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Gleaning the Rocky Shore? 2500 Years of Coastal Resource Use at Red Bluff 1, GunaiKurnai Country, SE Australia

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ABSTRACT

Shell middens in Gippsland along the eastern half of Victoria's coastline have usually been characterised as small, short-duration camp sites with relatively low shell densities and low taxonomic diversity. Here we present new excavation results from a dense, high-diversity site at Red Bluff near the eastern end of GunaiKurnai Country, a location that features the first intertidal rocky platform habitat between Wilsons Promontory in the west and Cape Conran in the east (a distance of 230 km). We found that the climbing sand dune at Red Bluff began to accumulate c. 2500 cal BP, and that over the past c. 1000 years in particular, the Old Ancestors kept the dune environment relatively open through cultural burning, repeatedly camping on the dune to obtain a range of resources from the adjacent rocky shore and sandy beach, estuary and river mouth. These resources include a broad range of shellfish taxa consistently dominated by high numbers of *Mytilus planulatus* and *Lunella undulata* and small to medium-sized fish, probably from rock platforms and sandy shallows, processed with locally sourced stone artefacts. Although exhibiting a degree of similarity in the harvesting of specific mollusc taxa through time, there is notable variability in taxonomic richness and diversity that emphasises differences in subsistence activities and an active engagement with structurally complex nearshore environments.

Résumé

Les amas coquilliers de Gippsland, le long de la moitié orientale du littoral de l'Etat/la région de Victoria, ont généralement été décrits comme de petits campements éphémères, caractérisés par une faible densité de coquillages et une faible diversité taxonomique. Nous présentons ici les résultats de nouvelles fouilles menées sur un site riche en biodiversité situé à Red Bluff, près de l'extrémité orientale du territoire GunaiKurnai. Ce site abrite la première plateforme d'habitat rocheux en zone intertidale entre

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Wilsons Promontory à l'Ouest et Cape Conran à l'Est (distance de 230 km). Nos résultats indiquent que la dune de sable de Red Bluff a commencé à se former il y a environ 2500 ans. Et, durant le dernier millénaire, les Ancêtres ont su maintenir l'environnement dunaire relativement ouvert par des feux dirigés, campant régulièrement sur la dune pour exploiter diverses ressources provenant du rivage et de la plage de sable adjacents, de l'estuaire et de l'embouchure du fleuve. Ces ressources comprennent une grande variété de mollusques, dominée par une forte concentration de *Mytilus planulatus* et de *Lunella undulata*, ainsi que des poissons de petite et moyenne taille probablement issus des criques et des zones sableuses peu profondes, transformés à l'aide d'outils en pierre d'origine locale. Bien que la récolte de certains mollusques présente une certaine similarité au fil du temps, la richesse et la diversité taxonomiques varient considérablement, soulignant les différences dans les modes de subsistance et l'interaction avec des environnements côtiers complexes.

1 | Introduction

Today, east of Melbourne—the capital of the State of Victoria in southeastern Australia—the coastal traveller encounters a broad diversity of habitats dominated by expansive beaches and near-shore lakes and lagoons often rich in wildlife, especially bird life. Taking the slower route along the coast, the remains of past camping activities, some dating back thousands of years, can be seen on the ground or lie buried deeper underfoot. Many of these ancient traces are shell 'middens' of varying density, structural complexity, and spatial spread. Relating to subsistence, these archaeological sites often consist of single shellfish species, especially those that lie along the outer dune sequences facing the open sea (Bass Strait) to the south. Those that lie more protected in and around the coastal lakes tend to contain a greater range of shellfish species, yet even here the individual middens tend not to be very large nor very dense, again often reminiscent of single meals or of infrequent returns. But along this long coastline, there is a major exception to this pattern: the long, dense and multi-layered shell midden complex at Red Bluff, near Lake Tyers, towards the eastern end of GunaiKurnai Country (Figure 1). Here, the shell deposit is exposed in the c. 2.5 m-tall profile of the dune, as years of undercutting and dune collapse from marine erosion have truncated layer upon layer of buried archaeological deposit along the dune face.

The expansive and dense shell midden complex at Red Bluff contrasts with the mostly smaller and sparser middens found along hundreds of kilometres to the west, making us wonder: what happened here? Why so many shells in this particular location? What did the Old Ancestors do here, and when? What subsistence activities did they practise over what appear to be many repeated returns? These are the questions we address in this paper by taking a collaborative approach that gives voice to both local cultural and zooarchaeological knowledge and enquiries (see, for example, GunaiKurnai Land and Waters Aboriginal Corporation et al. 2020; Rogers, David, et al. 2025).

1.1 | Background to Victorian Coastal Archaeology

Over some 60 years of research along the Victorian coast, based on a combination of site-specific analyses (e.g., Gaughwin and Brennan 1986; Zobel et al. 1984), regional studies (e.g., Coutts 1967; Frankel et al. 1989; Hotchin 1990; Richards 2012; for southern NSW, see Sullivan 1982) and broader syntheses (e.g., Bird and

Frankel 1991; Coutts 1981; Fresløv and Frankel 1999), a general characterisation of coastal occupation and resource use has emerged from the literature.

With a small number of notable exceptions, such as Seal Point at Cape Otway (Lourandos 1980, 1983) and Cape Bridgewater further to the southwest (Richards and Johnston 2004), in Eastern Maar and Gunditjmarra Country, respectively (both in western Victoria), shell deposits across Victoria have been characterised by archaeologists as small and/or comprised of thin, patchy layers of low-density shell, with the archaeological evidence for coastal occupation being thinly spread and fairly homogenous (e.g., Frankel 2017, 38; Frankel et al. 1989, 17).

In the available Victorian archaeological literature (see Supporting Information 1), local coastal productivity is often assumed to be the main determinant of site density and species representation at a site. In sites along rocky shores, there is thus usually a predominance of rocky shore species, and in sites near expansive sand beaches, sandy shore bivalves such as *Latona deltoidea* (the common pipi) commonly occur (Frankel et al. 1989, 17; Fresløv and Frankel 1999, 251). Changes identified in species and habitat exploitation in stratigraphic profiles are usually explained by shifting environments such as those caused by climate change or coastal siltation from more inland land practices (Coutts 1967; Hotchin 1990), or by changes in the way people organised their daily lives and annual routines for subsistence ('logistical reorganisation') as a result of environmental change, population increase, technological innovation or changing social arrangements (Zobel et al. 1984; although for NSW, see Mackay and White 1987; Sullivan 1982; 1987). In most of these scenarios, archaeologists have traditionally viewed the role of coastal resources to have been minor in settlement-subsistence decision-making relative to that of primary resources acquired from terrestrial and wetland ecosystems, with marine molluscs (shellfish and other soft-bodied marine fauna) contributing only a small dietary component. In this case, the coast formed only a minor environment from which subsistence resources were acquired, with broader economic strategies revolving around resource productivity further inland (where larger-bodied fauna, such as kangaroos and wallabies, feature more prominently in archaeological records) (Frankel 2017, 37; Frankel et al. 1989, 17; Fresløv and Frankel 1999, 251; Gaughwin and Brennan 1986; Zobel et al. 1984; see discussion in Poiner 1976). This is despite coastal habitats also being rich in both plants and terrestrial fauna. A pertinent and lasting lesson learnt mainly from ethnographic studies in northern Australia is that whereas shellfish may



FIGURE 1 | Map of eastern Victoria, showing the location of Red Bluff 1 and other excavated and published archaeological sites in and near the GunaiKurnai Land and Waters Aboriginal Corporation Registered Aboriginal Party (RAP) area.

only contribute a relatively small proportion of calories in a given subsistence economy, their value lies beyond their calorific contribution to the diet, being a *reliable* resource for much or all of the year and from year-to-year (Meehan 1982). Rarely have detailed analyses of local subsistence economies been undertaken in Victoria with such notions in mind, especially since the 1960s–1980s, when coastal archaeological research was at its apogee across southeastern Australia.

At the end of their systematic review of the Victorian coastal evidence, Fresløv and Frankel (1999, 251) noted that, and in light of the inconsistent quality of analyses undertaken so far, two pathways can be taken to better understand how the coast was used in the past: (1) understanding the broad picture that is across widespread regions such as large sections of southeastern Australia; and/or (2) documenting and understanding archaeological temporal trends and spatial patterns at detailed, site-specific locales. As they noted, the latter strategy enables local and/or short-term foraging strategies, that is, the *particular* activities of the past, to be revealed, and often in considerable detail. Here, we combine both approaches as nested scales by (1) reviewing the archaeological literature to understand the broad

picture (for the detailed review, see Supporting Information 1) to (2) position the detailed analysis of a small excavation at the site of Red Bluff 1 in East Gippsland in a broader geographical context to understand the nature of nearshore foraging in this specific part of GunaiKurnai Country.

1.2 | The New Excavations at Red Bluff

The Gippsland coast, stretching from Phillip Island in the west to Mallacoota in the east, covers c. 540 km of coastline (Figure 1). This area encompasses locally and regionally diverse environments, including sandy beaches and mudflats, mangroves, lakes and estuaries behind barrier dunes, and rocky platforms (Fresløv and Frankel 1999, 241). The Red Bluff 1 midden (VAHR code 8522-0023) at Lake Tyers Beach is an unusual and important site abutting the eastern end of Ninety Mile Beach, being the only registered stratified midden between Wilsons Promontory in the west and Cape Conran in the east (a distance of 230 km) associated with a rock platform¹. The midden is located just west of the coastal township of Lake Tyers Beach and Lake Tyers, in Krauatungalung clan lands, eastern GunaiKurnai Country. The

TABLE 1 | Mean depth below ground surface, thickness, and amount of excavated sediment for each XU, Red Bluff 1 Square A.

XU	SU	Mean depth at top of XU	Mean depth at middle of XU	Mean depth at base of XU	Mean thickness of XU	Area	Volume	Litres	Weight
		cm	cm	cm	cm	m ²	m ³	L	kg
1	1+2	0.0	3.6	7.2	7.2	0.385	0.028	2.6	3.0
2	2	7.2	8.9	10.6	3.4	0.420	0.014	4.0	3.4
3	2	10.6	12.7	14.7	4.1	0.515	0.021	3.0	2.5
4	2	14.7	15.3	15.9	1.2	0.515	0.006	3.0	3.1
5	2+3	15.9	17.4	18.9	3.0	0.515	0.015	3.5	3.5
6	2+3	18.9	20.0	21.1	2.2	0.500	0.011	3.0	2.8
7	3	21.1	22.9	24.6	3.5	0.500	0.018	4.0	4.4
8	3	24.6	25.4	26.1	1.5	0.500	0.008	3.0	3.2
9	3	26.1	27.4	28.6	2.5	0.510	0.013	3.5	3.5
10	3	28.6	30.1	31.6	3.0	0.510	0.015	4.5	4.8
11	3	31.6	33.4	35.1	3.5	0.510	0.018	5.0	5.0
12	3	35.1	36.7	38.3	3.2	0.520	0.017	5.5	5.5
13	3	38.3	39.0	41.7	3.4	0.520	0.018	6.0	5.6
14	3+4	41.7	43.5	45.3	3.6	0.550	0.020	6.0	5.4
15	3+4	45.3	46.7	48.1	2.8	0.640	0.018	6.5	6.0
16	4	48.1	49.3	50.4	2.3	0.655	0.015	6.0	5.8
17	4+5	50.4	51.3	52.2	1.8	0.670	0.012	4.5	4.4
18	4+5	52.2	53.7	55.2	3.0	0.755	0.023	7.0	7.2
19	4+5	55.2	56.5	57.7	2.5	0.835	0.021	5.5	6.0
20	4+5	57.7	59.1	60.4	2.7	0.855	0.023	5.0	5.5
21	5	60.4	61.3	62.1	1.7	0.855	0.015	6.0	7.0
22	5	62.1	63.2	64.3	2.2	0.855	0.019	6.0	6.5
23	5	64.3	65.3	66.2	1.9	0.860	0.016	6.0	6.0
24	5	66.2	67.6	68.9	2.7	0.845	0.023	7.0	7.2
25	5+6	68.9	70.5	72.1	3.2	0.845	0.027	7.0	7.5
26	5+6	72.1	73.1	74.1	2.0	0.875	0.018	6.0	7.2
27	5+6	74.1	75.3	76.4	2.3	0.850	0.020	7.0	7.2
28	5+6	76.4	78.0	79.6	3.2	0.860	0.028	8.5	8.6
29	6	79.6	81.2	82.8	3.2	0.865	0.028	9.0	9.5
30	6+7	82.8	85.8	88.8	6.0	1.010	0.061	23.5	24.0
31	6+7	88.8	90.8	92.7	3.9	1.030	0.040	16.0	17.3
32	6+7	92.7	95.2	97.7	5.0	1.000	0.050	13.0	12.8
33	6+7+8	97.7	98.6	99.4	1.7	1.030	0.018	9.0	9.0
34	7+8	99.4	101.7	104.0	4.6	1.030	0.047	15.5	17.4
35	7+8	104.0	105.9	107.7	3.7	1.030	0.038	15.5	14.6
36	7+8	107.7	111.8	115.8	8.1	1.030	0.083	29.0	29.9
37	8+9A	115.8	120.1	124.4	8.6	1.065	0.092	26.0	30.5
38	8+9A	124.4	125.2	126.0	1.6	1.065	0.017	10.0	10.5
39	9A	126.0	127.3	128.5	2.5	1.035	0.026	9.5	10.5
40	9A	128.5	130.2	131.9	3.4	1.035	0.035	11.5	12.4
41	9A	131.9	134.2	136.4	4.5	1.035	0.047	12.5	12.4

(Continues)

TABLE 1 | (Continued)

XU	SU	Mean depth at top of XU	Mean depth at middle of XU	Mean depth at base of XU	Mean thickness of XU	Area	Volume	Litres	Weight
		cm	cm	cm	cm	m ²	m ³	L	kg
42	9A	136.4	138.5	140.5	4.1	1.000	0.041	16.0	15.6
43	9A+9B	140.5	142.0	143.5	3.0	1.000	0.030	9.0	9.0
44	9A+9B	143.5	145.2	146.8	3.3	1.015	0.033	10.0	10.6
45	9A+9B	146.8	148.7	150.5	3.7	1.015	0.038	11.0	11.8
46	9B	150.5	152.2	153.9	3.4	0.820	0.028	8.0	9.5
47	9B	153.9	155.3	156.6	2.7	0.840	0.023	8.0	9.2
48	9B	156.6	158.0	159.4	2.8	0.810	0.023	8.0	9.0
49	9B	159.4	160.8	162.2	2.8	0.825	0.023	7.5	9.1
50	9B+9C	162.2	163.6	165.0	2.8	0.835	0.023	8.5	10.2
51	9B+9C	165.0	166.3	167.5	2.5	0.825	0.021	7.0	8.5
52	9B+9C	167.5	168.9	170.2	2.7	0.815	0.022	7.0	8.2
53	9B+9C+9D	170.2	171.5	172.8	2.6	0.815	0.021	7.0	8.8
54	9B+9C+9D	172.8	174.4	175.9	3.1	0.810	0.025	8.0	9.5
55A	9B+9C	175.9	177.3	178.7	2.8	0.510	0.014	6.0	7.0
55B	9C+9D	175.9	177.3	178.7	2.8	0.295	0.008	3.5	4.2
56A	9B+9C	178.7	180.4	182.0	3.3	0.365	0.012	5.0	5.2
56B	9C+9D	178.7	180.4	182.0	3.3	0.465	0.015	5.5	6.4
57A	9B+9C	182.0	183.4	184.7	2.7	0.275	0.007	3.0	3.6
57B	9C+9D	182.0	183.4	184.7	2.7	0.520	0.014	5.5	6.4
58A	9B+9C	184.7	186.2	187.6	2.9	0.200	0.006	2.0	2.5
58B	9C+9D	184.7	186.2	187.6	2.9	0.615	0.018	6.0	7.5
59A	9B+9C+9D	187.6	189.4	191.1	3.5	0.140	0.005	2.0	2.4
59B	9B+9C+9D	187.6	189.4	191.1	3.5	0.655	0.023	8.5	10.6
60	9B+9C+9D	191.1	192.6	194.0	2.9	0.785	0.023	9.0	10.0
61	9B+9C+9D	194.0	195.4	196.7	2.7	0.770	0.021	7.0	8.6
62	9B+9C+9D	196.7	198.2	199.7	3.0	0.775	0.023	9.0	10.7
63	9B+9C+9D	199.7	201.2	202.6	2.9	0.790	0.023	9.0	10.6
64	9D	202.6	204.2	205.8	3.2	0.800	0.026	9.0	11.2
65	9D+10	205.8	207.4	209.0	3.2	0.785	0.025	7.5	9.3
Total					3.2		1.692	557.1	603.8

Note: The numbers in bold in the SU column indicate the SU from which most of the excavated sediment came for that XU (the multiple SU contributions are due to an XU's location at a stratigraphic interface).

Red Bluff rocky headland is called 'Ninnie' in GunaiKurnai and is associated with a dog-Dreaming (GunaiKurnai cosmological) story. Elder Uncle Russell Mullett recalls Granny Kitty Johnson's cultural knowledge: 'The story relates to our ancestors being turned to stone for not feeding their *ban* (dogs) and being selfish', imbuing the area with special cultural importance in the process (see also Bulmer in Smyth 1878, 189).

The Red Bluff 1 midden is exposed for c. 50 m along the truncated dune face above the beach, extending east from the rocky headland to the outlet of an intermittent unnamed creek. Midden material is found along parts of the steep sides of the

creek and on either side of the steep footpath leading from the beach to the car park up to 75 m from the rear of the beach. Shell material exposed in the high dune above the shoreline indicates that the midden complex covers an area of c. 5360 m² within a 4 ha Crown land reserve proclaimed in 1935 and currently managed by Parks Victoria (Adams 1981, 350).

The midden complex has deteriorated over the several decades since it was first registered by Kym Thompson for the Victoria Archaeological Survey in 1984 and then by Hotchin (1986, 1990, 153) in 1986. Hotchin provided an assessment of the site for the Victoria Archaeological Survey at the request of the local

Aboriginal community. He found that the site was being impacted by pedestrian traffic, wind erosion and water run-off resulting in slumping of the exposed sections (Hotchin 1986). Hotchin collected three samples for radiocarbon dating: one charcoal sample from near the top of the deposit, which gave an age of 450 ± 60 BP (ANU-4976; 540–320 cal BP, 95% probability); and two samples from near the base of the deposit, one on *Ostrea angasi* (native or common mud oyster) shell with an age of 810 ± 70 BP (ANU-4975; 560–190 cal BP, 95% probability) and one on charcoal with an age of 450 ± 60 BP (ANU-4977; 540–320 cal BP, 95% probability) (Hotchin 1990, 158, 173)². A later survey of the reserve and an inspection of the site were carried out by Petra Schell for Parks Victoria with the local Aboriginal community (Lakes Entrance Aboriginal Corporation) in 2000, again recording the deterioration in the site, with wave action, especially during high tides, causing erosion resulting in slumping (Schell 2000, 24). Inspections of the site were also carried out by Joanna Freslöv in 1996 and 2008, each inspection noting the importance of the site, its deteriorating condition and inadequate protection and management, including a broken fence protecting the midden from pedestrian impact (Freslöv 1998, 11, 107, 111, 116). Continued erosion of the site's beach frontage was noticeable in 2021, just prior to our archaeological excavation.

2 | The Study Area

The midden sits in a dune that veneers a fluvially dissected topography incised within the Pliocene Haunted Hills Formation (Holdgate and Gallagher 2003). The dune is likely to have formed through inland aeolian sand transport along a small river valley that extends over 1600 m inland from the back of the beach. The dune caps the wall of the valley and does not form a linear feature that dams the base of the catchment. The system is therefore relatively unique for Gippsland, forming a climbing dune rather than a more classical linear foredune as found behind the beaches across the region.

The beach fronting the midden is underlain by extensive rocky outcrops, the same lithology as the eroding cliffs immediately adjacent to the site (Figure 2). These rocks are regularly exposed during storm events, indicating that the beach is ephemeral in nature. These rocky outcrops extend to at least 850 m offshore to a water depth of around 15 m. This subtidal rock zone is crossed by two sandbar systems, the shallowest at around 1 m water depth being active during non-storm conditions, and a deeper (3.2–4.9 m below mean sea level) bar likely active only during high-energy events. Geomorphologically, the beach can be considered a Class 1 geologically constrained system of Gallop et al. (2020).

The beach systems upstream of Red Bluff represent the northern end of an intertidal littoral zone that extends westward to Corner Inlet (Kennedy et al. 2020; Kennedy et al. 2024). Immediately west (updrift) of Red Bluff, a narrow coastal plain 130 m wide (Beach-Barrier 1) is found, characterised by several foredune ridges. This sequence extends to Lakes Entrance, being interrupted only by the intermittently closed entrance to Lake Bunga. Where the coastal plain is wider (400 m), a second beach barrier is found on the western shore of Lake Bunga (Beach-Barrier 2). This sequence also contains linear foredunes and is separated from Beach-

Barrier 1 by a back-barrier depression in which Cunningham Arm is also found (Figure 3).

2.1 | The Red Bluff 1 Excavation

A 50×50 cm excavation square ('Square A') was positioned towards the western end of the Holocene-age truncated dune face, 2.5 m east of the capping dune's abutment against the steep slope of the Late Pliocene (around 2.5 million years old) sedimentary rock bluff (Figures 4 and 5). Prior to excavation, the mixed 5–10 cm-thick wind-blown and colluvial deposits that had accumulated on the vertical face of the truncated dune were removed to expose the clean, in situ stratified deposits of the c. 2.09 m-deep column that makes up Square A (Figure 5D). The 15–20 cm-thick loose, culturally sterile sand (stratigraphic unit [SU] 1) at the top of the dune was then removed by hand trowel prior to excavation of Square A; about two-thirds of the loose sediments of SU1 were thus removed, the lower third being kept in situ and excavated in the standard manner described below (see Figure 6). Accumulated slumped deposits at the base of the dune face were also removed by hand trowel shortly prior to the excavation of Square A reaching that level.

The archaeological excavation of Square A proceeded in average 3.2 cm-thick artificial excavation units (XUs) within and following the orientation of their respective SUs (Table 1). The SUs were sub-divided into XUs to (1) enable taphonomic assessments of the sediments down the deposit; (2) assess the chronostratigraphy within as well as between SUs; (3) refine the excavated deposit into shorter-duration samples than would be possible by excavating entire SUs in single XUs; and (4) allow for assessment and differentiation of stratigraphic interfaces, where deposits demonstrably consist of mixed chronostratigraphic sediments (and thus occupational horizons). Individual stone artefacts and three to five individual pieces of charcoal (potentially to be used for radiocarbon dating) were collected in situ and their positions were plotted in three dimensions from each XU. Some shells were also collected in situ for dating, but radiocarbon ages were only obtained on charcoal due to the paucity of deltaR values available for this region. Photographs were taken at the end of each XU. At the completion of the excavation, all three walls of the excavated square were photographed, and the west and north sections were drawn. Each visible shell fragment and all other items, including roots, were drawn to scale on the section drawings. Excavated sediments were initially dry-sieved in 2 mm-mesh sieves in the field, but occasional rain clogged up the sieves and made this ineffective, so entire XUs were bagged for wet-sieving at the Monash University archaeology laboratory. As the sediments are living cultural items in GunaiKurnai worldviews, the fine, <2 mm-wide fraction that passed through the sieve was kept, air-dried and returned to the beach at the base of the excavation square upon completion of the laboratory work. During the excavation, unsieved bulk sediment samples of c. 100 g each were collected from each XU. At the completion of the excavation, the GunaiKurnai Land and Waters Aboriginal Corporation sandbagged this part of the dune face to protect the site from further tidal and storm erosion.

All sorting of excavated sediments was done in the Monash University archaeology laboratory after air-drying the wet-sieved



FIGURE 2 | The changing sandy and rocky character of the beach immediately fronting the archaeological site of Red Bluff 1. (A) Photo taken on 26 May 2025, the evening before the high tide. (B) Photo taken on 3 May 2021. Note the thick sand deposit along the upper beach, truncated by wave activity. (C) Photo taken on 28 May 2025, 2 days after photo A was taken. Note the lowered beach profile has exposed bedrock slabs. (D) Photo taken on 15 November 2024. Further beach lowering has exposed more of the rock slabs as well as the underlying rocky shore platform at the base of the cliffs in the distance (photos by Joanna Fresløv).

sediments. The sorted shell was then sent to the University of Sydney for identification and analysis. The bulk sediment samples were sent to the University of Melbourne, where textural analysis of the sediment was undertaken using a Beckman Coulter LP 13320 laser particle sizer.

2.2 | Stratigraphy

Red Bluff has a structurally complex set of interleaving layers that extend considerable distances along the dune face together with shorter, discontinuous lenses. Square A, located in a part of the dune and midden complex with dense archaeological shell horizons, has 10 major SUs, numbered SU1 at the top to SU10 at the base of the excavation, with SU9 sub-divided into four sub-SUs of slightly varying sediment characteristics (SU9A–D) (Figure 6). There is an overall fining trend within the sequence, with sediment decreasing in mean grain size from coarse sand in the upper XUs (down to XU15, at the top of SU4) to very fine sand at the base. Grain size-sorting also becomes poorer with depth, decreasing from moderately well-sorted in XU7–XU14 (SU3) to very poorly sorted below XU47 (SU9B). An outlier of an extremely poorly sorted very fine silt occurs within XU58B (SU9C and very top of SU9D).

The sequence can be subdivided into five textural units based on the size and sorting characteristics. The first is a coarsening downwards, moderately well-sorted coarse sand, between XU1 and XU13 (SU2–SU3). Underlying this unit is a second coarsening downwards sequence from XU16 to XU26 (SU4–SU5) of poorly

sorted fine to medium sand. A very poorly sorted fine to very fine sand occurs below these upper two sequences, which also decreases in grain size with depth (XU27–XU37, SU6–SU8). Mean sediment size then markedly increases in SU9A, and sorting improves from very poorly to poorly sorted (XU32–XU42). Size again decreases and sorting lessens in SU9B, with the transition zone of XU50–XU59B being characterised by very poorly sorted fine to very fine sand (Figure 7).

SU1 consists of loose aeolian sand capping the top of the dune, which in this area lies at a topographically lower elevation than at its apex further inland. It does not contain in situ cultural materials. The light olive brown (dry Munsell: 2.5Y 5/3) SU1 sand is neither compact nor consolidated. It has a pH of 8.16.

SU2 is a fine-to-medium, poorly sorted, dark greyish-brown (dry Munsell: 2.5Y 4/2) sandy shell midden horizon. It is neither compact nor consolidated. Its interfaces with SU1 above and SU3 below are gradual, each taking place over a depth of c. 3–5 cm. It has a pH of 9.03.

SU3, the coarsest unit, is a well-sorted to moderately well-sorted medium light brownish grey (dry Munsell: 10YR 6/2) sand with dark brownish root stains of c. 1.5 cm diameter. It is neither compact nor consolidated and devoid of in situ archaeological materials. The interface with underlying SU4 is c. 3 cm thick. It has a pH of 8.36.

SU4 is an archaeologically rich, dark grey to dark greyish-brown (dry Munsell: 2.5Y 4/1–4/2), poorly sorted fine sand layer. It is

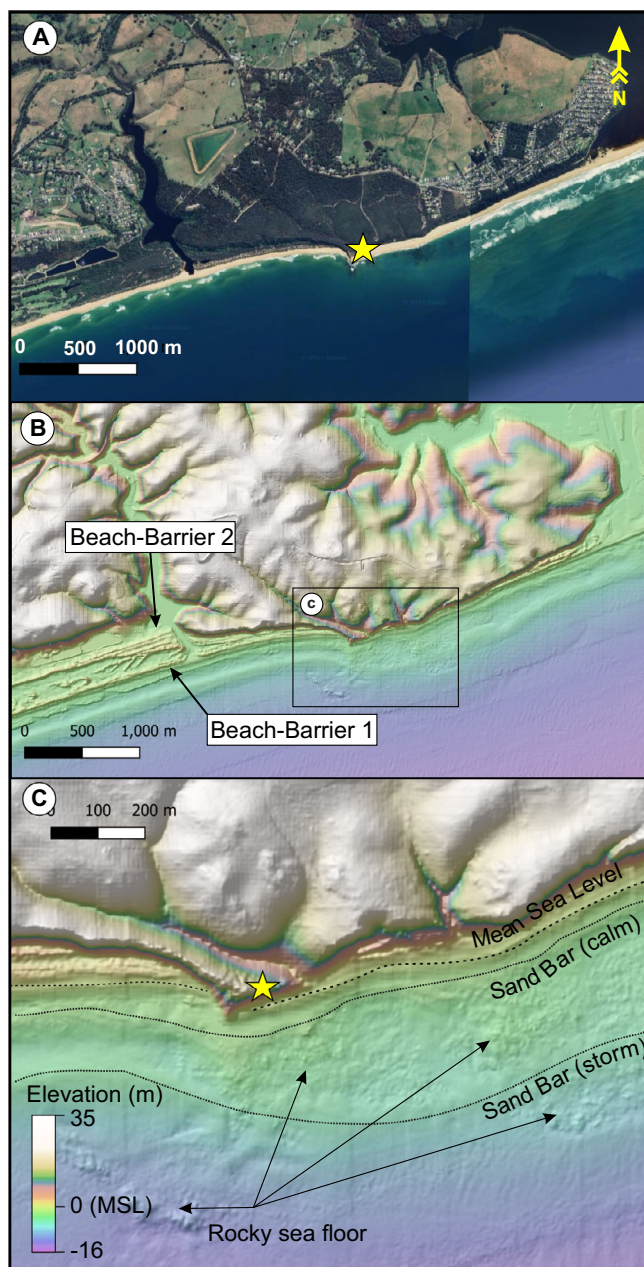


FIGURE 3 | Red Bluff area. (A) An aerial and (B) LiDAR image of the region surrounding the Red Bluff 1 excavation (location marked by the yellow star). (C) In the LiDAR of the region immediately around the site, the midden is located on the western side of the fluvial channel. A subtidal rocky sea floor appears to dominate the area immediately offshore of the site.

slightly consolidated and compact. The base of SU4 grades with SU5 over a depth of c. 3 cm. It has a pH of 9.03.

SU5 is an archaeologically rich, dark greyish brown (dry Munsell: 2.5Y 4/2), poorly sorted medium sand layer similar in texture, compaction and consolidation to SU4, but slightly more brownish in colour. The base of SU5 grades with SU6 over a depth of c. 3 cm. It has a pH of 9.25.

SU6 is the densest archaeological shell deposit in Square A. It is a fine to very fine, poorly to very poorly sorted, very dark grey (dry

Munsell: 2.5Y 3/1), compact and slightly consolidated sand layer. The base of SU6 is uneven and grades with SU7 over a depth of c. 7 cm. It has a pH of 9.46.

SU7 is a homogeneous, fine to very fine, dark greyish brown (dry Munsell: 2.5Y 4/2), compact and slightly consolidated sand layer. It contains in situ archaeological materials (mainly shell) that are sparser than in SU6. The base of SU7 is uneven and grades with SU8 over a depth that varies between c. 2 and 6 cm. It has a pH of 9.66.

SU8 is a distinctive, culturally sterile, homogeneous, very poorly sorted, coarse, reddish-brown (dry Munsell: 5YR 5/4) silt. It is very compact and very consolidated. It is devoid of charcoal. In some parts of the square, it is found in disparate patchy clumps amidst the fine to very fine sand of the SU7–SU8 interface. The base of SU8 is very well demarcated and interfaces with SU9A over a depth typically less than 2 cm. SU8 consists of collapsed blocks of the Late Pliocene Haunted Hills Formation whose edge rises as a steep slope 2.5 m to the west of Square A, above the Holocene sand-dune capping of the Red Bluff 1 archaeological site. It has a pH of 9.43.

SU9 consists of a sequence of sub-SUs of compact but loose to poorly consolidated aeolian sands forming the lower part of the dune. While a few isolated stone artefacts, shells and shell fragments were found in SU9, and small, isolated pieces of charcoal are present throughout, nowhere were distinct archaeological horizons observed (see below for discussion of the cultural items). The sub-SUs of SU9 grade one into the other over depths of up to c. 10 cm. SU9A is a poorly sorted fine sand, greyish brown (dry Munsell: 10YR 5/2) in colour; pH = 9.56. SU9B is a fine to very fine sand, light olive brown (dry Munsell: 2.5Y 5/3), lighter in colour than SU9A; pH = 9.49. SU9C is a fine sand, greyish brown (dry Munsell: 10YR 5/2), slightly darker than SU9B; pH = 9.50. SU9D is light olive brown (dry Munsell: 2.5Y 5/4) in colour, slightly lighter than SU9C; pH = 8.22. SU9D interfaces with SU10 over a depth of c. 5 cm.

SU10 is a coarser-grained sand and pebble layer at the base of the excavation. The pebbles are water-rolled and mostly up to c. 3 cm long. It is culturally sterile. The excavation stopped at the top of SU10.

2.3 | Chronology

Eighteen accelerator mass spectrometry (AMS) radiocarbon ages were obtained from Square A, dating the sequence from the base of SU9D just above SU10 upwards to SU2 (Figure 8 and Table 2). Additionally, six AMS radiocarbon ages were obtained on individual pieces of charcoal extracted from the truncated dune face up to 1 m west and 5 m east of Square A (Table 2). For the most part, the calibrated dates are in good chronostratigraphic order, especially from SU2 down to SU7 inclusive (no radiocarbon ages were obtained from SU1 and SU8 due to an absence of in situ charcoal). Where they are less well ordered, and therefore signal a greater degree of sediment mixing, is within the aeolian sands of SU9A–B, where the calibrated dates vary between 1590 and 980 cal BP (maximum range of calibrated dates at 95.4% probability); and again within SU9D, where a single date (Wk-53203: 5300–4980 cal



FIGURE 4 | Map of the Red Bluff archaeological site complex and location of the Red Bluff 1 Square A excavation. The midden complex's boundary marks the outer limits of its surface exposure; it is possible that sub-surface archaeological deposits are more expansive.

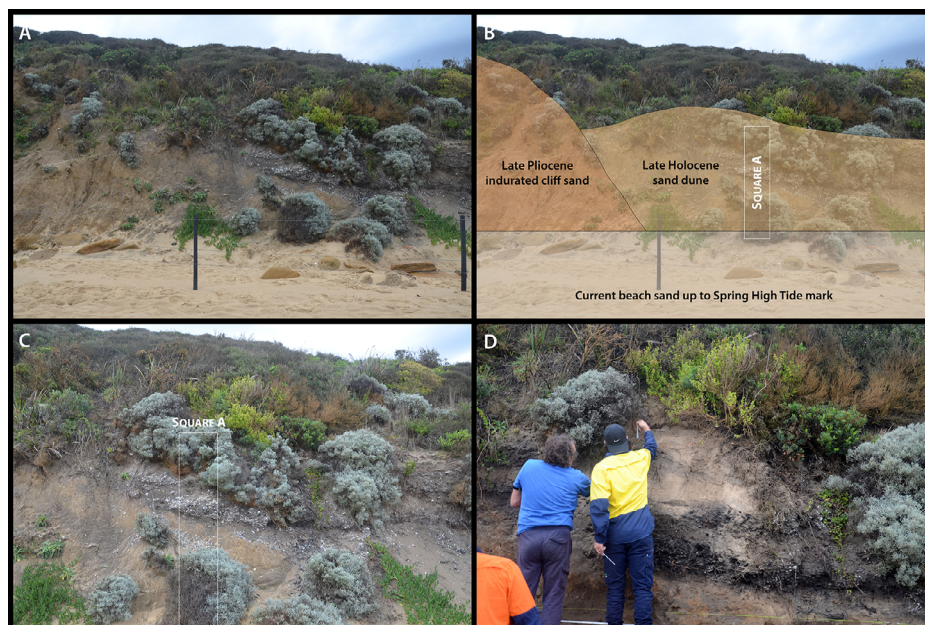


FIGURE 5 | Location of Square A at Red Bluff 1. (A and B) Position of Square A in the Holocene sand dune 2.5 m east of the Late Pliocene cliff. Note that the semi-transparent overlays on B represent the truncated Late Pliocene cliff and Late Holocene dune sediments. (C) Position of Square A prior to cleaning the truncated dune face before the start of excavation. (D) Cleaning the face of the dune in the area of Square A prior to excavation. The width of Square A is 50 cm (photos by Bruno David, courtesy of the GunaiKurnai Land and Waters Aboriginal Corporation).

BP) differs from three dates ranging between 2730 and 2350 cal BP (95.4% probability range). The poorly consolidated aeolian sands of SU9A–D had hinted at their poor chronostratigraphic resolution during excavation, as indicated by the gradual, poorly defined interfaces between the sub-SUs, which were typically c. 10 cm thick.

To determine the start and end date and duration of each SU and of each archaeological horizon, we have used Bayesian Sequence Analysis whereby radiocarbon ages are constrained

by prior stratigraphic information (Bronk Ramsey 2009a). The dates were grouped into multiple phases based on sequence with either contiguous or sequential boundaries, depending on field observations. Wk-53203 was removed from the model as the date was more than 2000 years different to three other dates from the lower dune (SU9D). Radiocarbon ages from SU9A and SU9B fall into two main age groupings but are mixed between the two stratigraphically poorly differentiated sub-SUs. For this reason, they have been modelled as a single phase. The internal consistency of the remaining calibrated dates was

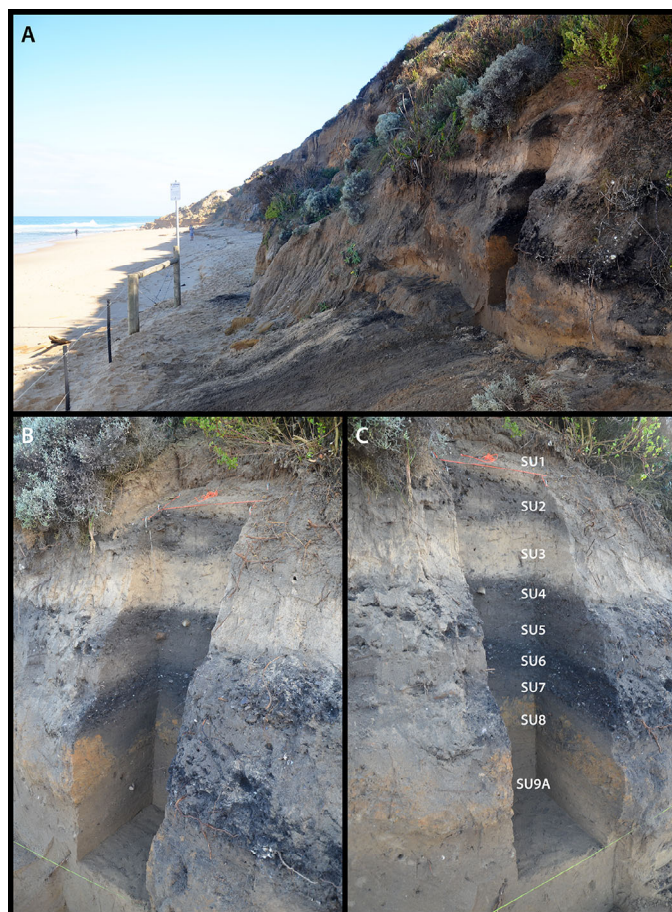


FIGURE 6 | The Square A excavation in progress, showing the well-defined stratigraphy of the upper parts of the dune deposit (with SU9B, SU9C, SU9D and SU10 not yet excavated and thus not labelled). (A) Looking west along the beach. (B) Looking northwest. (C) Looking northeast. The width of Square A is 50 cm (photos by Bruno David, courtesy of the GunaiKurnai Land and Waters Aboriginal Corporation).

assessed using a general t-type outlier in OxCal, with a prior outlier probability of 0.05 (Bronk Ramsey 2009b). The model results are presented in Figure 9 and Tables 3 and 4. This model gives good overall agreement, with no outliers. By convention, the Bayesian-modelled ages are reported in italics to differentiate them from individual unmodelled calibrated ages and rounded to the nearest 10 years.

2.4 | Macroscopic Charcoal Analysis

2.4.1 | Charcoal Analysis Methods

The analysis of charcoal from sediment sequences provides evidence for past fire activity and people–fire relationships. Such charcoal sequences can be linked to other kinds of evidence of past activities, enabling the reconstruction of fire regimes and land-management practices. Charcoal sequences are often overlooked in archaeological studies because of the complexity of interpreting the results. In buried archaeological deposits, charcoal assemblages can represent various natural and anthropogenic processes, so that understanding a site's taphonomic history is crucial for interpretation. Further, due to the production and aerial transport of charcoal being affected by fire size, intensity, and severity, charcoal can have blown

into a site from landscape fires that either burnt far away (not within the watershed) or nearby (within the watershed). Typical interpretations of shifts in charcoal particle sizes (macroscopic $>125\ \mu\text{m}$ vs. microscopic $<125\ \mu\text{m}$ long) suggest changes in local or regional source of fire, respectively, although some argue that both size classifications can signal local and regional fire activity. However, when paired with independent archaeological data, the analysis of charcoal from archaeological sediments can bolster and provide a more nuanced understanding of what people did across the landscape.

For this study, each XU (except the 'B' series of sub-XUs in XU55B–XU59B) (Table 1) was sampled for macroscopic ($>125\ \mu\text{m}$) charcoal and pollen analysis (i.e., XU1–XU65). Pollen processing followed a modified version of Faegri and Iversen (1989), including 10% KOH, 40% HF, acetolysis and heavy liquid floatation (sodium heteropolytungstate). However, neither pollen nor microscopic charcoal was counted due to the absence of preserved pollen suggesting unfavourable conditions for the preservation of organic microfossils. As a result, we focused on macroscopic (particles $>125\ \mu\text{m}$ long) charcoal analysis. A sediment sample of $1.25\ \text{cm}^3$ was taken from each XU and digested using 10% hydrogen peroxide (H_2O_2) sieved through 125 and 250 μm meshes and counted using a stereoscopic microscope at 10 $\times$ magnification. Macroscopic charcoal is presented as concentrations

TABLE 2 | AMS radiocarbon ages from Red Bluff 1.

Wk- Laboratory code	XU	SU	Sample weight (g)	%C	$\delta^{13}\text{C}$ (‰)*	^{14}C Age (BP)	Calibrated date (cal BP)
Samples from Square A							
52968	4	2	0.14	65.0	-24.5 ± 0.3	391 ± 16	500–320
52969	5	2	0.02	61.1	-22.5 ± 0.3	542 ± 17	550–500
52970	15	4	0.02	83.7	n/a	624 ± 16	630–540
52971	16	4	0.62	67.6	-24.7 ± 0.3	652 ± 16	650–550
52972	18	5	0.21	65.9	n/a	831 ± 16	730–670
52973	23	5	0.11	67.4	n/a	918 ± 17	900–730
52974	31	7	0.21	63.7	-23.2 ± 0.3	1045 ± 16	960–810
52975	32	7	0.09	63.3	-20.0 ± 0.6	1090 ± 17	970–920
52976	38	9A	0.99	64.9	-24.7 ± 0.3	1217 ± 17	1180–980
52977	40	9A	0.10	67.2	-26.4 ± 0.6	1605 ± 19	1530–1370
52978	42	9A	0.08	70.1	-24.2 ± 0.6	1240 ± 18	1180–1060
52979	44	9B	0.64	71.9	n/a	1522 ± 20	1410–1310
53199	47	9B	0.16	n/a	n/a	1318 ± 21	1280–1110
53200	49	9B	0.03	n/a	n/a	1671 ± 19	1590–1420
53202	57	9D	0.31	n/a	n/a	2497 ± 18	2710–2360
53203	60	9D	0.09	n/a	n/a	4527 ± 23	5300–4980
53204	63	9D	0.23	n/a	n/a	2517 ± 24	2730–2360
53205	64	9D	0.12	n/a	n/a	2483 ± 19	2710–2350
Samples from dune face up to 1 m west and 5 m east of Square A							
52964		6	0.51	70.0	n/a	992 ± 16	920–790
52966		Between 7 and 8 (SU absent in Square A)	0.45	65.8	-25.2 ± 0.3	1108 ± 17	1050–920
52965		Base of 7	0.80	70.9	n/a	1161 ± 17	1060–960
52967		Base of 7	0.52	66.2	n/a	1172 ± 16	1060–960
52963		9A	0.29	64.9	n/a	1546 ± 18	1430–1310
52962		9A–9B interface	0.65	60.8	n/a	1628 ± 18	1540–1420

Note: Each is on a single piece of charcoal collected in situ, with its position in the deposit recorded to 1 mm vertical and 1 cm horizontal precision. All the radiocarbon ages from Square A are back-plotted on the section drawing (Figure 8). *: Where the $\delta^{13}\text{C}$ values are not given ('n/a'), the ^{13}C stable isotope values were measured on prepared graphite using the AMS spectrometer. The radiocarbon age has therefore been corrected for isotopic fractionation. However, the AMS-measured $\delta^{13}\text{C}$ value can differ from the $\delta^{13}\text{C}$ of the original material. Age calibrations were performed in OxCal v4.4 (Bronk Ramsey 2025) using the SHCal20 atmospheric curve (Hogg et al. 2020) at 95.4% probability.

calculated from the summed charcoal counts and the sample volume (Figure 10).

2.4.2 | Macroscopic Charcoal and Fire Activity at Red Bluff 1

Our analysis reveals two distinct phases of fire activity at the Red Bluff 1 archaeological site (Figure 10). There is little to no presence of macroscopic charcoal from the base of the excavation in XU65 (SU10) to XU34 (SU8), and only a slight peak in XU41 (SU9A). Macroscopic charcoal concentrations increase dramatically between XU33 and XU14 (in SU7 to SU4 inclusive), with the largest peak in XU31 to XU28 (SU6). Two other distinct peaks are present in XU16 to XU17 (SU4). Following

a low phase of macroscopic charcoal concentrations between XU13 and XU8 (SU3), charcoal concentrations again increase markedly between XU6 and XU2 (SU2). Macroscopic charcoal concentrations decrease thereafter, in SU1.

These charcoal peaks correspond exactly with the dense archaeological deposits of SU7 to SU4 and again of SU2 (see below). Of particular interest is the minor charcoal peak in XU41, near the top of the SU9 dune sands just below the well-defined, very compact and very consolidated SU8 reddish-brown silt. SU8 consists of a collapsed block of Late Pliocene Haunted Hills Formation that slipped and came to rest on the SU9A dune's palaeosurface, 2.5 m to the east of the Late Pliocene bluff's sloping edge. We interpret the low charcoal peak shortly below SU8 to signal a local low-intensity landscape-scale fire that came

TABLE 3 | Results of the Bayesian sequence model.

Name	Modelled (BP)			
	68.3% prob.		95.4% prob.	
End Red Bluff SU2	490	360	520	160
WkA-52968 XU4	490	440	500	320
WkA-52969 XU5	540	510	550	500
SU2 midden				
Transition SU2 midden/SU3 dune	570	510	600	500
SU3 dune build-up				
Transition SU4 midden/SU3 dune	630	570	630	530
WkA-52970 XU15	630	600	640	550
WkA-52971 XU16	630	600	640	550
SU4 midden				
Transition SU4/SU5 midden	670	610	720	600
WkA-52972 XU18	730	690	740	670
WkA-52973 XU23	790	730	800	730
SU5 midden				
Transition SU5/SU6 midden	840	740	910	730
SU6 midden				
Transition SU6/SU7 midden	950	880	960	810
WkA-52974 XU31	960	910	960	900
WkA-52975 XU32	950	920	970	920
SU7 midden				
Transition SU7 midden/SU8 Late Pliocene dune collapse	990	930	1060	920
SU8 Late Pliocene dune collapse				
End SU9/Collapse of Late Pliocene dune	1110	990	1160	960
WkA-52976 XU38	1180	1050	1180	1000
WkA-52977 XU40	1510	1410	1530	1370
WkA-52978 XU42	1180	1070	1180	1060
WkA-52979 XU44	1380	1310	1410	1310
WkA-53199 XU47	1270	1200	1280	1110
WkA-53200 XU49	1570	1420	1580	1420
SU9A/B Pre-dense midden dune				
Start SU9B dune top	1670	1480	1900	1430
SU9C Paleo-surface of old dune				
Transition SU9D/SU9C dune	2610	2300	2690	2050
WkA-53202 XU57	2670	2370	2700	2360
WkA-53204 XU63	2660	2420	2700	2360
WkA-53205 XU64	2680	2370	2700	2360
SU9D Older low dune				
Start Red Bluff	2720	2470	2840	2370

Note: Rows highlighted in grey represent boundary ages.

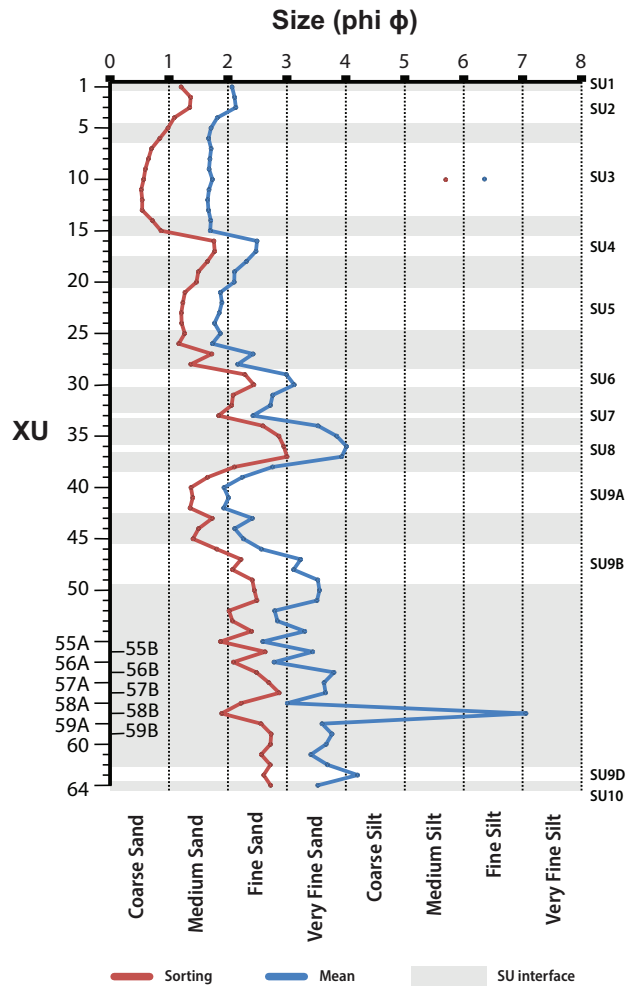


FIGURE 7 | Sediment texture sequence, Red Bluff 1 Square A.

to destabilise the Haunted Hills Formation's surface. The low intensity of the fire, suggesting cultural burning rather than one or more bushfires, is signalled by the slightness of the charcoal peak in this part of the sequence. It is of interest that this low charcoal peak suggesting cultural burning took place shortly prior to the dense archaeological layers (indicative of repeated camping activity) in this area of Red Bluff, suggesting clearing of the local heath prior to camping on what was then a low dune facing the shore.

2.4.3 | The Cultural Sequence: Excavated Materials

2.4.3.1 | Laboratory Methods. All excavated materials except for the items collected in situ and the bulk sediment samples were wet-sieved through 2 mm mesh, air-dried and sorted at the Monash University archaeology laboratory. The >2 mm sieve material was sorted by broad category of archaeological materials, including both 'natural' items (e.g., roots, insects), which can help inform on the site's taphonomy, and objects deposited by people in the past (e.g., charcoal, marine shell, animal bone, stone artefacts). For the stone artefacts, the analytical methods and terminology follow Clarkson and O'Connor (2006); all analyses were undertaken at the Monash University archaeology laboratory. The terrestrial

TABLE 4 | Results of the Bayesian sequence model showing span of and interval between main phases.

	Modelled years			
	68.3% prob.	95.4% prob.		
Span of SU2 midden	20	90	0	200
Interval: SU3 dune build-up	0	60	0	90
Span of SU4 midden	0	20	0	60
Span of SU5 midden	20	90	0	110
Interval: SU6 midden build-up	30	150	0	180
Span of SU7 midden	0	20	0	50
Interval between SU9A and SU7	0	120	0	190
Span of SU9 dune building	350	480	280	510
Interval between dune building	650	1010	300	1150

vertebrate fauna and avian remains were identified from the Monash University Archaeology Laboratory's reference collections, with weight (g) and the Number of Identifiable Specimens (NISP) recorded per XU. Samples containing fish remains were submitted to Fish Ageing Services (FAS) for identification. These samples were examined using a Leica research-grade stereo microscope (M80), illuminated with a mix of reflected and transmitted light. These fish samples were classified as either scale, vertebrae, operculum, cranium, spines, teeth or indeterminate and quantified by weight (g) and NISP.

2.4.3.2 | Distribution and description of cultural materials. Figure 11 and Table 5 quantify the excavated items by broad category, by XU. The only cultural item of very recent times found in the excavation was a small piece of plastic near the surface in XU1. Minor to moderate amounts of rootlets from grasses and heath occur throughout the sequence, especially in XU1–XU37 (corresponding with SU1–SU7) in the upper half of the deposit. No tree roots were encountered. The distinctiveness of the SUs' colours, textures and contents remains clearly evident despite some mostly very fine rootlet growth down the deposit. Insect casings (10 small fragments spread between XU1 and XU22) and insect fragments (5 fragments from a single small insect, all in XU21) are rare, and no insect burrows were identified during excavation. Only 18.6 g of ≥ 2 mm-wide gravel consisting of a total of 21 grains (residue from the 2 mm sieve) occur in the entire sequence, most ($N = 12$) near the base of the deposit between XU56 and XU65. Nine tiny grains of gravel measuring between 2 and 3 mm width also occur in XU31 and XU34, in the shell-dense SU6 and SU7; they probably came on people's feet or incidentally attached to shells brought into the site by people. All in all, the deposit shows no signs of major post-depositional taphonomic disturbance.

The stone artefacts consist of 25 flakes and flaked pieces, spread from XU2 (in SU2) down to XU59 (including examples from each of SU9A, SU9B and SU9D). While most ($N = 18$, 72%) of the flaked artefacts occur in the dense archaeological shell horizons of SU2 (2 artefacts), SU4 (1 artefact), SU6 (12 artefacts), SU7 (3 artefacts)

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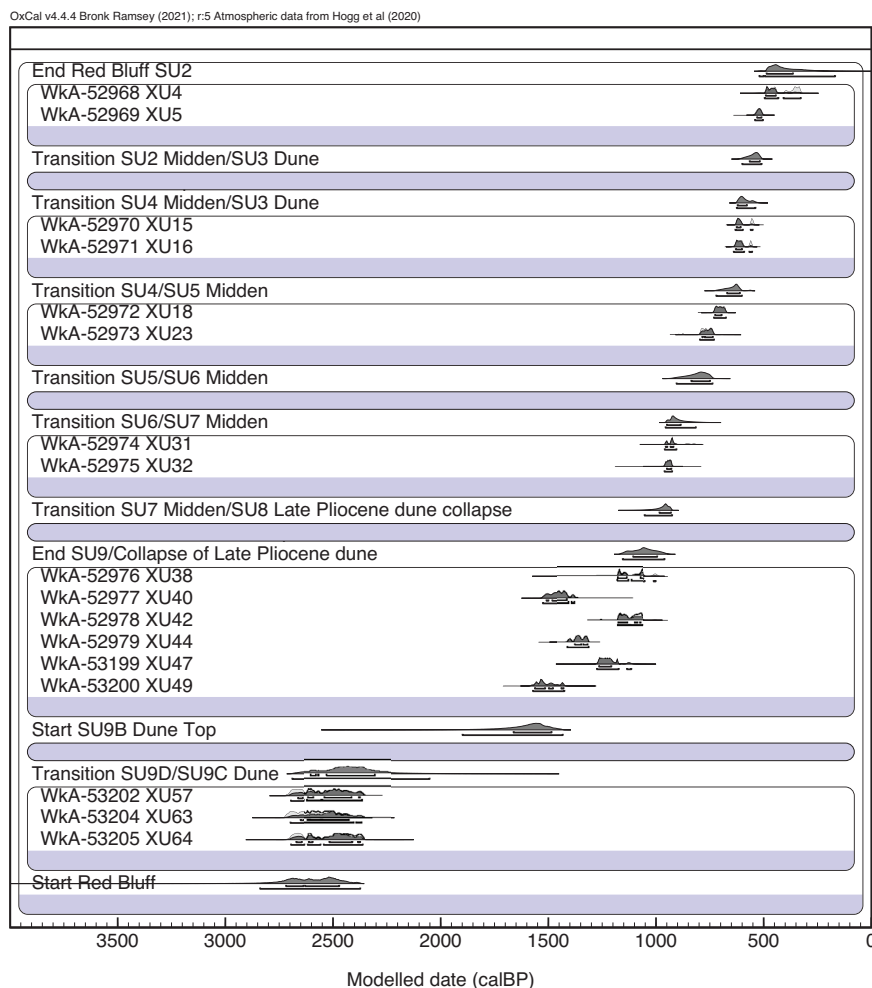


FIGURE 9 | Bayesian age model for radiocarbon dates from Red Bluff 1, grouped by SU. Black distributions represent boundary ages after Bayesian modelling.

and their stratigraphic interfaces, isolated examples occur down to XU59, 18 cm above the base of the excavation in the lower part of SU9. The raw materials consist of quartz ($N = 16$, 64%), feldspathic metasandstone ($N = 5$, 20%) and quartzite ($N = 4$, 16%). Most of the artefacts are tiny, with 9 (8 on quartz, 1 on quartzite) individually weighing <0.15 g and measuring <1.0 cm in maximum length, and another 10 (6 on quartz, 3 on feldspathic metasandstone, 1 on quartzite) individually weighing <0.64 g and measuring between 1.0 and 1.6 cm long. The presence of such a high proportion of tiny flakes and flaked pieces indicates that stone tools were made, used and/or maintained on-site. No unipolar cores are present. No formal tool types were found, and none of the flakes are retouched. The three largest quartz flaked artefacts (1 each from XU17, XU30 and XU31, in the dense archaeological shell layers of SU4 and the SU6–SU7 interface) have crushing on both distal and proximal ends, indicating bipolar flaking. No other raw material has bipolar crushing. The closest source of all three raw materials is in the immediate vicinity of the site, where they can be found as pebbles and cobbles; they can also be found around the shores of Lake Tyers c. 2 km to the east. Generally, stone tool manufacture and use using raw materials locally obtainable at the site (Figure 12), especially quartz pebbles, appears to have been a consistent but low-level activity.

In addition to the flaked artefacts, water-worn feldspathic metasandstone, quartz-rich metasandstone, subarkose arenite (i.e., quartz-rich sandstone) and quartzite cobbles from the beach adjacent to the dune were also brought to the site. Two (1 on feldspathic metasandstone, 1 on quartzite) occur in XU16 (SU4) and one (on quartzite) in XU32 (SU6+SU7), in the dense shell horizons. Three (1 each on feldspathic metasandstone, subarkose arenite and quartzite) also occur in the upper levels of SU9 (from XU42 to XU50, in SU9A and SU9B), where archaeological materials are sparse. Each weighs between 98 and 259 g and measures between 6.2 and 10.1 cm maximum length; they are thus all hammerstone-sized. There is minor pitting on the whole cobbles, but the cause of the pitting is ambiguous. There are also three water-rolled cobble fragments (as evident from the remnant cortex) that broke during use. They come from XU33 in the SU6–SU7 interface (both dense shell layers), XU37 and XU39 (both at the very top of SU9A where it interfaces with SU8) which represent a time when this stratigraphic level was a palaeosurface of the sand dune. The ones from XU33 and XU37 are on feldspathic metasandstone; that from XU39 is on quartzite. There is pitting on the cortex of each fragmented cobble, with the fragmentation of the cobbles emanating from a surface pit. None of the break edges are water-rolled (they remain sharp). We have therefore interpreted them as broken hammerstones. It

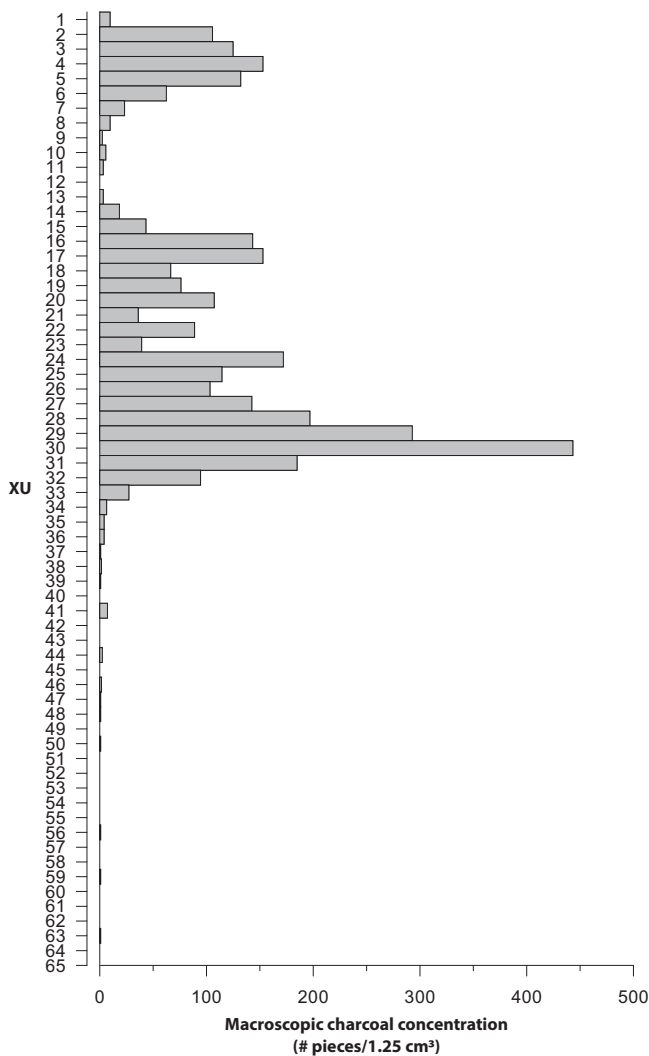


FIGURE 10 | Macroscopic (>125 µm long) charcoal concentrations by XU, Red Bluff 1 Square A.

is possible that the broken pitted cobbles and the whole cobbles with ambiguous pitting on their surfaces were used to process the shellfish for consumption (e.g., to break *Lunella undulata* shells; see below), but no definitive residues were seen on the cobbles under 5× magnification to confirm this.

A total NISP of 1336 animal bone fragments and teeth weighing 24.0 g were excavated. The vast majority (NISP = 1215, 20.2 g) are fish remains (97% of the determinate bone and teeth remains by NISP and 90% by weight); only 37 (2.2 g) are from terrestrial or avian fauna (the remaining NISP of 84, weighing 1.6 g, are indeterminate). Additionally, 277 whole and partial fish scales weighing 1.3 g were also found. The fish bones and teeth, and the fish scales, both peak in three distinct horizons: XU2–XU6 (SU2), XU16–XU24 (SU4 and upper SU5) and XU28–XU33 (SU6+SU7). These horizons correspond with the peaks of the other cultural materials, in particular the shell, >2 mm-length charcoal, and the microscopically quantified macrocharcoal particles. The weathered or damaged condition of the fish remains makes firm taxonomic identification difficult. Almost all of the fish bones and scales, however, are of small to medium-sized fish or of fish taxa that have large scales compared to body size. They are typically

from fish found in inter-tidal rock or sand pools at low tide or estuarine environments, such as species within the Labridae and Sparidae families (Gomon et al. 1994).

3 | Shell Analyses

3.1 | Laboratory Methods

By far the predominant cultural item in the deposit is shell. The marine shell was taxonomically identified and analysed at the University of Sydney, and the land and freshwater snails at the Queensland Museum. For both marine shells and land and freshwater snails, whole shells and diagnostic fragments were separated out and the remaining shell fragments bagged, counted and weighed as indeterminate shell by XU. The marine invertebrates were identified to the lowest taxonomic level possible (e.g., family, genus or species) with reference to comparative specimens housed by the University of Sydney, published material (Lamprell and Healy 1998; Lamprell and Whitehead 1992; Robin 2021; Sliker 2000) and online resources (Beechey 2024; Grove 2018; Museum Victoria 2023). Care was taken to avoid the over-identification of specimens. For example, where a fragment may have only retained diagnostic features or characteristics to family or genus level, it was not assumed that it was part of a dominant taxonomic group already identified to species level. The land and freshwater snails were identified by John Stanisic (Queensland Museum), with further information obtained from Hyman and Stanisic (2005), Ponder and Avern (2000) and Stanisic et al. (2017). All marine taxa identifications were checked using the World Register of Marine Species (WoRMS Editorial Board 2024) to ensure that the most up-to-date nomenclature was used.

We note that the blue mussel in southern Australia has variably been referred to as *Mytilus edulis*, *Mytilus galloprovincialis*, *Mytilus edulis planulatus* and *Mytilus planulatus*. Recent genetic studies (e.g., Popovic et al. 2020) suggest that there have been multiple phases of hybridisation between the Mediterranean/Atlantic Sea *Mytilus galloprovincialis* (blue mussel) and the endemic *Mytilus planulatus* (blue sea or edible mussel) during the Pleistocene over the past c. 100,000 years, and again with European translocations and invasions since colonial settlement in the late 1700s and 1800s. As this issue is complex and still to be fully resolved, we follow the nomenclature presented in Lamprell and Healy (1998) and use *Mytilus planulatus* (with this species name also listed by WoRMS as valid).

Following taxonomic identification and taphonomic assessment, the shell was then sub-divided into ‘subsistence’, ‘incidental’ and ‘natural’ taxa. The shell was examined for any indication of utilitarian or ornamental use; however, these types of modifications were not identified within the assemblage. ‘Subsistence’ species are those that were purposefully gathered for food (or potentially as a raw material). ‘Incidental’ species are those that appear to have been a by-product of the harvesting of subsistence species (as secondary or unintentional collections, including juvenile/immature individuals). The ‘natural’ category encompasses those specimens that were incorporated into the deposit from the surrounding environment (e.g., land snails) or via processes such as fluvial or aeolian transportation and redeposition. As our focus

TABLE 5 | Amounts of excavated materials by XU, Red Bluff1 Square A.

XU	SU	Taphonomic indicators										Cultural indicators									
		Insect					Land and freshwater gastropod shell					Terrestrial and bird, bone and teeth fragments					Fish, bone and teeth fragments				
		#	g	#	g	#	#	g	#	g	#	#	g	#	g	#	#	g	#	g	#
1	1+2	2	0.04								1.36	1.51									
2	2										2.42	11.96					59	0.48	61	0.04	
3	2	1	0.04			1	<0.01				6.02	6.21				13	0.11	15	0.13		
4	2			1	<0.01						2.24	3.35				14	0.18	15	0.19		
5	2+3										4.67	8.52	2	0.07		15	0.12	18	0.21		
6	2+3										3.59	2.22				7	0.05	8	0.08		
7	3	1	0.01								1.10	0.34									
8	3	1	0.03								1.01	0.08									
9	3										0.87	0.04									
10	3										1.51	0.27									
11	3										2.24	0.15									
12	3	1	0.07								2.65	0.02				1	0.01	1	0.01		
13	3										3.82	0.01									
14	3+4										4.04	0.05				4	0.04	4	0.04		
15	3+4	1	0.07								4.70	4.02				5	0.07	6	0.11		
16	4					1	<0.01				4.50	8.57				42	0.49	42	0.49		
17	4+5										6.30	3.79				60	0.82	65	0.86		
18	4+5					7	0.41				12.14	10.96				61	3.57	84	3.73		
19	4+5					6	<0.01				7.12	4.97				26	1.25	28	1.30		
20	4+5					8	0.05				6.13	3.03				41	2.46	41	2.46		
21	5	2	0.01			2	0.04				5.72	2.04	1	0.01		27	0.60	28	0.61		
22	5					3	0.33				14.76	1.07				19	0.13	19	0.13		
23	5	1	0.04								2.83	1.97	17	0.86		125	2.18	143	3.10		
24	5					4	<0.01				4.50	4.83				14	0.15	19	0.19		
25	5+6					1	<0.01				6.09	3.24				2	0.05	4	0.09		
26	5+6										5.16	5.14	1	0.01		2	0.02	4	0.06		
27	5+6										3.09	11.99				9	0.30	16	0.45		
28	5+6					4	0.04				5.20	30.94				45	0.43	46	0.44		
29	6					2	0.05				5.98	52.73				64	0.63	71	0.64		
30	6					17	0.11				10.82	73.95	13	0.95		152	1.31	182	3.39		
31	6+7					16	0.09				4.04	41.98	1	0.07		179	1.38	181	1.48		
32	7+9					10	0.04				2.44	25.02	1	0.01		152	2.43	157	2.63		
33	6+7+8					2	<0.01				0.93	5.92				68	0.76	68	0.76		
34	7+8										3.65	1.67				8	0.14	8	0.14		
35	7+8										2.40	2.36									
36	7+8										4.17	0.84									

(Continues)

Cultural indicators

Note: Asterisk (*) indicates possibly heat-fractured.

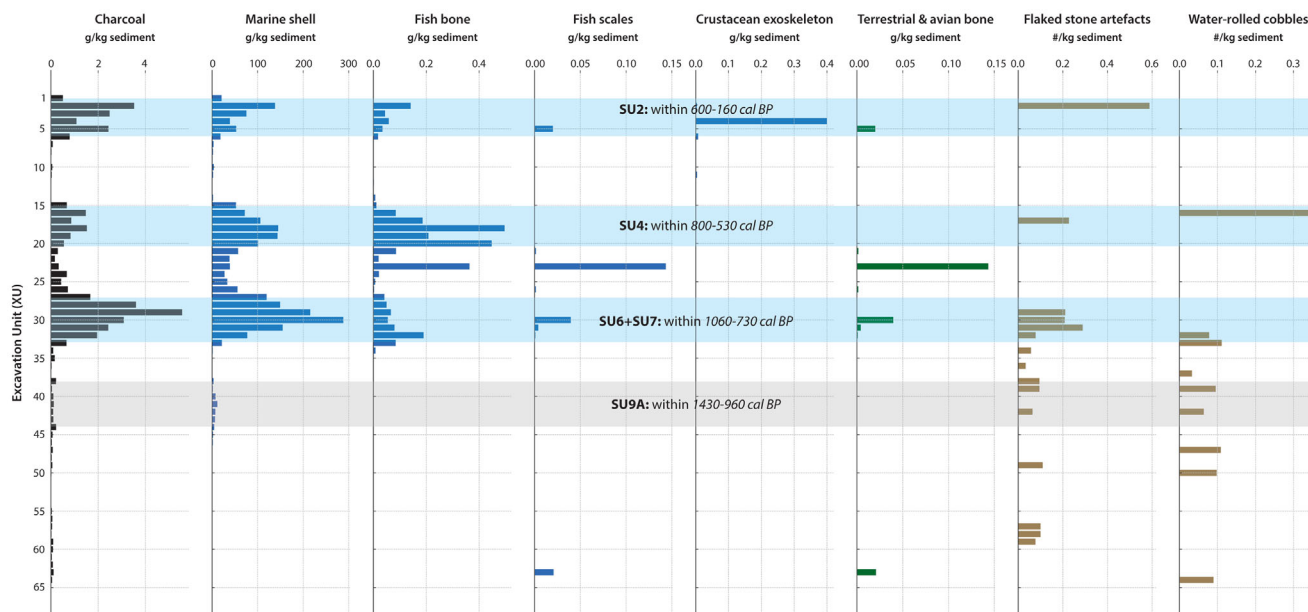


FIGURE 11 | Distribution of cultural materials including charcoal by XU, Red Bluff 1 Square A.



FIGURE 12 | Cobbles and pebbles of a range of raw materials eroding from the base of the Red Bluff cliff adjacent to the site (photo by Joanna Freslov).

is on identifying past foraging strategies, we have analysed all the subsistence and incidental specimens (following Szabó 2009, 186) so as to provide a more comprehensive understanding of the ways the Old Ancestors interacted with their environments. The ‘natural’ taxa, identified largely on taphonomic grounds and/or through degree of maturity (depending on the taxon), along with the indeterminate shell fragments whose attribution to ‘subsistence’, ‘incidental’ or ‘natural’ is ambiguous due to higher rates of fragmentation and weathering, have been excluded from the detailed analyses so as not to skew the results in unaccountable ways.

The NISP and weight (g) of each taxon were recorded by XU. Shell fragments without diagnostic characteristics were counted, bagged together by XU, and weighed. The calculation of Minimum Number of Individuals (MNI) was undertaken

following Harris et al. (2015) and Giovas (2009), using a range of taxon-specific non-repetitive elements (NREs), as per standard practice. For gastropods, the recorded NREs were the spire, aperture, aperture lip, posterior canal, anterior canal, umbilicus, and calcified opercula. For bivalves, NREs consisted of the umbo, the anterior and posterior portions of the hinge/dentition, and the anterior and posterior adductor muscle scars. The exception for the bivalves was the Mytilidae, due to their high levels of fragmentation. The peak of each Mytilidae umbo was thus counted (i.e., left and right combined) and divided by two to calculate the MNI. Polyplacophora (chiton) MNIs were based on the highest counts of the apex of the anterior and mucro of the posterior valves. The same NREs were applied to each XU for each taxon (following, e.g., Asmussen et al. 2022) to (1) ensure independence of quantification of taxonomic categories and (2) avoid effects of aggregation (e.g., Grayson 1984).

Species area curves are used to assess the adequacy of sample size and representativeness. Plotting sample size (in this case by MNI) against taxonomic richness (NTAXA) signals when sampling to redundancy has been reached (i.e., when no new taxa are added as sample size increases) (Lyman 2008). We have used multiple measures of richness and heterogeneity to assess species diversity. For these analyses, our original taxonomic categories are either grouped to the highest common level (e.g., family, genus) or certain categories are excluded to ensure independence of data. Taxonomic richness is defined as the number of species or other taxonomic categories (family, genus) in a sample and represented as NTAXA (Grayson 1984). In addition to NTAXA to assess species richness, the Shannon index (H) and Simpson’s index ($1-D$) are used to investigate assemblage heterogeneity (following Magurran 2004). For the Shannon index, values tend to fall between 1.5 and 3.5, indicating lower to higher diversity, respectively. Simpson’s index values fall between 0 and 1, with values closer to 1 indicating greater evenness in the sample. All diversity indices were calculated



FIGURE 13 | *Lunella undulata* operculum, length and width measurements (image by Patrick Faulkner).

using the Palaeontological Statistics (PAST) program version 4.16 (Hammer et al. 2001).

Biometric analyses were also undertaken to investigate shifts in shell size. High degrees of fragmentation among the two dominant taxa (the bivalve *M. planulatus* and the gastropod *L. undulata* [warrener]) effectively excluded direct measurements of shell lengths or the measurement of other shell features to estimate length based on regression analyses. However, the large number of unbroken *L. undulata* opercula provided a means to assess relative shell size (following Klein and Steele 2013) based on the measurement of maximum length and width (see Figure 13) using Mitutoyo digital callipers (to two decimal places of a millimetre). To include the broken opercula in the analysis, regression equation data to estimate *L. undulata* operculum length from their width derived by Sherwood et al. (2016) has also been applied to the Red Bluff 1 operculum assemblage. Statistical analyses to determine the distribution and significance of any differences in operculum size as a proxy for shell length were undertaken using the jamovi version 2.4.14 statistical package (The Jamovi Project 2023).

The habitat(s) in which each taxon lives was identified based on information provided in Beechey (2024), Grove (2018), Lamprell and Healy (1998), Lamprell and Whitehead (1992) and Museum Victoria (2023). Each taxon was thus attributed to a habitat based on its degree of exposure (codes 1–3) to assess potential foraging in areas ranging from open and highly exposed shores to more protected habitats. As many taxa can potentially inhabit areas covering a range of different substrates, combinations of substrate types were coded separately (substrate codes A–N, see Table 6). Seaweed (marine algae) and seagrass (marine flowering plants) beds are also incorporated into these habitat designations, with seaweed inhabiting rocky shores and seagrass often in soft sediment on more protected sandy coasts (Womersley 2005). This is similar to the recent hierarchical classification schemes developed and applied by Harris and Weisler (2017) and Rogers and Weisler (2022) for the Eastern Pacific, but in this case provides a simplified categorical scheme for analysing molluscan habitats represented at Red Bluff 1. The MNI values for each taxon attributed to a particular habitat code (e.g., 3-A, representing an exposed rock/seaweed habitat) were summed and converted to percentages for each XU.

3.2 | Assemblage Characteristics and Representativeness

The sum of the subsistence and incidental shell assemblage from the Red Bluff 1 excavations totals an MNI of 5131 (Supporting Information 2), with a NISP of 65,911 (Supporting Information 3). A large number of taxonomic categories, 94 in total, were identified across class, family, genus and species levels. Within the subsistence and incidental groups defined above, 46 taxa are subsistence and 74 are incidental, with 20 taxa appearing in both groups due to their juvenile/immature individuals assigned to the incidental group. The contribution to the total assemblage of the subsistence and incidental taxa varies depending on which measure of abundance is used. Subsistence taxa contribute 3879 MNI (75.6%) and 63,870 NISP (96.9%), whereas the incidental taxa contribute 1252 MNI (24.4%) and 2050 NISP (3.1%). This discrepancy in proportional contribution between MNI and NISP is due to the conservative approach taken in assigning MNI values based on preserved diagnostic features that were most common for the deposit as a whole, as well as higher rates of shell fragmentation for the taxonomic categories in the economic group (likely due to a combination of shell size and morphology, burning and processing). Spearman's rank correlation tests were applied to the NISP and MNI data to assess the relationship between the subsistence and incidental groups, the results of which indicate that there is a very strong, positive correlation between these two groups for NISP ($r_s(52) = 0.929$, $p < 0.001$) and MNI ($r_s(43) = 0.918$, $p < 0.001$). This shows that increasing or decreasing abundances of subsistence and incidental taxa are closely linked, thereby signalling that the deposition of subsistence and incidental shells was the result of related (or the same) foraging activities.

Figure 14 shows the total shell NISP and MNI values by XU, highlighting the close association of the two values down the deposit. This relationship is supported by a Spearman's rank correlation test, which indicates a very strong and positive correlation between the NISPs and MNIs ($r_s(43) = 0.957$, $p < 0.001$). The highest densities of shell occur as a trimodal curve, with a major peak between XU27 and XU33, together making up SU6 (peaking in XU30), with lesser peaks between XU15 and XU21, which make up SU4 (peaking in XU18) and again between XU2 and XU5, which represents SU2 (peaking in XU3) (see Figure 9 for the stratigraphic positioning of each XU). A much smaller peak also occurs between XU40 and XU42 in SU9A. Very small amounts of shell are scattered throughout the intervening XUs (as seen particularly in the NISPs). No shell was recovered from XU48, XU51–XU58A, XU59A, XU60 and XU65. The total taxonomic abundance of incidental shell is also presented in Figure 14 to reinforce the close association between the incidental and subsistence/total shell abundance values, with some deviation apparent in XU28–XU32 (in SU6, the main shell horizon). This deviation is primarily driven by an increase in the Mytilidae, notably juvenile *M. planulatus* and the small-bodied *Xenostrobus* spp.

In assessing the adequacy of the sample size and representativeness of the data, species area curves were constructed for species richness (NTAXA) against NISP and MNI as measures of sample size by XU. Both are depicted here, as NISP and MNI are each used below to determine species patterning through

TABLE 6 | Habitat categories applied to the Red Bluff 1 assemblage, based on degree of exposure (1–3) and substrate (A–N) preference.

1. Sheltered: covering environments such as bays, estuaries, lagoons or other habitat zone[s] that are protected from strong wave action	
2. Sheltered/Exposed: attributed to those taxa that are able to occupy a wide range of open and protected habitats	
3. Exposed: environments including open rocky shores or sandy beaches, i.e., those habitats subjected to stronger wave action	
A. Rock/Seaweed	B. Rock
C. Sand/Mud	D. Sand
E. Rock/Shell	F. Sand/Gravel
G. Seaweed/Seagrass	H. Mudflats/Sand/Seagrass
I. Rock/Mangroves	J. Rock/Sand
K. Mangrove/Shell	L. Rock/Sand/Mangrove/Seagrass
M. Sand/Mud/Gravel	N. Mudflats/Sand/Seagrass/Mangrove

time. The species area curves in Figure 15 (with a logarithmic trendline included for visual reference) indicate that taxonomic richness increases rapidly with sample size, and although there is a degree of data dispersal with increasing abundance (i.e., above 4000 NISP and 200 MNI), the curve begins to flatten (or approach asymptote) at these levels of abundance. Irrespective of the abundance measure used, the Red Bluff 1 assemblage data (represented by richness/NTAXA and abundance) are thus deemed to have been sampled to redundancy and are therefore representative.

3.3 | Taxonomic Distribution, Richness and Heterogeneity

The total proportional contribution of taxa is presented in Figure 16, focusing on the predominant (10 taxa contributing $\geq 1\%$ of the total MNI) and subdominant (15 taxa contributing $< 1\%$ but $> 0.1\%$ of the total MNI) taxonomic categories. The combined predominant and combined subdominant taxa represent 91.5% and 5.6% of the total MNI, respectively. There are 69 taxonomic categories not represented in Figure 16, with these contributing between 0.1% and 0.02% of the total MNI each, with a combined contribution of 2.9% of the total MNI. The two taxa that clearly dominate the assemblage are the bivalve *M. planulatus* (46.1% of the total MNI) and gastropod *L. undulata* (30.2% of the total MNI). This proportional contribution drops substantially to 4.3% and 3.2% of total MNI for *Xenostrobus* spp. and the Patellogastropoda, respectively, both of which are incidental taxa only. All the specimens assigned to the subclass level Patellogastropoda range in size between 3 and 8 mm, with the majority (at 84.8% MNI) exhibiting a high degree of weathering and chalkiness but no indications of water-rolling or abrasion. The remaining predominant and subdominant taxa that are primarily subsistence (with small numbers of incidental specimens also included) are the gastropods *Dicathais orbita* (cartrut shell), Turbinidae, *Cellana tramoserica* (common limpet), *Cellana* spp. and *Cabestana spengleri* (Spengler's triton) (between 1.7% and 0.2% of total MNI each), and the bivalves in the Glycymerididae, Mytilidae, Veneridae and Tellinidae families, and *Glycymeris* spp. and *Sunetta* spp. (between 1.2% and 0.2% of total MNI each). Finally, within this predominant/subdominant group are the chiton *Plaxiphora albida* and the giant black barnacle *Aus-*

tromegabalanus nigrescens (the largest acorn barnacle species in Australia), each contributing 0.6% of the total MNI.

Focusing on the two predominant taxa by MNI (Figure 17), the distributions of *M. planulatus* and *L. undulata* through the Red Bluff 1 sequence are broadly similar to each other and similar to the total shell distribution shown in Figure 14. Although XU58B–XU64 are not represented on this figure, due to the shell recovered from these XUs not preserving features enabling them to be allocated an MNI value, the small amount of shell in this lower part of the sequence is comprised of Mytilidae (NISP = 6) and *L. undulata* (NISP = 1) fragments. Although there are some slight differences in abundance through XU24–XU34 (base of SU5, SU6 and SU7), the highest peak in discard of these two taxa is each found in this horizon. Between XU15 and XU23 (SU4 and upper half of SU5), representing the second, albeit minor, peak in these taxa, there appears to be a slightly greater emphasis on *M. planulatus*. This is replicated also in the upper XUs (XU1–XU6, representing SU2 and its interface with SU1); however, abundance is lower again within this group of XUs. Any variability in the peaks and troughs of these two taxa (primarily in XU30 and XU31, at the base of SU6 as it interfaces with SU7) can be viewed as minor, with a Spearman's rank correlation test indicating a very strong and positive relationship in their abundance ($r_s(29) = 0.673$, $p < 0.001$). As one species increases in abundance through the sequence, so does the other, and they also decrease in tandem. As the predominant incidental taxon, and also as a species within the Mytilidae, the *Xenostrobus* spp. distribution suggests a close link with *M. planulatus*. Although not occurring consistently throughout the sequence, *Xenostrobus* spp. does peak in XU30–XU32 (base of SU6 and SU6–SU7 interface) and appears alongside *M. planulatus* in XU3–XU5 (SU2) and XU18 (base of SU4).

To evaluate richness and heterogeneity, the taxonomic categories were either grouped to their highest common level (e.g., family, genus), or certain categories were omitted to ensure the exclusivity of each taxon. Richness (NTAXA) and heterogeneity (Simpson's 1-D and Shannon *H*) are shown in Figure 18 by NISP and MNI. As these measures can be affected by sample size, with a large number of XUs containing very small samples, we have aggregated stratigraphically contiguous XUs based on the vertical distribution of shell in Figure 14 to ensure the results are robust. These groupings are XU1–XU6 (SU2), XU7–XU13

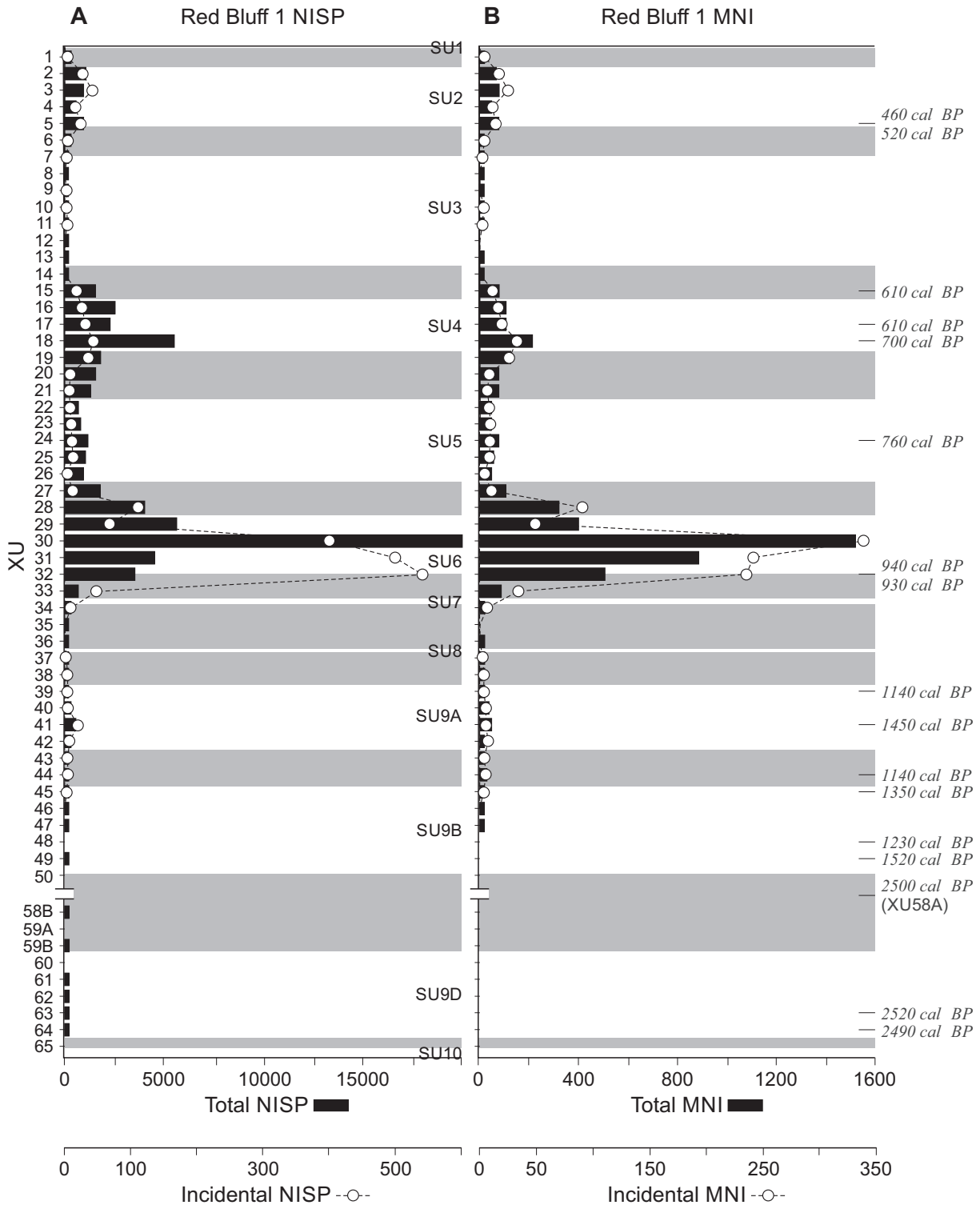


FIGURE 14 | Distribution of shell through the Red Bluff 1 sequence, with the incidental group NISP and MNI also represented as a comparative measure (note differences in scale). (A) By NISP. (B) By MNI. The grey lines represent the interfaces between SUs. The calibrated dates are modelled median ages.

(SU3), XU14–XU22 (SU4 and upper SU5), XU23–XU35 (lower SU5, SU6 and SU7), XU36–XU49 (SU9A and SU9B) and XU58B–XU64 (SU9D) (with the latter group only represented by NISP). Showing bimodal distributions, NTAXA values range between 2 and 83 for the NISP data and between 3 and 56 for the MNI data. In both cases, the major peak in taxonomic richness occurs in

XU23–XU35 (lower SU5, SU6 and SU7), and following a reduction in NTAXA values above these XUs, there is a minor peak higher up in XU1–XU6 (SU2). Lower richness values in XU7–XU13, XU36–XU49 and XU58B–XU64 (SU3 and SU9) are somewhat expected given the much lower abundance of shell in these XUs. Simpson's 1-*D* and Shannon *H* values exhibit similar trends, both

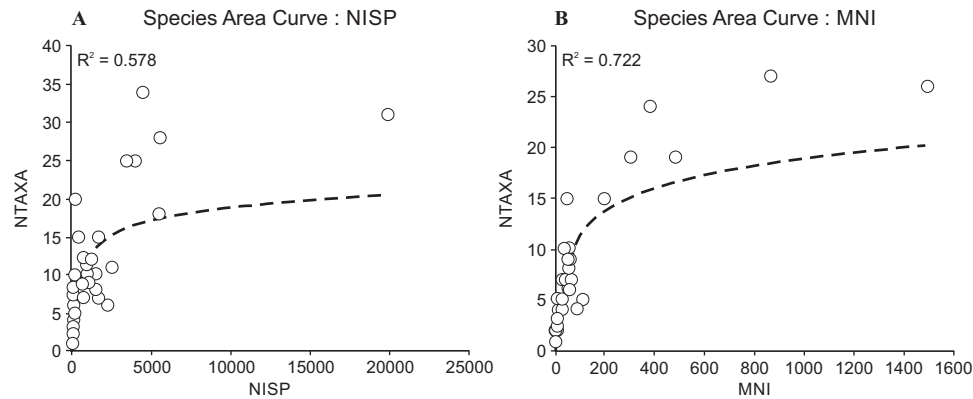


FIGURE 15 | Red Bluff 1 species area curves plotting species richness (NTAXA) against NISP (A) and MNI (B).

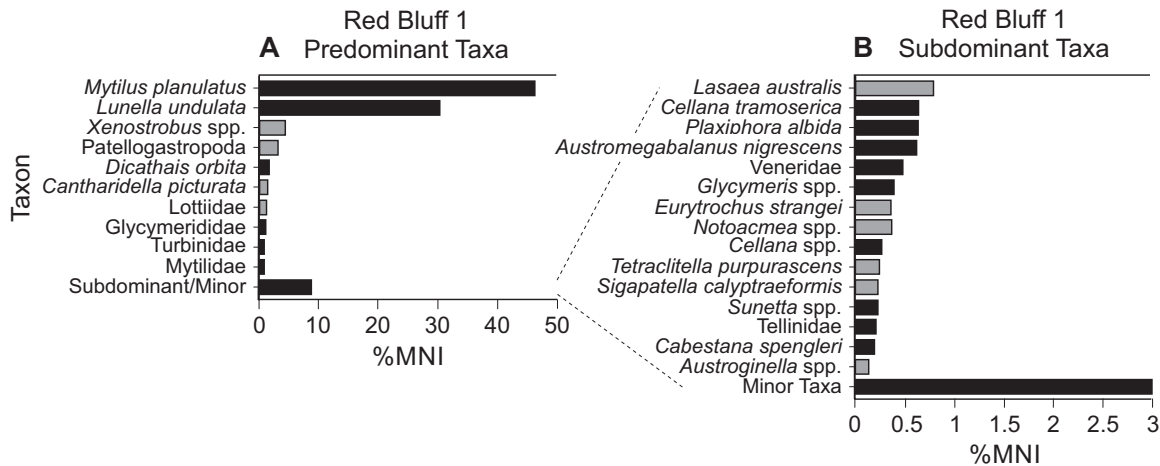


FIGURE 16 | Proportional abundance (% of the total MNI) of the predominant (A) and subdominant (B) taxa in the Red Bluff 1 shell assemblage. Grey bars indicate those taxa identified as being incidental only.

to the richness results and to each other, irrespective of the use of NISP or MNI (although the latter indicates slightly higher diversity, likely due to reduced sample sizes), with values peaking in XU23–XU35 (lower SU5, SU6 and SU7) and XU1–XU6 (SU2). Importantly, the degree of variability within and between these measures (as well as by NISP and MNI) is very minor. Overall, the 1-*D* values indicate a low to moderate degree of diversity, and the *H* values indicate a low degree of diversity through the Red Bluff 1 sequence, due primarily to the overwhelming dominance of a small number of taxa.

3.4 | Processing and Selection Patterns: Burning, Breakage and Shell Size

The total amount of burnt shell in the assemblage is 11,799 NISP (17.9% of the total shell assemblage), although this is likely to be an underestimate as burning was assessed visually based on observable patterns of thermal alteration, and some lightly burnt shell was probably not recognised as burnt. Evidence of burning on shell can be obscured by fragmentation and discolouration and is also affected by the structural properties of individual taxa (see Szabó and Oertle 2023). As such, these results should be viewed as indicative of burning patterns through the Red Bluff

1 sequence. Focusing on the two predominant taxa, *L. undulata* burnt specimens totalled 1698 NISP, and *M. planulatus* burnt specimens totalled 8684 NISP, representing 14.4% and 73.6% of the total burnt NISP, respectively. These data need to be viewed cautiously, as *L. undulata* burning patterns may be obscured by high levels of Vermetidae adherence to the exterior of the shell. The *M. planulatus* rates are likely substantially higher than their observed rates of burning due to the susceptibility of this taxon to fragmentation. Importantly, 62.5% of burnt *L. undulata* specimens are opercula and operculum fragments, the remainder being umbilicus and columella lip at the anterior section of the aperture. This localisation of burning evidence on the shell suggests purposeful processing of this species.

Shell fragmentation is measured using NISP:MNI ratios. For the total assemblage, fragmentation values range between 1.0 (XU47) (indicating that each shell fragment represents a whole shellfish, i.e., an intact shell assemblage) and 37.0 (XU9) (indicating that there are 37 fragments per shellfish, i.e., a highly fragmented shell assemblage), with an average of 15.1. The most highly fragmented horizons occur in XU9, XU14 (30.0) and XU42 (23.8), with a gradual increase from XU30 (13.2) to XU14. These data suggest that the overall degree of fragmentation through the sequence is relatively low. *M. planulatus* exhibits a different breakage pattern

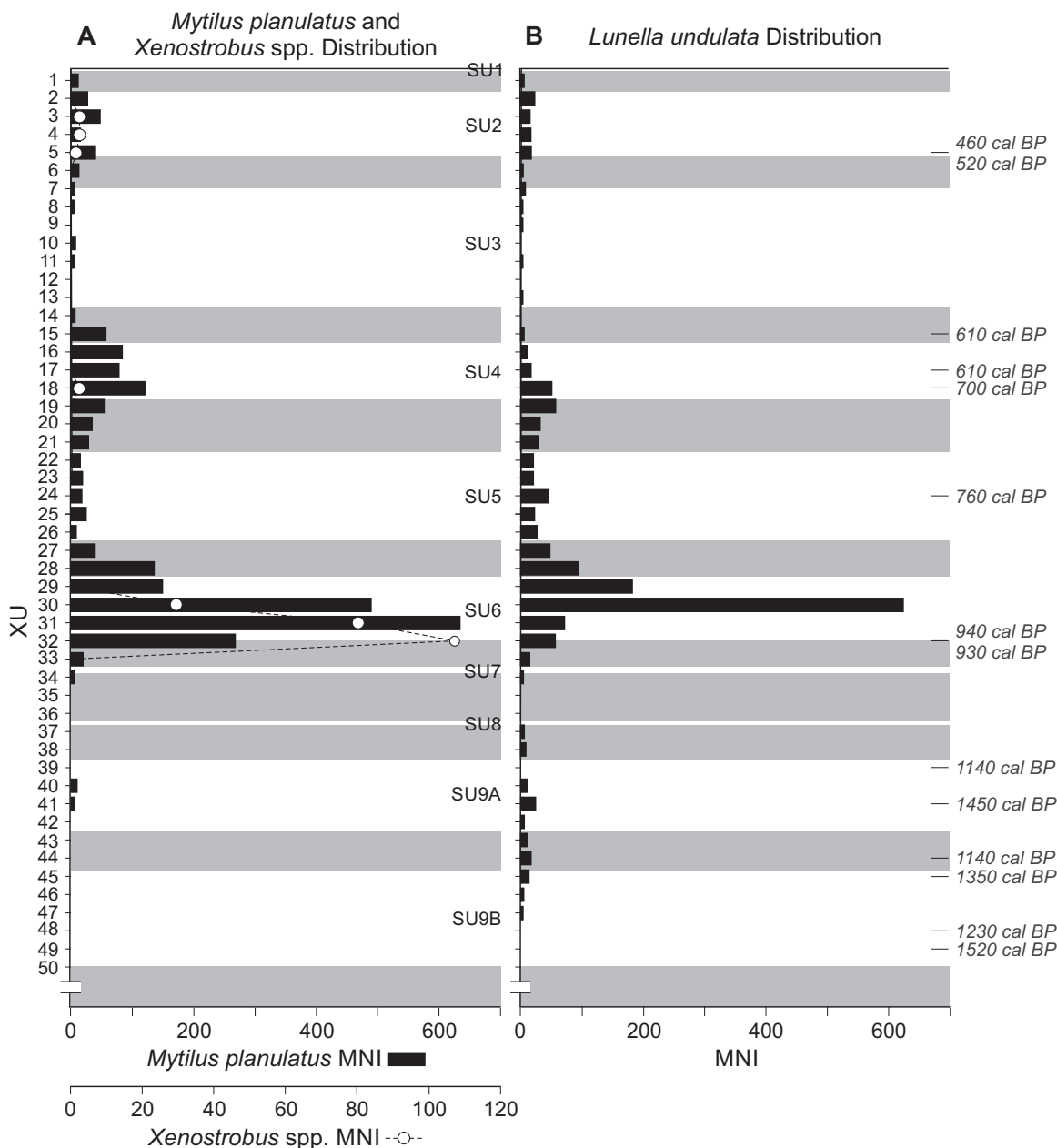


FIGURE 17 | Distribution of *Mytilus planulatus* (A) and *Lunella undulata* (B) through the Red Bluff 1 sequence, by MNI. *Xenostrobus* spp. MNI is also represented as a comparative measure alongside *M. planulatus* (A) (note the difference in scale). The grey lines represent the interfaces between SUs. The calibrated dates are modelled median ages.

due to its morphology. Its fragmentation rates range from 1.5 (XU34) to 64.0 (XU26), with an average of 22.1. The vertical distribution in fragmentation is multimodal, peaking in XU26, XU24 (52.8), XU18 (39.0), XU7 (25.0) and XU2 (27.4). This suggests that breakage and fragmentation for this taxon is complex and likely linked to a combination of processing, differential burning, exposure and trampling/compaction operating in different ways during the formation of the deposit. *Lunella undulata* fragmentation rates mirror more closely the total assemblage pattern, averaging 8.0 through the sequence, with minor peaks in XU42 (21.7), XU20 (20.5), XU15 (14.7), XU6 (15.0) and XU1 (16.3). Excluding these distributional peaks, the average fragmentation ratio is 7.0, ranging from 13.0 to 1.0, indicating a more consistent rate of breakage through the sequence than seen with *M.*

planulatus. In other words, warrener (*L. undulata*) is consistently broken through the deposit, whereas the degree of breakage of the mussels (*M. planulatus*) is sometimes very high but varies considerably through the deposit.

Inspection of the *L. undulata* breakage patterns through the sequence indicates systematic breakage of the shell producing the same patterns reported by McNiven (1996) from sites in Hibbs Bay, Lutruwita/Tasmania. Based on experimental assessments of breakage, McNiven (1996) interpreted these patterns as indicating that the shell was placed upside down on an anvil and the columella struck with a hammerstone anteriorly and adjacent to the operculum, producing the distinctive breakage patterns also found at Red Bluff 1 (Figure 19). This method of breakage is

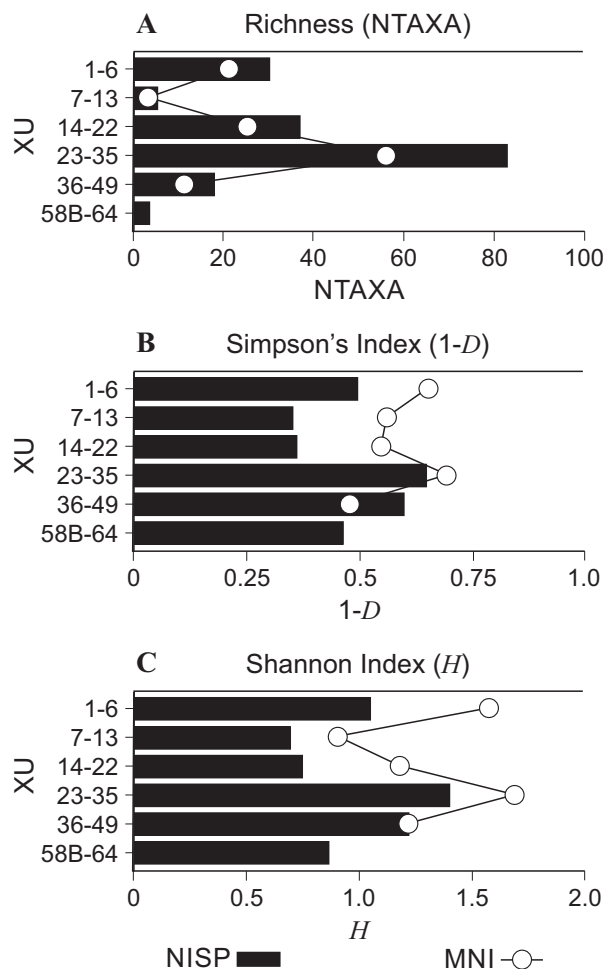


FIGURE 18 | Measures of taxonomic richness (A: NTAXA) and heterogeneity (B: Simpson's 1-D and C: Shannon H) at Red Bluff 1, by aggregated XUs.

supported by calculating the ratio of umbilicus/columella to spire fragments, as this mode of processing produces a large number of body fragments while minimising damage to these other shell features. Umbilicus/columella:spire ratios between 3.0 and 13.0 appear in XU6, XU41, XU42 and XU45, but for all other XUs the value falls below 2.0 (i.e., two umbilicus/columella fragments per spire), averaging 1.1 through XU2–XU5, XU16–XU34 and XU42. The consistency of this fragmentation pattern through the deposit signals a systematic method of processing *L. undulata* applied for the full c. 1740 years (from the start of SU9B at 1900 cal BP to the end of SU2 at 160 cal BP, at 95.4% probability) of the *L. undulata* sequence, combined with the regularity of burning around the aperture and operculum to remove the flesh for consumption.

Changes in *L. undulata* shell sizes through the sequence were investigated by analysing the size of the opercula. As *L. undulata* is one of the two most common taxa at Red Bluff 1, relative changes in size inform on shifts in shellfish predation pressures and/or habitat change. As noted above, fragmentation patterns were such that no consistent landmarks for measurement of the shell could be identified, meaning that regression-based biometric approaches for estimating shell size from fragmentary

remains could not be undertaken. Instead, operculum size was used as a proxy indicator for shell size (following the approach used by Klein and Steele 2013). The lengths of opercula for which only width could be measured were estimated using the six regression equations published by Sherwood et al. (2016). These equations were derived from areas in Victoria located to the west of Gippsland but in similar latitudes; therefore, the operculum length values calculated by these six equations were averaged, effectively representing the broader regional population. For the Red Bluff 1 assemblage, the XUs were aggregated in the same way as for the analyses of richness and heterogeneity, as listed above.

The descriptive statistics for reconstructed Red Bluff 1 opercula lengths from the published regression equations for the Victorian coast are presented in Table 7, with associated Shapiro–Wilk tests of normality in the distribution of the data by aggregated XUs. These operculum length data are also presented as box and violin plots in Figure 20. A Levene's test for equality of variance indicates that the assumption of homogeneity of variance was not violated ($F(4, 1095) = 1.19, p = 0.313$). In other words, this result indicates that the spread (or variance) of the data is similar across the samples represented by these aggregated XUs. Due to substantial differences in sample sizes between the XU groups and deviations from a normal distribution in the XU23–XU35 opercula sizes, non-parametric tests were employed to test for significant differences in opercula lengths through the Red Bluff 1 sequence. A Kruskal–Wallis H test indicates a significant difference in opercula sizes between the five aggregated XU groups (XU1–XU6, XU7–XU13, XU14–XU22, XU23–XU35, XU36–XU49) ($H(4, n = 1100) = 83.15, p < 0.001$). The effect size, which quantifies the magnitude of difference or association in statistical analysis (see Wolverton et al. 2016), is measured here using eta-squared. The effect size was weak ($\eta^2 = 0.072$), suggesting that the magnitude of difference in opercula length between the five XU groups analysed is not large. The results of Dunn's post hoc pairwise tests (with Bonferroni adjustment) are also shown in Figure 20, where there are significant differences. These results indicate a significant difference in opercula lengths (and therefore overall shell size) between XU1–XU6 and XU14–XU22 (with opercula increasing in size in XU1–XU6, in SU2, a rich archaeological horizon that follows c. 90 years of archaeologically depauperate dune sand build-up in SU3), between XU14–XU23 (SU4 and upper SU5) and XU24–XU35 (lower SU5–SU7) (with opercula decreasing in size in XU14–XU23, in the upper parts of this dense shell horizon), and between XU23–XU35 (lower SU5–SU7) and XU36–XU49 (SU9A+B) (with opercula increasing in size in XU23–XU35).

3.5 | Habitat Analysis

With all taxa inhabiting the shoreline gradient between the upper intertidal and shallow subtidal zones, our focus here is on understanding species distributions according to degree of habitat exposure and substrate. Reliable exposure and substrate information (as outlined in Table 6) were either not able to be determined for 10 taxonomic categories or, where potential habitats were too diverse to be meaningful, were determined at family or higher level. These 10 taxa were excluded from this analysis. They comprise only 4.4% MNI of the total assemblage, so would

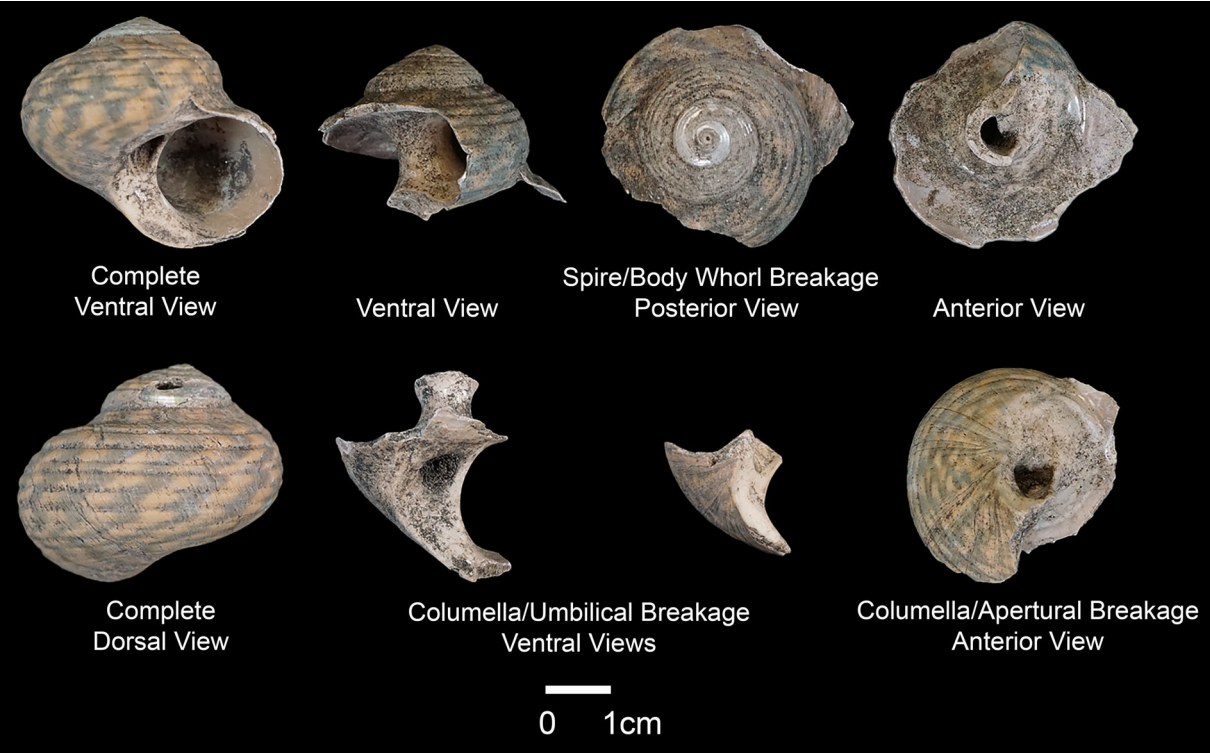


FIGURE 19 | Systematic breakage patterns of *Lunella undulata* for processing and meat extraction (image by Patrick Faulkner).

TABLE 7 | *Lunella undulata* operculum descriptive statistics and Shapiro–Wilk test results of normality in distribution.

XU Group	N	Mean	SD	Median	IQR	Mode	Min.	Max.	Shapiro–Wilk
XU1–XU6	54	15.2	3.06	15.7	4.23	12.3*	6.2	23.0	$W = 0.97; p = 0.157$
XU7–XU13	3	13.2	4.93	13.2	4.93	8.3*	8.3	18.1	$W = 1.00; p = 0.922$
XU14–XU22	181	13.3	4.68	12.9	4.68	11.2	4.5	21.7	$W = 0.99; p = 0.052$
XU23–XU35	807	15.5	3.98	16.1	3.98	16.5	4.9	21.2	$W = 0.97; p < 0.001$
XU36–XU49	55	13.7	3.98	13.4	3.98	12.9	8.5	20.4	$W = 0.98; p = 0.546$

Note: Asterisk (*) indicates more than one mode, with only the first reported).

not have a significant impact on the results. The predominant nine habitat zones for the assemblage by %MNI (where MNI >15) are shown in Figure 21. A further 16 habitat categories exhibiting different combinations of the potential exposure and substrate categories (substrate codes G–N) were not graphed. These 16 categories combined represent only 0.9% MNI of the assemblage (ranging between 0.02 and 0.12% MNI individually), indicating that a focus on the more predominant habitats would not skew representation of the targeted habitats. Only six of these categories are more firmly associated with seagrass, often in combination with soft substrates in more sheltered habitats (nine taxa and a combined 0.27% MNI), as opposed to seaweed beds. Unsurprisingly, given the dominance of *M. planulatus* and *L. undulata*, exposed rock/seaweed (habitat code 3-A) taxa dominate the assemblage by a substantial margin, with 11 taxa contributing 84.0% MNI. This is followed by additional hard substrate taxa, with sheltered/exposed rock/seaweed (habitat code 2-A, 6.4% MNI, 3 taxa), exposed rock (habitat code 3-B, 4.4% MNI, 16 taxa), exposed rock/shell (habitat code 3-E, 0.8% MNI, 1 taxon) and sheltered rock/shell (habitat code 1-E, 0.3% MNI,

2 taxa). The remaining four habitat categories (habitat codes 3-F, 1-C, 3-D and 1-B) cover sheltered or exposed locations with different combinations of sand, mud and/or gravel substrates, ranging between 0.4% and 1.7% MNI and 2–10 taxa.

A scatter plot of the summed MNI values for the predominant hard and soft substrate groups noted above is also presented in Figure 21. The slope of the trendline indicates that the relationship between these two groups is linear, with the R^2 value of 0.86 showing a good fit of this trendline to the data, even with some minor deviation in the dispersal of the data points. Spearman’s rank correlation tests were applied to assess the strength of the relationship between these hard and soft substrate groups, the results of which indicate that there is a very strong, positive correlation between these groups based on MNI ($r_s(23) = 0.822, p < 0.001$). As the abundance of hard substrate taxa increases through the sequence by XU, there is a concomitant increase in soft substrate taxonomic abundance. This suggests a degree of continuity in the range of accessible nearshore habitats close to Red Bluff 1.

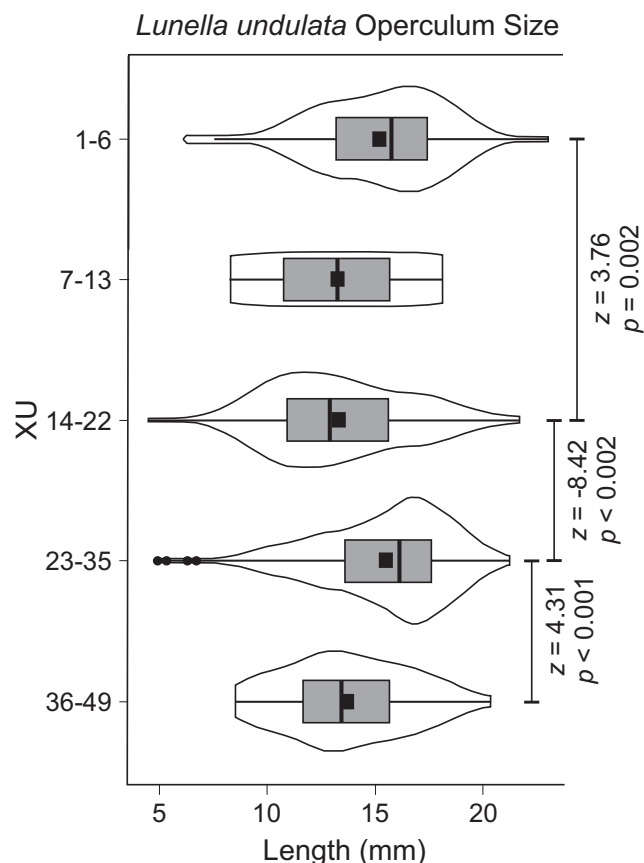


FIGURE 20 | Box and violin plot of *Lunella undulata* opercula lengths, by aggregated XU.

Although not included in the analyses above, the terrestrial and freshwater shells recovered from Red Bluff 1 are worth noting here. The freshwater gastropod species *Glacidorbis rusticus* was recovered from XU21 ($n = 1$ MNI), XU24 ($n = 2$ MNI) and XU28 ($n = 1$ MNI). This species inhabits coastal drainage areas, primarily in swamps, bogs, and streams and rivers, and is normally found on macrophytes (aquatic plants) and other vegetation such as moss or roots, or on pieces of wood (Ponder and Avern 2000). At Red Bluff it is most probably related to the stream in the small valley close to the excavation. According to Ponder and Avern (2000, 331), this species is distributed around Wilsons Promontory and in a small number of other localities in eastern Victoria. This appears to be one of the first, if not the first, records of this species in Gippsland. Five terrestrial gastropod species from four families were recovered from Red Bluff 1, these being *Elsothera* cf. *brazieri*, *Lucuropa* cf. *colliveri* (family Charopidae), *Magilaoma penolensis* (family Punctidae), *Austrorhytida* cf. *glaciamans* (family Rhytididae) and *Scelidoropa tamarensis* (family Cystopeltidae). The distribution of these taxa by MNI is shown in Table 8, along with their habitats (from Hyman and Stanisic 2005; Stanisic et al. 2017). One of these specimens (*S. tamarensis*, from XU25) was noted to be very fresh-looking and most likely represents a modern, post-depositional intrusion into this XU. The majority of individuals from the other four taxa were recovered from the dense shell deposit, being largely distributed between XU16 and XU34, with small numbers appearing in XU3, XU4 and XU39. All of these species occur in the

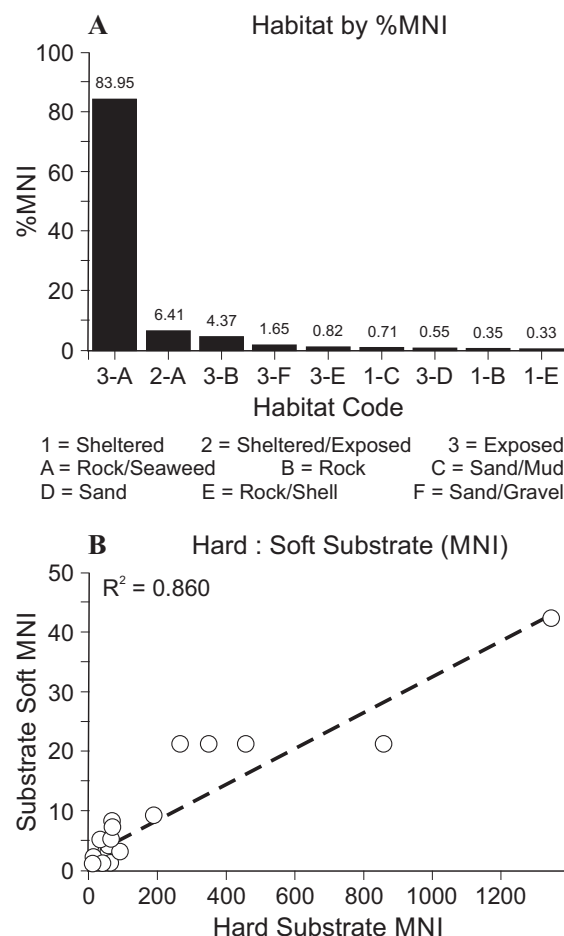


FIGURE 21 | Red Bluff 1's predominant shellfish habitats by %MNI (A) and scatterplot of predominant hard substrate taxa MNI:predominant soft substrate taxa MNI ratios (B).

Gippsland area today and represent the modern coastal habitats within the region.

4 | Discussion: What This All Means

Every place has a story (or stories) to tell, and Red Bluff 1 is no exception. It is important to remember that, as with all archaeological sites, a sampled area relates specifically to that location within the broader site and landscape, not necessarily to other parts of the same site or landscape. This is particularly so for the Red Bluff 1 excavation, which is a small sample (a single 50 × 50 cm column) of a very large site complex covering an area of c. 5000 m² (the size of the site complex was measured by its visible surface archaeological exposures and is probably even larger given the extent of the sand dune system and the limited size of the visible [exposed] buried archaeological deposit). Our excavations aimed to reveal initial information about the age and characteristics of the archaeological horizons, not their spatial variations. Nevertheless, the range of analyses presented here is indicative of the nearshore foraging behaviour represented by this specific excavated area.

There is a high degree of taxonomic richness (i.e., there are many species, consisting of molluscs and barnacles) in this assemblage,

TABLE 8 | Terrestrial and freshwater gastropod abundance (MNI) by XU and habitat.

Taxon	XU																		
	3	4	16	17	18	19	20	21	22	23	24	25	28	29	30	31	32	34	39
<i>Elsothera</i> cf. <i>brazieri</i>		1	1	1	6	3	4	1	2		3		2		13	9	8	1	1
Dry sclerophyll forest to temperate rainforest, coastal heath; under litter, logs, under rocks																			
<i>Lucuropa</i> cf. <i>colliveri</i>							1									1			
Wet forest; living in decaying litter																			
<i>Magilaoma</i> <i>penolensis</i>	1					2	3		1	1			1		2	5	2	1	
Dry to wet eucalypt forest and dune shrubland, often in coastal situations; living in litter																			
<i>Austrorhytida</i> cf. <i>glaciamans</i>				1	1	1								2	2	1			
Subalpine woodland, dry sclerophyll forest to beech forest; living under logs and rocks																			
<i>Scelidoropa</i> <i>tamarensis</i>												1*							
Dry forest, woodland and heath; living under timber and in litter																			
<i>Glacidorbis</i> <i>rusticus</i>								1			1		1						
Coastal drainage areas, primarily in swamps, bogs, and in streams and rivers																			

Note: Asterisk (*) indicates likely modern, intrusive specimen.

substantially higher than for the vast majority of sites reported across the southeastern coast of Australia (but see Colley 1997 for the southern NSW Disaster Bay sites) and more than for any of the other recorded shell middens in GunaiKurnai Country east of Wilsons Promontory. While this taxonomic richness is offset to some degree by the approaches taken previously, which often focused only on the taxa assumed to be of dietary importance and/or predominant in an assemblage (e.g., Gaughwin and Brennan 1986; Zobel et al. 1984), considering the full range of subsistence and incidental taxa present in an assemblage is important. This is particularly the case when assessing deposits dominated by a single or small number of species, such as those at Bratua 1 and 2 (Rogers, David, et al. 2025) and the Nooramunga midden complex (Rogers, Kenndey, et al. 2025). Sites that contain an expanded range of harvested species, like those at Wilsons Promontory (Coutts 1967) and Red Bluff 1, better allow for a consideration of shifting environmental conditions, as multiple habitats are represented both by the predominant species and by the rarer taxa. Incidental taxa, especially of tiny organisms, are particularly important in this regard, as they do not usually represent targeted harvests by the people who brought them to shore but rather incidentally accompany the selected resources. They are thus in themselves useful targeted habitat indicators, and not just of the subsistence shell (e.g., by being attached to them), but potentially also of other kinds of resources such as seagrass or kelp that may house particular invertebrates, including small molluscs.

While there was undoubtedly a consistent targeting of both *M. planulatus* and *L. undulata* through the Red Bluff 1 sequence, the degree of taxonomic richness and diversity varies notably through time. Richness and diversity are highest between XU23 and XU35 (lower half of SU5–SU7), with age ranges constrained from 730 to 1060 cal BP (the younger end of the individually modelled age for SU5 to the modelled boundary age for SU7, at 95.4% probability), suggesting that a broader range of species were then harvested alongside the two predominant taxa. The

reduction inNTAXA and lower diversity values in XU14–XU22 (SU4 and upper half of SU5), with age ranges constrained from 530 to 800 cal BP (the younger end of the boundary age for SU4 to the older end of the individually modelled carbon date for SU5, at 95.4% probability), indicates a subtle shift in emphasis, with foraging having become slightly more focused, shifting away from a more sweeping harvesting strategy that incorporated a broader spectrum of taxa. In the upper horizon of XU1–XU6 (SU2, dated between 160 and 600 cal BP, minimum and maximum modelled boundary ages, at 95.4% probability), the slight reduction in richness (compared with both XU14–XU22 and XU23–XU35) coupled with an increased species diversity indicates a further subtle change with the range of marine shellfish taxa decreasing alongside an increase in sub-dominant/minor taxa, albeit with *M. planulatus* and *L. undulata* still being the major targeted species. Similarly, there was a consistent focus on locally available exposed rocky habitats, often associated with seaweed beds, throughout the Red Bluff 1 sequence. Soft substrate habitats, like sand, mud and gravel, were also consistently exploited but to a minor degree. These habitat zones include exposed sandy beaches as well as more sheltered estuaries or river mouths, all of which would have been close to and within easy access of Red Bluff 1. This reinforces the previous interpretation of site content being determined by localised nearshore habitat productivity (Frankel et al. 1989; Fresløv and Frankel 1999).

Extending from this, there appear to be three main periods of occupation and shell discard in the sequence: (1) A major period encompassing XU23–XU35 (lower half of SU5–SU7) dated between 730 and 1060 cal BP; (2) a minor period between XU14–XU22 (SU4 and upper half of SU5) dated between 530 and 800 cal BP; and most recently (3) the XU1–XU6 (SU2) near the top of this part of the dune, dated between 160 and 600 cal BP and representing the final phase of occupation and discard prior to the onset of settler colonialism. At this stage, it is difficult to assess how the sparse shell remains in XU7–XU13

(SU3), XU36–XU49 (SU9A–SU9B) and XU58B–XU64 (SU9D) got there, although the specimens in these XUs do not exhibit the taphonomic signatures indicative of natural deposition. Rather, the shell in these XUs probably represents a combination of low-level, ephemeral discard from occupation near the area of Square A between the major phases and the post-depositional mixing of deposits, especially at stratigraphic interfaces. These horizons of lower shell content separate and thus allow us to better characterise the shell-rich horizons both for their contents and for what they imply about the deep-time stories and history of past shellfishing practices in the Red Bluff intertidal zone.

The variability in marine shellfish taxa and their abundance in archaeological sites across Victoria indicates that their generic description as small, thin and patchy may not be as broadly applicable as previously proposed (Frankel 2017; Frankel et al. 1989). The upper levels of the Red Bluff 1 deposit, encompassing XU1–XU6 (SU2), appear to conform to the generic characterisation of sparseness and low species diversity, but the older two dense horizons (XU14–XU22 [SU4 and upper half of SU5] and XU23–XU35 [lower half of SU5–SU7]) do not. This suggests that things were not always the same at and near the site. The challenge is to determine why the Old Ancestors varied their subsistence activities through time at Red Bluff: Do the changes in the shell remains mean that the ancestors just responded to the shifting resources as habitats changed, or, rather, were other factors also at play, such as changes in the use of favoured locations among residential, familial or special-activity groups and individuals, or varied or changing dietary preferences?

A major consideration in assessing the utilisation of the landscape by the Old Ancestors is how the geomorphology—the coastal landforms and intertidal zone—varied during their extended habitation of the region. Today, the sand beach fronting the midden is ephemeral and can be geomorphologically considered more akin to a rocky than a sandy shore. But it appears that in the past the landscape was less sandy, both on the beach topographically below the excavated site, and on the adjacent landforms where the site occurs in a climbing dune. The timing of occupation in the past c. 2500 years corresponds to a major period of geomorphic change throughout the entire coastal region of Gippsland. Kennedy et al. (2020) inferred from dating of the coastal landscapes further southwest that the addition of new sediment to the Ninety Mile Beach barrier system led to region-wide coastal progradation, infilling of former tidal entrances at Ocean Grange, and potentially the development of the narrow barrier that forms the seaward side of Bunga Arm. This movement of sand is thought to originate in the southwest, around Corner Inlet, and to have been transported northeast, meaning that Red Bluff would have been a natural groyne (a natural barrier extending into the sea) that blocked this flow and trapped marine sediments. Conceivably, prior to around 2500 cal BP, Red Bluff was an entirely rocky headland that only connected to the Ninety Mile Beach system once sand reached this location from the sea in a longshore direction. If this is the case, then Beach-Barrier 1 adjacent to Red Bluff would be of similar age to the midden site that is less than c. 2500 cal BP. The presence of the dunes as a camping location was therefore only possible due to sand accumulating around the headland and then transported further eastward, with

a portion blown into the creek valley as a climbing dune. Prior to this period, Red Bluff was a rocky promontory accessible only via its inland ridgelines rather than along the beach as occurs today. We should thus be thinking at two spatial scales simultaneously, with the sand of the climbing dune building up after 2500 cal BP at one spatial scale, while people camped on the dune after it started forming and then going to, and foraged for, shellfish in a range of habitats, including localised rocky platforms in the intertidal zone.

The slight peak in macroscopic charcoal concentration at XU41 also testifies to such landscape dynamics, in this case anthropic. Here the slight peak in macroscopic charcoal is associated with occasional cultural material and a small peak in both the major marine shell taxa, indicating occupation on the nearby Red Bluff dune-scape (Figures 8, 14 and 17). Of even greater interest, though, is that this earliest sign of low-intensity fire immediately precedes, and led to, the destabilisation of the Haunted Hills Formation slope just 2.5 m to the west of the excavated square, as evident by the redeposition onto what was then the abutting sand dune's surface in the area of Square A of the compact and consolidated SU8 silt block c. 1000 cal BP, a slope destabilisation that we here interpret to have resulted from the practice of cultural burning.

Finally, the burning and breakage patterns evident on the *L. undulata* shell throughout the Red Bluff 1 sequence are interesting, as they indicate a degree of consistency in processing strategies through time. The localised burning around the aperture and opercula suggests deliberate and regular placement of the shell in fireplaces during food preparation. This was then followed by the systematic breakage of the shell by placing it on an anvil and strategically breaking it through the columella to enable the flesh to be removed, a process identical to that described in detail by McNiven (1996) for *L. undulata* processing in Lutruwita/Tasmania. The repeated fracture of the anterior section of the columella through the application of direct force from something like a hammerstone while the shell was resting on a hard surface or anvil is archaeologically diagnostic, because it leaves a characteristic pattern on the broken shell. Sherwood et al. (2016, 16) noted that this is a practice that extended geographically across coastal Lutruwita/Tasmania, Victoria and into South Australia, although Red Bluff 1 appears to be the first published record of this practice from the Gippsland coast (see also Coutts 1978, 130). The pitted cobbles excavated at Red Bluff 1, some whole and some broken from impact pits, are consistent with their probable use as such hammerstones and anvils.

Macroscopic charcoal concentrations correspond to distinct horizons of human activity by the Old Ancestors between XU23–XU35 (lower half of SU5–SU7), XU14–XU22 (SU4 and upper half of SU5), and XU2–XU6 (SU2). The lowermost phase (XU23–XU35), with the highest peaks in macroscopic charcoal concentrations, align with the highest values of marine shell and fish-scale fragments, and flaked artefacts, including the largest quartz flaked artefacts (Figures 8, 11, 14 and 17; Table 5). Indeed, the highest macroscopic charcoal concentration peaks at XU29–XU31 correspond to the highest distributions of *M. planulatus* and *L. undulata* in the archaeological record (Figures 14 and 17). Further, within this phase, a slighter increase

in macroscopic charcoal concentration at XU14–XU22 is particularly associated with increases in the distribution of *M. planulatus* and *Xenostrobus* spp. (Figure 17). During the most recent horizon of human activity (XU2–XU6, representing SU2), with increases in the distribution of both predominant marine shell taxa, there is a distinct phase of macroscopic charcoal concentration (Figures 8 and 17). Here, the macroscopic charcoal concentration data support the processing strategies by the Old Ancestors, particularly the burning of *L. undulata*. These data may reflect the occupation and cooking of marine resources or the maintenance of the landscape surrounding the Red Bluff 1 site, or both (see Fletcher et al. 2024; Romano and Fletcher 2018).

Analysis of *L. undulata* opercula indicates an expanded range of sizes through the three main shell horizons, with the size data for XU23–XU35 (lower half of SU5–SU7) and XU1–XU6 (SU2) indicating greater selection of larger individuals. The sizes of the *L. undulata* opercula in XU14–XU22 (SU4 and upper half of SU5) are statistically significantly different to those of XU1–XU6 and XU23–XU35, having a similar range but with smaller mean and median values. While it is tempting to interpret the smaller size of *L. undulata* from XU14 to XU22 as having been driven by human predation, given continuous intensive shell deposition through the period 530–800 cal BP, the situation is often more complex than simply correlating size decrease with human activity (e.g., see discussion in Giovas et al. 2010). A range of other drivers may be in play that are not as easily accounted for by the available data, including short-term environmental/climatic change affecting reproduction and growth rates, a shift in the season of harvest, and/or a subtle logistical shift in *L. undulata* harvesting locations. For example, several studies have indicated that the micro-habitat variability (structural complexity, algal cover) has a substantial impact on the overall density and size distribution of *L. undulata* (Smoothey 2013; Worthington and Fairweather 1989). This is particularly relevant to Red Bluff, whose beach and intertidal zone can rapidly change from a sandy seagrass habitat to a rocky shore as individual storms can wash away the shallow sand covering the rock.

5 | Conclusion

Today, the large archaeological site of Red Bluff is located in a sand dune complex adjacent to a sandy beach with a sandy intertidal zone with sparse seagrass cover. The sandy beach is not, however, a permanent feature: it is a thin veneer that rests on top of a rocky intertidal platform that extends hundreds of metres offshore. The platform is periodically exposed at the shoreline after storms, only to be reburied in intervening calmer periods. In the past, this coastal system would have been different to what we see today. Prior to 2500 years ago, the area was most likely entirely rocky, with little or no sand present. The arrival of sand into the area, from longshore drift from the west, allowed sand to move around Red Bluff and onto the intertidal platform. Some of this material was then blown into the small river valley to form a climbing dune. The arrival of sand into this area created a unique shellfish habitat, one where both sandy and rocky species could thrive in close geographic proximity. The rocky platform closest to Red Bluff likely remained exposed, while in front of the creek outlet the system was sandy. The transition zone, which today

occurs directly in front of the excavation, is sandy most of the time, but rocky during stormy periods.

Stratigraphic analysis at Red Bluff 1 also reveals a trend of increasingly coarse sandy sediments through time from SU9 to SU2, indicating changing dune-building processes linked to regional geomorphic shifts over the past 2500 years. These changes likely transformed Red Bluff from a rocky promontory into a sand-trapping headland connected to the Ninety Mile Beach system, shaping both site formation and how the Old Ancestors accessed the rocky shore for foraging and use of the landscape. Embedded within this geomorphic context, the Red Bluff 1 excavation documents three main occupational phases, with the most intensive activity dated within 600 to 1060 cal BP (SU5–SU7), and additional phases within 530 to 910 cal BP (SU4–SU5) and within 160 to 600 cal BP (SU2). Prior to c. 1000 cal BP, in the lower dune sand deposits of SU9A–D, there is some but sparse evidence of people immediately near the area of the Red Bluff 1 excavation. From 2500 years ago, the Ninety Mile Beach was a very geomorphologically active area. It is probable that during SU9A–D, people were camping on a more stable surface further back from the current dune edge. This would explain why there are no dense concentrations of shell, charcoal, and stone artefacts in the SU9 sub-SUs, and instead occasional isolated cultural materials.

The dense, multi-layered Red Bluff 1 molluscan assemblage demonstrates long-term, repeated exploitation of rocky shore habitats and molluscs, particularly *M. planulatus* and *L. undulata*, which were gathered across the three main occupational phases. Soft substrate habitats, like sandy beaches, estuaries and river mouths, were also consistently exploited but to a minor degree. The Red Bluff 1 assemblage has the highest taxonomic diversity of shell middens currently known in GunaiKurnai Country. The taxonomic diversity evident at Red Bluff 1 also indicates that at any point in time, as represented both by the major archaeological horizons (represented largely by the individual SUs) and by their finer chronostratigraphic sub-divisions (represented by the individual XUs), a range of habitats were exploited, including rock platforms, sandy environments and mudflats. The implication is that the unusually species-rich, and dense, shell deposits at the site were due not just to a resource-rich intertidal environment, but to one that was taxonomically and habitat-diverse (a general point of peak occupation at ecotones previously made for coastal environments elsewhere; see, e.g., Cassels 1972). The most recent, upper levels of the Red Bluff 1 deposit (SU2) recorded low shell species diversity and shell sparseness, similar to general characterisations of Victorian middens. The older two, dense horizons instead recorded high shellfish species diversity and density, suggesting that the Old Ancestors used this part of Red Bluff more intensively between 530 and 1060 cal BP, at least for subsistence.

Another key element to emerge from our analyses is that *L. undulata* remains show consistent burning and breakage patterns throughout the Red Bluff 1 sequence. These patterns indicate a degree of consistency in processing strategies through time. The documented practice of *L. undulata* breakage was also used across Lutruwita/Tasmania, Victoria and into South Australia, indicating a shared gastronomy, with the evidence presented here the first published description of such systematic *Lunella*



FIGURE 22 | 'From the Cottages to the Red Bluff', 1877 painting by Flora Minter (later Gregson). Source: State Library of Victoria, <http://handle.slv.vic.gov.au/10381/281750>.

processing on the Gippsland coast. Finally, while fish bone is rarely identified in coastal Victorian middens, Red Bluff 1 contains some fish bones in the peak shell horizons. Notably, most of these bones are of small to medium-sized fish that would have been less than 200 g each. As these fish were likely collected from rock pools or sand pools near to the Red Bluff 1 site, this evidence emphasises the logistical relationship between the different subsistence elements represented within the site.

From these findings, we can paint a clearer picture of daily life at Red Bluff 1 over the past 2500 years. Or, rather, we can evoke daily life through a watercolour painted a few hundred metres to the west of Red Bluff 1 by local nineteenth century artist Flora Minter (later Flora Gregson).

On 22 March 1877, Gippsland artist Flora Minter (1854–1933) painted a scene of what she saw some 1.5 km to the west of the archaeological site of Red Bluff 1 (Figure 22). Like most artists who worked directly from nature, Minter recorded the precise date that she stood and painted at the site on the work itself (lower right, just above her signature). It signifies that this is a record of what she saw in front of her on that actual day. An easy familiarity with the coastal terrain of the region is expressed in Minter's confident handling of watercolour. Her choice of watercolour, a medium that requires particular expertise, was preferred by many artists for outdoor sketching: it required less equipment than painting in oils and so was more readily portable and its faster drying time made packing up easier at the end of the session. It appears that Flora Minter/Gregson never exhibited any of her paintings in her lifetime. She was a trained and accomplished artist who painted for herself rather than professionally. As Lythgoe (2001–2005) has noted, 'Her paintings are valuable and lively documents of the daily life she saw around her'. The scene to the west of Red Bluff brings to life elements of coastal

domestic life also evident in the archaeological record at Red Bluff 1, including fishing with spears in the shallows of low tide, temporary shade made of local boughs erected on the sand, and the slow pace of daily life outdoors on a sunny early autumn day. Yet while this mid- to late-nineteenth century rendition of life on the beach evokes well aspects of the Red Bluff 1 archaeology, signalling a continuity of cultural practice spanning some 40 generations, the archaeology of Red Bluff 1 a thousand years earlier also signals points of change.

The painting depicts a coastline at the very eastern tip of Ninety Mile Beach with Red Bluff at the end of the long beach. The site of Red Bluff 1 lies on the other side of the bluff, where the sandy beach is underlain by rock platform at shallow depth, a rocky intertidal zone that dominated the coastline. The most striking parallels between the painting and the archaeology are (1) the people fishing in the shallow sand pools, signalling how the Old Ancestors living at Red Bluff 1 may have caught the small to medium-sized scale-fish recorded from the deposit (then in sand or rock pools), and (2) the people camping on the sand, spaces socially organised with built shelters.

The story of Red Bluff 1 highlights the complexity and longevity of GunaiKurnai coastal lifeways in southeastern Australia, revealing a record of targeted rocky shore foraging along what is today a mainly sandy beach, systematic shellfish processing, and adaptive responses to changing coastal landscapes. The richness of the archaeological sequence underscores the importance of site-specific, high-resolution analyses that cut across disciplinary boundaries, hereby combining especially archaeology and coastal geomorphology (a collaborative practice with a long history in Australia) for understanding regional variability and for challenging long-standing assumptions about the marginality of coastal resources in the Victorian archaeological record.

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Conflicts of Interest

The authors declare that there is no financial support or relationship that may constitute a conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Endnotes

¹Kym Thompson recorded a disturbed, unstratified site in a blowout near a rock platform at Point Ricardo in the 1980s, about halfway between Marlo and Cape Conran, east of Red Bluff.

²In common with other researchers of the time, Hotchin 'corrected' his raw radiocarbon ages on marine shells by subtracting 450 years from the median age. This was done to account for the 'marine environmental factor'. Throughout this paper, after checking the original raw radiocarbon ages with their radiocarbon laboratories, we have added the 450 years back to the marine shell radiocarbon ages to allow for their calibration to cal BP in OxCal.

References

- Adams, J. 1981. *The Tambo Shire Centenary History*. Tambo Shire Council.
- Asmussen, B., P. Faulkner, K. Szabó, and S. Ulm. 2022. "The Molluscan Remains of Tanamu I: Subsistence and Resource Habitats." In *The Archaeology of Tanamu I: A Pre-Lapita to Post-Lapita Site From Caution Bay, South Coast of Mainland Papua New Guinea (Caution Bay Studies in Archaeology 2)*, edited by B. David K. Szabó M. Leavesley I.J. McNiven J. Ash, and T. Richards, 107–116. Archaeopress. <https://www.archaeopress.com/Archaeopress/download/9781803270883>.
- Beechey, D. 2024. "The Seashells of New South Wales." Accessed March 2025. <https://seashellsofnsww.org.au/index.htm>.
- Bird, C. F., and D. Frankel. 1991. "Chronology and Explanation in Western Victoria and South-East South Australia." *Archaeology in Oceania* 26, no. 1: 1–16. <https://www.jstor.org/stable/40386862>.
- Bronk Ramsey, C. 2009a. "Bayesian Analysis of Radiocarbon Dates." *Radiocarbon* 51, no. 1: 337–360. <https://doi.org/10.1017/S0033822200033865>.
- Bronk Ramsey, C. 2009b. "Dealing With Outliers and Offsets in Radiocarbon Dating." *Radiocarbon* 51, no. 3: 1023–1045. <https://doi.org/10.1017/S0033822200034093>.
- Bronk Ramsey, C. 2025. *OxCal Program v4.4, Radiocarbon Accelerator Unit*. University of Oxford. Accessed July 2025. <https://c14.arch.ox.ac.uk/oxcal.html>.
- Clarkson, C., and S. O'Connor. 2006. "An Introduction to Stone Artifact Analysis." In *Archaeology in Practice: A Student Guide to Archaeological Analyses*, edited by J. Balme and A. Paterson, 159–206. Blackwell Publishing Ltd.
- Colley, S. M. 1997. "A Pre-and Post-Contact Aboriginal Shell Midden at Disaster Bay, New South Wales South Coast." *Australian Archaeology* 45, no. 1: 1–19. <https://doi.org/10.1080/03122417.1997.11681593>.
- Coutts, P. J. F. 1967. "The Archaeology of Wilsons Promontory." Master's thesis, Australian National University.
- Coutts, P. J. F. 1978. *Readings in Victorian Prehistory. Volume 1: Archaeological Theory and Practice*. Victoria Archaeological Survey, Ministry for Conservation.
- Coutts, P. J. F. 1981. "Coastal Archaeology in Victoria, Part 1: The Morphology of Coastal Archaeology Sites." *Proceedings of The Royal Society of Victoria* 92, no. 1: 67–80. <https://biostor.org/reference/259530>.
- Faegri, K., and J. Iversen. 1989. *Textbook of Pollen Analysis*. 4th ed. The Blackburn Press.
- Fletcher, M.-S., A. Romano, S. Nichols, et al. 2024. "Lifting the Veil: Pyrogeographic Manipulation and the Leveraging of Environmental Change by People across the Vale of Belvoir, Tasmania, Australia." *Frontiers in Environmental Archaeology* 3: 1386339. <https://doi.org/10.3389/fearc.2024.1386339>.
- Frankel, D. 2017. *Between the Murray and the Sea: Aboriginal Archaeology of Southeastern Australia*. Sydney University Press.
- Frankel, D., D. Gaughwin, C. Bird, and R. Hall. 1989. "Coastal Archaeology in South Gippsland." *Australian Archaeology* 28, no. 1: 14–25. <https://doi.org/10.1080/03122417.1989.12093187>.
- Fresløv, J. 1998. *Effective Strategies for the Management of Coastal Aboriginal Archaeological Sites and Places in Victoria*. Aboriginal Affairs Victoria.
- Fresløv, J., and D. Frankel. 1999. "Abundant Fields? A Review of Coastal Archaeology in Victoria." In *Australian Coastal Archaeology*, edited by J. Hall and I. J. McNiven, 239–254. The Australian National University.
- Gallop, S. L., D. M. Kennedy, C. Loureiro, et al. 2020. "Geologically Controlled Sandy Beaches: Their Geomorphology, Morphodynamics and Classification." *Science of the Total Environment* 731: 139123. <https://doi.org/10.1016/j.scitotenv.2020.139123>.
- Gaughwin, D., and G. Brennan. 1986. "Stinker Bay Shell Midden." *Archaeology in Oceania* 21, no. 1: 63–68. <https://doi.org/10.1002/j.1834-4453.1986.tb00125.x>.
- Giovas, C. M. 2009. "The Shell Game: Analytic Problems in Archaeological Mollusc Quantification." *Journal of Archaeological Science* 36, no. 7: 1557–1564. <https://doi.org/10.1016/j.jas.2009.03.017>.
- Giovas, C. M., S. M. Fitzpatrick, M. Clark, and M. Abed. 2010. "Evidence for Size Increase in an Exploited Mollusc: Humped Conch (*Strombus gibberulus*) at Chelechol ra Orrak, Palau From ca. 3000–0 BP." *Journal of Archaeological Science* 37, no. 11: 2788–2798. <https://doi.org/10.1016/j.jas.2010.06.013>.
- Gomon, M. F., C. J. M. Glover, and R. H. Kuiter, eds. 1994. *The Fishes of Australia's South Coast*. State Print.
- Grayson, D. K. 1984. *Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas*. Academic Press.
- Grove, S. J. 2018. "A Guide to the Seashells and Other Marine Molluscs of Tasmania." Accessed March 2025. <https://molluscsoftasmania.org.au/>.
- Hammer, Ø., D. A. Harper, and P. D. Ryan. 2001. "PAST: Paleontological Statistics Software Package for Education and Data Analysis." *Palaeontologia Electronica* 4, no. 1: 9. http://palaeo-electronica.org/2001_1/past/issue1_01.htm.
- Harris, M., and M. Weisler. 2017. "Intertidal Foraging on Atolls: Prehistoric Forager Decision-Making at Ebon Atoll, Marshall Islands." *Journal of Island and Coastal Archaeology* 12, no. 2: 200–223. <https://doi.org/10.1080/15564894.2016.1167140>.
- Harris, M., M. Weisler, and P. Faulkner. 2015. "A Refined Protocol for Calculating MNI in Archaeological Molluscan Shell Assemblages: A Marshall Islands Case Study." *Journal of Archaeological Science* 57: 168–179. <https://doi.org/10.1016/j.jas.2015.01.017>.

- Hogg, A. G., T. J. Heaton, Q. Hua, et al. 2020. "SHCal20 Southern Hemisphere Calibration, 0–55,000 Years Cal BP." *Radiocarbon* 62, no. 4: 759–778. <https://doi.org/10.1017/RDC.2020.59>.
- Holdgate, G. R., and S. J. Gallagher. 2003. "Tertiary: A Period of Transition to Marine Basin Environments." In *Geology of Victoria*, edited by W. D. Birch, 289–335. Geological Society of Australia Special Publication 23. Geological Society of Australia (Victoria Division).
- Hotchin, K. L. 1986. *Report on Site Management Requirements on the Red Bluff Midden Site near Lakes Entrance*. Unpublished report to the Victoria Archaeological Survey, Melbourne.
- Hotchin, K. L. 1990. "Environmental and Cultural Change in the Gippsland Lakes Region, Victoria, Australia." PhD thesis, The Australian National University.
- Hyman, I., and J. Stanisic. 2005. "New Charopid Land Snails Chiefly From Limestone Outcrops in NSW (Eupulmonata: Charopidae)." *Memoirs of the Queensland Museum* 50: 219–302.
- Kennedy, D. M., T. S. Oliver, T. Tamura, et al. 2020. "Holocene Evolution of the Ninety Mile Beach Sand Barrier, Victoria, Australia: The Role of Sea Level, Sediment Supply and Climate." *Marine Geology* 430: 106366. <https://doi.org/10.1016/j.margeo.2020.106366>.
- Kennedy, D. M., B. Thom, R. Gell, and N. J. Rosengren. 2024. "Coastal Geomorphology and Geology of the Gippsland Lakes Region: A Review and Future Directions." *Proceedings of the Royal Society of Victoria* 136, no. 1: RS23018. <https://doi.org/10.1071/RS23018>.
- Klein, R. G., and T. E. Steele. 2013. "Archaeological Shellfish Size and Later Human Evolution in Africa." *Proceedings of the National Academy of Sciences* 110, no. 27: 10910–10915. <https://doi.org/10.1073/pnas.1304750110>.
- Lamprell, K., and J. Healy. 1998. *Bivalves of Australia. Volume 2*. Backhuys.
- Lamprell, K., and T. Whitehead. 1992. *Bivalves of Australia. Volume 1*. Crawford House Press.
- Lourandos, H. 1980. "Forces of Change: Aboriginal Technology and Population in South Western Victoria." PhD thesis, University of Sydney.
- Lourandos, H. 1983. "Intensification: A Late Pleistocene–Holocene Archaeological Sequence From Southwestern Victoria." *Archaeology in Oceania* 18, no. 2: 81–97. <https://doi.org/10.1002/arco.1983.18.2.81>.
- Lyman, R. L. 2008. *Quantitative Paleozoology*. Cambridge University Press.
- Lythgoe, D. 2001–2005. "Mount Moriac—The Minters Choose a Different Direction." Accessed August 2025. https://www.theminters.co.uk/johnspages/newstyle_helenspages_9.php.
- Mackay, R., and J. P. White. 1987. "Musselling in on the NSW Coast." *Archaeology in Oceania* 22, no. 3: 107–111. <https://doi.org/10.1002/j.1834-4453.1987.tb00174.x>.
- Magurran, A. E. 2004. *Measuring Biological Diversity*. Blackwell.
- McNiven, I. J. 1996. "Mid- to Late-Holocene Shell Deposits at Hibbs Bay, Southwest Tasmania: Implications for Aboriginal Occupation and Marine Resource exploitation." In *Report of the Southern Forests Archaeological Project. Volume 1. Site Descriptions, Stratigraphies and Chronologies*, edited by J. Allen, 219–247. School of Archaeology, La Trobe University.
- Meehan, B. 1982. *Shell Bed to Shell Midden*. Australian Institute of Aboriginal Studies.
- GunaiKurnai Land and Waters Aboriginal Corporation, et al. 2020. "Disrupting What, Whose Country, Whose Paradise?" *Australian Archaeology* 86, no. 3: 299–301.
- Museum Victoria. 2023. "Taxonomic Toolkit for Marine Life of Port Phillip Bay." Accessed March 2025. <https://portphillipmarinelife.net.au/>.
- Poiner, G. 1976. "The Process of the Year Among Aborigines of the Central and South Coast of New South Wales." *Archaeology & Physical Anthropology in Oceania* 11, no. 3: 186–206. <https://doi.org/10.1002/j.1834-4453.1976.tb00250.x>.
- Ponder, W. F., and G. J. Avern. 2000. "The Glacidorbidae (Mollusca: Gastropoda: Heterobranchia) of Australia." *Records of the Australian Museum* 52, no. 3: 307–353. <https://doi.org/10.3853/j.0067-1975.52.2000.1318>.
- Popovic, I., A. M. A. Matias, N. Bierne, and C. Riginos. 2020. "Twin Introductions by Independent Invader Mussel Lineages Are Both Associated With Recent Admixture With a Native Congener in Australia." *Evolutionary Applications* 13, no. 3: 515–532. <https://doi.org/10.1111/eva.12857>.
- Richards, T. 2012. "An Early-Holocene Aboriginal Coastal Landscape at Cape Duquesne, Southwest Victoria, Australia." In *Peopled Landscapes*, edited by S. G. Haberle and B. David, 63–102. ANU E Press.
- Richards, T., and R. Johnston. 2004. "Chronology and Evolution of an Aboriginal Landscape at Cape Bridgewater, South West Victoria." *Artefact* 27: 97–112.
- Robin, A. 2021. *Compendium of Marine Gastropods*. ConchBooks.
- Rogers, A. J., B. David, D. M. Kennedy, et al. 2025. "Gone With the Wind, Waves, and Walking: Prioritizing Research at Vulnerable Archaeological Sites in Coastal Zones." *Journal of Field Archaeology* 50, no. 4: 345–361. <https://doi.org/10.1080/00934690.2024.2398841>.
- Rogers, A. J., D. M. Kennedy, B. David, et al. 2025. "Adapting to Rapidly Transforming Seascapes in the Mid- to Late Holocene, Southeastern Australia." *Frontiers in Environmental Archaeology* 4: 1548062. <https://doi.org/10.3389/fearc.2025.1548062>.
- Rogers, A. J., and M. I. Weisler. 2022. "Risk, Reliability, and the Importance of Small-Bodied Molluscs Across the Hawaiian Windward–Leeward Divide." *Human Ecology* 50, no. 1: 141–165. <https://doi.org/10.1007/s10745-021-00297-y>.
- Romano, A., and M.-S. Fletcher. 2018. "Evidence for Reduced Environmental Variability in Response to Increasing Human Population Growth During the Late Holocene in Northwest Tasmania, Australia." *Quaternary Science Reviews* 197: 193–208. <https://doi.org/10.1016/j.quascirev.2018.07.001>.
- Schell, P. 2000. *Red Bluff Cultural Heritage Study*. Unpublished report to Parks Victoria, Melbourne.
- Sherwood, J., I. J. McNiven, L. Laurenson, T. Richards, and J. Bowler. 2016. "Prey Selection, Size, and Breakage Differences in *Turbo undulatus* Opercula Found Within Pacific Gull (*Larus pacificus*) Middens Compared to Aboriginal Middens and Natural Beach Deposits, Southeast Australia." *Journal of Archaeological Science: Reports* 6: 14–23. <https://doi.org/10.1016/j.jasrep.2016.01.018>.
- Slieker, F. J. A. 2000. *Chitons of the World: An Illustrated Synopsis of Recent Polyplacophora*. Mostra Mondiale Malacologia.
- Smoothey, A. F. 2013. "Habitat-Associations of Turban Snails on Intertidal and Subtidal Rocky Reefs." *PLOS One* 8, no. 5: e61257. <https://doi.org/10.1371/journal.pone.0061257>.
- Smyth, R. B. 1878. *The Aborigines of Victoria. Volume 2*. Government Printer.
- Stanisic, J., M. Shea, D. Potter, and O. Griffiths. 2017. *Australian Land Snails. Volume 2: A Field Guide to Southern, Central and Western Species*. Rivière des Anguilles, Bioculture Press.
- Sullivan, M. E. 1982. "Aboriginal Shell Middens in the Coastal Landscape of New South Wales." PhD thesis, Australian National University.
- Sullivan, M. E. 1987. "The Recent Prehistoric Exploitation of Edible Mussel in Aboriginal Shell Middens in Southern New South Wales." *Archaeology in Oceania* 22, no. 3: 97–106. <https://doi.org/10.1002/j.1834-4453.1987.tb00173.x>.
- Szabó, K. 2009. "Molluscan Remains From Fiji." In *The Early Prehistory of Fiji (Terra Australis 31)*, edited by G. Clark and A. Anderson, 183–211. ANU E Press.
- Szabó, K., and A. Oertle. 2023. "Shells and Fire—Indicators and Effects." In *Fires in GunaiKurnai Country: Landscape Fires and Their Impacts*

on Aboriginal Cultural Heritage Places and Artefacts in Southeastern Australia, edited by J. Buettel, B. David, R. Mullett, J. Fresløv, K. Szabó, and Gunaikurnai Land and Waters Aboriginal Corporation, 132–141. Archaeopress.

The Jamovi Project. 2023. “jamovi (Version 2.4).” Accessed March 2025. <https://www.jamovi.org>.

Womersley, H. B. S. 2005. *The Marine Benthic Flora of Southern Australia*. Government Printer.

WoRMS Editorial Board. 2024. “World Register of Marine Species.” Accessed March 2025. <https://www.marinespecies.org>. <https://doi.org/10.14284/170>.

Worthington, D. G., and P. G. Fairweather. 1989. “Shelter and Food: Interactions between *Turbo undulatum* (Archaeogastropoda: Turbinidae) and Coralline Algae on Rocky Seashores in New South Wales.” *Journal of Experimental Marine Biology and Ecology* 129, no. 1: 61–79. [https://doi.org/10.1016/0022-0981\(89\)90063-4](https://doi.org/10.1016/0022-0981(89)90063-4).

Zobel, D. E., R. L. Vanderwal, and D. Frankel. 1984. “The Moonlight Head Rockshelter.” *Proceedings of the Royal Society of Victoria* 96, no. 1: 1–24.

Wolverton, S., J. Dombrosky, and R. L. Lyman. 2016. “Practical Significance: Ordinal Scale Data and Effect Size in Zooarchaeology.” *International Journal of Osteoarchaeology* 26, no. 2: 255–265. <https://doi.org/10.1002/oa.2416>.

Cassels, R. 1972. “Locational Analysis of Prehistoric Settlement in New Zealand.” *Mankind* 8, no. 3: 212–222. <https://doi.org/10.1111/j.1835-9310.1972.tb00439.x>.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supporting File 1: arco70018-sup-0001-SupMat-1.docx **Supporting**

File 2: arco70018-sup-0002-SupMat-2.xlsx **Supporting File 3:**

arco70018-sup-0003-SupMat-3.xlsx