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TITLE: Antarctic penguin response to habitat change as Earth's troposphere reaches 2°C above preindustrial levels

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ABSTRACT:

We assess the response of pack ice penguins, Emperor (*Aptenodytes forsteri*) and Adélie (*Pygoscelis adeliae*), to habitat variability and, then, by modeling habitat alterations, the qualitative changes to their populations, size and distribution, as Earth's average tropospheric temperature reaches 2°C above preindustrial levels (ca. 1860), the benchmark set by the European Union in efforts to reduce greenhouse gases. First, we assessed models used in the Intergovernmental Panel on Climate Change Fourth Assessment Report (AR4) on penguin performance duplicating existing conditions in the Southern Ocean. We chose four models appropriate for gauging changes to penguin habitat: GFDL-CM2.1, GFDL-CM2.0, MIROC3.2(hi-res), and MRI-CGCM2.3.2a. Second, we analyzed the composited model ENSEMBLE to estimate the point of 2°C warming (2025-2052) and the projected changes to sea ice coverage (extent, persistence, and concentration), sea ice thickness, wind speeds, precipitation, and air temperatures. Third, we considered studies of ancient colonies and sediment cores and some recent modeling, which indicate the (space/time) large/centennial-scale penguin response to habitat limits of all ice or no ice. Then we considered results of statistical modeling at the temporal interannual-decadal scale in regard to penguin response over a continuum of rather complex, meso- to large-scale habitat conditions, some of which have opposing and others interacting effects. The ENSEMBLE meso/decadal-scale output projects a marked narrowing of penguins' zoogeographic range at the 2°C point. Colonies north of 70° S are projected to decrease or disappear: ~50% of Emperor colonies (40% of breeding population) and ~75% of Adélie colonies (70% of breeding population), but limited growth might occur south of 73° S. Net change would result largely from positive responses to increase in polynya persistence at high latitudes, overcome by decreases in pack ice cover at lower latitudes and, particularly for Emperors, ice thickness. Adélie Penguins might colonize new breeding habitat where concentrated pack ice diverges and/or disintegrating ice shelves expose coastline. Limiting increase will be decreased persistence of pack ice north of the Antarctic Circle, as this species requires daylight in its wintering areas. Adélies would be affected negatively by increasing snowfall, predicted to increase in certain areas owing to intrusions of warm, moist marine air due to changes in the Polar Jet Stream.

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