

# Supporting Information for “Colonisation-driven mercury cycling overrode industrial pollution in sub-Antarctic lakes”

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## Supporting Note 1. Site Description

### Study locations Sub-Antarctic Macquarie and Campbell Islands

*Macquarie Island* is a small (130 km<sup>2</sup>) UNESCO World Heritage listed sub-Antarctic island (54° S, 158° E) that is part of the island state of Tasmania, Australia. It is located approximately equal distance between Tasmania, New Zealand and Antarctica in the core of the Southern Hemisphere westerly wind belt. Wind on the island predominately comes from the west and northwest with mean annual wind speeds of measured at approximately 35 km/h between 1960 and 2010 (Bureau of Meteorology [2025]). Average annual rainfall on the island is 1005 mm, with an average of 221 days of rain per year. Mean daily sunshine hours on the island is 2.4 h, with mean minimum and maximum temperatures ranging between 3.1°C and 6.7°C respectively (Bureau of Meteorology [2025]). Macquarie Island is composed of uplifted ultramafic/mafic oceanic crust, predominately basalts and gabbros (Williamson 1988; Varne et al. 2000), and is part of the Macquarie Island Ridge Complex. The island is mostly composed of volcanic and sulphur-rich bedrock accompanied by their associated sediments (Cumpston 1968). The island has a low coastal terrace, with steep slopes, forming a plateau of approximately 180-430 m above sea level (Selkirk 1990). There are many lakes, both deep and shallow located across the island, both on the upper plateau (predominately oligotrophic) and on the coast (Meredith et al. 2022). Tussock, herbfield, bog and fledmark communities dominate the islands vegetation (Selkirk 1990).

Macquarie Island is home to more than 3 million seabirds, and is an important breeding site for at least 25 species of seabirds and seals (Selkirk 1990; Bird et al. 2025). Seabirds depend on the ocean around Macquarie Island, as a major food resource. Seabirds are distributed across the whole island and are predominantly species of Penguins, Albatross, Petrels, Storm petrels, Diving petrels, along with Macquarie Shags, Brown Skuas, Kelp Gulls, and Antarctic Terns (Bird et al. 2025). These seabirds transport nutrients and influence soil structure on the island (Bird et al. 2025). *Campbell Island (Motu Ihupuku)* is a small (112 km<sup>2</sup>) UNESCO World Heritage listed sub-Antarctic island (52.° S, 169.° E) that is part of New Zealand. The island is located approximately 600 km from New Zealand (Peat et al. 2003). Campbell Island is also located in the core of the Southern Hemisphere westerly wind belt, where wind comes from a predominately west/north west direction, with mean annual wind speeds of 32 km/h, with 1194 mm of precipitation per year (Saunders et al. 2015; Macara and Gibson 2025). Campbell Island

is a remnant shield volcano (6- 11 million years old), pre-dating the Last Glacial Maximum (Hodgson et al. 2014). The island has steep cliffs and its highest point is 569 m above sea level. The island has many streams, small ponds, and a few lakes. Many of the ponds are ephemeral, in particular on the western edge of the plateau. Campbell Island's vegetation is dominated by vascular plants, including endemic herbs and grasses (Saunders et al. 2015). While no archaeological evidence exists of Māori populations on Campbell Island/Motu Ihupuku, there are records of Polynesians venturing to Antarctic regions, and it is considered likely that they also ventured to Campbell Island while following migratory Southern right whales, *Eubalaena australis*, and Southern royal albatross, *Diomedea epomophora*, however, their presence was likely intermittent (Heritage New Zealand 2019).

Campbell Island, like Macquarie Island, is a significant breeding ground for seals, penguins and other seabirds (Brown et al. 2022). Campbell Island is home to many endemic insectivorous birds including the endangered Campbell Island teal (*Anas nesiotis*) and Campbell Island snipe (*Coenocorypha aucklandica perserverance*).

### European colonisation

Both Macquarie and Campbell Islands were discovered by Europeans in 1810 (Ling 1999). The islands were initially used primarily for sealing. On Macquarie Island, fur seals were almost completely eradicated within the first 10 years of sealing, while elephant seal populations were reduced by approximately 70% by the 1840s. Hunting subsequently expanded to penguins in the early 1900s, with thousands of king penguins killed per day (Hindell and Burton 1988). As seal fur and oil stocks declined, whaling became increasingly important (Ling 1999). Hunting on Macquarie Island ceased in 1919, by which time seal and penguin populations had been substantially reduced.

Rabbits were introduced to Macquarie Island in the 1870s. Their ecological impacts became increasingly evident from the 1950s, with populations reaching an estimated peak of ~350,000 in the 1970s and peaking again in the 2000s (Raymond et al. 2011). Rabbit overgrazing caused extensive vegetation loss and land degradation, resulting in landscape instability, erosion and landslips (Selkirk 1990; Saunders et al. 2013). Lake catchments were consequently disturbed through changes in nutrient inputs and increased soil erosion. Sediment records from this period therefore reflect a combination of disturbance, climate variability and local catchment processes. However, the influence of these factors is not expected to be consistent among lakes,

with catchment size, terrain and location on the island likely influencing the extent and nature of disturbance recorded in individual lakes.

Native bird populations on Macquarie Island were severely impacted following by the introduction of invasive mammals: rats by the early 19th century, cats by the 1820s, and rabbits in 1878. Rats and cats preyed on eggs, chicks and adult birds, while rabbit-driven vegetation loss and geomorphic disturbance degraded nesting habitat, particularly for burrowing petrels, contributing to major declines in several seabird populations (Raymond et al. 2011). Cats were eradicated by 2000, followed by rabbits, rats and mice by 2014, after which native vegetation and bird populations began to recover (Bergstrom et al. 2009; Travers et al. 2021).

Unlike Macquarie Island, rabbits were not introduced to Campbell Island. However, rats were introduced in the mid-1800s, while livestock, including sheep, goats and pigs, were introduced in the late 1800s. The island was subsequently used for farming until the 1930s, with fire and agricultural activities causing substantial landscape disturbance (Brown et al. 2022). Livestock were progressively removed during the 1970s and 1980s and were fully eradicated by the late 1980s. Rats also had substantial impacts on native bird populations through predation and were eradicated from the island in 2001 (Armitage 2007). Many bird populations have subsequently shown signs of recovery following rat eradication (Armitage 2007).

Macquarie Island has had a permanent research station since 1948, while Campbell Island's research station began operating in 1941 and was closed in 1995 when it was fully automated (Convey and Lebouvier 2009). Campbell Island is intermittently visited for research. Both Macquarie and Campbell Island receive tourist visits (Hall and Wouters 1994).

### **Site Selection**

The lakes in this study have no direct point-source pollution and were chosen to capture environmental variability across Macquarie Island, with Campbell Island included as a comparative reference site (Figure 1 and Table S 1). Multiple sites were selected in order to distinguish local variability from regional forcing.

*Macquarie Island:* A total of four lakes on Macquarie Island were selected: Lake 1 (54.5042°S, 158.9003 °E) and Emerald Lake (54.5465 °S, 158.8806 °E) on the west coast; Cumberland Tarn (54.6438 °S 158.8523 °E) located inland; and Green Gorge (54.6292°S, 158.8944°E) on the east

coast (Figure 1). The lakes were selected based on their distance to the west coast (Table S 1) and preservation of the top section of each record for analysing the last 500 years of sediment.

*Campbell Island:* DP2 (52.5602°S, 169.0603°E) was selected as a comparison site to the Macquarie Island lakes, because while it has the same overall climate as Macquarie Island, and is located in the same geographic region, it has a different history of human disturbance. In particular, it was considered to have a less anthropogenically disturbed catchment due to the lack of livestock near that part of the island and the absence of rabbits. DP2 is a small, shallow lake, located on the west coast of Campbell Island (Table S 1).

## Supporting Note 2: Methods

*Sediment cores* were sectioned into 0.5 cm sections for the top 20 cm followed by 1 cm sections for the remainder of each record. Sampling regimes were specific for each lake and each proxy based on core resolution and the proxy being measured.

*Moss* was collected at various locations around Macquarie Island in 2013 and used as reference vegetation samples for Hg isotopes. Soil was removed from the base of some moss samples. This soil was used as reference soil samples.

*Table S 1 Summary of site characteristics for lakes sampled on Macquarie and Campbell island, the table includes location, morphometric features, climatic conditions, and sediment core collection details.*

| Lake               | Island    | Lake area<br>(ha) | Catchment:<br>lake area | Lake depth<br>(m) | Latitude       | Longitude      | Altitude<br>(m) | Distance to<br>west coast<br>(km) | Annual<br>precipitation<br>(mm) | Core length<br>(cm)                                                               | Collection<br>year | Corer type                                                                  |
|--------------------|-----------|-------------------|-------------------------|-------------------|----------------|----------------|-----------------|-----------------------------------|---------------------------------|-----------------------------------------------------------------------------------|--------------------|-----------------------------------------------------------------------------|
| Lake 1             | Macquarie | 0.26              | 23                      | 0.5               | 54.5042°<br>S  | 158.9003<br>°E | 200             | 1                                 | 1005                            | 41                                                                                | 2018               | UWITEC<br>gravity corer                                                     |
| Emerald<br>Lake    | Macquarie | 1.08              | 4                       | 1.2               | 54.5465<br>°S  | 158.8806<br>°E | 170             | 1.01                              | 1005                            | 67                                                                                | 2010               | UWITEC<br>gravity corer                                                     |
| Cumberland<br>Tarn | Macquarie | 2.36              | 25                      | 1.1               | 54.6438<br>°S  | 158.8523<br>°E | 223             | 1.88                              | 1005                            | 69.5                                                                              | 2009               | UWITEC<br>gravity corer                                                     |
| Green Gorge        | Macquarie | 0.78              | 188                     | 1.6               | 54.6292<br>°S  | 158.8944<br>°E | 9               | 4.69                              | 1005                            | Surface = 52.5<br>Livingston =<br>82.5 cm,<br>collected<br>8.5cm below<br>surface | 2009               | Surface =<br>UWITEC<br>gravity corer<br>LIV =<br>Livingston<br>piston corer |
| DP2                | Campbell  | 0.1               | 3.4                     | 0.4               | -52.5602<br>°S | 169.0603<br>°E | 45              | 0.2                               | 1300                            | 38                                                                                | 2010               | Hand-collected                                                              |

*Total and stable isotope carbon and nitrogen analyses:* Sticks and rocks were removed before samples were ground with an agate mortar and pestle to achieve homogeneity. The samples for Total Organic Carbon (TOC) analyses were pre-treated 1 M HCL, followed by sonication at 60° C for 2 hours. Samples were then rinsed a minimum of three times with Milli-Q (MQ) water until a pH of 5 was reached, before being dried and crushed again to re-homogenise. Samples were weighed into tin capsules and introduced sequentially into an elemental analyser (Thermo Fisher Flash 2000 EA) using an autosampler, carbon (C) and nitrogen (N) were analysed separately. Each sample was combusted into CO<sub>2</sub> and N<sub>2</sub> in a combustion furnace (silvered cobaltous/ic oxide, chromium oxide, quartz chips and quartz wool) at 1020°C before being transferred with a helium carrier gas (100 mL/min) into a reduction furnace (copper) at 680°C, where any excess nitrous oxides are converted into N<sub>2</sub> and excess O<sub>2</sub> is removed. The analyte gases were then passed through a water trap before the CO<sub>2</sub> and N<sub>2</sub> were separated by a gas chromatography (GC) column at 45°C. The gases were then transferred to a Thermo Fisher ConFlo IV and into a Thermo Fisher Delta V Advantage isotope ratio mass spectrometer for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  measurements. The data were reported relative to International Atomic Energy Agency (IAEA) secondary standards that have been certified relative to VPDB for carbon and air for nitrogen

*Total Mercury concentration:* The direct mercury analyser-80 (DMA-80) was calibrated with aqueous Mercury (Hg) standard (AAS Sigma Aldrich traceCERT®, 1000 mg/L Hg in nitric acid). The DMA-80 has a lower detection limit of 0.01 ng of Hg. Absorbances of standards in nanograms were plotted against Hg concentrations to construct a calibration curve; the validity limit was set to an R<sup>2</sup> value of 0.99 or above. THg concentration using the DMA-80 was determined through thermal decomposition, amalgamation, and atomic absorption spectrometry. Final sample quantity for analyses was determined after a subset of samples were analysed from each sediment record to ensure all measurements were conducted using the same spectrometer cell 0, corresponding to the linear and most stable response range of the DMA detector. Two blanks and two Standard Reference Materials (SRMs) were analysed for every 40 samples. Between 10 and 100 mg of sample was weighed in nickel boats, with every 10<sup>th</sup> sample being a replicate. If replicate recovery exceeded 10% compared to the original sample, a triplicate was analysed. Several Standard Reference Materials were used: 2706, WQB1, CC141, BCR277R (Table S 10) to account for the variability in concentration and matrix of

the sediment. NIST SRM 1646a was also included for quality control because of its low Hg concentration, using its non-certified Hg value as an indicative reference.

Stable isotope mass balance model: The relative contribution of gaseous Hg<sup>0</sup> was calculated using a two-endmember linear isotope mass balance equation:

$$\Delta^{200}\text{Hg}_{\text{sample}} = f_{\text{Hg}^0}\Delta^{200}\text{Hg}_{\text{Hg}^0} + f_{\text{rainfall HgII}}\Delta^{200}\text{Hg}_{\text{rainfall HgII}}$$

where  $f_{\text{Hg}^0} + f_{\text{rainfall HgII}} = 1$ .

The contribution of gaseous Hg<sup>0</sup> was therefore calculated as:

$$f_{\text{Hg}^0} = \frac{\Delta^{200}\text{Hg}_{\text{sample}} - \Delta^{200}\text{Hg}_{\text{rainfall HgII}}}{\Delta^{200}\text{Hg}_{\text{Hg}^0} - \Delta^{200}\text{Hg}_{\text{rainfall HgII}}}$$

with the contribution of rainfall-associated Hg<sup>2+</sup> calculated as  $f_{\text{Hg}^{2+}} = 1 - f_{\text{Hg}^0}$ . Monte Carlo solutions producing source fractions outside the physically permissible range of 0–1 were excluded.

*Stable isotope mixing models:* To assess the relative contribution of potential Hg sources to each lake, a three endmember mixing model was developed. The three endmembers represent: 1) Atmospheric rainfall Hg<sup>II</sup>, measured on the sub-Antarctic Amsterdam Island (Li et al. 2023). Rainfall Hg<sup>II</sup> is used here instead of Atmospheric gaseous Hg<sup>0</sup>, due to the larger flux into lake sediment than direct Hg<sup>0</sup> deposition, thus capturing indirect deposition via erosional processes (Tang et al. 2026).

2) Guano from seals and penguins, Ross Sea Antarctica (Zheng et al. 2015) and albatross guano, Bird Island (Li et al. 2026). Guano measurements from Macquarie and Campbell Island were not available for this study and therefore guano endmembers were chosen from available literature as representative samples.

3) Catchment soil and moss (Table S 8) from Macquarie Island. Catchment soil and moss was not available from Campbell Island or directly from each lake catchment on Macquarie Island. Campbell Island has different geology and vegetation to Macquarie Island and therefore using Macquarie Island samples as catchment endmembers is a limitation of this study.

Figure S 8 illustrates the selected endmembers in relation to lake sediment samples.

Predicted isotope compositions were calculated using a linear mass-balance model:

$$\Delta^{199}\text{Hg}_{\text{pred}} = f_{\text{guano}} \times \Delta^{199}\text{Hg}_{\text{guano}} + f_{\text{rainfall HgII}} \times \Delta^{199}\text{Hg}_{\text{rainfall HgII}} + f_{\text{catchment}} \times \Delta^{199}\text{Hg}_{\text{catchment}}$$

$$\Delta^{200}\text{Hg}_{\text{pred}} = f_{\text{guano}} \times \Delta^{200}\text{Hg}_{\text{guano}} + f_{\text{rainfall HgII}} \times \Delta^{200}\text{Hg}_{\text{rainfall HgII}} + f_{\text{catchment}} \times \Delta^{200}\text{Hg}_{\text{catchment}}$$

$f_{\text{guano}}$  = fractional contribution of guano-derived Hg

$f_{\text{rainfall HgII}}$  = fractional contribution of atmospheric rainfall Hg<sup>II</sup>

$f_{\text{catchment}}$  = fractional contribution of catchment-derived Hg (Macquarie Island moss and soil)

where  $f_i$  represents the fractional contribution of Hg from source  $i$ , and  $\Delta^{xxx}\text{Hg}_i$  represents the isotope composition of that source.

Model performance was evaluated by calculating the squared Euclidean distance between the predicted and observed isotope compositions:

$$\text{Error} = (\Delta^{199}\text{Hg}_{\text{pred}} - \Delta^{199}\text{Hg}_{\text{obs}})^2 + (\Delta^{200}\text{Hg}_{\text{pred}} - \Delta^{200}\text{Hg}_{\text{obs}})^2$$

Rather than selecting a single optimum solution, the model retained the 1% of simulations with the lowest misfit, representing the ensemble of best-fitting source combinations. This rejection-sampling approach accounts for both endmember variability and uncertainty in source proportions without imposing prior assumptions on the relative importance of each source. For each sediment sample, the median source contribution and the 2.5<sup>th</sup> and 97.5<sup>th</sup> percentiles of the retained solutions were calculated to summarise the estimated contribution and associated uncertainty for each source.

*Table S 2 R packages and package version used for analyses and visualisation in RStudio in this study.*

| Package   | Version | Reference                  |
|-----------|---------|----------------------------|
| rplum     | 1.0.0   | (Aquino-López et al. 2018) |
| rbacon    | 3.5.2   | (Blaauw and Christen 2011) |
| readxl    | 1.4.3   | (Wickham 2023)             |
| dplyr     | 1.1.4   | (Wickham et al. 2023)      |
| tidyverse | 2.0.0   | (Wickham et al. 2019)      |
| ggplot2   | 3.5.2   | (Wickham 2016)             |
| cowplot   | 1.2.0   | (Wilke 2015)               |
| viridis   | 0.6.4   | (Garnier et al. 2023)      |

|               |        |                           |
|---------------|--------|---------------------------|
| gt            | 1.0.0  | (Iannone et al. 2020)     |
| writexl       | 1.5.1  | (Ooms 2024)               |
| patchwork     | 1.2.0  | (Pedersen 2024)           |
| ggthemes      | 5.1.0  | (Arnold 2024)             |
| sf            | 1.0.21 | (Pebesma and Bivand 2023) |
| rnaturalearth | 1.0.1  | (Massicotte et al. 2023)  |
| ggspatial     | 1.1.9  | (Dunnington 2023)         |
| vegan         | 2.6.4  | (Oksanen et al. 2023)     |
| plotly        | 4.10.4 | (Sievert 2020)            |

### Supporting Note 3: Results, Age-Depth Models

*Lake 1, Emerald Lake and Cumberland Tarn:* Lake 1, Emerald Lake, Cumberland Tarn, and Green Gorge's age depth models were constructed with  $^{210}\text{Pb}$  and  $^{14}\text{C}$  (Figure S 1 – S 4; Tables S 3 - S 4). Emerald Lake's age depth model additionally included  $^{239,240}\text{Pu}$  data (Table S 5; Schneider et al. (in press)). DP2's age depth model was constructed using exclusively  $^{14}\text{C}$  (Table S 3). Age depth models for Lake 1, Emerald Lake, and Cumberland Tarn were first presented and described by Schneider et al. (in press). In summary, the rplum age depth models for Lake 1, Emerald Lake and Cumberland are presented in Figures S 1-S 3, respectively, green Gorge is presented in Figure S 4, and DP2 in Figure S 5.

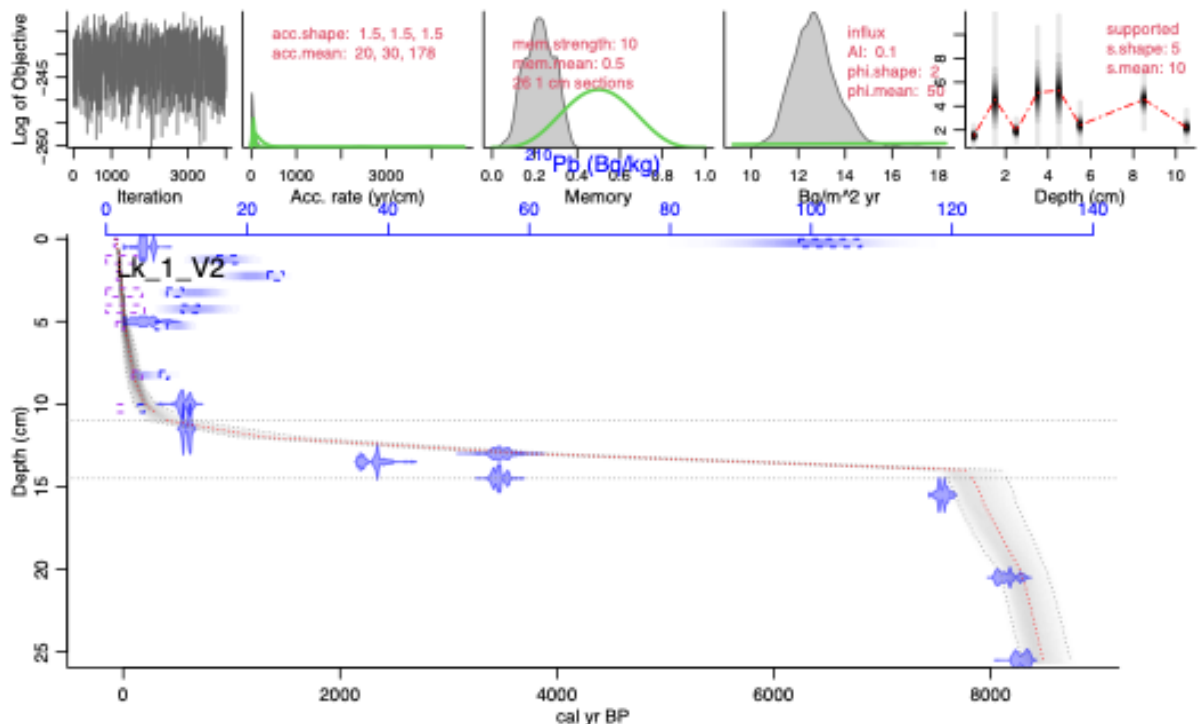


Figure S 1 Lake 1 rplum age depth model with uncertainty, Depth (cm) cal yr BP = calibrates years before present. Purple indicates  $^{210}\text{Pb}$  decay, blue indicated modelled ages. Horizontal grey dotted lines = boundary period. Grey is modelled uncertainty represented as minimum and maximum

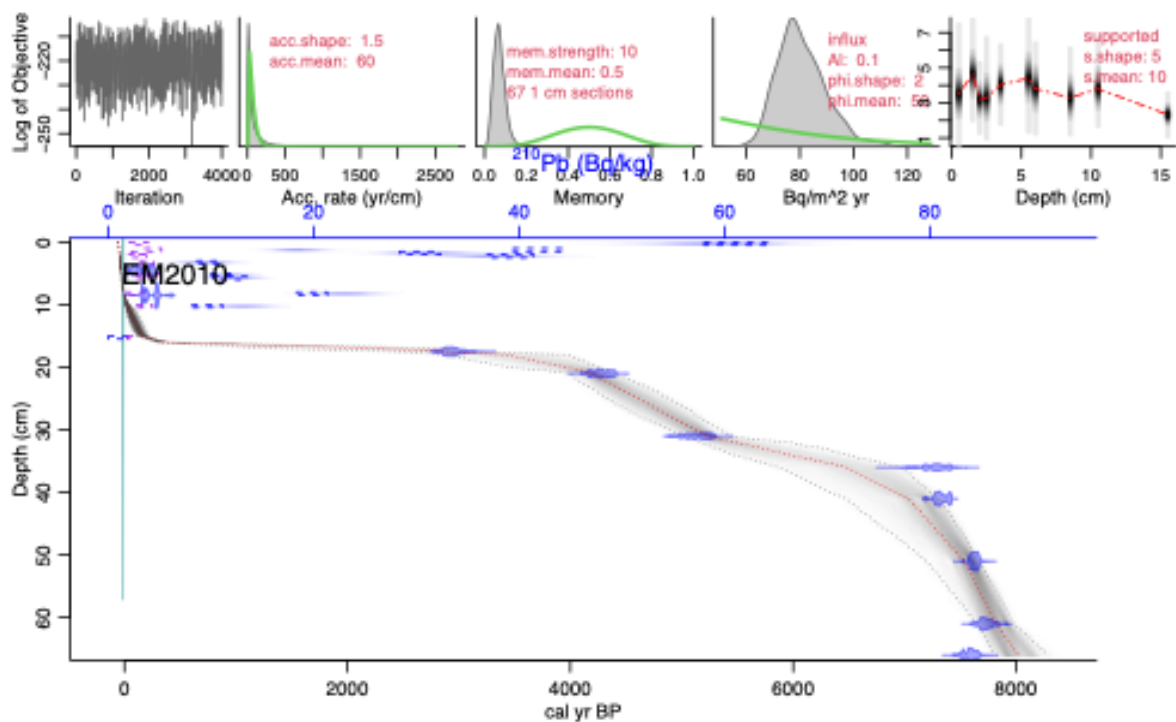


Figure S 2 Emerald Lake rplum age depth model with uncertainty, Depth (cm) cal yr BP = calibrates years before present. Purple indicates  $^{210}\text{Pb}$  decay, blue indicated modelled ages, aqua indicates the uncalibrated 1963 Pu date. Grey is modelled uncertainty represented as minimum and maximum

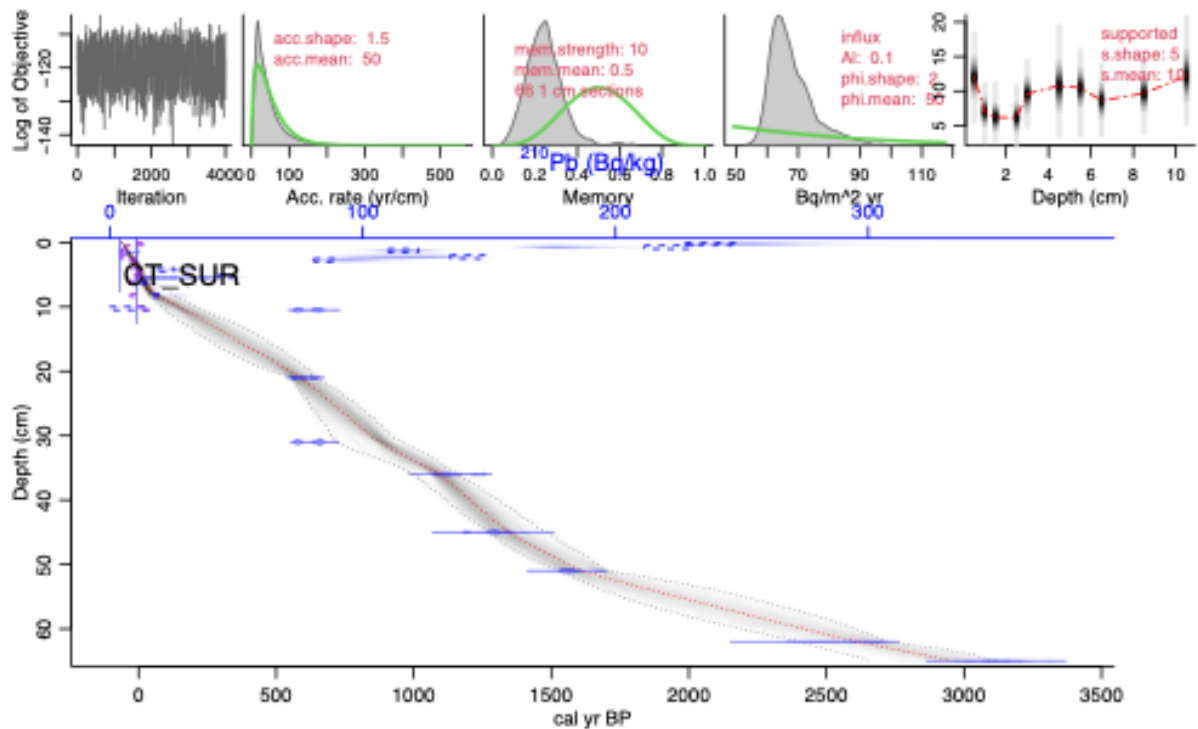


Figure S 3 Cumberland Tarn rplum age depth model with uncertainty, Depth (cm) cal yr BP = calibrates years before present. Purple indicates  $^{210}\text{Pb}$  decay, blue indicated modelled ages. Grey is modelled uncertainty represented as minimum and maximum

*Green Gorge:* The age–depth model for Green Gorge incorporates both  $^{14}\text{C}$  ( $n = 14$ ) and  $^{210}\text{Pb}$  ( $n = 9$ ) dating (Figure S 4). The  $^{210}\text{Pb}$  activity decreases with increasing depth but becomes undetectable below 2.5 cm. The Green Gorge age–depth model was constructed using two sediment cores, Surface and Livingston (Table S 1). The  $^{14}\text{C}$  ages do not overlap with the  $^{210}\text{Pb}$  profile, with the radiocarbon age obtained at 1 cm representing the oldest dated material at >2000 cal yr BP (calibrated years before present). Although these  $^{14}\text{C}$  dates were obtained from macrofossils, which have a lower risk of reservoir effects than bulk sediment, the possibility remains that some macrofossils incorporated older carbon prior to deposition. Given the large catchment of Green Gorge and the presence of wildlife throughout the catchment, older material may have been disturbed and subsequently incorporated into the upper 40 cm of the sediment record, resulting in substantial age variability. Sedimentation rates increased only slightly after the 1850s, potentially reflecting uncertainty in the age–depth model, but also the naturally heterogeneous sedimentary regime of Green Gorge prior to European arrival. As a lake draining a large catchment (Table S 1), its sediments integrate catchment in wash, inputs associated with wildlife activity, and material mobilised by natural geomorphic disturbance.. We therefore acknowledge the high age uncertainty associated with this record. Nevertheless, we retain Green Gorge as a reference site representing a contrasting ecological and catchment

setting to the other lakes and interpret its results primarily in a spatial rather than temporal context.

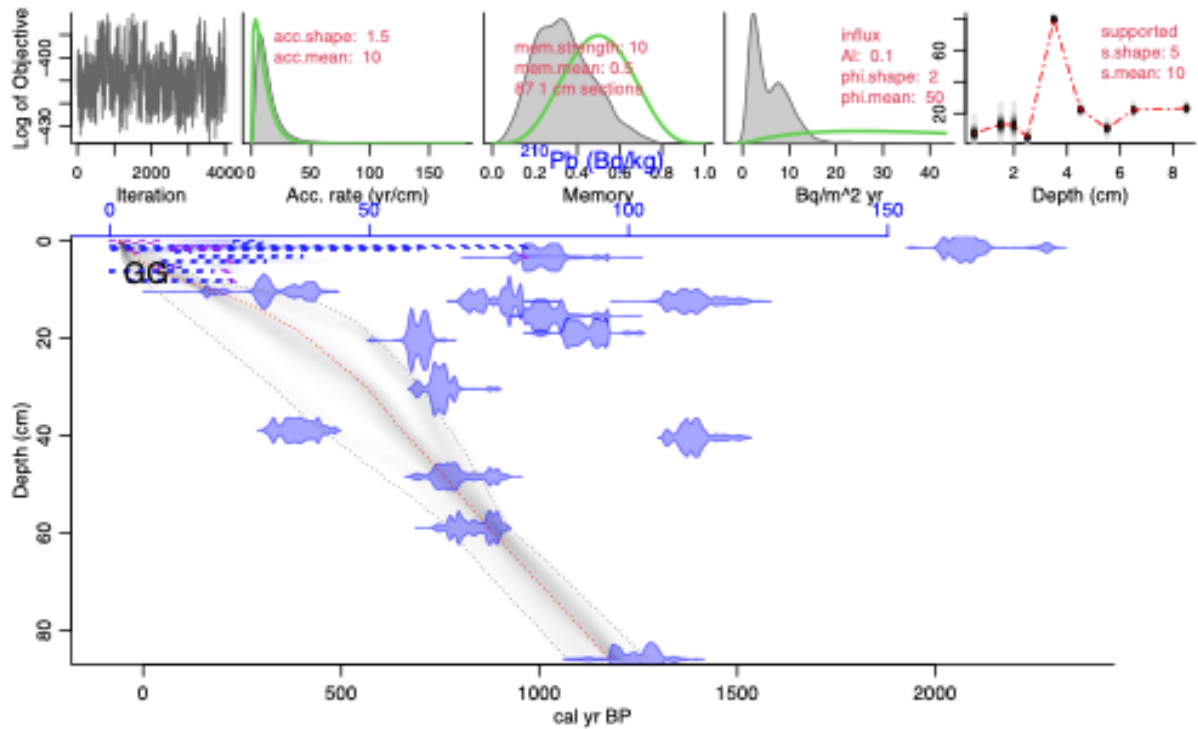


Figure S 4 Green Gorge rplum age depth model with uncertainty. Depth (cm) vs Cal yr BP (calibrated years before present). Purple indicates  $^{210}\text{Pb}$  decay, blue indicates modelled ages. Grey is modelled uncertainty represented as minimum and maximum

DP2: The age depth model for DP2 sediment record includes only  $^{14}\text{C}$  ( $n = 9$ ; Figure S 5). The unsupported  $^{210}\text{Pb}$  ( $n = 4$ ) was too low and considered background at the top of the record (Table S 4), and was therefore deemed not suitable for dating. There are two post bomb  $^{14}\text{C}$  dates, ensuring the top of the record is intact and modern (Table S 3). Due to plateaus in the calibration curve, there are large age uncertainties between 150 to 1000 Cal yr BP (Figure S 5 and Table S 3). Due to the large age uncertainty in this record, we use DP2 as a comparative site, with limited emphasis on the timing of changes.

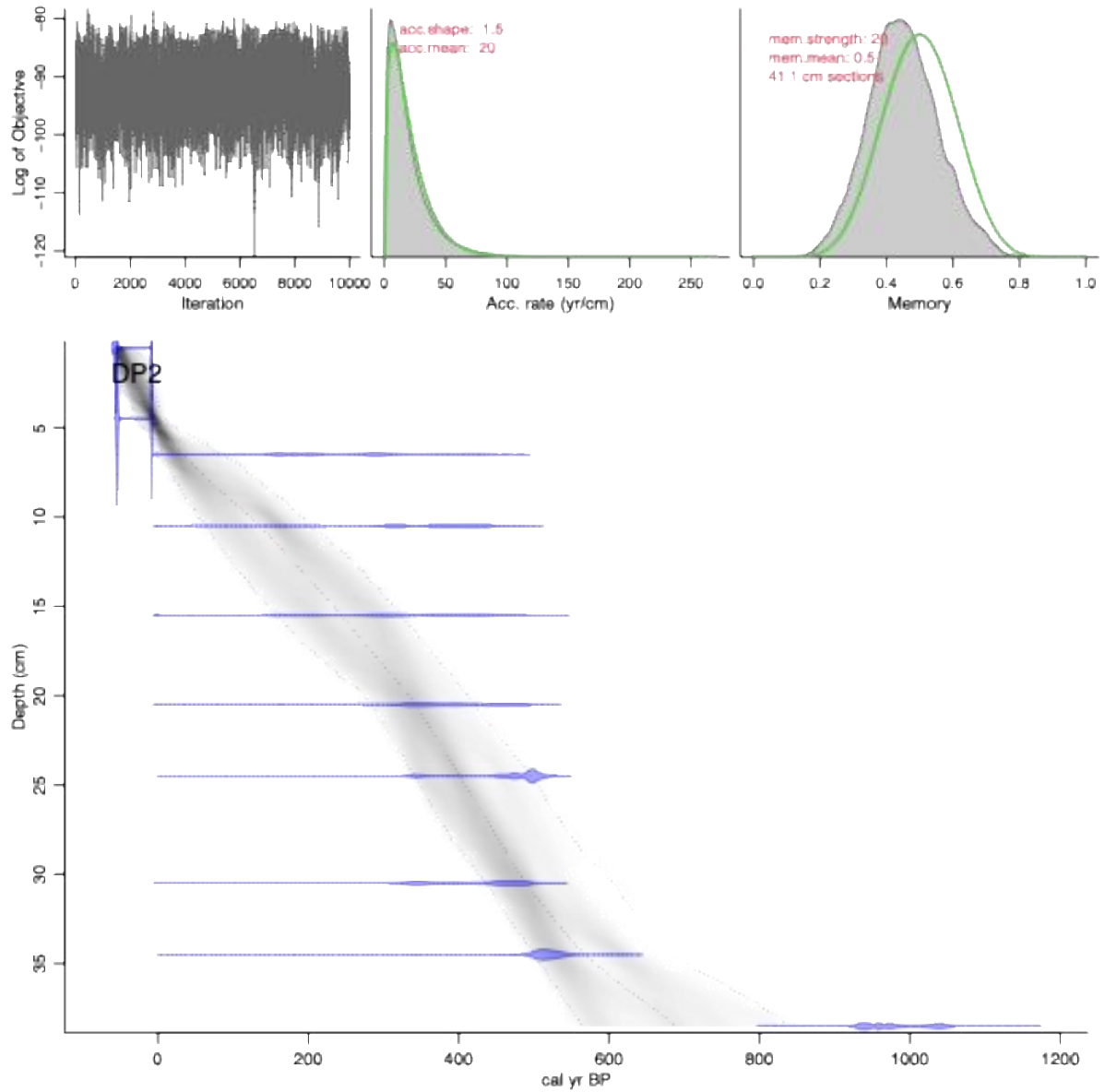


Figure S 5 DP2 rbacon age depth model with uncertainty. Depth (cm) vs cal yr BP (calibrated years before present). blue indicates modelled ages. Grey is modelled uncertainty represented as minimum and maximum.

*Table S 3 Radiocarbon data from Macquarie Island and Campbell Island lake sediment cores used to construct age depth models in this study. Macrofossil indicates terrestrial macrofossil.*

| Lake         | Core   | Lab Code   | Sample Type | Depth (cm) | $\delta(^{13}\text{C})$ ‰ | % Modern Carbon | F14C          | $^{14}\text{C}$ age | Reference                   |
|--------------|--------|------------|-------------|------------|---------------------------|-----------------|---------------|---------------------|-----------------------------|
| Lake 1       | LK1    | OZZ213     | Macrofossil | 0          | -25                       | 97.15±0.25      |               | 235±25              | Schneider et al. (in press) |
| Lake 1       | LK1    | OZAR42     | Macrofossil | 4.5        | -24.4± 0.7                | 97.28±0.75      |               | 220±70              | Schneider et al. (in press) |
| Lake 1       | LK1    | OZAE13     | Macrofossil | 9.5        | -24.2                     | 92.91±0.67      |               | 590±60              | Schneider et al. (in press) |
| Lake 1       | LK1    | SANU-76426 | Macrofossil | 11         |                           |                 | 0.925±0.00254 | 624±27              | Schneider et al. (in press) |
| Lake 1       | LK1    | OZZ194     | Macrofossil | 12.5       | -25                       | 66.32±0.45      |               | 3300±60             | Schneider et al. (in press) |
| Lake 1       | LK1    | OZZ214     | Macrofossil | 13         | -25                       | 74.49±0.23      |               | 2,365±25            | Schneider et al. (in press) |
| Lake 1       | LK1    | SANU-76927 | Macrofossil | 14         |                           |                 | 0.664±0.00207 | 3293±30             | Schneider et al. (in press) |
| Lake 1       | LK1    | SANU-75603 | Macrofossil | 15         |                           |                 | 0.433±0.00126 | 6729±28             | Schneider et al. (in press) |
| Lake 1       | LK1    | OZZ215     | Macrofossil | 20         | -24.1±0.1                 | 39.84±0.14      |               | 7,395±30            | Schneider et al. (in press) |
| Lake 1       | LK1    | SANU-75604 | Macrofossil | 25         |                           |                 | 0.392±0.00108 | 7522±27             | Schneider et al. (in press) |
| Lake 1       | LK1    | OZZ216     | Macrofossil | 30         | -25.6±0.1                 | 38.28±0.15      |               | 7,715±35            | Schneider et al. (in press) |
| Lake 1       | LK1    | SANU-75605 | Macrofossil | 35         |                           |                 | 0.384±0.00114 | 7687±29             | Schneider et al. (in press) |
| Lake 1       | LK1    | OZZ217     | Macrofossil | 41         | -24±0.1                   | 37.68±0.14      |               | 7,840±30            | Schneider et al. (in press) |
| Emerald Lake | EM2010 | SANU-75606 | Macrofossil | 4          |                           |                 | 0.978±0.00210 | 178±22              | Schneider et al. (in press) |
| Emerald Lake | EM2010 | SANU-76427 | Macrofossil | 8          |                           |                 | 0.968±0.00240 | 264±25              | Schneider et al. (in press) |
| Emerald Lake | EM2010 | SANU-77905 | Macrofossil | 17         |                           |                 | 0.701±0.00350 | 2859±45             | Schneider et al. (in press) |

|                 |        |            |             |    |            |            |                     |         |                             |
|-----------------|--------|------------|-------------|----|------------|------------|---------------------|---------|-----------------------------|
| Emerald Lake    | EM2010 | SANU-75607 | Macrofossil | 20 |            |            | 0.616±0.00190       | 3893±30 | Schneider et al. (in press) |
| Emerald Lake    | EM2010 | OZBM91     | Macrofossil | 30 | -28±0.2    | 57.01±0.26 |                     | 4510±40 | Schneider et al. (in press) |
| Emerald Lake    | EM2010 | SANU-76929 | Macrofossil | 35 |            |            | 0.451±0.00480       | 6400±90 | Schneider et al. (in press) |
| Emerald Lake    | EM2010 | SANU-75609 | Macrofossil | 40 |            |            | 0.449±0.00120       | 6432±27 | Schneider et al. (in press) |
| Emerald Lake    | EM2010 | SANU-75610 | Macrofossil | 50 |            |            | 0.428±0.00110       | 6812±26 | Schneider et al. (in press) |
| Emerald Lake    | EM2010 | SANU-76429 | Macrofossil | 60 |            |            | 0.422±0.00190       | 6923±42 | Schneider et al. (in press) |
| Emerald Lake    | EM2010 | OZBM92     | Macrofossil | 65 | -28.1      | 43.13±0.25 |                     | 6760±50 | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | SANU-75617 | Macrofossil | 1  |            |            | 1.016±0.00236       | >modern | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | SANU-76930 | Macrofossil | 5  |            |            | 0.984±0.00288       | 129±29  | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | SANU-76931 | Macrofossil | 10 |            |            | 0.914±0.00261       | 726±28  | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | SANU-75618 | Macrofossil | 20 |            |            | 0.919±0.00173       | 678±20  | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | SANU-75619 | Macrofossil | 30 |            |            | 0.912±0.00185       | 738±21  | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | SANU-76606 | Macrofossil | 35 |            |            | 0.853±0.00178       | 1277±22 | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | OZBM97     | Macrofossil | 44 | -21.10±0.1 | 83.76±0.34 |                     | 1420±40 | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | SANU-75620 | Macrofossil | 50 |            |            | 0.809±0.00161       | 1706±21 | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | OZBM98     | Macrofossil | 61 | -25.90±0.1 | 73.31±0.31 |                     | 2490±40 | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | SANU-76226 | Macrofossil | 61 |            |            | 0.723±0.00191       | 2604±26 | Schneider et al. (in press) |
| Cumberland Tarn | CT_SUR | SANU-76820 | Macrofossil | 64 |            |            | 0.688±0.00184       | 3000±26 | (Schneider et al. in press) |
| Green Gorge     | GG_SUR | SANU-75625 | Macrofossil | 1  |            |            | 0.76527423±0.015211 | 2149±21 | This study                  |

|             |            |               |                    |           |                  |                   |                      |               |                   |
|-------------|------------|---------------|--------------------|-----------|------------------|-------------------|----------------------|---------------|-------------------|
| Green Gorge | GG_SUR     | SANU-76932    | Macrofossil        | 3         |                  |                   | 0.86655019±0.0030614 | 1151±33       | This study        |
| Green Gorge | GG_SUR     | OZBM93        | Macrofossil        | 10        | -27.5±0.2        | 96.36±0.34        |                      | 300±30        | This study        |
| Green Gorge | GG_SUR     | SANU-76607    | Macrofossil        | 15        |                  |                   | 0.86301096±0.0019026 | 1183±23       | This study        |
| Green Gorge | GG_SUR     | SANU-75626    | Macrofossil        | 20        |                  |                   | 0.90442081±0.0017841 | 807±21        | This study        |
| Green Gorge | GG_SUR     | SANU-75627    | Macrofossil        | 30        |                  |                   | 0.89550899±0.0017254 | 887±20        | This study        |
| Green Gorge | GG_SUR     | SANU-76609    | Macrofossil        | 40        |                  |                   | 0.82450708±0.0018885 | 1550±23       | This study        |
| Green Gorge | GG_SUR     | OZBM94        | Macrofossil        | 48        | -26.3±0.1        | 89.13±0.3         |                      | 920±35        | This study        |
| Green Gorge | GG_LIV     | OZBM95        | Macrofossil        | 13        | -26.1±0.1        | 82.51±0.32        |                      | 1540±40       | This study        |
| Green Gorge | GG_LIV     | SANU-76225    | Macrofossil        | 13        |                  |                   | 0.87830253±0.0020296 | 1042±24       | This study        |
| Green Gorge | GG_LIV     | SANU-75621    | Macrofossil        | 20        |                  |                   | 0.85721269±0.0016279 | 1238±20       | This study        |
| Green Gorge | GG_LIV     | SANU-75623    | Macrofossil        | 40        |                  |                   | 0.95558782±0.0017253 | 365±20        | This study        |
| Green Gorge | GG_LIV     | SANU-75624    | Macrofossil        | 60        |                  |                   | 0.88767374±0.0016521 | 957±20        | This study        |
| Green Gorge | GG_LIV     | OZBM96        | Macrofossil        | 87        | -28.2±0.2        | 84.13±0.32        |                      | 1390±40       | This study        |
| DP2         | DP2        | OZW028        | Macrofossil        | 0         | -26.3±0.1        | 107.02±0.34       |                      | Modern        | This study        |
| DP2         | DP2        | SANU-76610    | Macrofossil        | 4         |                  |                   | 1.0779±0.0022        | Modern        | This study        |
| DP2         | DP2        | OZW029        | Macrofossil        | 6         | -25*             | 96.82±0.47        |                      | 260±40        | This study        |
| DP2         | DP2        | OZU923        | Macrofossil        | 10        | -24.3±0.1        | 95.98±0.45        |                      | 330±40        | This study        |
| DP2         | DP2        | OZU924        | Macrofossil        | 15        | -25*             | 96.24±0.61        |                      | 310±60        | This study        |
| DP2         | DP2        | OZU925        | Macrofossil        | 20        | -24.9±0.1        | 95.19±0.4         |                      | 395±35        | This study        |
| DP2         | DP2        | OZW030        | Macrofossil        | 24        | -24.4±0.1        | 94.33±0.27        |                      | 470±25        | This study        |
| DP2         | DP2        | OZU926        | Macrofossil        | 30        | -25.2±0.1        | 94.94±0.37        |                      | 415±35        | This study        |
| <b>DP2</b>  | <b>DP2</b> | <b>OZU927</b> | <b>Macrofossil</b> | <b>34</b> | <b>-24.6±0.2</b> | <b>93.72±0.39</b> |                      | <b>520±35</b> | <b>This study</b> |

\*The value of  $\delta(13C)$  is assumed. Not enough material was available for measurement, therefore a measured value was not possible

Table S 4  $^{210}\text{Pb}$  data for Macquarie Island and Campbell Island. DBD (dry bulk density). Corrected year indicates year unsupported  $^{210}\text{Pb}$  was corrected to (year the core was collected). CFCS = constant flux constant sedimentation, CRS = constant rate supply.

| Lake (Core)           | Corrected year                | ID   | Depth (cm) | DBD (g/cm <sup>3</sup> ) | Total $^{210}\text{Pb}$ (Bq/kg) | Supported $^{210}\text{Pb}$ (Bq/kg) | Uncorrected Unsupported $^{210}\text{Pb}$ (Bq/kg) | Corrected Unsupported $^{210}\text{Pb}$ (Bq/kg) | Calculated CFCS Ages (years) | Calculated CRS Ages (years) | CRS model Mass Accumulations rates (g/cm <sup>2</sup> /year) |
|-----------------------|-------------------------------|------|------------|--------------------------|---------------------------------|-------------------------------------|---------------------------------------------------|-------------------------------------------------|------------------------------|-----------------------------|--------------------------------------------------------------|
| Emerald Lake (EM2010) | 1 <sup>st</sup> April 2010    | Z207 | 0-0.5      | 0.8122                   | 61±3                            | 3±1                                 | 58±3                                              | 89±5                                            | 2±2                          | 3±2                         | 0.064±0.004                                                  |
|                       |                               | Z834 | 1-1.5      | 0.8199                   | 42±2                            | 4±1                                 | 38±3                                              | 59±4                                            | 10±4                         | 15±3                        | 0.065±0.007                                                  |
|                       |                               | Z835 | 1.5-2      | 0.638                    | 30±2                            | 3±1                                 | 28±2                                              | 43±3                                            | 14±5                         | 20±3                        | 0.075±0.009                                                  |
|                       |                               | Z208 | 2-2.5      | 0.6708                   | 39±2                            | 3±1                                 | 36±2                                              | 55±4                                            | 17±6                         | 26±4                        | 0.050±0.006                                                  |
|                       |                               | Z836 | 3-3.5      | 0.7088                   | 10±1                            | 4±1                                 | 6±1                                               | 9±2                                             | 24±8                         | 33±4                        | 0.234±0.051                                                  |
|                       |                               | Z209 | 5-5.5      | 0.6430                   | 11±1                            | 4±1                                 | 7±1                                               | 11±2                                            | 38±13                        | 40±4                        | 0.165±0.038                                                  |
|                       |                               | Z837 | 5.5-6      | 0.5219                   | 12±2                            | 3±1                                 | 8±2                                               | 13±3                                            | 41±14                        | 42±5                        | 0.126±0.023                                                  |
|                       |                               | Z210 | 8-8.5      | 0.5146                   | 20±2                            | 3±1                                 | 17±2                                              | 26±3                                            | 54±18                        | 62±6                        | 0.034±0.006                                                  |
|                       |                               | Z838 | 10-10.5    | 0.6178                   | 10±1                            | 4±1                                 | 6±2                                               | 10±3                                            | 65±22                        | 96±10                       | 0.033±0.010                                                  |
|                       |                               | Z839 | 15-15.5    | 0.9463                   | 1±1                             | 2±0                                 | Not detected                                      | Not detected                                    | NA                           | NA                          | NA                                                           |
| Lake 1 (LK1)          | 1 <sup>st</sup> December 2018 | W263 | 0-0.5      | 0.16                     | 103±4<br>-                      | 1.4±0.3                             | 101±4-                                            | 104±5                                           | 3±3                          | 5±2                         | 0.005±0.00                                                   |
|                       |                               | Z219 | 1-1.5      | 0.14                     | 17±1                            | 2.2±2.2                             | 15±3                                              | 17±3                                            | 13±3                         | 21±10                       | 0.019±0.006                                                  |
|                       |                               | W264 | 2-2.5      | 0.14                     | 24±1                            | 1.8±0.3                             | 22±1                                              | 23±1                                            | 23±4                         | 31±11                       | 0.011±0.004                                                  |
|                       |                               | Z220 | 3-3.5      | 0.14                     | 10±1                            | 2.6±2.6                             | 7±3                                               | 8±3                                             | 33±5                         | 40±13                       | 0.022±0.012                                                  |
|                       |                               | Z221 | 3.5-4      | 0.14                     | 12±1                            | 2.7±2.7                             | 9±3                                               | 11±3                                            | 38±6                         | 44±14                       | 0.015±0.007                                                  |
|                       |                               | W265 | 5-5.5      | 0.14                     | 8±1                             | 2.0±0.6                             | 6±1                                               | 6±1                                             | 53±8                         | 56±17                       | 0.019±0.010                                                  |
|                       |                               | W266 | 8-8.5      | 0.14                     | 8±1                             | 4.4±0.7                             | 4±1                                               | 4±1                                             | 82±11                        | 83±24                       | 0.012±0.010                                                  |
|                       |                               | W267 | 10-10.5    | 0.11                     | 5.0±0.5                         | 2.0±0.4                             | 3±1                                               | 3±1                                             | 100±14                       | 109±37                      | 0.007±0.008                                                  |
|                       |                               | W268 | 15-15.5    | 0.11                     | 2.2±0.4                         | 1.7±0.4                             | 0.5±0.5                                           | 0.5±0.5                                         | 139±19                       | 172±101                     | 0.006±0.019                                                  |
|                       |                               | Z215 | 0-0.5      | 0.2079                   | 238±10                          | 12±2                                | 225±10                                            | 348±16                                          | 4±4                          | 4.0±0.0                     | 0.013±0.001                                                  |

|                             |                                  |      |         |          |        |      |        |        |        |           |             |
|-----------------------------|----------------------------------|------|---------|----------|--------|------|--------|--------|--------|-----------|-------------|
| Cumberland Tarn<br>(CT_SUR) | 1 <sup>st</sup> November<br>2009 | Z840 | 0.5-1   | 0.2243   | 221±10 | 7±1  | 214±10 | 341±16 | 13±5   | 13.5±0.1  | 0.010±0.001 |
|                             |                                  | Z841 | 1-1.5   | 0.2144   | 116±6  | 6±1  | 110±6  | 175±10 | 22±6   | 22.9±0.1  | 0.014±0.002 |
|                             |                                  | Z216 | 2-2.5   | 0.1726   | 142±7  | 6±1  | 136±7  | 210±11 | 39±8   | 42.9±0.2  | 0.006±0.001 |
|                             |                                  | Z842 | 2.5-3   | 0.1662   | 85±4   | 10±1 | 75±5   | 120±7  | 46±9   | 55.0±0.2  | 0.008±0.001 |
|                             |                                  | Z843 | 4-4.5   | 0.1692   | 22±3   | 11±2 | 11±4   | 18±6   | 67±13  | 74.5±0.3  | 0.028±0.009 |
|                             |                                  | Z217 | 5-5.5   | 0.1865   | 46±3   | 11±2 | 35±3   | 53±5   | 82±15  | 88.8±0.4  | 0.006±0.002 |
|                             |                                  | Z844 | 6-6.5   | 0.1784   | 14±2   | 9±1  | 5±2    | 8±4    | 97±18  | 106.3±0.5 | 0.024±0.010 |
|                             |                                  | Z218 | 8-8.5   | 0.2179   | 19±2   | 10±1 | 9±2    | 14±3   | 130±24 | 146.1±0.9 | 0.004±0.003 |
| Green Gorge<br>(GG_SUR)     | 1 <sup>st</sup> October<br>2009  | Z845 | 10-10.5 | 0.1099   | 8±8    | 13±2 | -5±8   | -8±13  | NA     | NA        | NA          |
|                             |                                  | Z211 | 0-0.5   | 0.17     | 27±3   | 5±5  | 22±5   | 34±9   | 4±5    | 4±4       | 0.012±0.013 |
|                             |                                  | Z595 | 1-1.5   | 0.11     | 40±40  | 17±5 | 23±41  | 36±64  | 18±9   | 19±31     | 0.007±0.010 |
|                             |                                  | Z596 | 1.5-2   | 0.15     | 30±30  | 17±5 | 13±30  | 20±47  | 24±11  | 28±31     | 0.009±0.017 |
|                             |                                  | Z212 | 2-2.5   | 0.16     | 14±2   | 5±1  | 10±2   | 15±3   | 32±14  | 36±32     | 0.010±0.005 |
|                             |                                  | Z213 | 5-5.5   | 0.32     | 12±1   | 11±2 | 2±2    | 3±3    | NA     | NA        | NA          |
|                             |                                  | Z597 | 3-3.5   | 0.17     | 27     | 80   | -53    | -83    | NA     | NA        | NA          |
|                             |                                  | Z598 | 4-4.5   | 0.20     | 20     | 23   | -3     | -5     | NA     | NA        | NA          |
| DP2                         | 1 <sup>st</sup> February<br>2010 | Z599 | 6-6.5   | 0.36     | 10     | 23   | -13    | -20    | NA     | NA        | NA          |
|                             |                                  | Z214 | 8-8.5   | 0.25     | 14     | 24   | -10    | -16    | NA     | NA        | NA          |
|                             |                                  | Z830 | 0-1     | 0.76957  | 33±2   | 14±2 | 19±3   | 29±5   | NA     | NA        | NA          |
|                             |                                  | Z831 | 2-3     | 1.01189  | 15±1   | 24±2 | NA     | NA     | NA     | NA        | NA          |
|                             |                                  | Z832 | 5-6     | 1.081855 | 14±1   | 24±2 | NA     | NA     | NA     | NA        | NA          |
|                             |                                  | Z833 | 8-9     | 0.809418 | 15±1   | 22±2 | NA     | NA     | NA     | NA        | NA          |

Table S 5 Total Plutonium (Pu) and  $^{240}\text{Pu}/^{239}\text{Pu}$  atom ratio results for Emerald Lake

| Laboratory Code | Depth | Total Pu conc (pg/g) | $^{240}\text{Pu}/^{239}\text{Pu}$ atom ratio |
|-----------------|-------|----------------------|----------------------------------------------|
|-----------------|-------|----------------------|----------------------------------------------|

|       |      |                 |             |
|-------|------|-----------------|-------------|
| 12910 | 1    | 0.06032±0.00213 | 0.161±0.008 |
| 12911 | 2.5  | 0.10233±0.00213 | 0.152±0.004 |
| 12912 | 3.5  | 0.21206±0.00213 | 0.143±0.003 |
| 12913 | 4.5  | 0.23914±0.00213 | 0.153±0.004 |
| 12914 | 5    | 0.23303±0.00213 | 0.182±0.004 |
| 13242 | 5.5  | 0.22180±0.00213 | 0.152±0.004 |
| 13243 | 6    | 0.20799±0.00213 | 0.186±0.005 |
| 12915 | 6.5  | 0.25781±0.00580 | 0.226±0.005 |
| 13244 | 7    | 0.59700±0.01415 | 0.223±0.006 |
| 12916 | 7.5  | 0.12509±0.00289 | 0.233±0.006 |
| 12917 | 8.5  | 0.02124±0.00077 | 0.215±0.012 |
| 12918 | 11.5 | 0.00076±0.00006 | 0.196±0.023 |
| 12919 | 14.5 | 0.00007±0.00002 | 0.203±0.104 |

## Supporting Note 4: Results, geochemistry and mixing models for lake sediment records, moss, soil, and surface sediment.

*Table S 6 Summary of proxies separated by pre and post 1850 CE, avg = average ± standard deviation, min = minimum, max = maximum. TOC = total organic carbon, TOC/TN = total organic carbon/ total nitrogen,  $\delta^{13}\text{C}$  = carbon isotope,  $\delta^{15}\text{N}$  = nitrogen isotope, THg/TOC = total mercury/total organic carbon, THg = total mercury, TN = total nitrogen.  $\Delta^{199} - \Delta^{204}\text{Hg}$  = mercury isotope mass independent fractionation, and  $\delta^{202}\text{Hg}$  = mercury isotope mass dependent fractionation.*

| Proxy | Period    | Lake 1       |       |       | Emerald Lake |      |       | Cumberland Tarn |      |       | Green Gorge  |       |       | DP2        |      |      |
|-------|-----------|--------------|-------|-------|--------------|------|-------|-----------------|------|-------|--------------|-------|-------|------------|------|------|
|       |           | avg          | min   | max   | avg          | min  | max   | avg             | min  | max   | avg          | min   | max   | avg        | min  | max  |
| TOC   | Post-1850 | 38.93 ± 4.23 | 29.63 | 42.93 | 7.11 ± 3.8   | 2.05 | 16.39 | 11.27 ± 1.43    | 9.12 | 13.29 | 33.26 ± 8.01 | 21.53 | 42.52 | 3.1 ± 1.58 | 1.6  | 6.16 |
| TOC   | Pre-1850  | 31.45 ± 1.21 | 30.6  | 32.31 | 0.81 ± 0.47  | 0.42 | 1.49  | 10.13 ± 1.04    | 7.85 | 11.06 | 24.53 ± 10   | 10.12 | 36.61 | 3.8 ± 1.2  | 2.41 | 6.35 |

|                     |           |                |        |        |               |        |        |               |        |        |               |        |        |               |        |        |
|---------------------|-----------|----------------|--------|--------|---------------|--------|--------|---------------|--------|--------|---------------|--------|--------|---------------|--------|--------|
| TN                  | Post-1850 | 2.4 ± 0.42     | 1.27   | 2.67   | 0.47 ± 0.24   | 0.23   | 1.12   | 0.86 ± 0.08   | 0.71   | 0.99   | 2.06 ± 0.46   | 1.41   | 2.67   | 0.2 ± 0.11    | 0.1    | 0.44   |
| TN                  | Pre-1850  | 2.45 ± 0.17    | 2.32   | 2.57   | 0.1 ± 0.02    | 0.08   | 0.13   | 0.87 ± 0.14   | 0.59   | 1.07   | 1.44 ± 0.48   | 0.68   | 1.92   | 0.23 ± 0.06   | 0.14   | 0.33   |
| TOC/TN              | Post-1850 | 19.36 ± 3.13   | 16.01  | 27.33  | 18.12 ± 6.29  | 10.46  | 31.66  | 15.33 ± 1.96  | 12.75  | 19.91  | 18.78 ± 0.89  | 17.59  | 20.13  | 18 ± 0.83     | 16.39  | 19.06  |
| TOC/TN              | Pre-1850  | 15.07 ± 1.63   | 13.92  | 16.22  | 9.04 ± 3.36   | 6.51   | 13.81  | 13.99 ± 1.57  | 11.65  | 16.06  | 18.63 ± 3.85  | 14.62  | 26.61  | 19.45 ± 1.82  | 17.41  | 22.3   |
| δ <sup>13</sup> C   | Post-1850 | -26.71 ± 0.27  | -27.16 | -26.30 | -25.51 ± 0.8  | -26.61 | -23.78 | -22.84 ± 0.32 | -23.48 | -22.46 | -28.55 ± 0.64 | -29.21 | -27.57 | -27.27 ± 0.52 | -28.30 | -26.72 |
| δ <sup>13</sup> C   | Pre-1850  | -25.95 ± 0.19  | -26.09 | -25.82 | -24.08 ± 0.48 | -24.55 | -23.49 | -23.51 ± 0.26 | -24.03 | -23.23 | -27.40 ± 0.85 | -28.49 | -26.19 | -27.45 ± 0.27 | -27.99 | -27.12 |
| δ <sup>15</sup> N   | Post-1850 | 5.49 ± 0.47    | 4.66   | 6.32   | 6.64 ± 0.87   | 5.39   | 8.16   | -0.15 ± 0.66  | -1.40  | 1.21   | 6.07 ± 0.46   | 5.54   | 6.77   | 10.97 ± 0.95  | 9.38   | 11.96  |
| δ <sup>15</sup> N   | Pre-1850  | 3.56 ± 0.31    | 3.35   | 3.78   | 5.38 ± 0.4    | 5.01   | 5.9    | -0.47 ± 0.18  | -0.61  | -0.04  | 6.18 ± 0.71   | 5.34   | 7.48   | 11.32 ± 0.58  | 10.17  | 11.94  |
| THg                 | Post-1850 | 132.43 ± 15.63 | 99.65  | 156.4  | 40.9 ± 25.99  | 12.79  | 146.3  | 80.36 ± 28.33 | 48.32  | 154.7  | 164.1 ± 29.09 | 128.5  | 231.4  | 58.65 ± 15.13 | 37.92  | 81.91  |
| THg                 | Pre-1850  | 97.11 ± 11.43  | 84.84  | 107.5  | 7.39 ± 2.5    | 4.7    | 11.73  | 47.22 ± 11.78 | 26.19  | 65.76  | 124.8 ± 25.06 | 74.29  | 178.3  | 48.68 ± 7.48  | 37.17  | 65.68  |
| THg/TOC             | Post-1850 | 3.43 ± 0.21    | 3.22   | 3.81   | 6.38 ± 2.06   | 2.35   | 8.92   | 7.65 ± 2.92   | 4.59   | 14.28  | 5.56 ± 1.15   | 3.86   | 7.07   | 21.25 ± 8.55  | 13.29  | 38.68  |
| THg/TOC             | Pre-1850  | 2.92 ± 0.21    | 2.77   | 3.07   | 9.5 ± 2.56    | 6.68   | 12.1   | 4.94 ± 1.13   | 3.52   | 6.82   | 6.31 ± 2.45   | 3.96   | 10.23  | 14.64 ± 4.84  | 8.37   | 23.66  |
| HgAR                | Post-1850 | 22.08 ± 16.07  | 1.32   | 47.08  | 40.1 ± 40.53  | 3.6    | 137    | 12.37 ± 10.1  | 2.15   | 37.29  | 18.25 ± 6.47  | 11.35  | 31.16  | 37.41 ± 22.2  | 12.36  | 83.59  |
| HgAR                | Pre-1850  | 0.3 ± 0.18     | 0.09   | 0.42   | 1.72 ± 1.64   | 0.02   | 4.31   | 2.2 ± 0.66    | 1.59   | 4.29   | 16.57 ± 5.43  | 8.57   | 27.96  | 21.43 ± 5.07  | 13.01  | 29.38  |
| Δ <sup>199</sup> Hg | Post-1850 | 0.55 ± 0.15    | 0.36   | 0.75   | 0.63 ± 0.12   | 0.51   | 0.95   | 1.07 ± 0.05   | 0.95   | 1.15   | 0.25 ± 0.03   | 0.22   | 0.31   | 0.21 ± 0.12   | 0.01   | 0.32   |
| Δ <sup>199</sup> Hg | Pre-1850  | NA ± NA        | NA     | NA     | 1.14 ± 0.06   | 1.07   | 1.19   | 0.93 ± 0.15   | 0.79   | 1.12   | 0.45 ± 0.31   | 0.04   | 0.7    | 0.24 ± 0.12   | 0.08   | 0.37   |
| Δ <sup>200</sup> Hg | Post-1850 | -0.06 ± 0.02   | -0.09  | -0.03  | -0.04 ± 0.02  | -0.06  | -0.01  | -0.03 ± 0.02  | -0.06  | 0      | -0.04 ± 0.02  | -0.07  | -0.02  | -0.04 ± 0.02  | -0.06  | -0.02  |
| Δ <sup>200</sup> Hg | Pre-1850  | NA ± NA        | NA     | NA     | -0.03 ± 0.02  | -0.05  | -0.02  | -0.04 ± 0.03  | -0.08  | 0      | -0.04 ± 0.01  | -0.04  | -0.03  | -0.04 ± 0.03  | -0.09  | -0.01  |
| Δ <sup>201</sup> Hg | Post-1850 | 0.37 ± 0.11    | 0.19   | 0.49   | 0.43 ± 0.1    | 0.32   | 0.71   | 0.59 ± 0.07   | 0.44   | 0.68   | 0.21 ± 0.04   | 0.15   | 0.26   | 0.17 ± 0.08   | 0.04   | 0.27   |

|                         |           |                  |       |       |                  |       |       |                  |       |       |                  |       |       |                  |       |       |
|-------------------------|-----------|------------------|-------|-------|------------------|-------|-------|------------------|-------|-------|------------------|-------|-------|------------------|-------|-------|
| $\Delta^{201}\text{Hg}$ | Pre-1850  | NA $\pm$ NA      | NA    | NA    | 0.83 $\pm$ 0.06  | 0.76  | 0.86  | 0.51 $\pm$ 0.09  | 0.41  | 0.62  | 0.41 $\pm$ 0.25  | 0.08  | 0.6   | 0.2 $\pm$ 0.09   | 0.11  | 0.32  |
| $\Delta^{204}\text{Hg}$ | Post-1850 | 0.09 $\pm$ 0.05  | 0.04  | 0.18  | 0.07 $\pm$ 0.05  | -0.04 | 0.15  | 0.07 $\pm$ 0.04  | 0     | 0.13  | 0.15 $\pm$ 0.03  | 0.12  | 0.19  | 0.07 $\pm$ 0.04  | 0.02  | 0.11  |
| $\Delta^{204}\text{Hg}$ | Pre-1850  | NA $\pm$ NA      | NA    | NA    | 0.06 $\pm$ 0.04  | 0.02  | 0.11  | 0.06 $\pm$ 0.07  | -0.03 | 0.13  | 0.09 $\pm$ 0.09  | 0     | 0.19  | 0.11 $\pm$ 0.04  | 0.05  | 0.15  |
| $\delta^{202}\text{Hg}$ | Post-1850 | -0.88 $\pm$ 0.09 | -1.02 | -0.80 | -0.69 $\pm$ 0.11 | -0.87 | -0.50 | -0.04 $\pm$ 0.06 | -0.12 | 0.05  | -0.87 $\pm$ 0.07 | -0.98 | -0.80 | -1.31 $\pm$ 0.1  | -1.42 | -1.19 |
| $\delta^{202}\text{Hg}$ | Pre-1850  | NA $\pm$ NA      | NA    | NA    | -0.56 $\pm$ 0.1  | -0.66 | -0.47 | -0.41 $\pm$ 0.15 | -0.60 | -0.27 | -0.71 $\pm$ 0.26 | -1.13 | -0.51 | -1.28 $\pm$ 0.06 | -1.34 | -1.20 |

Table S 7 Summary of proxies for soil and moss, avg = average, std = standard deviation, min = minimum, max = maximum. TOC = total organic carbon,  $\delta^{13}\text{C}$  = carbon isotope,  $\delta^{15}\text{N}$  = nitrogen isotope, TN = total nitrogen.  $\Delta^{199} - \Delta^{204}\text{Hg}$  = mercury isotope mass independent fractionation, and  $\delta^{202}\text{Hg}$  = mercury isotope mass dependent fractionation.

| proxy                   | Soil   |      |       |       | Moss   |       |       |       |
|-------------------------|--------|------|-------|-------|--------|-------|-------|-------|
|                         | Avg    | SD   | Min   | Max   | Avg    | SD    | Min   | Max   |
| TN                      | NA     | NA   | NA    | NA    | 0.53   | 0.25  | 0.16  | 1.01  |
| TOC                     | NA     | NA   | NA    | NA    | 35.5   | 10.6  | 10    | 43.7  |
| $\delta^{13}\text{C}$   | NA     | NA   | NA    | NA    | -27.7  | 2.4   | -31.4 | -22.4 |
| $\delta^{15}\text{N}$   | NA     | NA   | NA    | NA    | -1.17  | 4.48  | -9.80 | 6.2   |
| $\Delta^{199}\text{Hg}$ | -0.087 | 0.13 | -0.23 | 0     | -0.082 | 0.30  | -0.58 | 0.16  |
| $\Delta^{200}\text{Hg}$ | -0.04  | 0.01 | -0.05 | -0.03 | -0.046 | 0.027 | -0.08 | -0.02 |
| $\Delta^{201}\text{Hg}$ | -0.11  | 0.08 | -0.2  | -0.05 | -0.12  | 0.27  | -0.58 | 0.09  |
| $\Delta^{204}\text{Hg}$ | 0.12   | 0.03 | 0.09  | 0.15  | 0.092  | 0.016 | 0.07  | 0.11  |
| $\delta^{202}\text{Hg}$ | -0.69  | 0.37 | -1.09 | -0.37 | -0.86  | 0.59  | -1.87 | -0.4  |

Table S 8 Welch's-t-test for pre and post 1850 grouping of statistical significance, set to  $p < 0.05$ .

| proxy | Lake 1  |              | Emerald Lake |              | Cumberland Tarn |              | Green Gorge |              | DP2     |              |
|-------|---------|--------------|--------------|--------------|-----------------|--------------|-------------|--------------|---------|--------------|
|       | p.value | significance | p.value      | significance | p.value         | significance | p.value     | significance | p.value | significance |

|                         |          |     |          |     |          |     |          |     |          |
|-------------------------|----------|-----|----------|-----|----------|-----|----------|-----|----------|
| Sedimentation rate      | 4.71e-06 | *** | 2.84e-05 | *** | 5.69e-05 | *** | 0.0261   | *   | 0.158    |
| TOC                     | 0.00205  | **  | 5.66e-05 | *** | 0.0615   |     | 0.0833   |     | 0.296    |
| TN                      | 0.826    |     | 0.000112 | *** | 0.908    |     | 0.0249   | *   | 0.479    |
| TOC/TN                  | 0.0706   |     | 0.00373  | **  | 0.116    |     | 0.617    |     | 0.041 *  |
| $\delta^{13}\text{C}$   | 0.0447   | *   | 0.00198  | **  | 0.000123 | *** | 0.0106   | *   | 0.356    |
| $\delta^{15}\text{N}$   | 0.0159   | *   | 0.00177  | **  | 0.136    |     | 0.73     |     | 0.362    |
| THg                     | 0.0149   | *   | 6.59e-07 | *** | 0.000135 | *** | 0.000111 | *** | 0.0752   |
| HgAR                    | 7.88e-06 | *** | 5.9e-05  | *** | 0.000517 | *** | 0.395    |     | 0.0499 * |
| THg/TOC                 | 0.138    |     | 0.0857   |     | 0.0142   | *   | 0.456    |     | 0.0612   |
| $\delta^{202}\text{Hg}$ |          |     | 0.134    |     | 0.00344  | **  | 0.256    |     | 0.593    |
| $\Delta^{199}\text{Hg}$ |          |     | 5.18e-05 | *** | 0.106    |     | 0.221    |     | 0.706    |
| $\Delta^{200}\text{Hg}$ |          |     | 0.361    |     | 0.572    |     | 0.915    |     | 0.98     |
| $\Delta^{201}\text{Hg}$ |          |     | 0.000132 | *** | 0.125    |     | 0.148    |     | 0.575    |
| $\Delta^{204}\text{Hg}$ |          |     | 0.829    |     | 0.643    |     | 0.179    |     | 0.11     |

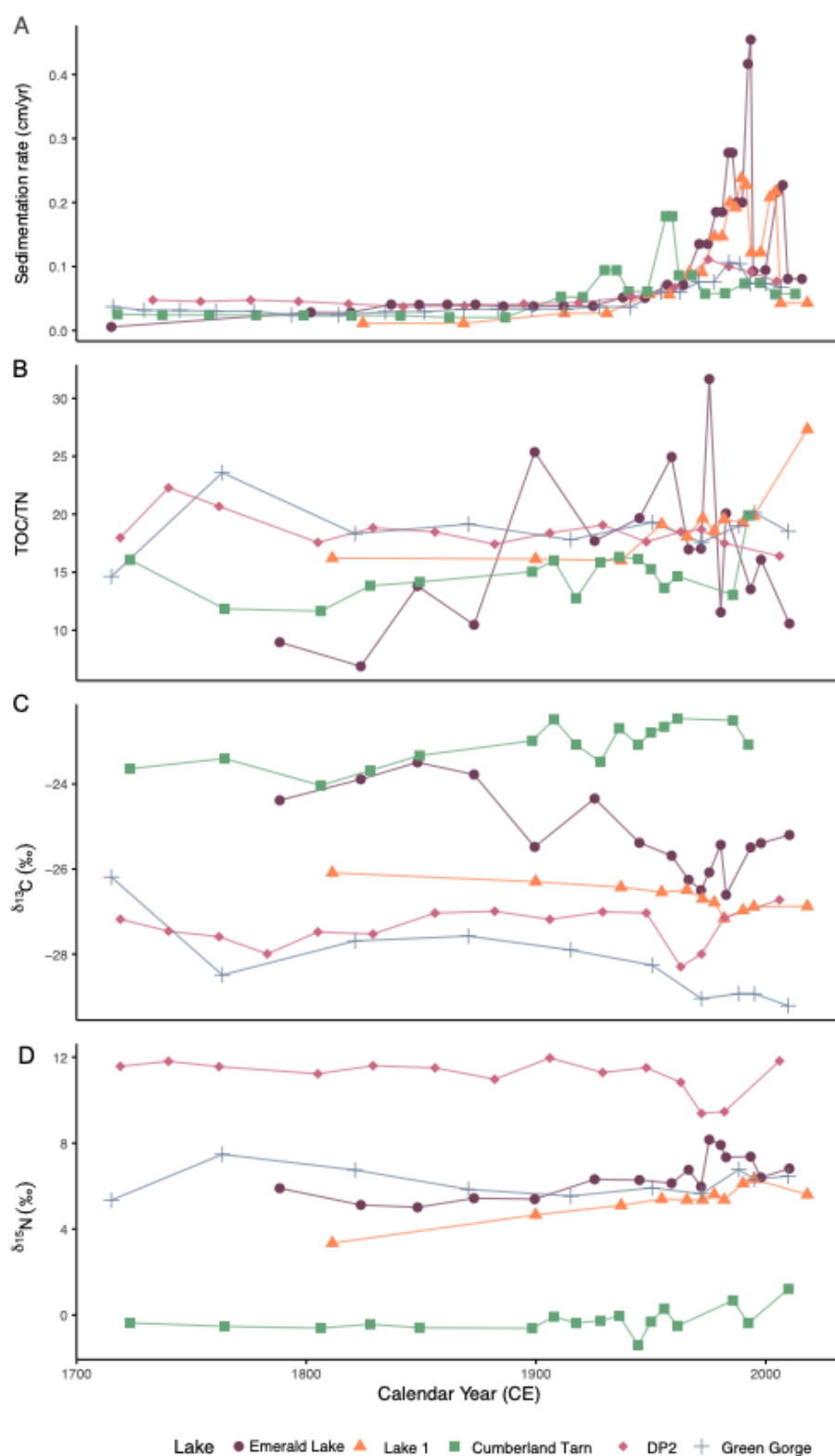


Figure S 6 Time trend (CE) of sedimentation rate (A), total organic carbon to total nitrogen ratio, TOC/TN (B),  $\delta^{13}\text{C}$  (C), and  $\delta^{15}\text{N}$  (D) in Lake 1 (orange triangle), Emerald Lake (purple circle), Cumberland Tarn (green square), Green Gorge (light blue cross), and DP2 (pink diamond).

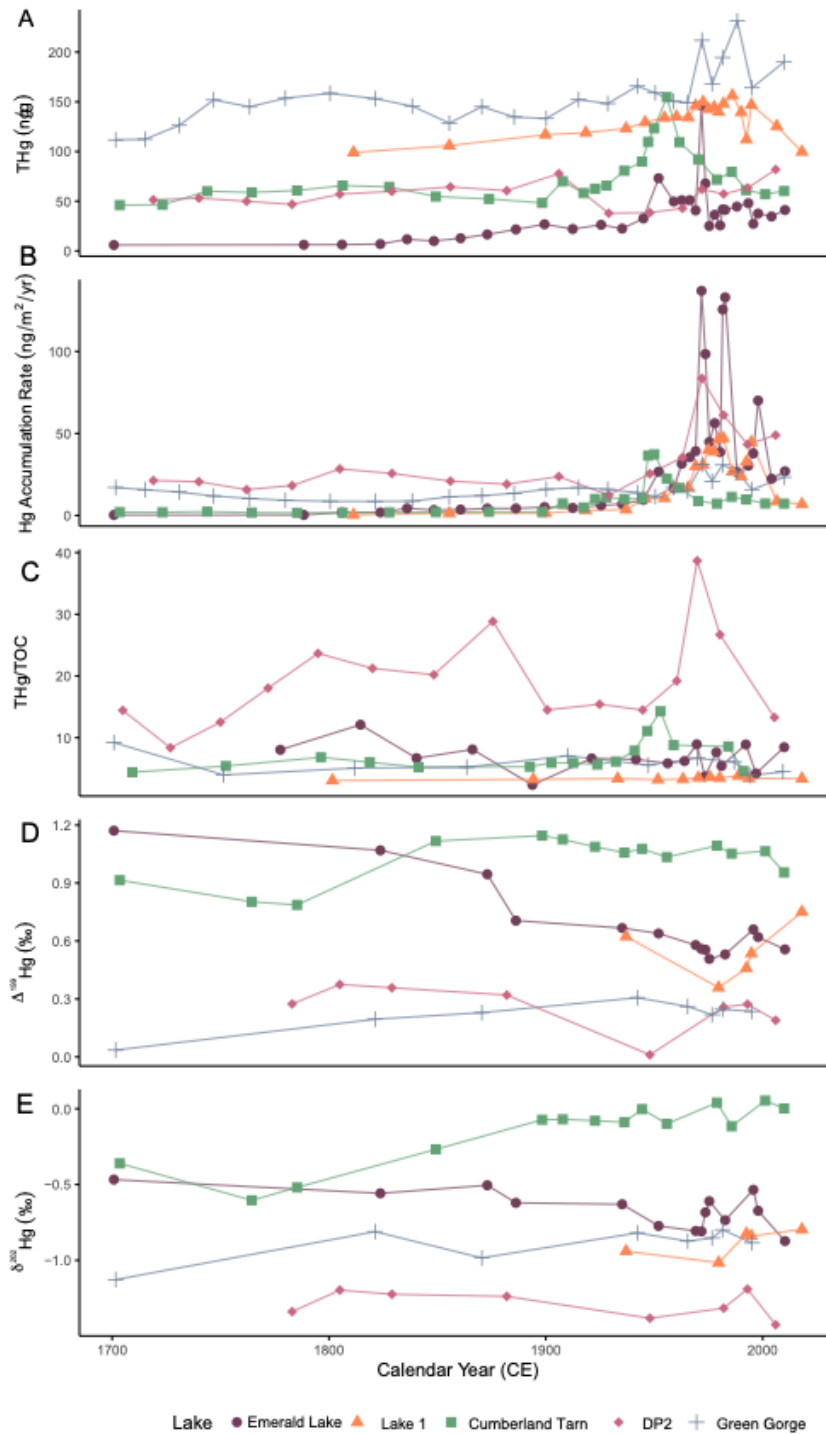


Figure S 7 Time trend (CE) of THg (A), HgAR (B), THg/TOC (C),  $\Delta^{199}\text{Hg}$  (D),  $\delta^{202}\text{Hg}$  (E) in Lake 1 (orange triangle), Emerald Lake (purple circle), Cumberland Tarn (green square), Green Gorge (light blue cross), and DP2 (pink diamond).

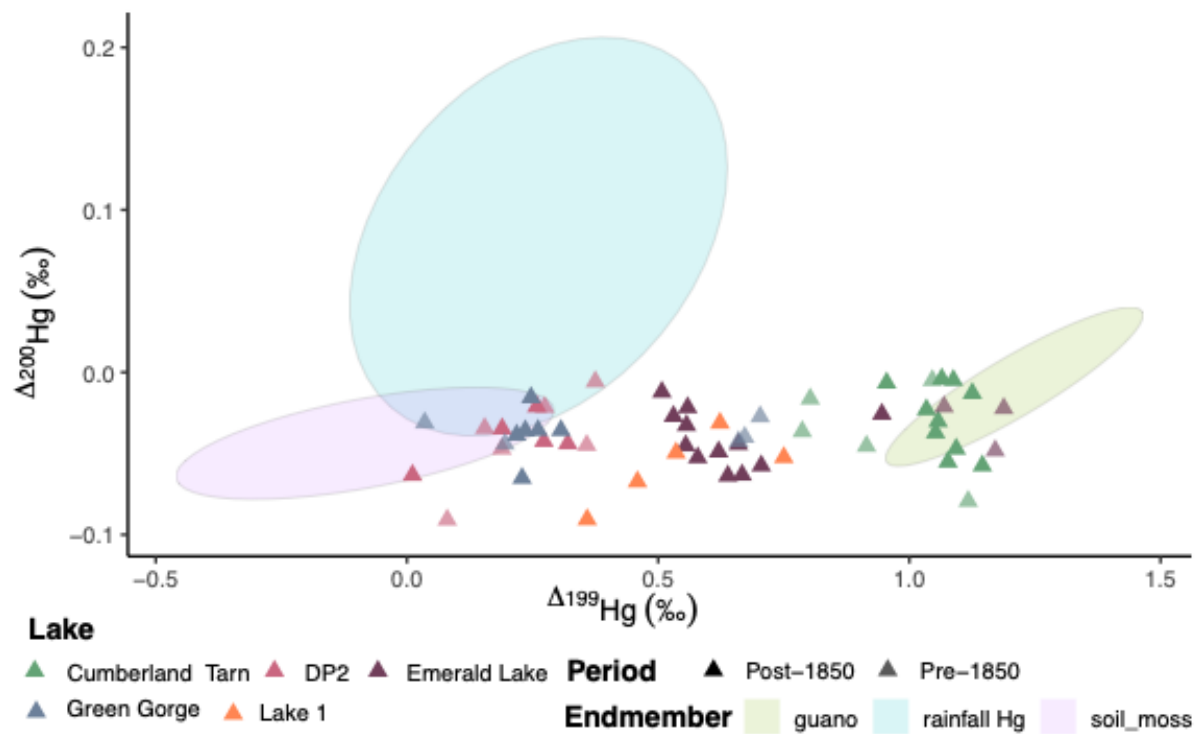


Figure S 8 Three endmember stable Hg isotope mixing model of  $\Delta^{199}\text{Hg}$  and  $\Delta^{200}\text{Hg}$ . Endmembers are represented with ISD ellipses, guano (Zheng et al. 2015; Li et al. 2026) in green, rainfall  $\text{Hg}^{\text{II}}$  (Li et al. 2023) in blue, and catchment Hg (Soil/moss) in pink.

## Supporting Note 5: Certified Reference Material (CRM) and quality control (QC) for Hg, Hg isotopes, TN, TOC, $\delta^{15}\text{N}$ , and $\delta^{13}\text{C}$

Table S 9 Certified reference material (CRM) for total Hg concentration (THg) measured using a direct mercury analyses (DMA80). *n* indicates number of replicates run.

| CRM                                              | Reported concentration ng/g | n  | Average concentration | Average recovery |
|--------------------------------------------------|-----------------------------|----|-----------------------|------------------|
| Internal standard NIST 1646a, Estuarine Sediment | 40                          | 10 | 36.20 $\pm$ 2.67      | 90.51            |
| EMRM WQB1, Lake Ontario Sediment                 | 1060                        | 13 | 1080.57 $\pm$ 63.46   | 101.94           |
| NIST-2706 New jersey Soil                        | 132.9                       | 8  | 149.32 $\pm$ 3.30     | 112.36           |
| RM-Cc141 Loam Soil                               | 83                          | 6  | 81.56 $\pm$ 4.32      | 98.27            |
| BCR-277R Estuarine Sediment                      | 128                         | 10 | 139.09 $\pm$ 13.31    | 108.67           |

Table S 10 certified reference material for Hg isotope analyses (‰)

| Standard            | Name                 | n  | $\delta^{202}\text{Hg}$ | 2SD  | $\Delta^{199}\text{Hg}$ | 2SD  | $\Delta^{200}\text{Hg}$ | 2SD  | $\Delta^{201}\text{Hg}$ | 2SD  | $\Delta^{204}\text{Hg}$ | 2SD  |
|---------------------|----------------------|----|-------------------------|------|-------------------------|------|-------------------------|------|-------------------------|------|-------------------------|------|
| Procedural Standard | GSD11a               | 4  | -                       | 0.08 | -                       | 0.01 | -0.01                   | 0.04 | -                       | 0.02 | 0.00                    | 0.05 |
| Secondary Standard  | UM-Almad (NIST 8610) | 17 | -                       | 0.07 | -                       | 0.05 | 0.01                    | 0.03 | -                       | 0.05 | 0.00                    | 0.08 |
|                     |                      | 3  | 0.56                    |      | 0.02                    |      |                         |      | 0.04                    |      |                         |      |

Table S 11 Certified reference material (CRM) and quality control (QC) for nitrogen, carbon,  $\delta^{15}/^{14}\text{NAIR}\%$  and  $\delta^{13}/^{12}\text{CV-PDB}\%$

| Name                                     | Nitrogen %      | $\delta^{15}/^{14}\text{NAIR}\%$ | Carbon %        | $\delta^{13}/^{12}\text{CV-PDB}\%$ |
|------------------------------------------|-----------------|----------------------------------|-----------------|------------------------------------|
| IAEA USGS-40 L-Glutamic Acid             | 9.5 $\pm$ 0.3   | -4.5 $\pm$ 0.1                   | 40.9 $\pm$ 0.5  | -26.4 $\pm$ 0.04                   |
| IAEA USGS-41a L-Glutamic Acid            | 9.5 $\pm$ 0.2   | 47.5 $\pm$ 0.2                   | 41.4 $\pm$ 1.0  | 36.6 $\pm$ 0.1                     |
| Elemental Microanalysis B2045 Methionine | 9.4 $\pm$ 0.1   | 0.73 $\pm$ 0.1                   | 40.4 $\pm$ 0.2  | -29.58 $\pm$ 0.3                   |
| CERTIFIED VALUES for QC1 - B2151         | 0.52 $\pm$ 0.02 | 4.32 $\pm$ 0.2                   | 7.45 $\pm$ 0.14 | -28.85 $\pm$ 0.1                   |
| AVERAGE (n = 4)                          | 0.5 $\pm$ 0     | 4.3 $\pm$ 0.1                    | 7.1 $\pm$ 0.1   | -28.9 $\pm$ 0.1                    |
| AVERAGE (n = 5)                          | 0.5 $\pm$ 0     | 4.3 $\pm$ 0.1                    | 7.1 $\pm$ 0.1   | -28.9 $\pm$ 0.2                    |
| AVERAGE (n = 3)                          | 0.5 $\pm$ 0     | 4.2 $\pm$ 0.5                    | 7.2 $\pm$ 0.2   | -28.9 $\pm$ 0                      |
| CERTIFIED VALUES for QC2 - B2178         | 0.27 $\pm$ 0.02 | 5.99 $\pm$ 0.28                  | 3.19 $\pm$ 0.07 | -27.63 $\pm$ 0.16                  |
| AVERAGE (n = 4)                          | 0.3 $\pm$ 0     | 6.2 $\pm$ 0.1                    | 3.2 $\pm$ 0.1   | -27.5 $\pm$ 0.1                    |
| AVERAGE (n = 5)                          | 0.3 $\pm$ 0     | 6.1 $\pm$ 0.1                    | 3.2 $\pm$ 0.1   | -27.5 $\pm$ 0.1                    |
| AVERAGE (n = 3)                          | 0.3 $\pm$ 0     | 6.2 $\pm$ 0.3                    | 3.2 $\pm$ 0     | -27.5 $\pm$ 0.1                    |

## Supporting Note 6: Data used in this study

Table S 12 Lake sediment data measured in this study. Cal BP = calibrated years before present, CE = Common Era, THg = total mercury, HgAR = mercury accumulation rate, TOC = total organic carbon, TN = total nitrogen, TOC/TN = total organic carbon/ total nitrogen, THg/TOC = total mercury/ total organic carbon, Sed rate = sedimentation rate. CT = Cumberland Tarn, EM = Emerald Lake, GG = Green Gorge, LK1 = Lake 1.

| Lake | Depth | Cal BP | CE   | THg    | HgAR        | TOC   | TN   | $\delta^{13}\text{C}$ | $\delta^{15}\text{N}$ | TOC/<br>TN | $\delta^{202}\text{H}$ | $\Delta^{199}\text{Hg}$ | $\Delta^{200}\text{Hg}$ | $\Delta^{201}\text{Hg}$ | $\Delta^{204}\text{Hg}$ | THg/<br>TOC | Sed<br>rate |
|------|-------|--------|------|--------|-------------|-------|------|-----------------------|-----------------------|------------|------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------|-------------|
|      | cm    | yrs    | yrs  | ug/g   | ng/m/y<br>r | %     | %    | ‰                     | ‰                     |            | ‰                      | ‰                       | ‰                       | ‰                       |                         |             | cm/y<br>r   |
| CT   | 0     | -59.9  | 2010 | 60.24  | 7.20        |       | 0.91 |                       | 1.21                  |            | 0.00                   | 0.95                    | -0.01                   | 0.44                    | 0.09                    |             |             |
| CT   | 0.5   | -51.2  | 2001 | 57.10  | 7.28        |       |      |                       |                       |            | 0.05                   | 1.06                    | 0.00                    | 0.55                    | 0.03                    |             | 0.06        |
| CT   | 1     | -42.4  | 1992 | 61.06  | 9.77        | 13.29 | 0.78 | -23.07                | -0.37                 | 19.91      |                        |                         |                         |                         |                         | 4.59        | 0.06        |
| CT   | 1.5   | -35.7  | 1986 | 79.52  | 11.33       | 9.28  | 0.83 | -22.50                | 0.68                  | 13.05      | -0.12                  | 1.05                    | -0.04                   | 0.59                    | 0.11                    | 8.57        | 0.07        |
| CT   | 2     | -28.9  | 1979 | 71.70  | 7.19        |       |      |                       |                       |            | 0.04                   | 1.09                    | -0.05                   | 0.64                    | 0.08                    |             | 0.07        |
| CT   | 2.5   | -20.3  | 1970 | 92.04  | 8.79        |       |      |                       |                       |            |                        |                         |                         |                         |                         |             | 0.06        |
| CT   | 3     | -11.6  | 1962 | 109.36 | 16.82       | 12.44 | 0.99 | -22.46                | -0.51                 | 14.65      |                        |                         |                         |                         |                         | 8.79        | 0.06        |
| CT   | 3.5   | -5.8   | 1956 | 154.70 | 22.47       | 10.83 | 0.93 | -22.65                | 0.30                  | 13.64      | -0.10                  | 1.03                    | -0.02                   | 0.48                    | 0.00                    | 14.2<br>8   | 0.09        |
| CT   | 4     | 0      | 1950 | 123.44 | 37.29       | 11.14 | 0.85 | -22.79                | -0.31                 | 15.27      |                        |                         |                         |                         |                         | 11.0<br>8   | 0.09        |
| CT   | 4.5   | 2.8    | 1947 | 109.69 | 36.52       |       |      |                       |                       |            |                        |                         |                         |                         |                         |             | 0.18        |
| CT   | 5     | 5.6    | 1944 | 89.81  | 10.21       | 11.36 | 0.82 | -23.08                | -1.40                 | 16.14      | 0.00                   | 1.08                    | -0.06                   | 0.61                    | 0.08                    | 7.90        | 0.18        |
| CT   | 5.5   | 13.8   | 1936 | 80.73  | 10.07       | 13.16 | 0.94 | -22.69                | -0.04                 | 16.32      | -0.09                  | 1.06                    | -0.03                   | 0.61                    | 0.10                    | 6.13        | 0.06        |
| CT   | 6     | 22     | 1928 | 65.66  | 11.05       | 11.62 | 0.86 | -23.48                | -0.27                 | 15.85      |                        |                         |                         |                         |                         | 5.65        | 0.06        |
| CT   | 6.5   | 27.3   | 1923 | 62.53  | 10.08       |       |      |                       |                       |            | -0.08                  | 1.09                    | 0.00                    | 0.63                    | 0.13                    |             | 0.09        |
| CT   | 7     | 32.6   | 1917 | 58.26  | 4.83        | 9.85  | 0.90 | -23.07                | -0.37                 | 12.75      |                        |                         |                         |                         |                         | 5.92        | 0.09        |
| CT   | 7.5   | 42.2   | 1908 | 70.07  | 7.31        | 11.82 | 0.86 | -22.48                | -0.08                 | 16.01      | -0.07                  | 1.13                    | -0.01                   | 0.63                    | 0.08                    | 5.93        | 0.05        |
| CT   | 8     | 51.7   | 1898 | 48.32  | 2.15        | 9.12  | 0.71 | -22.98                | -0.61                 | 15.04      | -0.07                  | 1.15                    | -0.06                   | 0.68                    | 0.04                    | 5.30        | 0.05        |
| CT   | 8.5   | 76.2   | 1874 | 52.31  | 2.23        |       |      |                       |                       |            |                        |                         |                         |                         |                         |             | 0.02        |
| CT   | 9     | 100.7  | 1849 | 54.70  | 2.04        | 10.49 | 0.86 | -23.33                | -0.59                 | 14.15      | -0.27                  | 1.12                    | -0.08                   | 0.62                    | -0.03                   | 5.21        | 0.02        |

|     |      |       |      |       |       |       |      |        |       |       |       |      |       |      |      |       |      |
|-----|------|-------|------|-------|-------|-------|------|--------|-------|-------|-------|------|-------|------|------|-------|------|
| CT  | 9.5  | 122.2 | 1828 | 64.44 | 1.89  | 10.70 | 0.90 | -23.68 | -0.43 | 13.84 |       |      |       |      |      | 6.02  | 0.02 |
| CT  | 10   | 143.7 | 1806 | 65.76 | 1.72  | 9.64  | 0.97 | -24.03 | -0.61 | 11.65 |       |      |       |      |      | 6.82  | 0.02 |
| CT  | 10.5 | 164.7 | 1785 | 60.80 | 1.63  |       |      |        |       |       | -0.52 | 0.79 | -0.04 | 0.45 | 0.13 |       | 0.02 |
| CT  | 11   | 185.6 | 1764 | 58.86 | 1.78  | 10.90 | 1.07 | -23.40 | -0.53 | 11.84 | -0.60 | 0.80 | -0.02 | 0.41 | 0.08 | 5.40  | 0.02 |
| CT  | 11.5 | 206.2 | 1744 | 60.05 | 2.35  |       |      |        |       |       |       |      |       |      |      |       | 0.02 |
| CT  | 12   | 226.8 | 1723 | 46.44 | 1.96  | 10.54 | 0.77 | -23.64 | -0.37 | 16.07 |       |      |       |      |      | 4.41  | 0.02 |
| CT  | 12.5 | 246.5 | 1704 | 46.09 | 2.06  |       |      |        |       |       | -0.36 | 0.91 | -0.05 | 0.47 | 0.10 |       | 0.03 |
| CT  | 13   | 266.2 | 1684 | 50.06 | 1.98  |       | 0.98 |        | -0.56 |       |       |      |       |      |      |       | 0.03 |
| CT  | 13.5 | 286.3 | 1664 | 41.15 | 1.89  |       |      |        |       |       |       |      |       |      |      |       | 0.02 |
| CT  | 14   | 306.3 | 1644 | 27.63 | 3.08  | 7.85  | 0.59 | -23.23 | -0.50 | 15.54 |       |      |       |      |      | 3.52  | 0.03 |
| CT  | 14.5 | 326.4 | 1624 | 26.19 | 2.90  |       |      |        |       |       | -0.30 | 1.05 | 0.00  | 0.59 | 0.01 |       | 0.02 |
| CT  | 15   | 346.5 | 1604 | 39.47 | 4.29  |       |      |        |       |       |       |      |       |      |      |       | 0.02 |
| CT  | 15.5 | 366.4 | 1584 | 36.34 | 1.59  |       |      |        |       |       |       |      |       |      |      |       | 0.03 |
| CT  | 16   | 386.2 | 1564 | 37.79 | 1.70  | 9.87  | 0.81 | -23.32 | -0.04 | 14.31 |       |      |       |      |      | 3.83  | 0.03 |
| CT  | 16.5 | 406.8 | 1543 | 41.31 | 2.04  |       |      |        |       |       |       |      |       |      |      |       | 0.02 |
| CT  | 17   | 427.3 | 1523 | 47.34 | 2.43  | 11.06 | 0.89 | -23.44 | -0.57 | 14.49 |       |      |       |      |      | 4.28  | 0.02 |
| CT  | 17.5 | 448.4 | 1502 | 45.52 | 2.31  |       |      |        |       |       |       |      |       |      |      |       | 0.02 |
| DP2 | 0    | -56   | 2006 | 81.91 | 48.98 | 6.16  | 0.44 | -26.72 | 11.83 | 16.39 | -1.42 | 0.19 | -0.03 | 0.15 | 0.05 | 13.29 |      |
| DP2 | 1    | -43   | 1993 | 63.21 | 43.32 |       |      |        |       |       | -1.19 | 0.27 | -0.04 | 0.20 | 0.08 |       | 0.08 |
| DP2 | 2    | -32   | 1982 | 57.30 | 61.22 | 2.15  | 0.14 | -27.14 | 9.46  | 17.49 | -1.32 | 0.26 | -0.02 | 0.18 | 0.02 | 26.69 | 0.09 |
| DP2 | 3    | -22   | 1972 | 62.01 | 83.59 | 1.60  | 0.10 | -28.00 | 9.38  | 18.68 |       |      |       |      |      | 38.68 | 0.10 |
| DP2 | 4    | -13   | 1963 | 42.84 | 35.41 | 2.23  | 0.14 | -28.30 | 10.83 | 18.48 |       |      |       |      |      | 19.20 | 0.11 |
| DP2 | 5    | 2     | 1948 | 38.55 | 25.49 | 2.66  | 0.18 | -27.03 | 11.51 | 17.62 | -1.38 | 0.01 | -0.06 | 0.04 | 0.11 | 14.48 | 0.07 |
| DP2 | 6    | 21    | 1929 | 37.92 | 12.36 | 2.46  | 0.15 | -27.01 | 11.29 | 19.06 |       |      |       |      |      | 15.42 | 0.05 |
| DP2 | 7    | 44    | 1906 | 77.75 | 23.71 | 5.36  | 0.34 | -27.18 | 11.96 | 18.38 |       |      |       |      |      | 14.50 | 0.04 |

[illegible]

|    |      |       |      |        |        |       |      |        |      |       |       |      |       |      |      |       |      |
|----|------|-------|------|--------|--------|-------|------|--------|------|-------|-------|------|-------|------|------|-------|------|
| EM | 1    | -47.9 | 1998 | 37.60  | 70.06  | 8.93  | 0.65 | -25.39 | 6.40 | 16.08 | -0.67 | 0.62 | -0.05 | 0.39 | 0.03 | 4.21  | 0.08 |
| EM | 1.5  | -45.7 | 1996 | 27.28  | 37.84  |       |      |        |      |       | -0.53 | 0.66 | -0.04 | 0.42 | 0.08 |       | 0.23 |
| EM | 2    | -43.4 | 1993 | 48.02  | 30.39  | 5.39  | 0.47 | -25.49 | 7.37 | 13.53 |       |      |       |      |      | 8.90  | 0.22 |
| EM | 2.5  | -38.1 | 1988 | 44.59  | 26.55  |       |      |        |      |       |       |      |       |      |      |       | 0.09 |
| EM | 3    | -32.7 | 1983 | 41.28  | 133.00 | 7.62  | 0.44 | -26.61 | 7.34 | 20.07 | -0.74 | 0.53 | -0.03 | 0.38 | 0.11 | 5.42  | 0.09 |
| EM | 3.5  | -31.6 | 1982 | 41.75  | 125.60 |       |      |        |      |       |       |      |       |      |      |       | 0.45 |
| EM | 4    | -30.4 | 1980 | 25.70  | 38.60  | 3.37  | 0.34 | -25.43 | 7.91 | 11.55 |       |      |       |      |      | 7.62  | 0.42 |
| EM | 4.5  | -27.9 | 1978 | 36.31  | 56.28  |       |      |        |      |       |       |      |       |      |      |       | 0.20 |
| EM | 5    | -25.4 | 1975 | 25.09  | 44.81  | 6.73  | 0.25 | -26.08 | 8.16 | 31.66 | -0.61 | 0.51 | -0.01 | 0.32 | 0.14 | 3.73  | 0.20 |
| EM | 5.5  | -23.6 | 1974 | 67.89  | 98.43  |       |      |        |      |       | -0.68 | 0.55 | -0.05 | 0.39 | 0.15 |       | 0.28 |
| EM | 6    | -21.8 | 1972 | 146.26 | 136.99 | 16.39 | 1.12 | -26.50 | 5.98 | 17.03 | -0.81 | 0.56 | -0.02 | 0.42 | 0.09 | 8.92  | 0.28 |
| EM | 6.5  | -19.1 | 1969 | 40.80  | 39.22  |       |      |        |      |       | -0.81 | 0.58 | -0.05 | 0.41 | 0.06 |       | 0.19 |
| EM | 7    | -16.4 | 1966 | 51.06  | 35.50  | 8.22  | 0.57 | -26.25 | 6.76 | 16.96 |       |      |       |      |      | 6.21  | 0.19 |
| EM | 7.5  | -12.7 | 1963 | 51.00  | 31.54  |       |      |        |      |       |       |      |       |      |      |       | 0.14 |
| EM | 8    | -9    | 1959 | 49.69  | 16.70  | 8.50  | 0.40 | -25.68 | 6.13 | 24.94 |       |      |       |      |      | 5.85  | 0.14 |
| EM | 8.5  | -2    | 1952 | 73.15  | 26.69  |       |      |        |      |       | -0.77 | 0.64 | -0.06 | 0.45 | 0.04 |       | 0.07 |
| EM | 9    | 5     | 1945 | 32.69  | 9.49   | 5.04  | 0.30 | -25.38 | 6.28 | 19.67 |       |      |       |      |      | 6.48  | 0.07 |
| EM | 9.5  | 14.8  | 1935 | 22.45  | 6.95   |       |      |        |      |       | -0.63 | 0.67 | -0.06 | 0.42 | 0.08 |       | 0.05 |
| EM | 10   | 24.5  | 1926 | 26.25  | 6.19   | 3.95  | 0.26 | -24.34 | 6.31 | 17.70 |       |      |       |      |      | 6.65  | 0.05 |
| EM | 10.5 | 37.6  | 1912 | 22.05  | 4.60   |       |      |        |      |       |       |      |       |      |      |       | 0.04 |
| EM | 11   | 50.6  | 1899 | 26.81  | 5.13   | 11.39 | 0.52 | -25.48 | 5.39 | 25.37 |       |      |       |      |      | 2.35  | 0.04 |
| EM | 11.5 | 63.8  | 1886 | 21.63  | 4.30   |       |      |        |      |       | -0.62 | 0.71 | -0.06 | 0.47 | 0.02 |       | 0.04 |
| EM | 12   | 77    | 1873 | 16.55  | 4.27   | 2.05  | 0.23 | -23.78 | 5.44 | 10.46 | -0.50 | 0.95 | -0.03 | 0.71 | 0.09 | 8.09  | 0.04 |
| EM | 12.5 | 89.3  | 1861 | 12.79  | 3.60   |       |      |        |      |       |       |      |       |      |      |       | 0.04 |
| EM | 13   | 101.6 | 1848 | 9.95   | 3.33   | 1.49  | 0.13 | -23.49 | 5.01 | 13.81 |       |      |       |      |      | 6.68  | 0.04 |
| EM | 13.5 | 114   | 1836 | 11.73  | 4.31   |       |      |        |      |       |       |      |       |      |      |       | 0.04 |
| EM | 14   | 126.3 | 1824 | 6.91   | 1.88   | 0.57  | 0.10 | -23.89 | 5.12 | 6.88  | -0.56 | 1.07 | -0.02 | 0.76 | 0.11 | 12.10 | 0.04 |
| EM | 14.5 | 144   | 1806 | 6.37   | 1.82   |       |      |        |      |       |       |      |       |      |      |       | 0.03 |
| EM | 15   | 161.6 | 1788 | 6.17   | 0.33   | 0.77  | 0.10 | -24.38 | 5.90 | 8.96  |       |      |       |      |      | 8.04  | 0.03 |
| EM | 15.5 | 249.2 | 1701 | 5.93   | 0.32   |       |      |        |      |       | -0.47 | 1.17 | -0.05 | 0.86 | 0.06 |       | 0.01 |

|    |      |       |      |        |       |       |      |        |      |       |       |      |       |      |      |       |      |
|----|------|-------|------|--------|-------|-------|------|--------|------|-------|-------|------|-------|------|------|-------|------|
| EM | 16   | 336.7 | 1613 | 4.70   | 0.02  | 0.42  | 0.08 | -24.55 | 5.49 | 6.51  | -0.66 | 1.19 | -0.02 | 0.85 | 0.02 | 11.17 | 0.01 |
| GG | 0    | -59.8 | 2010 | 189.94 | 23.31 | 42.43 | 2.67 | -29.21 | 6.47 | 18.52 |       |      |       |      |      | 4.48  |      |
| GG | 1    | -45.1 | 1995 | 164.08 | 15.76 | 42.52 | 2.46 | -28.93 | 6.31 | 20.13 | -0.89 | 0.24 | -0.04 | 0.17 | 0.15 | 3.86  | 0.07 |
| GG | 1.5  | -38.3 | 1988 | 231.40 | 26.59 | 38.19 | 2.35 | -28.93 | 6.77 | 18.98 |       |      |       |      |      | 6.06  | 0.07 |
| GG | 2    | -31.5 | 1982 | 194.51 | 30.82 |       |      |        |      |       | -0.80 | 0.25 | -0.02 | 0.15 | 0.12 |       | 0.07 |
| GG | 2.5  | -26.7 | 1977 | 167.95 | 20.86 |       |      |        |      |       | -0.85 | 0.22 | -0.04 | 0.22 | 0.19 |       | 0.10 |
| GG | 3    | -22   | 1972 | 211.83 | 31.16 | 31.72 | 2.10 | -29.05 | 5.64 | 17.59 |       |      |       |      |      | 6.68  | 0.11 |
| GG | 3.5  | -15.4 | 1965 | 149.11 | 15.03 |       |      |        |      |       | -0.87 | 0.26 | -0.04 | 0.24 | 0.13 |       | 0.08 |
| GG | 4    | -8.8  | 1959 | 150.51 | 17.07 |       |      |        |      |       |       |      |       |      |      |       | 0.08 |
| GG | 4.5  | -0.5  | 1951 | 158.96 | 11.55 | 28.65 | 1.73 | -28.26 | 5.92 | 19.30 |       |      |       |      |      | 5.55  | 0.06 |
| GG | 5    | 7.8   | 1942 | 165.80 | 13.88 |       |      |        |      |       | -0.82 | 0.31 | -0.04 | 0.26 | 0.14 |       | 0.06 |
| GG | 5.5  | 21.4  | 1929 | 148.19 | 15.98 |       |      |        |      |       |       |      |       |      |      |       | 0.04 |
| GG | 6    | 34.9  | 1915 | 152.21 | 16.97 | 21.53 | 1.41 | -27.90 | 5.54 | 17.80 |       |      |       |      |      | 7.07  | 0.04 |
| GG | 6.5  | 49.8  | 1900 | 133.21 | 15.98 |       |      |        |      |       |       |      |       |      |      |       | 0.03 |
| GG | 7    | 64.6  | 1885 | 134.70 | 13.54 |       |      |        |      |       |       |      |       |      |      |       | 0.03 |
| GG | 7.5  | 79.5  | 1871 | 145.15 | 12.08 | 27.80 | 1.69 | -27.57 | 5.85 | 19.15 | -0.98 | 0.23 | -0.07 | 0.20 | 0.17 | 5.22  | 0.03 |
| GG | 8    | 94.5  | 1856 | 128.52 | 11.35 |       |      |        |      |       |       |      |       |      |      |       | 0.03 |
| GG | 8.5  | 111.6 | 1838 | 145.64 | 8.75  |       |      |        |      |       |       |      |       |      |      |       | 0.03 |
| GG | 9    | 128.8 | 1821 | 153.21 | 8.57  | 30.19 | 1.92 | -27.69 | 6.75 | 18.33 | -0.81 | 0.20 | -0.04 | 0.20 | 0.15 | 5.07  | 0.03 |
| GG | 9.5  | 149.5 | 1801 | 158.55 | 8.63  |       |      |        |      |       |       |      |       |      |      |       | 0.02 |
| GG | 10   | 170.1 | 1780 | 153.62 | 9.26  |       |      |        |      |       |       |      |       |      |      |       | 0.02 |
| GG | 10.5 | 186.6 | 1763 | 145.06 | 10.35 | 36.61 | 1.81 | -28.49 | 7.48 | 23.59 |       |      |       |      |      | 3.96  | 0.03 |
| GG | 11   | 203.2 | 1747 | 151.92 | 11.87 |       |      |        |      |       |       |      |       |      |      |       | 0.03 |
| GG | 11.5 | 219.1 | 1731 | 126.30 | 14.28 |       |      |        |      |       |       |      |       |      |      |       | 0.03 |
| GG | 12   | 234.9 | 1715 | 112.30 | 15.74 | 12.19 | 0.97 | -26.19 | 5.34 | 14.62 |       |      |       |      |      | 9.21  | 0.03 |
| GG | 12.5 | 248.4 | 1702 | 111.75 | 17.07 |       |      |        |      |       | -1.13 | 0.04 | -0.03 | 0.08 | 0.19 |       | 0.04 |
| GG | 13   | 261.9 | 1688 | 153.48 | 20.97 |       |      |        |      |       |       |      |       |      |      |       | 0.04 |
| GG | 13.5 | 274.9 | 1675 | 178.31 | 19.23 | 31.14 | 1.85 | -28.17 | 5.65 | 19.64 |       |      |       |      |      | 5.73  | 0.04 |
| GG | 14   | 287.9 | 1662 | 82.23  | 12.28 |       |      |        |      |       |       |      |       |      |      |       | 0.04 |
| GG | 14.5 | 300.3 | 1650 | 74.29  | 14.97 |       |      |        |      |       | -0.54 | 0.66 | -0.04 | 0.57 | 0.00 |       | 0.04 |
| GG | 15   | 312.6 | 1637 | 128.97 | 27.96 | 16.55 | 1.14 | -26.76 | 6.29 | 16.88 |       |      |       |      |      | 7.79  | 0.04 |

|     |      |       |      |        |       |       |      |        |      |       |       |      |       |      |      |       |  |      |
|-----|------|-------|------|--------|-------|-------|------|--------|------|-------|-------|------|-------|------|------|-------|--|------|
| GG  | 15.5 | 324.1 | 1626 | 107.53 | 20.13 |       |      |        |      |       |       |      |       |      |      |       |  | 0.04 |
| GG  | 16   | 335.5 | 1615 | 133.82 | 18.27 |       |      |        |      |       |       |      |       |      |      |       |  | 0.04 |
| GG  | 16.5 | 346   | 1604 | 136.05 | 18.06 | 30.29 | 1.87 | -28.11 | 5.93 | 18.93 |       |      |       |      |      | 4.49  |  | 0.05 |
| GG  | 17   | 356.6 | 1593 | 103.76 | 12.96 |       |      |        |      |       |       |      |       |      |      |       |  | 0.05 |
| GG  | 17.5 | 366.9 | 1583 | 101.68 | 14.21 |       |      |        |      |       | -0.51 | 0.67 | -0.04 | 0.60 | 0.00 |       |  | 0.05 |
| GG  | 18   | 377.2 | 1573 | 103.49 | 15.97 | 10.12 | 0.68 | -26.48 | 5.56 | 17.47 |       |      |       |      |      | 10.23 |  | 0.05 |
| GG  | 18.5 | 387.4 | 1563 | 123.20 | 25.77 |       |      |        |      |       |       |      |       |      |      |       |  | 0.05 |
| GG  | 19   | 397.6 | 1552 | 111.68 | 22.06 |       |      |        |      |       |       |      |       |      |      |       |  | 0.05 |
| GG  | 19.5 | 406   | 1544 | 111.13 | 21.43 |       |      |        |      |       |       |      |       |      |      |       |  | 0.06 |
| GG  | 20   | 414.4 | 1536 | 117.46 | 18.42 |       |      |        |      |       |       |      |       |      |      |       |  | 0.06 |
| GG  | 20.5 | 422.2 | 1528 |        |       |       |      |        |      |       |       |      |       |      |      |       |  | 0.06 |
| GG  | 21   | 429.9 | 1520 | 116.45 | 19.01 | 29.13 | 1.28 | -27.28 | 6.44 | 26.61 | -0.58 | 0.70 | -0.03 | 0.60 | 0.09 | 4.00  |  | 0.06 |
| GG  | 21.5 | 437.5 | 1513 |        |       |       |      |        |      |       |       |      |       |      |      |       |  | 0.07 |
| GG  | 22   | 445.1 | 1505 | 101.94 | 24.67 |       |      |        |      |       |       |      |       |      |      |       |  | 0.07 |
| LK1 | 0    | -68.1 | 2018 | 99.65  | 6.87  | 29.63 | 1.27 | -26.87 | 5.61 | 27.33 | -0.80 | 0.75 | -0.05 | 0.49 | 0.05 | 3.36  |  |      |
| LK1 | 0.5  | -56.5 | 2007 | 125.48 | 8.58  |       |      |        |      |       |       |      |       |      |      |       |  | 0.04 |
| LK1 | 1    | -44.8 | 1995 | 146.91 | 44.71 | 42.93 | 2.52 | -26.88 | 6.32 | 19.85 | -0.84 | 0.54 | -0.05 | 0.42 | 0.18 | 3.42  |  | 0.04 |
| LK1 | 1.5  | -42.5 | 1993 | 112.11 | 32.70 |       |      |        |      |       | -0.83 | 0.46 | -0.07 | 0.35 | 0.08 |       |  | 0.22 |
| LK1 | 2    | -40.1 | 1990 | 139.52 | 23.82 | 36.61 | 2.22 | -26.97 | 6.13 | 19.25 |       |      |       |      |      | 3.81  |  | 0.21 |
| LK1 | 2.5  | -36   | 1986 | 156.42 | 26.71 |       |      |        |      |       |       |      |       |      |      |       |  | 0.12 |
| LK1 | 3    | -31.9 | 1982 | 147.97 | 47.08 | 42.47 | 2.53 | -27.16 | 5.36 | 19.58 |       |      |       |      |      | 3.48  |  | 0.12 |
| LK1 | 3.5  | -29.7 | 1980 | 139.92 | 46.64 |       |      |        |      |       | -1.02 | 0.36 | -0.09 | 0.19 | 0.04 |       |  | 0.23 |
| LK1 | 4    | -27.6 | 1978 | 144.48 | 38.90 | 39.90 | 2.51 | -26.78 | 5.61 | 18.55 |       |      |       |      |      | 3.62  |  | 0.24 |
| LK1 | 4.5  | -25   | 1975 | 142.62 | 39.93 |       |      |        |      |       |       |      |       |      |      |       |  | 0.19 |
| LK1 | 5    | -22.5 | 1973 | 149.74 | 30.83 | 42.64 | 2.53 | -26.70 | 5.36 | 19.66 |       |      |       |      |      | 3.51  |  | 0.20 |
| LK1 | 5.5  | -19.1 | 1969 | 146.13 | 30.09 |       |      |        |      |       |       |      |       |      |      |       |  | 0.15 |
| LK1 | 6    | -15.7 | 1966 | 134.31 | 17.09 | 40.93 | 2.64 | -26.49 | 5.36 | 18.06 |       |      |       |      |      | 3.28  |  | 0.15 |
| LK1 | 6.5  | -10.2 | 1960 | 135.10 | 17.19 |       |      |        |      |       |       |      |       |      |      |       |  | 0.09 |
| LK1 | 7    | -4.7  | 1955 | 133.95 | 10.54 | 41.65 | 2.54 | -26.54 | 5.40 | 19.14 |       |      |       |      |      | 3.22  |  | 0.09 |
| LK1 | 7.5  | 4.2   | 1946 | 129.35 | 10.29 |       |      |        |      |       |       |      |       |      |      |       |  | 0.06 |
| LK1 | 8    | 13    | 1937 | 123.26 | 3.64  | 36.57 | 2.67 | -26.43 | 5.10 | 16.01 | -0.94 | 0.62 | -0.03 | 0.40 | 0.11 | 3.37  |  | 0.06 |

|     |      |       |      |        |      |       |      |        |      |       |  |      |      |
|-----|------|-------|------|--------|------|-------|------|--------|------|-------|--|------|------|
| LK1 | 8.5  | 31.6  | 1918 | 118.89 | 3.20 |       |      |        |      |       |  |      | 0.03 |
| LK1 | 9    | 50.2  | 1900 | 116.94 | 1.45 | 35.98 | 2.60 | -26.30 | 4.66 | 16.13 |  | 3.25 | 0.03 |
| LK1 | 9.5  | 94.5  | 1856 | 105.88 | 1.32 |       |      |        |      |       |  |      | 0.01 |
| LK1 | 10   | 138.7 | 1811 | 99.04  | 0.39 | 32.31 | 2.32 | -26.09 | 3.35 | 16.22 |  | 3.07 | 0.01 |
| LK1 | 10.5 | 279.6 | 1670 | 107.46 | 0.42 |       |      |        |      |       |  |      | 0.00 |

## References

- Aquino-López, M.A., Blaauw, M., Christen, J.A. and Sanderson, N.K. 2018. Bayesian Analysis of 210 Pb Dating: MA Aquino-López et al. *Journal of Agricultural, Biological and Environmental Statistics* 23(3), pp. 317–333.
- Armitage, I. 2007. Further evidence for the natural re-establishment of the pipit (*Anthus novaeseelandiae aucklandicus*) on Campbell Island, New Zealand. *Notornis* 54, pp. 226–228.
- Arnold, J. 2024. ggthemes: Extra Themes, Scales and Geoms for 'ggplot2'. R package version 5.1. 0. Arnold, J.(2024). *Ggthemes: Extra Themes, Scales and Geoms for 'Ggplot2'*. *R Package Version 5.1*.
- Bergstrom, D.M., Lucieer, A., Kiefer, K., Wasley, J., Belbin, L., Pedersen, T.K. and Chown, S.L. 2009. Indirect effects of invasive species removal devastate World Heritage Island. *Journal of Applied Ecology* 46(1), pp. 73–81. doi: 10.1111/j.1365-2664.2008.01601.x.
- Bird, J.P., Travers, T.D. and McInnes, J.C. 2025. Seasonal and decadal changes in seabird abundance in inshore waters at subantarctic Macquarie Island. *Emu - Austral Ornithology* 125(2), pp. 108–122. doi: 10.1080/01584197.2025.2478028.
- Blaauw, M. and Christen, J.A. 2011. Flexible paleoclimate age-depth models using an autoregressive gamma process.
- Brown, D.A., Cox, F.S. and Fergus, A.J. 2022. The eradication of Campbell Island sheep and subsequent ecological response. *New Zealand Journal of Ecology* 46(3).
- Bureau of Meteorology. 2025. *Climate statistics for Australian locations*. Available at: [https://www.bom.gov.au/climate/averages/tables/cw\\_300004.shtml](https://www.bom.gov.au/climate/averages/tables/cw_300004.shtml) [Accessed: 17 October 2025].
- Convey, P. and Lebouvier, M. 2009. Environmental change and human impacts on terrestrial ecosystems of the sub-Antarctic islands between their discovery and the mid-twentieth century. pp. 33–44.
- Cumpston, J.S. 1968. Macquarie Island.
- Dunnington, D. 2023. ggspatial: Spatial Data Framework for ggplot2. R package version 1.1. 5.
- Garnier, S., Ross, N., Rudis, R., Camargo, P.A., Sciaini, M. and Scherer, C. 2023. Viridis (Lite)—Colorblind-Friendly Color Maps for R. 2024. *Viridis Package Version 0.6 4*.
- Hall, M. and Wouters, M. 1994. Managing nature tourism in the Sub-Antarctic. *Annals of Tourism Research* 21(2), pp. 355–374.
- Heritage New Zealand. 2019. *Campbell Island/Motu Ihupuku Historic Area*. Available at: <https://www.heritage.org.nz/list-details/9700/Listing> [Accessed: 28 July 2026].
- Hindell, M.A. and Burton, H.R. 1988. The History of the Elephant Seal Industry at Macquarie Island and an Estimate of the Pre-Sealing Numbers. 122(1).

- Hodgson, D.A. et al. 2014. Terrestrial and submarine evidence for the extent and timing of the Last Glacial Maximum and the onset of deglaciation on the maritime-Antarctic and sub-Antarctic islands. *Quaternary Science Reviews* 100, pp. 137–158.
- Iannone, R. et al. 2020. Gt: Easily create presentation-ready display tables. (*No Title*).
- Li, C. et al. 2023. A peat core Hg stable isotope reconstruction of Holocene atmospheric Hg deposition at Amsterdam Island (37.8oS). *Geochimica et Cosmochimica Acta* 341, pp. 62–74. doi: 10.1016/j.gca.2022.11.024.
- Li, C. et al. 2026. Southern Ocean seabird population shifts over the Holocene revealed by peat sequestration of mercury from guano. *Proceedings of the National Academy of Sciences* 123(16), p. e2533681123. doi: 10.1073/pnas.2533681123.
- Ling, J. 1999. Exploitation of fur seals and sea lions from Australian, New Zealand and adjacent subantarctic islands during the eighteenth, nineteenth and twentieth centuries. *Australian Zoologist* 31(2), pp. 323–350.
- Macara, G. and Gibson, P.B. 2025. The climate and weather of Campbell Island/Motu Ihupuku: historic observations and projected changes.
- Massicotte, P., South, A. and Hufkens, K. 2023. rnaturalearth: World map data from natural earth. *R package version* 1(1).
- Meredith, K.T., Saunders, K.M., McDonough, L.K. and McGeoch, M. 2022. Hydrochemical and isotopic baselines for understanding hydrological processes across Macquarie Island. *Scientific Reports* 12(1), p. 21266. doi: 10.1038/s41598-022-25115-3.
- Oksanen, J. et al. 2023. vegan: Community Ecology Package. R package version 2.6-4. 2022. *Cited Here*. Available at: <https://scholar.google.com/scholar?cluster=9409012528102721205&hl=en&oi=scholar> [Accessed: 8 December 2025].
- Ooms, J. 2024. writexl: Export data frames to Excel “xlsx” format. *R package version* 1(1).
- Peat, N., Apse, A., De Roy, T. and Westerskov, K. 2003. *Subantarctic New Zealand: a rare heritage*. Department of Conservation.
- Pebesma, E. and Bivand, R. 2023. *Spatial data science: with applications in R*. CRC press.
- Pedersen, T. 2024. patchwork: The Composer of Plots. R package version 1.2. 0. 2024. URL <https://CRAN.R-project.org/package=patchwork>.
- Raymond, B., McInnes, J., Dambacher, J.M., Way, S. and Bergstrom, D.M. 2011. Qualitative modelling of invasive species eradication on subantarctic Macquarie Island. *Journal of Applied Ecology* 48(1), pp. 181–191. doi: 10.1111/j.1365-2664.2010.01916.x.
- Saunders, K.M., Harrison, J.J., Hodgson, D.A., de Jong, R., Mauchle, F. and McMinn, A. 2013. Ecosystem impacts of feral rabbits on World Heritage sub-Antarctic Macquarie Island: A palaeoecological perspective. *Anthropocene* 3, pp. 1–8. doi: 10.1016/j.ancene.2014.01.001.

Saunders, K.M., Hodgson, D.A., Mcmurtrie, S. and Grosjean, M. 2015. A diatom–conductivity transfer function for reconstructing past changes in the Southern Hemisphere westerly winds over the Southern Ocean. *Journal of Quaternary Science* 30(5), pp. 464–477. doi: 10.1002/jqs.2788.

Schneider, M.A. et al. in press. Reframing Anthropocene metal pollution: The overlooked role of colonisation in the Southern Hemisphere. *Global Environmental Change Advances*.

Selkirk, P.M. 1990. *Subantarctic Macquarie Island: environment and biology*. Cambridge [England] ; Cambridge University Press.

Sievert, C. 2020. *Interactive web-based data visualization with R, plotly, and shiny*. CRC Press.

Tang, K. et al. 2026. Declines in riverine mercury export from china driven by water pollution controls. *Environmental Science & Technology* 60(9), pp. 7123–7133.

Travers, T., Lea, M.-A., Alderman, R., Terauds, A. and Shaw, J. 2021. Bottom-up effect of eradications: The unintended consequences for top-order predators when eradicating invasive prey. *Journal of Applied Ecology* 58(4), pp. 801–811. doi: 10.1111/1365-2664.13828.

Varne, R., Brown, A.V. and Falloon, T. 2000. Macquarie Island: its geology, structural history, and the timing and tectonic setting of its N-MORB to E-MORB magmatism.

Wickham, H. 2016. Getting Started with ggplot2. In: Wickham, H. ed. *ggplot2: Elegant Graphics for Data Analysis*. Cham: Springer International Publishing, pp. 11–31. Available at: [https://doi.org/10.1007/978-3-319-24277-4\\_2](https://doi.org/10.1007/978-3-319-24277-4_2).

Wickham, H. et al. 2019. Welcome to the Tidyverse. *Journal of open source software* 4(43), p. 1686.

Wickham, H. 2023. Bryan J. readxl: Read Excel Files. R package version 1.4. 3. *The R Foundation for Statistical Computing*.

Wickham, H., François, R., Henry, L., Müller, K. and Vaughan, D. 2023. dplyr: A grammar of data manipulation.

Wilke, C.O. 2015. cowplot: Streamlined plot theme and plot annotations for 'ggplot2'. *CRAN: Contributed packages*.

Williamson, P. 1988. Origin, structural and tectonic history of the Macquarie Island region. pp. 27–43.

Zheng, W., Xie, Z. and Bergquist, B.A. 2015. Mercury Stable Isotopes in Ornithogenic Deposits As Tracers of Historical Cycling of Mercury in Ross Sea, Antarctica. *Environmental Science & Technology* 49(13), pp. 7623–7632. doi: 10.1021/acs.est.5b00523.