NON-SIGNIFICANT EFFECT OF EL NIÑO ON THE NEST OCCUPANCY AND BREEDING SUCCESS OF MARKHAM'S STORM PETREL *HYDROBATES MARKHAMI*

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ABSTRACT

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The impact of the El Niño varies across seabirds, usually altering the distribution and causing population declines. Understanding El Niño's effects is thus critical for conservation. We monitored 296 nests of the little-known *Hydrobates markhami* during three seasons (2021–2023). We tested annual differences in individual breeding success and nest occupancy against the Southern Oscillation Index and found no effect. Our findings can be explained by the storm petrels' diet, which is more closely related to primary production than is the prey of other seabirds. Alternatively, individuals may compensate for the effects of El Niño by changing foraging strategies.

Key words: La Niña, El Niño, *Oceanodroma*, *Hydrobates*, seabirds, Pacific Ocean

INTRODUCTION

The Humboldt Current is an upwelling-driven eastern boundary current that, owing to high productivity, supports large communities of oceanic life. This ecosystem is influenced by both the warm (El Niño) and cold (La Niña) phases of El Niño Southern Oscillation (ENSO), which alters oceanographic conditions. Several aspects of marine life are affected, depending on the intrinsic life history traits of each species, as well as the phase and intensity of ENSO (Anderson 1989, Woehler & Hobday 2023). Consequently, some species show distribution changes and can suffer population declines during the El Niño phase due to reduced food resources (Ainley *et al.* 1988).

The effect of ENSO is well-known in some seabird species (Murphy 1936, 1981). It is widely reported that El Niño can impact the fitness of some species by impacting breeding success and survival (e.g., boobies; Ancona *et al.* 2011, Champagnon *et al.* 2018, Howard *et al.* 2021). The effects on tubenoses are less known but include impacts on chick growth (Cruz & Cruz 1990), lower nesting success (Schreiber & Schreiber 1984), changes in assemblage richness (Ainley *et al.* 1988, Ribic *et al.* 1992), and colony desertions (Valle *et al.* 1987).

Understanding the effects of El Niño on species' populations is becoming a matter of urgency because climate change is increasing the frequency of extreme ENSO events (Cai *et al.* 2014). The frequency of El Niño is particularly important when assessing climate impacts on seabirds (Velarde & Ezcurra 2018). For this reason, we aimed to assess the effect of El Niño on the nest occupancy and breeding success of Markham's Storm Petrel *Hydrobates markhami*.

METHODS

Markham's Storm Petrel is endemic to the Humboldt Current (Medrano *et al.* 2021). Pairs lay eggs in natural cavities under saltpeter deposits. This occurs between 200–1100 m above sea level on the coast, though egg-laying may take place up to 25 km inland (Barros *et al.* 2019, Medrano *et al.* 2019). The species is listed as Near Threatened by the IUCN (Medrano *et al.* 2021).

We worked at four breeding sites (Chuño, Chaca, Camarones, Jarza) in northern Chile, at the Arica colony (population size 30 000–40 000 breeding pairs; see Barros *et al.* 2019 and Medrano *et al.* 2019 for a detailed description of the colony). We monitored the status of 296 nests monthly during three breeding seasons, 2021–2023. We compiled information on nest occupancy and the status of each nest every month, which allowed us to analyse whether each nest was successful (i.e., produced a chick that fledged). To classify a year in El Niño or La Niña, we used data from the Southern Oscillation Index (SOI; NCEI n.d.). The breeding seasons in 2021 (SOI 0.3–1.9) and 2022 (SOI 0.5–2.1) were classified as La Niña, and 2023 (SOI −1.3 to 1.4) was classified as El Niño. We then assessed whether occupancy rates and breeding success differed between El Niño and La Niña years.

To compare between years, we built linear mixed models (LMM) using the package "lme" in R (Bates 2005), with year as a fixed factor, breeding site as a random factor, and breeding success as a binomial response variable. We also built a second model with the same fixed and random factors but with occupancy as a binomial response variable.

RESULTS AND DISCUSSION

The occupancy rates (average ± standard deviation, SD) were 0.78 ± 0.12 in 2021, 0.75 ± 0.12 in 2022, and 0.78 ± 0.11 in 2023 (Fig. 1). We found no differences between the El Niño year (2023) and the La Niña years (2021: LMM estimate = −0.09, P value = 0.99; 2022: LMM estimate = −0.06, P value = 0.93).

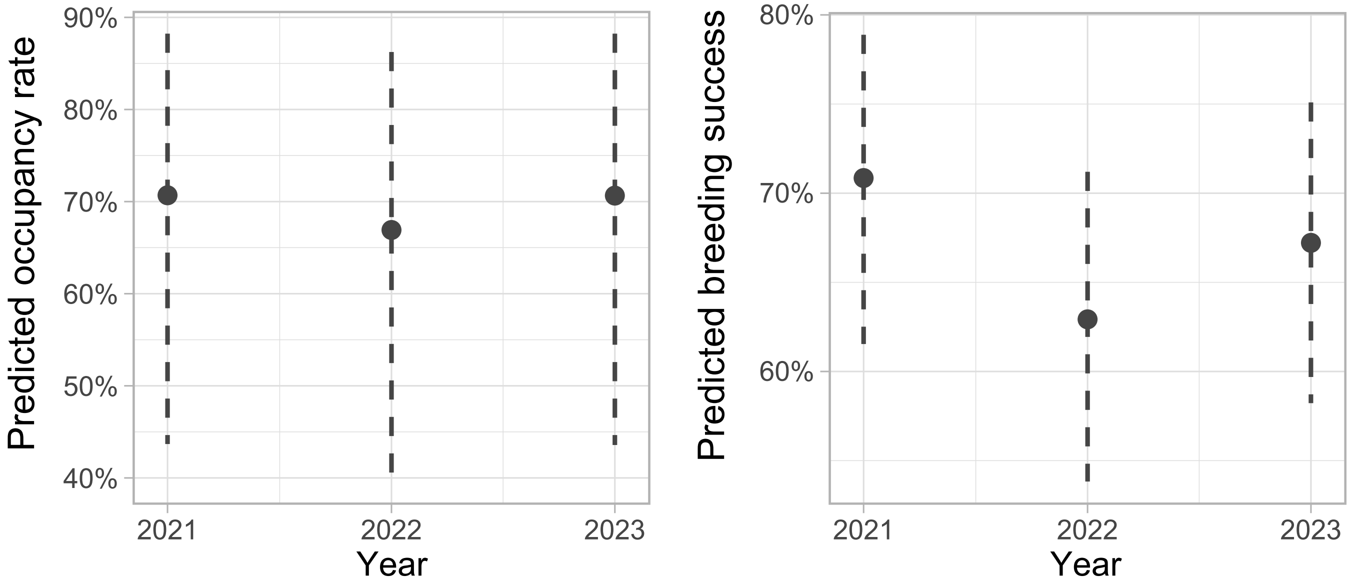

Fig. 1. Predicted occupancy rate and breeding success of Markham's Storm Petrel *Hydrobates markhami* during La Niña years (2021–2022) and an El Niño year (2023) in the Humboldt Current. The points represent the mean of that year, whereas the dotted lines represent the standard deviation.

Breeding success averaged 0.7 ± 0.01 in 2021, 0.62 ± 0.02 in 2022, and 0.66 ± 0.01 in 2023 (Fig. 1). We found no differences between the El Niño year (2023) and the La Niña years (2021: LMM estimate = 0.17, *P* value = 0.78; 2022: LMM estimate = −0.18, *P* value = 0.70).

While Markham's Storm Petrel showed little response to ENSO variability, the Wedge-rumped Storm Petrel *H. tethys* of the Galapagos Islands is known to exhibit high rates of nest desertion during El Niño (Valle *et al.* 1987). A major difference between these two eastern-Pacific species is that Wedge-rumped Storm Petrel occurs in more oceanic waters compared to Markham's Storm Petrel (Spear & Ainley 2007). This may have something to do with their different responses to ENSO, although the actual mechanism is unknown.

Seabirds exhibit diverse responses during oceanographic events such as El Niño (Jaksic & Fariña 2010), and many seabird species of the Humboldt Current are famous for their response: they fail to breed and incur high mortality during intense warm events, whereas breeding success can be spectacular during cold events (Murphy 1936, 1981; Tovar 1987). In some species, such as the reproductively conservative Galapagos Petrel *Pterodroma phaeopygia*, chicks show a lower growth rate during an El Niño event, which is mitigated by a longer chick-rearing period in those conditions. Therefore, breeding success is little affected (Cruz & Cruz 1990). During the 1983 El Niño event, Schreiber & Schreiber (1984) reported lower breeding success than in previous years for Sooty Terns *Onychoprion fuscatus* at Kiritimati, Republic of Kiribati; and only 51% of Black Noddy *Anous minutus* pairs successfully fledged young, compared to 65% in 1981 and 69% in 1984. In many seabird species (e.g., European Storm Petrel *Hydrobates pelagicus*), birds can skip a breeding season and take a sabbatical year (Soldatini *et al.* 2016). Perhaps our time series was too short, but we saw little evidence of sabbatical years despite appreciable ocean variability. We did not measure the chick growth rate, but like the procellariiform Galapagos Petrel, a change in the chick growth rate might be a mechanism that allowed Markham's Storm Petrels to fledge chicks successfully.

We recommend continued assessments of ENSO effects on the breeding of Markham's Storm Petrel by compiling a much longer time series, which might show greater extremes than observed during the three years of our study. Moreover, climate change can intensify ENSO variability (Cai *et al.* 2014), which may in turn cause clearer responses in this species. Further research is required to understand the effect of ENSO on other life history traits, such as survival rates and migration.

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AUTHOR CONTRIBUTIONS

FM conducted the conceptualization, formal analysis, methodology, fieldwork, visualization, and writing of the original draft. BG conducted data curation, methodology, fieldwork, and project administration. PG conducted project administration and fieldwork. RP and NC conducted fieldwork. GA conducted data curation and fieldwork. RS conducted funding acquisition and fieldwork. IT conducted funding acquisition and fieldwork. All the authors reviewed the first draft.

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