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SHORT COMMUNICATION

Exploring palaeoecology in the Northern Territory: the Walanjiwurru rockshelter, vegetation dynamics and shifting social landscapes in Marra Country

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Abstract
This paper presents a palynological analysis of sediments from Walanjiwurru 1, a rockshelter located in the Country of the Marra Aboriginal people at Limmen National Park in the Northern Territory (Australia). Analysis seeks to test rockshelter sediments as a framework for research in an environmentally difficult location, and to explore how the palaeoecological record may capture the diversity of people-nature relationships over time in the Northern Territory. The Walanjiwurru 1 pollen record provides an approximate 500-year insight into the rockshelter's surrounding landscape. Two plant communities demonstrate local presence across this time frame—foremost a drier eucalypt woodland, and a wetter fringing *Melaleuca* dominated habitat, each with an integrated series of monsoonal forest taxa. With only subtle shifts in vegetation, the Marra's consistent maintenance of relations with their landscape is observable, and this is discussed in relation to the Walanjiwurru 1's archaeology and regional European settler colonialism. Charcoal recovery from Walanjiwurru 1 is derived from in situ campfires, making it difficult to conclude on the response of plant types and vegetation communities to long-term landscape burning. Future palaeoecological research off-site from the rockshelter has therefore been recommended.

Keywords Pollen · Charcoal · Late-Holocene · Northern Australia · Rockshelter · Collaborative research

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Introduction

Palaeoecology is an emerging discipline within Australia's Northern Territory, 'budding' in comparison to the breadth of research conducted in the east and southeast of the continent (Reeves et al. 2013; Rehn et al. 2021a and see maps presented in Mooney et al. 2011). The role for palaeoecology is to ask what structures the dynamics of current northern Australian environments and how vulnerable are they to tipping points in change. For the Northern Territory specifically, its landscapes reflect more than 60,000 years of cumulative Indigenous engagement and transformation (David et al. 2019), but are subject to the comparatively recent breakdown of long-standing Aboriginal landscape practices following colonial land expropriations, and the partial replacement with those of European land managers, particularly in the area of fire management (Russell-Smith et al. 2003; Ansell et al. 2019). For palaeoecology to more thoroughly explore landscape changes during colonialism is also a valuable undertaking. The Northern Territory savannas are notably facing disproportionally large shifts in ecosystem properties (Laurance et al. 2011; Bergstrom et al. 2021) and

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within these temperate Australian understandings of environmental function, people-environment relationships, and implications for land-use and land-management, are simply not applicable to these northern, monsoonal environments.

The complication facing palaeoecology is that the Northern Territory presents a difficult research location. The terrain's remoteness of access, together with the age and geological stability of the landscape and contrasting seasonal climate have created poor conditions for organic preservation, which have inhibited widespread development and investigation of sites suitable for time-depth investigations. What is evident therefore in current efforts to build the discipline, is the use of less traditional site types, namely caves/rockshelters (Clarkson and Wallis 2003; Rowe et al. 2020) and sinkholes (Rowe et al. 2019, 2022; Rehn et al. 2021b), both protected environments allowing soft sediments (and potentially, preserved pollen and microcharcoal) to accumulate in good chronostratigraphic order. Caves/rockshelters and sinkholes are both found in physiographically different environments from lakes and swamps, providing valuable palaeoecological potential (Rowe et al. 2020). Sandstone rockshelters are by far the most prevalent stratified archaeological site type that undergo archaeological excavation in the Northern Territory (cf. Jones 1985; Clarkson et al. 2017; David et al. 2019). Camacho et al. (2000) and Rowe et al. (2020, 2022) provide discussion on the interpretation of micro-botanical proxy assemblages from rockshelters and sinkholes, and outline the considerations required in how varied proxy types reach and are incorporated into such sites, including the balance required in researching cultural introductions, as well as differential particle preservation verses destruction properties.

This paper adds to the experimental yet foundational methodology of rockshelter use for palaeoecological reconstructions through analysis of sediments from the Walanjiwurru 1 site, of the Walanjiwurru area located in the Country of the Marra Aboriginal people at Limmen National Park in the Northern Territory's southwestern Gulf of Carpentaria region. For palaeoecology, Walanjiwurru is located within a new mainland study region of the Northern Territory. However, this opportunity provides more than just a practical research option capable of filling a geographical gap. It provides a valuable opening toward exploring how vegetation communities and/or ecological resources form part of Aboriginal social landscapes, and whether plant-themed philosophies and relational-engagements that underpin lifeways in the region are apparent when interpreting palaeorecords. Walanjiwurru forms part of a developing collaborative research project between the area's Traditional Owners, their communities, and university researchers. This project represents the first archaeological research to be undertaken in this region and thus far has explored ancestral geographies and cultural places, the nature of 'contact' with European pastoralists, and the role of rock art as a marker of interregional interaction (Brady et al. 2019, 2020, 2022; Ash et al. 2022). This project also benefits from an extensive body of ethnographic data collected from Marra people over 40 years (see Bradley 2018 for a review). Such data adds a critical component to positioning the archaeology within its ethnographic contexts. This palynological trial is the first step toward providing an additional, aligned dimension to the project's interests in generating new knowledge about the archaeology of the mainland southwest of the Gulf of Carpentaria. It also adds to Traditional Owner interests in using archaeological research to contribute to the production of a plan of management for Limmen National Park, while sharing that knowledge with future generations. Where contemporary Marra interpretations of the archaeological record are emphasized, the palaeoecology will also be embedded into this framework of contemporary engagement with research results. This paper serves as a dual first step; testing rockshelter sediments as a framework for research in an environmentally difficult location, and targeting broader interests in the palaeoecological record to capture the diversity of human-nature relationships in the Northern Territory.

Study context: site description and the archaeological excavation

The Walanjiwurru 1 rockshelter is located approximately 58 km inland from the southwestern Gulf of Carpentaria coast, situated within Limmen National Park, 1 km west of the Limmen River and 90 km south of the Roper River (Fig. 1). It is in Marra Country, one of four language groups of the southwest Gulf land-and-sea region, and is associated with the Mambali clan. The site consists of two interconnecting, east-facing and slightly inward-sloping sandstone overhangs and was created in the Ancestral Past by the actions of two Taipan snakes (Karrimala). A range of cultural materials feature, including an extensive rock art assemblage, grindstones, flaked stone artefacts, Cypress Pine (*marnunggurrun*, *Callitris intratropica*) logs that display cut marks, and European-contact period artefacts including stone, glass, and metal fragments (see Brady et al. 2019; Ash et al. 2022).

The study region is highly variable in climate and structural geology. The geology has been extensively investigated as part of the Northern Territory Geological Survey (Ahmad and Munson 2013) and Cuff et al. (2009) detail the major landform-land unit patterns. Inland uplands (hinterlands) comprise undulating terrain with scattered, steep hills and a dissected plateau. These merge into lower rises, coastal terraces, alluvial plains, and tidal flats (Baker et al. 2005). Walanjiwurru 1 is situated in an elevated area of linear ridges with intervening colluvial slopes and alluvial corridors (Aldrick and Wilson 1990; Ash et al.

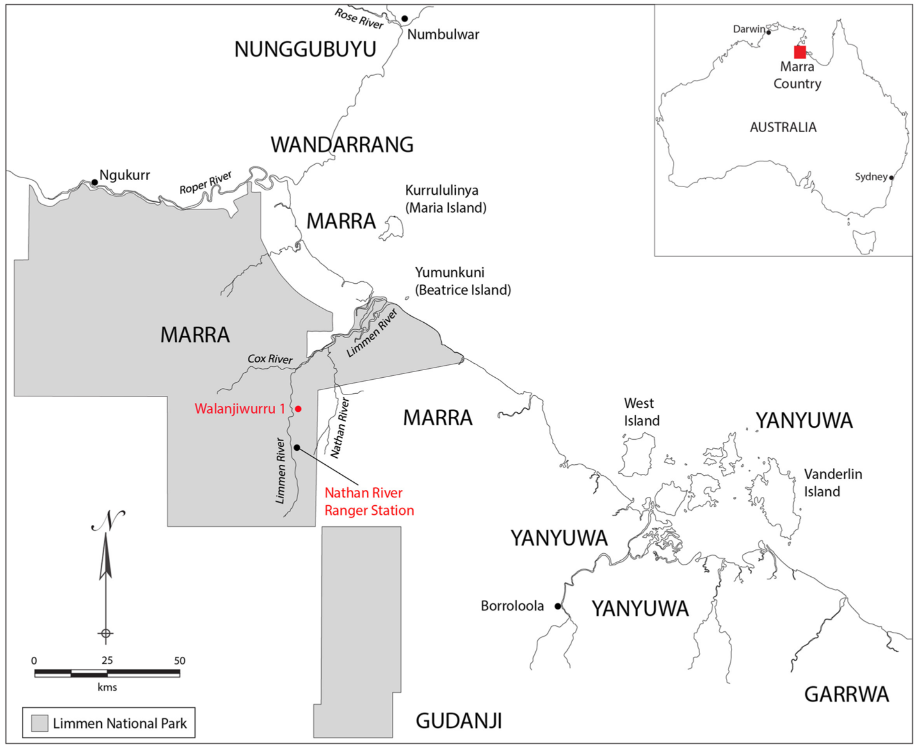


Fig. 1 Location map showing language group distribution in the southwest Gulf of Carpentaria and location of the Walanjiwurru 1 rockshelter in Marra Country

2022). In 2019, an excavation was undertaken within the larger of the two shelters, measured as ca. 7 m deep, 10 m wide and 5 m high. Boulders at the northern and southern ends frame a central area of flat sandy floor (Fig. 2). The southwest Gulf region experiences a tropical semi-arid monsoonal climate with strongly seasonal rainfall and uniformly high temperatures. The region is subject to a range of fluctuating conditions as it sits in a transitional area between Australia's Tropical Savanna and Hot Grassland (winter drought) climatic zones (Stern et al. 2000; Bureau of Meteorology 2011; modified classifications of the Köppen global scheme).

Thirty-five regional vegetation communities have been recognised and described by Aldrick and Wilson (1990), also reported on by Cuff et al. (2009) and further mapped by Fox et al. (2001). Coastal vegetation is dominated by mangroves and bare tidal flats with near coastal plains, lower slopes and drainage depressions showing a predominance of *Melaleuca* woodlands. Upland *Eucalyptus/Corymbia* vegetation communities are extensive and occupy the rocky plateau and ridges of the Walanjiwurru site area (Fig. 2); canopy taxa include, *C. dichromophloia*, *C. terminalis*, *E. miniata*, *E. tetrodonta* and *E. leucophloia;* note 'eucalypt' is used as a collective term referring to both *Eucalyptus* and *Corymbia*, following Ladiges et al. (1995). Variation in ground flora and/or the sub-canopy shrubby mid-storey within eucalypt communities reflects fire-regime, degrees of soil development and the influence of water-table fluctuations (Baker et al. 2005). Monsoonal vine forest associations are of regional importance with respect to floristic diversity and provide significant refugial habitats. These have restricted occurrences, often in positions protected from fire, those with a direct water supply and/or available soil moisture (Baker et al. 2005). Cuff et al. (2009, p 162) describe wetland systems as 'a prominent component of the regional vegetation mosaic' and the southwest Gulf, in particular in the Limmen River region, is known for an occurrence of freshwater springs (CSIRO 2009; of note is that the Limmen River region was the site of the area's first pastoral station in 1884, named 'Valley of Springs', Brady et al. 2022). A year-round freshwater spring is located within approximately 200 m south of the study site (Fig. 2). A fire history spanning 2000–2019 based on the Northern Australian Fire Information (NAFI 2020) dataset reveals a burning frequency of 2–5 years across a ~ 10 km^2 grid surrounding Walanjiwurru, considered typical of the northeastern Northern Territory-Gulf coast (Russell-Smith and Yates 2007).

Pollen and microcharcoal examination: methods

A 1 × 1 m pit (Walanjiwurru 1, Square A) was excavated in July 2019 using archaeological techniques described in Ash et al. (2022). Excavation was in average 2.1 cm excavation unit (XU) divisions within stratigraphic units (SU) and sub-units, up until intruding rocks closed out the sediment profile (68.2 cm deep). Ash et al. (2022) provide a detailed description of stratigraphy. A bulk sediment sample for soil

Fig. 2 Study site and surroundings: **a** near-site environment with Walanjiwurru 1 at left of photo; **b** internal view of the Walanjiwurru 1 rockshelter with excavation pit; **c** view upslope facing Walanjiwurru 1 rockshelter; **d** intervening lowland landscape, looking south. Photos provided by author LMB

and palynological analyses was collected from each XU; however only the main SU sequence was chemically processed for pollen. Other SU sub-units, associated with two combustion features (hearths), were eliminated from the pollen study because the precise chronostratigraphic relationships of these minor units to the principal unit were unclear at the time of analysis.

Standard chemical treatments were undertaken on 2 cm^3 sediment subsamples ($Na_4P_2O_7$, KOH, HCL, the acetolysis method and C_2H_5OH washes; see also Bennett and Willis 2001), incorporating sieving at 7 µm and 125 µm and *Lycopodium* spike addition (Lund University batch 3862). Final residues were mounted in glycerol. Pollen sums are a minimum of 100 grains per sample with grains described based upon regionally representative floral collections (CR), online resources including the Australasian Pollen and Spore Atlas (http://apsa.anu.edu.au/), references such as Brock (2001), and sources such as FloraNT (http://eflora.nt.gov.au/). Local plant collections and documentation of plant identifications, associations and habitat types were undertaken for the research of Walsh (2021) by Marra Rangers Shaun Evans and David Barrett, and James Vincent (botanist and former Senior Ranger based at the Nathan River Ranger Station, Parks & Wildlife Commission of the Northern Territory). Microcharcoal particles (black, opaque, angular, > 10 µm in length) were counted simultaneously with the pollen. Data were plotted using TGView (Grimm 2004) and a stratigraphically constrained dendrogram was produced via CONISS (Grimm 1987, 2004).

Radiocarbon dates and archaeological chronological division of the Walanjiwurru 1 Square A sequence (summarised in Table 1) were taken from Ash et al. (2022) as interpretative guidelines for this study. Changes in the stone tools (raw materials, treatment and technology) have been used to describe distinct phases of Marra activities as undertaken at Walanjiwurru 1 through the late Holocene and into the historical past. These phases are also summarised in Table 1.

Pollen and microcharcoal examination: results

At Walanjiwurru 1, pollen recovery decreased with depth. Good pollen preservation and statistically appropriate concentration is limited to the upper 12 XUs, corresponding to approximately the past 500 calibrated years. Between XU13 and XU15 (> 493–286 cal BP), pollen is recorded in a presence-absence format only. Through deeper remaining XUs, pollen grains were degraded, contorted and increasingly sporadic. Results are presented in Fig. 3, divided into four distinct pollen-plant zones and corresponding to archaeological phases 2 and 3 (Ash et al. 2022, Table 2).

In summary, thirty-one pollen types were identified, representing a wide range of plant taxa. The assemblage predominately reflects the immediate site-surrounding rocky ridgelines and outcrops extending out to the sloping corridors facing the orientation of the rockshelter. A smaller pollen signal from the nearby spring and/or wetter drainage lines has also been captured. The assemblage is dominated (up to 80%) by the Myrtaceae family (incorporating

Table 1 Interpretative guidelines: Radiocarbon sample results and calibrated age ranges from Walanjiwurru 1 Square A, alongside archaeological assemblage phases used to describe Marra activities (adapted from Ash et al. 2022)

Stratigr. units (SU)	Excavation units (XU)	^{14}C age (with XU)	Age-range, cal BP (median)	Archaeol. phase	Site activities interpretation summary
6 to 4a	9a to 15a	296 ± 28 (11a)	> 443–286 (371) to 305–6 (194)	2	Range of stone raw materials indicates open and established social networks
3 to 1	8a to surface	222 ± 27 (8a)	< 305–6 (194) onwards	3	Makassan and/or European colonization signatures (glass and metal artefacts appear). Shift in raw materials, to focus on locally available resources

No pollen was preserved in the lowermost Phase 1 sediments (dating to ca. 2,200–2,300 cal BP); this early phase is therefore not described here

Western colonial presence is estimated from AD 1845 (being the year explorer Ludwig Leichhardt first passed through the study region). Earlier dates for the introduction of non-Aboriginal cultural items are likely owing to histories of Makassan trepang gathering in the Gulf of Carpentaria

Eucalyptus, *Corymbia* and *Melaleuca* pollen). All other taxa were recorded under 20% and notably 10% of the pollen sum.

Microcharcoal particles were observed throughout the sequence and did not appear to deteriorate until XU15 (onwards). Increased deposition was recorded in XU4, 5, 8, 12 and was most prominent in XU6 (< 200 calibrated years). Overall, microcharcoal values rise and fall with greater fluctuation spanning XU6–XU14. Concentrations of microcharcoal above XU6 progressively decline through to the surface.

Discussion and outlook

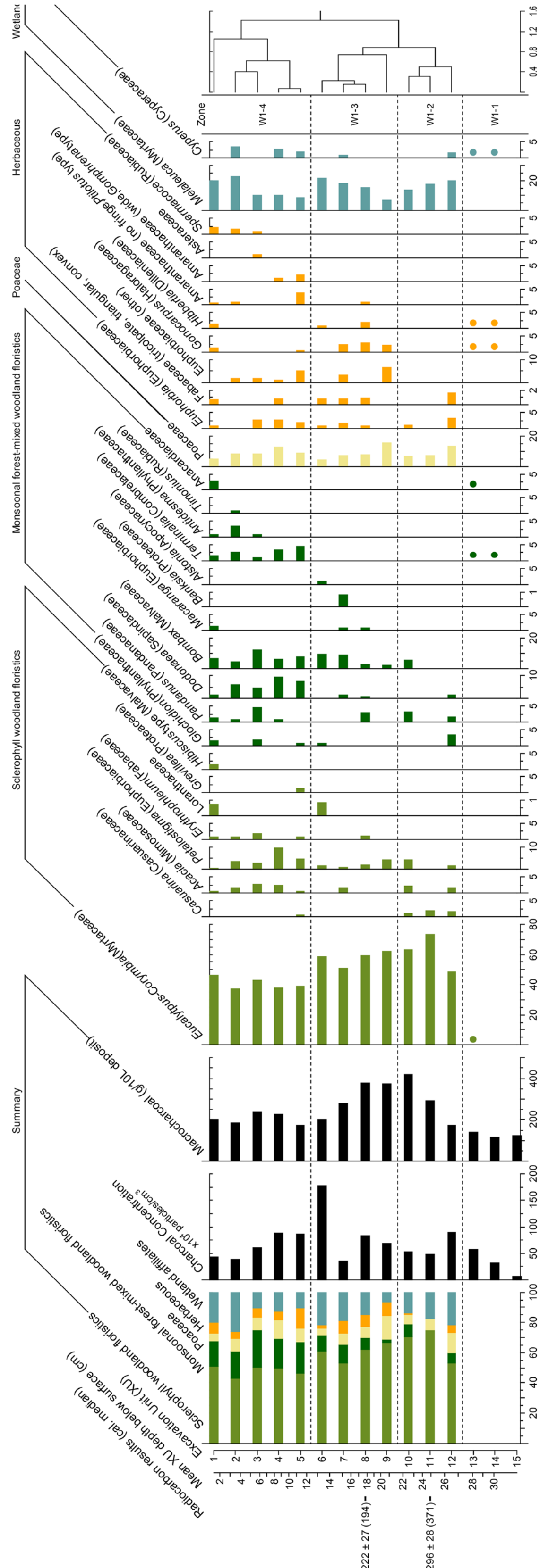
The Walanjiwurru 1 pollen record provides an approximate 500-year insight into the rockshelter's surrounding vegetation landscape. Two plant communities maintained local presence across this time frame: foremost a drier eucalypt woodland, and a wetter fringing *Melaleuca* dominated habitat. Monsoonal forest associations (including vine-forests and vine-thickets) do not appear to have been a discrete vegetation type, but rather an integrated series of taxa, having contributed to a mixed mid-stratum of trees and shrubs within the eucalypt canopy. Forest and/or thicket related taxa may have been positioned so as to merge toward and into the wetter *Melaleuca* growth, establishing an understorey ecotone between the two major plant communities, and therefore forming a local landscape feature in this way. The bulk of vegetation compositional change around Walanjiwurru 1 occurred within this mid-stratum woody sub-canopy, also evident in a shifting suite of herbs located amongst the grasses. That herbs occupied the cracks and fissures across rocky scree is also a possibility; this maintained proximity to the rockshelter for moisture and landscape-fire protection. Poaceae pollen values indicate open grassland ecosystems were not present within the catchment in the past 500 years. No long-distance coastal pollen has been captured within the sediment sequence.

Plant shifts in the record were subtle. We suggest that a change-and-response pattern revolved around fluctuations in *Eucalyptus* and *Corymbia* presence, notably the opportunities afforded by canopy reduction. The dominant *Eucalyptus*-*Corymbia* pollen demonstrates woodlands remained structurally stable overall, equally reflected in the almost uniform eucalypt versus Poaceae balance. Grass cover declined relative to increased eucalypt cover prior to the onset of European disruptions to the landscape, from the early 1870s onwards (see Brady et al. 2022 for a historical overview). With a slight eucalypt decrease after AD 1845, grasses expanded. Greater secondary, mid-understorey tree taxa and mixed shrubs (both sclerophyll and forest affiliated) also coincided with decreased eucalypts after AD 1845, suggestive of not only tree-grass competitive dynamics but also eucalypt-non-eucalypt woody competition. It is interesting to see a stronger *Eucalyptus*-*Corymbia* co-existence with *Bombax* and *Terminalia*, than with sclerophyll components such as *Erythrophleum*. Taxa including *Acacia*, *Petalostigma* and *Dodonaea* comprised the shrub layer, and were always present in some form.

A herbaceous shift after ca. 493 cal BP toward open-canopy and dry adapted taxon inclusions (e.g., from damp-situated *Gonocarpus* to an assemblage including Amaranthaceae saltbush types and Asteraceae) is associated with the upper decline in eucalypt cover. An intermingling of moist to dry undergrowth patches through time is therefore indicated, noting that total woody composition does not indicate any drying significant enough to influence tree and/or shrub turnover.

Walanjiwurru 1's nearby spring remained consistent enough to have maintained a *Melaleuca* community throughout the record. The periodic presence of taxa such as

Fig. 3 Walanjiwurru 1 percentage pollen diagram plotted against ▶ depth, radiocarbon results, and excavation units. All individual taxon percentages are derived from the total pollen sum. The taxonomic level at which grain identification was most confident is that provided first. Macrocharcol data has been provided by Ash et al. (2022)



Pandanus, *Banksia*, *Casuarina* and *Cyperus* may represent temporary expansions and diversification in surface water availability and wetter-land ecosystem(s). Whether or not the spring-wetland was able to provide fire protection as an added function to facilitate plant complexity and density is unclear at this stage in the research. As discussed by Rowe et al. (2020) and Wallis (2000, 2001), wetland environments contain important economic and/or subsistence plant taxa and therefore their pollen needs to be considered also as potential cultural representatives within the assemblage.

There is no obvious correlation between the pollen and microcharcoal results in Fig. 3, making it difficult to conclude on the response of any particular plant type or whole vegetation community to fire as a form of widespread disturbance or long-term landscape influencer. Microcharcoal concentrations correlate with Ash et al. (2022, Fig. 8; included here in Fig. 3) macrocharcoal recovery to within the upper 15 XUs (recovery labelled as cultural). In turn, high proportions of heat-altered stone artefacts were also recorded after 493 cal BP and Ash et al. (2022) theorize on campfire maintenance and/or cooking fires as repeatedly built up on the Walanjiwurru rockshelter floor. Vannieuwenhuyse et al. (2017) provide additional guidance by discussing the nature of rockshelter burnt bedding deposits and their anthropogenic origin. Therefore, in the majority, microcharcoal at Walanjiwurru 1 is seen as derived from in situ campfires. Any capturing of off-site burning is likely only a small (and overwhelmed) proportion of the results. Wallis (2000) makes the same conclusion in micro-particle analyses from rockshelters based in Western Australia. Onsite rockshelter campfires may also have contributed to Walanjiwurru 1's lesser and/or damaged pollen recovery.

In looking ahead, this 500-year rockshelter experiment and early-stage collaboration provide three valuable insights. Firstly, it is through rockshelter sedimentary evidence that paleoecology can start to explore the Northern Territory's escarpment plateaus (e.g., Arnhem Plateau), following therefore the natural progression from plateau to lowland to coast, eventually allowing for an ordered geo-temporal overview of landscape changes and the complex relationships between plants and their environment in this part of Australia (cf. Brock 2001). Secondly, with multidisciplinary study of rockshelter sequences, rounded understandings can be pieced together of sequences in people's activity and changing ecological context (cf. Hunt and Fiacconi 2018). From the archaeological viewpoint of Ash et al. (2022), greater Marra community reliance on local environments

Table 2 Walanjiwurru 1 Square A pollen zone summary (bss refers to below sediment surface)

Pollen zone	Pollen assemblage	Charcoal trend
Zone 4 XU5-XU1 11.46–1.43 cm bss	Eucalypt pollen declines in this zone (but remains dominant) in combination with a rise in other woody taxa, comparative to proportions of herbs and grass pollen. *Petalostigma*, *Bombax*, *Dodonaea* and *Terminalia* pollen are the most notable among the non-eucalypt types. *Melaleuca* values fall and rise. Sedge pollen increases but remains patchy sample-to-sample	Step-wise, concentrations decline from their previous peak toward the surface
Zone 3 XU9–XU6 20.81–13.41 cm bss	Eucalypt pollen consistently maintains high proportions in this zone. Smaller trees, representative of an understorey, are mostly sporadic (*Acacia*, *Erythrophleum*, *Glochidion*, *Pandanus*, *Banksia*, *Alstonia*). *Petalostigma*, *Bombax*, *Donodaea* and *Macaranga* pollen types are more constant. *Casuarina* pollen is now absent. Poaceae pollen declines slightly (to 4%) as herbaceous types rise and diversify. *Melaleuca* values return to near 20% and sedges remain minor	Higher volumes recorded, peaking in XU6. Greater fluctuation evident between samples in this zone
Zone 2 XU12–XU10 26.51–22.41 cm bss	Improved pollen grain quality from W1-1. Dominated by eucalypts (up to 73% pollen sum) with peak canopy at XU11. Mixed secondary tree-shrub pollen (all < 10%) includes ongoing *Casuarina*, but patchy *Acacia*, *Petalostigma*, *Glochidion*, *Pandanus*, *Dodonaea* and *Bombax*. Poaceae values average 9%, without extensive sedge and herb co-occurrence. *Melaleuca* pollen is common (up to 20%, declining across the upper zone boundary)	Rise in charcoal from W1-1 initially continues, then steadies
Zone 1 XU15–XU13 31.47–28.06 cm bss	Poor pollen condition and recovery. Where present, sclerophyll woody taxon types consist of eucalypts, mixed with *Terminalia* and Anacardiaceae representatives. Herbaceous pollen types area recorded in favour of grasses	Lowest recorded particles in this zone; increasing pattern on approaching the W1-2 boundary

and raw materials occurred in the recent past compared to further back in time. Ash et al. (2022) also place Walanjuwurru 1 near long-term well-used walking routes. The pollen is able to link this finding with sclerophyll woodland; not lacking plant diversity but stable in terms of a dominant *Eucalyptus-Corymbia* presence and their influential role on variations in other taxa. Walanjiwurru 1's water availability and ongoing wetter-land habitats have also been indicated, highlighting landscape resources. Thirdly, to have been able to provide palaeoecological detail for the past 500-year time window is highly unique. For example, such resolution has not been captured in pollen records from the three nearest Holocene study sites, despite their 'traditional' lake site types (central Gulf lowlands and offshore islands: Shulmeister 1992; Prebble et al. 2005; Rehn et al. 2021b; Rowe et al. 2022). This period of the very late Holocene has also been largely overlooked in early archaeological investigations in favour of searching for longer chronologies, however with recent studies in Arnhem Land shifting this focus to the recent past (Shine et al. 2013, 2015, 2016; Wesley et al. 2018a, b). Understanding the dynamics of Indigenous society and interactions with regional and local palaeoecology is important when there were significant influences driven by external cultural contact (e.g., Makassan trepang contact and European incursions). With nineteenth century European colonisation of Northern Australia, patterns of Indigenous settlement and land management changed. Pastoralism most rapidly impacted the management of Country in the Northern Territory, but even in areas never permanently settled by Europeans, still the disrupted cultural, economic and social situations meant that people left their Country, or were removed, and customary practices were altered (Woinarski et al. 2007). All of the mainland southwest Gulf was subject to settler colonialism. What is clear from Ash et al. (2022) discussions is the colonialism impact as evident in stone artefact raw materials, but at the same time the Marra's attempts toward maintaining a degree of attachment to place and people, even if only local to sites such as Walanjuwurru 1. When viewed in conjunction with the palaeoecological data, this striving towards maintenance of relations with landscape (albeit reduced) is observable in management consistency, in only subtle shifts in vegetation. It may be viewed in a similar way to the proposals of Head and Fullagar (1997); that is, an archaeological 'event' may be more of a palaeoecological 'process'. Therefore it follows that broad, blanket statements about post 1840s alterations in southwest Gulf environments will likely miss a greater mosaic effect from adjusted relations with landscapes, both changed and continued. That is, if places like Walanjiwurru reflect how the Marra managed colonialism, it may also be expected that other parts of the Country reflect this less, evidenced therefore in sharper vegetation shifts. Modern observational environmental accounts are able to document the biodiversity and environmental-health legacy now left behind by Indigenous dispossession (Burrows et al. 2006; Bird et al. 2013), but it remains important to investigate further to directly chart through palaeoecology the switch in ecological systems arising from colonial settlement.

Conclusion

In conclusion, one methodological recommendation can be made (see also Rowe et al. 2020). Hope (1982) argues that discrete archaeological pollen deposits are more reliably interpreted if there is a regional off-site pollen sequence with which they can be compared. Hunt and Fiacconi (2018) also advocate for paired and comparative pollen studies. While gains have been made, for Walanjiwurru it is suggested off-site palaeoecological sampling options be explored. With additional sources of data for comparison, regional to local palaeovegetation and landscape resource interpretations would be strengthened, and palaeoclimate information added. Importantly though, a multi-scalar approach will expand the collaborative, interpretative and applied framework for Marra Traditional Owners. Providing a detailed 500-year time window has been a unique aspect of this study. Sampling away from direct community settlement and/or high use locations will be important to provide a record of landscape fire history in particular, and in doing so, better narrow the ecological nature of contact with European pastoralists and ensuing shift in environmental-social-landscapes and relational values.

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Declarations

Conflict of interest The authors have no competing interests to declare.

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