A stable isotopic investigation into the causes of decline in a sub-Antarctic predator, the rockhopper penguin *Eudyptes chrysocome*

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Abstract

The rockhopper penguin *Eudyptes chrysocome* is a conspicuous apex marine predator that has experienced marked population declines throughout most of its circumpolar breeding distribution. The cause(s) for the declines remain elusive, but the relatively large spatio-temporal scale over which population decreases have occurred implies that ecosystem-scale, at-sea factors are likely to be involved. We employ stable isotope analyses of carbon (13C/12C, expressed as δ13C) and nitrogen (15N/14N, δ15N) in time-series of rockhopper penguin feather samples, dating back to 1861, in order to reconstruct the species' ecological history. Specifically, we examine whether rockhopper penguin population decline has been associated with a shift towards lower primary productivity in the ecosystem in which they feed, or with a shift to a diet of lower trophic status and lower quality, and we use long-term temperature records to evaluate whether shifts in isotope ratios are associated with annual variations in sea surface temperature. Having controlled temporally for the Suess Effect and for increases in CO2 concentrations in seawater, we found that overall, δ13C signatures decreased significantly over time in rockhopper penguins from seven breeding sites, supporting the hypothesis that decreases in primary productivity, and hence, carrying capacity, for which δ13C signature is a proxy, have been associated with the decline of penguin populations. There was some evidence of a long-term decline in δ15N at some sites, and strong evidence that δ15N signatures were negatively related to sea surface temperatures across sites, indicative of a shift in diet to prey of lower trophic status over time and in warm years. However, a site-by-site analysis revealed divergent isotopic trends among sites: five of seven sites exhibited significant temporal or temperature-related trends in isotope signatures. This study highlights the utility of stable isotope analyses when applied over relatively long time scales to apex predators.