Late Holocene lake ecosystem changes and the Southern Hemisphere Westerlies (SHW) on sub-Antarctic Macquarie Island

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Outstanding Student & PhD candidate Presentation contest

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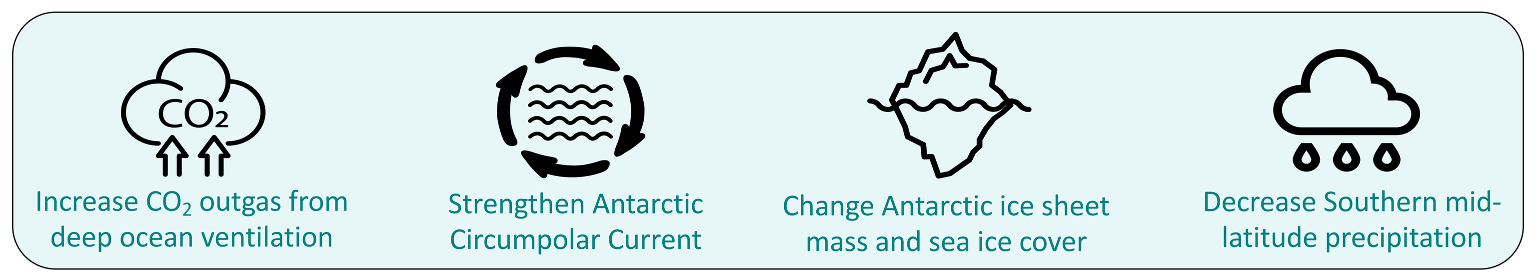
SUMMARY

- Utilising the strong wind-blown sea spray-lake conductivity-diatom relationship, this study directly reconstructed the SHW variability.
- The SHW intensity was relatively stronger between ~3000–2300 cal BP and ~1000–0 cal BP; and relatively weaker between ~2300–1000 cal BP.
- Invasive rabbit-induced profound lake ecosystem change is manifested by an increase in sediment input and within-lake diatom production.
- Rabbit influence overrides wind influence after 1950 CE, compromising the top section of the core from reliable wind reconstruction.

1 INTRODUCTION

Variations in the position and strength of the SHW can profoundly affect climate. Observations document a recent strengthening and poleward migration of the SHW, which are predicted to[1,2,3]:



Reconstructing past SHW changes is crucial for understanding the natural variability of the SHW and for constraining model predictions. Proxy(-ies) reconstructions often rely on their indirect relationship with the SHW, which can be confounded by other casual factors[4,5]. This study aims to directly reconstruct SHW variability at Macquarie Island over the past 3000 years and to identify periods of ecosystem shifts related to rabbit introduction.

2 STUDY SITE – LAKE TIOBUNGA, MACQUARIE ISLAND

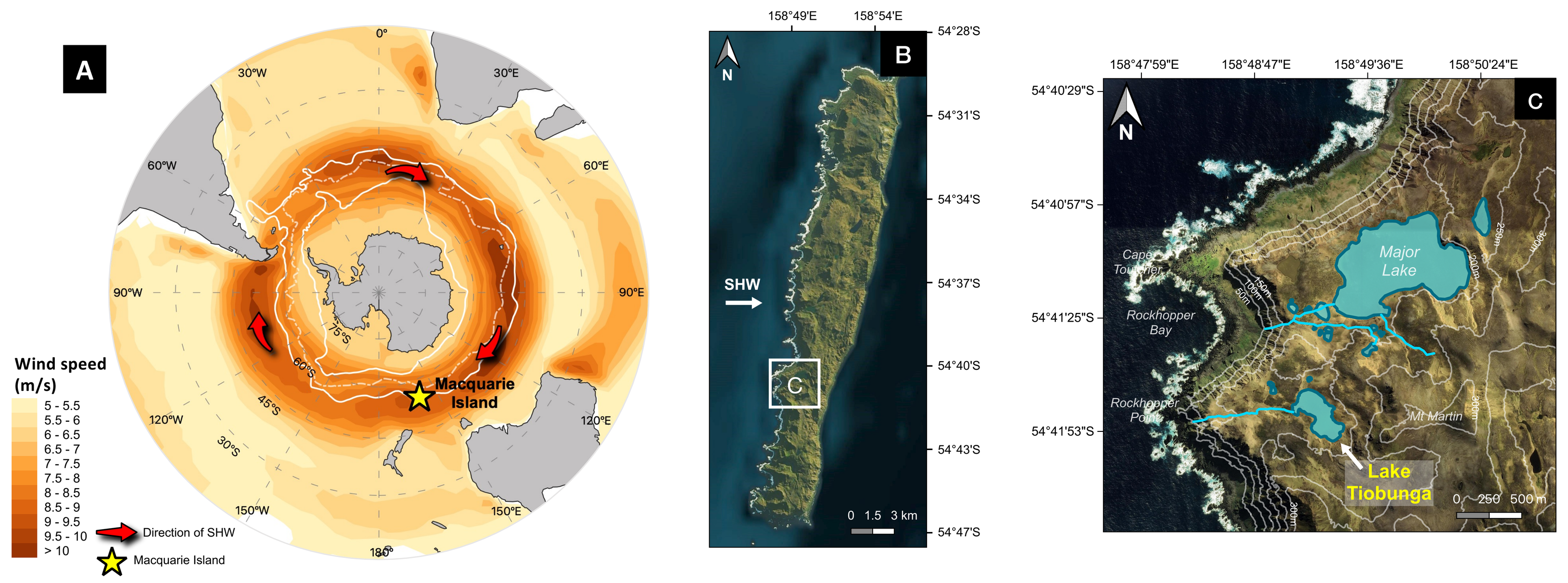
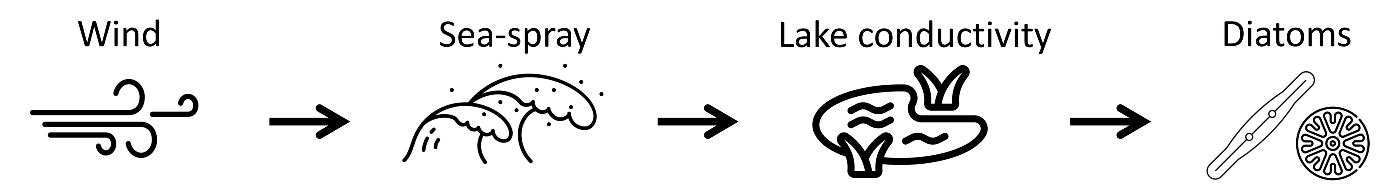


Figure 1. A) The modern core belt of the SHW and the location of Macquarie Island (star). **B)** Macquarie Island showing the prevailing direction of SHW. White square indicates the location of panel C. **C)** Lake Tiobunga and local hydrology and topography.

3 METHODOLOGY

Direct relationship between wind and proxy



Lake chemistry on Macquarie Island (and on other subantarctic islands[5]) shows a strong west-to-east gradient of decreasing conductivity due to the prevailing westerly wind-blown sea spray and minerogenic aerosol input[6, 7]. Exploiting the significant wind-sea-spray-lake conductivity relationship (especially on the west coast), changes in the the dominant diatoms species and assemblage PC1 scores reflect changes in wind strength[4].

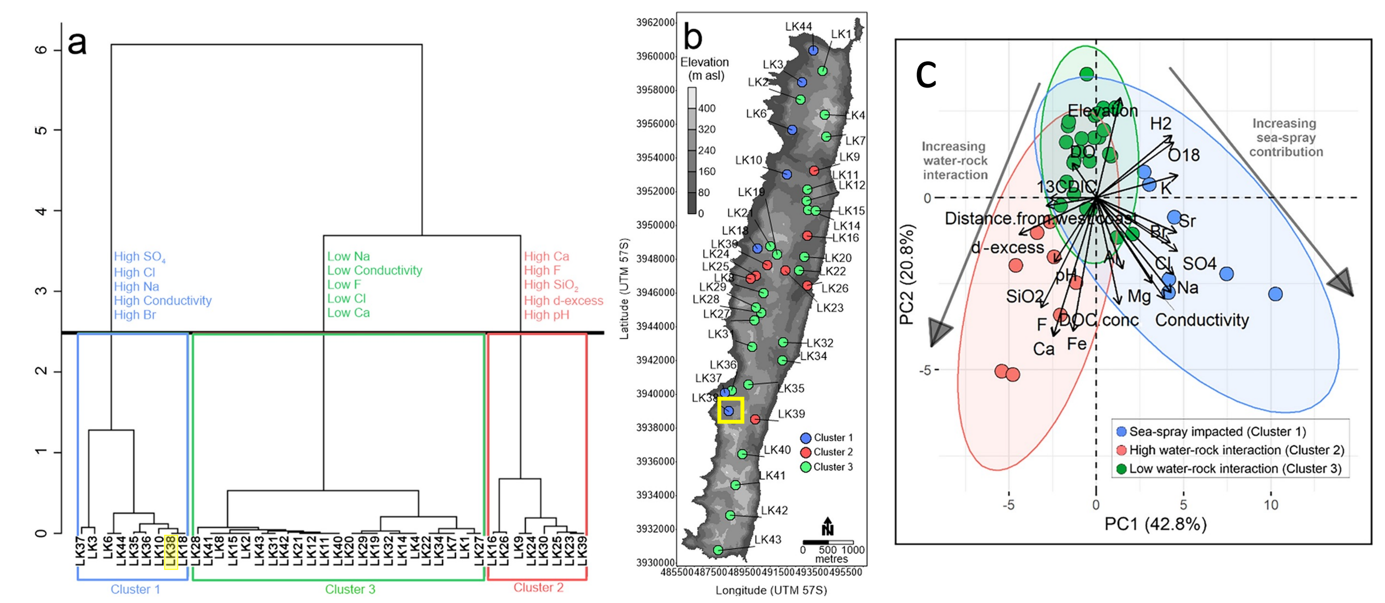


Figure 2. Adapted from Meredith et al. (2022)[8] **A)** Hierarchical cluster analysis of lake water chemistry variables on Macquarie Island, showing three lake clusters and the five most significant variables associated with each cluster. **B)** Lake Tiobunga (LK38) indicated by yellow square. **C)** Principal Component Analysis (PCA) of Macquarie Island lake variables.

4 RESULTS - RABBIT-INDUCED ECOSYSTEM CHANGES

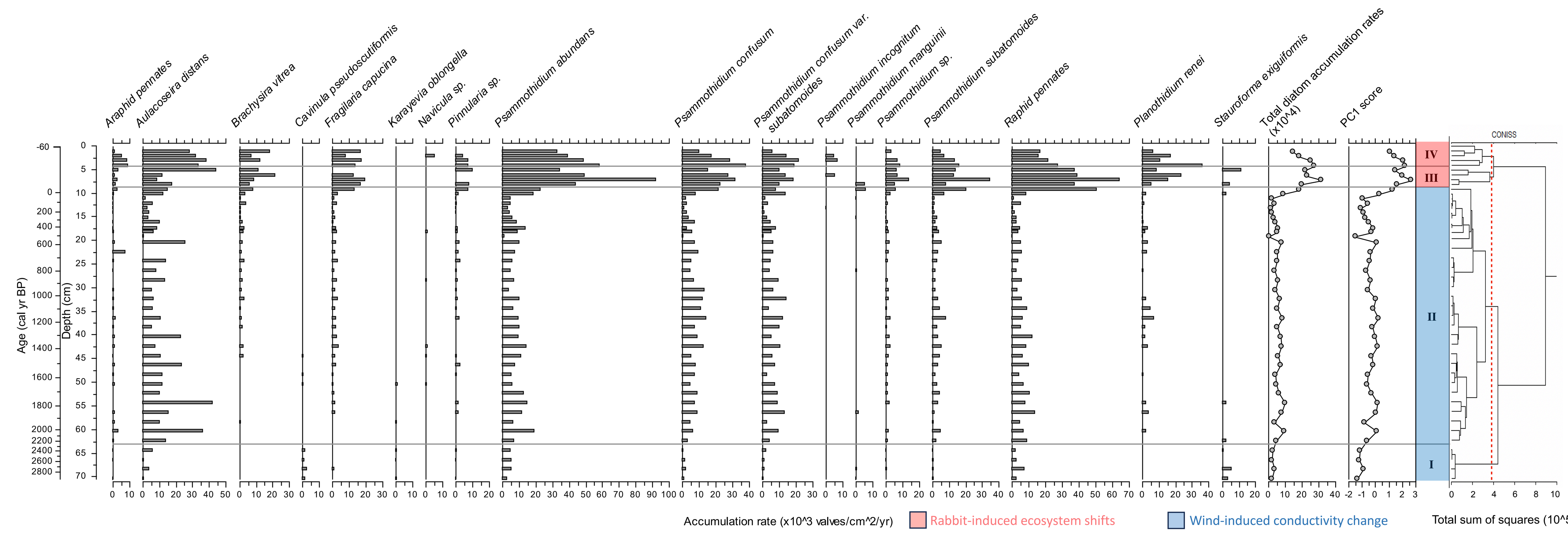


Figure 3. Stratigraphical diagram of diatom accumulation rates, PC1 score and CONISS cluster analysis-inferred zones at Lake Tiobunga. Zone III and IV (pink) respond to rabbit-induced ecosystem shifts after ~1950 CE. Zone I and II (blue) respond to changes in wind-induced conductivity.

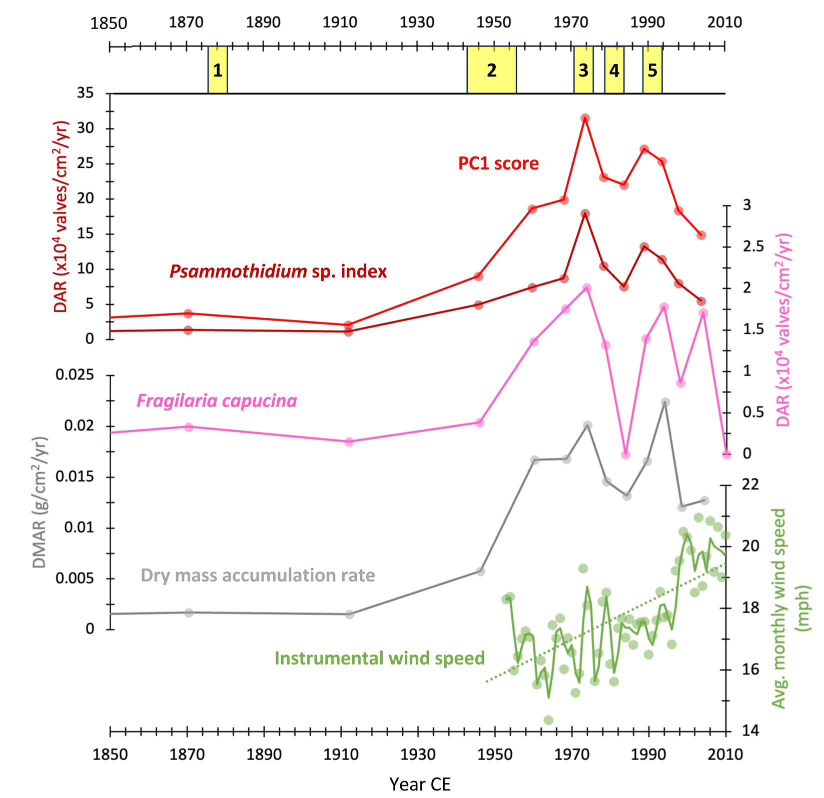


Figure 4. Selected diatom species accumulation rate, dry mass accumulation rate and instrumental wind data from Lake Tiobunga between 1850–2010 CE.

Historical timeline of rabbit influence[9,10]

1. First rabbit introduction
2. Lake productivity increase
3. Peak in rabbit population
4. Decline in rabbit population from eradication program
5. Rebound of rabbit population due to unsuccessful eradication

- Rabbit burrowing and grazing led to increased catchment erosion, slope instability and organic input[11].
- *Fragilaria capucina* – Indicator of catchment-related changes and increase in sediment accumulation[12, 13].

5 RESULTS – SOUTHERN HEMISPHERE WESTERLIES RECONSTRUCTION

- *Psammothidium* sp. index – The sum of the dominant *Psammothidium* species (low conductivity species)[14, 15].
- ~3000–2300 cal yr BP – Relatively strong SHW
- ~2300–1000 cal yr BP – Weakened SHW
- After ~1000 cal yr BP – Strengthened SHW
- Superimposed by centennial fluctuations

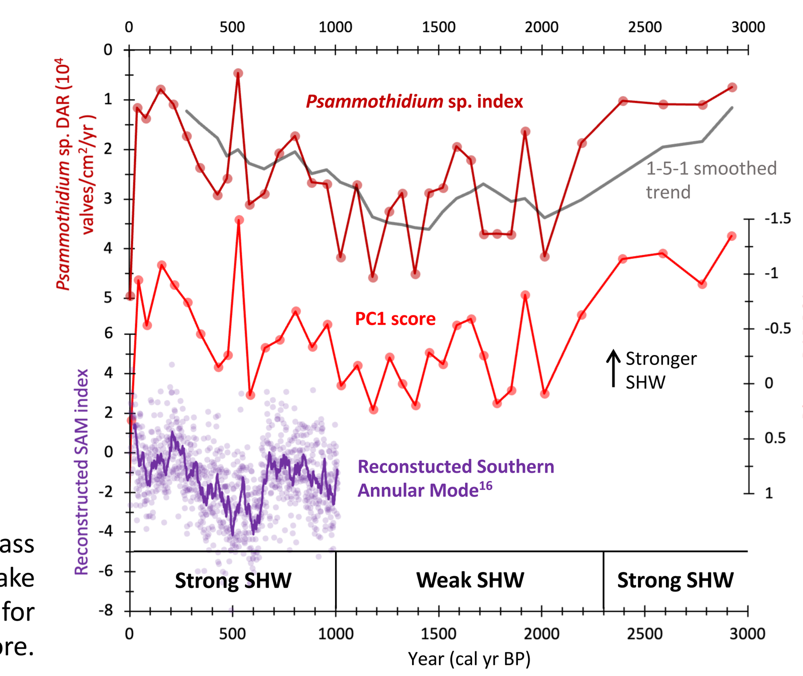


Figure 5. Selected of diatom accumulation rate, dry mass accumulation rate and instrumental wind data from Lake Tiobunga between 1850–2010 CE. Note inverted axes for *Psammothidium* sp. index and PC1 score.

6 CONCLUSIONS AND IMPLICATIONS

- The diatom sequence from Lake Tiobunga provides a record of late Holocene SHW variability in the Australasian sector of the Southern Ocean, contributing to the SHW database.
- This study has demonstrated the use of diatoms as a proxy that is directly related to wind strength, which can be adopted at other localities.
- None wind-related ecosystem shifts have been discerned from wind-induced changes through the complement of historical accounts.

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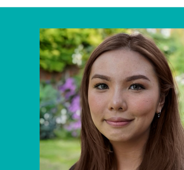

I am a PhD student at the University of Cambridge, currently researching palaeoclimate, volcanism and human ecology in Eastern Africa. I use research methods in palaeoecology and tephrostratigraphy. Please reach out to me if you would like to discuss about my research.

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