

## **ROYAL PENGUIN PHENOLOGY: CHANGES IN THE TIMING OF EGG-LAYING OF A SUB-ANTARCTIC PREDATOR IN RESPONSE TO A CHANGING MARINE ENVIRONMENT**

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The earth's biota is experiencing fast and dramatic changes due to a rapidly changing climate. Early indications of climate induced changes in a system include changes in phenology; the sequence and timing of key events in a species annual cycle. There is convincing evidence from phenological changes of many bird species that there has been a general advancement of key events, such as the timing of egg-laying. However, interpreting these phenological shifts is not straightforward because they represent a paradox: changes in phenology can be seen as either positive where species are adapting to changing climatic conditions or negative where the changes negatively affect the biota.

Seabirds are especially sensitive indicators of changes in marine ecosystems because they integrate and/or amplify the effects of climate forcing on lower levels in food chains. Royal penguins are particularly well suited to such an investigation because they: are abundant, are a dominant consumer of Southern Ocean resources and they display highly synchronous breeding time tables. We studied laying dates of royal penguins in the 1960s and again in the 1990s to determine whether any such changes had occurred in the sub-Antarctic.

On average, 75 nests were monitored each year during the 6 years of the study in the 1960s, compared to 50 during the 1990s. The median laying dates in the 1960s ranged from 21 October to 25 October (overall median = 23 October), while those from the 1990s ranged from 19 October to 22 October (overall median = 20 October). This represents a three-day decrease in laying date over the 34 years of the study of 3.5 days ( $t_{7,8}=7.85$ ,  $p < 0.001$ ). The rate of change over the 34 years of the study was  $-0.108$  days.year<sup>-1</sup>. We found that median laying data was influenced by the Southern Oscillation Index (SOI) and thus providing evidence of the mechanism driving the change in laying date. There was positive relationship between SOI and median laying date. Laying date is later in years of high SOI which equates to lower productivity and this is in accordance with observations from the Antarctic continent where later laying dates were associated with lower sea ice, *i.e.* less food.

In order to assess the biological consequences of climate change it is not enough to only demonstrate phenological changes because disparate patterns can arise from the same proximate cause. Importantly, to predict the effects that a changing climate may have on the breeding time tables of animals requires not only a quantification of the links between the phenology shift and the magnitude of the climatic change but also an examination of the mechanisms driving the changes as shown above.