IMPORTANT BIRD AREA ANT 110 MUSKEGBUKTA, QUEEN MAUD LAND, EAST ANTARCTICA: A CASE STUDY

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ABSTRACT

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The nomination of Important Bird Areas (IBAs) is a useful approach to determine where valuable biodiversity areas occur. In Antarctica, 204 areas have been designated as IBAs, 34 of which contain Emperor Penguin *Aptenodytes forsteri* colonies. The dynamic nature of the Antarctic environment presents challenges to IBA nominations, particularly for a species such as the Emperor Penguin, whose colonies can shift markedly in location across years. This paper uses IBA ANT 110 Muskegbukta as a case study to explore how changes in local and regional fast ice conditions result in relocation of a colony beyond the nominated IBA boundary. Because the situation at IBA ANT 110 is not unique, a broader review of IBAs containing Emperor Penguin populations is required.

Key words: *Aptenodytes forsteri*, colony movements, Emperor Penguin, IBA, Antarctica

INTRODUCTION

The Important Bird and Biodiversity Areas (IBA) program, formerly known as Important Bird Areas, was established by Birdlife International in 1979 and initially covered only sites in Europe. Over time, the program expanded and IBAs are now identified in nearly every country, totalling more than 13,000 sites and covering marine, freshwater, and terrestrial areas (Waliczky et al., 2019). By 2017, 2,621 IBAs had been nominated for seabirds, of which 62% encompassed breeding colonies and the remainder comprised marine areas (Donald et al., 2019). The southernmost IBAs (south of 60°S) were first listed in the Antarctic Peninsula region in 2010, and the remaining Antarctic sites were assessed between 2013 and 2015. An inventory published in 2015 catalogued 204 IBAs in Antarctica, providing site descriptions, maps, species lists, and information on colony size and area (Harris et al., 2015). Antarctic IBAs primarily target the breeding areas of Antarctic seabirds, although some efforts have been made to nominate marine IBAs (mIBAs) to document important foraging areas based on tracking data (e.g., Dias et al., 2018). A detailed discussion of these areas is outside the scope of this paper.

Although listing an area as an IBA does not, per se, offer formal site protection, these nominations—based on systematically applied, standardized criteria—have been widely used by a range of stakeholders, including policy makers and environmental managers. In several cases, the European Court of Justice acknowledged the value of the scientific approach of the IBA program to identify areas worth protecting (Ramirez et al., 2017). This helped various IBAs gain legal protection and has led to improved conservation outcomes for many threatened species in Europe. For example, the White-headed Duck *Oxyura leucocephala* is globally endangered. Its population decreased from more than 100,000 individuals in the early 20th century to about 20,000 by 1996. In Europe, this duck is now found only in Spain, where numbers fell from approximately 400 in the 1950s to just 22 individuals by 1977. The population decline was driven by habitat degradation and loss, pollution, and hunting. In Spain, the entire population (about 2,000 birds in 2013) occurs in IBAs, 90% of which are designated as Specially Protected Areas (see Deinet et al., 2013, for further examples). IBAs have also been recognized in multilateral environmental agreements, including the Ramsar Convention, the Convention on Biological Diversity, and the Convention on Migratory Species (Waliczky et al., 2019).

Globally, approximately 22% of IBAs are fully protected inside Protected Areas and nearly three quarters (72.7%) are at least partially protected. Nevertheless, a substantial proportion of critical bird breeding sites remains vulnerable to pressures from human activities (Waliczky et al., 2019).

Identification of an IBA is based on a set of standardized criteria and thresholds designed to ensure that the conservation status of a viable population or populations can be secured or improved (see Appendix 1, available on the website). The Global Standard for the Identification of Key Biodiversity Areas (KBAs) was adopted by the council of the International Union for Conservation of Nature (IUCN) in April 2016 (Birdlife International, 2020) and comprises four global criteria (Table A1, Appendix 1).

The assessment of Emperor Penguin *Aptenodytes forsteri* colonies for IBA status was based on two selection criteria. Under Criterion A1, "Globally Threatened Species," a site qualifies if a species is listed on the IUCN Red List as Vulnerable, Endangered, or Critically Endangered. Sites supporting a Near Threatened species also qualified if the number of breeding pairs at a site exceeded the threshold established for this species. Criterion A4, "Globally Important Congregations," applied to areas that were regularly or predictably occupied by ≥ 1% of the global population of one or several species (Harris et al., 2015). At the time the Antarctic IBA report was published (Harris et al., 2015), Emperor Penguins were listed as Near Threatened. One criterion for IBA designation is that a population exceeds the threshold of 1% of the global population. For Emperor Penguins in 2015, this number was based on the most recent available global population estimate of 238,000 pairs

(Fretwell et al., 2012). Approximately one-third of the colonies known at that time exceeded the threshold of 2,380 pairs (Harris et al., 2015).

Of the more than 60 known Emperor Penguin colonies, 34 are located within designated IBAs, 31 of which are occupied exclusively by Emperor Penguins. In Queen Maud Land, three Emperor Penguin colonies qualified for IBA status: Muskegbukta (IBA ANT 110), Princess Ragnhild Coast (IBA ANT 114), and Riiser-Larsen Peninsula (IBA ANT 115). The colony at IBA ANT 110, also known as the South African National Antarctic Expedition (SANAE) colony (e.g., Woehler, 1993), is a particularly dynamic colony and is the focus of the current work. Harris et al. (2015) list the coordinates for Muskegbukta as 70.0°S, 01.42°W, which correspond to the area currently used by the SANAE colony. Their report notes that Fretwell et al. (2012) refer to this colony as "Sanae". To maintain consistency, and as used by South Africa, the colony name should be capitalized.

The history of the SANAE colony provides valuable insights into the challenges that can arise when listing Emperor Penguin colonies as IBAs. These challenges relate to features unique to this species, such as the winter breeding period and the remoteness of colonies, both of which make obtaining reliable population estimates difficult. The optimal time for census work would be during winter when males incubate. However, optical satellite imagery is not available for Antarctica from approximately late April to late August, preventing Emperor Penguin colony monitoring during this period. By the time optical satellite images cover the Antarctic coastline, the chick rearing season is well underway. Adding to the challenge, the dynamic environment the penguins inhabit potentially increases colony mobility. While certain colonies, such as those at Kloa Point (66.64°S, 57.28°E),

TABLE 1
Positions of African National Antarctic Expedition (SANAE) Emperor Penguins *Aptenodytes forsteri* (sub-)colonies, 1979–2024

Date	Latitude (°S)[a]	Longitude (°W)	Distance between sub-colonies (km)	Source[b]
1979	**1**. 70.120	01.910		Condy (1979)
	2. 70.290	02.880	41	
	3. 70.410	03.440	25	
Oct 2009	70.051	01.376		Fretwell & Trathan (2009)
04 Nov 2005	70.034	01.325		Quickbird
28 Oct 2009	69.999	01.431		Quickbird
05 Oct 2010	69.993	01.432		Quickbird
14 Sep 2011	**1**. 69.997	01.290		Quickbird
	2. 70.093	01.219	11	
24 Sep 2012	70.081	01.249		Worldview I
27 Sep 2014	70.073	01.245		Quickbird
15 Aug 2015	70.067	01.247		Worldview I
02 Dec 2016	**1.** 69.956	01.309		Sentinel-2
	2. 70.068	01.229	13	
13 Oct 2017	**1.** 69.956	01.292		Sentinel-2
	2. 70.022	01.263	7	
	3. 70.063	01.236	5	
08 Oct 2018	**1.** 69.949	01.267		Sentinel-2
	2. 70.015	01.246	7	
	3. 70.064	01.217	6	
26 Oct 2019	**1.** 69.938	01.298		Sentinel-2
	2. 70.009	01.259	8	
	3. 70.053	01.241	5	
07 Sep 2020	69.938	01.292		Sentinel-2
05 Oct 2021	**1.** 69.926	01.328		Sentinel-2
	2. 70.029	01.292	12	
	3. 70.039	01.330	2	
30 Sep 2022	69.922	01.357		Sentinel-2
25 Sep 2023	69.918	01.303		Sentinel-2
23 Sep 2024	69.905	01.328		Sentinel-2

[a] Bold numbers indicate the number of sub-colonies. Early satellite images did not cover the entire western side of Trolltunga; sub-colonies could have existed.

[b] See Methods for colony locations determined from optical satellite imagery (Quickbird, Worldview I, Sentinel-2)

Kemp Land, and Amanda Bay (69.24°S, 76.83°E), Princess Elizabeth Land, have occupied the same few square kilometres of fast ice for several decades (Wienecke et al., 2024), others, such as the colonies at the Mertz Glacier and the Lazarev Ice Shelf, have moved up to tens of kilometres over varying periods (e.g., Ancel et al., 2014; Fretwell & Trathan, 2019; LaRue et al., 2015; Wienecke et al., 2024).

Since its first sighting in 1979, the SANAE colony has relocated several times over substantial distances, probably due to changes in the local fast ice environment. Only limited ground observations are available that predate the era of high-resolution satellite imagery, but they mark the beginning of this story. Examples of other Emperor Penguin colonies are also provided for broader context.

METHODS

Coordinates for the SANAE colony were published in Condy 1979 and Fretwell & Trathan 2009. Optical satellite imagery from different sources was used to determine the locations of the colony (see Table 1). For the period 2005–2015, Quickbird and Worldview I images were obtained from https://imagehunter.apollomapping.com. From 2016–2024, colony locations were determined using high resolution Sentinel-2 imagery in the Copernicus browser of the European Space Agency (https://browser.dataspace.copernicus.eu).

Distances between colony locations were calculated as great circle distances using the latitude/longitude distance calculator provided by the National Hurricane Center (2023).

RESULTS AND DISCUSSION

Early History of the SANAE Colony

In 1979, P.R. Condy published the results of an at-sea penguin survey conducted in the King Haakon VII Sea from January to February 1977 (Condy, 1979). In a postscript, the author also reported the sighting of Emperor Penguins at three locations in January–March 1979 (Fig. 1). Neither precise dates nor locations were specified. However, a map in Condy (1979; Fig. 2) shows the outline of the Fimbul Ice Shelf (70.5°S, 0.2°W), various rifts or bays ("bukta" in Norwegian) present at the time, and the locations of Emperor Penguin aggregations.

At colony 1, Condy (1979) counted 84 adults, of which 51 were moulting. Thirty-seven moulting chicks were also present. At colony 3, 27 of 34 adults were moulting, but none of the six chicks had moulted yet. Colony 2 was only seen through binoculars and was estimated to be twice the size of colony 1. The distance between colony 2 and the ship may have been too large to distinguish between adults and chicks. Note that Emperor Penguins

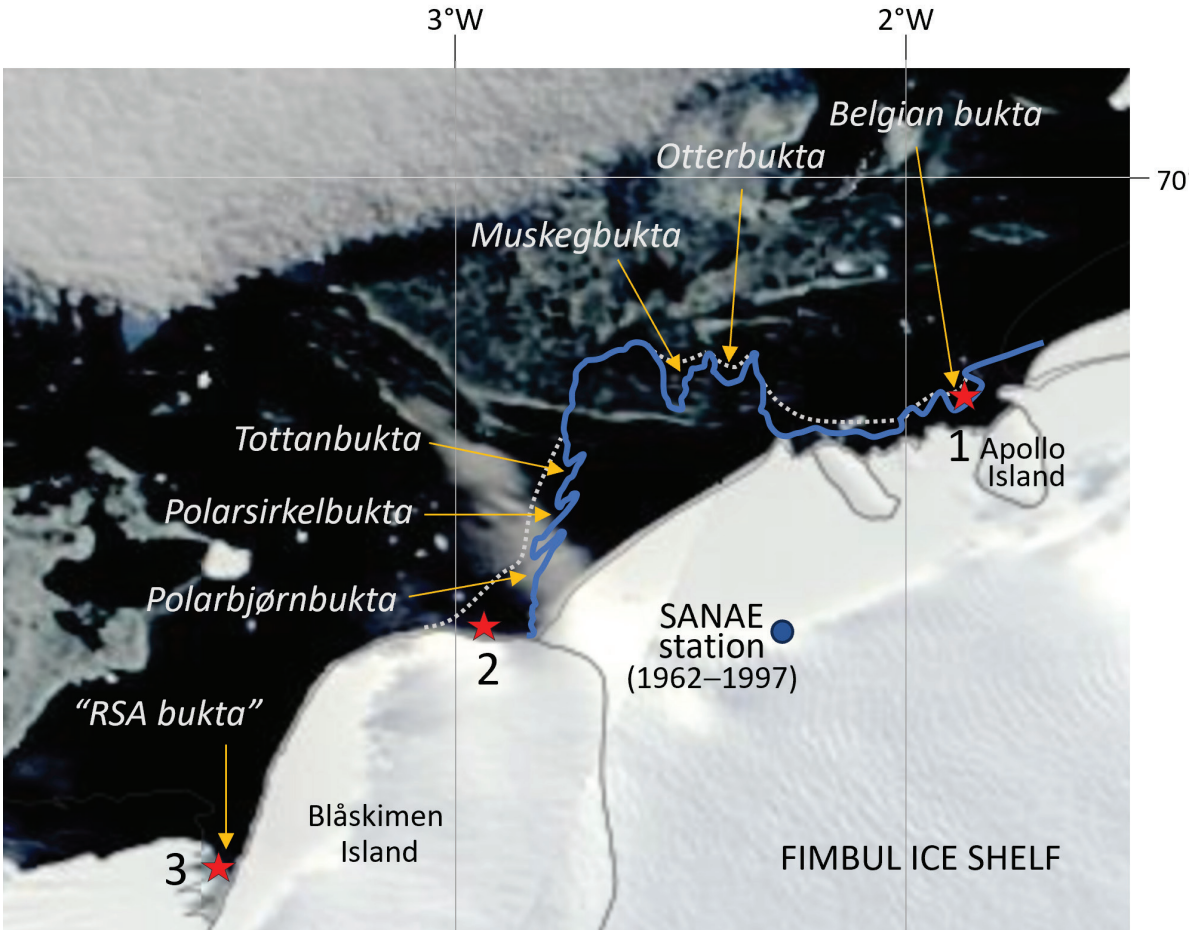

Fig. 1. Locations of Emperor Penguins *Aptenodytes forsteri*, according to Condy (1979), laid over a satellite image. The blue line shows the approximate northern edge of the Fimbul Ice Shelf, East Antarctica, in the 1970s as shown in Condy (1979). The grey stippled lines represent the edge of the fast ice in early 1979. Stars and numbers are colony locations as reported by Condy (1979). Image: Worldview, 01 March 2000 (https://worldview.earthdata.nasa.gov).

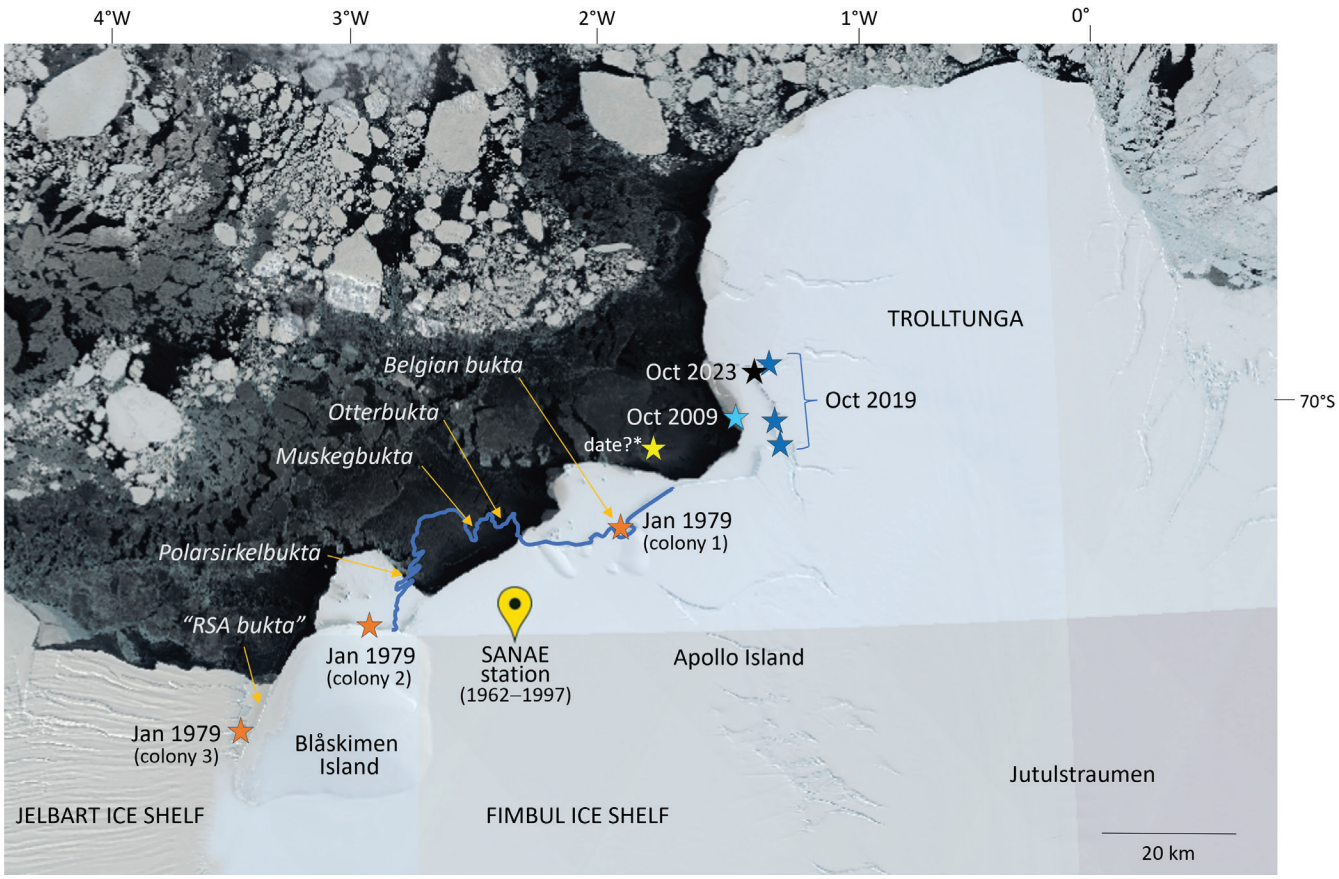

Fig. 2. Known aggregations of Emperor Penguins *Aptenodytes forsteri* near South African National Antarctic Expedition (SANAE) station, Queen Maud Land, East Antarctica, 1979–2023. The location indicated by the yellow asterisk is from Enticott (1986), and the 2009 position (light blue asterisk) is from Fretwell et al. (2012). Image: Sentinel-2, 06 November 2020 (https://browser.dataspace.copernicus.eu).

were not sighted at these locations in February 1976 and 1977 (Condy, 1979), nor have they been seen there since.

As commercially available, portable geo-positioning devices entered the market only in 1989 (Aerospace, n.d.), the precise coordinates of the three colonies could not be determined by Condy (1979). Instead, the author mentioned the coordinates of the nearest research station, that of the South African National Antarctic Expedition (SANAE), located on the Fimbul Ice Shelf, about 12 km east of Blåskimen Island (70.50°S, 03.0°W) (Fig. 1). Since the station gradually moved north with the ice and was buried under snow, it was rebuilt three times (SANAE I to III) at 70.32°S, 02.35°W, after which it was moved inland to 71.68°S, 02.85°W. SANAE IV has been occupied year-round since 1997 (Council of Managers of National Antarctic Programs [COMNAP], 2017).

Based on Condy's (1979) information, the distances from SANAE station to the three colonies were approximately 25, 20, and 44 km for colonies 1, 2, and 3, respectively. Colonies 1 and 3 were nearly 70 km apart. The presence of moulting chicks indicates that Emperor Penguins were breeding there. Given the distances between the sites, it is unlikely that any exchange occurred between the three groups within a single season; therefore, it was reasonable at the time to consider them as separate colonies.

From 1979 to 1985, members of the FitzPatrick Institute, University of Cape Town, South Africa, collected ship-based records of Emperor Penguins off Queen Maud Land. Most records were observations of Emperor Penguins at sea, usually in small numbers, during voyages made largely outside the breeding season. Occasionally, a few Emperor Penguins were seen around moored ships and on the ice shelf (Enticott, 1986). Enticott reported roughly 500 individuals on fast ice at 70.05°S, 01.82°W (Fig. 2). Without documentation of the observation date or presence of chicks, it is unclear whether this aggregation was part of a breeding colony or a group of (pre-)moulters.

During the 1986 winter, mammals and seabirds were censused along the track of the German icebreaker *Polarstern*, which travelled along the Greenwich meridian towards Queen Maud Land. Pack ice formed a 250-km-wide band extending outward from the continent, with 90%–95% ice concentration in the southern part of the zone. Over approximately seven weeks (July to September), 89 Emperor Penguins were sighted singly or in small groups in the southern part of the pack ice region, roughly from 04.5°W to 08.0°E. The northernmost sighting occurred at 63.67°S, approximately 700 km off the breeding colony (single) somewhere near SANAE station (Plötz et al., 1991). Given the dense sea ice, the ship would not have been able to get close enough to the coast to observe a colony.

The first Antarctica-wide synoptic satellite-based survey of Emperor Penguin colonies, published in 2009, detected a small colony at 70.05°S, 01.38°W (image date not available; Fretwell & Trathan, 2009). The authors concluded that the SANAE colony had relocated

47 km from its previously reported position. In 2012, the SANAE colony location was listed at 70.0°S, 01.42°W, on 28 October 2009 (Fretwell et al., 2012). Only one colony site was mentioned, and the relocation distance was based on coordinates from SANAE station rather than from locations shown in Condy (1979). Based on the three colonies listed in Condy (1979), the distances from the 2009 location to Condy's colonies 1, 2, and 3 were approximately 33, 73, and 98 km, respectively (Fig. 2). The 2009 location was about 17 km east of the aggregation of Emperor Penguins reported by Enticott (1986).

At least since 2005, Emperor Penguins have occupied the fast ice west of Trolltunga (Table 1), an ice tongue that is the northward extension of Jutulstraumen, the largest outlet glacier in the region, stretching from 20°W to 15°E (Swithinbank, 1988). Since the ice front moves northwards at a rate of about 740 $m \cdot y^{-1}$ (Sharma et al., 2025), minor changes in colony locations occur naturally as the sub-colonies, or colony, shift with it. Over time, this can amount to a displacement of several kilometres. Similar observations have been made at other colonies, such as Karelin Bay (66.39°S, 85.38°E), Princess Elizabeth Land, where the colony was gradually forced northward by the advance of the West Ice Shelf (Wienecke et al., 2024).

Colony Locations and Ice Conditions

Local fast ice conditions are among the factors that determine where Emperor Penguin colonies can gather (for other factors, see Santora et al., 2020). Fast ice areas need not be very large, but the surface must be relatively smooth and level. Importantly, the fast ice must persist from March/April to December/January, the period required for the penguins to raise their chicks to fledging. West of Trolltunga, ice conditions changed at least twice since 1979, likely influencing colony locations.

Sometime between 1979 and 2000, the front of the Fimbul Ice Shelf retreated along about 40 km of coast northeast of Blåskimen Island, including the various bays referred to in Condy (1979). The only bay still extant is "RSA bukta" (not listed in the Scientific Committee on Antarctic Research [SCAR] Composite Gazetteer [SCAR, 2014]), west of Blåskimen Island, which was not affected by this loss of shelf ice. The northern part of the Fimbul Ice Shelf must have persisted for some time for Norwegians to have named several small embayments in the shelf. One of these, Polarsirkel bukta, was used occasionally by Norwegian ships in the early years of Antarctic operations (Henriksen, 2007). A piece of the shelf, with an area of 300 km^2 or more, must have broken off during this period; alternatively, the shelf ice may have disintegrated gradually. In any case, Polarbjørn, Polarsirkel, Tottan, Muskeg, and Otter bays no longer exist, although all remain listed in the SCAR Composite Gazetteer of Antarctica (SCAR, 2014). Whether the loss occurred abruptly or progressively, it may have triggered penguins to move farther east to the western side of Trolltunga (Fig. 2), where the SANAE colony has persisted, since at least 2005.

Another noticeable loss of glacial ice occurred in 2011, when an iceberg approximately 25 km long (area > 200 km^2) calved northeast of Apollo Island (Fig. 3A). This event reduced both the width and length of a rift in the ice tongue—from 5.5 km wide and about 20 km long in September 2010 to about 1 km wide and only 5.3 km long one year later. In September 2010, Emperor Penguins had assembled on the fast ice near the opening of the rift, at 69.99°S, 01.22°W. By 2011, two separate groups, or sub-colonies, had formed: the northern group was about 5 km east of the 2010 colony position, and the southern group had gathered 11 km south of the new entrance of the diminished rift (Fig. 3E, Table 1). During 2017–2019 and in 2021, a third sub-colony formed between the northern and southern sub-colonies. This central sub-colony was the smallest aggregation and,

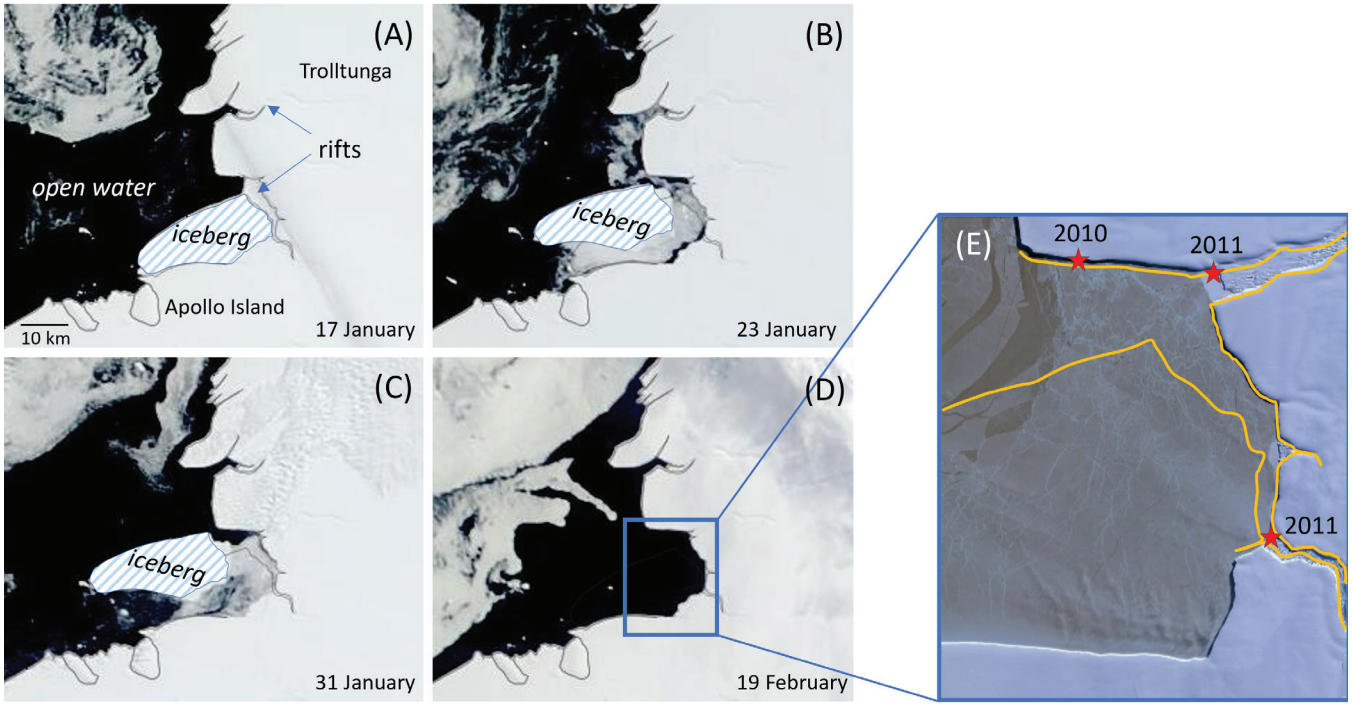

Fig. 3. Changes in ice conditions southwestern side of Trolltunga, Norway, in 2011: (A) 17 January, (B) 23 January, (C) 31 January, (D) 19 February. Panel (E) shows colony positions in October 2010 and September 2011. The yellow line represents the previous edge of the ice shelf. Images: (A) to (D) Worldview (https://worldview.earthdata.nasa.gov); (E) Sentinel-2, 05 September 2011 (https://browser.dataspace.copernicus.eu).

at distances of 2–6 km, was closer to the southern than the northern sub-colony, which was 7–13 km away. Given the local icescape, it is likely that the sub-colonies were separated from the start of the breeding season and functioned as independent units throughout. It is unlikely that significant movement occurred between sub-colonies during the breeding season.

In 2020 and again during 2022–2024, the three sub-colonies merged into one colony, as all penguins congregated at the site of the northernmost sub-colony. By 03 April 2020, no fast ice had formed on the western side of Trolltunga along approximately 70 km of the ice front. However, an area of thick multiyear fast ice in the rift previously used by the northern sub-colony enabled the penguins to access a safe breeding area (Fig. 4).

Condy (1979) observed the three emperor aggregations only once and, given the distances between them, assumed they represented separate colonies. Based on the current knowledge, however, these penguins appear to comprise a single population. In some years, they still separate into different sub-colonies, a behaviour also seen in other Emperor Penguin colonies. For example, the Sabrina Coast colony (66.17°S, 121.13°E) in Wilkes Land formed two and four sub-colonies that remained several kilometres apart throughout the season in 2019 and 2021, respectively, but formed a single colony in other years (Wienecke et al., 2024). Such colonies may be described as temporally limited "meta-populations," as they reunite into one colony in some years. The drivers of this behaviour are unknown, but local fast ice conditions—such as timing of formation and rugosity—likely play a role. Emperor Penguins have persisted through multiple ice ages and interglacial periods, evolving in a dynamic environment and adapting to conditions that may vary annually or over longer time scales (Ainley & Wilson, 2024). However, in areas where fast ice is scarce, such as current coastal areas of Queen Maud Land, their long-term persistence may be challenging.

As mentioned above, Condy (1979) provided a map of the locations of three aggregations of Emperor Penguins in 1979. The map

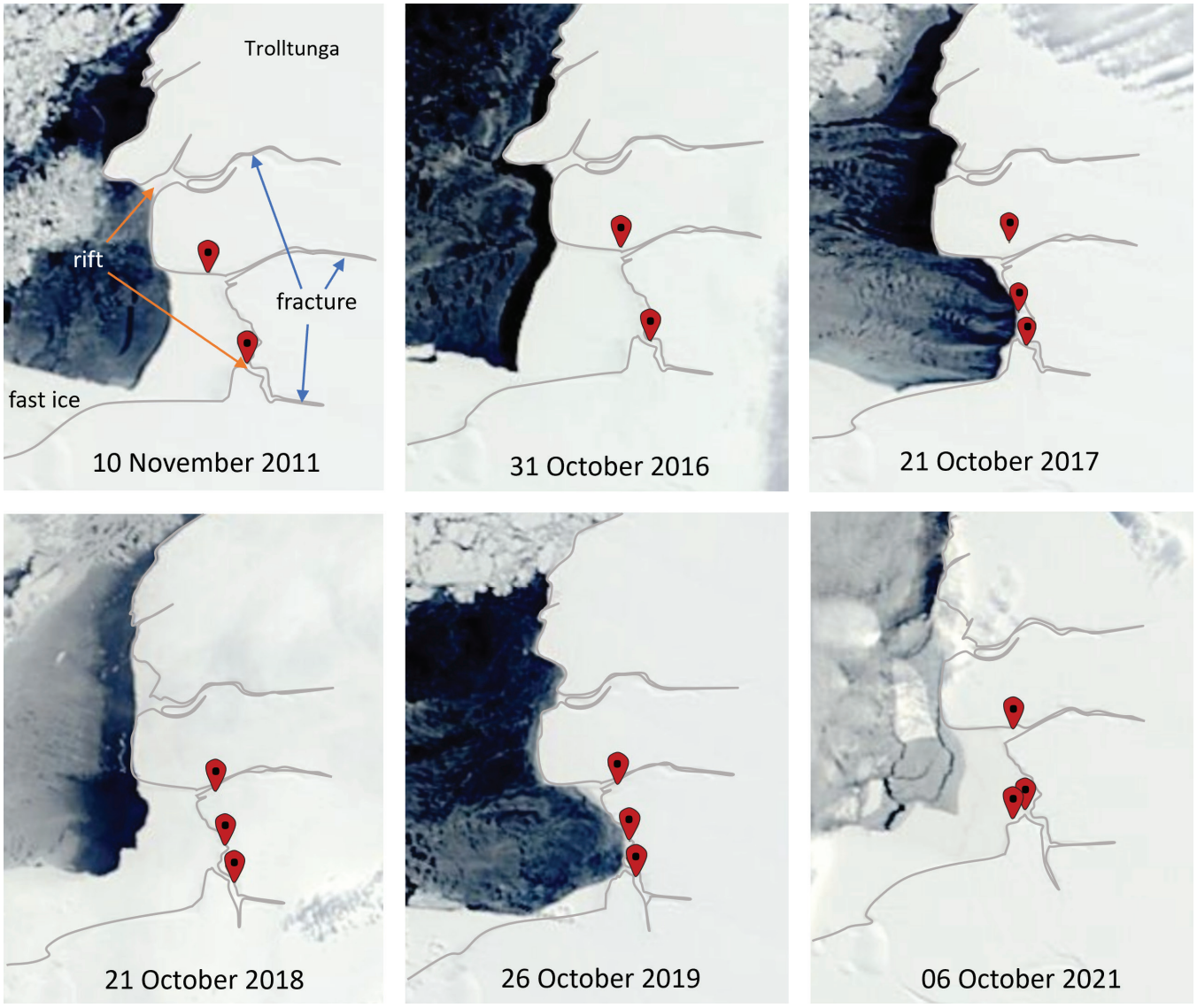

Fig. 4. Locations of Emperor Penguin *Aptenodytes forsteri* sub-colonies at the South African National Antarctic Expedition (SANAE) colony, Queen Maud Land, East Antarctica, in different years. Images: Worldview (https://worldview.earthdata.nasa.gov).

extends from approximately 03.7°W (just west of "RSA bukta") to about 01.7°W (just east of Belgian bukta), including Muskegbukta at longitude 02.5°W. The outline of the Fimbul Ice Shelf front as it existed in the 1970s is shown in Fig. 1, illustrating the substantial loss of shelf ice since that time. Although the exact date of this ice loss is unknown, the portion of shelf ice extending roughly north of Blåskimen Island had already disappeared by March 2000. The shape of this northerly protrusion resembles the shape of Trolltunga, albeit at a smaller spatial scale. It is possible that, when IBA ANT 110 was designated, Trolltunga was mistaken for the shelf ice with its various bays, as shown in Condy (1979) (see Fig. 2). However, Muskegbukta—originally named by Norway—was located at 70.17°S, 02.58°W (SCAR, 2014), about 41 km west of the most recent colony location. Furthermore, the designated area of IBA ANT 110 is 431 ha (4.3 km^2) (Harris et al., 2015), encompassing only the northernmost aggregation, which in October 2024 was located at 69.90°S, 01.32°W. Due to the movement of the ice tongue, the main colony area is now nearly 12 km north of the location recorded for this colony in 2015 (70.0°S, 01.42°W) (Harris et al., 2015).

Given the current evidence, it is recommended that, when Antarctic IBAs are eventually reviewed, the coordinates for IBA ANT 110 be updated and that the site be referred to as SANAE Colony, Trolltunga.

Changes at Other Antarctic IBAs

The events at the SANAE colony are not unique (see Wienecke et al., 2024). For example, in 2010, the breeding area of IBA ANT 160, the Mertz Glacier Emperor Penguin colony (66.90°S, 146.62°E) in George V Land, was lost when an iceberg collided with the ice tongue (Ancel et al., 2014), shortening it by about 70 km and decreasing its area by 2,500 km^2. The fast ice extent east of the glacier tongue is variable but was irrevocably reduced. In October 2009, fast ice covered > 10,000 km^2, compared with only 1,400 km^2 in October 2012. The pre-2010 colony site became an area of open water and pack ice. Over the next two years, the colony relocated to a new position > 70 km south of the previous location, where it has remained (Wienecke et al., 2024). Because this event occurred before the colony received IBA designation, the general area covered by this IBA is still valid. However, one important change is that the two sub-colonies have since reunited, and the slightly more northerly site is no longer occupied (Wienecke et al., 2024).

A different scenario unfolded at IBA ANT 105, the Halley Bay colony (75.49°S, 27.29°W) at the northern edge of the Brunt Ice Shelf, Coats Land. This colony once supported > 15,000 breeding pairs (Hempel & Stonehouse, 1987). In three consecutive years, the fast ice in the colony area broke out (Fretwell & Trathan, 2019). In October–November 2015–2017, the distance from the colony to the fast ice edge measured only 0.7–1 km. After these events, nearly the entire colony moved ~59 km south to Cape Dedo, the site of the IBA ANT 104 Dawson-Lambton colony (76.08°S, 26.72°W) (Fretwell & Trathan, 2019), where most penguins remain to this day. A small group returned to the northwestern part of the Brunt Ice Shelf in 2018 and continued to gather in the general area until 2023, when a major calving event occurred. On 23/24 January 2023, A-81, a giant iceberg (~1,500 km^2), broke off the western Brunt Ice Shelf, turning the Halley Bay colony site into open water (Marsh et al., 2024). During the 2023 and 2024 breeding seasons, the remaining colony, of unknown size, relocated to 75.45°S, 26.24°W, just east of the McDonald Ice Rumples (see Table A3, Appendix 1 for details).

In the 2015 report on Antarctic IBAs, the coordinates given for Halley Bay are 75.45°S, 27.41°W. The distance between this location and the most recently recorded position of the colony is about 33 km—farther east and well outside the boundaries of IBA ANT 105, which covered 500 ha (5 km^2) (Harris et al., 2015). The original site of IBA ANT 105 no longer exists, and the current population size is unknown. Thus, it is unclear whether this colony still fulfils the population threshold for IBA designation (2,380 pairs; Harris et al., 2015).

The change in local conditions at the Mertz Glacier colony occurred on a much larger spatial scale, and the colony had to relocate over a longer distance than the Halley Bay colony. However, the collision at the Mertz Glacier ice tongue occurred in February, when all chicks had already fledged and the penguins were no longer present. East of the Mertz Glacier, fast ice can cover > 1,600 km^2 even in a poor year (e.g., 2023 and 2024), giving the local colony greater opportunity to relocate to a safer location farther south, at least for the time being.

Considerations for IBA Nomination of Emperor Penguin Colonies

The constantly changing environment of Emperor Penguins poses some challenges for the designation of Emperor Penguin colonies as IBAs. Colonies may relocate when conditions in traditional breeding areas become unsuitable, rendering previously designated IBA boundaries invalid. This is the case for IBA ANT 110. Muskegbukta was nominated as an IBA in 2015, but the colony has since shifted east and north, well beyond the 4.3 km^2 that originally comprised the IBA. Since 2018, changes in local fast ice conditions transformed the previous IBA site into an area of open water. Additionally, several times in the last decade, the colony separated into two to three sub-colonies, complicating the IBA unless areas of potentially tens of square kilometres are included. Even if the colony were to remain in the rift it currently occupies, movement of the Trolltunga is causing a gradual shift northward, even if fast ice conditions were to remain unchanged. Finally, the geographic feature after which IBA ANT 110 was named, Muskegbukta, no longer exists.

The changing situation at the colonies discussed here, and at others, indicates that a review of Emperor Penguin IBAs is needed. This review should include reassessment of colony locations, and IBA boundaries, and populations. At least four colonies are potential candidates for IBA nomination as their populations likely exceed the population threshold: (1) the Vanhöffen colony (66.06°S, 86.48°E in 2024), which was discovered only recently (Fretwell, 2024); (2) the Ninnis Bank colony (66.81°S, 149.49°E); (3) the Cape Gates colony (73.67°S, 122.71°W); and (4) the Princess Astrid Coast colony (69.94°S, 08.14°W) (Fig. 5).

Regarding colony size and the global population, criterion A4 of Birdlife International's *Guidelines for the Application of the IBA Criteria* (BirdLife International, 2020) addresses "Globally important congregations." Central to the selection of Emperor Penguin colonies as IBAs is criterion A4ii, which states that a colony may qualify for nomination if 1% or more of a global population

regularly attends a breeding site. However, as noted above, obtaining reliable population data for Emperor Penguins is challenging because of the remoteness of most colonies and the species' winter breeding cycle. Since the first global population estimate of 238,000 breeding pairs (Fretwell et al., 2012), several new, generally small colonies were discovered, increasing the estimated global population by approximately 5%–10% (249,900–261,800 breeding pairs) (Fretwell & Trathan 2021). This estimate was derived primarily from satellite imagery taken in spring rather than winter.

The most accurate estimate of the number of breeding pairs attending a colony is obtained by censusing incubating males, as one male is assumed to represent one breeding pair. As the breeding season progresses from incubation to fledging (winter to spring), however, the number of adults present in a colony decreases, and from about November onwards, chicks—which are very difficult to count in satellite images—outnumber the adults (Wienecke et al., 2024). LaRue et al. (2024) refined the global estimate to be approximately 250,000 adult birds, rather than breeding pairs. This

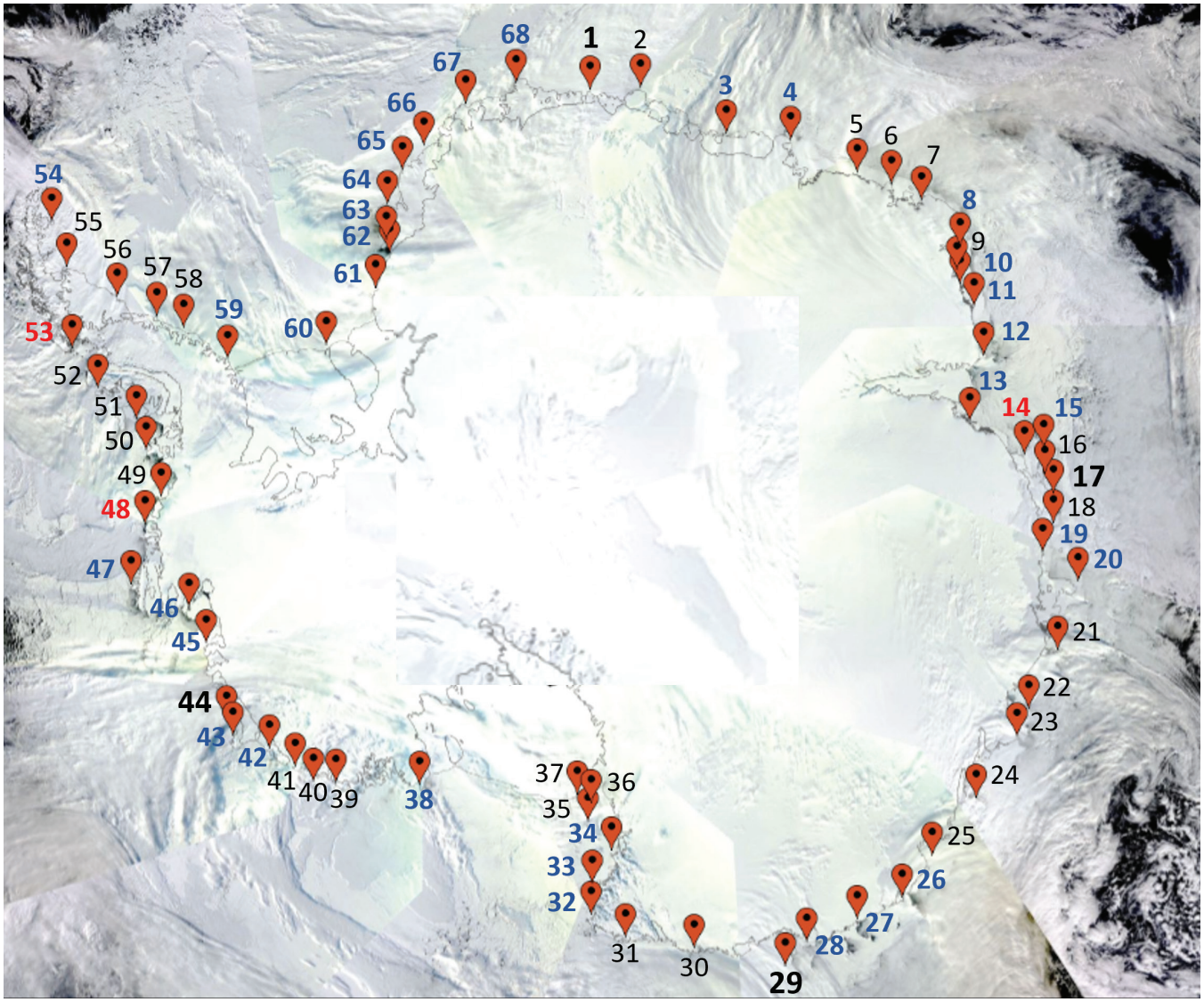

Fig. 5. Emperor Penguin *Aptenodytes forsteri* colonies known in 2024. Blue number = Important Bird Area (IBA); red number = no longer extant; bold black number = colony that would qualify as an IBA but is not yet listed. IBAs as listed in Harris et al. (2015): 1–Astrid Coast; 2–Lazarev Ice Shelf; 3–Ragnhild Coast; 4–Riiser-Larsen Peninsula; 5–Umebosi; 6–Casey Bay; 7–Amundsen Bay; 8–Kloa Point; 9–Fold Island; 10–Taylor Glacier; 11–Auster; 12–Flutter (Cape Darnley); 13–Amanda Bay; 14–Barrier Bay; 15–West Ice Shelf; 16–Karelin Bay; 17–Vanhöffen; 18–Posadowsky Bay; 19–Haswell Island; 20–Shackleton Ice Shelf; 21–Bowen Island; 22–Petersen Bank; 23–Cape Poinsett; 24–Sabrina Coast; 25–Porpoise Bay; 26–Dibble Glacier; 27–Pointe Géologie; 28–Mertz Glacier; 29–Ninnis Bank; 30–Davies Bay; 31–Yule Bay; 32–Cape Roget; 33–Coulman Island; 34–Cape Washington; 35–Franklin Island; 36–Beaufort Island; 37–Cape Crozier; 38–Cape Colbeck; 39–Rupert Coast; 40–Cruzen Island; 41–Verleger Point; 42–Ledda Bay; 43–Thurston Glacier; 44–Cape Gates; 45–Bear Peninsula; 46–Brownson Islands; 47–Noville Peninsula; 48–Pfrogner Point; 49–Bryan Coast; 50–Smyley; 51–Verdi Inlet; 52–Rothschild Island; 53–Dion Islands; 54–Snowhill Island; 55–Jason Peninsula; 56–Gipps Ice Rise; 57–Smith Peninsula; 58–Dolleman Island; 59–Cape Darlington; 60–Gould Island; 61–Luitpold Coast; 62–Dawson-Lampton Ice Tongue; 63–Halley Bay; 64–Stancomb-Wills Glacier; 65–Drescher Inlet; 66–Riiser-Larsen Ice Shelf; 67–Atka Bay; 68–SANAE. Image: Worldview, 18 September 2024 (https://worldview.earthdata.nasa.gov).

estimate nearly halves the previously assumed global population size. Nevertheless, given the limitations outlined above, using the number of adults as a metric for spring population estimates appears more appropriate than using the number of breeding pairs. Even if absolute numbers of adults attending a colony cannot be determined, relative comparisons of colony size in October/November can still provide valuable insights into temporal and spatial variation in colony size.

IBAs are defined not only by population size but also by area. The guidelines do not specify standardized criteria for delineating IBA boundaries. For some colonies, the area accepted as IBA was based on pre-existing limits. For example, IBA ANT 128 Amanda Bay became an Antarctic Specially Protected Area in 2006. The management plan defines its boundary, which was subsequently adopted as the IBA boundary. Where pre-defined or natural boundaries, such as the coast of small islands, do not exist, an area of 5 km^2 (equivalent to a circle with a diameter of 2.5 km) is generally accepted, with the colony taken as the centroid (Harris et al., 2015). For Emperor Penguins, however, this approach may not be applicable because colony locations can shift both within and between seasons (Harris et al., 2015; Wienecke et al., 2024). Many Emperor Penguin colonies utilise approximately the same area from year to year, but may still shift their precise position by more than 5 km in response to variations in conditions and quality of local fast ice (Wienecke et al., 2024). Consequently, the area a colony is likely to occupy over period of several years (e.g., five years) may exceed 5 km^2 or fall entirely outside the designated IBA.

CONCLUSIONS

Birdlife International's *Guidelines for the Application of the IBA Criteria* (BirdLife International, 2020) call for a review of the 1% population threshold every four years. A reassessment of the global population of Emperor Penguins is therefore warranted, as most population estimates are more than 15 years old (see Table A2, Appendix 1). Although some new population data have become available since the initial assessment in 2009 (e.g., Fretwell & Trathan, 2021; Wienecke et al., 2024), population sizes for several colonies must still be estimated or updated.

Given the rapidly changing conditions in the Antarctic environment and the potential for colony relocations, it is necessary to monitor Emperor Penguin colonies across Antarctica, or at least by region (LaRue et al., 2015). It is imperative to standardise, as far as is practical, the timing of population surveys and to report count units consistently (ideally as numbers of chicks, or numbers of adults and chicks counted separately).

In addition, the criteria for identifying IBAs have been revised to align with those of the *Global Standard for the Identification of Key Biodiversity Areas* (Birdlife International, 2020) since the report on Antarctic IBAs was published. Hence, a review is also needed to update the designation of Antarctic IBAs.

Finally, the issues discussed here regarding the nomination of IBAs for Emperor Penguins are also relevant to other types of conservation areas, including marine IBAs and KBAs.

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