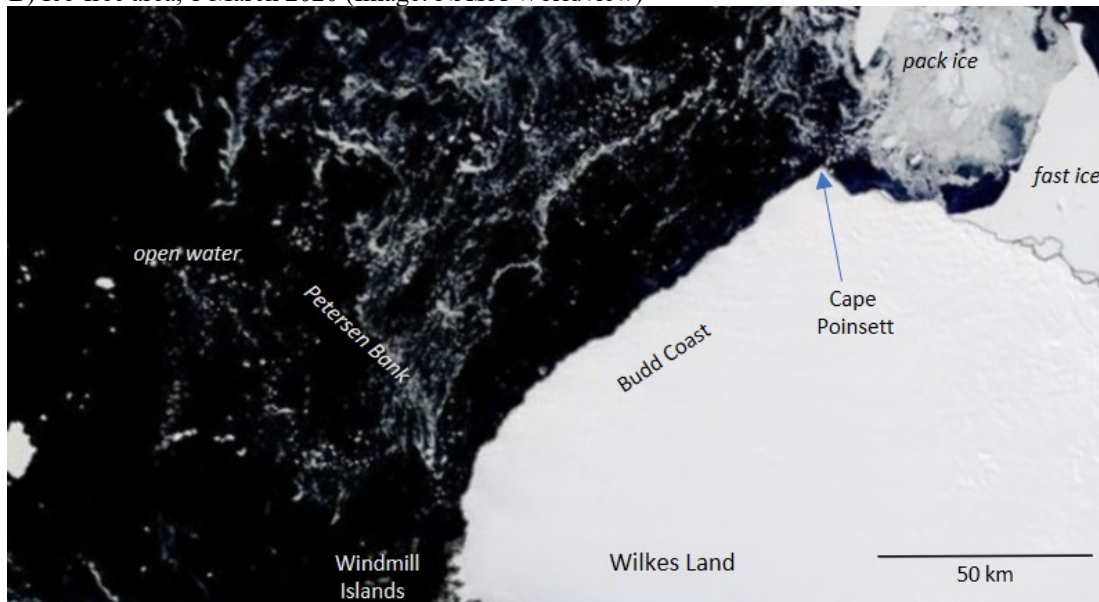
References	<p>⁽¹⁾ Cowan AN (1979) Ornithological studies at Casey, Antarctica, 1977–1978. <i>Australian Bird Watcher</i> 8, 69–90</p> <p>⁽²⁾ Melick D, Bremmers W (1995) A recently discovered breeding colony of emperor penguins (<i>Aptenodytes forsteri</i>) on the Budd Coast, Wilkes Land, East Antarctica. <i>Polar Record</i> 31, 426–427</p> <p>⁽³⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p> <p>⁽⁴⁾ This study</p>
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Images

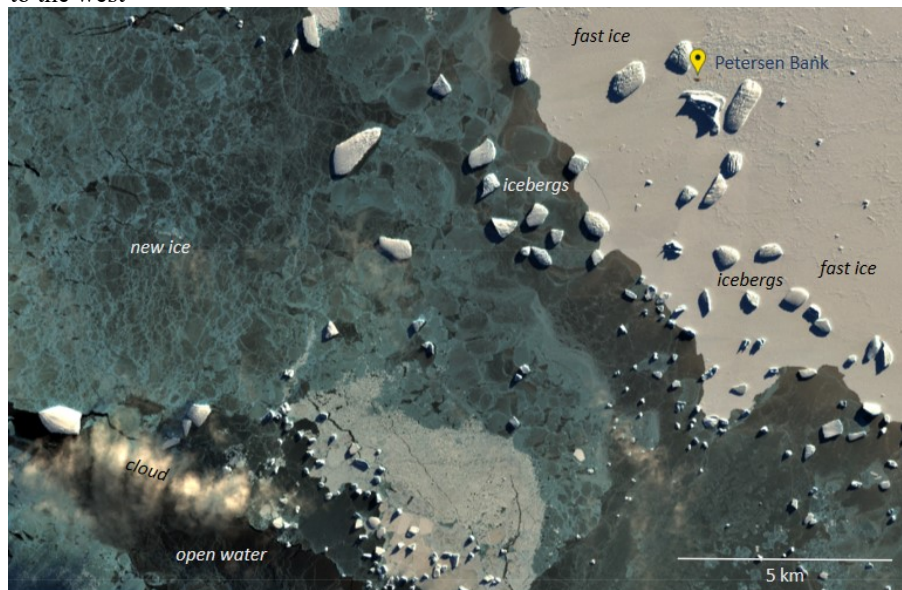
A) Regional fast ice extent, 25 October 2021 (Image: NASA Worldview)



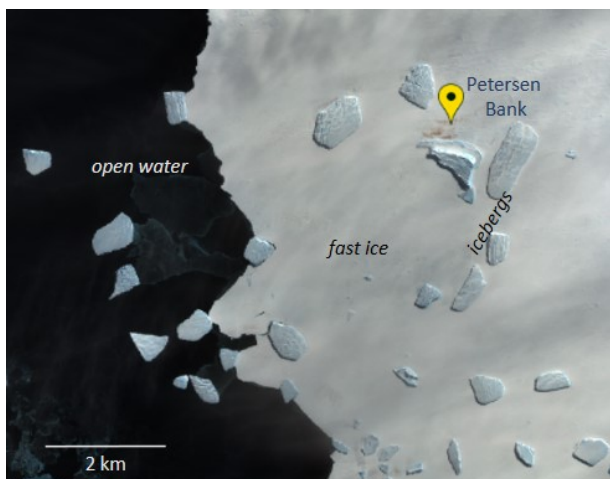
B) Ice-free area, 1 March 2020 (Image: NASA Worldview)



C) Colony location and distance to fast ice edge on 25 August 2019. Note new ice to the west



D) Colony location and fast ice edge on 27 October 2019



E) Open water at the colony location on 23 November 2019



Colony	19. Cape Poinsett
Region	Budd Coast, Wilkes Land (100.5°E–136°E), East Antarctica
Recent location	65.79°S, 113.57°E
Date	10 October 2023
Interannual colony movement	1–5 km
Size	Unknown
Fast ice extent	In September 2013, the colony area was at the north western point of a fast ice sheet that extended from Cape Poinsett south eastwards, past the Totten Glacier (116.4°E) to Cape Southard (65.58°S, 121.77°E), nearly reaching the Dalton Ice Tongue (121.8°E) in the east (Image A). At the time, its area measured >44,000 km ² . In September 2015, the fast ice covered <12,000 km ² (Image B). Since then, the eastern edge of this fast ice sheet has rarely extended beyond the Totten Glacier.
Ice break out/formation	The fast ice in this region is extensive, but in the northwestern area where the colony tends to occur, it appears to be rather unstable (Images C to F). From 2010 to 2021, the fast ice tended to persist until late November/early December on a large scale. Ice breakout and formation vary notably from year to year.
Maximal distance to fast ice edge	11.2 km (3 September 2018)
Minimal distance to fast ice edge	0 km (15 October 2022)
Average distance to fast ice edge	3.1 ± 2.8 km
Early fast ice breakout	17 December 2020; 14 October 2021; 15 October 2022
Distance from coast	<0.1 km
Colony description	The colony occurs on the fast ice at the eastern side of Cape Poinsett, the northernmost point of the Budd Coast. At the cape's eastern side, the coastline turns sharply south via Cape Bjalokosa (66.07°S, 114.13°E) to the usually ice-filled Colvocoresses Bay, north of the Williamson Glacier Tongue (66.08°S, 114.83°E). The location of the colony is often <5 km from the edge of the fast ice, even in September/October.
History	<p>Not much is known about this small colony as it was discovered only recently in a satellite image at 65.78°S, 113.24°E in November 2019 ⁽¹⁾. Incidentally, the colony occurred at 65.78°S, 113.242°E already in September 2018.</p> <p>In 2019, a dark stain was visible on 25 August nestled against the ice cliff. During September 2019, the colony moved ~200 m away from the ice cliff and ~300 m southeast of the location in August. By the end of September, it had shifted ~350 m north of the August location into a gap between the ice cliff and a small berg (~0.6 km²). Here, it was roughly 3 km from the fast ice edge. However, new ice had formed that increased the distance from the colony to open water (large tide cracks) to just over 13 km. Towards the end of September, most of this ice had gone, reducing the distance to ~5.5 km. Throughout October, the colony continued to move around in this area (~0.2 km²). By mid- to late November, it was ~2 km southeast of the location in August at 65.81°S, 113.28°E, still only ~3.3 km from the fast ice edge. By 3 December 2019, it had moved another ~2 km east; the distance to the fast ice edge now measured only ~2.8 km.</p> <p>In 2020, the situation was similar to 2019 in that the colony occurred again between the same small iceberg and the ice cliff. In mid-December 2020, the small berg started to drift away. In March 2021, another very small berg (~0.1 km²) had attached in roughly the same position as the previous berg, and in September 2021, the colony was again between the berg and the ice cliffs at 65.77°S, 113.24°E. The polynya had formed to the north, and the penguins were less than 100 m from the fast ice edge. Open water also existed east of the colony. Around 14 October 2021, much of the fast ice broke out south of the colony area, and three days later the remaining ice had cracked. It is possible that at least some of penguins relocated ~1 km farther south (~65.78°S, 113.24°E) where extensive fast ice still existed, but by 27 October, there were no signs of any penguins.</p> <p>The year 2022 was also a poor one for this colony. The polynya was extensive and the colony</p>

History	<p>formed again close to the edge of the fast ice. By 7 October, hardly any fast ice was left, and by 15 October a vast area of ice had shattered, and the colony was set adrift on an ice floe.</p> <p>In 2023, frequent cloud cover, particularly in November and December, made it difficult to observe the colony. The colony was sighted at ~65.81°S, 113.28°E on 3 April. Two groups occupied a similar area to that used in 2022, while another group was ~1.3 km farther north, and was 3 km from the ice edge. By 20 September, most penguins appear to have moved ~2 km north and stayed in this location at least until 9 November; a faint stain was still visible ~1.8 km to the south. It is unknown whether all groups merged at some stage.</p> <p>Sometime in mid-December, ~680 m ice was lost off the fast ice edge. The colony location barely changed from mid-September onward and the ice at the colony location was still present on 19 December.</p> <p>In December 2023 and January 2024, >9,000 km² of fast ice area remained east of Cape Poinsette. In comparison, in January 2022 and 2023, most ice had broken up, and January 2021, the fast ice had disappeared. Although extensive fast ice exists in the region, it is not equally stable from year to year. Also, the loss of even a few square kilometres of fast ice is enough to destroy the colony area because of its vicinity to the ice edge (Image D & E).</p>
Population estimates/counts	None
References	⁽¹⁾ Fretwell P, Trathan PN (2021) Discovery of new colonies by Sentinel2 reveals good and bad news for emperor penguins. <i>Remote Sensing in Ecology and Conservation</i> 7, 139–153

Images

A) Regional fast ice extent, 23 September 2013 (Image: NASA Worldview)



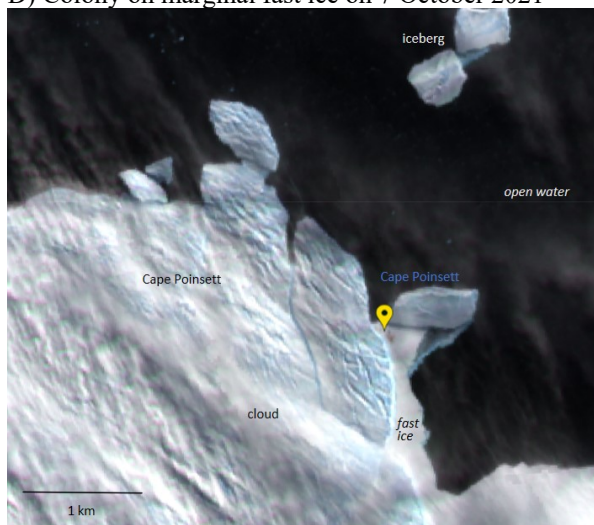
B) Regional fast ice extent on 29 September 2015 (Image: NASA Worldview)



C) Colony locations from 2018–2021 (Background image: 19 August 2019)



D) Colony on marginal fast ice on 7 October 2021



E) Colony on ice floe on 15 October 2022

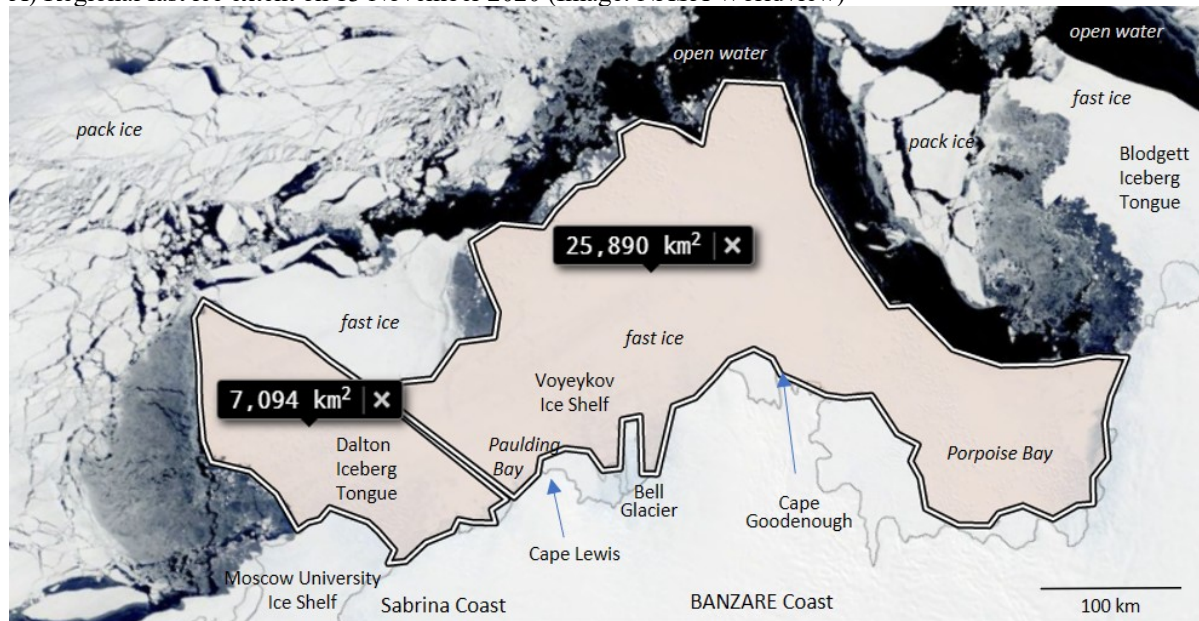


Colony	20. Sabrina Coast
Region	Dalton Iceberg Tongue, Sabrina Coast, Wilkes Land (100.5°E–136°E), East Antarctica
Recent location	66.17°S, 121.13°E
Date	27 November 2023
Interannual movement	1–6 km
Size	~4,000 breeding pairs ⁽¹⁾
Fast ice	On its eastern side, the Dalton Iceberg Tongue extends ~140 km north from the coast in Paulding Bay (66.6°S, 123.4°E). In the west, it stretches north from the eastern section of the Moscow University Ice Shelf (67°S, 121°E). West of Cape Lewis (66.5°S, 124.5°E), it meets the Voyeykov Ice Shelf which reaches east to Cape Goodenough (66.27°S, 126.12°E). The fast ice area can include Porpoise Bay (66.5°S, 128.5°E) (Image A). The Dalton Iceberg Tongue covers >7,000 km ² ; the fast ice of the Voyeykov Ice Shelf plus the ice in Porpoise Bay (east of the ice tongue) can add another 26,000 km ² . In years when fast ice is extensive, it can stretch along ~400 km of coast.
Ice break out/formation	The fast ice usually persists into late November but large chunks can break out in the east in October (Image B). In summer, the iceberg tongue may disintegrate (Image C).
Maximal distance to fast ice edge	7.5 km (13 November 2021)
Minimal distance to fast ice edge	0.9 km 22 November 2022
Average distance to fast ice edge	4.4 ± 2.0 km
Early fast ice breakout	18 December 2022; 31 December 2023
Distance from coast	~90 km
Colony description	The colony occurs on the western side of the Dalton Iceberg Tongue, ~7 km, and east of a long row of grounded icebergs. The colony is ~93 km north of the Antarctic coast and ~59 km north of the edge of the Moscow University Ice Shelf. The colony is often in rough terrain where a jumble of floes freezes together.
History	<p>The colony is situated on fast ice, a long way from the Antarctic coast. In 2014, it was discovered in a satellite image at 66.177°S, 121.058°E, and was thought to comprise 1,000–2,000 birds ⁽²⁾.</p> <p>Since 2014, it has occupied roughly the same area. On 24 September 2018, the penguins were ~2.7 km north-northwest from this position, on the eastern side of a very small iceberg (~470 x 300 m), and ~2.5 km east of the line of grounded bergs one of which they had partially occupied (Image D).</p> <p>In 2019, the penguins again utilized the same general area, but the colony had split into two groups. The first group was ~2.2 km west of the 2018 position; the second group ~7.2 south of the first group, and itself separated into two small units. Some 2.5 km east of these two groups, another stained area (~820 m long) was also visible. From 30 August to 29 September, this group seemed to have moved east to west. It is unknown whether there was any traffic between the groups, but they remained separate units for the duration of the 2019 season.</p> <p>Only one group formed in the 2020 season. Again, it was positioned on the eastern side of a very small berg, ~5 km southeast of the 2019 location. Directly south of this small berg was a fraction of a berg (~230 x 150m) that some penguins occupied in November 2020.</p> <p>By 4 April 2021, four sub-colonies had formed that remained separated throughout the season (Image E). The distances between them ranged from 2.6–5.4 km. On 18 October 2021, one group was <200 m from the fast ice edge, compared to 4.8 km of the most distant group. Vast areas of fast ice broke out at the eastern side of the ice tongue in October 2021. But the penguins were unaffected by this at the western side of the ice tongue (Image F).</p> <p>Throughout 2022, the Dalton Ice Tongue was noticeably narrower than in previous years. In September 2022, the ice tongue was only 14–20 km wide, and its northern edge was some 50 km farther south than in 2019 (Images G and H). The colony had split into three groups</p>

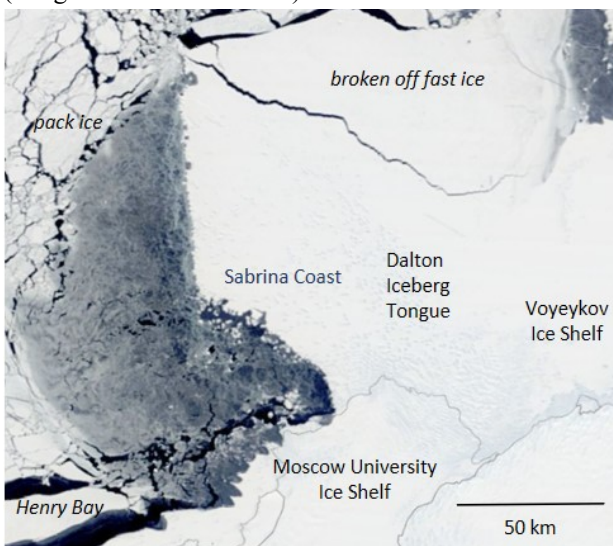
History	<p>that were up to 5.1 km east of the 2019 position. About 3.5 km east of the biggest group was a large tide crack and to the west the fast ice edge was only about 7 km from this group.</p> <p>The colony was in approximately the same area as before, but its distance to the ice edge decreased from 7.7 km in mid-September to 0.9 km in late November. This was due to change in the fast ice conditions rather than due to movement of the colony. In comparison, in 2020, the distance between colony and fast ice edge ranged from 5.9–6.6 km from September to December.</p> <p>On 2 December 2022, the colony was overflown and photographed. The images were taken through the windows of a fixed-wing aircraft and were of average quality. The colony was split into two groups. The estimates obtained indicated that in total some 672 adults and 4,234 chicks were present.</p> <p>In early December 2022, the colony seemed to fare well. The two groups spread out over 3 km. The fast ice edge was only ~200 m from the nearest penguins. By 18 December 2022, the ice in the colony area had broken up. No staining was visible. It is unknown whether any chick lives were lost due to this breakout.</p> <p>In 2023, observations were difficult due to frequent and extensive cloud cover. The colony gathered ~2 km south east of the 2022 location. From mid-September to early December, its distance from the ice edge averaged 5.9 ± 1.4 km. By 18 December, a large tide crack had opened and divided the colony area. The ice remained in place for a few more days but by 3 January 2024, the ice had gone. How these events affected the colony is unknown.</p>
Population estimates/counts	672 adults and 4,278 chicks (2 December 2022) ⁽¹⁾
References	<p>⁽¹⁾ This study</p> <p>⁽²⁾ Fretwell P, Trathan PN (2021) Discovery of new colonies by Sentinel2 reveals good and bad news for emperor penguins. <i>Remote Sensing in Ecology and Conservation</i> 7, 139–153</p>

Images

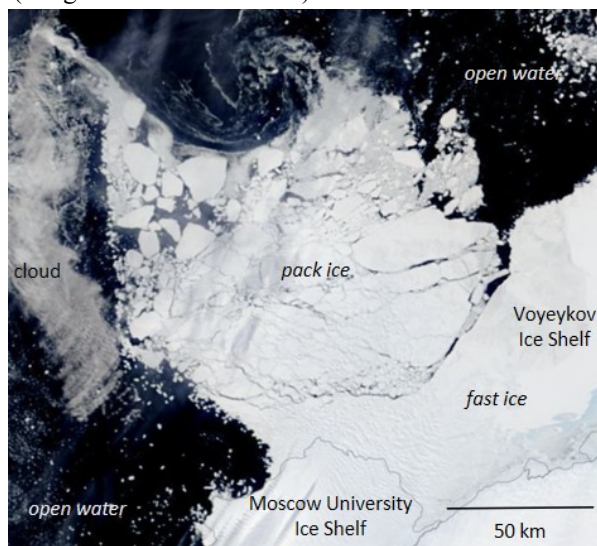
A) Regional fast ice extent on 13 November 2020 (Image: NASA Worldview)



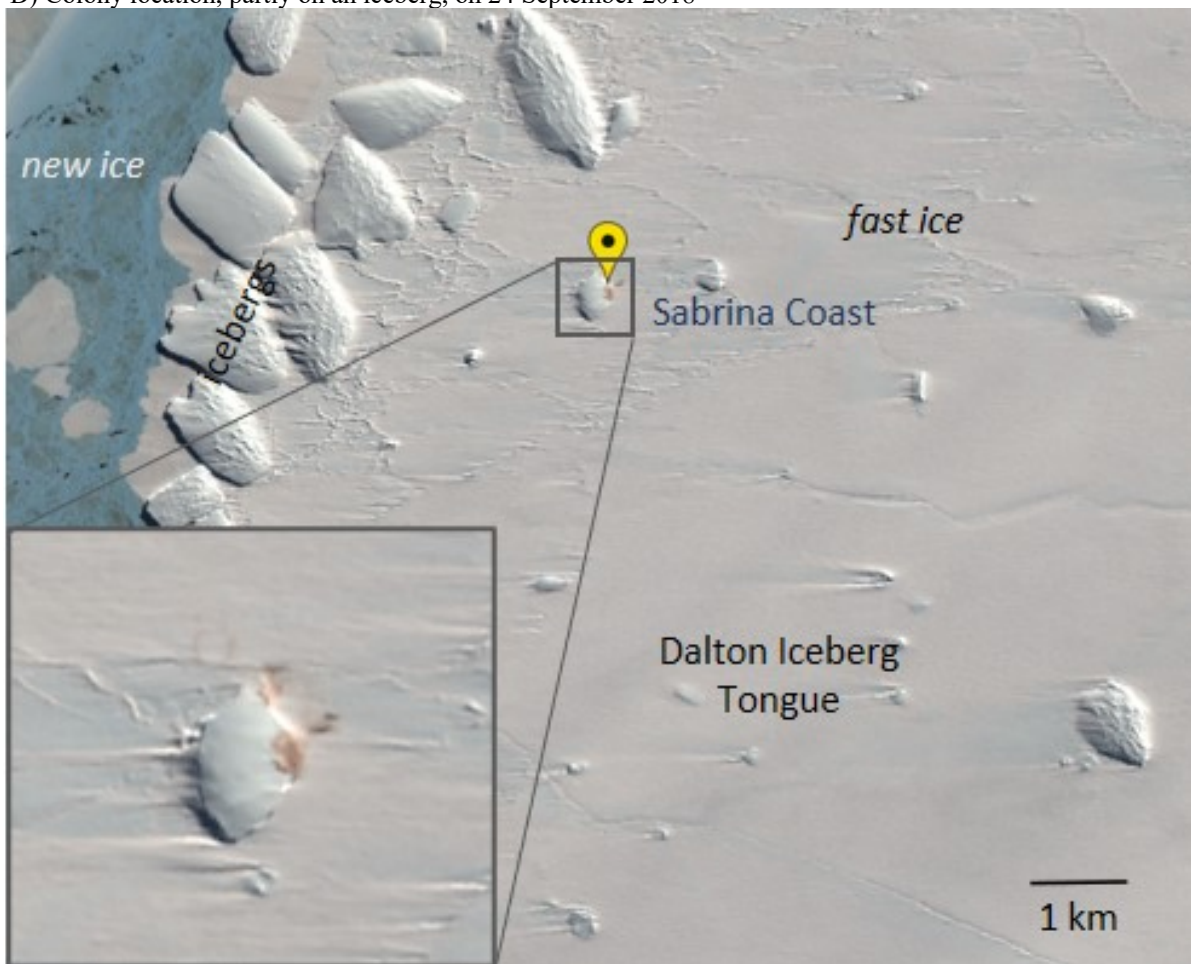
B) Dalton Iceberg Tongue on 13 November 2020
(Image: NASA Worldview)



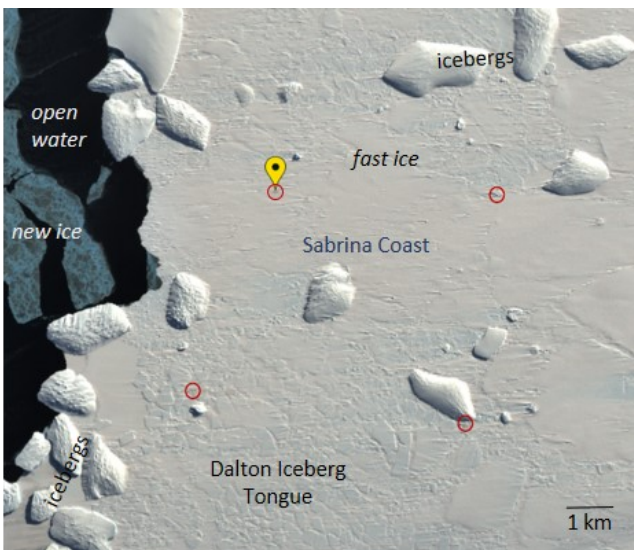
C) Disintegrated iceberg tongue on 2 February 2020
(Image: NASA Worldview)



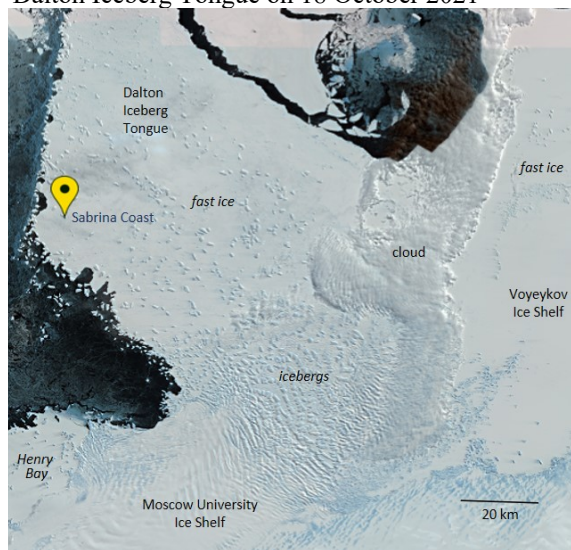
D) Colony location, partly on an iceberg, on 24 September 2018



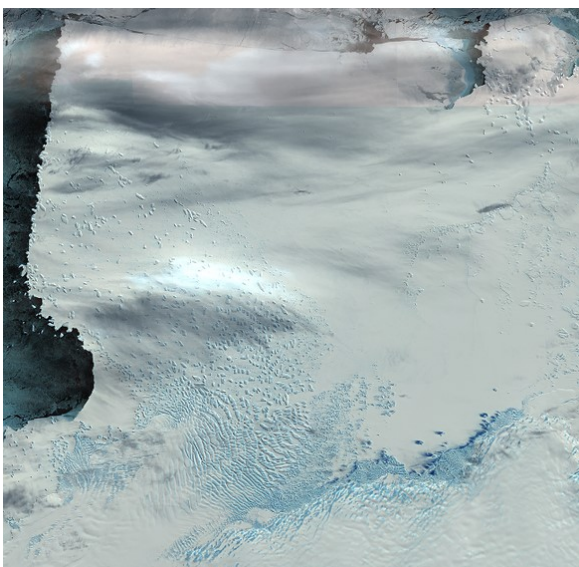
E) Locations of four sub-colonies on 8 September 2021



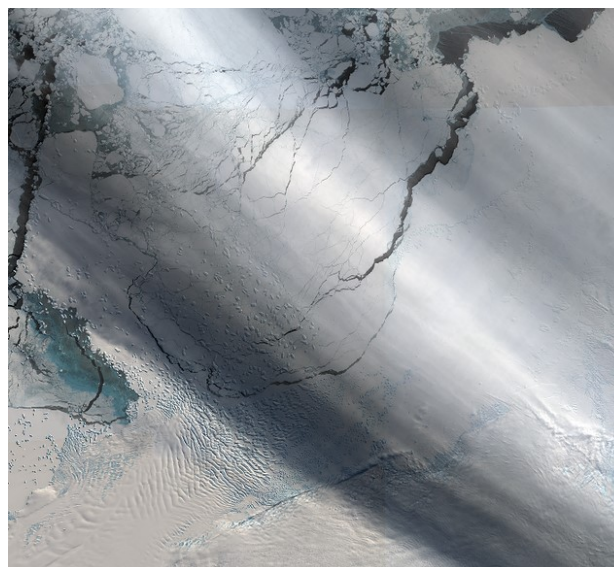
F) Colony location and fast ice extent of the Dalton Iceberg Tongue on 18 October 2021



G) Extent of the Dalton Ice Tongue on 29 September 2019



H) Dalton Ice Tongue on 13 September 2022

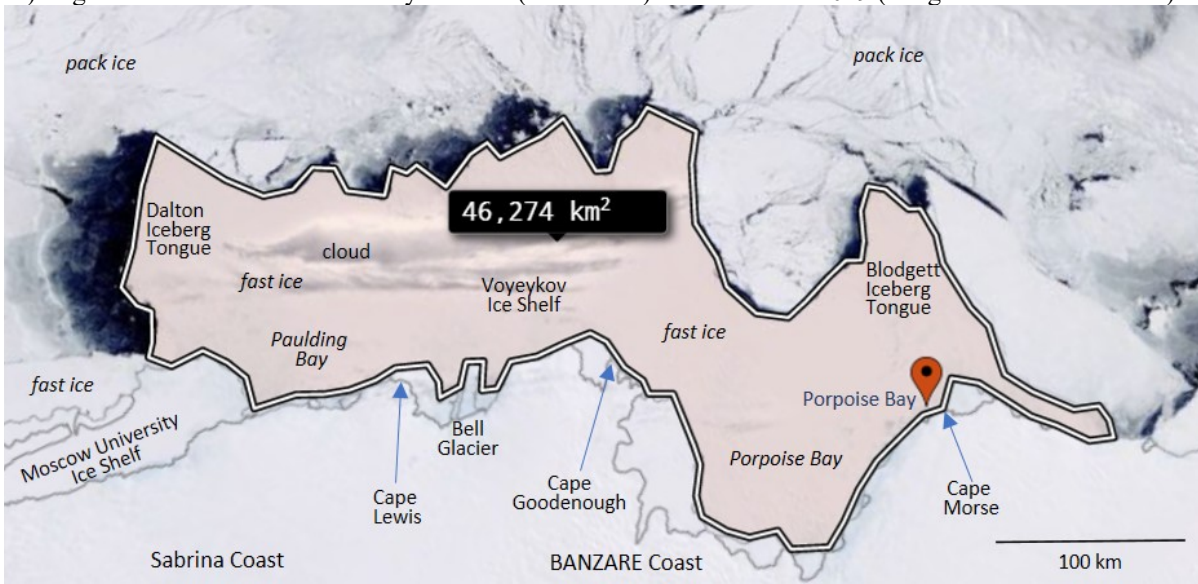


Colony	21. Porpoise Bay
Region	BANZARE Coast, Wilkes Land (100.5°E–136°E), East Antarctica
Recent location	66.27°S, 130.04°E
Date	12 October 2023
Interannual colony movement	5–13 km
Size	>1,000 pairs (2019) ⁽¹⁾
Fast ice	In this region, in heavy ice years, the fast ice can extend westwards from the Blodgett Iceberg Tongue (130°E) and join the Dalton Iceberg Tongue covering >46,000 km ² (e.g. in October 2019; Image A). However, at times the fast ice area is considerably smaller; e.g. in October 2020, the fast ice area measured >11,000 km ² . It extended from the Morse Glacier (66.27°S, 130.08°E) at the eastern side of Porpoise Bay to the May Glacier (66.18°S, 130.67°E) (Image B & C). At its narrowest, it is ~38 km wide, and at its widest ~116 km. At times, it connects with the fast ice in northern Porpoise Bay forming a continuous fast ice sheet with the Voyeykov Ice Shelf and the Dalton Iceberg Tongue (Image B).
Ice break out/formation	On the eastern side, the ice can break up in early October. On the western side, it tends to persist longer although large areas of fast ice are lost north of Porpoise Bay. When this occurs, the distance from the colony to the nearest open water is reduced greatly. In March 2019, Porpoise Bay was still covered extensively in fast ice reaching ~90 km north and connecting to the Blodgett Iceberg Tongue. In comparison, in March 2021, the bay was largely ice-free but the iceberg tongue persisted. The bay appeared to re-freeze in May 2021.
Maximal distance to fast ice edge	92 km (2 October 2023)
Minimal distance to fast ice edge	<1 km (16 November 2022)
Average distance to fast ice edge	45.7 ± 30.0 km
Early fast ice breakout	16 November 2022
Distance from coast	<5 km
Colony description	The colony is located at the southwestern side of the Blodgett Iceberg Tongue, and the northeastern side of Porpoise Bay. This colony is probably relatively small and tends to form on open fast ice where it is exposed to strong easterly winds. Large fields of icebergs exist north and east of the colony as icebergs calve off the Morse and Freeman (66.17°S, 132.42°E) glaciers east of the colony (Image C).
History	<p>The colony was sighted in a satellite image from 15 October 2017 at 66.27°S, 129.750°E ⁽¹⁾, in an open area of fast ice, nearly 15 km west of Cape Morse (66.320°S, 130.17°E). The fast ice was extensive, and in October, the edge of the fast ice was about 60 km east of the colony.</p> <p>In early April 2018, the fast ice edge was ~36 km east of Cape Morse, and the colony had established itself at 66.272°S, 129.958°E, at the northern side of a small iceberg (~790 x 800 m) north of the Morse Glacier. This location was ~8.3 km farther east than in 2017.</p> <p>On 9 November 2019, the colony occurred at 66.33°S, 129.71°E, 12.9 km southwest of the position in April 2018. Blue ice occurred in the lee of the local icebergs which may be the reason why the colony formed in an open, snow-covered area between two small bergs ~2 km west of the Morse Glacier bergs. The edge of the fast ice was 72 km west northwest. The ice was very solid, i.e., no cracks were visible (Image D). From April to early December, the colony shifted 10.7 km southwest</p> <p>In September 2020, the colony had settled at 66.27°S, 129.98°E, again on an open, snow-covered plain east of a small iceberg, and 14.9 km northeast of their location in December 2019. A polynya had opened in the eastern part of Porpoise Bay. Hence, on 4 September, the fast ice edge was nearly 28 km west of the colony (Image E). The polynya continued to expand south and east, so that by the end of September the colony was just over 1 km from the edge of the fast ice. However, the ocean surface had started to refreeze in most of the bay. A large crack was apparent ~22 km west of the fast ice edge.</p>

History	<p>Most of the new ice disappeared, but the refroze, in October. The penguins had moved close to a small iceberg, part of a cluster of bergs that held the local fast ice in place until mid-February 2021. Note that the 2017 location was on thin ice for most of the 2020 winter, and became open water in November 2020.</p> <p>The situation was different 2021. In March, the colony was ~3.5 km northeast of its 2020 position (Image F), but then moved towards the small berg where they were in the previous year. They remained in this area throughout the season. In 2021, the fast ice was extensive reaching from the Dalton Iceberg Tongue in the west, past the Dibble Glacier to Cape Bickerton (136.9°E) in the east. Even in December, the distance from the colony to the ice was about 60 km to the northeast and the northwest.</p> <p>In 2022, the fast ice edge was barely 1 km from the nearest penguins and by 16 November, the colony was right at the edge of the fast ice, east of a grounded iceberg. It remained there throughout the season.</p> <p>On 2 September 2023, a cluster of groups occurred at the north eastern side of the Morse Glacier (130°E). From mid-October to early November, the colony moved ~1.1 km west. The useable Sentinel2 image was taken on 1 November. The fast ice largely persisted; the ice edge was ~76 km northwest and ~32 km northeast from the colony.</p> <p>Although the Blodgett Ice Tongue provides a vast area of fast ice, the ice in Porpoise Bay itself is highly variable, and with it the distance between the colony and the fast ice edge. In the six years 2018–2023, the colony moved 5–13 km between years, generally in the area off the Morse Glacier Tongue (Image F). This colony experiences some of the most notable inter-annual changes in the distance to the fast ice edge. In 2019 and 2022, the distance averaged 62.3 ± 11.8 km and 58.2 ± 12.7 km from September to December, respectively. In comparison, in 2020 the colony averaged 4.7 ± 9.3 km.</p> <p>To what extent these noticeable changes affect breeding success is unknown.</p>
Population estimates/counts	>1,000 pairs (2019) ⁽¹⁾
References	⁽¹⁾ Fretwell P, Trathan PN (2021) Discovery of new colonies by Sentinel2 reveals good and bad news for emperor penguins. <i>Remote Sensing in Ecology and Conservation</i> 7, 139–153

Images

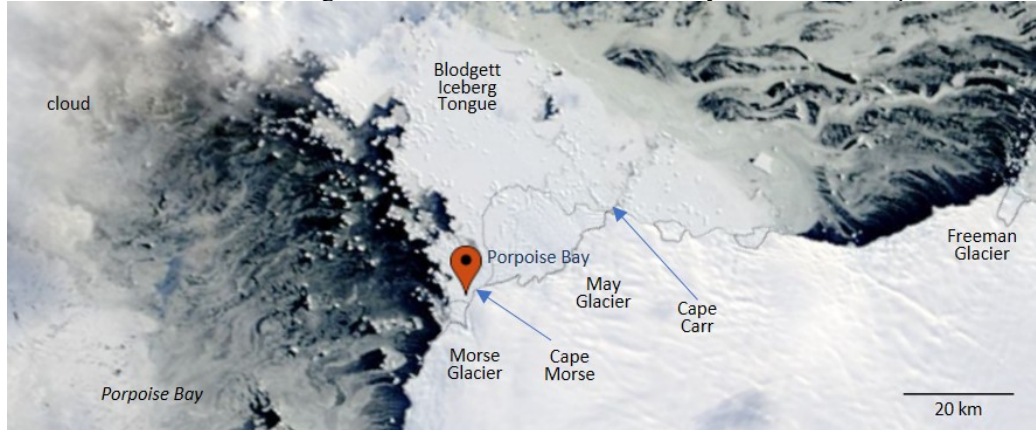
A) Regional fast ice extent and colony location (red marker) on 24 October 2019 (Image: NASA Worldview)



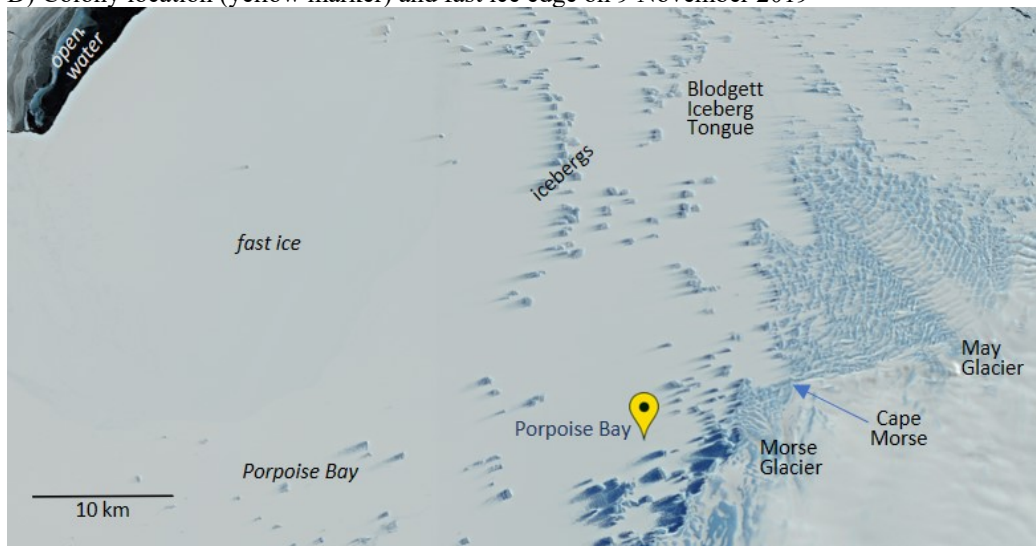
B) In October 2020, the Blodgett Iceberg Tongue (>11,000 km²) did not connect to the fast ice to its west (Image: NASA Worldview)



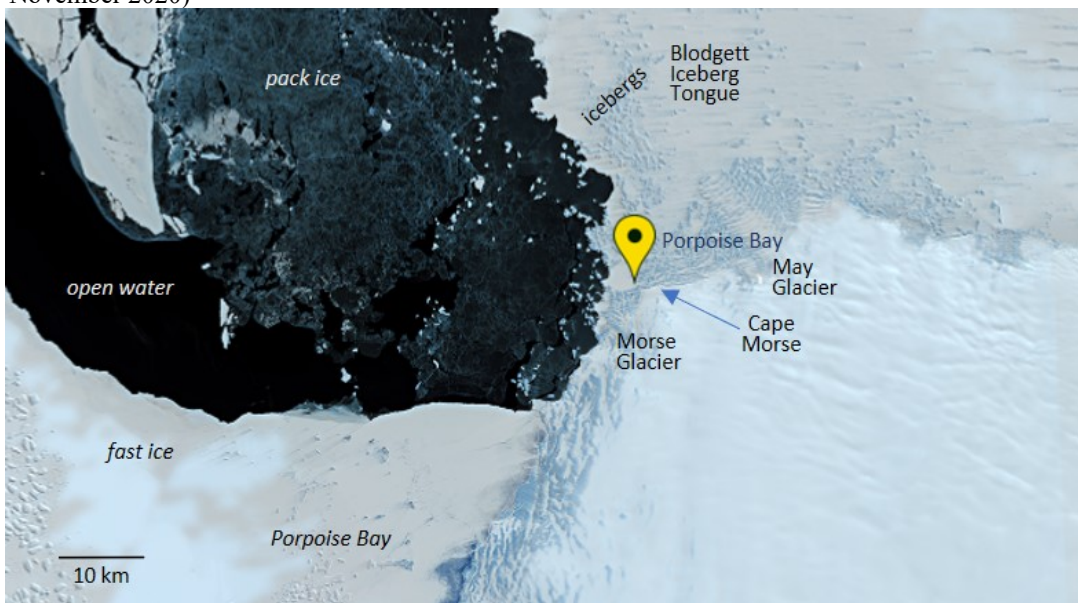
C) Colony location on 31 April 2021 (Image: NASA Worldview). Easterly winds push pack-ice against the eastern side of the ice tongue. On the western side, the easterly winds drive the pack westwards.



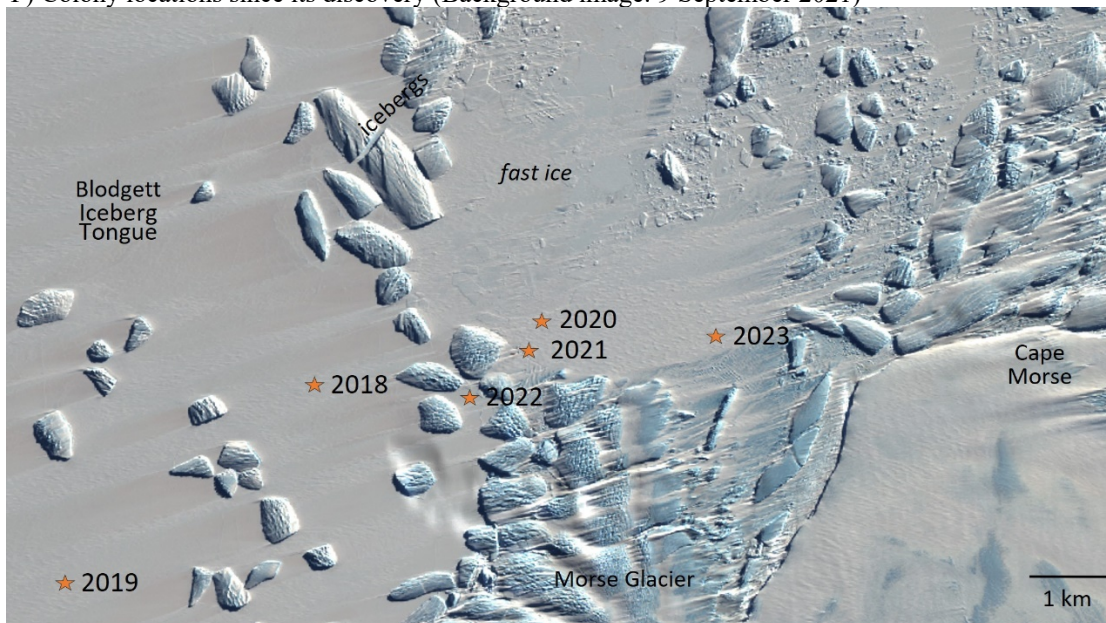
D) Colony location (yellow marker) and fast ice edge on 9 November 2019



E) A lot of ice was lost in mid-September. The colony is ~1 km from the fast ice edge (Image: 13 November 2020)



F) Colony locations since its discovery (Background image: 9 September 2021)

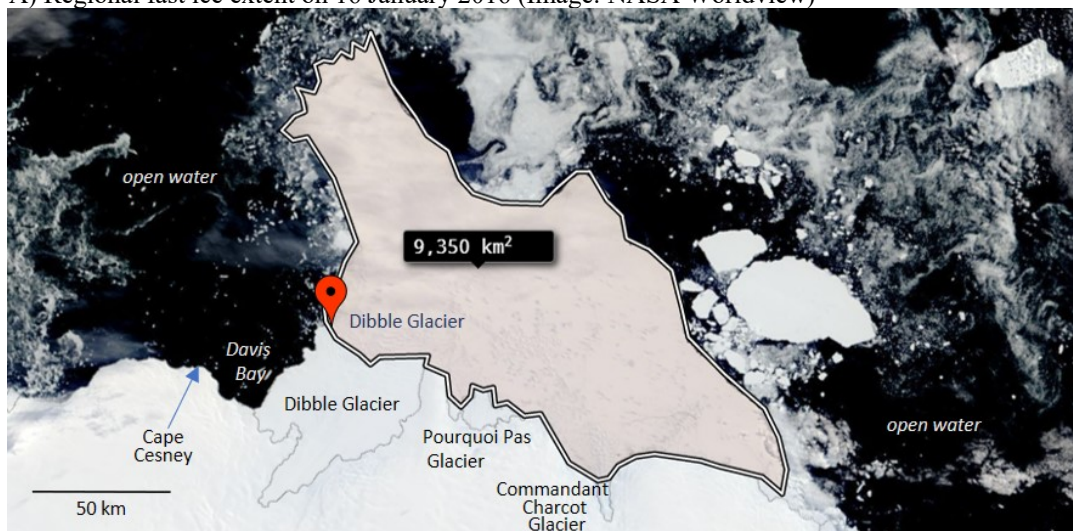


Colony	22. Dibble Glacier
Region	Wilkes Coast (Clarie Coast), Wilkes Land (100.5°E–136°E), East Antarctica
Recent location	65.96°S, 134.70°E
Date	16 October 2023
Interannual colony movement	0–5 km
Size	12,476 adults (12 October 2009) ⁽¹⁾
Fast ice	The Dibble Iceberg Tongue stretches ~120 km north from the large Dibble Glacier (65.83°S, 135.0°E). Longitudinally, it extends eastwards from Davis Bay (~134.4°E) to Cape Bickerton (66.3°S, 136.83°E). The Pourquoi Pas (65.929°S, 134.728°E) and Commandant Charcot (65.929°S, 134.728°E) glaciers feed into this area. The iceberg tongue varies in size and can cover >9,300 km ² as late as January (Image A) well into March. In the 2016 winter, it reached east as far as Cape Gray (66.84°S, 143.49°E), east of Commonwealth Bay, covering an additional 32,000+ km ² (Image B). Since 2018, the fast ice extended east only to the Français Glacier (66.55°S, 138.25°E), west of Cape Pépin (66.5°S, 138.5°E). At the western side of the ice tongue, the fast ice can vary markedly between years (e.g. Images C & D).
Ice break out/formation	In years with heavy ice conditions (e.g. 2016), the ice tongue and associated fast ice can persist over summer. Since 2018, most of the fast ice area of the ice tongue was much smaller than in 2016. In some years, it remained well into February (Image E), while it completely disintegrated in summer in other years (Image F).
Maximal distance to fast ice edge	38 km (4 September 2020)
Minimal distance to fast ice edge	0.4 km (25 December 2023)
Average distance to fast ice edge	13.7 ± 9.8 km
Early fast ice breakout	None observed
Distance from coast	~20 km
Colony description	The colony is situated on the fast ice at the western side of the Dibble Iceberg Tongue, and north of the Dibble Glacier. Icebergs are abundant here. This large colony usually splits into several suburbs. The distances between groups vary annually.
History	<p>The colony was discovered at 66.01°S, 134.79°E in a satellite image from 12 October 2009 ⁽¹⁾. In 2009, the regional fast ice was extensive and reached Cape Gray (66.8°S, 143.49°E), ~340 km east of the colony, at the western side of Commonwealth Bay (Image B). The colony itself was only ~10 km from the western ice edge of the iceberg tongue.</p> <p>Given its proximity to the glacier tongue that generates a dynamic environment with regard to calving and movement of icebergs, it is unsurprising that the colony adjusted its position over the years, but on a small scale. Overall, the penguins remained in the same area where the most northerly (2020) and most southerly (2009) positions are only ~10 km apart (Image G). The front of the glacier tongue has remained relatively unchanged from 2009–2021, but the number of icebergs has increased.</p> <p>The distance from the colony to open water is difficult to determine. In satellite images, the fast ice edge is clearly visible, but there tend to be several kilometres of new ice as well. If this new ice is solid, the penguins have to travel farther to reach open water. For example, in September 2020, the distance was ~38 km (Image C), but a month later only 18 km. From 2018–2020, the new ice had usually turned to open water in late October/early November.</p> <p>The colony had split into two (2019, 2020), three (2018, 2021) and five (2022) suburbs ~0.6–3.3 km apart. Whether the penguins travelled between the suburbs or remained in their suburbs is unknown.</p> <p>The three small groups visible (460–700 m apart) in 2021, appeared to cover a smaller area than in previous years, but the colour of stain was deep. Either fewer penguins were present, or the group density was higher than in images of previous years.</p> <p>The colony divided into 5 distinct groups in 2022, spread out over nearly 6 km and separated</p>

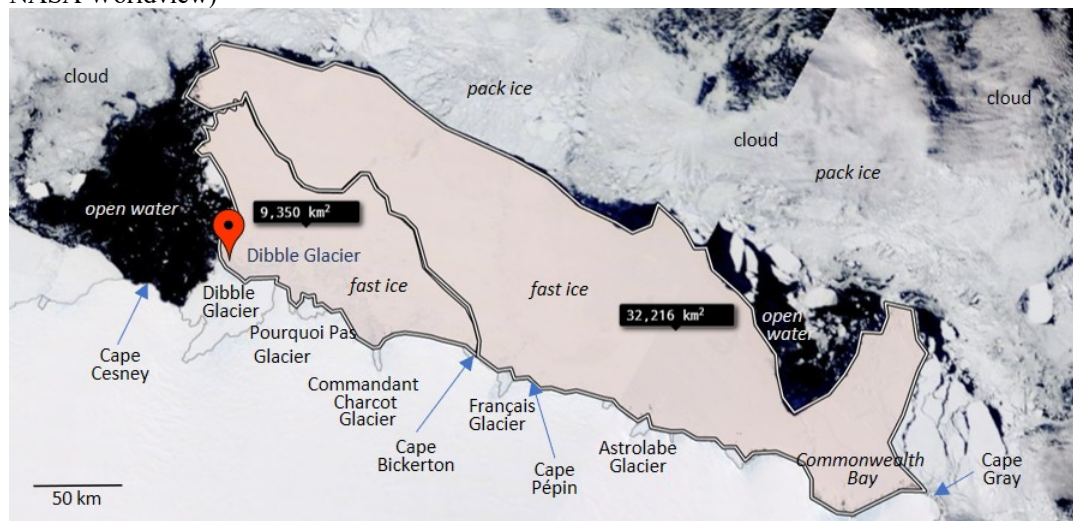
History	<p>by small icebergs. These groups existed throughout the season; it is unknown whether any penguins moved between the groups. Some fast ice broke out west of the suburbs, but although one group was suddenly very close to the ice edge, there was no loss as this group was located behind a small iceberg.</p> <p>In 2023, the penguins had congregated in one group ~1.5 km southwest of the 2022 position. The fast ice was extensive. The Dibble Glacier Iceberg Tongue reached >120 km north. The ice edge was ~32 km to the west and ~167 km to the east (~139°E). The eastern ice continued to consolidate and three weeks later covered >44,500 km², reaching past Commonwealth Bay to Cape Gray (~144.5°E). On 15 November, the western ice edge was still 20.8 km from the colony, but 10 days later, this distance was only 2.9 km, and was further reduced to 1.7 km by 15 December. In 2023, this colony may have had a close call, but whether any chicks were lost is unknown.</p>
Population estimates/counts	12,476 adults (12 October 2009)
References	<p>⁽¹⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2012) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p>

Images

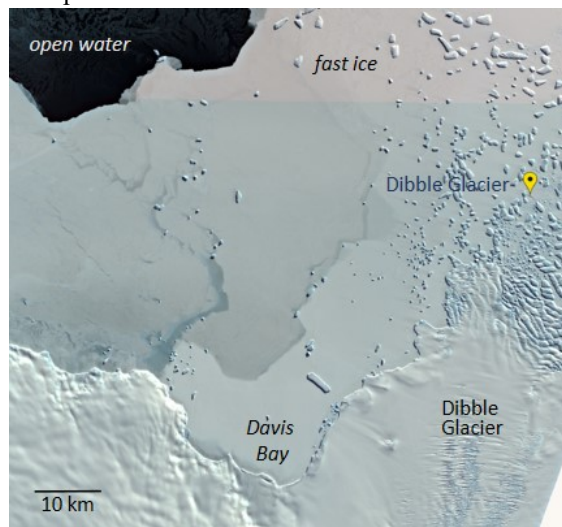
A) Regional fast ice extent on 16 January 2016 (Image: NASA Worldview)



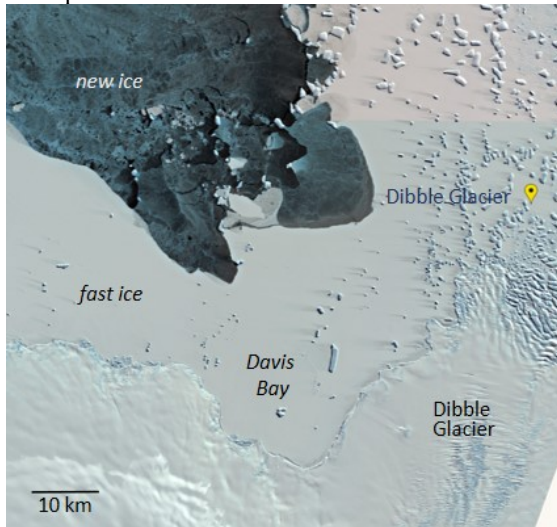
B) Regional fast ice extent on 16 November 2016 overlaid with ice extent from Image A (Image: NASA Worldview)



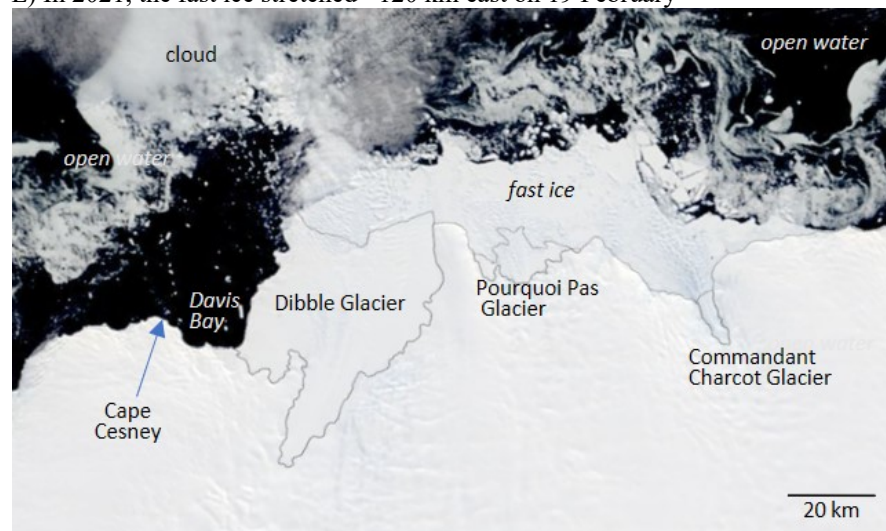
C) Fast ice extent and colony location, 4 September 2020



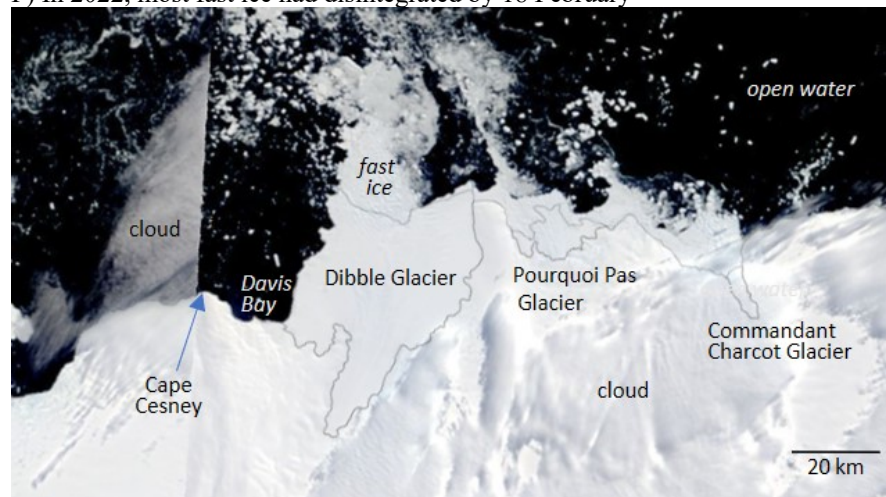
D) Fast ice extent and colony location, 9 September 2021

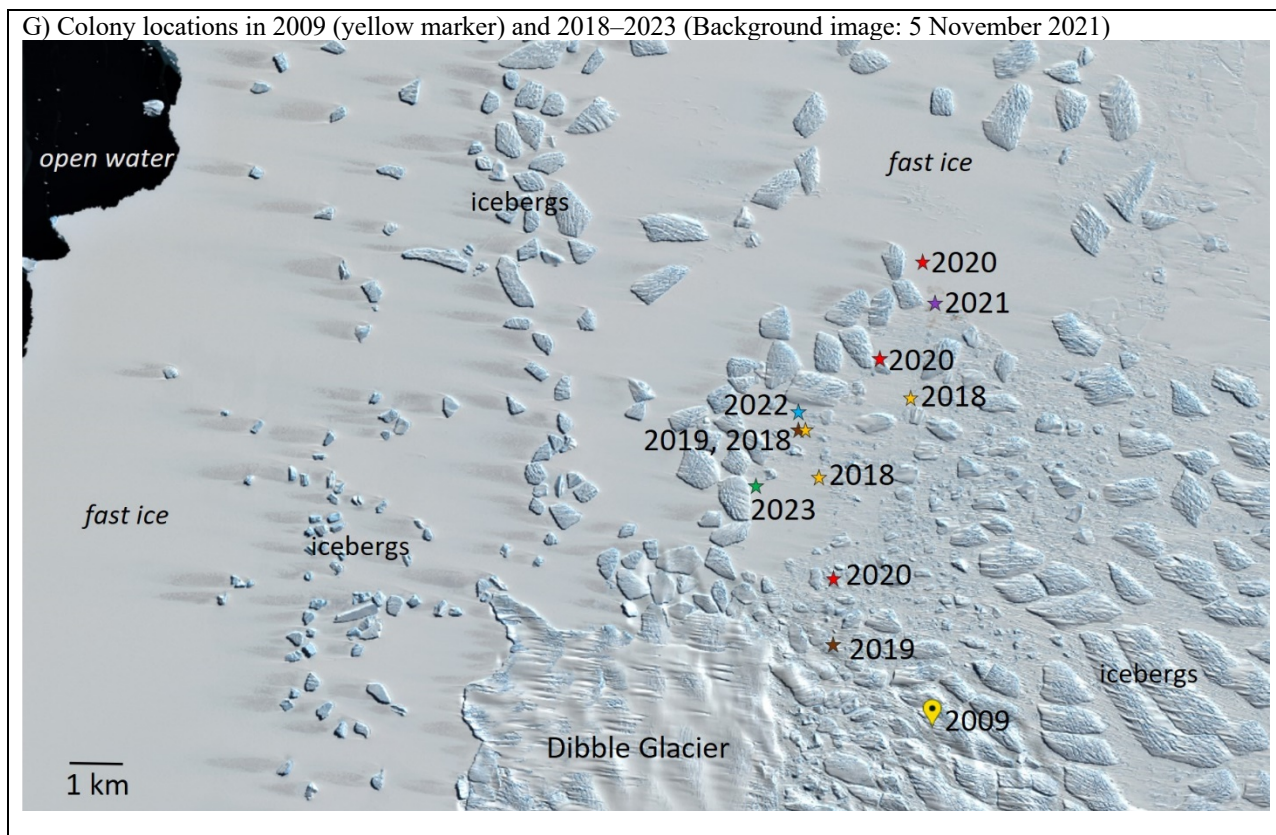


E) In 2021, the fast ice stretched ~120 km east on 19 February



F) In 2022, most fast ice had disintegrated by 18 February





Colony	23. Pointe Géologie (ASPA 120)
Region	Adélie Coast, Adélie Land (67°E–139°E), East Antarctica
Recent location	66.67°S, 140.02°E
Date	24 October 2022
Interannual colony movement	0–1 km
Size	Up to 4,500 breeding pairs ⁽¹⁾
Fast ice	The fast ice in the region is highly variable. Since 2010, it covered >46,000 km ² along ~500 km of coastline, for example in October 2014 (Image A). It reached from Cape Keltie (66.07°S, 133.37°E), just west of the Dibble Iceberg Tongue, to Cape de la Motte (66.0°S, 144.43°E). Via a narrow ice bridge (~10 km) on its eastern side, it was connected to the fast ice of Porpoise Bay and continued on to the Voyeykov Ice Shelf and the Dalton Iceberg Tongue. In comparison, in October 2015, the fast ice area measured ~8,200 km ² extending from the Liotard Glacier (66.62°S, 139.5°E) to the eastern side of Commonwealth Bay near Cape Gray (66.84°S, 143.49°E) (Image B). Large areas of fast ice can be lost as early as September (Images C & D).
Ice break out/formation	The fast ice can start to diminish in late October and can large be gone in mid-November (e.g. 2021). It generally reforms in April.
Maximal distance to fast ice edge	72 km (30 September 2019)
Minimal distance to fast ice edge	0 km (22 December 2021)
Average distance to fast ice edge	11.3 ± 13.1 km
Early fast ice breakout	None observed
Distance from coast	<1 km
Colony description	The colony is located on the fast ice between the island of the Pointe Géologie Archipelago, east of the Astrolabe Glacier (66.75°S, 139.92°E). In September, the colony may occur in the area around Pointe Noire at the southern side of Petrel Island (Île Péterels), and Larmarck and Jean Rostand islands (Image E). In November, it may shift south towards the ice cliffs of the glacier.
History	<p>This colony has been studied for several decades, and many publications are available. It was discovered at 66.67°S, 140.02°E in November 1950, and visited for 5 days in June 1951 ⁽²⁾.</p> <p>The penguins were densely huddled and the first population estimate was obtained by approximating the area the birds occupied. Assuming that there were 9 to 10 birds m⁻², an estimate was obtained of 5,000 ± 500 birds ⁽²⁾. Since 1952, the colony has been monitored continuously. Summarized counts are available for 1952–2000 ⁽³⁾ and 1952–2010 ⁽⁴⁾; in the latter, individual counts were published in the Online Resources.</p> <p>The number of breeding pairs had nearly halved by the mid-1970s, remained relatively stable until the mid-2000s and then started to increase again ⁽¹⁾. Changes in the marine environment leading to reduced breeding success are likely to have affected the population ⁽³⁾.</p> <p>The colony has occupied the same area of fast ice among the small islands of the Pointe Géologie Archipelago ever since its discovery.</p> <p>Generally, the colony is <10 km from the fast ice edge. But in 2019, extensive fast ice and highly consolidated pack-ice increased the distance from the colony to open water to ~72 km. This lasted from ~20 August until 21 September, when the ice broke out reducing the distance the penguins had to walk to ~19 km. This event occurred at a crucial time in the penguins' breeding cycle, namely when young chicks were being provisioned by their parents. Greatly increased travel times are likely to reduce the number of meals a chick receives during that period.</p> <p>In 2022, the fast ice extent was very low in the area. In early September, the northern fast ice edge was ~13 km north of Petrel Island. But by 18 October, it had reached the shores of</p>

History	<p>Petrel Island. The colony had moved off the fast ice and onto the glacial ice via an ice slope south near the Bon Docteur Nunatak, a small coastal nunatak ~400 m south of Rostand Island (Image F). In mid-November, even less fast ice was left in the archipelago, and the narrow strip of fast ice at the western side of the Astrolabe Glacier had gone. The traditional breeding area was still frozen, but the penguins remained near the nunatak. By mid-December, part of the colony had shifted ~500 m father south onto blue ice and appeared to remain there for the remainder of the season.</p> <p>In 2023, the colony moved again onto the ice slope south of the Bon Docteur Nunatak and remained there until the end of the season. On solid ground, the penguins were not affected by the receding fast ice. On 2 November, the ice edge was ~36 km from the colony, ~14.8 km on 22 November, and by 18 December only 0.7 km.</p>
Population estimates/counts	<p>5,000 ± 500 birds (24–29 June 1951)⁽²⁾; 6,075 pairs (1952)⁽¹⁾; 5,751 ± 363 (1952–1975)^{(1)*}; 3,052 ± 575 (1976–2004)^{(1)*}; 3,425 ± 381 (2005–2018)^{(1)*}; 2,456 pairs (1 October 2009)⁽⁵⁾; 4,500 pairs (2016)⁽¹⁾; 3,396 pairs (2018)⁽¹⁾ * Annual winter counts available in Online Resources⁽¹⁾</p>
References	<p>⁽¹⁾ Barbraud C, Delord K, Bost CA, Chaigne A, Marchteau C, Weimerskirch H (2020) Population trends of penguins in the French Southern Territories. <i>Polar Biology</i> 43, 835–850 ⁽²⁾ Cendron J (1952) Une visite hivernale à une rookerie de manchots empereurs. <i>Revue d'Écologie, La Terre et la Vie</i> 40, 101–108 ⁽³⁾ Barbraud C, Weimerskirch H (2001) Emperor penguins and climate change. <i>Nature</i> 411, 183–186 ⁽⁴⁾ Barbraud C, Gavriilo M, Mizin Y, Weimerskirch H (2011) Comparison of emperor penguin declines between Pointe Géologie and Haswell Island over the past 50 years. <i>Antarctic Science</i> 23, 461–468 ⁽⁵⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2009) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p>

Images

A) Regional fast ice extent, 25 October 2014 (Image: NASA Worldview)



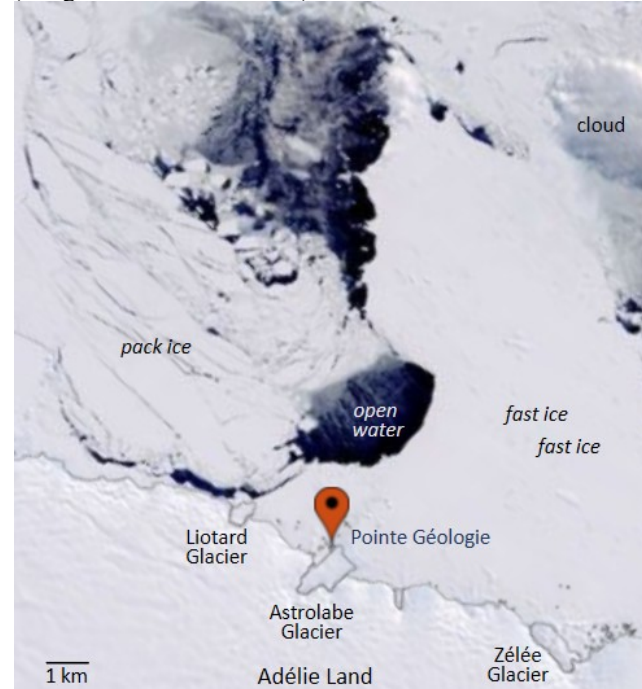
B) Regional fast ice extent, 25 October 2015 (Image: NASA Worldview)



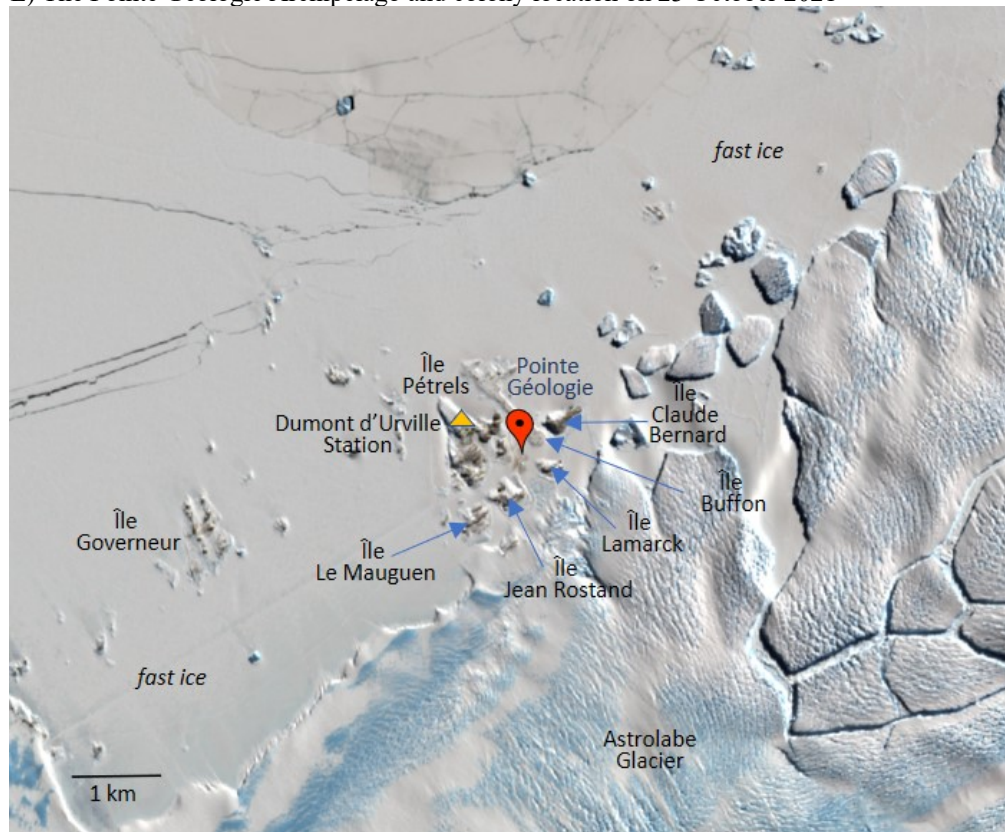
C) Colony location and fast ice on 17 September (Image: NASA Worldview)



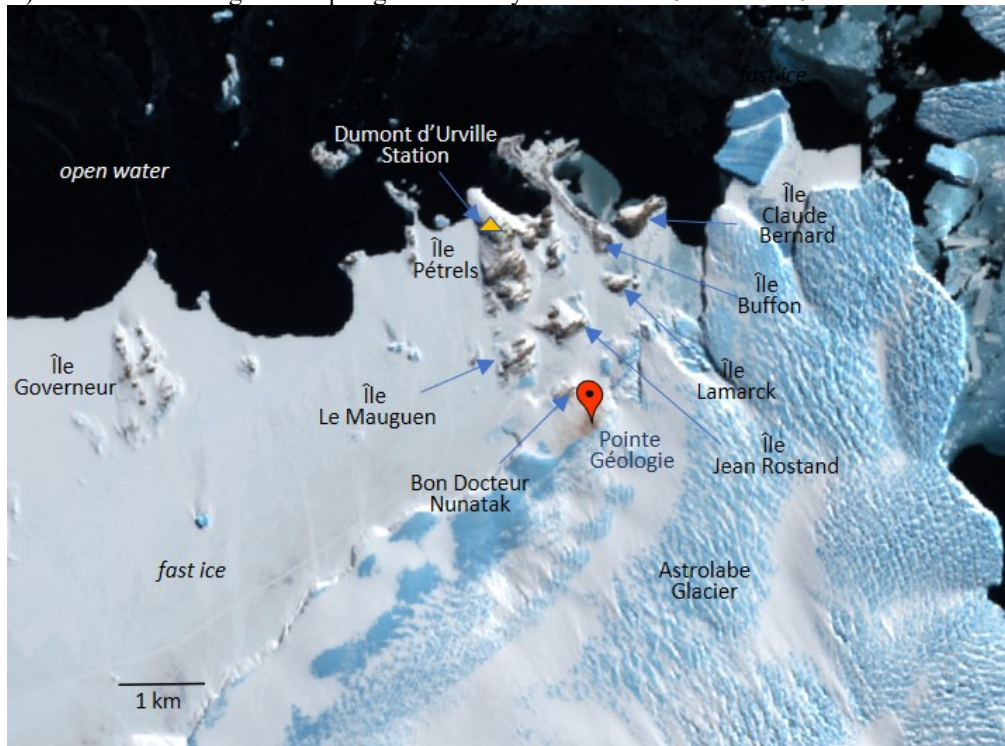
D) Colony location and fast ice on 20 September 2019 (Image: NASA Worldview)



E) The Pointe Géologie Archipelago and colony location on 23 October 2021



F) The Pointe Géologie Archipelago and colony location on 28 October 2022

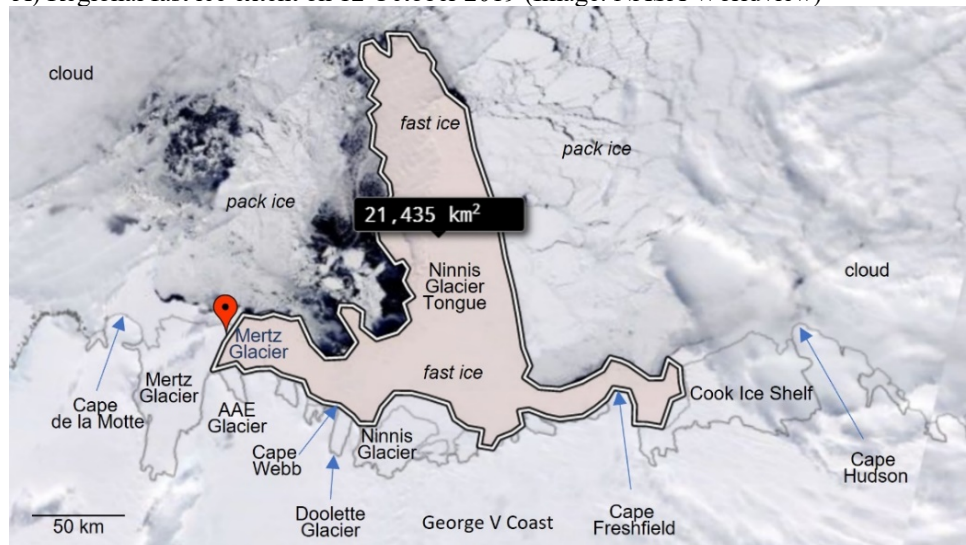


Colony	24. Mertz Glacier
Region	George V Coast, George V Land, East Antarctica
Recent location	67.26°S, 146.01°E
Date	13 October 2023
Interannual colony movement	4–7 km <i>Note: historically, the colony moved 15 km from 2009 to 2018</i>
Size	7,400 pairs ⁽¹⁾
Fast ice	In years with extensive fast ice (e.g. 2019), up to ~22,000 km ² can extend along ~300 km of coast from the eastern side of the Mertz Glacier (67.67°S, 144.5°E) in the west to the Cook Ice Shelf (68.67°S, 152.50°E) in the east (Image A). The fast ice area includes the large Ninnis Glacier Tongue that extends ~260 km north of the Ninnis Glacier (68.67°S, 152.50°E). At times (e.g. 2018), the fast ice reaches only from the eastern side of the Mertz Glacier to Cape Webb (67.92°S, 146.84°E), west of the Doolette Glacier (68.67°S, 152.50°E), covering only ~2,000 km ² (Image B).
Ice break out/formation	Depending on the winter extent, the fast ice in Fisher Bay can persist throughout summer (e.g. 2018/2019) south of ~67.4°S. However, at the northern fast ice edge, the fast ice can start to disintegrate in mid-November. It usually re-forms in March/April.
Maximal distance to fast ice edge	25 km (8 September 2020)
Minimal distance to fast ice edge	0.6 km (17 December 2020)
Average distance to fast ice edge	8.8 ± 6.1 km
Early fast ice breakout	21 November 2018
Distance from coast	~40 km
Colony description	The colony is located on the fast ice east of the Mertz Glacier north of Fisher Bay (67.5°S, 145.67°E), and in the northern area of the fast ice. The fast ice edge can be >20 km from the colony (Image C), but in some years, it is <10 km distant (Image D).
History	In August 1999, large numbers of emperor penguins were sighted at the northern end of the Mertz Glacier Tongue from a ship visiting the Mertz Polynya, but a colony was not found ⁽²⁾ . In a satellite image from 17 November 2009, a colony was visible next to the Mertz Glacier at 66.982°S, 146.62°E; an estimated 4,781 adults were present ⁽³⁾ . In February 2010, a large iceberg, B9B, collided with the Mertz Glacier Ice Tongue leading to the calving of an 80 x 40 km iceberg, C28 ⁽¹⁾ . This event destroyed the previous breeding area of the penguins, turning it into an area of pack-ice and open water (Image C). In November 2012, French researchers surveyed the northern edge of the remaining ice tongue from the air trying to find the colony ⁽¹⁾ . It appeared that the colony had relocated 49 km farther south but had split into two units. One occurred on the fast ice east of the ice tongue at 67.317°S, 145.867°E among icebergs, and comprised 1,520 adults and 1,750 chicks (1 November). The second group was at 67.233°S, 145.500°E, 18 km farther west near the northern edge of the ice tongue, and very exposed. Here, 2,300 adults and 3,980 chicks were counted on 2 November ⁽¹⁾ . Since then, the two groups have reunited forming again a single colony. Since at least 2018, the colony has been ~45 km south of the 2009 position (Image D). The penguins occupy the fast ice right next to the ice tongue, and only a few kilometres from the fast ice edge, but that distance varies with year (Image D and E) and within season (Image F and G). Post-calving of C-28, the colony has used roughly the same area, northeast of the Mertz Glacier Tongue (Image H), and only a short distance from the ice edge but usually

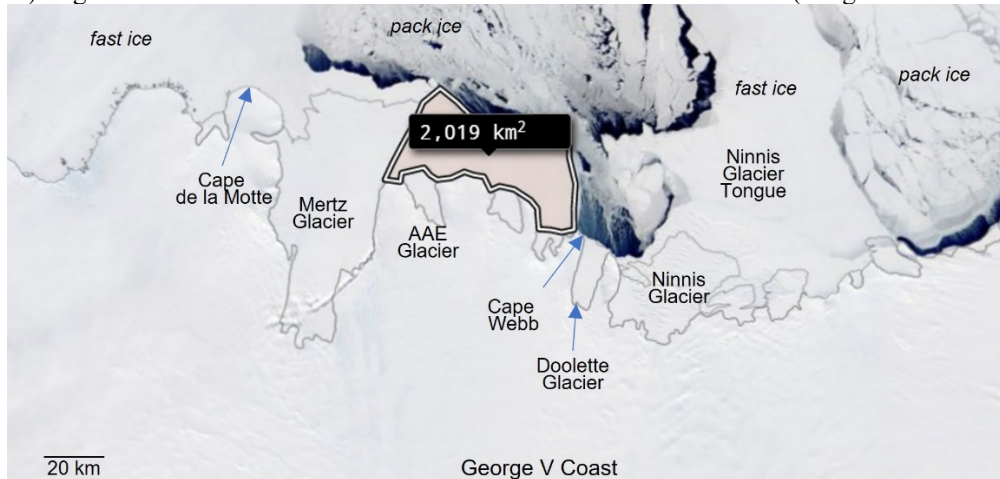
History	<p>very close to the nearest iceberg where fast ice usually exists until early January.</p> <p>In November 2018, the colony was in the same area as the eastern group (Group 1) in 2012. On 19 November, ~340 km² of fast ice broke out, leaving a very narrow band where the penguins were. The following day, the colony area broke out as well. It is unknown whether this event negatively affected chick survival.</p> <p>Occasionally, for example in 2022, the colony splits into several groups up to 3.6 km apart that remain separated from each other throughout the season. In the 2022, when the sea froze, it comprised a jumble of floes that generated a very uneven surface. Two small groups were first visible in a satellite image from 1 April 2022. The southernmost had gathered on smooth fast ice south of the area of uneven ice, approximately 1 km from the second group. By September, a third group had formed some 3.6 km northeast of the other two groups. Here is where the darkest stain was seen in December 2022. It appears that most penguins had moved to this location where they were only about 1.3 km from the edge of the fast ice. By 27 December 2022, this stain had faded markedly; most penguins had probably departed the colony area by then. By 6 January 2023, the colony area was open water.</p> <p>In September 2023, the colony was ~1 km northwest where the northern most group was in 2022. A new, small ice berg had calved off the ice tongue and was frozen in the fast ice. The southern edge of the berg was ablated and many penguins appear to have moved onto it although the fast ice next to the berg seemed rather smooth. However, a tide crack had opened ~600 m from the nearest penguins. From September to early December 2023, the fast ice edge averaged 7.2 ± 1.3 km from the edge of the colony. Cloud covered made observations difficult in December, but the distance decreased from 5.6 km on 2 December to 0.5 km on 29 December and by 8 January 2024, there was only open water in the area. It is unknown whether the colony was affected by these events or not.</p>
Population estimates/counts	<p>4,781 adults (17 November 2009) ⁽³⁾;</p> <p>Group 1: 1,520 adults and 1,750 chicks (1 November 2012),</p> <p>Group 2: 2,300 adults and 3,980 chicks (2 November 2012) ⁽¹⁾</p>
References	<p>⁽¹⁾ Ancel A, Cristofari R, Fretwell PT, Trathan PN, Wienecke B, Boureau M, Morinay J, Blanc S, Le Maho Y, Le Bohec C (2014) Emperors in hiding: when ice-breakers and satellites complement each other in Antarctic exploration. <i>PLoS ONE</i> 9, e100404</p> <p>⁽²⁾ Ancel A, Rodary D, Wienecke B (1999) Exploration biologique de la polynie de Mertz. <i>Rapport d'Activite' de l'IFRTP</i>, pp 40–44</p> <p>⁽³⁾ Fretwell P, La Rue M, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter, C, Trathan PN (2012) An emperor penguin population estimate: the first global, synoptic survey of a species from space. <i>PLoS ONE</i> 7, e33751</p>

Images

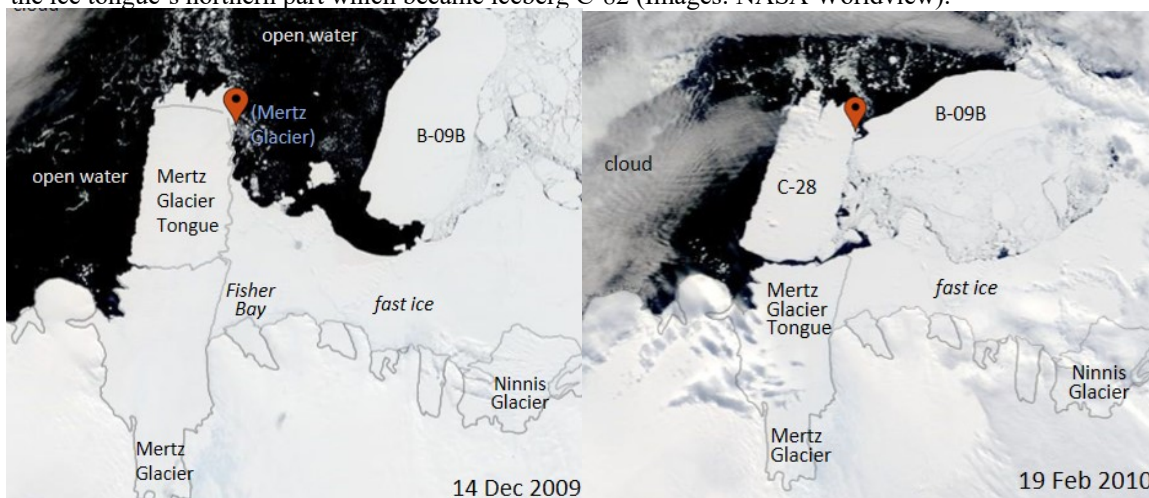
A) Regional fast ice extent on 12 October 2019 (Image: NASA Worldview)



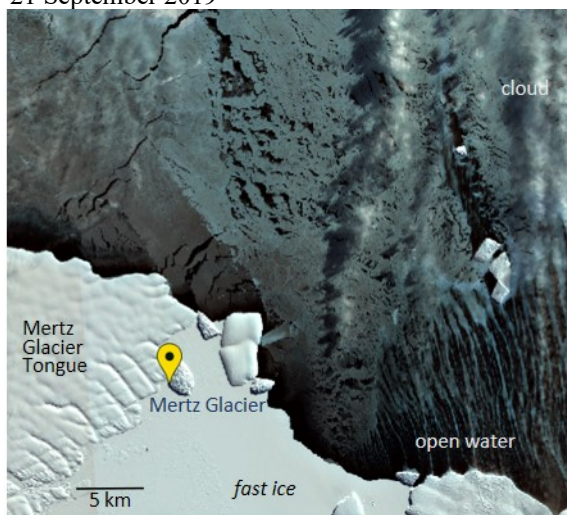
B) Regional fast ice extent east of the Mertz Glacier on 10 October 2018 (Image: NASA Worldview)



C) Collision of iceberg B-09B and the Mertz Glacier Tongue. In mid-February, the collision caused the loss of the ice tongue's northern part which became iceberg C-28 (Images: NASA Worldview).



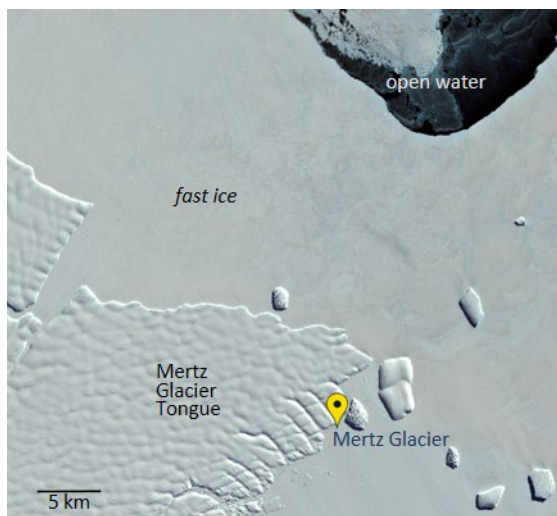
E) Colony location and fast ice edge, 21 September 2019



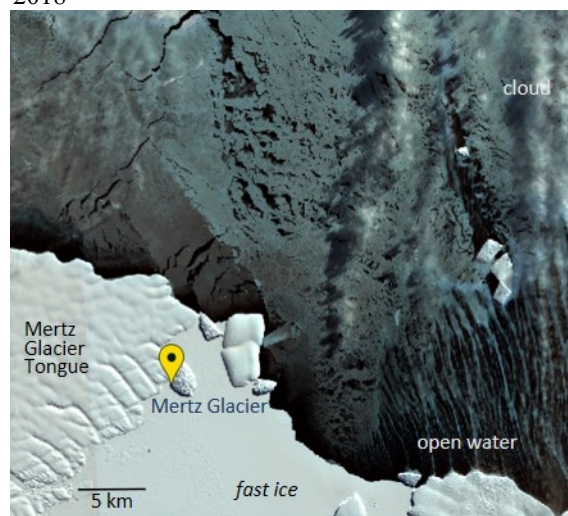
D) Colony location and fast ice edge, 8 September 2020



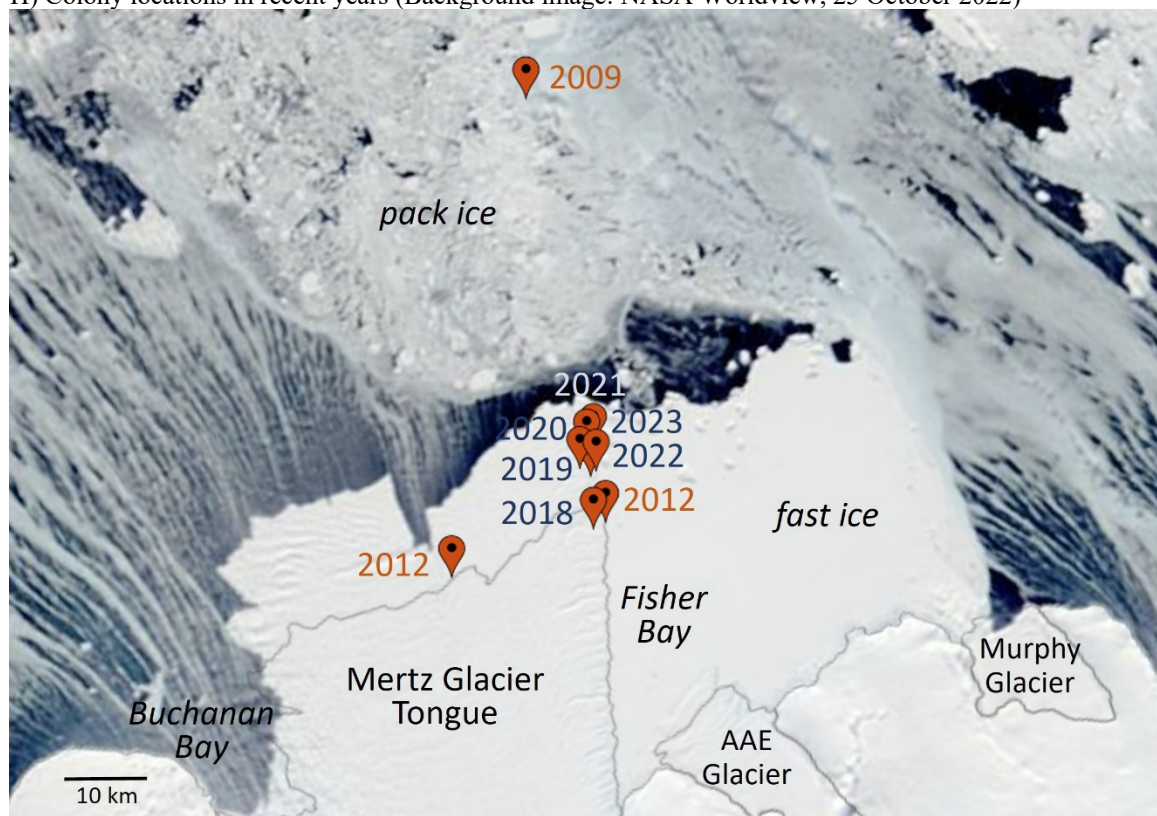
F) Colony on fast ice on 8 November 2018



G) Colony location after ice break out on 25 November 2018



H) Colony locations in recent years (Background image: NASA Worldview, 25 October 2022)



Colony	25. Ninnis Bank
Region	George V Coast, George V Land, East Antarctica
Recent location	66.85°S, 149.94°E
Date	13 November 2023
Interannual colony movement	1–2 km
Size	Unknown
Fast ice	<p>Most of the fast ice in this area is part of the vast Ninnis Glacier Tongue. On 12 October 2018, ~12,900 km² stretched ~260 km from the Antarctic coast from 68.4°S to 66.0°S. The fast ice attached along ~120 km of coastline and coastal features such as the glacier tongue. A 570 km long edge was exposed to the ocean, and particularly to pack-ice on its eastern side (Image A). In some years, the regional fast ice extends from the Mertz Glacier (67.67°S, 144.5°E) in the west to the Cook Ice Shelf (68.67°S, 152.50°E) in the east, covering ~22,000 km².</p> <p>At times, the northern part of the fast ice becomes detached. For example, in October 2018, ~5,000 km² of the northern fast ice became separated as the ice in the middle section had disintegrated (Image B). A multitude of small icebergs kept the northern section in place, but it was no longer attached to the continent (ex-fast ice).</p>
Ice break out/formation	Generally, the fast ice breaks up in mid to late February and starts to re-form in early April.
Maximal distance to fast ice edge	29 km (16 September 2020)
Minimal distance to fast ice edge	0.8 km (3 December 2023)
Average distance to fast ice edge	9.6 ± 7.0 km
Early fast ice breakout	12 December 2020; 8 November 2022
Distance from coast	~175 km
Colony description	<p>The colony establishes among small icebergs on the fast ice north of the Ninnis Bank (67.4°S, 147.6°E) and east of the Mertz Depression (66.5°S, 147.5°E). Located ~185 km north of Horn Bluff (68.35°S, 149.76°E) and the Williams Glacier (68.40°S, 149.59°E), it is the colony most distant from the Antarctic coast ⁽¹⁾, but it is not the most northerly one. The colony occurs on the eastern side of an elongated ice tongue ~65 km wide. The nearest open water is <25 km from the colony in the east, but >40 km to the west. However, currents and winds can drive huge amounts of pack-ice, at times very dense, onto the eastern side of the ice tongue. When the pack-ice is very dense, the distance to the western ice edge is much nearer.</p>
History	<p>On 12 February, during the 1959 ANARE relief expedition, the supply vessel <i>Magga Dan</i> sailed along “an apparently endless succession of icebergs” that were grounded on Virik Bank (~149°E) ⁽¹⁾, these days also known as Ninnis Bank ⁽¹⁾. Philip Law, director of Australia’s Antarctic Division, recorded “numerous emperor penguins” probably on the sea ice among the bergs ⁽¹⁾. A precise location of the sighting is not available. Law suggested that a large colony existed somewhere on the fast ice tongue off the Ninnis Glacier.</p> <p>Some 59 years later, a colony was discovered in a satellite image from 28 August 2018. This colony was not on or near the glacier tongue but located at 66.723°S, 149.677°E on the fast ice north of the submarine Ninnis Bank ⁽²⁾.</p> <p>The colony is very difficult to observe as cloud frequently covers the area. It is ~175 km north of the coast on a vast sheet of fast ice that can extend to 66.1°S. This fast ice forms among hundreds of small, grounded icebergs, especially in the northern part. However, in some years this fast ice becomes ex-fast ice (Image B).</p> <p>In 2020, around 27 October, the middle section of the fast ice broke up and disintegrated. On 17 November, much of the fast ice west of the colony was lost, leaving the colony on a precariously small piece of fast ice <2.5 km from the western ice edge, and just over 5 km from the eastern edge although heavy pack-ice moved in a few days later (Images C–E). By</p>

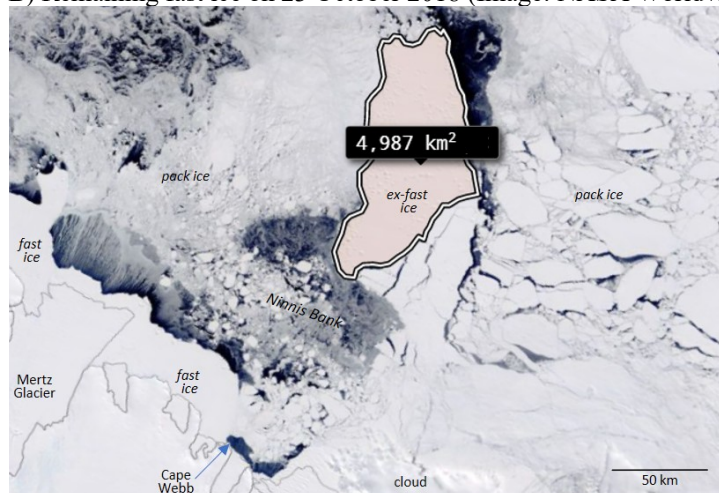
History	<p>12 December 2020, the colony area was open water.</p> <p>In 2021, the colony came precariously close to the fast ice edge. This was a close encounter with tragedy for the colony. It occurred rather late in the breeding season; thus, it is possible that most chicks would have survived. But if these breaks out happen earlier, the colony will be in danger.</p> <p>In 2022, the sea ice reached record lows throughout the Southern Ocean. In the area of the Ninnis Bank, fast ice started to disintegrate south of the colony in late August. On 29 September 2022, the colony was only ~2.3 km from the fast ice edge (Image F), and by 8 November 2022, the fast ice had completely disintegrated and the previous colony area was open water (Images G & H). This breakout occurred at a time when the chicks would not have been ready to enter the water. Thus, it is highly likely that the colony experienced complete breeding failure in 2022.</p> <p>In 2023, overall sea ice extent was even less than in 2022. The colony occurred ~20 km southwest compared to 2022, but again at the eastern side of the ice tongue in an area that was rather unstable previously. The colony location did not change much throughout the 2023 season, but the cover of pack-ice east of the colony changed dramatically in extent. On 14 September, the distance from the colony to the ice edge was 2.2 km. When heavy pack-ice moved in, it extended to ~22 km in mid-November, but was only 0.8 km in early December. Tide cracks had opened ~2 km west of the colony. These changes occurred on a local scale; the fast ice sheet south of the colony persisted throughout December and started to break up only around 11 January 2024, but the ice remained largely in place. The width of the ice sheet at the latitude of the colony reduced from ~48 km in late November to <18 km on 21 December. Even in late January 2024, the ice at the colony area appeared to have persisted, but it is unknown whether the quality of the ice changed.</p>
Population estimates/counts	Unknown, but possibly 2,000–4,000 pairs ⁽²⁾
References	<p>⁽¹⁾ Law P (1959) Australian coastal explorations in Antarctica, 1959. <i>The Geographical Journal</i> 127, 427–435</p> <p>⁽²⁾ Fretwell P, Trathan PN (2021) Discovery of new colonies by Sentinel2 reveals good and bad news for emperor penguins. <i>Remote Sensing in Ecology and Conservation</i> 7, 139–153</p>

Images

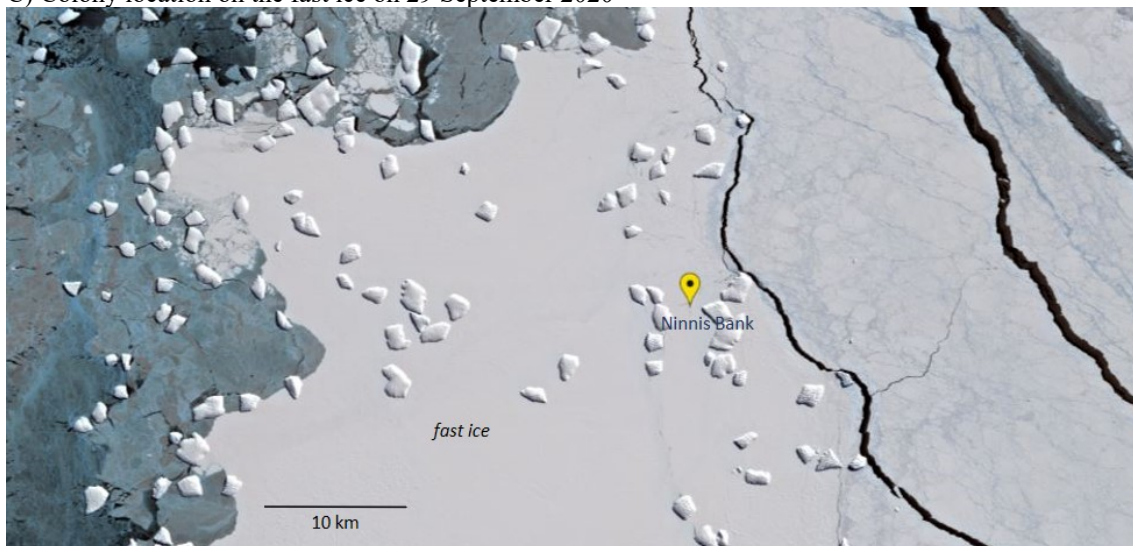
A) Fast ice extent over the Ninnis Bank, 15 October 2018 (Image: NASA Worldview)



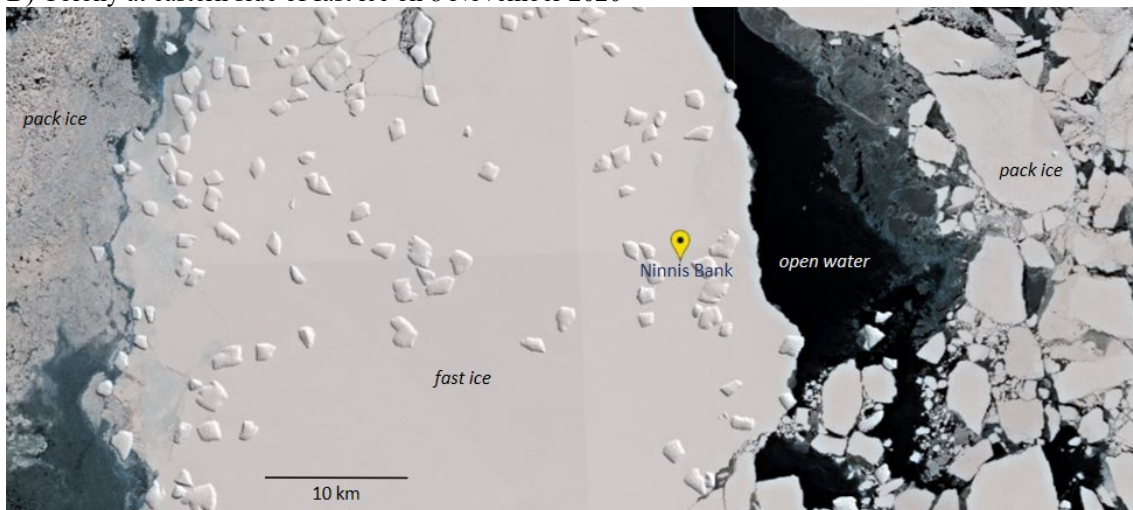
B) Remaining fast ice on 23 October 2018 (Image: NASA Worldview)



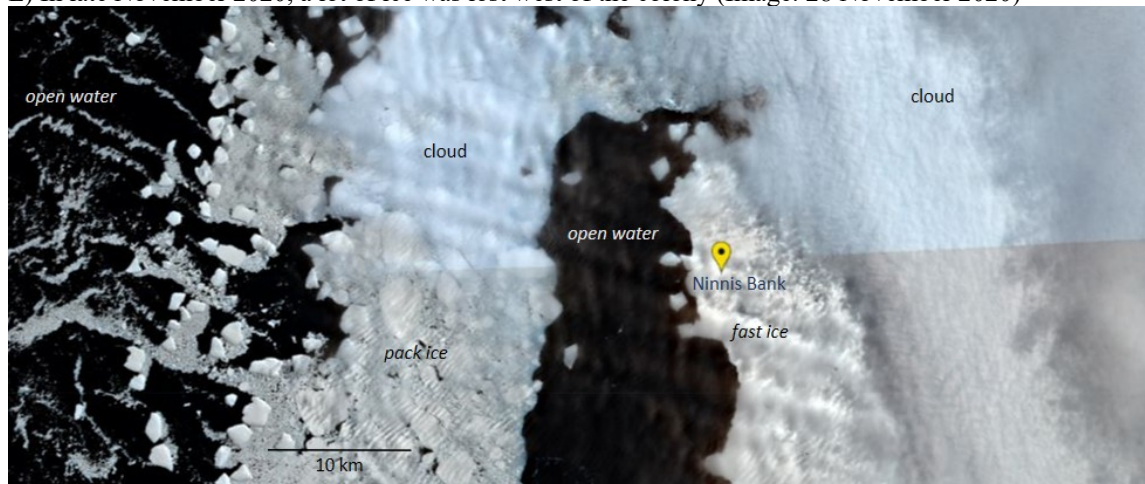
C) Colony location on the fast ice on 29 September 2020



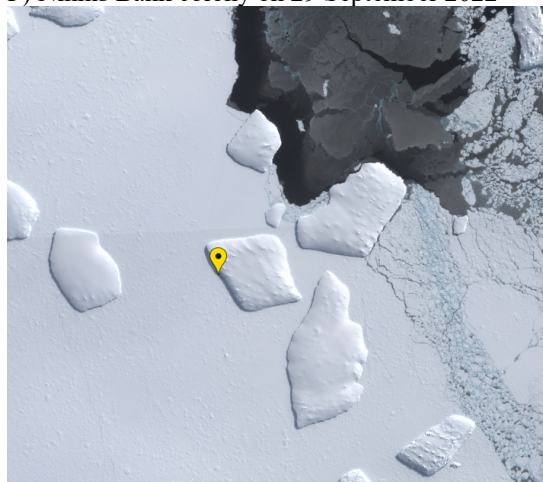
D) Colony at eastern side of fast ice on 8 November 2020



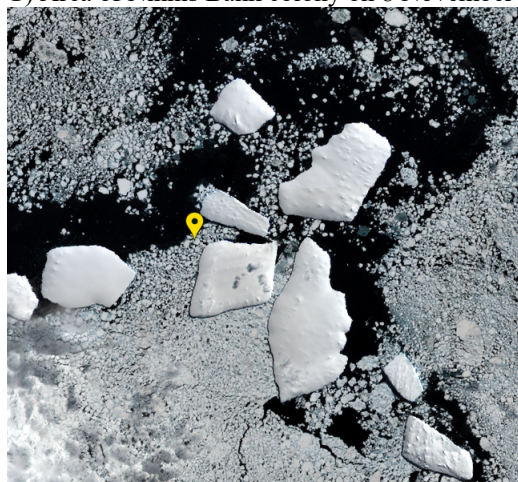
E) In late November 2020, a lot of ice was lost west of the colony (Image: 28 November 2020)



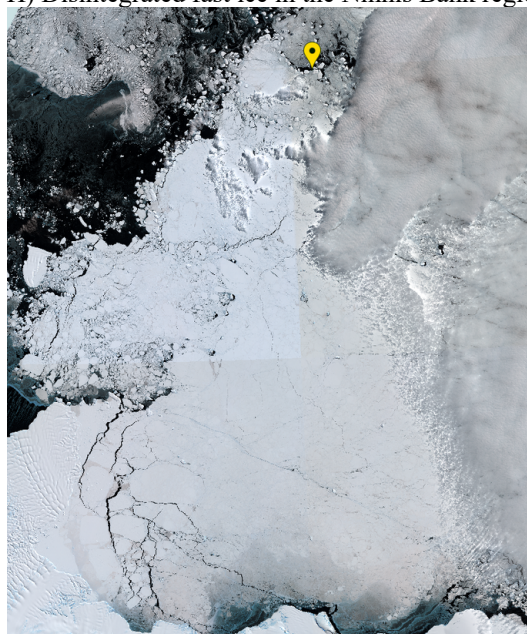
F) Ninnis Bank colony on 29 September 2022



G) Area of Ninnis Bank colony on 8 November 2022



H) Disintegrated fast ice in the Ninnis Bank region on 8 November 2022

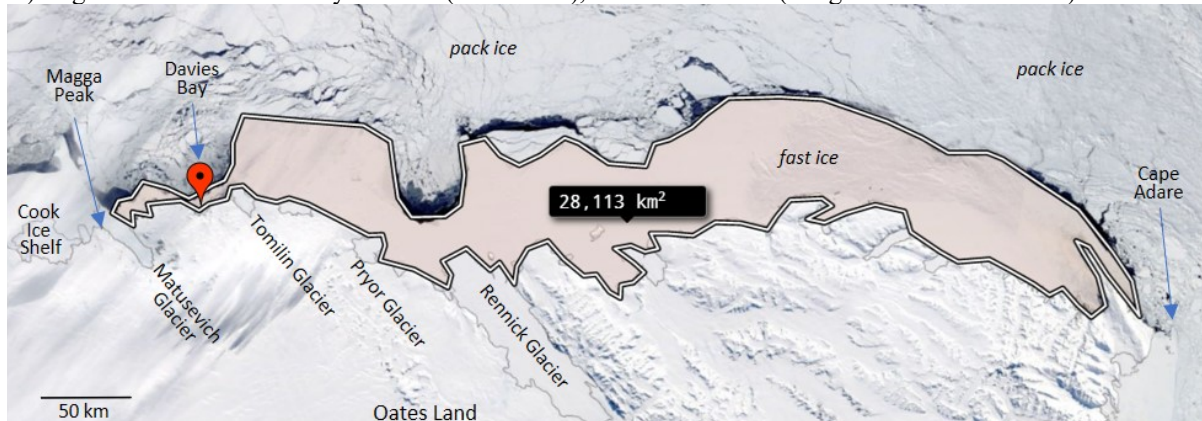


Colony	26. Davies Bay
Region	Davies Bay, Oates Coast, Oates Land, East Antarctica
Recent location	69.34°S, 158.41°E
Date	26 October 2023
Interannual colony movement	0–4 km
Size	unknown, possibly up to 2,000 pairs ⁽¹⁾
Fast ice	The regional fast ice can reach from the Matusевич Glacier (69.33°S, 157.45°E) in the west to Cape Adare (71.28°S, 170.23°E) in the east covering >28,000 km ² (e.g. October 2021) (Image A). Davies Bay is at the western end of this sheet of fast ice where the fast ice can break out west of the Paternostro Glacier (69.36°S, 158.67°E) as early as September (Image B), leaving only a remnant in the colony area (<4 km from coast to fast ice edge). In most years since 2,000, fast ice is very limited in Davies Bay, but large areas exist east and west of the bay. Between Williamson Head (69.17°S, 157.88°E) and the tongue of the Tomilin Glacier (69.44°S, 159.06°E), fast ice is minimal and covers only small areas in Davies Bay.
Ice break out/formation	The fast ice in the bay can break out in early to mid-December, and may refreeze in March.
Maximal distance to fast ice edge	16.5 km (5 September 2021)
Minimal distance to fast ice edge	0 km (6 December 2020, 1 October 2022, 11 November 2023)
Average distance to fast ice edge	4.6 ± 4.5 km
Early fast ice breakout	Partial breakout 6 December 2020, and possibly 11 November 2023; complete breakout by 1 October 2022
Distance from coast	~0.1 km
Colony description	The colony is located on the fast ice in the southwestern part of Davies Bay, in a small embayment formed by the ice tongue of McLeod Glacier (69.35°S, 158.41°E) in the west, the Arthurson Ridge (69.37°S, 158.50°E) in the south, and the ice tongue of the Paternostro Glacier (69.36°S, 158.67°E) in the east.
History	<p>On 21 February 1959, emperor penguins were sighted near Magga Peak (69.15°S, 157.12°E) ⁽²⁾, just west of the Matusевич Glacier — called “Pennell Glacier” by P Law ⁽³⁾ who recorded the sighting a day earlier (20 February). Law suspected that in winter a colony existed nearby. According to Horne ⁽²⁾, 90 adult emperor penguins were sighted. Unfortunately, a precise location was not provided. The coordinates listed in Horne (1983) are of the Wilson Hills. The penguins sighted in 1959 were probably moulting, or post-moult birds. The nearest colony, Davies Bay, is ~57 km farther east from Magga Peak.</p> <p>In 2009, in a Landsat satellite image from 12 January 2002, a colony was detected at 69.328°S, 158.410°E ⁽⁴⁾, on the western side of the McLeod Glacier tongue and east of Stanwix Ridge (69.32°S, 158.39°E), ~3 km west of the current position on the other side of the ice tongue. In January 2002, the northern edge of the ice tongue only reached ~69.34°S, and it is possible that the penguins had gathered there.</p> <p>On 11 October 2009, faecal stains were visible at 69.35°S, 158.49°E ⁽⁴⁾, <0.2 km from the northern part of Arthurson Ridge and east of the McLeod Glacier.</p> <p>By 2018, the McLeod Glacier tongue had advanced ~3 km since 2002 to 69.31°S; in this season, the colony split into two groups ~1.5 km apart. The groups were separated by an arm of the ice tongue protruding eastwards (Image C). By December 2018, the eastern group (~0.4 km north of the northern extreme of Arthurson Ridge) was noticeably larger than the western group.</p> <p>The penguins occupied nearly the same area in 2019 and 2020 as the large group did in 2018, and had formed again one colony (Image D). Note that in 2020, the penguins were on the fast ice, not on the top of the glacier. The Sentinel2 picture in Image C is from 2018 and does not show that the glacial ice had moved slightly north.</p> <p>Fast ice conditions appeared to be suboptimal in 2020. Large tide cracks were visible near the</p>

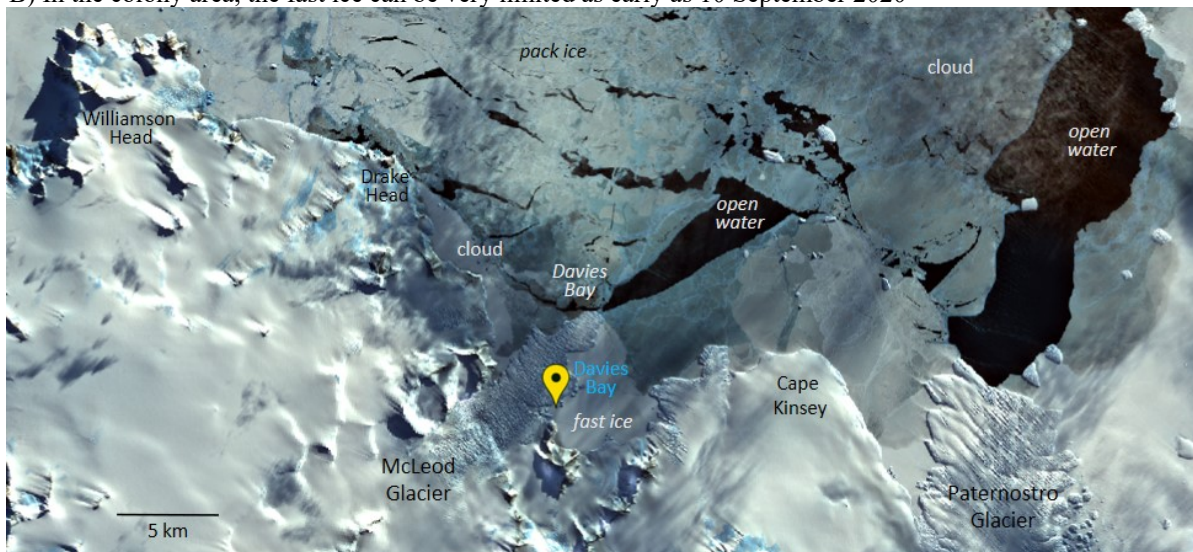
History	<p>colony as early as October. Part of the colony ice broke out in early December, and by the end of December, the colony ceased to exist. It is likely that at least part of the 2020 cohort of chicks did not survive.</p> <p>In 2021, the colony formed ~200 m north of the ice cliffs of the McLeod Glacier Ice Tongue Glacier (69.35°S, 158.41°E) (Image E), after the northern part of the tongue (~12.5 km² and 6.4 km length) had broken off around 22 February 2021 (Image F and G). In 2021, the colony appeared right at the front of the small McLeod Glacier, just over 1 km of where they had been in 2009 (Image D). In early December, a large tide crack opened near the colony, and by early January 2023, the colony area was lost. It is possible that the majority of the chicks survived.</p> <p>In 2022, the colony reformed in nearly the same area as in 2021 at the northern edge of the McLeod Glacier Tongue. Very little fast ice had formed here and the nearest penguins were <400 m from the fast ice edge. By 16 November, the ice had gone. It is highly likely that not many, if any, chicks survived.</p> <p>As in previous years, the area covered in fast ice was minimal in Davies Bay in 2023. On 22 September, two small fast ice areas existed in the bay measuring ~140 km² and 190 km². The colony was at the western side of the McLeod Glacier on the larger fast ice area ~1.5 km from the fast ice edge, the same position it had occupied in 2009. In early November, part of the small ice section broke out, and by 11 November, it had disappeared. The colony had moved ~350 m eastwards onto fast ice in a “canyon” formed by a break in the iceberg tongue. The ice area was only ~3,000 m² and continued to decrease in size. The penguins moved deeper into the gap. By 1 December, only ~1,000 m² of fast ice remained. Dense cloud cover throughout December made it difficult to observe this colony. It is unclear whether this colony had sustained any losses.</p>
Population estimates/counts	None available
References	<p>(1) Trathan PN, Wienecke B, Barbraud C, Jenouvrier S, Kooyman G, Le Bohec C, Ainley DG, Ancel A, Zitterbart DP, Chown SL, LaRue M (2020) The emperor penguin — vulnerable to projected rates of warming and sea ice loss. <i>Biological Conservation</i> 241, 108216</p> <p>(2) Horne RSC (1983) The distribution of penguin breeding colonies in the Australian Antarctic Territory, Heard Island, the McDonald Islands, and Macquarie Island. <i>ANARE Research Notes</i> 9, 7–11</p> <p>(3) Law P (1962) The exploration of Oates Land, Antarctica. <i>ANARE Reports Series A, Vol 1, Commonwealth of Australia, Department of External Affairs</i>, p 24</p> <p>(4) Fretwell PT, Trathan PN (2009) Penguins from space: faecal stains reveal the location of emperor penguin colonies. <i>Global Ecology and Biogeography</i> 18, 543–552</p>

Images

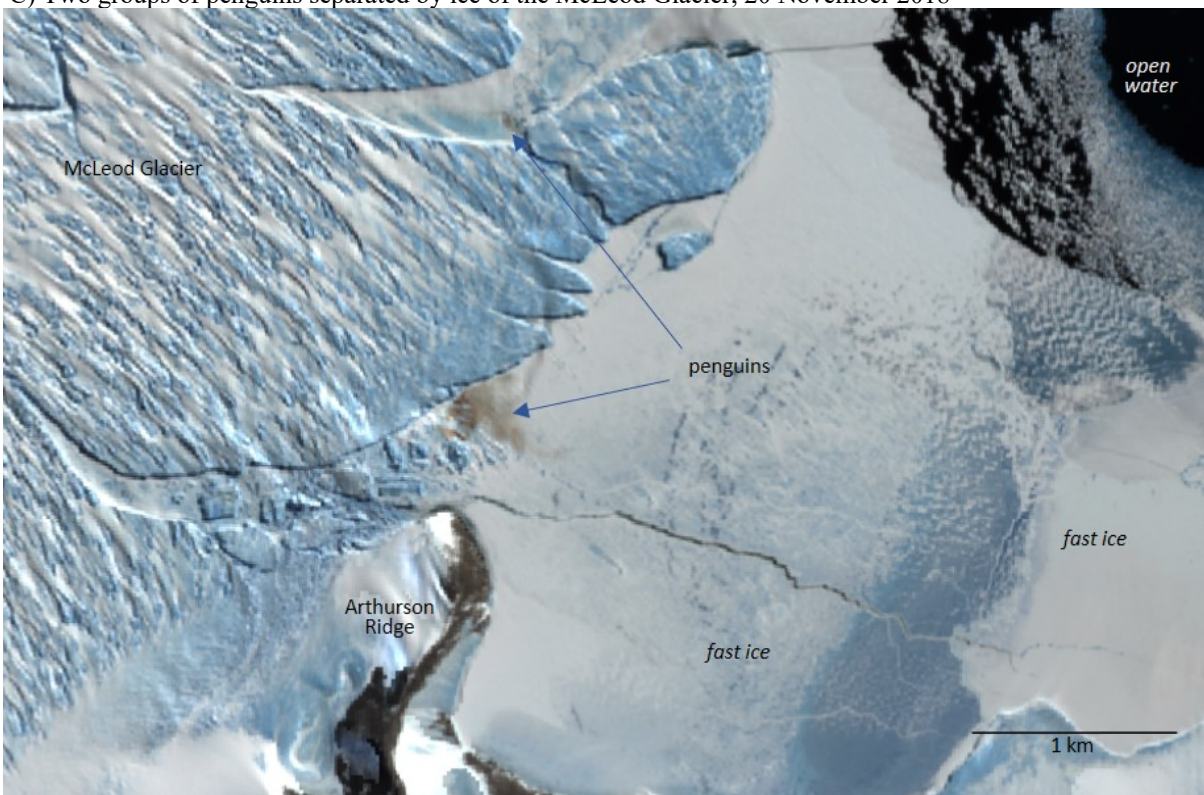
A) Regional fast ice and colony location (red marker), 18 October 2021 (Image: NASA Worldview)



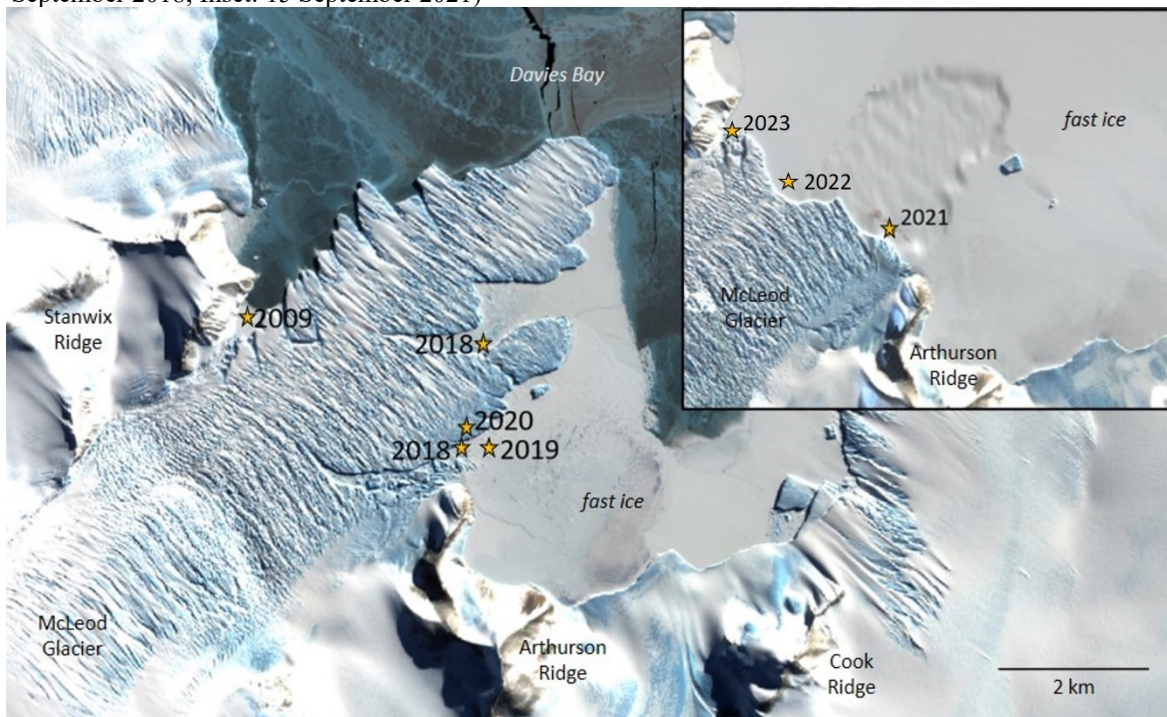
B) In the colony area, the fast ice can be very limited as early as 10 September 2020



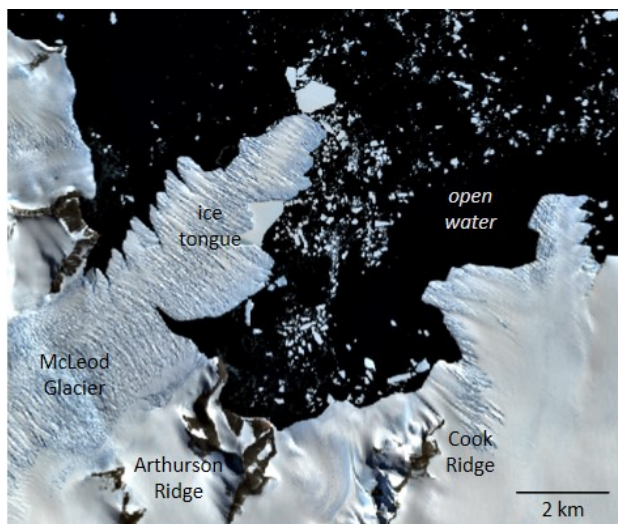
C) Two groups of penguins separated by ice of the McLeod Glacier, 20 November 2018



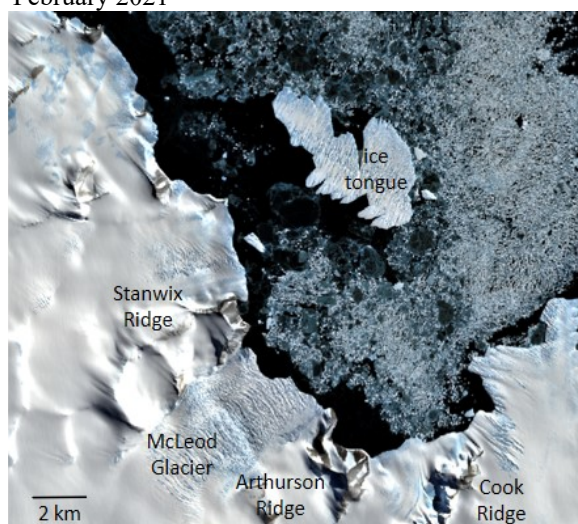
D) Colony locations in 2009, 2018–2022 in Davies Bay near McLeod Glacier (Background images: 28 September 2018; Inset: 15 September 2021)



E) Open water in Davies Bay, 7 February 2021



F) Part of McLeod Glacier Tongue broke off, 27 February 2021

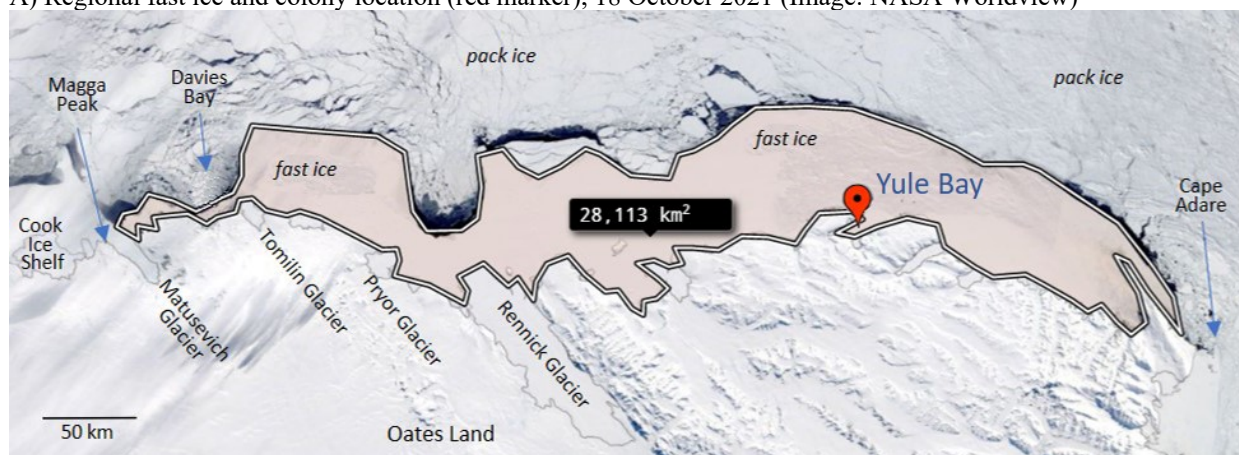


Colony	27. Yule Bay
Region	Yule Bay, Pennell Coast, Oates Land, East Antarctica
Recent location	70.72°S, 166.48°E
Date	9 November 2023
Interannual colony movement	0–1 km
Size	>1,000 pairs ⁽¹⁾
Fast ice	The regional fast ice can reach from the Matusевич Glacier (69.33°S, 157.45°E) in the west to Cape Adare (71.28°S, 170.23°E) in the east covering >28,000 km ² (e.g. October 2021) (Image A). Davies Bay is at the western end of this sheet of fast ice where the fast ice can break out west of the Paternostro Glacier (69.36°S, 158.67°E) as early as September (Image B), leaving only a remnant in the colony area (<4 km from coast to fast ice edge).
Ice break out/formation	From 2001 to 2023, the fast ice in the bay diminished greatly in only three years (2010, 2020, and 2023).
Maximal distance to fast ice edge	80.4 km (23 September 2023)
Minimal distance to fast ice edge	27 km (18 December 2018)
Average distance to fast ice edge	56.3 ± 12.2 km
Early fast ice breakout	None observed
Distance from coast	<4 km
Colony description	Yule Bay lies east of Frecker Ridge (70.87°S, 167.33°E) and the Kirkby Glacier (70.72°S, 166.33°E) and roughly north of the Tapsell Foreland (70.87°S, 167.°E). The O'Hara (70.81°S, 166.64°E) and Fortenberry (70.80°S, 166.95°E) glaciers feed into the bay. Bates Point and Ackroyd Point, only ~5.9 km apart, form the entrance to the inner, western part of the bay where the colony is located on the fast ice south of the Missen Ridge (70.68°S, 166.40°E), near the ice tongue of Chapman Glacier (70.72°S, 166.37°E). In 2022, the penguins temporarily occupied the eastern part of the ice tongue.
History	Emperor penguins were encountered at the eastern side of Yule Bay in three consecutive summers (1979/80 to 1982/83) ⁽²⁾ by members of the German GANOVEX I – III expeditions led by Franz Tessensohn of the Federal Institute of Geosciences and Resources ⁽³⁾ . In December 1981, the MV <i>Gotland II</i> reached the fast ice edge ~27 km north off Yule Bay. A field camp was briefly established at “Birthday Ridge” on Surgeon Island (70.66°S, 167.00°E) ⁽⁴⁾ . However, the expedition ship sank on 18 December 1981 after having been beset in severe ice conditions, cutting short the expedition ⁽⁵⁾ . Members of the party who reached Surgeon Island or who flew to a hut at the Lillie Glacier (70.67°S, 163.92°E) may have seen emperor penguins, but official records about sightings appear not to exist. Wilson and Taylor (1984) mentioned the presence of emperor penguins but said nothing about their breeding status or estimated numbers ⁽²⁾ . If the location provided by Wilson and Taylor (1984) was where emperor penguins were sighted, and if indeed this sighting was made in February, then it may not have been the actual breeding ground but a moult location. The only detail provided by Wilson and Taylor (1984) is that the information was obtained as personal communication from Tessensohn ⁽²⁾ , who died in March 2019 ⁽⁶⁾ . The existence of the Yule Bay colony was confirmed via satellite imagery in 2019 ⁽¹⁾ , ~10 km farther west than indicated in 1984 ⁽²⁾ . From 2018–2023, the colony occupied the western area of Yule Bay ~1 km south of Missen Ridge and 1–1.5 km east of the Chapman Glacier.
Population estimates/counts	None available
References	⁽¹⁾ Fretwell P, Trathan PN (2021) Discovery of new colonies by Sentinel2 reveals good and bad news for emperor penguins. <i>Remote Sensing in Ecology and Conservation</i> 7,

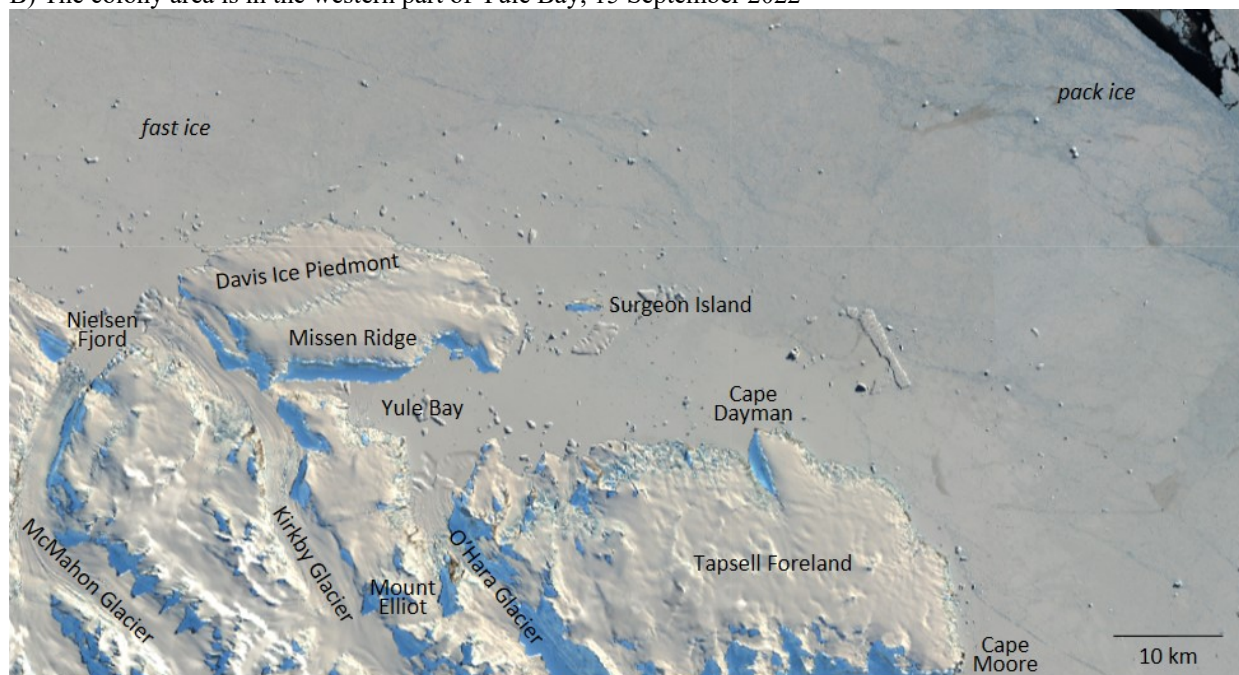
References	<p>139–153</p> <p>(2) Wilson G, Taylor RH (1984) Distribution and abundance of penguins in the Ross Sea sector of Antarctica. <i>New Zealand Antarctic Record</i> 6, 1–7</p> <p>(3) Estrada S, Damaske D, Läufer A, Piepjohn K (2009) Thirty years of terrestrial polar research by the Federal Institute for Geosciences and Natural Resources — a retrospective. <i>Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover</i></p> <p>(4) Kappen L (1983) Ecology and physiology of the Antarctic fruticose lichen <i>Usnea sulphura</i> (Koenig) Th. Fries. <i>Polar Biology</i> 1, 249–255</p> <p>(5) Strübing K (2017) The sinking of the German M/V Gotland II in Dec 1981. IICWG-XVIII, Session on Antarctic Shipping Challenges. September 26, 2017 – Hobart, Australia</p> <p>(5) Kleinschmidt G, Läufer A, Piepjohn K (2019) In memoriam Dr. Franz Tessensohn, <i>Polarforschung, Bremerhaven, Alfred Wegener Institute for Polar and Marine Research & German Society of Polar Research</i> 88, 157–158</p>
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Images

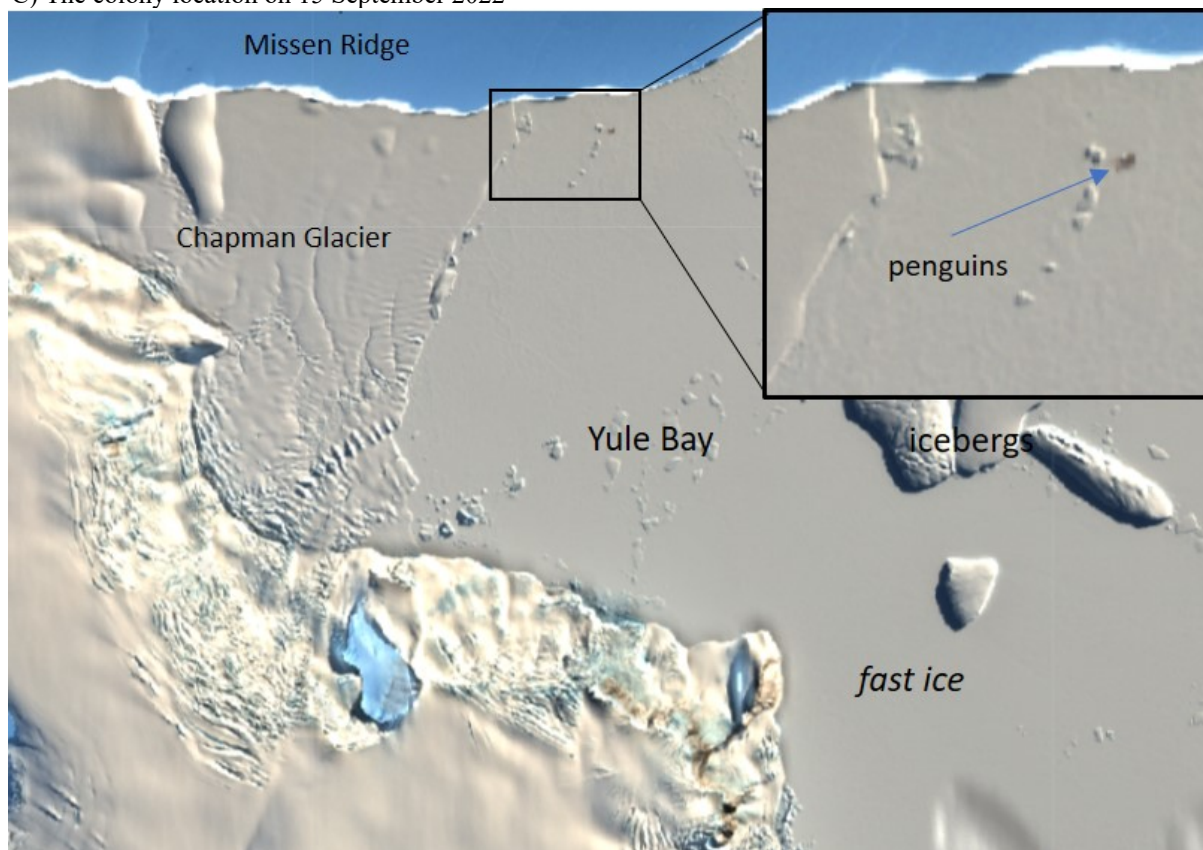
A) Regional fast ice and colony location (red marker), 18 October 2021 (Image: NASA Worldview)



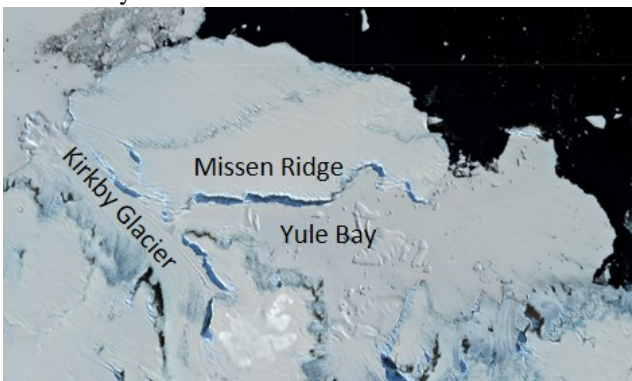
B) The colony area is in the western part of Yule Bay, 15 September 2022



C) The colony location on 15 September 2022



D) Yule Bay often remains frozen over summer, 10 February 2022



E) Substantial ice loss in Yule Bay on 12 February 2023

