Seabird mechanisms of response to changing ocean stratification

How does increasing ocean stratification influence top predators in the North Pacific?

Authors

Helen Killeen, William J. Sydeman, Sarah Ann Thompson, Trond Kristiansen, Brian Hoover, Gammon Koval, and Marisol García-Reyes

Affiliation

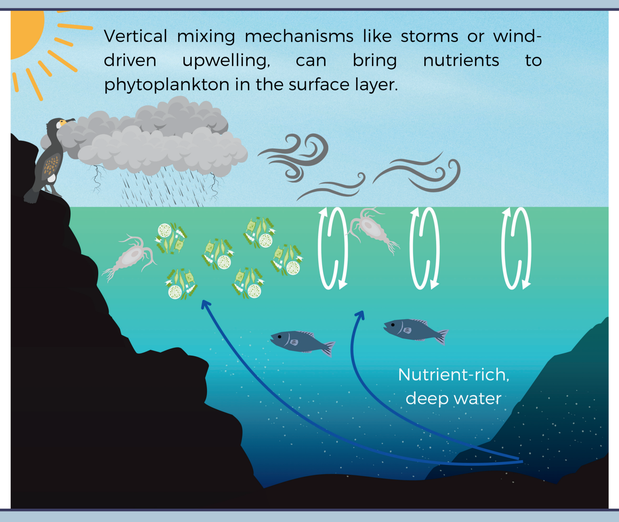
Farallon Institute, Petaluma, CA, USA

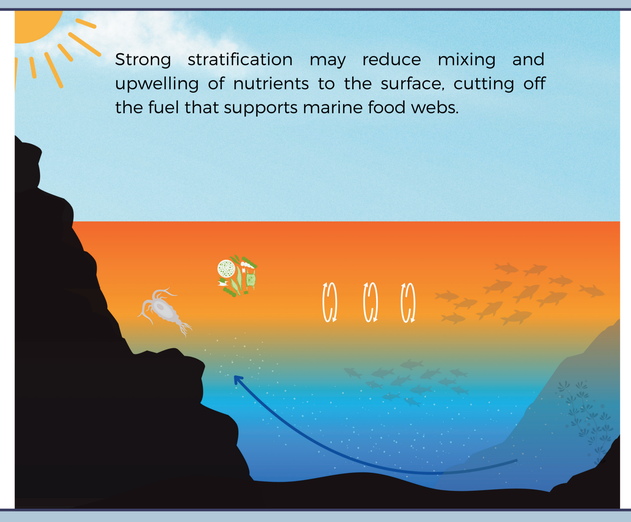
Contact

Helen Killeen
hkilleen@faralloninstitute.org
github.com/hjkilleen

Introduction

Increasing thermal (and density) stratification can limit ocean mixing, affecting nutrient availability and lower trophic level productivity. Stratification may thereby impact predator trophic dynamics and reproductive performance by affecting prey abundance or the accessibility of prey in the epipelagic zone. These mechanisms are particularly threatening for marine predators, such as seabirds, whose foraging range is vertically constrained to the surface layer of the ocean.





Objective

In this study, we test the hypothesis that stratification impacts seabird productivity through food availability in the North Pacific.

Methodology

1. We used **structural equation modeling** (SEM, *psem* R package) to assess linkages between stratification (potential energy anomaly), primary production (chl-*a* concentration), prey availability (fishery-independent surveys), and piscivorous/omnivorous seabird breeding productivity at 7 sites (Figure 1).
2. Stratification values were derived from the GLORYS12 ocean reanalysis and chl-*a* values were extracted from the Global Ocean Biogeochemistry Hindcast; both were extracted from a 300-km radius surrounding colonies preceding breeding
3. Prey availability estimates are derived from fishery-independent surveys of seabird prey near colonies

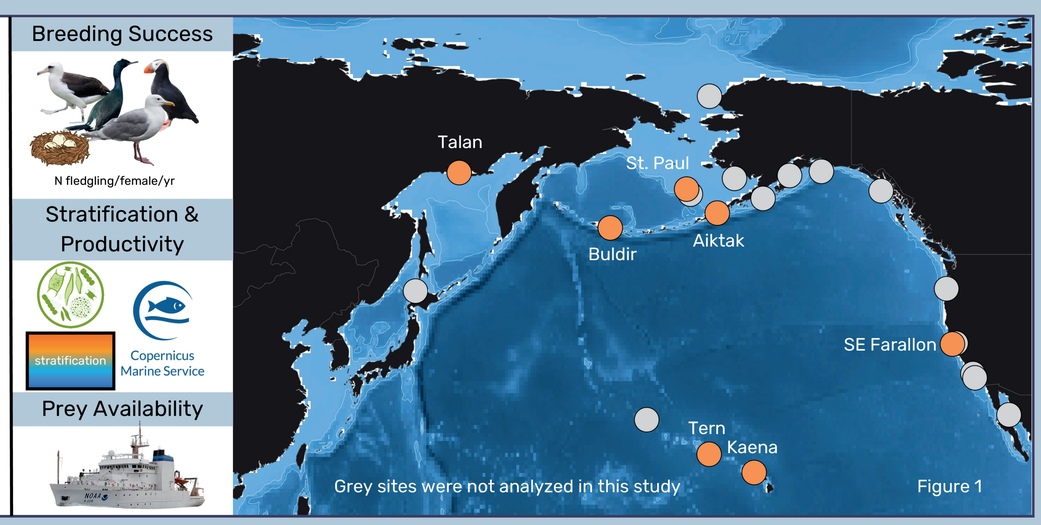


Figure 1

Results

Trophically-mediated effects

- Two sites exhibit indirect, bottom-up stratification effects on seabird breeding productivity
- Stratification has negative indirect effect on SE Farallon breeding productivity of -.07
- *Next step:* Add measures of secondary productivity as these are likely to further resolve indirect pathways

Southeast Farallon Island

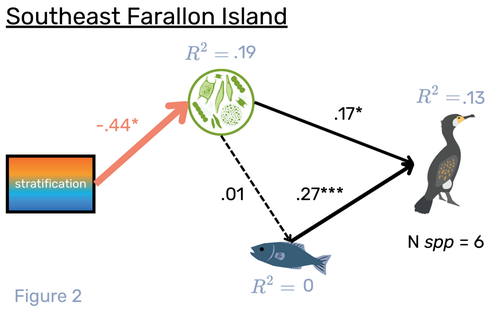


Figure 2

St. Paul Island

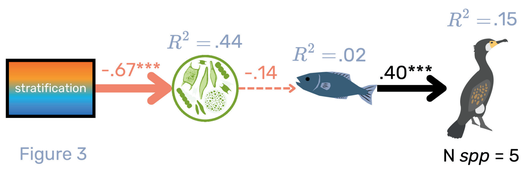


Figure 3

Trait-mediated effects

- Kaena and Tern, in the Hawaiian Islands, exhibit direct, positive stratification effects on seabird breeding productivity (0.48, *p<0.01*)
- Stratification may be associated with distributional heterogeneity of albatross prey within their North Pacific foraging range

Kaena & Tern (Hawaiian Islands)

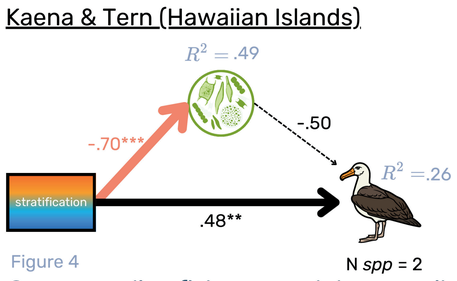


Figure 4

Corresponding fish survey data unavailable

Approximate foraging range of Laysan (green) and black-footed albatross (red) relative to Kaena & Tern colonies (Orben *et al.* 2021)

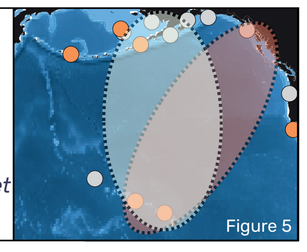


Figure 5

No effects

- Talan, Aiktak (7 *spp*), and Buldir (8 *spp*) islands did not exhibit evidence of either trophically- or trait-mediated effects of stratification on seabird breeding success
- However, when limited to surface foraging species only (black- and red-legged kittiwakes, glaucous-winged gulls), there was marginal evidence of a negative, trait-mediated effect

Talan Island

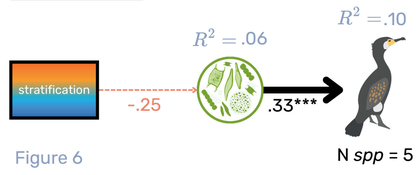


Figure 6

Corresponding fish survey data unavailable

Brandts cormorant (*Phalacrocorax penicillatus*) adults and chicks on Alcatraz Island off central California. Photo credit: Maggie Lee Post

Conclusion

This study characterizes pathways through which stratification impacts a taxonomically diverse group of marine predators, improving our understanding of the ecological implications of climate change.

- Localized stratification can indirectly reduce apex predator reproductive productivity in the North Pacific via bottom-up processes, but effects vary regionally
- Stratification may also influence foraging efficiency of some seabirds, particularly wide-ranging and surface foraging species

Acknowledgements

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