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THE ANTARCTIC
THE EMPEROR PENGUIN'S MARCH TOWARDS EXTINCTION



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The Emperor Penguin, now officially classified as “Endangered”

Catastrophic breeding failures, increased mortality and a declining global population all suggest that the emperor penguin, a species endemic to Antarctica will be at risk of extinction in the coming decades.

In April 2026, the International Union for Conservation of Nature (IUCN) reclassified the emperor penguin (*Aptenodytes forsteri*) from ‘Near Threatened’ to ‘Endangered’. The assessment shows a global population median decline of 59% by 2073, over three generations. This decision follows its listing in 2022 as a ‘threatened’ species under the US Endangered Species Act (ESA). Both classifications are based on twenty-five years of research linking observations on climate and population dynamics. The threat is no longer hypothetical: population declines and breeding failures are already being observed, while projections reveal the growing risk of extinction being recognized by international conservation authorities.

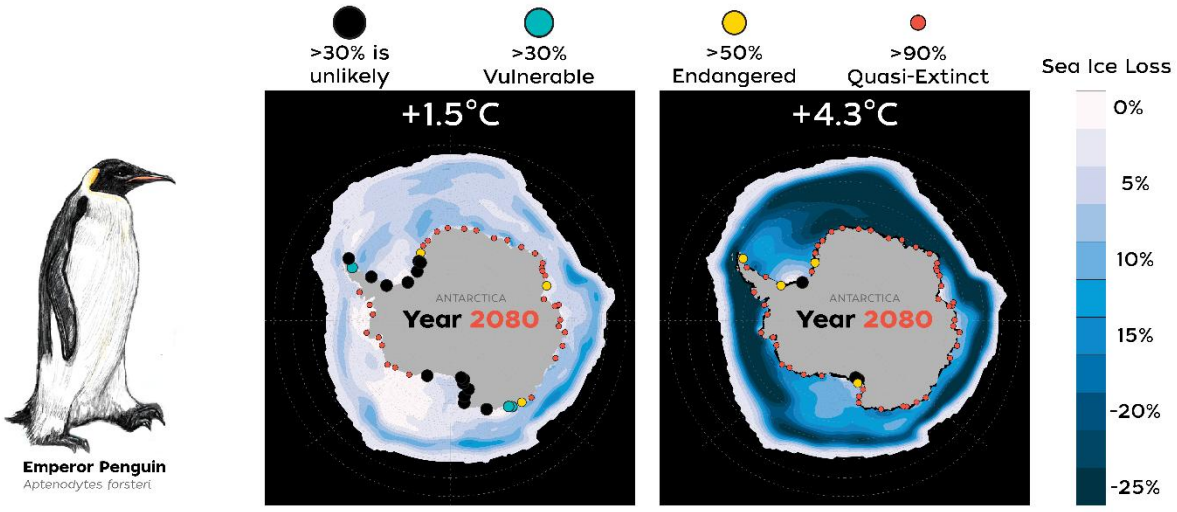


Figure 1 – Projections for the future of emperor penguin populations by 2080, based on two global warming scenarios (+1.5°C or 4.3°C by 2100). The circles represent colonies, with their colors indicating the extent of the projected decline. The shades of blue illustrate the retreat of sea ice. *Credit: Jenouvrier and al., 2021.*

‘By 2050, at least two out of three colonies would be nearly gone extinct under scenarios based on current energy trends and prevailing policies’

The emperor penguin is the only bird to breed in Antarctica during the southern winter. Adults arrive at their colony in March or April. The female lays a single egg in May or June, and passes it to the male, who incubates it on his feet for approximately two months without feeding. After hatching in July or August, the parents take turns travelling to the ocean and looking after the chick. The chick must develop waterproof plumage before leaving the sea ice in December or January. Successful breeding depends on stable *landfast sea ice* (fixed platform of sea ice attached to the coastline) which must remain intact until the chicks are ready to enter the ocean (Fig. 2). Landfast ice must form early enough to accommodate the colony and remain intact until the chicks have developed their waterproof plumage. If it breaks up too early, the chicks may fall into the water and drown. However, sea ice that extends too far from the coast is also dangerous: it forces the parents to travel long distances between the colony and feeding grounds, prolongs the time between meals and reduces the chicks' chances of survival.

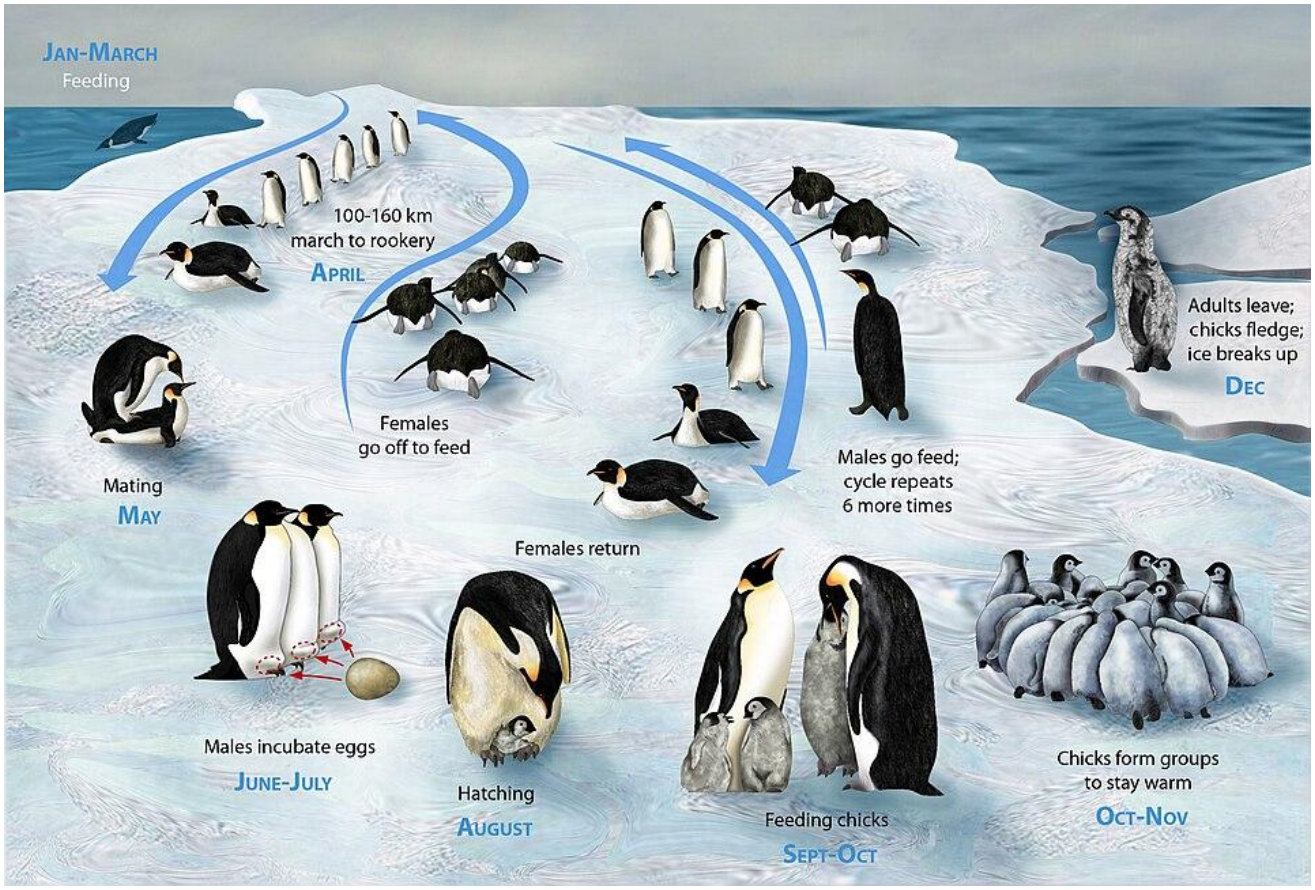


Figure 2– The life cycle of the emperor penguin is closely linked to sea ice. *Crédit : Zina Deretsky, National Science Foundation, U.S. Antarctic Program Photo Library.*

For emperor penguins, as for other Antarctic seabirds such as Adélie penguins and snow petrels, sea ice presents a Goldilocks problem: not too much, not too little, but just the right amount. This delicate balance explains why the relationship between sea ice

conditions and penguin populations is not simply linear. Ice has a direct effect on the stability of the breeding site and an indirect effect on the availability and access to prey, particularly krill and fish. It also influences the *moult* (the 4 to 6 weeks period during which adults renew their plumage) and must remain on the sea ice, as their plumage no longer allows them to maintain their thermal insulation in the water. Any change in the extent of the sea ice, the length of the sea ice presence or the dates of sea ice onset and break-up, can disrupt several stages of the emperor penguin's life cycle.

The Pointe Géologie colony, located in Terre Adélie, near the French research station Dumont d'Urville was featured in Luc Jacquet's documentary 'March of the Penguins'. French scientists have monitored this colony since the 1950s, which provided one of the earliest warning signs of the effects of changing sea ice conditions on emperor penguins. Between 1973 and 1981, winter sea ice extent off Terre Adélie declined substantially. This period was accompanied by increased adult mortality, particularly among males, and the colony lost approximately half of its breeding pairs. Subsequently, years of poor breeding success became more frequent, preventing the colony from recovering to its former size. Extensive sea ice can also reduce breeding success. When the distance between the colony and open water exceeds approximately 50 km, parents must travel farther to feed their chicks, potentially reducing chick survival.

What initially appeared to be an isolated crisis at Pointe Géologie soon became part of a much broader pattern, as similar warning signs emerged at other emperor penguin colonies across Antarctica. At Halley Bay, the second-largest known colony (around 20,000 breeding pairs) around the continent, the early sea ice break-up had caused an almost total breeding failure for three consecutive seasons, from 2016 to 2018. Fifty-five kilometers to the south, the emperor penguin colony at Dawson-Lambton had simultaneously experienced a dramatic increase, rising from an estimated 1,280 pairs in 2015 to 14,612 in 2018. This increase suggests that some penguins from Halley Bay may have relocated to Dawson-Lambton following the breeding failures at their original colony. The devastating consequences of early sea ice break-up became particularly evident in 2022. In the central and eastern Bellingshausen Sea, four of the five colonies monitored by satellite likely experienced complete breeding failure, as the sea ice broke up before the chicks had developed their waterproof plumage and were able to survive in the water. Across Antarctica, nineteen of the sixty-six (Fig. 3) known colonies were affected by early sea ice break-up in 2022. Although Antarctic sea ice extent reached a record low in 2023, local conditions varied. In the Bellingshausen Sea, landfast sea ice re-formed at some breeding sites, but emperor penguin numbers remained low. The extent of sea ice is therefore not sufficient to explain the fate of a colony. The configuration of

the coastline, winds, the presence of icebergs and, above all, the stability of the sea ice until the chicks fledge in December or January also play a crucial role.

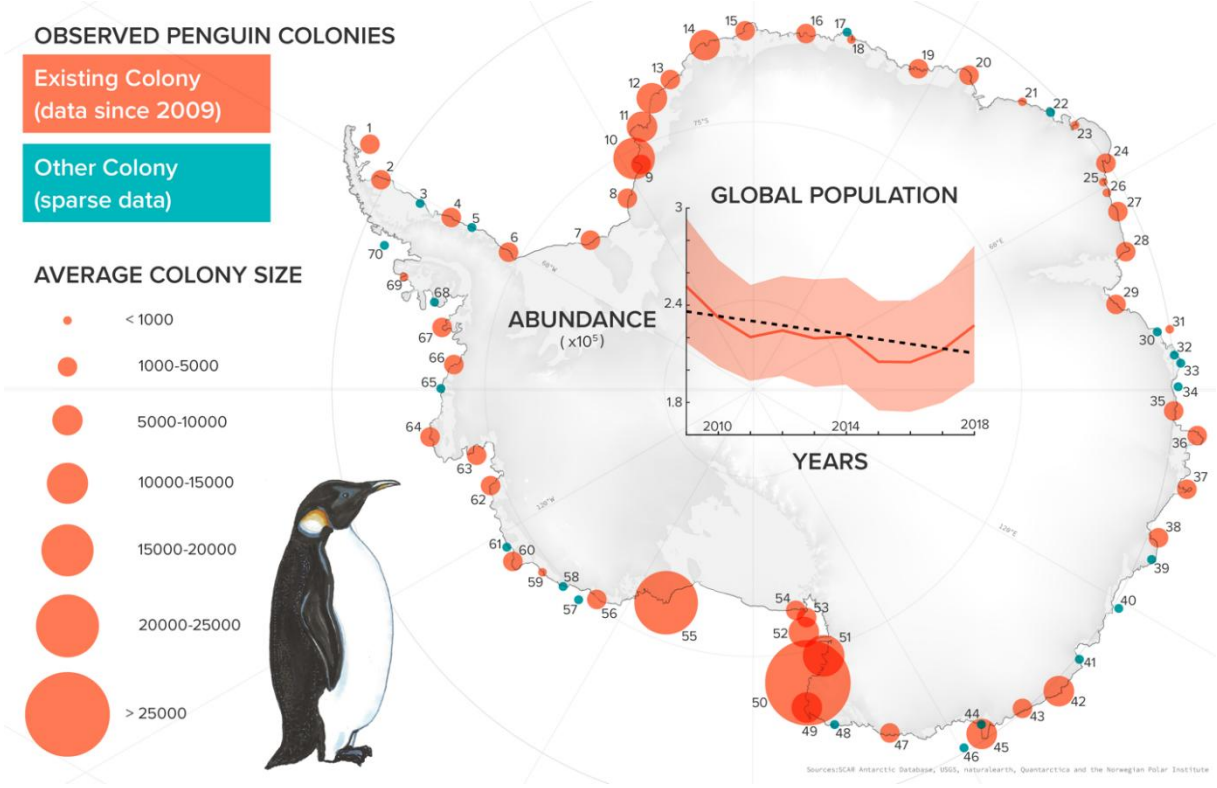


Figure 3 – Distribution and trends in emperor penguin populations in Antarctica. Each circle represents a colony, and its size is proportional to the average number of individuals. Colonies for which data has been available since 2009 are shown in orange; those for which less data are shown in blue. The central graph shows the trend in the global population between 2009 and 2018. *Source: La Rue et al., 2024.*

Satellite imagery allows researchers to monitor sea ice conditions and track changes in emperor penguin colonies across remote and inaccessible regions of Antarctica. Guano deposits ('the droppings and urine of penguins and other seabirds'), visible in satellite imagery, allow researchers to identify emperor penguin colonies, while very high-resolution satellite images can be used to estimate the number of adults present at each colony. These observations are carried out during the Antarctic spring, when there is sufficient light and the penguins are still gathered on the sea ice. Between 2009 and 2018, a satellite-based study of 50 emperor penguin colonies estimated a median decline of 9.6% in the number of adults present during spring, corresponding to a mean trend of −1.3% per year. Although the magnitude of this decline remains uncertain, the analysis indicated an 81% probability of a population decrease. These findings provide the first evidence of a probable continent-wide decline, although changes in the number of adults observed do not necessarily reflect equivalent changes in the breeding population.

When breeding sites become unsuitable, emperor penguins may relocate to other colonies or establish new breeding sites. As a result, a colony may disappear from satellite

images one season and reappear elsewhere the next. They may also settle on an *ice* shelf (floating extension of an ice cap that extends out into the ocean) at a low elevation. Satellite monitoring of three colonies between 1984 and 2024 showed that these can return close to their former location following a major *glacial calving* (the breaking off of large blocks of ice that become icebergs). This behavioural flexibility explains why the reproductive failure of a colony does not immediately mean the disappearance of all its birds. How far can emperor penguins disperse between colonies? A study published in 2025 combining genetic data, satellite surveys and demographic data from sixty-six colonies concluded that the most likely behaviour is semi-informed dispersal: the birds are likely to leave a habitat that has become unfavourable, but their settlement in another colony involves an element of chance. The estimated average dispersal distance is around 414 kilometres. Dispersal between colonies is generally limited, but major disturbances can trigger substantial movements of individuals to other breeding sites. The frequency of dispersal is linked to environmental conditions: it increases when food resources become scarce or when access to open water is increasingly distant. It also varies significantly between regions: in the Amundsen and Bellingshausen Seas, an average of 15.7 per cent of individuals leave their colony each year to join another.

Whilst this mobility may increase the projected global population by up to 7 per cent compared with a simulation without dispersal, its influence remains limited in comparison with the impact of climate change induced by greenhouse gas (GHG) emissions. Movement only helps if a stable and accessible platform exists at the same time in another location. Emperor penguins therefore show considerable behavioral flexibility, but their ability to adapt to changing conditions has its limits. Ice shelves can also offer local refuge, but many feature cliffs or slopes that are insurmountable for penguins. Evolutionary adaptation may also be possible: natural selection could favour different breeding schedules, alternative behaviours or new habitat preferences. However, the species has a generation time of around sixteen years, reaches maturity late and lays only one egg per breeding cycle. Ice, meanwhile, can change profoundly within a few decades. The number of generations available to respond to this environmental shift is therefore limited. At the current rate of climate change, a sufficiently rapid evolutionary response seems unlikely. The Weddell and Ross seas could offer temporary refuges. Ecosystem projections show that the effects of climate change on sea ice, primary productivity, krill, fish and penguins vary greatly from region to region. The effects of climate change on the growth rate of emperor penguin populations are emerging later in the Weddell and Ross seas than elsewhere in Antarctica, mainly during the second half of the century. These regions could provide temporary refuges for some

of the largest emperor penguin colonies, but they would not offer permanent protection. Even under moderately high emissions, population growth rates are projected to decline in these regions during the second half of the century.

Ecological models help determine whether the population collapses observed at individual colonies are isolated events or early warning signs of a broader decline across Antarctica. They link GHG emission scenarios to changes in ice cover and occurrence of extreme events, and then link these changes to survival, reproduction and movements between colonies. A colony is considered nearly extinct when its population becomes so small that its long-term persistence is threatened, even if a few individuals remain.

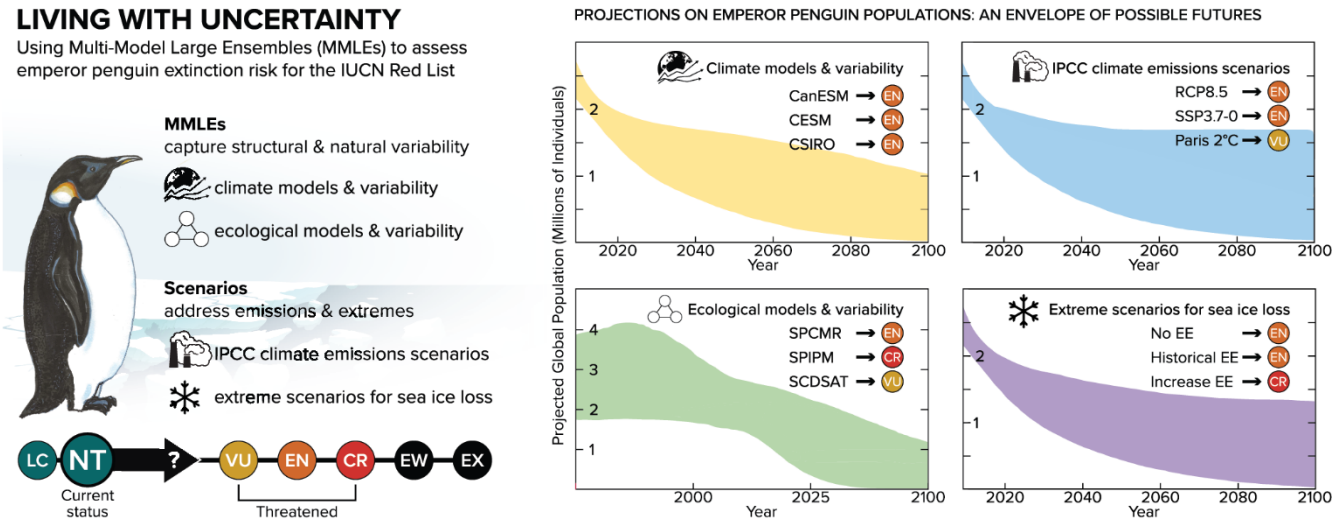


Figure 4 – Several uncertainties, a single direction of change. Diagram showing the four categories of uncertainty — emissions, climate models and variability, biological models, and frequency of extreme events — converging towards a set of population trajectories. *Source: Jenouvrier et al., Biological Conservation, 2025.*

In 2021, a study assessed the status of emperor penguins using three criteria from the US ESA framework: population resilience, redundancy across colonies, and representation across different ecological environments. The study projected that by 2050, approximately two-thirds of emperor penguin colonies could be quasi-extinct across a range of emissions scenarios, including those reflecting current energy trends and policies. Under continued high emissions (RCP8.5 scenario, the IPCC's scenario, with a temperature rise of +4.3° C by 2100), almost all colonies could become quasi-extinct by 2100. The 2021 study recommended classifying the emperor penguin as a 'threatened' species. The United States responded to this recommendation in 2022.

An assessment published in 2025 revisited the issue to meet the criteria of the IUCN Global Red List of Threatened Species. The assessment covers three generations, looking ahead to 2073 and combines three ecological models: two based on long-term population monitoring and one on satellite observations. It projects a median decline of

59 per cent in the global population by 2073, with a credibility interval ranging from a 30 per cent to a 98 per cent decline. This result supports the 'Endangered' category ultimately adopted by the IUCN in 2026. However, the projections vary considerably depending on the assumptions and scenarios considered. Under high GHG emissions, climate models converge on an 'Endangered' classification. A trajectory compatible with the 2 °C target of the Paris Agreement reduces the decline and corresponds to the 'Vulnerable' category. If extreme breeding failures would become more frequent as sea ice declines, emperor penguins could instead meet the IUCN criteria for Critically Endangered, indicating a risk of near-global extinction before the end of the century.

The 2025 study accounted for several sources of uncertainty in projecting the future of emperor penguin populations. (Fig. 4). The first relates to our societal choices: future GHG emissions will depend on policies, technologies and energy choices. The researchers therefore compared two high-emission scenarios with a low-emission trajectory compatible with stabilisation at 2 °C. A second source of uncertainty comes from climate projections. Different Earth system models represent the atmosphere, ocean and Antarctic sea ice differently, leading to differences in their projections of future climate change. In addition, natural climate variability produces a range of possible climate model trajectories, even within the same model and emissions scenario. The study used large ensembles of simulations from several climate models to capture both inter-model differences and internal climate fluctuations. A third source of uncertainty comes from the ecological models used to project population change. These models differ in how they represent the effects of changing sea ice conditions on emperor penguin population dynamics. The analysis combined three ecological models based on distinct data and assumptions. Finally, a fourth uncertainty concerns extreme events. Their future frequency is difficult to calculate, particularly when ice break-up depends on glacial calving or a local configuration that is poorly represented by climate models. Three scenarios were therefore compared to assess the consequences of extreme events on reproduction: no additional reproductive failures due to extreme events, maintenance of the historical frequency of extreme events, or an increase in this frequency as sea ice declines. The analysis also considered two minimum colony-size thresholds to account for the importance of huddling, a behavior that allows emperor penguins to conserve heat by gathering closely together during the Antarctic winter. Additional uncertainty arises from satellite-based population estimates and from extrapolating relationships between climate and demography, established primarily at Pointe Géologie, to other colonies across Antarctica. The 2025 study therefore incorporates these several sources of uncertainty into its projections, which partly explains their wide range. At the colony

level, depending on the model and threshold used, between 24 per cent and 100 per cent could meet the criteria for the 'Endangered' category by 2073.

In the end, the species' classifications in 2022 (ESA) and 2026 (IUCN) demonstrate the value of scientific projections. Modelling has linked decades of field and satellite observations to two international conservation decisions[1]. These classifications raise awareness of the risks facing emperor penguins, inform research and conservation efforts, and encourage policymakers to consider the species' future. They also highlight an important point: scientific uncertainty does not mean that we lack knowledge. When uncertainty is explicitly accounted for in projections, the results can still provide a strong basis for precautionary action, particularly when the consequences may be irreversible.

Despite uncertainties in climate and ecological projections, the various studies converge on the same conclusion: without a significant reduction in GHG emissions, emperor penguin populations will experience a major decline during the 21st century. The emperor penguin's march towards extinction is not inevitable. Reducing GHG emissions may not save every colony, but it can preserve more sea ice, maintain potential refuges and increase opportunities for dispersal. Ultimately, the species' future will depend largely on the choices societies make today.

Stéphanie JENOUVRIER[2] for POLAR WATCH[3]

[1] At the 48th Antarctic Treaty Consultative Meeting (Hiroshima, 2026), the Committee on Environmental Protection (28th meeting of the CEP) considered the SCAR assessment, which recommended designating the emperor penguin as 'specially protected species' under Article 3 of Annex II to the Protocol on Environmental Protection to the Antarctic Treaty. Many Members expressed their support for this recommendation, which they considered to be based on the best available scientific evidence and the precautionary principle; however, no consensus could be reached. China and Russia opposed this measure on the grounds that it would fail to reverse the decline in populations linked to the retreat of sea ice and that this decline was not caused by human activities in the Antarctic region. They also stated that existing tools, such as ASPAs, provide adequate protection. Finally, China, supported by Russia, contested the conclusiveness of SCAR's scientific diagnosis. (Editor's note).

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[3] The opinions expressed in this article are the responsibility of the author.

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