Title: House sparrows as sentinels of childhood lead exposure

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Abstract: Our understanding of connections between human and animal health has advanced substantially since the canary was introduced as a sentinel of toxic conditions in coal mines. Nonetheless, development of wildlife sentinels for monitoring human exposure to toxins has been limited. Here, we capitalised on a three-decade long child blood lead monitoring program (> 20,000 measurements), to demonstrate that the globally ubiquitous and human commensal house sparrow (*Passer domesticus*) can be used as a sentinel of human health risks in urban environments impacted by lead mining. We show that sparrows are a viable proxy for the measurement of blood lead levels in children at a neighbourhood scale (0.28 km^2), and could be used to monitor changes in lead exposure risks over time. In support of the generalisability of this approach, the blood lead relationship established in our focal mining city enabled us to accurately predict elevated blood lead levels in children from another mining city using only sparrows from the second location. Using lead concentrations and isotopic compositions from environmental and biological matrices, we identified shared sources and pathways of lead exposure in sparrows and children, with strong links to contamination from local mining emissions. Our findings show how human commensal species can be used to identify and predict human health risks over time and space. Moreover, they affirm the emerging paradigm that humans and animals share these risks, and highlight the true ecological cost of contaminated environments.

Introduction: Morbidity and mortality patterns in humans are inextricably linked to environmental contamination (1), with pollution responsible for an estimated nine million premature deaths annually (2). Effective action against global pollution requires more effective monitoring, and greater public awareness of the links between contaminated environments and human health (2). However, monitoring contaminant exposures in human populations, especially during childhood, is costly and raises significant logistical and ethical issues (3).

Organisms that are sensitive to pollutants have long been recognized as useful indicators of environments detrimental to human health (4). However, links between exposure as measured in these organisms, and impacts on human populations are difficult to establish due to the disparate pathways and scales over which these exposures occur (5). Given these complexities, it is not surprising that research on animal sentinels tends to focus on the direct transfer of contaminants through food chains (6), even though links between human and animal health are not solely confined to food chain interactions (7).

This knowledge gap highlights the growing need to escape the silos within which we compartmentalise our understanding of the human, animal and environmental health domains. The One Health Initiative (8), which seeks to unite human and veterinary health along with the environmental sciences, identifies the crux of the problem. By separating these domains, we limit our understanding of interconnections between the natural systems which underlie our health, and the health of the organisms around us.

Bioindicator species can be used to monitor the impacts of environmental pollutants at a population, community, or even ecosystem scale (9). However, those with most utility for understanding the effects of pollution on human health are likely to be commensal, sedentary (non-migratory) species that share our environment (5, 10). The free-ranging wild house sparrow (*Passer domesticus*) is one such species due to its global distribution, close association with humans, and sedentary nature (11, 12). Studies in Europe (13), North America (14), and Africa (15), have linked changes in biomarkers of exposure and effect to sparrow populations inhabiting different environments with varying levels of contamination, and similarly, for the congeneric tree sparrow *Passer montanus* in Asia (16).

These studies have demonstrated the capacity of sparrows to indicate pollution at broad geographic scales, often across urban and rural land uses. However, public health interventions benefit from information at a finer spatial scale, where it can inform the management of human health risks in the same areas where sentinel species such as sparrows are sampled. For instance, the use of canaries in coal mines was an effective warning system because it provided a spatially and temporally biologically relevant indication of underground air quality for nearby miners.

Lead (Pb) is one of the oldest and most ubiquitous contaminants of the Anthropocene (17). Globally, exposure to environmental Pb has resulted in adverse health outcomes across a broad range of organisms (7, 18), and is estimated to cause around 900,000 premature human deaths annually (2). While Pb emissions have declined in many areas due to the replacement of Pb additives in fuel, Pb contamination remains widespread across urban environments globally, and poses a particular hazard to humans living around active mining and smelting facilities (19). Within these areas, children are disproportionately exposed to Pb in soil, dust and water, due to behaviours such as crawling and frequent hand to mouth contact (18). Children are also most susceptible to the neurological and developmental effects of Pb exposure (18). There is a global need to identify areas where children are at greatest risk of exposure to environmental Pb contamination, such that it can be managed through remediation or avoidance (20).

This study investigates the relationship between environmental Pb contamination and Pb exposure in house sparrows and children inhabiting the remote Australian mining cities of Broken Hill in western New South Wales, and Mount Isa in northeast Queensland (fig. 1). In both cities, prolonged Pb ore extraction, processing and transport activities have polluted surrounding urban areas with atmospheric emissions, creating soil Pb contamination gradients which decline away from mining operations (21, 22). To benchmark blood Pb levels in sparrows from these mining cities, we also sampled populations from 5 additional sites in towns and cities representing ‘background’ levels of Pb from urban areas unaffected by Pb mining and smelting operations (fig. 1). By drawing on quantitative and spatially overlapping human, animal and environmental data (23), this study aimed to provide an integrated assessment of health risks arising from anthropogenic pollution within an urban ecosystem.

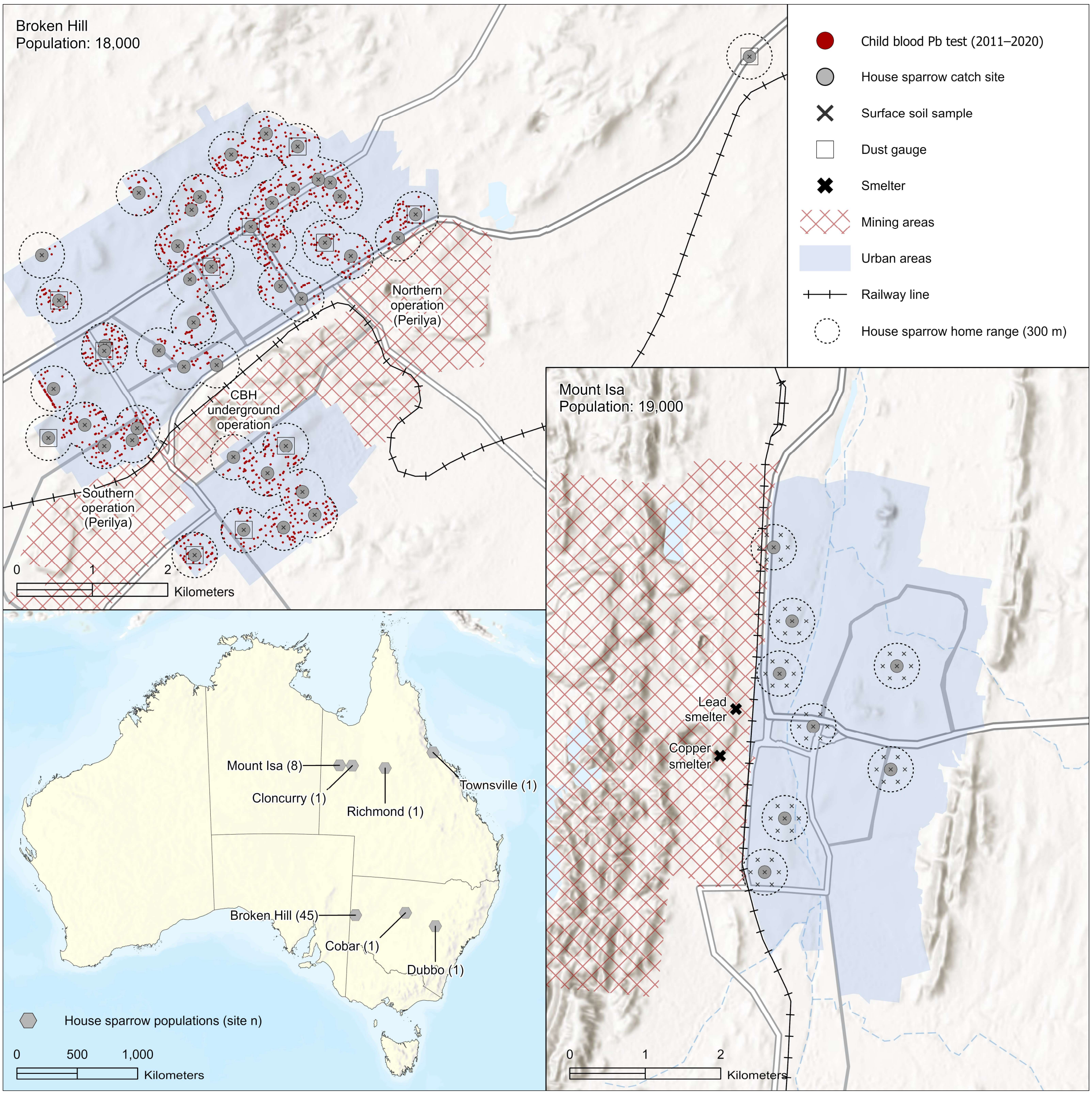

Fig. 1. Map of sparrow sampling sites. Location of sparrow catch sites and associated environmental samples in Broken Hill and Mount Isa. Also shown are locations of relevant infrastructure, urban areas, and sources of Pb contamination, including mining and smelting areas. Dotted lines around each site designate the estimated home range (300 m radius) of sparrows captured from that location. For Broken Hill, red points indicate the approximate distribution of blood Pb measurements from children living within the home range of one or more sparrow catch sites. Regional map shows location of all towns and cities where sparrows were sampled.

Results and discussion: Our comparison of Pb exposure in sparrows and children leveraged data from extensive human biomonitoring programs established in response to elevated blood Pb levels in local children (24). At Broken Hill, the availability of 30 years (1991–2020) of anonymysed blood Pb data geolocated to the home address of tested children enabled us to spatially join and compare the distribution of blood Pb levels in children and sparrows over different time intervals. At Mount Isa, geolocated address information was not available, and child blood Pb levels were reported as categorical ranges (< 5 µg/dL, ≥ 5 µg/dL, ≥ 10 µg/dL) (25). Nonetheless, data from Mount Isa enabled us to compare our findings from Broken Hill to a context similarly impacted by mining and smelting emissions. In line with standards for the reporting of epidemiological evidence under the One Health approach (23), additional detail on the selection, sampling, analysis and reporting of human, animal and environmental data is provided in the Methods and references (25, 26).

Using literature estimates for the maximum home range of a house sparrow (27) (300 m radius around each catch site = 0.28 km^2), we spatially linked blood Pb measured in sparrows in 2020 to the co-located population of Broken Hill children (fig. 1). In linking this data, we used the preceding decade (2011–2020) of blood Pb measurements from children aged 1–4 years, as child blood Pb levels in Broken Hill have remained relatively stable over this period. We identified a spatially robust relationship between geometric mean blood Pb in sparrows and nearby (< 300 m) children at each catch site (Pearson $r = 0.74$, $p < 0.01$, $n = 44$; fig. 2A). This was despite a large difference in the geometric mean blood Pb level of sparrows (25.3 µg/dL, $n = 226$) and nearby children (5.3 µg/dL, $n = 4190$; table S1). In the environmental context of Broken Hill, a sparrow blood Pb of around 20 µg/dL corresponds to a child blood Pb of 5 µg/dL (child blood Pb = 0.07 × sparrow blood Pb + 3.63; fig. 2A; table S2). This is the human blood Pb intervention level at which further investigation of an individual's risk of Pb exposure is recommended. Importantly, we have established this relationship at a scale that is relevant to the assessment and management of Pb exposure risks in urban environments (0.28 km^2), and have done so using measurements from a relatively small cohort of sparrows ($n = 226$). While these findings are based on a high density of sites ($n = 44$), a power analysis indicates that as few as four sites, or approximately 20 sparrows, are needed to establish a statistically significant relationship between the blood Pb of sparrows and children (see Methods).

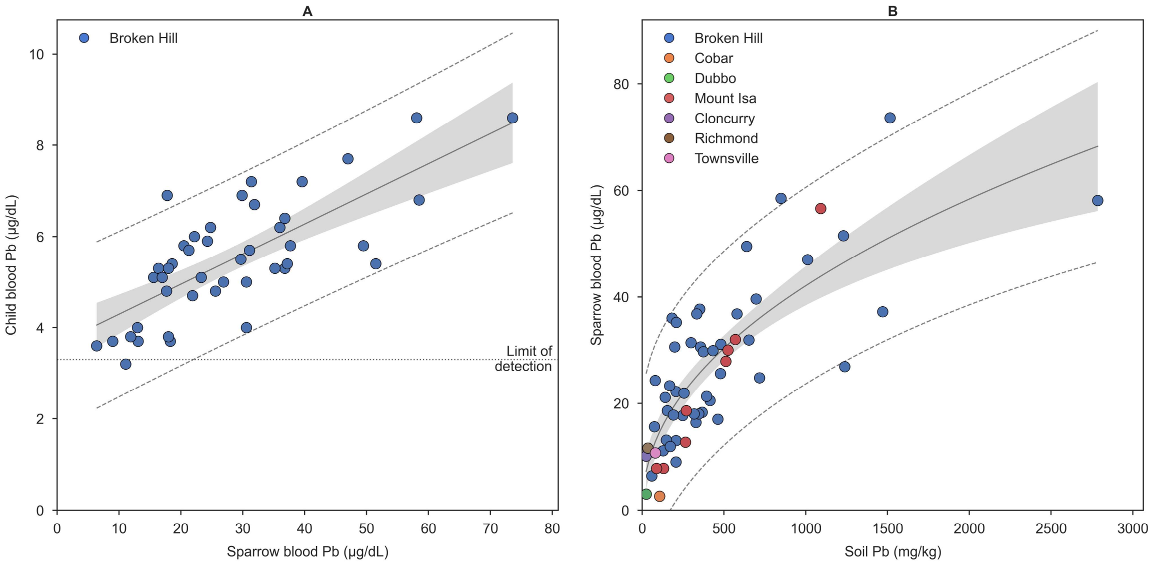

Fig. 2. Co-located blood and soil Pb relationships. (**A**) Relationship between Broken Hill sparrow and child blood Pb concentrations (n = 44; child blood Pb = 0.07 × sparrow blood Pb + 3.63; linear regression ± 95% confidence interval ± 95% prediction interval). Points represent geometric mean blood Pb concentration of sparrows and nearby (< 300 m) children for each catch site. Dotted line indicates the lower limit of detection of the LeadCare II blood Pb analyser (3.3 µg/dL) used for the majority of blood Pb screening in Broken Hill between 2011–2020 (26). (**B**) Relationship between soil Pb and sparrow blood Pb concentrations (n = 58; sparrow blood Pb = 1.05 × soil $\text{Pb}^{0.53}$; power regression ± 95% confidence interval ± 95% prediction interval). Points represent geometric mean soil Pb and sparrow blood Pb concentrations for each site, with colour designating the regional location of that site.

Geometric mean soil Pb concentrations were strongly related to sparrow blood Pb across all the sites included in this study (Spearman $r_s = 0.78$, $p < 0.01$, $n = 58$; fig. 2B). This relationship was stronger than that observed between soil Pb and nearby (< 300 m) child blood Pb measurements in Broken Hill (Spearman $r_s = 0.50$, $p < 0.01$, $n = 44$). Here, our findings reflect differences in the geographic scales over which environmental Pb exposure typically occurs in sparrows and children. Children are primarily exposed to Pb within and around the home (18), and are therefore more susceptible to localised heterogeneity in soil Pb contamination, such as that arising from the targeted remediation of homes and public spaces (24, 28). As such, in many mining and smelting impacted urban areas, airborne Pb is considered a stronger predictor of child blood Pb levels than soil Pb (26). Accordingly, we observed a similar relationship between Pb deposition rates and blood Pb in sparrows (Spearman $r_s = 0.68$, $p = 0.02$, $n = 12$) and children (Spearman $r_s = 0.65$, $p < 0.03$, $n = 11$). Sparrows, on the other hand, are typically active over a larger geographic area than children, and are therefore less sensitive to local variability in soil Pb contamination. The strong relationship between sparrow blood Pb and soil

Pb affirms this (fig. 2B), and suggests that the measurement of sparrows can cut through much of the geochemical noise inherent in contaminated urban environments.

A powerful test of whether sentinel species can be used to monitor health risks in human populations is to explore if the blood Pb relationship established between sparrows and children in Broken Hill (fig. 2A) can be used to predict blood Pb levels in a new location. Mount Isa provided a relevant Pb mining context in which to test the generalisability of our findings, as median sparrow blood Pb and soil Pb from this location was not significantly different to our data from Broken Hill ($p > 0.05$; table S3), suggesting that child blood Pb might also be comparable between these locations. Accordingly, we applied the linear blood Pb relationship (child blood Pb = 0.06 × sparrow blood Pb + 3.98) established in Broken Hill to blood Pb measurements from Mount Isa sparrows (n = 67) to predict the distribution of blood Pb levels in nearby Mount Isa children (fig. 3A–B). We compared our predictions to the most recently available (2016–2018) and demographically consistent (children aged 0–4 years) data from Mount Isa (n = 1014) (25). Based on the population of children represented by each of our sites (fig. 3C), we estimated that 24.3% (0.1% ≥ 10 µg/dL) of children in Mount Isa would have a blood Pb ≥ 5 µg/dL, the human intervention level (fig. 3D; table S4). This sentinel-driven prediction corresponded closely to the 24.0% (3.9% ≥ 10 µg/dL) of Mount Isa children measured with a blood Pb ≥ 5 µg/dL between 2016–2018 (25), and emphasises the broad applicability of this approach for monitoring environmental Pb exposure risks in children.

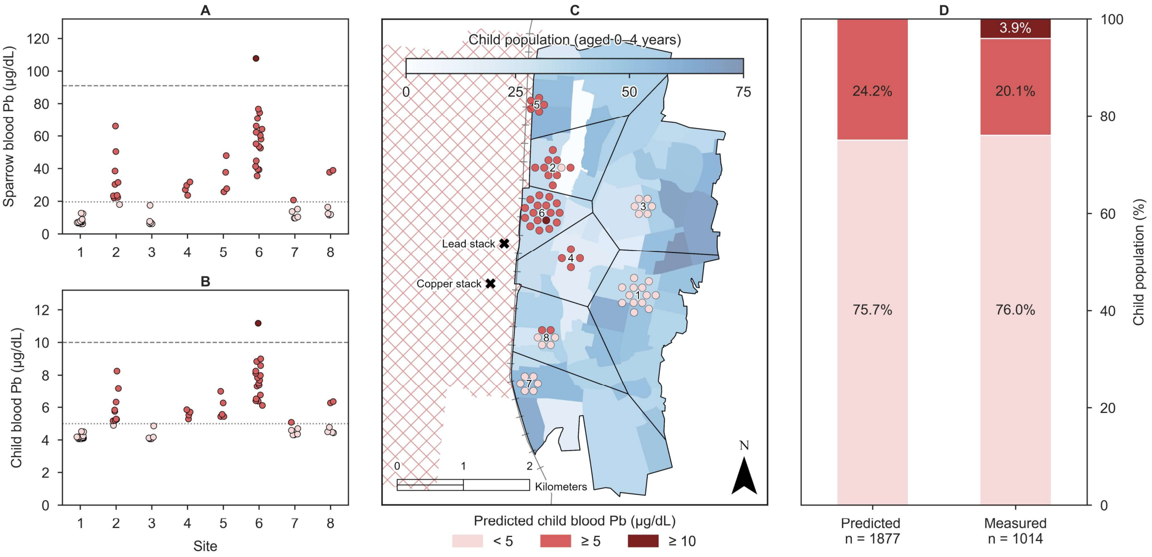

Fig. 3. Predicted distribution of Mount Isa child blood Pb. (**A**) Measured distribution of individual sparrow blood Pb levels at each site in Mount Isa (n = 67). Horizontal lines indicate sparrow blood Pb thresholds at which a nearby child is predicted to have a blood Pb level of ≥ 5 µg/dL (dotted line) or ≥ 10 µg/dL (dashed line) based

on data from Broken Hill. (**B**) Predicted distribution of child blood Pb levels ≥ 5 µg/dL (dotted line) or ≥ 10 µg/dL (dashed line) at each Mount Isa site based on measured distribution of sparrow blood Pb levels at that site. (**C**) Map of predicted child blood Pb levels around sites in Mount Isa. Thiessen polygons are used to designate the population of Mount Isa children represented by each site. (**D**) Percentage of children in Mount Isa estimated to have a blood Pb level ≥ 5 µg/dL or ≥ 10 µg/dL, compared to measured exceedances of these same thresholds between 2016–2018 (25).

We do not expect the relationship between blood Pb in sparrows and children to be the same in all environmental contexts, especially where the sources and pathways of Pb exposure are different. Indeed, comparison of historical blood Pb data from Broken Hill suggests that, even within the same city, the relationship between Pb exposure in sparrows and children has changed over time. When we compared our blood Pb measurements from sparrows to historical child blood Pb data, we found the strongest relationships in the earliest years of child blood Pb screening. For example, contemporary sparrow blood Pb levels were more strongly associated with blood Pb measured in children from 1991 (Pearson $r = 0.77$, $p < 0.01$, $n = 43$; fig. 4A) — the first year of systematic blood Pb screening in Broken Hill — than any other individual year for which data were available (e.g., fig. 4B; table S5). We cannot definitively ascertain the reasons for this decoupling without more temporally explicit sparrow blood Pb data. Nonetheless, it is likely driven by changes in environmental conditions contributing to Pb exposure risks over time (24, 28), and the corresponding shifts in human responses to these risks.

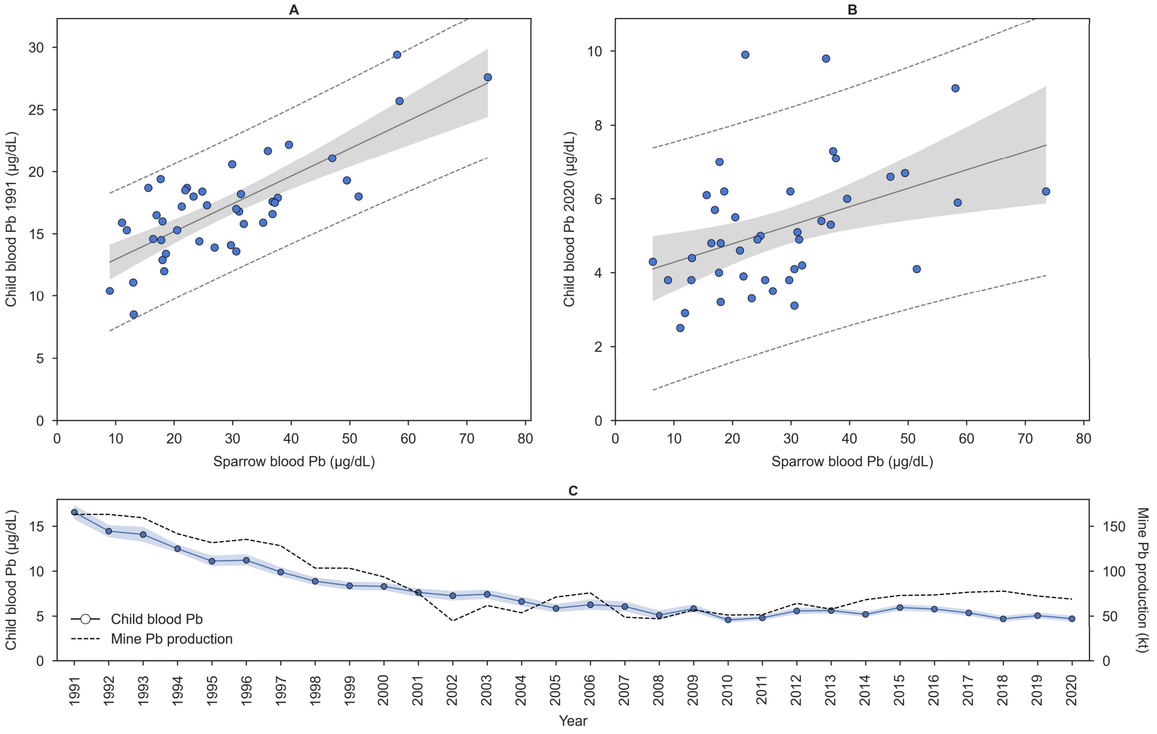

Fig. 4. Relationship between sparrow blood Pb and historical child blood Pb. (**A**, **B**) Comparison of relationship between blood Pb of contemporary sparrows and nearby (< 300 m) children measured in (**A**) 1991 and (**B**) 2020 from each catch site (n = 43; linear regression ± 95% confidence interval ± 95% prediction interval). Points represent geometric mean blood Pb concentrations of sparrows and nearby (< 300 m) children for each catch site. (**C**) Comparison of annual geometric mean child blood Pb concentrations (± 95% confidence interval) and Pb production from Broken Hill mines. Mine Pb production data between 1991–2012 is based on previously published data, with values from 2013–2020 derived from unpublished estimates of Pb production from the same author (29).

In 1991, both annual mining Pb production rates (29) (a robust proxy for atmospheric Pb emissions (26)) and child blood Pb levels were higher than any other year in the following three decades (fig. 4C). At this time, environmental and social interventions targeting Pb contamination and exposure risks within the community were also in their infancy (24). Consequently, Pb exposures in children were occuring in an environmental context characterised by elevated Pb emissions and largely unmitigated Pb contamination in soil and dust. Blood Pb levels in sparrows are closely linked to the distribution of Pb contamination in soil reservoirs (fig. 2B), and therefore correlate strongly with child blood Pb levels from this period. Conversely, as Pb production, Pb emissions, and child blood Pb concentrations have declined over time (fig. 4C; table S5), and interventions targeting Pb contamination, such as the remediation of residential areas (24, 28), have grown more widespread, the home environment of many children has become increasingly decoupled from the prevailing distribution of Pb contamination in Broken Hill. This is reflected by an increase in the relative variability of child blood Pb concentrations over time, and a corresponding decline in the strength of the blood Pb relationship between sparrows and children (table S5). Though this decoupling highlights the greater agency of humans to modify conditions within their surrounding environment, it also shows how wildlife sentinels have the potential to validate, and even quantify, the effectiveness of human responses to Pb contamination through remediation and other inteventions.

To investigate similarities between sources and pathways of Pb exposure in sparrows and children, we compared sparrow blood Pb isotopic compositions ($^{206}Pb/^{207}Pb$, $^{208}Pb/^{207}Pb$) with those previously reported for children measured in the early years of blood Pb screening in Broken Hill (30). We found that the distribution of sparrow and child blood Pb isotopic compositions aligned closely with previously published data on surface soil (30, 31), deposited dust (this study and reference (21)), and house dust samples (32), and were more similar in composition to Broken Hill ore Pb (see Methods) than to local samples of uncontaminated soil (30) (fig. 5A; table S6). Using these data, we estimated the contribution of Broken Hill ore Pb to the environmental and biological matrices included in this study. We found the highest median contribution of ore Pb in deposited dust (90%), followed by surface soil (90%), house dust (81%), sparrow blood (69%) and child blood (65%) (fig. 5B; table S6). We also observed declines in the contribution of orebody Pb to these matrices with distance from mining and smelting operations (fig. 5C; table S7). These patterns reflect the dispersal, deposition, and mixing of point-source Pb emissions with secondary contributions from residential (e.g., paint and petrol; table S6) and geogenic (e.g., weathering and erosion of unmineralised bedrock) Pb sources, and their subsequent uptake by sparrows and children.

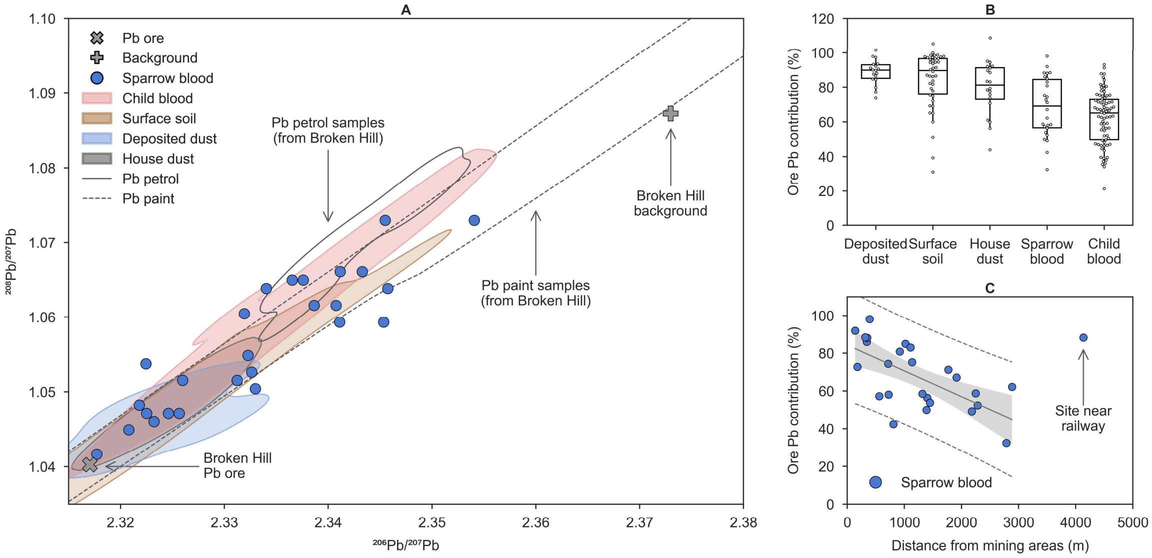

Fig. 5. Environmental and biological Pb isotopic compositions. (**A**) Comparison of Pb isotopic compositions (^{206}Pb/^{207}Pb, ^{208}Pb/^{207}Pb) of Broken Hill Pb ore (median; n = 5), background soil (30) (median; n = 11), sparrow blood (n = 26), child blood (30) (n = 78), surface soil (30, 31) (n = 42), deposited dust (this study and reference (21); n = 18), house dust (32) (n = 20), and Pb petrol (n = 10) and paint (n = 21) samples from Broken Hill (30) (see Methods; table S6). (**B**) Estimated contribution of Broken Hill Pb ore to the Pb isotopic compositions of environmental and biological samples included in this study. Boxplots summarise the 5th, 25th, 50th, 75th and 95th percentiles of the dataset with distribution of individual points also shown. (**C**) Estimated contribution of Broken Hill orebody Pb to sparrow blood Pb isotopic compositions with respect to distance from mining areas (linear regression ± 95% confidence intervals ± 95% prediction intervals). One site located along a railway previously used for the transport of Pb ore concentrate (31) was excluded from the linear regression model.

While inhalation of aerosolised Pb undoubtedly occurs in this species, soil ingestion is likely the primary pathway of Pb uptake in sparrows due to their proclivity for ground foraging and ingestion of grit (11). This is supported by the strong association detected between co-located soil Pb and sparrow blood Pb across all the catch sites included in this study (Spearman r_s = 0.78, $p < 0.01$, n = 58). While we acknowledge that indoor dust may represent a more important source of Pb uptaken by children, a significant proportion of indoor dust originates from nearby soil reservoirs (33). Soil and indoor dust Pb concentrations are also related in Broken Hill (Spearman r_s = 0.53, $p < 0.01$, n = 62 (32)). This correlation accounts for the overlap between sparrow blood Pb isotopic compositions and those measured in the indoor dust of Broken Hill homes (32) (table S6). Furthermore, sparrows are likely exposed to Pb in nesting cavities, where sources and pathways of Pb ingress would likely be more analogous to those contributing to the contamination of indoor environments. We did not identify a significant difference between the median blood Pb concentration of juvenile (< 4 months old (11)) and adult sparrows ($p > 0.05$; table S8), which indicates that blood Pb levels in these younger birds are a consequence of exposure occurring within, or shortly after leaving the nest.

In this study, we observed significant spatial variability in sparrow blood Pb concentrations across local scales, with distance from Pb emissions sources (table S7), and at regional scales, across towns and cities with and without significant Pb mining and smelting operations (fig. 2B; table S1). On a global scale, Pb contamination is widespread and there are hundreds, if not thousands of contexts in which soil Pb levels are equivalent to Broken Hill and Mount Isa (1). We suggest that due to their extensive distribution and close association with people, the human commensal sparrow provides an opportunity to rapidly and efficiently assess risks to children from Pb in the environment (fig. 6). For example, in Europe, Africa, and North and South America, significant Pb contamination and child blood Pb hotspots are associated with high density human and sparrow populations (fig. 6A–F) (34). In parts of Asia, the highly commensal house sparrow is replaced ecologically by its congener, the tree sparrow (*Passer montanus*), which could serve a similar purpose (35).

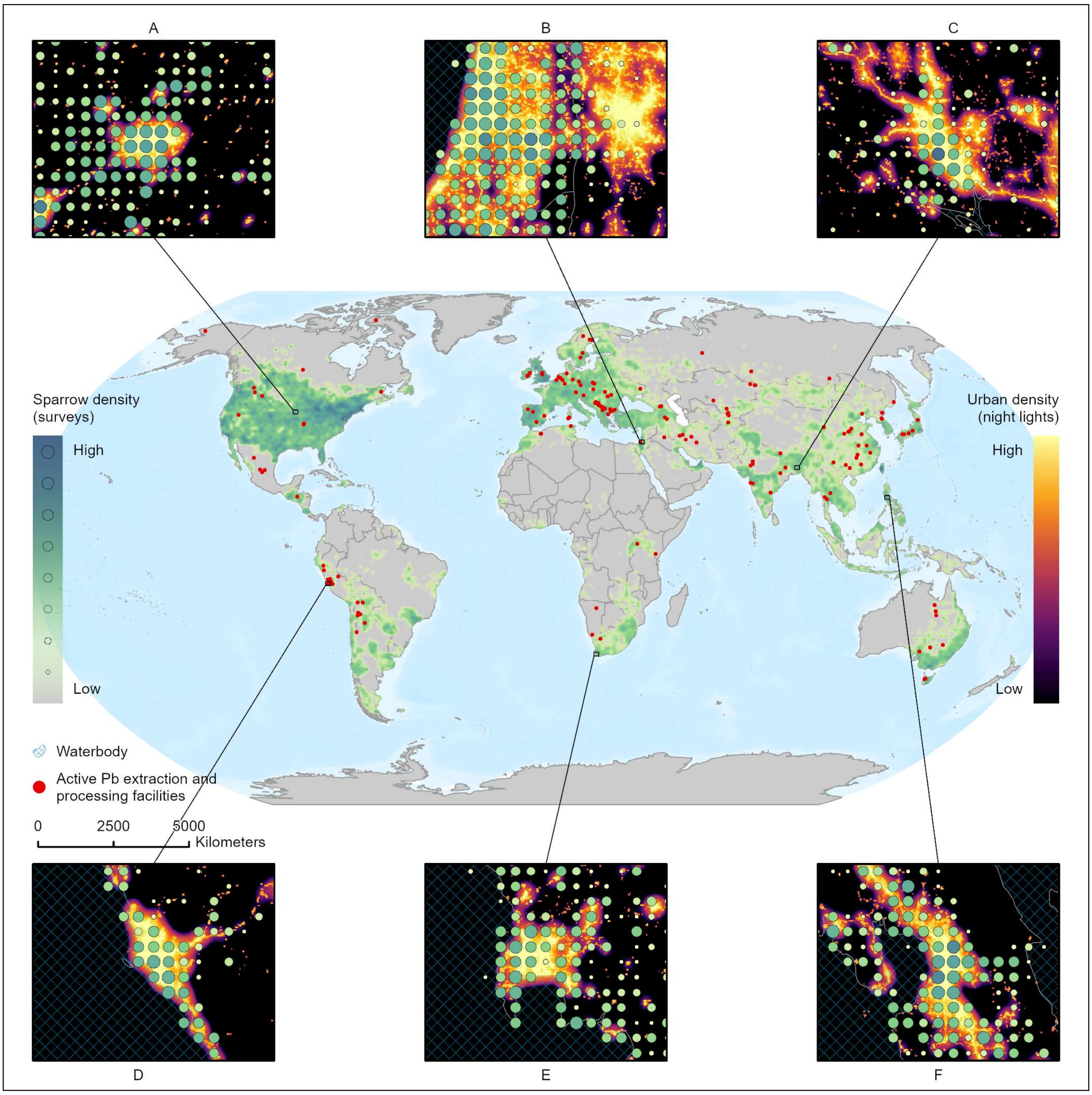

Fig. 6. Global distribution of human commensal sparrow species. Global map shows distribution and relative density of house sparrows (*Passer domesticus*), Italian sparrows (*Passer italiae*), and Spanish sparrows (*Passer hispaniolensis*). Eurasian tree sparrows (*Passer montanus*) are included in regions where the aforementioned species are not present, as this species is known to fulfill a similar human commensal niche in their absence (35). Survey data for all species were obtained from eBird, an online database of bird distribution and abundance (36). The relative density of sparrows (bilinearly resampled as 100 km^2 grid cells) is estimated based on counts of surveys from 2013–2022 that included one or more individual of the selected species. Locations of recently active Pb extraction and processing facilities are also shown (37, 38). Inset (a–f) maps show the relative density of sparrows (centroids of 10 km^2 grid cells) relative to urbanised areas indicated by remotely sensed nocturnal visible light emissions (39). The outlined regions represent a limited selection of Pb exposure hotspots where blood Pb levels in children are comparable to those reported in this study ((**A**) Omaha, United States of America (40); (**B**) West Bank, Palestine (41); (**C**) Tungi, Bangladesh (42); (**D**) Lima, Peru (43); (**E**) Cape Town, South Africa (44); (**F**) Manila, Philippines (45)).

While Pb contamination remains a pervasive and globally relevant health risk, human populated areas are hotspots for a far more complex range of potentially toxic elements and chemical compounds (17). Inputs of these contaminants are constantly changing, and their measurement in wildlife sentinels such as sparrows will provide an early indication of the risks they pose to human health. This is not without limitations, as the sources and pathways of exposure to different contaminants will not always align between human and animal populations (5). Furthermore, while direct soil and air monitoring can undoubtedly provide insight into the levels of contamination in the environment, the use of an effective sentinel animal provides greater awareness of the extent to which the contamination is biologically available to organisms, including humans, living in that environment (46).

Finally, we are not suggesting that the use of wildlife sentinels could or should supplant established environmental and epidemiological approaches to monitoring contaminant exposures in humans. In urban animals, clinical signs of exposure to toxic levels of contamination have often provided impetus for the more systematic monitoring and management of related human health risks (6, 7). This was the case in Broken Hill, where a high incidence of local dogs dying from Pb poisoning contributed to the establishment of the child blood Pb monitoring program in 1991 (47). Here, we have shown that even at sublethal and subtoxic levels, contaminant exposures measured in animals cohabiting human populated areas should be considered in light of their potential implications for human health.

Just as miners used canaries, we have demonstrated that house sparrows, a human commensal and sedentary species, are effective predictive sentinels for Pb exposure risks in children. We have shown how sparrows, and potentially similar species, could be used as a monitoring tool to prevent deleterious health outcomes associated with exposure to Pb during the early stages of development. Our study provides robust evidence for the main tenet of the One Health approach; that human, animal and environmental health are tightly intertwined (48). Our corroboration of this idea will help to reduce the growing perception that humans are disconnected from nature (48-50), and promote transformative actions aimed at sustainability across all species.

Methods:

Biological sampling

Fieldwork was conducted between September and December 2020 in Broken Hill, Dubbo, and Cobar, and in March 2022 in Mount Isa, Cloncurry, Richmond and Townsville. Sampling was authorised by the Macquarie University Animal Ethics Committee (AEC #2020/011). House sparrows were caught with mist nets. Captured birds were identified for sex and age, and banded. Blood was sampled onsite through the brachial vein of each bird using 75 µL Livingstone Microhematocrit Capillary Tubes. A 50 µL blood sample was taken and stored in tubes containing a dilute solution of HCL specifically for the quantification of blood Pb concentrations using a Meridian Bioscience LeadCare Plus blood Pb analyser. At each site, an average of 5 individuals were sampled for this purpose for a total of 304 birds. Where permitted by blood flow, another 50 µL blood sample was taken and stored in 1.5 mL Eppendorf Tubes for the additional analysis of blood Pb concentrations (n = 52) and Pb isotopic compositions (n = 26) using inductively coupled plasma mass spectrometry (ICP-MS).

Environmental sampling

To link sparrow blood Pb levels to environmental Pb contamination, we sampled surface soil at each catch site. Soil samples were collected in triplicate (n = 3) from the upper 2 cm of the soil profile at locations approximately 1 m equidistant. Samples were collected as near to the catching location as possible. Clean fill and imported soil was avoided. In Mount Isa, Cloncurry, Richmond and Townsville, additional soil samples (n = 6) were collected at evenly distributed locations within about 100 m of the catch site. This was done to improve the characterisation of environmental Pb contamination around each site. In total, 240 soil samples were collected from 58 sites.

Deposited dust was collected using dust deposition gauges installed at 12 of the Broken Hill catch sites. Dust gauges consisted of a 30 by 30 cm acrylic sheet mounted 1 m off the ground in an open area. After an average of 10 days, a 15 by 15 cm dust wipe (Ghost Wipe) was used to sample deposited dust from the dust gauge surface using established methods (51).

Anodic stripping voltammetry (ASV)

Most sparrow blood samples (n = 304) were analysed using a point-of-care Meridian Bioscience LeadCare Plus blood Pb analyser with a detection range of 1.9–65.0 µg/dL. This instrument uses anodic stripping voltammetry (ASV) to measure the Pb concentration of a whole blood sample mixed with a dilute solution of HCl. In line with typical reporting practices for child blood Pb screening data in Broken Hill (26), sparrow blood Pb measurements outside the detection limits of this instrument are reported as equivalent to these limits. Since 2009, a similar point-of-care instrument, the Meridian Bioscience LeadCare II blood Pb analyser, has been used for most child blood Pb screening in Broken Hill (26). The LeadCare II instrument has a narrower detection range (3.3–65.0 µg/dL) than the LeadCare Plus instrument. Sparrow blood Pb data was validated with inductively coupled plasma mass spectrometry (ICP-MS) of paired blood samples taken from the same sparrow, as detailed below.

Portable X-ray fluorescence (pXRF)

Soil samples were analysed with an Olympus Vanta portable X-ray fluorescence spectrometer (pXRF) fitted with a 50 kV tungsten (W) anode tube. Soil samples were dried and sieved to < 250 µm. Approximately 10 g of soil was transferred to sample cups for pXRF analysis. Cupped samples were analysed using the proprietary soil mode for a total test time of 60 s with 20 s per measurement condition (Beams I–III, 15–50 kV). Values are reported in mg/kg. Concentrations below instrument limits of detection are substituted with a value equivalent to half of this limit (table S9). Standard pXRF operating procedures including the measurement of National Institute of Standards and Technology (NIST) Standard Reference Materials (SRM) 2709a (San Joaquin Soil; n = 20) and 2711a (Montana II soil; n = 20; table S9).

Inductively coupled plasma mass spectrometry (ICP-MS)

Dust wipes (n = 12) and a subset of sparrow blood samples were sent for analysis of Pb concentrations (n = 52) and Pb isotopic compositions (n = 26) using an Agilent 7900 Q-ICP-MS at the National Measurement Institute, New South Wales, Australia. Concentrations initially reported in mg/kg were converted to µg/dL assuming a avian blood density of 1.05 g/mL (52). Concentrations below limits of detection were substituted with a value equivalent to half of this limit (table S10). Reference material Seronorm Trace Elements Whole Blood was used for analytical validation (table S10).

For the analysis of Pb isotopic compositions, between 3–4 blood samples from sites in Broken Hill were combined to ensure sufficient sample volume for analysis. Sample digest solutions were analysed with samples bracketed by concentration matched NIST SRM 981 (common Pb isotopic standard). Raw counts were corrected for blanks and potential isobaric interference, and then corrected for mass discrimination and instrument drift using the mean of NIST SRM 981 measurements. Instrument performance was assessed relative to NIST 2709a (53-57) and previous analyses of Broken Hill Pb ore (31, 32, 58-60), and returned values within the range of published data (table S11).

Linear data adjustment

Of the 52 blood samples analysed with ICP-MS, 34 could be matched to corresponding ASV blood Pb measurements. One sample was excluded due to potential contamination during field sampling (i.e., returned an anomalously high Pb concentration with respect to both its paired sample and corresponding samples from the same location). Of the remaining samples, 30 returned Pb concentrations within the limits of detection for either analytical method and so could be directly compared. The Pb concentrations of paired house sparrow blood samples measured using ASV and ICP-MS were strongly correlated (Pearson $r = 0.93$, $p < 0.01$, $n = 38$). However, a Bland-Altman analysis indicated a strong negative bias for blood Pb measured using ASV compared to ICP-MS (fig. S1).

Previous studies of Pb exposure in avian species have reported comparative underestimations of blood Pb concentrations when comparing ASV measurements to those of more analytically robust laboratory methods (61-65). Using established methods (65), we accounted for this underestimation by fitting an ordinary least squares regression to corresponding ASV (independent variable) and ICP-MS (dependent variable) natural-log blood Pb measurements (table S12). Adjustment of the subset of natural-log ASV blood Pb concentrations using the modelled slope and intercept ($\ln(y) = 0.81 \times \ln(x) + 1.30$) improved the correspondence between ASV and ICP-MS measurements following conversion back to a linear scale (fig. S1). This regression equations was therefore repeated to adjust the full dataset of ASV blood Pb concentrations ($n = 304$). The upper and lower limits of detection for the LeadCare Plus instrument used in this study (1.9–65.0 μg/dL) were adjusted accordingly (6.2–107.8 μg/dL). Only 1% ($n = 3/304$) of blood Pb measurements exceeded the upper limit, suggesting that this method captured the upper range of blood Pb levels amongst the studied populations. Unpaired blood samples analysed with ICP-MS ($n = 18$) were incorporated into the adjusted ASV dataset ($n = 304$), bringing the total number of sparrows for which a blood Pb measurement was available to 322.

Source attribution modelling

A vector based model was used to estimate the proportion of house sparrow blood and deposited dust Pb isotopic compositions attributable to Broken Hill Pb ore (66). Model endmembers were isolated from median Pb isotopic compositions previously published for samples of Broken Hill Pb ore ($^{206}Pb/^{207}Pb = 1.040$; $^{208}Pb/^{207}Pb = 2.317$) (31, 32, 58-60) and background soil sampled from uncontaminated areas around Broken Hill ($^{206}Pb/^{207}Pb = 1.087$; $^{208}Pb/^{207}Pb = 2.373$) (30). We applied the model to data from this study and previously published data on Pb isotopic compositions from deposited dust (n = 18; this study (n = 12) and reference (21) (n = 6)), surface soil (n = 42) (30, 31), house dust (n = 20) (32), sparrow blood (n = 26; this study), and child blood samples (n = 78; excluding one highly anomalous sample ($^{206}Pb/^{207}Pb = 1.102$; $^{208}Pb/^{207}Pb = 2.378$)) (30).

Child blood lead data

The availability of geolocated child blood Pb screening data from Broken Hill enabled comparison of blood Pb levels in sparrows and nearby children. Access to child blood Pb data was approved following ethics assessment by NSW Greater Western Human Research Ethics Committee (#2020/ETH01783) and in concurrence with Macquarie University's Human Research Ethics Committee. The NSW Greater Western Human Research Ethics Committee granted a waiver of the usual requirement for the consent of the individual to the use of their health information in a research project. Data from children aged 1–4 years that were tested in the years 2011–2020 were included, as the blood Pb of Broken Hill children has remained relatively stable over this period (table S5). Data from children under 1 year of age were excluded as there was no systematic testing of children in this age group between 2013–2016. If a child was tested more than once throughout the year, only the first test result for that year was included. Using the same criteria, we also compared sparrow and child blood Pb in each individual year for which child blood Pb screening data was available (1991–2020). We did this to explore how changes in Pb exposure risks in Broken Hill have influenced the relationship between historical child blood Pb levels and those of contemporary sparrows.

Geolocated child blood Pb measurements from Broken Hill were spatially joined to sparrow catch sites using a 300 m fixed radius around each site. The 300 m radius was based on the largest reported home range of a house sparrow measured using radio telemetric tracking (27). Between 2011–2020, a total of 4190 unique child blood Pb measurements that met the aforementioned inclusion criteria were spatially joined to one or more sites. The number of unique measurements joined to one ore more sites for individual years between 1991–2020 are reported in table S5.

To determine the generalisability of the blood Pb relationship established between sparrows and children in Broken Hill, we used the linear regression model from this location to predict child blood Pb levels in Mount Isa. To improve the granularity of this prediction, we applied the model to individual sparrow blood Pb measurements from Mount Isa, and predicted the corresponding distribution of blood Pb in nearby children. In validating our predictions, we used the most recently available child blood Pb data from Mount Isa, which was collected between 2016–2018 and included 1014 measurements from children between the ages of 0–4 years (25). Geolocated address information was not available for Mount Isa data, and measured blood Pb data were reported categorically as concentration ranges (< 5 µg/dL, ≥ 5 µg/dL, ≥ 10 µg/dL). Consequently, the number of children predicted to have a blood Pb level within one of these concentration ranges was calculated based on the population of children (aged 0–4 years) living within the urban area represented by each site. Population data (2016) was obtained from Australian Bureau of Statistics Statistical Area Level 1 geographic boundaries (67) and extrapolated to the urban area represented by each site using Thiessen polygons.

Statistical and spatial analyses

Statistical and spatial analyses were conducted using ArcGIS Pro 3.0.1 and Python 3.9.1. Concentrations of Pb measured in biological and environmental matrices were non-normally distributed and were therefore summarised for each site using the geometric mean. Geometric mean Pb concentrations in sparrow blood, child blood, and soil from each site, along with coefficients of variation and sample counts are reported in data S1. Ordinary least squares (OLS) regression was used to model the linear relationship between sparrow and child blood Pb. A power regression was used to model the apparent non-linear relationship between soil Pb and sparrow blood Pb. Pearson or Spearman correlation coefficients were used to determine associations between biochemical, geochemical and geographical variables depending on their linearity and the presence of outliers. To determine the minimum number of sites needed to establish a statistically significant relationship between child and sparrow blood Pb concentrations, we conducted a power analysis using Cohen's d as a measure of effect size, which we derived from the observed Pearson correlation coefficients. This analysis was performed to achieve a statistical power of 0.80 and an alpha level of 0.05. The Mann-Whitney U test was used to identify differences in soil and blood Pb concentrations depending on location, and the age and sex of sparrows.

Acknowledgements: We thank community members from the studied towns and cities for granting us access to their businesses, homes and gardens for sampling; the Broken Hill Environmental Lead Program for their ongoing support of the project; and G.M. Mudd for their provision of Pb production data from Broken Hill. Thanks also to C.P. Landrigan, P.M. Rabinowitz and M.R. Gillings for their insightful feedback on a previous version of the

manuscript. The NSW Greater Western Human Research Ethics Committee granted access to child blood lead data from Broken Hill.

Funding: This research was funded by an Australian Research Council Discovery Project grant (DP200100832).

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Investigation: MMG, RT, TH, SCG

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Funding acquisition: SCG

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Competing interests: Mark Patrick Taylor has undertaken work for and received funding from the Broken Hill Environmental Lead Program of the NSW Environment Protection Authority (EPA). He has received funding for lead and other trace metal related work from the Australian Federal Government. He has also prepared commissioned reports and provided expert advice on environmental contamination and human health for a range of bodies, including the Australian Building Codes Board (lead in plumbing fittings and materials), lawyers, governments, union agencies, and private companies. He has also served as an expert in plaintiff cases of childhood lead poisoning relating to Mount Isa, Queensland and Kabwe, Zambia. No other authors declare a competing interest.

Data and materials availability: Data supporting the findings of this study are available within the paper and its Supplementary Materials (specifically, data S1–S7). Child blood Pb data from Broken Hill are not openly available due to reasons of personal privacy, though are summarised in tables S1 and S5. Data from Mount Isa is freely available from the Queensland Department of Health Disclosure Log 2017–2018 (DOH-DL 17/18-048, p. 133).

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Supplementary Materials for

House sparrows as sentinels of childhood lead exposure

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The PDF file includes:

Fig. S1

Tables S1 to S12

Other Supplementary Materials for this manuscript include the following:

Data S1 to S7

Fig. S1.

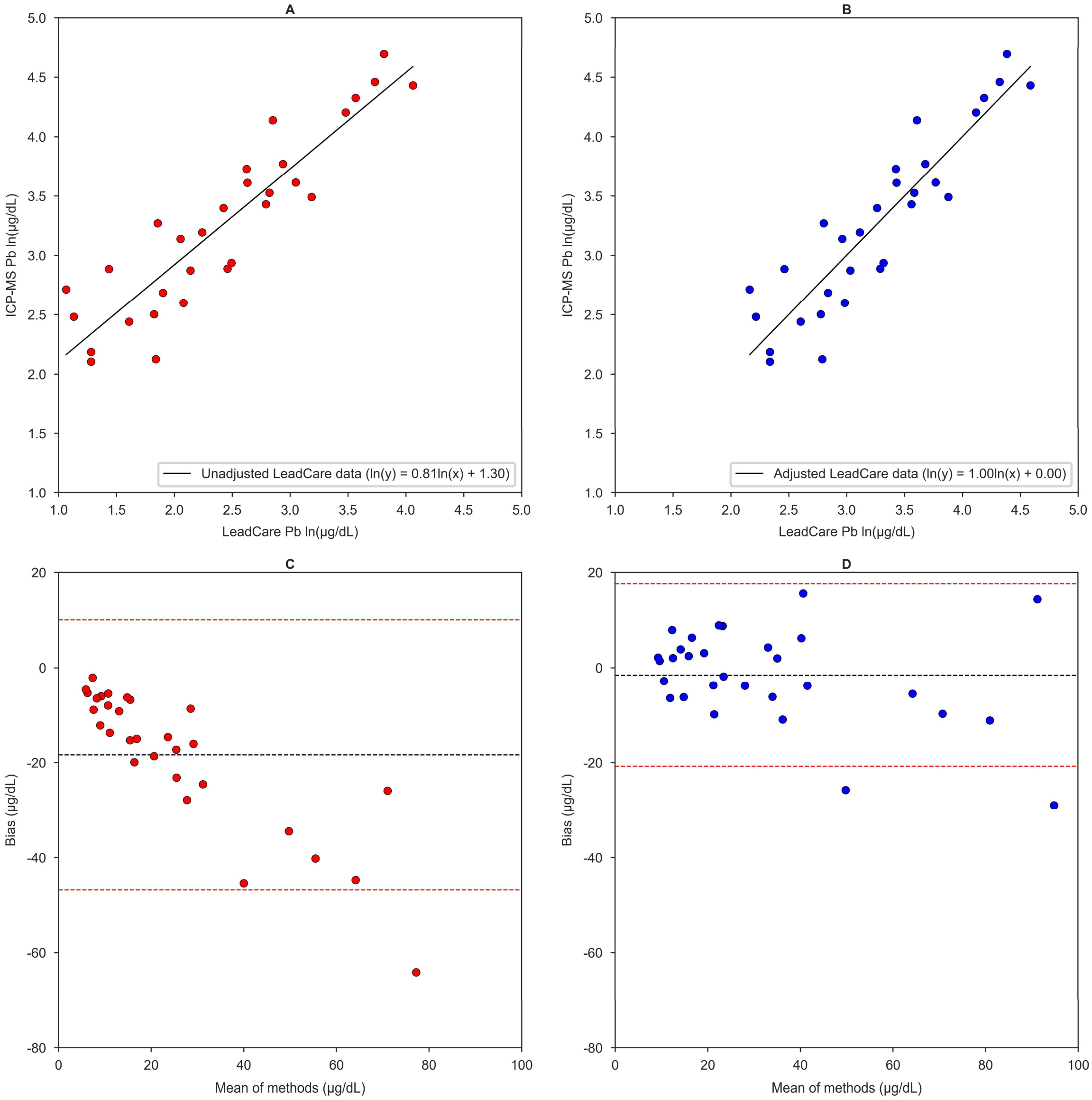

Fig. S1. (**A**) Linear regression model for paired natural-log LeadCare and ICP-MS measurements of sparrow blood Pb (n = 30) used to adjust LeadCare data. (**B**) Linear regression model for paired natural-log LeadCare and ICP-MS measurements of sparrow blood Pb following linear adjustment of LeadCare data. (**C**) and (**D**) Bland-Altman plot describing analytical agreement between ICP-MS and LeadCare measurements of blood Pb concentrations before (**C**) and after (**D**) adjustment of LeadCare data.

Table S1.

	Sparrow blood Pb (µg/dL)			Child blood Pb (µg/dL)
	Broken Hill	**Mount Isa**	**Other locations**	**Broken Hill**
Min	6.2	6.2	2.6	1.0
25th percentile	16.3	9.7	2.6	3.0
Median	26	23.6	7.5	5.0
75th percentile	41.4	40.5	10.6	8.2
Max	107.8	107.8	101.5	65.0
Mean	31.4	29.4	11	6.7
SD	21.1	22.8	18.2	5.5
Upper 95% CI	34.2	34.9	17.6	6.8
Lower 95% CI	28.6	23.9	4.4	6.5
Geometric mean	25.3	21.4	6.9	5.3
Count	226	67	29	4190

	Surface soil Pb (mg/kg)			Dust Pb (µg/m^2/day)
	Broken Hill	**Mount Isa**	**Other locations**	**Broken Hill**
Min	57	54	8	5
25th percentile	187	181	24	60
Median	339	354	39	81
75th percentile	603	598	72	133
Max	3214	3341	371	175
Mean	510	500	61	91
SD	556	561	66	57
Upper 95% CI	604	630	84	123
Lower 95% CI	416	370	38	59
Geometric mean	345	329	43	65
Count	135	72	33	12

Table S1. Summary statistics for Pb concentrations in sparrow blood, child blood (2011–2020), surface soil, and deposited dust across Broken Hill and Mount Isa. Other locations (Cobar, Dubbo, Cloncurry, Richmond, Townsville) are combined.

Table S2.

Slope (± SE)	0.07 (± 0.01)	**Intercept (± SE)**	3.63 (± 0.29)
Coefficient (r^2)	0.55	**Y-estimate SE**	0.87
F statistic	51.27	**DF**	42.00
Regression sum of squares (SST)	39.10	**Residual sum of squares (RSS)**	32.03

Table S2. Statistics for ordinary least squares regression calculated between geometric mean sparrow blood Pb (independent variable) and child blood Pb (dependent variable) at each catch site.

Table S3.

Variable	Group 1	Group 2	Group 1 (n)	Group 2 (n)	U Statistic	P-value
Blood Pb	Broken Hill	Mount Isa	226	67	8349	0.2017
Blood Pb	Broken Hill	Other locations	226	29	5831	< 0.0001
Blood Pb	Mount Isa	Other locations	67	29	1588	< 0.0001
Soil Pb	Broken Hill	Mount Isa	135	72	4898	0.9272
Soil Pb	Broken Hill	Other locations	135	33	4287	< 0.0001
Soil Pb	Mount Isa	Other locations	72	33	2255	< 0.0001

Table S3. Results of Mann-Whitney U test comparing median soil and blood Pb across the studied locations.

Table S4.

Site	Sparrow blood Pb (n)	Sparrow blood Pb (µg/dL)[a]	Predicted child blood Pb (µg/dL)	Predicted population < 5 µg/dL	Predicted population ≥ 5 µg/dL	Predicted population ≥ 10 µg/dL	Total population[b]
1	13	7.8	4.2	502	0	0	502
2	10	30	5.7	21	84	0	105
3	6	7.8	4.2	550	0	0	550
4	4	27.9	5.6	0	68	0	68
5	5	32	5.9	0	208	0	208
6	17	56.6	7.6	0	36	2	38
7	6	12.7	4.5	229	0	0	229
8	6	18.6	4.9	118	59	0	177

[a] *Geometric mean*

[b] *Estimated number of children living closest to each site.*

	Total < 5 µg/dL	Total ≥ 5 µg/dL	Total ≥ 10 µg/dL	Total
Predicted	1420	455	2	1877
Measured	771	204	39	1014

	% < 5 µg/dL	% ≥ 5 µg/dL	% ≥ 10 µg/dL
Predicted	75.7	24.2	0.1
Measured	76.0	20.1	3.9

Table S4. Summary data for output of linear regression model (child blood Pb = 0.07 × sparrow blood Pb + 3.63) used to predict child blood Pb levels in Mount Isa using blood Pb measurements from individual Mount Isa sparrows (n = 67). Predictions are extrapolated to the total population of Mount Isa children and are reported as percentages within the blood Pb concentration ranges of < 5 µg/dL, ≥ 5 µg/dL (excluding ≥ 10 µg/dL) or ≥ 10 µg/dL. Results are benchmarked against reported exceedances of these same concentrations amongst Mount Isa children measured between 2016–2017 (25).

Table S5.

Year	Pearson r	P-value	Sites (n)	Tests (n) (female/male)	Child blood Pb (µg/dL)	GCV (%)	Mined Pb (tonnes)
1991	0.7862	< 0.0001	43	466 (205/261)	16.6	65	163303
1992	0.6210	< 0.0001	43	449 (215/234)	14.5	66	163249
1993	0.5519	0.0002	43	327 (147/180)	14.1	75	159502
1994	0.6047	< 0.0001	43	567 (252/315)	12.5	58	141747
1995	0.7245	< 0.0001	43	454 (199/255)	11.1	73	131726
1996	0.6525	< 0.0001	43	338 (152/186)	11.2	72	135447
1997	0.5691	0.0001	43	410 (177/233)	9.9	70	128396
1998	0.6069	< 0.0001	42	447 (198/249)	8.9	71	103524
1999	0.6220	< 0.0001	43	408 (185/223)	8.4	77	103323
2000	0.4703	0.0017	43	375 (196/179)	8.3	74	93642
2001	0.5306	0.0003	44	341 (167/174)	7.6	83	75424
2002	0.5886	< 0.0001	44	333 (148/185)	7.3	97	44620
2003	0.5975	< 0.0001	43	298 (137/161)	7.4	92	61800
2004	0.3750	0.0100	42	303 (128/175)	6.6	101	53700
2005	0.3309	0.0323	43	325 (146/179)	5.9	108	71200
2006	0.4945	0.0009	42	254 (107/147)	6.3	110	75900
2007	0.5575	0.0001	43	265 (112/153)	6.1	110	48800
2008	0.4321	0.0050	41	209 (112/97)	5.1	114	47000
2009	0.2020	0.2050	42	224 (111/113)	5.8	75	56900
2010	0.4352	0.0040	43	239 (127/112)	4.6	70	51200
2011	0.6320	< 0.0001	43	331 (161/170)	4.8	75	51600
2012	0.7055	< 0.0001	43	401 (192/209)	5.6	91	64187
2013	0.6355	< 0.0001	44	435 (219/216)	5.6	89	57730
2014	0.4520	0.0026	43	444 (213/231)	5.2	83	68248
2015	0.5919	< 0.0001	44	418 (212/206)	6	84	73022
2016	0.5648	0.0001	44	450 (223/227)	5.8	84	73557
2017	0.5403	0.0002	44	465 (218/247)	5.4	101	76612
2018	0.4251	0.0045	44	387 (186/201)	4.7	98	77799
2019	0.5258	0.0003	42	433 (214/219)	5.1	105	72381
2020	0.4182	0.0053	43	426 (213/213)	4.7	102	68923

Table S5. Pearson correlation coefficients for the relationship between sparrow blood Pb and child blood Pb for each individual year of child blood Pb screening in Broken Hill included in this study (1991–2020). For each year, the total number of unique child blood Pb tests joined to one or more sites, the geometric mean child blood Pb, the geometric coefficient of variation (GCV) of child blood Pb, and the total annual production of Pb in Broken Hill are provided. Data from 1991–2012 is based on published estimates, with data from 2013–2020 unpublished estimates from the same author *(29)*.

Table S6.

	Sparrow blood Pb (this study)			**Child blood Pb** (30)		
	^{206}Pb/^{207}Pb	**^{208}Pb/^{207}Pb**	**Ore Pb %**	**^{206}Pb/^{207}Pb**	**^{206}Pb/^{207}Pb**	**^{208}Pb/^{207}Pb**
Min	1.0417	2.3177	32	1.0443	2.3203	21
Median	1.0571	2.3328	69	1.0598	2.3341	65
Max	1.0730	2.3541	98	1.1019	2.3781	93
Mean	1.0567	2.3334	69	1.0613	2.3360	62
SD	0.0089	0.0095	17	0.0093	0.0089	15
Count	26	26	26	78	78	78
	Deposited dust Pb (this study)			**Deposited dust Pb (published data)** (21)		
	^{206}Pb/^{207}Pb	**^{208}Pb/^{207}Pb**	**Ore Pb %**	**^{206}Pb/^{207}Pb**	**^{208}Pb/^{207}Pb**	**Ore Pb %**
Min	1.0406	2.3153	74	1.0410	2.3190	85
Median	1.0444	2.3220	91	1.0465	2.3230	88
Max	1.0526	2.3323	102	1.0480	2.3260	97
Mean	1.0456	2.3234	89	1.0457	2.3230	89
SD	0.0036	0.0054	8	0.0025	0.0028	4
Count	12	12	12	6	6	6
	Surface soil (30, 31)			**House dust** (32)		
	^{206}Pb/^{207}Pb	**^{208}Pb/^{207}Pb**	**Ore Pb %**	**^{206}Pb/^{207}Pb**	**^{208}Pb/^{207}Pb**	**Ore Pb %**
Min	1.0380	2.3140	31	1.0373	2.3112	44
Median	1.0458	2.3223	90	1.0477	2.3274	81
Max	1.0787	2.3520	105	1.1111	2.3944	109
Mean	1.0484	2.3254	84	1.0526	2.3303	80
SD	0.0088	0.0088	17	0.0153	0.0169	16
Count	42	42	42	20	20	20
	Broken Hill ore Pb (31, 32, 58-60)			**Background soil Pb** (30)		
	^{206}Pb/^{207}Pb	**^{208}Pb/^{207}Pb**		**^{206}Pb/^{207}Pb**	**^{208}Pb/^{207}Pb**	
Min	1.0390	2.3102		1.0422	2.3190	
Median	1.0403	2.3170		1.0873	2.3730	
Max	1.0428	2.3253		1.1957	2.6317	
Mean	1.0405	2.3178		1.1024	2.4192	
SD	0.0014	0.0057		0.0597	0.1116	
Count	5	5		11	11	
	Broken Hill Pb paint (30)			**Broken Hill Pb petrol** (30)		
	^{206}Pb/^{207}Pb	**^{208}Pb/^{207}Pb**	**Ore Pb %**	**^{206}Pb/^{207}Pb**	**^{208}Pb/^{207}Pb**	**Ore Pb %**
Min	1.0396	2.3173	5	1.0613	2.3372	35
Median	1.0572	2.3346	92	1.0685	2.3403	52
Max	1.1496	2.4303	116	1.0770	2.3497	61
Mean	1.0714	2.3494	68	1.0701	2.3423	48
SD	0.0343	0.0359	36	0.0051	0.0044	8
Count	21	21	21	10	10	10

Table S6. Summary statistics for Pb isotopic compositions (^{206}Pb/^{207}Pb; ^{208}Pb/^{207}Pb) and estimated contribution of Broken Hill ore Pb in different environmental and biological matrices included in this study. Includes previously published data and data first reported in this study.

Table S7.

Variable A	Variable B	Spearman r_s	P-value	Sites (n)
Distance	**Soil Pb**	-0.6669	< 0.0001	53
Distance	**Dust Pb**	-0.8811	0.0002	12
Distance	**Deposited dust Pb (ore Pb %)**	-0.7400	0.0059	12
Distance	**Sparrow blood Pb**	-0.6416	< 0.0001	53
Distance	**Sparrow blood Pb (ore Pb %)**	-0.6166	< 0.0001	29
Distance	**Child blood Pb**	-0.7435	< 0.0001	44

Table S7. Spearman correlation coefficients for relationship between distance from mining areas in Broken Hill and Mount Isa and Pb concentrations measured in various environmental and biological matrices included in this study.

Table S8.

Variable	**Group 1**	**Group 2**	**Group 1 (n)**	**Group 2 (n)**	**U Statistic**	**P-value**
Blood Pb	Adult	Juvenile	227	81	8721	0.4922
Blood Pb	Female	Male	122	145	9984	0.0702

Table S8. Results of Mann-Whitney U test comparing median blood Pb between adult and juvenile, and male and female sparrows.

Table S9.

	Pb
Limit of detection (mg/kg)	5
Silicate blank (mg/kg)	< 5
NIST 2711a	
Certified value (mg/kg)	1400
Mean recovery (%)	95
Mean RSD (%)	1
NIST 2709a	
Certified value (mg/kg)	17
Mean recovery (%)	93
Mean RSD (%)	7
Soil duplicates	
Duplicate A mean recovery (%)	100
Duplicate B mean recovery (%)	100
Duplicate mean RSD (%)	2

Table S9. Quality assurance and quality control data for Vanta VMW pXRF analyses of Pb concentrations from sieved (< 250 µm) and cupped surface soil samples. Mean recoveries and mean RSDs are reported for silicate blank (n = 15), NIST 2711a (n = 15) and NIST 2709a (n = 15) analyses. Mean recoveries and mean RSD are also reported for duplicate A (n = 25; sample kept stationary with respect to pXRF analysis window between measurements) and B (n = 25; sample moved with respect to pXRF analysis window between measurements) analyses.

Table S10.

	Sparrow blood Pb	Dust wipe Pb
Limit of reporting (mg/kg)	0.05	0.05
Blank (mg/kg)	< 0.05	< 0.05
Control recovery (%)	104 (± 7)[a]	97
Matrix spike recovery (%)	97 (± 3)[a]	101
Duplicates (n)	4	1

[a] *Mean (± SD)*

Table S10. Quality assurance and control data for ICP-MS analyses of Pb concentrations in
95 sparrow blood and dust wipes. Reference material Seronorm™ Trace Elements Whole Blood
was used for analytical validation of Pb concentrations in sparrow blood. Recovery data for
deposited dust wipe Pb and house sparrow blood Pb are reported separately.

Table S11.

	NIST 2709a (n = 3)			Broken Hill ore (n = 3)		
	^{204}Pb/^{206}Pb	^{207}Pb/^{206}Pb	^{208}Pb/^{206}Pb	^{204}Pb/^{206}Pb	^{207}Pb/^{206}Pb	^{208}Pb/^{206}Pb
Published mean	0.0524	0.8210	2.0400	0.0625	0.9620	2.2260
Measured mean	0.0523	0.8205	2.0415	0.0626	0.9605	2.2345
Measured SD	0.0004	0.0015	0.0029	0.0002	0.0026	0.0079
Mean RSD (%)	0.20	0.04	0.05	0.11	0.11	0.27
Mean recovery (%)	99.71	99.94	100.07	100.16	99.84	100.38

Table S11. Method validation data for ICP-MS analysis of Pb isotopic compositions. Instrument performance was assessed relative to previously published Pb isotopic compositions for NIST 2709a (53-57) and Broken Hill ore Pb (31, 32, 58-60).

Table S12.

Slope (± SE)	0.81 (± 0.07)	**Intercept (± SE)**	1.30 (± 0.18)
Coefficient (r^2)	0.83	**Y-estimate (SE)**	0.31
F statistic	134.23	**DF**	28.00
Regression sum of squares (SST)	13.09	**Residual sum of squares (RSS)**	2.73

Table S12. Summary statistics for ordinary least squares regression equation calculated for the relationship between the natural-log Pb concentration of paired blood samples analysed with LeadCare (independent variable) and ICP-MS (dependent variable).

Data S1. Geometric means (GM), geometric coefficients of variation (GCV) and sample counts for Pb measurements in sparrows, surface soil, and child blood (2011 – 2020) from catch sites across the study locations.

Data S2. Individual sparrow blood Pb concentrations across all sites included in this study (n = 322). Where recorded, the sex (Male/Female/Unknown) and age (Adult/Juvenile/Unknown) of each sparrow are provided. Sites are from Broken Hill (BH), Cobar (CB), Dubbo (DB), Mount Isa (MI), Cloncurry (CC), Richmond (RM) and Townsville (TV). This dataset includes blood Pb measurements analysed using ASV (n = 304) and subsequently adjusted using data from paired blood samples analysed with ICP-MS (n = 30). Unpaired ICP-MS measurements are also included (n = 18).

Data S3. Individual surface soil Pb concentrations across all sites included in this study (n = 240). Sites are from Broken Hill (BH), Cobar (CB), Dubbo (DB), Mount Isa (MI), Cloncurry (CC), Richmond (RM) and Townsville (TV). All soil samples are sieved to < 250 µm, cupped and analysed using pXRF.

Data S4. Dust wipe Pb concentrations (µg/sample) and deposited dust Pb loading rates (µg/m^2/day) sampled from dust deposition gauges in Broken Hill. Associated Pb isotopic compositions (^{206}Pb/^{207}Pb, ^{208}Pb/^{207}Pb) and estimated contribution of Broken Hill ore Pb (66) are provided for each sample. The period of days indicates the number of days the dust gauge was left to collect deposited dust before being sampled with a dust wipe.

Data S5. Broken Hill Sparrow blood Pb isotopic compositions (^{206}Pb/^{207}Pb, ^{208}Pb/^{207}Pb) and estimated contribution of Broken Hill ore Pb (66). Combined blood sample count indicates number of samples combined to ensure sufficient sample volume for ICP-MS analysis of Pb isotopic compositions.

Data S6. ICP-MS and LeadCare blood Pb measurements from paired sparrow blood samples before and after LeadCare data adjustment using natural-log values.

Data S7. Summary geographic information for each catch site. Distance (m) from mining areas is calculated from the nearest outer boundary of mining operations as defined by Australian Statistical Geography Standard Mesh Blocks (67).

Data S1

Site ID	Matrix 1	GM Pb (µg/dL)	GCV (%)	Sample count	Matrix 2	GM Pb (mg/kg)	GCV (%)	Sample count	Matrix 3	GM Pb (µg/dL)	GCV (%)	Sample count
BH_01	Sparrow blood	31.4	33	5	Surface soil	299	24	3	Child blood	7.2	103	95
BH_02	Sparrow blood	36.8	76	5	Surface soil	580	10	3	Child blood	5.3	104	158
BH_03	Sparrow blood	49.5	42	5	Surface soil	639	6	3	Child blood	5.8	85	85
BH_04	Sparrow blood	39.6	73	4	Surface soil	697	8	3	Child blood	7.2	92	189
BH_05	Sparrow blood	9	51	6	Surface soil	207	20	3	Child blood	3.7	54	94
BH_06	Sparrow blood	31.1	41	8	Surface soil	481	43	3	Child blood	5.7	85	167
BH_07	Sparrow blood	22.2	49	6	Surface soil	207	9	3	Child blood	6	90	39
BH_08	Sparrow blood	36	50	5	Surface soil	183	17	3	Child blood	6.3	97	49
BH_09	Sparrow blood	20.5	87	5	Surface soil	415	21	3	Child blood	5.8	93	175
BH_10	Sparrow blood	37.7	32	5	Surface soil	352	37	3	Child blood	5.8	95	25
BH_11	Sparrow blood	31.9	54	5	Surface soil	653	28	3	Child blood	6.7	116	36
BH_12	Sparrow blood	58.5	44	16	Surface soil	849	116	3	Child blood	6.8	98	74
BH_13	Sparrow blood	35.2	59	6	Surface soil	209	23	3	Child blood	5.3	77	92
BH_14	Sparrow blood	15.6	64	5	Surface soil	75	8	3	Child blood	5.1	82	168
BH_15	Sparrow blood	58.1	26	7	Surface soil	2786	12	3	Child blood	8.6	97	112
BH_16	Sparrow blood	30.6	N/A	1	Surface soil	357	42	3	Child blood	5	92	201
BH_17	Sparrow blood	18.3	60	6	Surface soil	367	14	3	Child blood	3.7	38	22
BH_20	Sparrow blood	23.3	N/A	1	Surface soil	168	7	3	Child blood	5.1	71	166
BH_22	Sparrow blood	11.1	71	5	Surface soil	128	14	3	Child blood	3.2	67	58
BH_23	Sparrow blood	21.9	34	6	Surface soil	256	124	3	Child blood	4.7	87	195
BH_24	Sparrow blood	24.8	13	5	Surface soil	718	2	3	Child blood	6.2	95	129
BH_25	Sparrow blood	13	54	5	Surface soil	207	12	3	Child blood	4	67	183
BH_26	Sparrow blood	25.6	14	4	Surface soil	479	30	3	Child blood	4.8	89	198
BH_27	Sparrow blood	18.6	7	5	Surface soil	154	18	3	Child blood	5.4	95	155
BH_28	Sparrow blood	37.2	77	5	Surface soil	1471	99	3	Child blood	5.4	88	102
BH_29	Sparrow blood	73.6	21	6	Surface soil	1516	33	3	Child blood	8.6	112	171
BH_30	Sparrow blood	16.4	N/A	1	Surface soil	329	116	3	Child blood	5.3	103	95
BH_31	Sparrow blood	18	68	5	Surface soil	346	15	3	Child blood	5.3	85	189
BH_32	Sparrow blood	17.7	N/A	1	Surface soil	248	12	3	Child blood	4.9	94	147
BH_33	Sparrow blood	13.1	51	5	Surface soil	148	15	3	Child blood	3.7	71	113
BH_34	Sparrow blood	21.1	84	5	Surface soil	141	9	3	Child blood	N/A	N/A	0
BH_35	Sparrow blood	6.4	7	5	Surface soil	59	5	3	Child blood	3.6	35	8
BH_36	Sparrow blood	30.6	493	2	Surface soil	199	19	3	Child blood	4	82	123
BH_37	Sparrow blood	24.3	30	5	Surface soil	80	23	3	Child blood	5.9	93	181
BH_38	Sparrow blood	11.9	54	15	Surface soil	172	2	3	Child blood	3.8	66	84
BH_39	Sparrow blood	17	62	5	Surface soil	463	58	3	Child blood	5.1	82	177
BH_40	Sparrow blood	29.7	14	2	Surface soil	374	21	3	Child blood	5.5	82	153
BH_41	Sparrow blood	21.3	37	2	Surface soil	394	12	3	Child blood	5.7	79	155
BH_42	Sparrow blood	51.5	46	5	Surface soil	1231	25	3	Child blood	5.4	79	110
BH_43	Sparrow blood	29.9	40	5	Surface soil	433	23	3	Child blood	6.9	75	117
BH_44	Sparrow blood	26.9	27	5	Surface soil	1239	19	3	Child blood	5	94	143
BH_45	Sparrow blood	18	45	4	Surface soil	318	7	3	Child blood	3.9	75	132
BH_47	Sparrow blood	36.8	19	5	Surface soil	334	18	3	Child blood	6.4	108	209
BH_48	Sparrow blood	47	18	2	Surface soil	1012	1	3	Child blood	7.7	80	159
BH_50	Sparrow blood	17.8	51	5	Surface soil	191	14	3	Child blood	6.9	114	114
CB_01	Sparrow blood	2.6	0	5	Surface soil	107	41	3	Child blood	N/A	N/A	0
DB_01	Sparrow blood	3	39	5	Surface soil	25	17	3	Child blood	N/A	N/A	0
MI_01	Sparrow blood	7.8	27	13	Surface soil	131	74	9	Child blood	N/A	N/A	0
MI_02	Sparrow blood	30	51	10	Surface soil	525	28	9	Child blood	N/A	N/A	0
MI_03	Sparrow blood	7.8	50	6	Surface soil	88	31	9	Child blood	N/A	N/A	0
MI_04	Sparrow blood	27.9	14	4	Surface soil	512	76	9	Child blood	N/A	N/A	0
MI_05	Sparrow blood	32	32	5	Surface soil	570	59	9	Child blood	N/A	N/A	0
MI_06	Sparrow blood	56.6	33	17	Surface soil	1092	106	9	Child blood	N/A	N/A	0
MI_07	Sparrow blood	12.7	36	6	Surface soil	265	57	9	Child blood	N/A	N/A	0
MI_08	Sparrow blood	18.6	78	6	Surface soil	270	72	9	Child blood	N/A	N/A	0
CC_01	Sparrow blood	10.1	22	5	Surface soil	24	110	9	Child blood	N/A	N/A	0
RM_01	Sparrow blood	11.6	145	10	Surface soil	35	73	9	Child blood	N/A	N/A	0
TV_01	Sparrow blood	10.7	31	4	Surface soil	81	98	9	Child blood	N/A	N/A	0

Data S2

Sample ID	Blood Pb (µg/dL)	Sex (M/F/U)	Age (A/J/U)	Location	Method
BH_01_HS_01	37	M	A	BH	ASV
BH_01_HS_02	36.6	M	A	BH	ASV
BH_01_HS_03	21.3	M	A	BH	ASV
BH_01_HS_04	25.3	M	A	BH	ASV
BH_01_HS_06	41.7	F	A	BH	ASV
BH_02_HS_01	26.6	F	A	BH	ASV
BH_02_HS_02	49.4	F	A	BH	ASV
BH_02_HS_03	46.1	F	A	BH	ASV
BH_02_HS_04	68	F	A	BH	ASV
BH_02_HS_05	16.3	M	A	BH	ASV
BH_03_HS_01	45.6	F	A	BH	ASV
BH_03_HS_02	35.9	M	A	BH	ASV
BH_03_HS_03	62.8	M	A	BH	ASV
BH_03_HS_04	36.2	M	A	BH	ASV
BH_03_HS_05	79.8	F	A	BH	ASV
BH_04_HS_01	35.2	M	A	BH	ASV
BH_04_HS_03	31.5	U	J	BH	ASV
BH_04_HS_04	87.4	F	A	BH	ASV
BH_04_HS_05	25.3	M	A	BH	ASV
BH_05_HS_02	15	F	A	BH	ASV
BH_05_HS_03	15	F	A	BH	ASV
BH_05_HS_04	6.2	M	A	BH	ASV
BH_05_HS_05	8.2	F	A	BH	ASV
BH_05_HS_06	6.2	F	A	BH	ASV
BH_05_HS_07	7.3	M	A	BH	ICP-MS
BH_06_HS_01	31.8	F	A	BH	ASV
BH_06_HS_02	37.3	U	J	BH	ASV
BH_06_HS_03	26.8	U	J	BH	ASV
BH_06_HS_04	23.6	U	J	BH	ASV
BH_06_HS_05	22.6	U	J	BH	ASV
BH_06_HS_06	38.1	M	A	BH	ASV
BH_06_HS_07	60.3	F	A	BH	ASV
BH_06_HS_08	22.4	F	A	BH	ASV
BH_07_HS_01	15.8	F	A	BH	ASV
BH_07_HS_02	22.6	U	J	BH	ASV
BH_07_HS_03	42.5	F	A	BH	ASV
BH_07_HS_06	26	F	A	BH	ASV
BH_07_HS_07	22.4	F	A	BH	ASV
BH_07_HS_11	13.6	M	A	BH	ICP-MS
BH_08_HS_01	62.2	M	A	BH	ASV
BH_08_HS_02	33.1	U	J	BH	ASV
BH_08_HS_03	45.2	F	A	BH	ASV
BH_08_HS_04	30.9	M	A	BH	ASV
BH_08_HS_05	21.1	F	A	BH	ASV
BH_09_HS_01	14.2	M	A	BH	ASV
BH_09_HS_02	8.2	M	A	BH	ASV
BH_09_HS_03	27.9	M	A	BH	ASV
BH_09_HS_04	37.7	F	A	BH	ASV
BH_09_HS_05	29.7	F	A	BH	ASV
BH_10_HS_01	31.5	F	A	BH	ASV
BH_10_HS_02	49.4	M	A	BH	ASV
BH_10_HS_03	25.5	M	A	BH	ASV
BH_10_HS_04	44.3	M	A	BH	ASV
BH_10_HS_05	43.4	M	A	BH	ASV
BH_11_HS_01	19.3	M	A	BH	ASV
BH_11_HS_02	55.7	M	A	BH	ASV
BH_11_HS_03	37	F	A	BH	ASV
BH_11_HS_04	37.7	M	A	BH	ASV
BH_11_HS_05	22	M	A	BH	ASV
BH_12_HS_01	66.7	F	A	BH	ASV
BH_12_HS_02	107.8	M	A	BH	ASV
BH_12_HS_03	54.1	F	A	BH	ASV
BH_12_HS_05	70.1	F	A	BH	ASV
BH_12_HS_06	99.5	M	A	BH	ASV
BH_12_HS_07	85.6	F	A	BH	ASV
BH_12_HS_09	46.1	M	A	BH	ICP-MS
BH_12_HS_22	70.1	M	A	BH	ASV
BH_12_HS_23	29.4	U	J	BH	ASV
BH_12_HS_24	70.1	U	J	BH	ASV
BH_12_HS_25	40.4	F	A	BH	ASV
BH_12_HS_27	36.6	M	A	BH	ASV
BH_12_HS_28	53.5	U	J	BH	ASV
BH_12_HS_29	44.7	U	J	BH	ASV

BH_12_HS_30	46.1	U	J	BH	ASV
BH_12_HS_31	74.9	U	J	BH	ASV
BH_13_HS_01	15.2	U	J	BH	ASV
BH_13_HS_02	48.9	F	A	BH	ASV
BH_13_HS_03	45.2	F	A	BH	ASV
BH_13_HS_04	27.7	M	A	BH	ASV
BH_13_HS_05	47.9	M	A	BH	ASV
BH_13_HS_06	42.9	F	A	BH	ASV
BH_14_HS_01	17.1	F	A	BH	ASV
BH_14_HS_02	9.2	M	A	BH	ASV
BH_14_HS_03	33.8	U	J	BH	ASV
BH_14_HS_04	15	F	A	BH	ASV
BH_14_HS_05	11.7	M	A	BH	ASV
BH_15_HS_01	79.8	F	A	BH	ASV
BH_15_HS_02	64.1	F	A	BH	ASV
BH_15_HS_03	49.9	F	A	BH	ASV
BH_15_HS_04	66.7	F	A	BH	ASV
BH_15_HS_05	66	M	A	BH	ASV
BH_15_HS_08	49.9	M	A	BH	ASV
BH_15_HS_20	40	M	A	BH	ICP-MS
BH_16_HS_01	30.6	M	A	BH	ASV
BH_17_HS_01	17.5	F	A	BH	ASV
BH_17_HS_02	9.2	M	A	BH	ASV
BH_17_HS_03	19.3	F	A	BH	ASV
BH_17_HS_04	18.4	F	A	BH	ASV
BH_17_HS_05	40.4	F	A	BH	ASV
BH_17_HS_06	16.3	F	A	BH	ASV
BH_20_HS_01	23.3	F	A	BH	ASV
BH_22_HS_01	12.2	F	A	BH	ASV
BH_22_HS_02	6.2	M	A	BH	ASV
BH_22_HS_03	25.8	F	A	BH	ASV
BH_22_HS_04	10.4	M	A	BH	ASV
BH_22_HS_05	8.2	M	A	BH	ASV
BH_23_HS_01	17.1	M	A	BH	ASV
BH_23_HS_02	30	F	A	BH	ASV
BH_23_HS_03	27.7	M	A	BH	ASV
BH_23_HS_04	27.1	F	A	BH	ASV
BH_23_HS_05	19.3	F	A	BH	ASV
BH_23_HS_07	15	M	A	BH	ICP-MS
BH_24_HS_01	26.8	M	A	BH	ASV
BH_24_HS_02	20.1	M	A	BH	ASV
BH_24_HS_03	26.6	M	A	BH	ASV
BH_24_HS_04	24.5	M	A	BH	ASV
BH_24_HS_05	26.6	M	A	BH	ASV
BH_25_HS_01	13.5	F	A	BH	ASV
BH_25_HS_02	18.5	M	A	BH	ASV
BH_25_HS_03	16.1	M	A	BH	ASV
BH_25_HS_04	6.2	M	A	BH	ASV
BH_25_HS_05	15	M	A	BH	ASV
BH_26_HS_01	28.8	F	A	BH	ASV
BH_26_HS_02	21.3	M	A	BH	ASV
BH_26_HS_03	26	M	A	BH	ASV
BH_26_HS_04	27.1	M	A	BH	ASV
BH_27_HS_02	17.5	M	A	BH	ASV
BH_27_HS_03	20.7	M	A	BH	ASV
BH_27_HS_04	18.9	F	A	BH	ASV
BH_27_HS_05	18	M	A	BH	ASV
BH_27_HS_06	18.2	U	J	BH	ASV
BH_28_HS_01	39.6	M	A	BH	ASV
BH_28_HS_02	17.3	M	A	BH	ASV
BH_28_HS_03	58	M	A	BH	ASV
BH_28_HS_04	26	M	A	BH	ASV
BH_28_HS_05	68.7	F	A	BH	ASV
BH_29_HS_01	85.6	M	A	BH	ASV
BH_29_HS_02	75.2	F	A	BH	ASV
BH_29_HS_03	66	F	A	BH	ASV
BH_29_HS_04	61.6	M	A	BH	ASV
BH_29_HS_05	98.5	M	A	BH	ASV
BH_29_HS_07	61.6	F	A	BH	ASV
BH_30_HS_01	16.4	M	A	BH	ASV
BH_31_HS_01	30.3	M	A	BH	ASV
BH_31_HS_02	23.1	M	A	BH	ASV
BH_31_HS_03	18.9	M	A	BH	ASV
BH_31_HS_04	18.9	F	A	BH	ASV

BH_31_HS_09	7.6	M	A	BH	ICP-MS
BH_32_HS_03	17.7	M	A	BH	ICP-MS
BH_33_HS_01	15	F	A	BH	ASV
BH_33_HS_02	10.4	M	A	BH	ASV
BH_33_HS_03	7.5	M	A	BH	ASV
BH_33_HS_04	14.6	F	A	BH	ASV
BH_33_HS_05	22.4	U	J	BH	ASV
BH_34_HS_01	32.8	U	J	BH	ASV
BH_34_HS_02	17.3	M	A	BH	ASV
BH_34_HS_03	12.4	F	A	BH	ASV
BH_34_HS_04	48.4	M	A	BH	ASV
BH_34_HS_05	12.4	F	A	BH	ASV
BH_35_HS_01	6.2	U	J	BH	ASV
BH_35_HS_02	6.2	F	A	BH	ASV
BH_35_HS_03	6.2	M	A	BH	ASV
BH_35_HS_04	6.2	M	A	BH	ASV
BH_35_HS_05	7.2	F	A	BH	ASV
BH_36_HS_01	107.8	M	A	BH	ASV
BH_36_HS_02	8.7	M	A	BH	ASV
BH_37_HS_01	35.5	F	A	BH	ASV
BH_37_HS_02	17.5	M	A	BH	ASV
BH_37_HS_03	23.3	U	J	BH	ASV
BH_37_HS_04	27.1	F	A	BH	ASV
BH_37_HS_05	21.6	M	A	BH	ICP-MS
BH_38_HS_01	18.5	F	A	BH	ASV
BH_38_HS_02	10.4	M	A	BH	ASV
BH_38_HS_03	13.5	M	A	BH	ASV
BH_38_HS_04	7	F	A	BH	ASV
BH_38_HS_05	7.2	U	J	BH	ASV
BH_38_HS_17	6.2	F	A	BH	ASV
BH_38_HS_18	7	M	A	BH	ASV
BH_38_HS_19	24.8	U	J	BH	ASV
BH_38_HS_21	18.7	F	A	BH	ASV
BH_38_HS_22	13.3	M	A	BH	ASV
BH_38_HS_23	9.4	U	J	BH	ASV
BH_38_HS_24	14.6	M	A	BH	ASV
BH_38_HS_25	10.1	M	A	BH	ASV
BH_38_HS_26	16.9	F	A	BH	ASV
BH_38_HS_27	16.3	M	A	BH	ASV
BH_39_HS_01	35.9	F	A	BH	ASV
BH_39_HS_02	11.5	U	J	BH	ASV
BH_39_HS_03	19.7	M	A	BH	ASV
BH_39_HS_04	11	M	A	BH	ASV
BH_39_HS_05	16.1	M	A	BH	ASV
BH_40_HS_01	27.1	M	A	BH	ASV
BH_40_HS_02	32.5	U	J	BH	ASV
BH_41_HS_01	26.6	U	J	BH	ASV
BH_41_HS_02	17.1	F	A	BH	ASV
BH_42_HS_01	48.9	M	A	BH	ASV
BH_42_HS_02	53	U	J	BH	ASV
BH_42_HS_03	72.2	M	A	BH	ASV
BH_42_HS_04	69.4	U	J	BH	ASV
BH_42_HS_05	27.9	F	A	BH	ASV
BH_43_HS_01	30.6	F	A	BH	ASV
BH_43_HS_02	19.5	M	A	BH	ASV
BH_43_HS_03	34.1	M	A	BH	ASV
BH_43_HS_04	24.8	U	J	BH	ASV
BH_43_HS_05	47.5	U	J	BH	ASV
BH_44_HS_01	23.6	U	J	BH	ASV
BH_44_HS_02	39.6	F	A	BH	ASV
BH_44_HS_03	26.8	F	A	BH	ASV
BH_44_HS_04	26.3	U	J	BH	ASV
BH_44_HS_05	21.3	M	A	BH	ASV
BH_45_HS_01	24	M	A	BH	ASV
BH_45_HS_02	12.2	M	A	BH	ASV
BH_45_HS_03	25.5	M	A	BH	ASV
BH_45_HS_04	14.2	M	A	BH	ASV
BH_47_HS_01	30	U	J	BH	ASV
BH_47_HS_02	33.1	M	A	BH	ASV
BH_47_HS_03	37.7	U	J	BH	ASV
BH_47_HS_04	47.5	U	J	BH	ASV
BH_47_HS_05	38.1	U	J	BH	ASV
BH_48_HS_01	53	M	A	BH	ASV
BH_48_HS_02	41.7	U	J	BH	ASV

BH_50_HS_01	10.8	U	J	BH	ASV
BH_50_HS_02	12.4	M	A	BH	ASV
BH_50_HS_03	24.3	M	A	BH	ASV
BH_50_HS_04	27.7	M	A	BH	ASV
BH_50_HS_05	20.1	U	J	BH	ASV
CB_01_HS_49	2.6	N/A	N/A	CB	ICP-MS
CB_01_HS_50	2.6	N/A	N/A	CB	ICP-MS
CB_01_HS_52	2.6	N/A	N/A	CB	ICP-MS
CB_01_HS_53	2.6	N/A	N/A	CB	ICP-MS
CB_01_HS_59	2.6	N/A	N/A	CB	ICP-MS
DB_01_HS_67	2.6	N/A	N/A	DB	ICP-MS
DB_01_HS_68	2.6	N/A	N/A	DB	ICP-MS
DB_01_HS_69	2.6	N/A	N/A	DB	ICP-MS
DB_01_HS_70	2.6	N/A	N/A	DB	ICP-MS
DB_01_HS_73	5.4	N/A	N/A	DB	ICP-MS
MI_01_HS_77	12.4	N/A	N/A	MI	ASV
MI_01_HS_78	12.7	N/A	N/A	MI	ASV
MI_01_HS_79	6.7	N/A	N/A	MI	ASV
MI_01_HS_80	7.9	N/A	N/A	MI	ASV
MI_01_HS_81	7.9	F	A	MI	ASV
MI_01_HS_82	7	M	J	MI	ASV
MI_01_HS_83	8.9	F	A	MI	ASV
MI_01_HS_84	7.7	M	J	MI	ASV
MI_01_HS_85	7.2	N/A	J	MI	ASV
MI_01_HS_86	6.2	M	J	MI	ASV
MI_01_HS_87	7.2	M	J	MI	ASV
MI_01_HS_88	6.2	N/A	J	MI	ASV
MI_01_HS_89	6.2	F	A	MI	ASV
MI_02_HS_90	31.5	M	A	MI	ASV
MI_02_HS_91	22	F	A	MI	ASV
MI_02_HS_92	23.3	F	A	MI	ASV
MI_02_HS_93	30.3	F	J	MI	ASV
MI_02_HS_94	22.4	F	A	MI	ASV
MI_02_HS_95	66	F	A	MI	ASV
MI_02_HS_96	38.5	F	A	MI	ASV
MI_02_HS_97	50.4	F	A	MI	ASV
MI_02_HS_98	23.6	M	J	MI	ASV
MI_02_HS_99	18	M	J	MI	ASV
MI_03_HS_00	6.2	M	A	MI	ASV
MI_03_HS_01	7	F	A	MI	ASV
MI_03_HS_02	17.5	F	A	MI	ASV
MI_03_HS_03	6.2	M	A	MI	ASV
MI_03_HS_04	6.4	M	A	MI	ASV
MI_03_HS_05	7.7	M	A	MI	ASV
MI_04_HS_15	23.6	F	J	MI	ASV
MI_04_HS_16	31.8	F	A	MI	ASV
MI_04_HS_19	27.1	F	J	MI	ASV
MI_04_HS_20	29.7	F	J	MI	ASV
MI_05_HS_17	27.7	F	A	MI	ASV
MI_05_HS_18	47.9	F	J	MI	ASV
MI_05_HS_21	37.7	F	A	MI	ASV
MI_05_HS_22	25.8	M	J	MI	ASV
MI_05_HS_23	25.8	F	A	MI	ASV
MI_06_HS_24	52.5	M	A	MI	ASV
MI_06_HS_25	35.5	M	A	MI	ASV
MI_06_HS_26	64.1	F	J	MI	ASV
MI_06_HS_27	41.3	M	J	MI	ASV
MI_06_HS_28	39.6	M	A	MI	ASV
MI_06_HS_29	60.3	M	J	MI	ASV
MI_06_HS_30	58	M	J	MI	ASV
MI_06_HS_31	66	F	J	MI	ASV
MI_06_HS_32	76.7	M	J	MI	ASV
MI_06_HS_33	70.8	F	J	MI	ASV
MI_06_HS_34	107.8	M	J	MI	ASV
MI_06_HS_35	53.5	F	J	MI	ASV
MI_06_HS_36	44.7	F	J	MI	ASV
MI_06_HS_37	62.2	M	A	MI	ASV
MI_06_HS_38	39.3	M	J	MI	ASV
MI_06_HS_39	74.4	F	J	MI	ASV
MI_06_HS_40	55.1	F	J	MI	ASV
MI_07_HS_41	13.7	M	J	MI	ASV
MI_07_HS_42	20.7	F	A	MI	ASV
MI_07_HS_43	9.7	F	A	MI	ASV
MI_07_HS_44	9.7	F	J	MI	ASV

MI_07_HS_45	15.2	M	A	MI	ASV
MI_07_HS_46	10.4	F	J	MI	ASV
MI_08_HS_47	37.7	F	A	MI	ASV
MI_08_HS_48	16.4	F	A	MI	ASV
MI_08_HS_49	11.5	M	J	MI	ASV
MI_08_HS_50	11.9	F	A	MI	ASV
MI_08_HS_51	38.9	F	J	MI	ASV
MI_08_HS_52	12.4	M	A	MI	ASV
CC_01_HS_53	9.2	M	A	CC	ASV
CC_01_HS_54	7.5	F	J	CC	ASV
CC_01_HS_55	12.4	F	J	CC	ASV
CC_01_HS_56	11.5	F	J	CC	ASV
CC_01_HS_57	10.8	F	J	CC	ASV
RM_01_HS_01	6.7	M	A	RM	ASV
RM_01_HS_05	6.2	M	A	RM	ASV
RM_01_HS_08	101.5	M	A	RM	ASV
RM_01_HS_12	9.7	M	A	RM	ASV
RM_01_HS_83	28.5	F	J	RM	ASV
RM_01_HS_84	6.2	M	A	RM	ASV
RM_01_HS_85	13.5	M	A	RM	ASV
RM_01_HS_86	6.2	F	J	RM	ASV
RM_01_HS_87	8.7	F	A	RM	ASV
RM_01_HS_95	8.7	F	A	RM	ASV
TV_01_HS_59	8.2	F	J	TV	ASV
TV_01_HS_60	9.9	M	J	TV	ASV
TV_01_HS_61	10.6	F	J	TV	ASV
TV_01_HS_62	15.5	M	J	TV	ASV

Data S3

Sample ID	Soil Pb (mg/kg)	Location	Method
BH_01_SS_A	339	BH	pXRF
BH_01_SS_B	233	BH	pXRF
BH_01_SS_C	340	BH	pXRF
BH_02_SS_A	556	BH	pXRF
BH_02_SS_B	645	BH	pXRF
BH_02_SS_C	544	BH	pXRF
BH_03_SS_A	661	BH	pXRF
BH_03_SS_B	657	BH	pXRF
BH_03_SS_C	600	BH	pXRF
BH_04_SS_A	764	BH	pXRF
BH_04_SS_B	656	BH	pXRF
BH_04_SS_C	676	BH	pXRF
BH_05_SS_A	193	BH	pXRF
BH_05_SS_B	254	BH	pXRF
BH_05_SS_C	181	BH	pXRF
BH_06_SS_A	575	BH	pXRF
BH_06_SS_B	606	BH	pXRF
BH_06_SS_C	320	BH	pXRF
BH_07_SS_A	226	BH	pXRF
BH_07_SS_B	209	BH	pXRF
BH_07_SS_C	189	BH	pXRF
BH_08_SS_A	211	BH	pXRF
BH_08_SS_B	154	BH	pXRF
BH_08_SS_C	188	BH	pXRF
BH_09_SS_A	408	BH	pXRF
BH_09_SS_B	506	BH	pXRF
BH_09_SS_C	346	BH	pXRF
BH_10_SS_A	422	BH	pXRF
BH_10_SS_B	244	BH	pXRF
BH_10_SS_C	422	BH	pXRF
BH_11_SS_A	607	BH	pXRF
BH_11_SS_B	532	BH	pXRF
BH_11_SS_C	864	BH	pXRF
BH_12_SS_A	367	BH	pXRF
BH_12_SS_B	994	BH	pXRF
BH_12_SS_C	1679	BH	pXRF
BH_13_SS_A	168	BH	pXRF
BH_13_SS_B	214	BH	pXRF
BH_13_SS_C	253	BH	pXRF
BH_14_SS_A	72	BH	pXRF
BH_14_SS_B	82	BH	pXRF
BH_14_SS_C	72	BH	pXRF
BH_15_SS_A	3168	BH	pXRF
BH_15_SS_B	2571	BH	pXRF
BH_15_SS_C	2656	BH	pXRF
BH_16_SS_A	321	BH	pXRF
BH_16_SS_B	530	BH	pXRF
BH_16_SS_C	268	BH	pXRF
BH_17_SS_A	316	BH	pXRF

BH_17_SS_B	387	BH	pXRF
BH_17_SS_C	405	BH	pXRF
BH_20_SS_A	182	BH	pXRF
BH_20_SS_B	161	BH	pXRF
BH_20_SS_C	162	BH	pXRF
BH_22_SS_A	138	BH	pXRF
BH_22_SS_B	139	BH	pXRF
BH_22_SS_C	110	BH	pXRF
BH_23_SS_A	324	BH	pXRF
BH_23_SS_B	104	BH	pXRF
BH_23_SS_C	495	BH	pXRF
BH_24_SS_A	700	BH	pXRF
BH_24_SS_B	727	BH	pXRF
BH_24_SS_C	726	BH	pXRF
BH_25_SS_A	201	BH	pXRF
BH_25_SS_B	188	BH	pXRF
BH_25_SS_C	235	BH	pXRF
BH_26_SS_A	608	BH	pXRF
BH_26_SS_B	498	BH	pXRF
BH_26_SS_C	362	BH	pXRF
BH_27_SS_A	144	BH	pXRF
BH_27_SS_B	186	BH	pXRF
BH_27_SS_C	136	BH	pXRF
BH_28_SS_A	869	BH	pXRF
BH_28_SS_B	1140	BH	pXRF
BH_28_SS_C	3214	BH	pXRF
BH_29_SS_A	1929	BH	pXRF
BH_29_SS_B	1103	BH	pXRF
BH_29_SS_C	1636	BH	pXRF
BH_30_SS_A	595	BH	pXRF
BH_30_SS_B	138	BH	pXRF
BH_30_SS_C	434	BH	pXRF
BH_31_SS_A	305	BH	pXRF
BH_31_SS_B	400	BH	pXRF
BH_31_SS_C	340	BH	pXRF
BH_32_SS_A	233	BH	pXRF
BH_32_SS_B	281	BH	pXRF
BH_32_SS_C	232	BH	pXRF
BH_33_SS_A	127	BH	pXRF
BH_33_SS_B	152	BH	pXRF
BH_33_SS_C	167	BH	pXRF
BH_34_SS_A	148	BH	pXRF
BH_34_SS_B	128	BH	pXRF
BH_34_SS_C	147	BH	pXRF
BH_35_SS_A	57	BH	pXRF
BH_35_SS_B	63	BH	pXRF
BH_35_SS_C	58	BH	pXRF
BH_36_SS_A	215	BH	pXRF
BH_36_SS_B	224	BH	pXRF
BH_36_SS_C	163	BH	pXRF

BH_37_SS_A	71	BH	pXRF
BH_37_SS_B	71	BH	pXRF
BH_37_SS_C	102	BH	pXRF
BH_38_SS_A	175	BH	pXRF
BH_38_SS_B	168	BH	pXRF
BH_38_SS_C	172	BH	pXRF
BH_39_SS_A	422	BH	pXRF
BH_39_SS_B	759	BH	pXRF
BH_39_SS_C	309	BH	pXRF
BH_40_SS_A	456	BH	pXRF
BH_40_SS_B	365	BH	pXRF
BH_40_SS_C	314	BH	pXRF
BH_41_SS_A	447	BH	pXRF
BH_41_SS_B	363	BH	pXRF
BH_41_SS_C	378	BH	pXRF
BH_42_SS_A	1203	BH	pXRF
BH_42_SS_B	1555	BH	pXRF
BH_42_SS_C	996	BH	pXRF
BH_43_SS_A	493	BH	pXRF
BH_43_SS_B	342	BH	pXRF
BH_43_SS_C	481	BH	pXRF
BH_44_SS_A	1503	BH	pXRF
BH_44_SS_B	1070	BH	pXRF
BH_44_SS_C	1183	BH	pXRF
BH_45_SS_A	339	BH	pXRF
BH_45_SS_B	296	BH	pXRF
BH_45_SS_C	321	BH	pXRF
BH_47_SS_A	303	BH	pXRF
BH_47_SS_B	405	BH	pXRF
BH_47_SS_C	304	BH	pXRF
BH_48_SS_A	1025	BH	pXRF
BH_48_SS_B	999	BH	pXRF
BH_48_SS_C	1011	BH	pXRF
BH_50_SS_A	207	BH	pXRF
BH_50_SS_B	163	BH	pXRF
BH_50_SS_C	205	BH	pXRF
CB_01_SS_A	127	CB	pXRF
CB_01_SS_B	135	CB	pXRF
CB_01_SS_C	72	CB	pXRF
DB_01_SS_A	22	DB	pXRF
DB_01_SS_B	24	DB	pXRF
DB_01_SS_C	30	DB	pXRF
MI_01_SS_A	182	MI	pXRF
MI_01_SS_B	200	MI	pXRF
MI_01_SS_C	268	MI	pXRF
MI_01_SS_D	54	MI	pXRF
MI_01_SS_E	99	MI	pXRF
MI_01_SS_F	99	MI	pXRF
MI_01_SS_G	75	MI	pXRF
MI_01_SS_H	250	MI	pXRF

MI_01_SS_I	119	MI	pXRF
MI_02_SS_A	363	MI	pXRF
MI_02_SS_B	602	MI	pXRF
MI_02_SS_C	588	MI	pXRF
MI_02_SS_D	629	MI	pXRF
MI_02_SS_E	671	MI	pXRF
MI_02_SS_F	529	MI	pXRF
MI_02_SS_G	530	MI	pXRF
MI_02_SS_H	597	MI	pXRF
MI_02_SS_I	333	MI	pXRF
MI_03_SS_A	87	MI	pXRF
MI_03_SS_B	103	MI	pXRF
MI_03_SS_C	88	MI	pXRF
MI_03_SS_D	90	MI	pXRF
MI_03_SS_E	126	MI	pXRF
MI_03_SS_F	104	MI	pXRF
MI_03_SS_G	106	MI	pXRF
MI_03_SS_H	61	MI	pXRF
MI_03_SS_I	55	MI	pXRF
MI_04_SS_A	484	MI	pXRF
MI_04_SS_B	551	MI	pXRF
MI_04_SS_C	728	MI	pXRF
MI_04_SS_D	250	MI	pXRF
MI_04_SS_E	351	MI	pXRF
MI_04_SS_F	1531	MI	pXRF
MI_04_SS_G	297	MI	pXRF
MI_04_SS_H	390	MI	pXRF
MI_04_SS_I	803	MI	pXRF
MI_05_SS_A	454	MI	pXRF
MI_05_SS_B	356	MI	pXRF
MI_05_SS_C	1592	MI	pXRF
MI_05_SS_D	600	MI	pXRF
MI_05_SS_E	381	MI	pXRF
MI_05_SS_F	519	MI	pXRF
MI_05_SS_G	828	MI	pXRF
MI_05_SS_H	428	MI	pXRF
MI_05_SS_I	585	MI	pXRF
MI_06_SS_A	985	MI	pXRF
MI_06_SS_B	627	MI	pXRF
MI_06_SS_C	420	MI	pXRF
MI_06_SS_D	947	MI	pXRF
MI_06_SS_E	633	MI	pXRF
MI_06_SS_F	2243	MI	pXRF
MI_06_SS_G	3341	MI	pXRF
MI_06_SS_H	748	MI	pXRF
MI_06_SS_I	2525	MI	pXRF
MI_07_SS_A	278	MI	pXRF
MI_07_SS_B	290	MI	pXRF
MI_07_SS_C	242	MI	pXRF
MI_07_SS_D	177	MI	pXRF

Data S3

MI_07_SS_E	220	MI	pXRF
MI_07_SS_F	175	MI	pXRF
MI_07_SS_G	645	MI	pXRF
MI_07_SS_H	442	MI	pXRF
MI_07_SS_I	172	MI	pXRF
MI_08_SS_A	240	MI	pXRF
MI_08_SS_B	223	MI	pXRF
MI_08_SS_C	233	MI	pXRF
MI_08_SS_D	545	MI	pXRF
MI_08_SS_E	84	MI	pXRF
MI_08_SS_F	503	MI	pXRF
MI_08_SS_G	322	MI	pXRF
MI_08_SS_H	281	MI	pXRF
MI_08_SS_I	292	MI	pXRF
CC_01_SS_A	58	CC	pXRF
CC_01_SS_B	29	CC	pXRF
CC_01_SS_C	38	CC	pXRF
CC_01_SS_D	12	CC	pXRF
CC_01_SS_E	8	CC	pXRF
CC_01_SS_F	76	CC	pXRF
CC_01_SS_G	14	CC	pXRF
CC_01_SS_H	19	CC	pXRF
CC_01_SS_I	20	CC	pXRF
RM_01_SS_D	38	RM	pXRF
RM_01_SS_E	20	RM	pXRF
RM_01_SS_F	39	RM	pXRF
RM_01_SS_G	27	RM	pXRF
RM_01_SS_H	18	RM	pXRF
RM_01_SS_I	28	RM	pXRF
RM_01_SS_A	32	RM	pXRF
RM_01_SS_B	61	RM	pXRF
RM_01_SS_C	104	RM	pXRF
TV_01_SS_A	66	TV	pXRF
TV_01_SS_B	75	TV	pXRF
TV_01_SS_C	63	TV	pXRF
TV_01_SS_D	58	TV	pXRF
TV_01_SS_E	81	TV	pXRF
TV_01_SS_F	371	TV	pXRF
TV_01_SS_G	149	TV	pXRF
TV_01_SS_H	39	TV	pXRF
TV_01_SS_I	48	TV	pXRF

Data S4

Sample ID	Period (days)	Deposited dust Pb (μg/sample)	Deposited dust Pb (μg/m^2/day)	206Pb/ 207Pb	208Pb/ 207Pb	Ore Pb contribution %
BH_02_DD	10	71.5	79	1.0471	2.3204	91
BH_05_DD	19	21.5	13	1.0526	2.3316	74
BH_06_DD	8	126	175	1.0428	2.317	98
BH_15_DD	11	161	163	1.0406	2.3153	102
BH_17_DD	8	44.9	62	1.0428	2.3212	93
BH_26_DD	9	87.2	108	1.0438	2.3225	91
BH_31_DD	8	38.9	54	1.0449	2.3281	84
BH_34_DD	17	7.22	5	1.0515	2.327	80
BH_38_DD	9	51	63	1.0449	2.3229	90
BH_42_DD	8	59.2	82	1.0482	2.3323	77
BH_43_DD	9	100	123	1.0438	2.3215	92
BH_44 _DD	5	74.4	165	1.0438	2.3205	93

Data S5

Sample ID	Combined blood sample count	206Pb/207Pb	208Pb/207Pb	Ore Pb contribution (%)
BH_01_HS	4	1.0593	2.3411	58
BH_02_HS	4	1.0616	2.3408	56
BH_04_HS	3	1.0471	2.3246	86
BH_05_HS	4	1.0661	2.3412	52
BH_06_HS	4	1.0482	2.3218	88
BH_07_HS	4	1.0515	2.326	81
BH_11_HS	4	1.046	2.3232	88
BH_12_HS	4	1.0449	2.3208	92
BH_15_HS	4	1.0417	2.3177	98
BH_17_HS	4	1.073	2.3455	42
BH_22_HS	3	1.073	2.3541	32
BH_25_HS	4	1.0616	2.3386	59
BH_26_HS	4	1.0661	2.3433	50
BH_27_HS	4	1.0604	2.3319	67
BH_28_HS	4	1.0471	2.3257	85
BH_31_HS	4	1.0593	2.3453	54
BH_34_HS	4	1.0471	2.3225	88
BH_35_HS	4	1.0638	2.334	62
BH_37_HS	4	1.0515	2.3312	75
BH_38_HS	4	1.0549	2.3323	71
BH_39_HS	4	1.0537	2.3224	83
BH_42_HS	3	1.0504	2.333	74
BH_43_HS	4	1.0526	2.3326	73
BH_44_HS	3	1.065	2.3376	57
BH_45_HS	3	1.0638	2.3457	49
BH_50_HS	3	1.065	2.3365	58

Data S6

Sample ID	ICP-MS blood Pb (µg/dL)	Unadjusted LeadCare blood Pb (µg/dL)	Natural-log adjusted LeadCare blood Pb (µg/dL)
BH_01_HS_01	62.69	17.3	36.91
BH_02_HS_05	8.37	6.3	16.30
BH_03_HS_05	109.31	45.2	80.31
BH_03_HS_02	34.05	16.8	36.05
BH_04_HS_01	30.91	16.3	35.18
BH_06_HS_08	24.38	9.4	22.53
BH_08_HS_04	37.05	13.9	30.92
BH_10_HS_05	37.14	21.1	43.35
BH_11_HS_01	23.08	7.8	19.37
BH_13_HS_04	18.85	12.1	27.64
BH_14_HS_05	17.91	4.2	11.74
BH_16_HS_01	41.65	13.8	30.74
BH_17_HS_02	11.97	3.1	9.18
BH_22_HS_04	8.9	3.6	10.36
BH_24_HS_01	17.97	11.7	26.90
BH_25_HS_03	12.21	6.2	16.09
BH_26_HS_03	29.95	11.3	26.15
BH_27_HS_03	17.68	8.5	20.77
BH_28_HS_01	43.45	18.9	39.65
BH_29_HS_02	86.52	41.8	75.39
BH_29_HS_03	75.6	35.4	65.90
BH_29_HS_07	66.99	32.5	61.50
BH_29_HS_05	84.02	58.1	98.41
BH_30_HS_01	26.32	6.4	16.51
BH_33_HS_02	8.2	3.6	10.36
BH_34_HS_04	32.84	24.2	48.44
BH_36_HS_02	15.07	2.9	8.70
BH_38_HS_03	11.48	5	13.52
BH_39_HS_03	13.44	8	19.77
BH_41_HS_02	14.65	6.7	17.13

Data S7

Site ID	Location	Year	Longitude	Latitude	EPSG	Distance (m)
BH_01	Broken Hill	2020	141.4668	-31.954	4326	725
BH_02	Broken Hill	2020	141.4621	-31.947	4326	1400
BH_03	Broken Hill	2020	141.483	-31.9474	4326	33
BH_04	Broken Hill	2020	141.4477	-31.972	4326	343
BH_05	Broken Hill	2020	141.4356	-31.9573	4326	2283
BH_06	Broken Hill	2020	141.4569	-31.9868	4326	351
BH_07	Broken Hill	2020	141.4501	-31.9625	4326	919
BH_08	Broken Hill	2020	141.4698	-31.9553	4326	456
BH_09	Broken Hill	2020	141.4744	-31.9428	4326	914
BH_10	Broken Hill	2020	141.4538	-31.9643	4326	539
BH_11	Broken Hill	2020	141.4584	-31.9639	4326	314
BH_12	Broken Hill	2020	141.4615	-31.9748	4326	138
BH_13	Broken Hill	2020	141.4548	-31.9589	4326	954
BH_14	Broken Hill	2020	141.4692	-31.9829	4326	1205
BH_15	Broken Hill	2020	141.4688	-31.9731	4326	393
BH_16	Broken Hill	2020	141.4425	-31.9623	4326	1436
BH_17	Broken Hill	2020	141.4352	-31.9738	4326	808
BH_20	Broken Hill	2020	141.4677	-31.9422	4326	1350
BH_22	Broken Hill	2020	141.446	-31.9438	4326	2787
BH_23	Broken Hill	2020	141.4648	-31.944	4326	1414
BH_24	Broken Hill	2020	141.4432	-31.9744	4326	320
BH_25	Broken Hill	2020	141.4587	-31.9385	4326	2250
BH_26	Broken Hill	2020	141.4424	-31.963	4326	1388
BH_27	Broken Hill	2020	141.4519	-31.9499	4326	1915
BH_28	Broken Hill	2020	141.4716	-31.9785	4326	1019
BH_29	Broken Hill	2020	141.4665	-31.9765	4326	570
BH_30	Broken Hill	2020	141.4539	-31.9538	4326	1460
BH_31	Broken Hill	2020	141.4568	-31.9521	4326	1447
BH_32	Broken Hill	2020	141.4403	-31.972	4326	691
BH_33	Broken Hill	2020	141.4634	-31.9358	4326	2141
BH_34	Broken Hill	2020	141.531	-31.923	4326	4135
BH_35	Broken Hill	2020	141.4328	-31.952	4326	2885
BH_36	Broken Hill	2020	141.4546	-31.9438	4326	2178
BH_37	Broken Hill	2020	141.4729	-31.9412	4326	1135
BH_38	Broken Hill	2020	141.468	-31.9371	4326	1770
BH_39	Broken Hill	2020	141.4735	-31.9812	4326	1109
BH_40	Broken Hill	2020	141.4764	-31.9498	4326	180
BH_41	Broken Hill	2020	141.4712	-31.9409	4326	1252
BH_42	Broken Hill	2020	141.4636	-31.9835	4326	716
BH_43	Broken Hill	2020	141.4852	-31.9444	4326	180
BH_44	Broken Hill	2020	141.4727	-31.9484	4326	561
BH_45	Broken Hill	2020	141.4536	-31.9454	4326	2181
BH_47	Broken Hill	2020	141.4655	-31.9491	4326	1006
BH_48	Broken Hill	2020	141.4471	-31.9735	4326	289
BH_50	Broken Hill	2020	141.4356	-31.9679	4326	1316
CB_01	Cobar	2020	145.8494	-31.4977	4326	N/A
DB_01	Dubbo	2020	148.5961	-32.2433	4326	N/A
MI_01	Mount Isa	2022	139.5026	-20.7297	4326	1796
MI_02	Mount Isa	2022	139.4892	-20.7125	4326	352
MI_03	Mount Isa	2022	139.5029	-20.7173	4326	1773
MI_04	Mount Isa	2022	139.4925	-20.725	4326	815
MI_05	Mount Isa	2022	139.4864	-20.7037	4326	68
MI_06	Mount Isa	2022	139.4879	-20.7188	4326	324
MI_07	Mount Isa	2022	139.4871	-20.7428	4326	249
MI_08	Mount Isa	2022	139.4894	-20.7362	4326	496
CC_01	Cloncurry	2022	140.5125	-20.7052	4326	N/A
RM_01	Richmond	2022	143.1411	-20.7308	4326	N/A
TV_01	Townsville	2022	146.8216	-19.2577	4326	N/A