Climate change as an emerging threat to Emperor Penguins

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Brief Overview

The Emperor Penguin (*Aptenodytes forsteri*) is uniquely adapted to breed in the Antarctic winter, mainly on stable sea-ice. Climate change may negatively impact the species by changing the extent, formation and persistence of sea-ice. However, many factors may influence Emperor Penguin population success, and different colonies in different areas can have opposing population changes. The current published evidence indicates that understanding of the influence of climate change on Emperor Penguin populations is not yet fully developed. At present, following the Intergovernmental Panel on Climate Change (IPCC) guidance on descriptions of uncertainty, the available evidence can be considered limited to medium, but with high agreement. Thus, negative climate change-related impacts on the Emperor Penguin can be considered likely.

Detailed Overview

The Emperor Penguin (*Aptenodytes forsteri*) is uniquely adapted to breed in the Antarctic winter – eggs are laid and chicks reared mainly on stable sea-ice. Climate change is bringing increasing pressure to bear on the Antarctic. It is impacting upon the physical environment, on which species like the Emperor Penguin largely depends[1, 2]. Emperor Penguin adult survival is linked to the extent and stability of sea-ice in winter[3, 4], and stable ice conditions are required for the moult5. Climate change is altering the extent and composition of sea-ice[1, 2, 6]. Sea-ice extent is influenced by the interconnected atmosphere-ice-ocean system of the Southern Ocean, which is the most complex, hardest to study, and least understood of Earth's biomes[1]. Overall, sea-ice area has been expanding slightly in Antarctica since the 1970s, but with large regional variations in both increases and declines[2]. Sea-ice expansion may be due at least partly to climate change melting ice shelves, which in turn results in a cool, fresh surface layer on the sea which delays sea-ice from melting[6].

Because Emperor Penguins are mostly dependent on stable sea-ice to breed, an increase in regional warming due to climate change may negatively impact their population by changing the extent,

formation and persistence of ice[5]. In 2001, research showed that an Emperor Penguin colony at Terre Adélie was particularly vulnerable to climate change because of the effect of the reduction of sea-ice extent[3]. Further modelling of the Terre Adélie population estimated that the probability of extinction of the Emperor Penguins in the area could be at least 36%[7], and up to 81% by the year 2100[8]. The research also emphasized that an increased frequency of warm events, with subsequent decrease in sea-ice extent, would reduce Emperor Penguin population viability there. If the Earth warms more than 2°C above preindustrial levels, a likely scenario[9], it has been estimated that approximately 40% of the entire Emperor Penguin breeding population may decrease or disappear[10]. In 2011, the loss of a small Emperor Penguin colony (~150 breeding pairs) was recorded and attributed to regional climate warming[11].

Many factors may influence the ongoing viability of Emperor Penguin populations, and it has been shown that colonies in different areas can have contrasting population changes[12], which is also the case for other penguin species[12].The concern that climate change may accelerate declines in Emperor Penguin populations has been raised previously[3, 7, 8, 10-12] (ATCM XXX/IP5, ATCM XXXV/IP45, ATCM XXXIII/WP16). Current evidence suggests that understanding of the influence of climate change on Emperor Penguin populations is not yet comprehensive[3, 7, 8, 10-13]. However, population declines have been demonstrated[3, 14] and are projected to become more extensive[7, 8, 10.]

The discovery of new colonies of Emperor Penguins in 2012 has meant an upward revision of total population size estimates from ~155 000 to ~238 000 breeding pairs[15]. Also, satellite and aerial-surveys have, for the first time, documented Emperor Penguins breeding on ice-shelves, as opposed to sea-ice. These findings suggest that the species may have a larger population size than formerly thought, and may be capable of adapting their behaviour in the face of changes to their primary breeding habitat[16]. At present, following the Intergovernmental Panel on Climate Change (IPCC) guidance on descriptions of uncertainty[17], the available evidence can be considered *limited to medium*, but with *high agreement*. Thus, negative climate change-related impacts on the Emperor Penguin can be considered *likely*.

Key Events

1992

The link between climate and sea-ice extent on the population success for Emperor[18] and Chinstrap [19] penguins is suggested by Croxall and Fraser, Trivelpiece and Ainley, with explicit acknowledgment of the complexity and need for further research.

1999

A study by Smith et al. finds that climate change and the demographics of penguins may be related, but does not consider the Emperor Penguin[20].

2001

A study by Barbraud and Weimerskirch highlights the decline of Emperor Penguin populations at a single colony (Terre Adélie) and implicates the contrasting impact of climate change via sea-ice extent on demographics [3].

A study by Micol and Jouventin posits that the influence of sea ice on Emperor penguin populations is unclear, but do not test for the impacts of sea-ice extent directly[21].

2002

A review by Croxall, Tranthan and Murphy[5] explicitly discusses the potential links between demographics and climate change and acknowledges the complexity of the Southern Ocean ecosystem. It suggests that changes in the habitat features of sea ice may cause a reduction in adult survival of Emperor Penguins.

2003

Declining trends in seabird populations (including Emperor Penguins) together with indications of a simultaneous decrease in secondary production in sub-Antarctic waters and the reduction of sea-ice extent indicate that a major ecosystem shift are shown by Weimerskich et al. to have occurred in the Southern Ocean[22].

2004

The IUCN Red List evaluates the Emperor Penguin as a species of "Least Concern", meaning a species that has been assessed and found to be of little risk of extinction[23].

2005

A demographic model by Jenouvrier, Barband and Weimerskirch for Terre Adélie suggests that the Emperor Penguin population is positively influenced by sea-ice extent through its effect on adult survival, and that the population could be negatively affected by reduced sea ice due to climate change[4].

Simultaneous, but opposing changes in two penguin species populations over a decade (including Emperor Penguins), and concomitant changes in climate are reported by Ainley et al. for the Southern Ocean[24].

2006

A global review by Parmesan of ecological and evolutionary responses to recent climate change highlights the threat posed by climate change to the Emperor Penguin[25].

2007

A study by Murphy et al. [26] documents climatically driven fluctuations in the Southern Ocean, which cause changes in sea surface temperature, and related fluctuations in winter sea-ice extent.

SCAR presents ATCM XXX/IP5, which recognizes the potential threat of climate change to the Emperor Penguin.

2008

The IUCN Red Lists re-evaluates the Emperor Penguin and again designates it as a species of "Least Concern"[23].

Emperor Penguin chick abundance is found by Barber-Meyer, Kooyman and Ponganis to be correlated with sea-ice extent and sea surface temperature, but not consistently so across different colonies[12].

Emperor Penguins are identified by Boersma as potential sentinels of global change for marine ecosystems[27].

2009

The IUCN Red Lists re-evaluates the Emperor Penguin and again designates it as a species of "Least Concern" (IUCN 2012), although Turner et al.[1] and Forcada and Trathan[28] recognise the potentially negative consequence of climate change on sea-ice extent and its negative implications for the Emperor Penguin.

A study by Jenouvrier et al. couples demographic models and a suite of IPCC climate change models, to show that the probability of quasi-extinction of Emperor Penguins at Terre Adélie (a decline of 95% or more) is at least 36% by 2100[7]. The paper highlights that increased frequency of warm events, which may decrease sea-ice extent, will reduce Emperor Penguin population viability.

At the same time, a study by Fretwell and Tranthan[29] uses satellite data to estimate Emperor Penguins colonies by detecting faecal stains on the sea-ice. It documents ten previously unknown colonies of Emperor Penguins in Antarctica providing a vital geographical resource for future studies. However, six colonies known from old, ground-based records were not found on the satellite imagery, for unknown reasons[29].

Turner et al. report that the mean extent of Antarctic sea-ice has been recorded to increase since the late 1970s[2].

2010

A modelling study by Ainley et al. documents the fate of Emperor Penguins across Antarctica should the Earth's average tropospheric temperature reach 2°C above preindustrial levels, which is predicted to occur at c. 2025-2052[10]. In that scenario, approximately 50% of colonies North of 70° South are projected to decrease or disappear, which is 40% of the entire breeding population.

2011

Tranthan, Fretwell and Stonehouse record the first loss of a small Emperor Penguin colony of ~150 breeding pairs is made and regional warming implicated (Dion Islands, West Antarctic Peninsula, see[11].

2012

The IUCN Red Lists revaluates the Emperor Penguin, but now designates it as "Near-Threatened" [26], meaning it is considered a species that may be threatened by extinction in the near-future. The assessment cites the potential impact of climate change through its impact on sea-ice extent as the major contributor, but acknowledges the uncertainty in the assessment.

An updated coupled demographic-climate change model by Jenouvrier et al. addresses more model uncertainty, predicts decline of 81% by the year 2100 for the Terre Adélie Emperor Penguin population [8].

Continued work by Croxall (18) using satellite data to measure Emperor Penguin colonies expands the previous population estimate by more than about ~60 000 pairs to about ~238 000 breeding pairs.

Fretwell et al. report that disparate population trends documented for other penguin species in the Southern Ocean potentially suggest limitations of the climate change and the 'sea-ice explanation' for population declines in Emperor Penguin's[16].

Bromwich et al.[30] confirm that West Antarctica is one of the fastest warming regions on the planet, but the causes of the warming remain the subject of investigation[31]. Stammerjohn et al. report that regionally, climate change has likely led to earlier sea-ice retreat in some regions, but delayed retreat in others[32].

2013

Bintanja et al. report that cold plumes of fresh water from melting beneath the Antarctic ice shelves cool sea water and helps to explain the paradoxical increases in sea-ice extent [2, 6].

2014

Fraser et al. use satellite and aerial-survey operations and show four new colonies of Emperor Penguins on ice shelves, as an alternative to sea ice, which may mitigate some of the consequences of sea-ice loss for Emperor Penguins[19].

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