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THE MOYJIL SITE, SOUTH-WEST VICTORIA, AUSTRALIA: SHELLS AS EVIDENCE OF THE DEPOSIT'S ORIGIN

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ABSTRACT: Characteristics of marine shellfish and other species found in a Last Interglacial (LIG) shell deposit at Point Ritchie (Moyjil) at Warrnambool in south-western Victoria have been compared to those from modern and LIG natural beach deposits, Holocene Aboriginal middens and modern Pacific Gull (*Larus pacificus*) middens. The research was aimed at determining whether properties such as shell speciation, size or taphonomy could identify the mechanism responsible for formation of the Moyjil deposit. Marine species found in the Moyjil deposit resemble those found in both Aboriginal and Pacific Gull middens and are non-discriminatory for the two types. Taphonomic properties such as wear and breakage pattern of opercula of the dominant species, *Lunella undulata* (syn. *Turbo undulatus*), are non-diagnostic because of post-depositional erosion and transport effects in the available specimens. The size of *L. undulata* opercula show clear bias toward larger individuals, in common with Aboriginal and seabird middens, when compared to natural shell deposits. Statistical analysis (ANOVA) of the size distributions shows a greater similarity of the Moyjil deposit to the two seabird middens than the two Aboriginal middens. Small individuals (operculum <10 mm diameter) of *L. undulata* as well as smaller shellfish species are absent from the seabird middens studied, but they are present in Aboriginal middens and in the Moyjil deposit. Overall, we conclude that shell properties alone are not sufficient to distinguish which predator collected the shellfish occurring in the deposit.

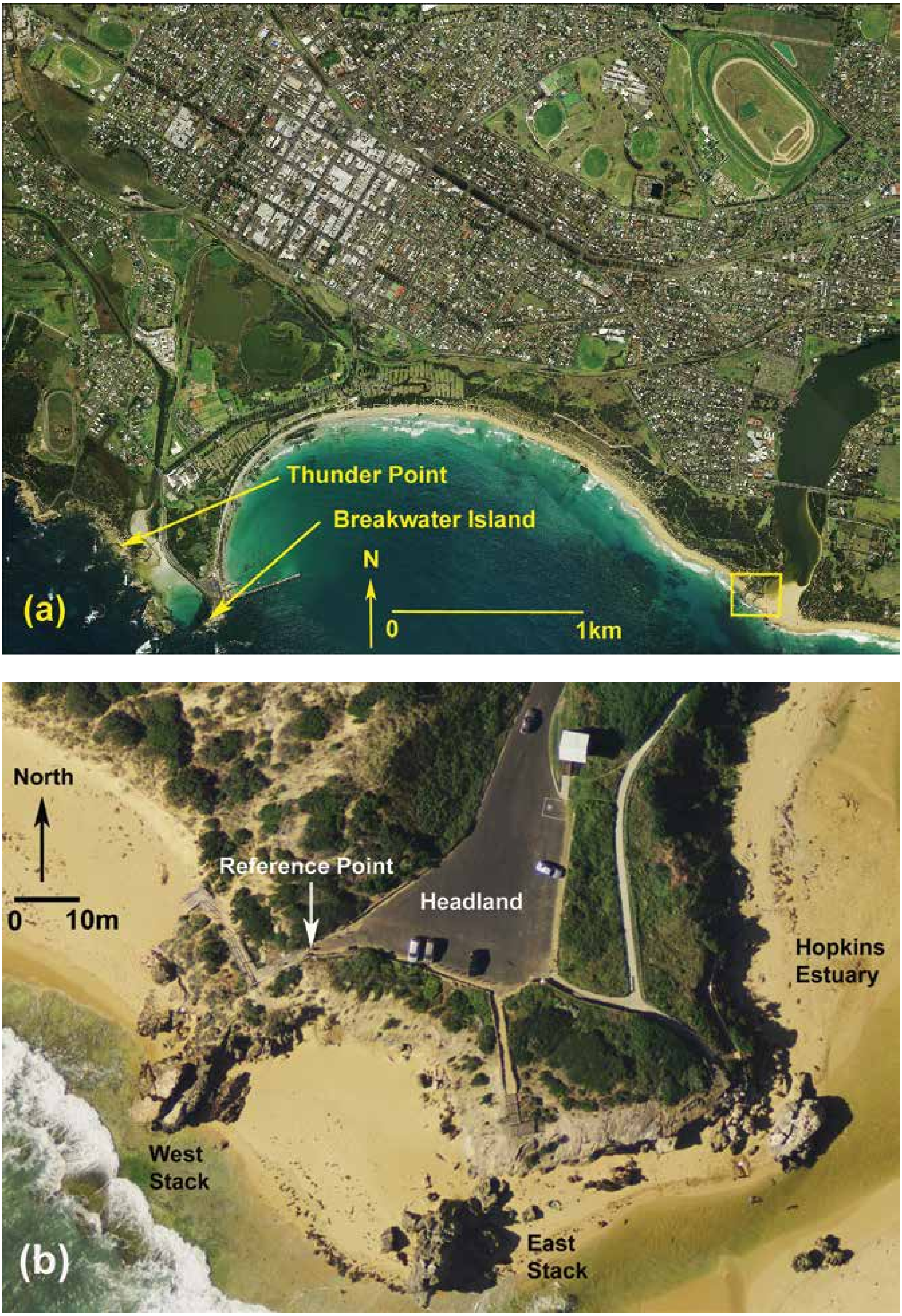
Keywords: operculum, *Turbo undulatus*, *Lunella undulata*, midden, storm beach, Pacific Gull, *Larus pacificus*, Point Ritchie

Moyjil is the Aboriginal name for the western headland of the Hopkins River mouth, located on Victoria's south-west coast (Figure 1). Europeans named the headland Point Ritchie. It contains an unusual shell deposit referred to here as the Moyjil deposit, previously described by Sherwood et al. (1994) and Nair and Sherwood (2007). This shell deposit, firmly cemented in calcarenite, gave an age estimated as 60±20ka based on carbon-14, amino acid racemisation (AAR), electron spin resonance (ESR) and thermoluminescence measurements (Sherwood et al. 1994). Characteristics of the shell deposit led Nair and Sherwood (2007) to conclude that it was a midden and not a natural beach deposit (e.g. absence of water-rounded edges and other beach debris). They were unable to conclude whether humans or another species were responsible for the midden's creation. They noted that middens of seabirds and humans share many characteristics and that further work was needed to identify discriminatory criteria for these types.

An Aboriginal site of this antiquity in south-eastern Australia would be of great significance for theories concerning the arrival of people on the continent (Hiscock 2008). Subsequent research has thus focused on two areas. First, the age of the deposit has been redetermined based on detailed stratigraphic analysis and previously untried instrumental techniques such as optically stimulated luminescence (OSL), laser ablation uranium/thorium dating, and AAR by high performance liquid chromatography. This work, which gives a Last Interglacial (LIG) age (post 120–125ka) for the deposit, is reported elsewhere (Sherwood et al. 2018). Second, examinations of the shells (reported here) and accompanying discoloured stones (the latter suggestive of heating; Bowler et al. 2018) has been undertaken to determine if these studies can identify the site's origin.

The lack of obvious cultural materials (especially stone artefacts) in association with the shell deposits at Moyjil creates ambiguity concerning the origin of the shell deposits. Absence of stone artefacts is a characteristic of

Figure 1 (at right): (a) Warrnambool, south-west Victoria, Australia, showing the Moyjil (Point Ritchie) headland on the west bank of the Hopkins River entrance(square), and two other shell deposit sites referred to in the text.
(b) Enlarged photograph of the square in Figure 1(a) showing the flat-topped headland and adjacent East and West Stacks. Distances across the headland are measured from the reference point. East and West Stacks are 50 m apart. Aerial photographs courtesy of Warrnambool City Council and Aboriginal Victoria.


Thunder Point
Breakwater Island
N
(a)
0
1km
North
0
10m
Reference Point
Headland
Hopkins Estuary
West Stack
East Stack
(b)

numerous Aboriginal Holocene midden sites along the west coast of Victoria (Coutts 1981: 70). Godfrey (1989: 66) reported that only 'some' of the late Holocene middens of the Discovery Bay region 'were stratified and had apparently burnt rock and flint artefacts associated with them'. This pattern most likely reflects a focus of site activities upon the cooking and consumption of shellfish, and fish and plant foods in some cases — activities that have little or no need for flaked stone tools. Absence of stone artefacts in middens has been archaeologically recorded elsewhere in Australia (e.g. Attenbrow 1992: 17) and shell-only midden deposits have been recorded ethnographically (e.g. Meehan 1982).

Seabirds are known to create shell deposits resembling Aboriginal middens in Australia (Teichert & Seventy 1947; Horton 1978; Jones & Allen 1978; Dortch et al. 1984; Dortch 1991; Sim 1991). In particular, Pacific Gulls (*Larus pacificus*) of south-east Australia create large accumulations of mostly broken shells as a result of dropping live shellfish on to rocks (anvil rocks) to break the shell and allow access to the animal inside for food. Sherwood et al. (2016) have investigated the taphonomy and size distribution of *L. undulata* (syn. *Turbo undulatus*) opercula in modern natural (beach) and Pacific Gull deposits, and Aboriginal Holocene shell deposits of south-east Australia. *L. undulata* is a gastropod inhabiting rocky coasts at mid-tide and lower levels. It dominated the shell assemblages in the deposits studied by Sherwood et al. (2016) and is also the dominant species in the Moyjil deposit investigated here. Taphonomic characteristics such as water rounding, discolouration (attributed to burning), the extent of damage to the outer rim of the opercula, and opercula size distribution proved useful as diagnostic indicators of shell deposit origin.

Given its visual similarity to both Pacific Gull and Aboriginal middens, we apply these criteria to the Moyjil deposit to examine whether its origin can be identified. Our study focuses on: (1) shell species present in the Moyjil deposit, (2) taphonomic characteristics of shells of the dominant species *L. undulata*, and (3) size distribution of *L. undulata* individuals.

A note on taxonomy

The World Register of Marine Species (WoRMS) does not currently list some of the marine molluscs cited here by names formerly accepted within Australia (see Table 1). For example, *Turbo undulatus* and *Turbo torquatus* are placed in the genus *Lunella* — as *L. undulata* and *L. torquata.* We have retained former species names alongside the WoRMS designations in this paper in order to maintain connectivity with extensive Australian literature using the former names.

SITE DESCRIPTION

The Hopkins River enters the Southern Ocean on the eastern side of Warrnambool in Victoria's south-west (Figure 1). On its western side, the river mouth is dominated by a rocky headland rising sharply to 12 m above present sea level (Figure 1). Seaward of the headland are two rock stacks designated East Stack (closest to the river mouth) and West Stack. The two stacks are separated by a small embayment ~50 m wide. East Stack is composed of aeolian calcarenite and has a remnant calcrete cap. This calcarenite forms the basal unit of the headland and West Stack, which is connected to the headland by a short (~15 m) ridge. Shells are found on West Stack's surface and within a sand layer on the headland cliff.

The basic stratigraphy of the Moyjil headland has been previously described (Sherwood et al. 1994; Nair & Sherwood 2007). Carey et al. (2018) have revised this stratigraphy, revealing a more complex evolution of the headland than previously realised. The terminology of Carey et al. (2018) will be used here, with cross-referencing to the earlier Nair and Sherwood (2007) stratigraphic nomenclature where appropriate.

Within the headland a sequence of calcarenites (units R, S and T) and associated now-lithified *terra rossa* soils have infilled a valley or swale in the basal calcarenite (unit V; Figure 2). Subsequent erosion of this complex and development of a thick (~10 cm) groundwater calcrete (unit Rcp in Carey et al. 2018 or the Lower Calcrete of Nair & Sherwood 2007) have created a palaeosurface beneath the headland (identified as Ground surface alpha [Gsα] by Carey et al. 2018). OSL dating of quartz grains in the unit R calcarenite immediately below the Rcp calcrete gave an age of 239±17 ka — close to the Penultimate Interglacial (MIS 7) maximum (~220 ka; Sherwood et al. 2018). Unit Rcp post-dates emplacement of unit R.

Overlying Gsα is a partly cemented yellow-brown calcarenite sand (the Headland Bed of Nair & Sherwood 2007 or unit Q2 in Carey et al. 2018). Unit Q2 forms a 0.5–2 m thick layer containing specimens of shell and other marine species, occasional discoloured pebbles, charcoal pieces and terrestrial snails indicating sand accumulation in a dry heathland environment (Nair & Sherwood 2007). Unit Q2 was deposited shortly after the LIG sea level maximum (120–125ka) based on stratigraphy and dating investigations (Sherwood et al. 2018). Subsequently a second calcrete (unit Q2cs) formed in the subsoil of a *terra rossa* developed on unit Q2 (the Upper Calcrete of Nair and Sherwood [2007]). This soil is now largely removed by erosion to expose a second ground surface (Gsβ; Figure 2). Ash from the eruption of Tower Hill volcano blanketed unit Q2cs at 35±3 ka (Sherwood et al. 2004) and is overlain by the uppermost layer on the headland, consisting of

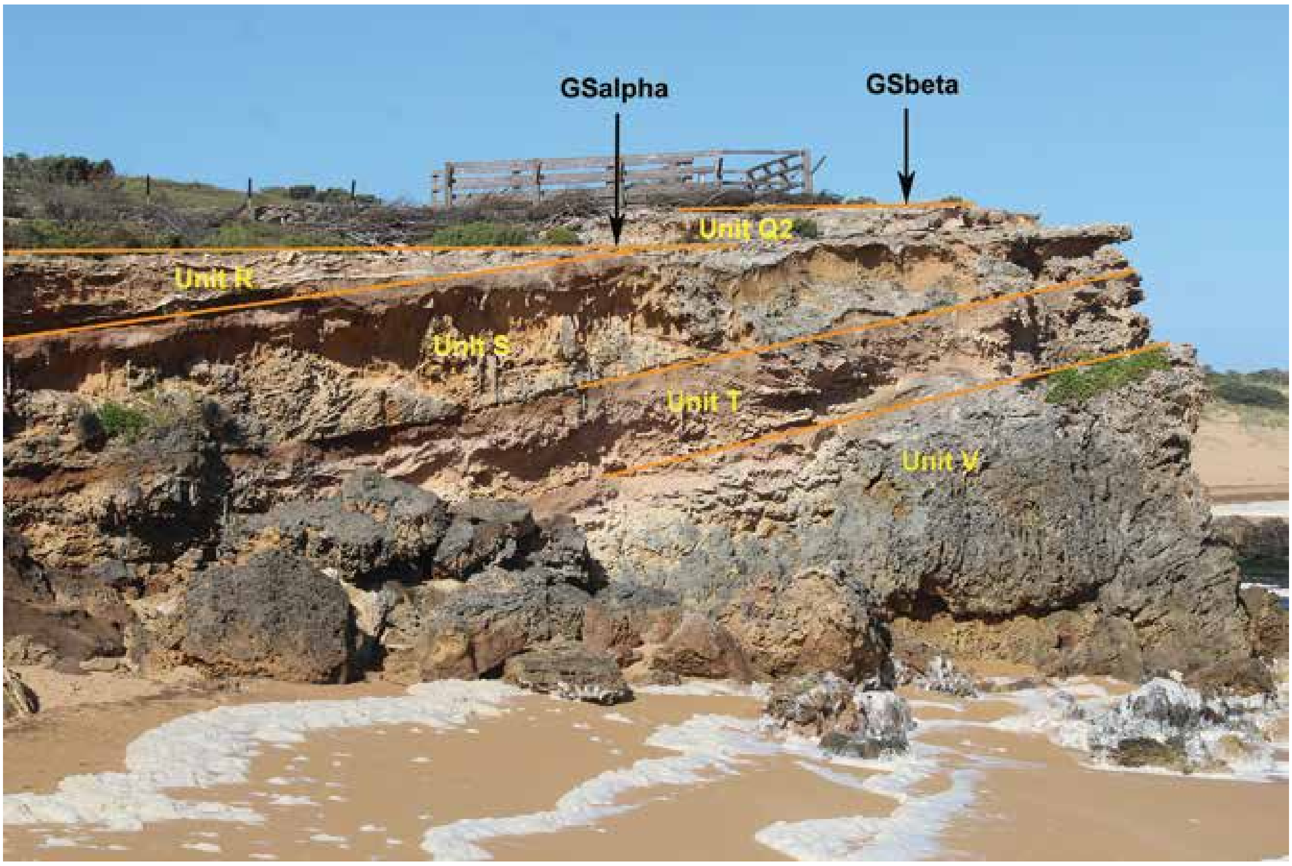


Figure 2: Major stratigraphic units of the Moyjil headland. Photograph of the headland opposite East Stack (see Figure 1). Photograph taken from the beach between the two stacks, looking east. GS = Ground surface (see text for details). Photograph: J.E. Sherwood.

uncemented Holocene sands containing Aboriginal shell middens, three of which have given conventional carbon-14 ages on marine shells of 5930±100, 3900±50 and 1000±80 y BP (Godfrey et al. 1996: 19, 22, 34; Sherwood et al. 1994: 98).

Nine remnant LIG beach deposits occur at Moyjil, varying from thin veneers pasted on cliff faces to well-developed visored notches. The highest of these (5.8–6 m AHD) is on the ridge connecting West Stack to the headland and about 6 m from the cliff face. West Stack has sand-filled, visored notches on its east and west flanks with their bases at 3.5–4.5 m AHD. Gill and Amin (1975) have provided evidence of LIG sea levels at 7.5 m and 4 m in south-west Victoria. Sherwood et al. (1994) have assigned LIG ages to shell deposits at Narrawong (~4 m AHD) and Goose Lagoon (3.2 m AHD).

Unit V forms the basal unit of West Stack. It is overlain by a thick calcarenite (unit T) and its associated *terra rossa*. The surface of the stack is capped with unit Rcp calcrete, also part of an original Gsα. On top of it is a thin veneer of unit Q2 sand containing abundant shell and stones, some with dark discolouration suggestive of heating.

Marine shells of the Moyjil deposit occur in three settings within unit Q2 — firmly embedded in West Stack, loose on the surface of West Stack, and within the unit Q2 calcarenite.

West Stack (embedded shells)

On the calcrete surface (Gsα) there is a complex and chaotic mixture of stones (many discoloured), shells (mostly fragmented *L. undulata* with sharp edges), calcarenite and a fine-grained laminated cement (Figure 3). This assemblage is interpreted as a slurry of fine to coarse material flowing away from the headland, across a now eroded bridge, which was triggered by a major disturbance event (possibly seismic activity; Carey et al. 2018). Sometime after 1907 (a postcard with this date shows an intact West Stack with a horizontal surface; Carey et al. 2018, Figure 7) the upper portion of West Stack broke into four pieces. Two of these, West Stack North (WsN) and West Stack South (WsS), fell to the west side of the stack where they remain leaning at low angle against the lower portion of the stack with their upper surfaces at least 5m above sea level. These blocks contain the shell deposit. Two other pieces fell to the east and are leaning against the stack at beach level. No shell, discoloured stones or other slurry evidence occurs on the eastern blocks.

Figure 3: Close-up of a section of the West Stack midden deposit at Moyjil, 14 July 2011. Photograph: Ian J. McNiven.

West Stack (loose shells)

Weathering of the cemented deposit on top of West Stack has released some embedded shell material. The late Edmund Gill, who first recognised the potential significance of the site, collected as much of this loose material as possible in his early investigations. This material, supplemented by later collections, and now held by one of us (JS) came from the surfaces of WsN and WsS, including from erosion pits on WsS that appear to have acted as a trap for eroded material over time.

Headland (unit Q2 shells)

Occasional inspection of the eroding face of unit Q2 by Gill and Sherwood has revealed various marine shells, crustacean fragments and a fish otolith (Nair & Sherwood 2007; Figure 4). Under the influence of wind, rain and sea spray, the exposed cliff face of unit Q2 is eroding landward at a rate of a few millimetres a year, continually revealing new faunal specimens. Gill, and later Sherwood, have collected over 60 specimens from the cliff face, the latter most recently under permit from Aboriginal Victoria. The distribution of specimens has extended vertically across the thickness of unit Q2 and laterally for nearly 70 m (to the limit of unit Q2 exposure).

Stratigraphic correlation of the shells on West Stack with those in the headland's unit Q2 is based on the following:

- The near identical elevation (8.2 ± 0.2 m AHD) of the surface of West Stack and the headland's Gsα when West Stack blocks are restored to their original positions (Sherwood et al. 2018, Figure 4).
- The horizontal surface of a restored West Stack (shown before collapse in a 1907 postcard) is less than 15 m from the horizontal Gsα of the headland.
- Where they are closest, both the surface of West Stack and Gsα are underlain by a calcrete and units T and V (Sherwood et al. 2018, Figure 4).

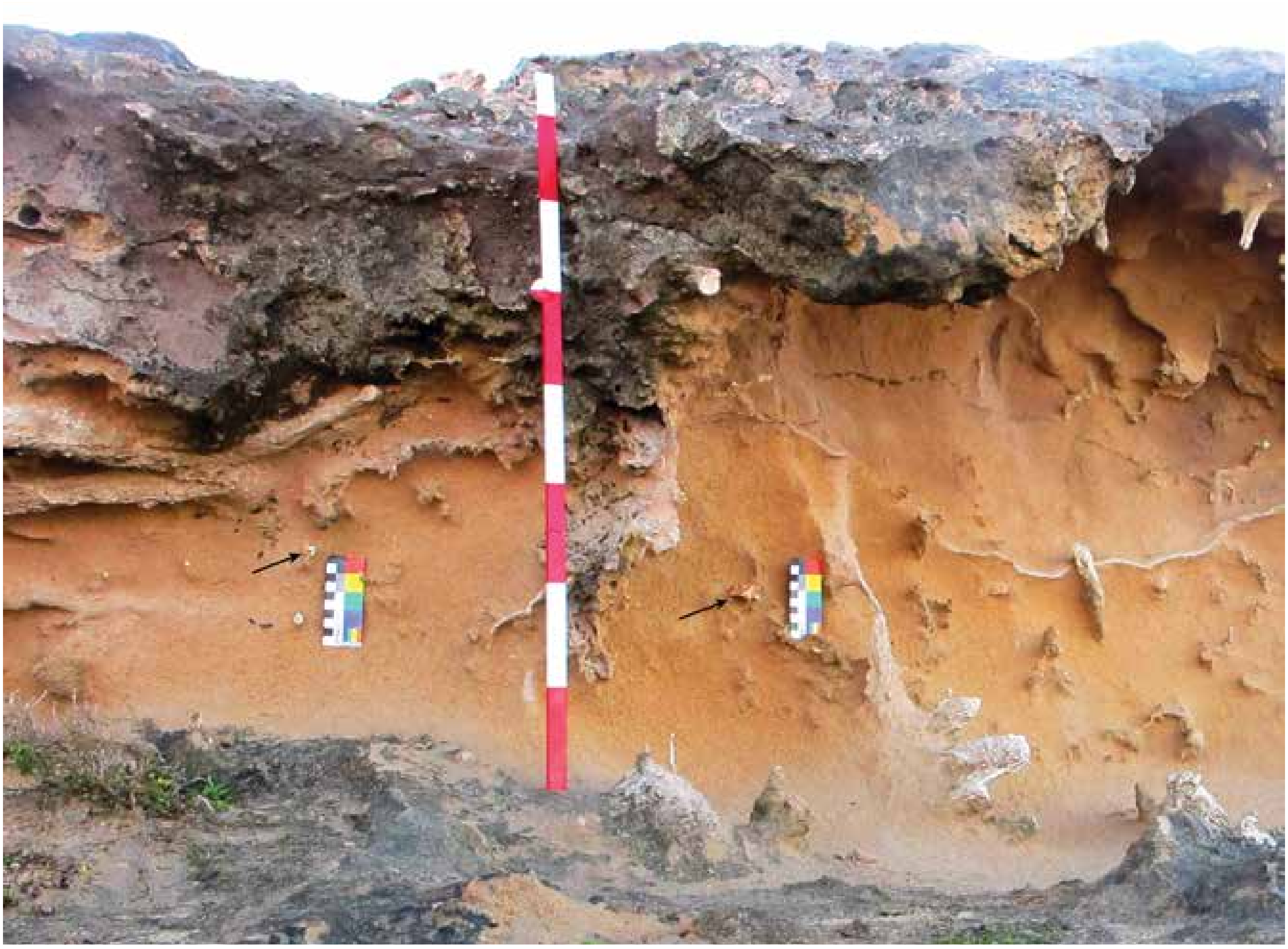


Figure 4: Close-up of shells exposed in headland calcareous dune sands (unit Q2) at Moyjil, showing a *Lunella undulata* shell fragment (left) and a whole *Haliotis rubra* shell (right), 5 July 2012. Small scales = 10 cm. Large scale in 10 cm units. Photograph: Ian J. McNiven.

- On West Stack and the headland, discoloured, blackened stones occur on the calcrete.
- The dominant shells at each location, *L. undulata* and *Sabia conica*, lack water-rounded surfaces.
- The shells on both West Stack and in unit Q2 gave ages beyond the limit of carbon-14 dating (1 shell from the headland, 4 from West Stack; Sherwood et al. 1994; Nair & Sherwood 2007) and occupy the same LIG aminozone as determined by amino acid racemisation (4 shells from West Stack, 2 from the headland; AAR ratios subsequently averaged in Sherwood et al. 1994).

A LIG age for shells on West Stack is further supported by the presence there of a *Lunella torquata* operculum, considered to be a LIG index fossil for western Victoria (Valentine 1965). Goede (1989) measured equivalent doses (ED) for *L. undulata* shells for his electron spin resonance dating of shell deposits at Moyjil. Three samples from two LIG beach deposits at the headland gave EDs of 126, 149 and 176 Gray. A shell from the West Stack deposit had a similar ED (106 Gray). He concluded all deposits were from the LIG, with West Stack deposit possibly younger than the LIG beach deposits.

METHODS

Shells embedded in West Stack's unit Q2 were not excavated for study. Loose material observed on the surface has been collected several times. The limited extent of the shell deposit here, combined with its cementation and potential significance, meant that invasive or destructive techniques were not considered desirable. Opercula are available from two sources on West Stack: (1) those still embedded in the sedimentary matrix on the stack or found loose but with sedimentary matrix adhering, and (2) loose complete and partial opercula collected by Edmund Gill and John Sherwood (N=145). These were collected from the surface of both stacks (WsN and WsS) and from the erosion pits on WsS (into which they are presumed to have been washed).

Greatest reliance must be placed on results from the *in situ* opercula sample set. Loose opercula are most likely to have weathered from the West Stack deposit over time, based on the isolated location of the stack, speciation and taphonomy (i.e. all loose shells look old and identical to cemented *in situ* shells and many feature cemented calcarenite). It is considered unlikely that the loose shells were deposited on the stack after the *in situ* shells had become cemented in place. Nevertheless, data for each sample set are reported separately.

Two opercula collected from unit Q2 sands were included with the *in situ* opercula from West Stack for analysis because of their presumed common origin.

The dimensions and taphonomic properties of the sampled *L. undulata* shells and opercula were measured following techniques outlined in Sherwood et al. (2016). The *L. undulata* operculum has an oval shape with a flat inner surface and a domed outer surface (Figure 5). The circumferential edge of the dome is a thin flange. Properties observed or measured were one or both of the operculum length and width, evidence of water rounding, discolouration (as evidence of burning), completeness of the operculum flange, location of breakages to the flange, and the extent of fracturing and breakage of the dome. Where only one of either operculum length or width could be measured (due to breakage or partial burial of the embedded operculum), the second dimension was determined from a linear regression of length (L) against width (W) of opercula for which both measurements were obtainable (see equation i):

$$W = 0.870 * L \ (N = 15; R^2 = 0.97) \ldots. (i)$$

The gradient of equation (i) is within the range reported for *L. undulata* from other deposits (0.862–0.883; Sherwood et al. 2016).

To determine the completeness of the operculum rim the outer flange was divided into eight segments as described in Sherwood et al. (2016). The fraction of undamaged flange remaining was visually estimated in eighths. A score of 8/8 indicates no damage to the flange and >7/8 as minor chipping involving less than 1/8th of the flange. Only opercula judged to be at least half complete were included in this analysis to avoid ‘double counting’ of smaller fragments from the same operculum. In order to identify which sections of the flange were damaged, the eight segments were defined according to the highest part of the operculum central dome (Figure 5).

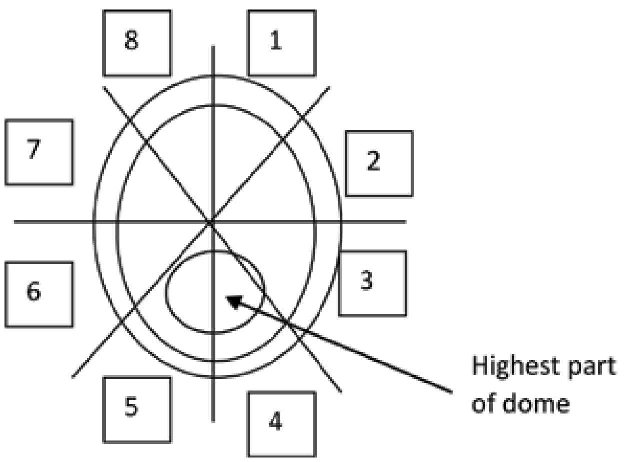


Figure 5: Schematic plan view of a *Lunella undulata* operculum illustrating the scheme used to conceptually segment the operculum to estimate the extent and location of damage to the outer flange. Source: Sherwood et al. 2016.

Recovery of specimens from unit Q2 on the headland was accompanied by a record of location both vertically within the deposit and horizontally with reference to obvious physical features of the unit Rcp and unit Q2cs calcretes. The nature of any shell breakage was also noted. Length and width of almost entire *L. undulata* shells were measured with vernier calipers. For incomplete shells these were recorded as minimum dimensions.

Last Interglacial beach deposits

Dimensions of *L. undulata* opercula from LIG beach deposits at two locations, Goose Lagoon and Moyjil, were measured to compare with those found in the unit Q2 shell bed at Moyjil. Goose Lagoon is located 30 km west of Warrnambool and is a sandy beach deposit on basalt in farmland approximately 1 km from the coast. It has been dated as LIG (Sherwood et al. 1994) and contains both *L. undulata* and *L. torquata* as well as many other species (Gill 1971; McKenzie et al. 1990). All observable *L. undulata* opercula larger than ~5 mm diameter were collected from the exposed surface of the deposit. Sherwood et al. (1994) recommended that it be regarded as a reference LIG deposit for western Victoria.

At nine locations around the Moyjil headland and adjacent stacks, cemented remains of a LIG beach at elevations of 2–6 m above present sea level are preserved. Beds contain water-rounded shells (mostly *Lunella* species), coarse sand and rounded clasts ranging from pebbles to boulders. LIG ages for three of these have been determined by AAR (three deposits; Sherwood et al. 2018) and ESR (two deposits; Goede 1989). Opercula in two of these shell deposits were sampled. First, the East Stack Notch deposit is contained within a prominent visored notch on the south side of East Stack, which is packed with water-rounded boulders, coarse sand and shell. Its base is at 2.9 m AHD. As many opercula as possible were measured *in situ* on the surface of the shell deposit. Specimens were strongly cemented and in most cases it proved difficult to remove them. Second, the Below West Stack deposit of shell, sand and cobbles occurs on the east side of West Stack near beach level (base at 2.2 m AHD). Cementation was not as great at this deposit and it was possible to remove opercula for measurement. Data from both deposits were combined for subsequent analysis. Only opercula observed to still retain a circumferential flange were measured.

Other sites

In addition, properties of *L. undulata* opercula from sites described by Sherwood et al. (2016) were compared to those found in the Moyjil deposit, namely:

1. Two modern Pacific Gull (*L. pacificus*) middens at Point Avoid and Golden Island Lookout, on South Australia's Eyre Peninsula.
2. Natural modern beach deposits at Thunder Point and Breakwater Island at Warrnambool (see Figure 1a).
3. Aboriginal Holocene shell middens from Cape Duquesne near Portland, Victoria (100 km west of Warrnambool), and in the uppermost unconsolidated sands at Moyjil.

Statistical analysis

The statistical analysis of *Lunella* opercula size followed the method outlined in Sherwood et al. (2016: 18). Ten sample sets were analysed:

- West Stack loose and embedded shells (i.e. two sample sets)
- Holocene Aboriginal middens at Moyjil and Cape Duquesne
- LIG beach deposits at Moyjil and Goose Lagoon
- Modern beach deposits at Warrnambool's Breakwater Island and Thunder Point
- Modern Pacific Gull middens from South Australia's Point Avoid and Golden Island.

For each set, metrical properties of the opercula population (mean length, standard deviation, standard error, and maximum and minimum lengths) were calculated. To aid visual assessment of similarities between the various opercula populations, cumulative frequency plots were prepared using 3 mm size class intervals over the range 0–27 mm (the largest operculum measured was 25.4 mm). Differences between opercula populations from the different shell deposits were quantitatively investigated using a bootstrapped (n=1000) one-way ANOVA and the SPSS statistical package. Transformation of the length data using both Log (base 10) and square root functions had no effect on the homogeneity of their variances (i.e. they remained significantly different). ANOVA tests on untransformed length data were combined with Graham-Howell post-hoc tests to identify significant differences between the populations. The latter test makes no assumptions about equality of variances.

RESULTS AND DISCUSSION

Shell species

Four ecological communities are represented in the faunal assemblage of the Moyjil deposit on West Stack and the Headland (Table 1):

1. *Terrestrial dry heath to woodland*. Nair and Sherwood (2007) reported three small non-marine gastropod species within unit Q2 sands of the headland — *Magilaoma penolensis*, *Strangesta gawleri*, and *Scelidoropa officeri* (syn. *Pernagera officeri).* These land snails inhabit leaf litter and ground cover of dry habitats such as coastal heath, dry scrub and dry woodland (Smith & Kershaw 1979: 151; Stanisic et al. 2010: 176).
2. *Salty to brackish wetlands*. Small gastropods from salty aquatic terrestrial environments (e.g. lakes), but also terrestrial with marine influences (e.g. lagoons) and marine environments (i.e. intertidal zone), are found scattered through unit Q2 sands of the headland. Five species were identified by Nair and Sherwood (2007) — *Austrosuccinea australis*, *Salinator fragilis*, *Coxiella striata*, *Hydrococcus brazieri*, and *Zeacumantus plumbeus* (syn. *Batillaria (Batillariella) estuarina*). Subsequently a second *Hydrococcus* species, larger than *H. brazier*, has been found and tentatively identified as *H. tasmanicus* (see Smith & Kershaw 1979: 56).
3. *Rocky coast marine*. Ten species of marine shellfish, all found in rocky ocean coasts, have been found in the Moyjil deposit. Seven species were identified by Nair and Sherwood (2007; common names after Macpherson & Gabriel 1962); these are mostly warrener (*L. undulata*) with smaller representations of heavy turbo (*L. torquata*), bonnet limpet (*Sabia conica*), dog winkle (*Dicathais orbita* [syn. *Thais orbita*]), blacklip abalone (*Haliotis rubra*), chiton (*Plaxiphora albida*), and lateral-striped limpet (*Patelloida* sp. cf *latistrigata*). Three additional species have subsequently been identified in low numbers — striped-mouth conniwink (*Bembicium* sp. cf *nanum*), lineated cominella (*Cominella lineolata*) and noddiwink (*Austrolittorina* sp. cf *unifasciata* [syn. *Nodolittorina* sp. cf *unifasciata*]). Nair and Sherwood (2007) also identified a crab claw fragment from the Reef Crab (*Ozius truncatus*).
4. *Pelagic marine/estuarine.* The right sagittal otolith of the mulloway (*Argyrosomus japonicus*), a fish of the open ocean and estuarine environments, has been recovered from unit Q2.

Nair and Sherwood (2007) inferred that deposition of unit Q2 occurred in a near-shore scrubby environment with nearby estuarine or lagoonal habitats. The relatively small number of tiny brackish water species is consistent with transport by wind. The high physical integrity of terrestrial and brackish water specimens suggests short distances of transport.

Table 1: Moyjil deposit faunal species found on West Stack or eroding from the headland exposure of unit Q2 up to March 2016 and their habitats. Data from Nair and Sherwood (2007) with subsequent additions by the current authors.

Habitat	Taxon	WoRMS Nomenclature [f]
Terrestrial dry heath to woodland	*Magilaoma penolensis*	
	Strangesta gawleri	
	Pernagera officeri	*Scelidoropa officeri*
Salty to brackish wetlands	*Succinea (Austrosuccinea) australis*	
	Hydrococcus sp. cf *tasmanicus* [a]	
	Salinator fragilis	
	Hydrococcus brazieri	
	Batillaria (Batillariella) estuarina	*Zeacumantus plumbeus*
	Coxiella striata	
Rocky coast marine	Mollusca:	
	Turbo undulatus	*Lunella undulata*
	Turbo torquatus [d]	*Lunella torquata*
	Sabia conica [b]	
	Thais orbita	*Dicathais orbita*
	Bembicium sp. cf *nanum* [a d]	
	Haliotis rubra	
	Plaxiphora albida	
	Patelloida sp. cf *latistrigata* [c]	
	Cominella lineolata [a d]	
	Nodolittorina sp. cf *unifasciata* [a e]	*Austrolittorina sp. cf unifasciata*
	Crustacea:	
	Ozius truncatus [e]	
Pelagic marine/estuarine	Vertebrata:	
	Argyrosomus hololepidotus [e]	

[a] Found since Nair and Sherwood (2007).
[b] *Sabia conica* listed as *Hipponyx conica* in Nair and Sherwood (2007).
[c] Listed as Limpet Family Acmaeidae in Nair and Sherwood (2007).
[d] Single specimen from West Stack.
[e] Marine species only found in the unit Q2 sands.
[f] WoRMS Editorial Board (2018). Names shown replace former names where indicated, if there is no entry in this column the former name is currently accepted.

Comparisons with Aboriginal middens. All of the mollusc species deriving from the following ecological communities — terrestrial dry heath to woodland (three species) and salty to brackish wetlands (six species), are considered to have been deposited naturally within the unit Q2 sands on the headland, either through onsite deaths (e.g. land snails) or wind transport (e.g. aquatic gastropods). The latter is plausible given that it is highly likely that the palaeo-Hopkins River mouth located adjacent to Moyjil was associated with estuarine habitats during the LIG (Nair & Sherwood 2007). Most of these species are considered to be of minimal subsistence value for hunter-gatherers.

In marked contrast, many of the rocky platform mollusc shells and the crab and fish remains are of a size and availability that renders them viable and attractive foods for hunter-gatherers. The most abundant larger mollusc in both the headland and West Stack deposits is *L. undulata* (Nair & Sherwood 2007). *Lunella* can be considered a high-ranked hunter-gatherer food item given its size (one of the largest marine gastropods available along the Victorian coastline after *Haliotis* spp.), abundance and ease of access, collection and preparation. It is for this reason that *L. undulata* is a high-ranking mollusc within Holocene Aboriginal headland midden sites along the Victorian coastline (e.g. Coutts 1970; Jones & Allen 1978; Lourandos 1980; Richards 2012). Indeed, late Holocene middens located within sand dunes backing Moyjil are dominated by *L. undulata* (Context 2014). The absence of *L. torquata* in Victorian Holocene Aboriginal middens is expected as the species is regionally extinct and found in warmer east-coastal waters to the north (e.g. around Sydney NSW). Valentine (1965) has identified *L. torquata* as an index fossil for the LIG in Victoria.

The eight remaining rocky platform shellfish species found within the headland deposit are also considered known or potential Aboriginal midden items. For example, the large molluscs *D. orbita* and *H. rubra*, and to a lesser extent the small molluscs *S. conica*, *C. lineolata* and *B. nanum*, have been identified in Holocene Aboriginal middens along the west coast of Victoria (e.g. Context 2014; Lourandos 1980; Richards 2012; Richards & Johnston 2004; Zobel et al. 1984). While *D. orbita* and *H. rubra* were targeted species during foraging, *S. conica* is known to attach to the outer surface of *L. undulata*, and possibly along with *C. lineolata* and *B. nanum* was bycatch (see Richards 2012: 92). *P. albida* and *Patelloida* sp. cf *latistrigata* have not specifically been recorded in western Victoria middens, but they belong to classes of shellfish (i.e. chitons and limpets respectively) represented in western Victorian Aboriginal headland middens (e.g. Richards 2012; Richards & Johnston 2004; Zobel et al. 1984). *Austrolittorina* has not been recorded within Aboriginal middens of western Victoria and may represent bycatch or have been a LIG wind-blown inclusion because it occurs at or above the high-tide mark on rocky shores (Macpherson & Gabriel 1962; as *Melarapha unifasciata*).

While rocky platform mollusc species recovered from the Moyjil deposit are known or potential Aboriginal food items, numerous rocky platform mollusc species recovered from Aboriginal midden sites in western Victoria are missing from it. The most obvious of the missing high-ranking rocky platform taxa are limpets (*Cellana* spp.), Beaked mussel (*Brachidontes rostratus*), edible mussel (*Mytilus planulatus*) and silver kelp shell (*Bankivia fasciata*) (Godfrey 1989; Richards 2012; Richards & Johnston 2004; Zobel et al. 1984). Of these, the absence of *Cellana* spp. requires explanation**.** Today this species of large limpet (up to 6 cm) is 'very common in the upper and mid intertidal zone of rocky shores where there is strong wave action' (Wilson et al. 1993: 36). It seems unlikely that if this large, edible mollusc was available for collection it would have been ignored by people who foraged in the same habitat for *Lunella* spp. That *Cellana* spp. may not have been present at Moyjil during the LIG is suggested strongly by its similar absence in the adjacent LIG beach deposits (Nair 2005: 108–110). Differences may be expected in the availability of shell species through time, for example *M. planulatus* is found in early Holocene middens at Discovery Bay yet it 'no longer inhabits the rock platforms' in this region (Godfrey 1989: 66; see also Bird & Frankel 2001: 73).

Comparisons with Pacific Gull middens. Modern Pacific Gulls (*L. pacificus*) create two types of faunal deposits associated with food procurement and consumption — drop-zone anvil deposits and roosting/nesting deposits with the remains of regurgitated pellets. In terms of the former, Pacific Gulls (and related gull *Larus* spp.) across the world drop molluscs from a few metres onto flat-topped rocks near the shore to break open shells to aid extraction of flesh for food (e.g. Barash et al. 1975; Farr 1978; Maron 1982; Sim 1991; Siegfried 1977; Teichert & Seventy 1947). In addition, Pacific Gulls have also been observed to drop shells onto sand, either through inexperience or play (Farr 1978; Ortega & Bekoff 1987; Tarr 1961; see also Gamble & Cristol 2002; Ingolfsson & Estrella 1978; Kent 1981).

Jones and Allen (1978) documented what they believed to be a Pacific Gull 'old nest or feeding place' on Steep Head Island in Bass Strait (Tasmania). It contained seven taxa, including molluscs, crabs/crayfish and birds. Shellfish were represented by chiton, *L. undulata, C. solida*, *B. rostratus* and little black horse mussel (*Xenostrobus pulex* [syn. *Modiolus pulex*]). Coulson and Coulson's (1993: Table 1) analysis of Pacific Gull pellets from Green Island (south-eastern Tasmania) revealed at least 13 taxa, with the following proportions (expressed as % of total number of pellets): crabs (56%), fish (47%), molluscs (28%), sea urchins (9%) and cephalopods (7%). Shellfish were represented by chitons *P. albida* and *Sypharochiton pelliserpentis* (syn. *Chiton pelliserpentis*) and *L. undulata*. Leitch et al.'s (2014: Table 1) analysis of 515 Pacific Gull pellets on Seal Island (Bass Strait) revealed 50 prey taxa: birds (61%), fish (12%), crabs (6%), cephalopods (6%), molluscs (2%), and mammals (1%). Shellfish included noddiwink (*A. unifasciata*), chiton (*Ischnochiton australis*) and dog whelk (Nassariidae). Many of the larger fish were likely scavenged from nearby seal colonies. Lindsay and Meathrel's (2008) analysis of 2478 pellets and 8611 food 'particles' from within and near Pacific Gull nesting sites on the Furneaux Islands (Bass Strait) revealed 128 prey taxa, of which the 'major prey types' were birds, sea urchins, molluscs, crabs and fish, with relative proportions varying in relation to local environmental differences. Molluscs included *B. rostratus*, painted lady (*Phasianella australis*) and queen scallop (*Equichlamys bifrons*).

Sherwood et al. (2016) noted that Pacific Gull drop-zone anvil sites on the Eyre Peninsula (South Australia) feature considerable deposits of broken, sharp-edged shell fragments. The opercula of *L. undulata* was often swallowed along with the animal at these sites, resulting in a relatively low operculum:shell ratio. In addition to *L. undulata* (shells and opercula), which dominate drop-zone anvil faunal assemblages, minor amounts of *D. orbita*, *S. conica*, chiton, reef crab (*Ozius truncatus*) and carcasses of the short-tailed shearwater (*Puffinus tenuirostris*) were found. Sherwood et al. (2016: 17) suggested that the *S. conica* shells were probably collected incidentally when the seabirds captured *L. undulata*. At roosting sites, Sherwood et al. (2016) found regurgitated pellets containing the opercula and other hard parts such as chiton plates and fish bones, but few shells. Roosting and anvil sites can occur together resulting in a more balanced ratio of opercula to shells.

The Moyjil headland deposit also revealed two complete abalone (*H. rubra*) shells with maximum lengths of 7.9 cm and 8.4 cm. As *H. rubra* shells in Victorian waters have been recorded up to 16.4 cm in length, with sexual maturity reached between 9 cm and 11 cm (McShane et al. 1988; Prince et al. 1988: 79), it is clear that both of the Moyjil abalone shells are juveniles. *H. rubra* are found together with *L. undulata* in the lower intertidal and adjacent subtidal zones, where they are often the most abundant mobile gastropods (Crozier et al. 2007; Ferns & Hough 2002; Hart et al. 2005). As large (≥9 cm) *H. rubra* are more abundant than the middle-size class (5–9 cm) (Prince et al. 1988: 81), adult abalone would have been a more attractive option for Aboriginal foragers. However, archaeological samples of *H. rubra* in Tasmanian Aboriginal middens indicate that up to 30% of shells are juveniles (Bowdler 1984: Table 51; McNiven 1996: Table 5). Although none of the above studies on Pacific Gull deposits make mention of abalone, Barker and Vestjens (1989: 283) note generally that Pacific Gull diets include abalone (*Haliotis* sp.). As removal of large abalone from rocks requires some mechanical skill and strength to overcome their considerable suction adhesion to rocks, it is likely that large adult abalone are beyond the foraging capacity of Pacific Gulls. While no data are available on the size of abalone taken by Pacific Gulls, live abalone (shells + animal) up to 9–10 cm in length represent the recorded upper limit of 150–200g for individual prey items of Pacific Gulls (Leitch et al. 2014: 218; Saunders 2009: 23). In comparison, Sim (1991:74) reported that abalone shells in middens created by oystercatchers (*Haematopus* spp.; a bird smaller than Pacific Gulls) in Bass Strait had a maximum length of 6 cm, which is the known mollusc prey size limit of oystercatchers (Goss-Custard et al. 1987; Zwarts et al. 1996).

From this information on modern Pacific Gull faunal deposit diversity, it is apparent West Stack and headland deposits at Moyjil share much in common with Pacific Gull drop-zone anvil sites but less so for nesting/roosting sites. In terms of the latter, the absence of bird bones within the Moyjil deposits is atypical of Pacific Gull nesting/roosting sites. Similarly, only a single fish bone (mulloway) has been recorded at Moyjil whereas fish bones are common at Pacific Gull nesting/roosting sites. The dominance of Moyjil deposits by fragmented remains of *L. undulata* is typical of Pacific Gull drop-zone anvil sites documented by Sherwood et al. (2016).

Distribution of shells

West Stack. The highest density of marine shells is found on the two West Stack blocks — WsS and WsN — but the high degree of cementation of shells in matrix makes quantitative assessment difficult. Nair and Sherwood (2007) conducted three quadrat surveys (one on WsS and two on WsN), each covering an area 25 x 25 cm. Combined total abundances of embedded specimens across the quadrats were: *L. undulata* shell (N=57), *L. undulata* opercula (N=10), *L. torquata* opercula (N=1), *S. conica* shell (N=11), *D. orbita* shell (N=1) and unidentified fragments (N=674). The greatly fractured nature of the shells is demonstrated by over ten times as many shell fragments as shells (the latter defined as containing a recognisable columella and at least part of a body whorl).

Loose material collected from the surface of West Stack shows similar characteristics of both species and fragmentation. The total mass of shell material presently archived from the surface of West Stack (1902 g) consists of: *Lunella* shell fragments showing characteristic striped patterning (12.3%), gastropod columella fragments (21.8%), *Lunella* protoconch and part of the spire apex (3.7%, N=48), *L. undulata* opercula (whole or part) (11.9%, N=145), *S. conica* shell (1.8%, N=32), chiton plates (1.2%, N=22), *D. orbita* shell (0.3%, N=1) and *Patelloida* cf. *latistrigata* (0.05%, N=2). The percentages are based on mass of each subset and N is the number of identified specimens (NISP) of each taxon.

Distribution along the Headland (unit Q2 exposure). An informal reference point was established as the junction of the top of unit Q2cs and the eastern side of steps leading to the beach from the Moyjil carpark's western side (Figure 1). Distances from this reference point were defined by circular arcs cutting across the headland with the reference point as centre. The number of shells found in 10 m intervals east of the reference point are given in Table 2. The greatest number of marine taxa have been found at the western end of the unit Q2 exposure (i.e. close to West Stack). This is also where the unit Q2 layer is thickest (>2 m). Shells

Table 2: Lateral distribution of marine species recovered from the headland exposure of unit Q2 at Moyjil.

Taxon	Distance from reference point (m)						
	0–10	>10-20	>20–30	>30–40	>40–50	>50–60	>60–70
Lunella undulata shell	11	7	3	3	2		2
Lunella undulata operculum	2	1	1				
Sabia conica	1	1	1				
Chiton plate	2	3		2	1		
Crustacea	5	1	1				
Haliotis rubra			1				1
Mulloway otolith			1				
Unidentified fragments	2	2	1		1	1	1
Dicathais orbita	1						
Austrolittorina sp.		4					
Total	24	19	9	5	4	1	4

have been found across the entire thickness of unit Q2, including cemented to the underside of the overlying unit Q2cs where unit Q2 thickness is greatest. The evidence supports a model for shell accumulation predominantly at the western end of the headland close to West Stack. Deposition continued throughout the accumulation of the unit Q2 sand sheet.

Taphonomy of L. undulata on West Stack (loose opercula)

Completeness of rim. Table 3 compares the circumferential distribution of flange damage for West Stack loose opercula (N=91) to those reported by Sherwood et al. (2016) for modern beach deposits, modern Pacific Gull middens and Holocene Aboriginal middens. A relatively small proportion of the West Stack loose opercula have complete (8/8) or near complete (>7/8) flanges. The total percentage of such opercula (26.4%) more closely matches that of the two modern beach deposits (23.5% and 23.4%) than the seabird (50.9% and 56.7%) or Aboriginal middens (75.7% and 80.7%). The relatively high proportion of incomplete flanges (i.e. between 7/8 and 4/8 complete) also resembles that of the storm beaches.

Table 3: Completeness of the rim or circumferential flange of *Lunella undulata* opercula found in different depositional environments. Data expressed as a percentage of all opercula examined. All but West Stack (loose) data from Sherwood et al. (2016). Fractions visually estimated in eighths.

Intact fractions	Modern Gull middens		Beach deposits		Holocene Aboriginal middens		Moyjil deposit –West Stack (loose)
	Point Avoid	Golden Island Lookout	Breakwater Island	Thunder Point	Moyjil	Cape Duquesne	
8/8	47.9	43.7	16.4	15.6	70.9	74.4	14.3
>7/8	13.0	13.0	7.0	7.9	4.8	6.3	12.1
7/8	16.4	20.7	11.3	13.8	4.8	6.1	15.4
6/8	13.7	13.0	14.8	15.3	3.9	5.4	19.8
5/8	6.2	6.1	11.6	18.8	0.9	2.7	20.9
4/8	2.7	2.7	13.6	8.5	6.1	3.3	8.8
3/8	0	0.4	4.1	5.3	4.8	1.8	3.3
2/8	0	0.4	3.1	3.5	2.6	0	3.3
1/8	0	0	2.1	2.4	0.9	0.2	2.2
0/8	0	0	16.1	8.8	0.4*	0	0

*A single black operculum fragment.

Location of flange damage. Assessment of the location(s) of flange damage was possible for 66 complete or near complete opercula. Segments 1, 2 and 8 (Figure 5), furthest from the high point of the dome and located furthest from the columella, showed the greatest incidence of damage. In this respect the West Stack loose opercula are similar to the Cape Duquesne Aboriginal midden and the two seabird middens (Table 4). Although Sim (1991: 68, 70) suggested that such flange damage is diagnostic of gull impact to opercula, Sherwood et al. (2016) demonstrated that similar damage can also be found on opercula from Aboriginal middens. As such, this pattern of opercula damage is not helpful in discriminating origin — these segments are normally where the flange is widest and so most vulnerable to damage under impact.

Water rounding. Of 91 opercula examined, only four show evidence of rounding. The domes of these four opercula appeared to have had surface layers removed to reveal the spiral growth layers beneath. The opercula also appeared whiter than others. This weathering effect has not been observed in natural beach deposits, and no opercula of similar appearance have been recorded from other sites examined by Sherwood et al. (2016). Such opercula are a small percentage of the West Stack loose specimens (4.3%). It is possible they represent more heavily weathered opercula among those freed from the cementing matrix. Most (95.7%) of the opercula had sharp-edged breakage surfaces and/or unworn flanges, a much greater percentage than for beach deposits at Breakwater Island and Thunder Point (64% and 40% respectively) and similar to the 99–100% reported for Aboriginal and Pacific Gull middens (Sherwood et al. 2016).

Damage to the central dome. The central dome is the thickest and most robust part of the operculum. It can show damage such as boring and pitting by marine organisms (bioerosion) as well as breakage and cracking — the latter often starting from the intersection of the growth spiral with the outer edge of the operculum (Sherwood et al. 2016). Damage to domes was from cracking (58%) and breakage (i.e. incomplete domes; 51%) with no evidence of bioerosion recorded. The proportion of broken domes is much higher than the 8.4–25.2% recorded for Pacific Gull middens, Aboriginal middens and beach deposits by Sherwood et al. (2016). This characteristic showed overlap across the different types of shell deposits and so was not useful as a discriminatory feature in their study.

Conclusions from taphonomy of loose opercula. The West Stack loose opercula have suffered a high degree of damage. The frequency of damage to the flange resembles that found in beach deposits, while damage to the dome occurs in a higher proportion of opercula than for any of the shell deposits examined by Sherwood et al. (2016). When the low proportion of opercula showing evidence of water rounding is considered, the taphonomic evidence suggests that damage occurred post-depositionally (perhaps by treadage or the impacts of shells subsequently dropped on them) and/or as a result of weathering and erosive transport to their final collection sites. As such, taphonomic evidence fails to help discriminate between shell deposition by birds or Aboriginal people at Moyjil.

Size of Lunella undulata

Headland shells from unit Q2. Of 26 *L. undulata* shells or partial shells presently held, two are complete (or slightly damaged) shells, seventeen have a columella with one or more whorls remaining (either complete or damaged), and seven are fragments identifiable by the characteristic external shell striping of the species. There is no evidence

Table 4: Percentage occurrence of damage to individual segments in *Lunella undulata* opercula with incomplete flanges. N is the number of damaged opercula described from each site (adapted from Sherwood et al. 2016).

Segment	% Damaged			
	Cape Duquesne early Holocene Aboriginal midden (N=136)	Point Avoid modern gull midden (N=84)	Golden Island Lookout modern gull midden (N=156)	Moyjil Deposit – West Stack (loose) (N=66)
1	64	70	69	77
2	54	36	27	71
3	29	17	10	11
4	4	1	5	4
5	8	2	4	9
6	12	13	9	14
7	21	25	28	35
8	45	44	56	54

Table 5: Analysis of size distribution of *Lunella undulata* opercula based on their maximum dimension (L = length). The number of opercula measured and percentage of opercula lengths smaller than 10 mm and greater than 20 mm is also shown for each site.

Statistic	West Stack		Holocene Aboriginal middens		LIG beach deposits		Modern beach deposits		Modern gull middens	
	Embedded	Loose	Moyjil	Cape Duquesne	Moyjil	Goose Lagoon	Thunder Point	Breakwater Island	Golden Island Lookout	Point Avoid
Count	28	76	200	541	82	83	280	567	261	146
Mean (mm)	17.9	18.4	16.0	13.8	15.3	13.6	10.9	15.2	18.4	17.4
Std dev.	3.3	2.4	3.9	2.35	3.5	2.6	2.55	5.17	1.77	1.57
Std error	0.624	0.275	0.276	0.101	0.387	0.285	0.152	0.217	0.110	0.130
Max. (mm)	21.8	21.7	23.5	22.2	21.8	20.0	19.4	25.45	22.65	22.4
Min. (mm)	4.0	8.1	7.3	7.2	7.6	7.1	6.7	6.1	11.7	12.8
<10 mm%	3.6	1.2	4.5	2.8	9.8	8.4	44.6	26.1	0	0
>20 mm%	21.4	26.6	16.0	1.3	8.5	0.0	0.0	21.5	17.2	0.04

of water rounding on any of the specimens. Excavation of several freshly exposed shells has revealed that their damage was not the result of exposure by weathering but was present on burial of the shell.

For twenty of these shells it was possible to either directly measure one or more of shell length, shell width or diameter of opening, and so infer shell length by comparison to modern shells. The majority (80%) of the shells have a length >4 cm either measured directly (N=6) or inferred (N=10). This is close to the maximum length of 5 cm reported for this species (MacPherson & Gabriel 1962). Three of the four shells with lengths <4 cm had lengths between 2.4 and 2.9 cm, while the fourth was over 3.5 cm long. All four *L. undulata* opercula recently recovered from unit Q2 were complete (i.e. undamaged flanges) and large, with lengths between 17.5 and 21.0 mm. This small sample does not allow conclusions based on taphonomy to be made on origin. The dominance of large *L. undulata* shells and opercula is consistent with predator (human and/or bird) selection.

West Stack opercula. Table 5 compares statistical properties of *L. undulata* opercula populations from the Moyjil deposit with those of shell deposits previously reported by Sherwood et al. (2016) and two previously unstudied Last Interglacial beach deposits. The West Stack loose and embedded opercula have comparable mean lengths that are similar to those from Pacific Gull middens at Golden Island Lookout and Point Avoid. These are larger than the mean lengths for both Aboriginal middens and the four beach deposits. Maximum lengths exceed 21 mm for all sites except for the modern Thunder Point and LIG Goose Lagoon beach deposits. The smaller lengths in these deposits may reflect lower available energies to transport opercula (i.e. more sheltered depositional environments). West Stack has a small (<5%) population of opercula less than 10 mm long, as do the two Aboriginal middens. The seabird middens have no individuals this small, while the beach deposits have higher proportions (8–45%).

In summary, the West Stack loose and embedded opercula populations share similar statistical properties for length. They differ from the LIG and modern beach deposits in having a larger mean size and lower proportion of small (<10 mm) opercula and a higher proportion of large (>20 mm) opercula (except for Breakwater Island). The proportion of smaller individuals (<10 mm) is close to that of the two Aboriginal middens (i.e. <5%) while mean length is closer to that of the two seabird middens (>17.5 mm). The proportion of larger opercula (>20 mm) is high compared with all sites except for the beach deposit on Breakwater Island. The Moyjil late Holocene Aboriginal midden and Golden Island Lookout seabird midden also show a high (>16%) proportion of larger opercula. Additional information on the population structure is given by cumulative frequency plots based on 3 mm length intervals. These show the similarity of populations of West Stack embedded and loose opercula (Figure 6) and the embedded West Stack opercula and seabird middens (Figure 7). The broader size range of Aboriginal midden populations compared with West Stack is shown in Figure 8.

Table 6: Results of a one-way ANOVA of length from various *Lunella undulata* opercula populations in south-east Australia.

Site	**West Stack**		**Aboriginal middens**		**LIG beach deposits**		**Modern beach deposits**		**Gull middens**	
	Embedded	Loose	MAM	CDAM	MLIG	GLIG	BI	TP	PA	GPL
WS (embedded)				***	*	***	*	***		
WS (loose)			***	***	***	***	***	***	**	
MAM		***		***		***		***	**	***
CDAM	***	***	***		**		***	***	***	***
MLIG	*	***		**		*		***	**	***
GLIG	***	***	***		*		**	***	***	***
BI	*	***		***		**		***	***	***
TP	***	***	***	***	***	***	***		***	***
PA		**	**	***	**	***	***	***		***
GPL			***	***	***	***	***	***	***	

* Difference is significant at $P = 0.01\text{-}0.05$, ** difference is highly significant at $P = 0.001\text{-}0.009$, *** difference is very highly significant at $P < 0.001$.
Abbreviations: WS - West Stack; MAM-Moyjil Holocene Aboriginal Midden; CDAM – Cape Dequesne Holocene Aboriginal Midden; MLIG – Moyjil Last Interglacial beach deposit; GLIG – Goose Lagoon Interglacial beach deposit; BI – Breakwater Island modern beach deposit; TP –Thunder Point modern beach deposit; PA – Point Avoid modern bird midden; GPL – Golden Point Lookout modern bird midden.

The ANOVA analysis of opercula lengths from the ten populations is summarised in Table 6, which shows that nine paired populations did not have significantly different size distributions (i.e. $P > 0.05$). Most paired size distributions were very highly significantly different ($N=28$; $P < 0.001$), highly significantly different ($N=5$; $P < 0.01$) or significantly different ($N=3$; $P < 0.05$). Population pairs with distributions that were not significantly different are:

(a) The two West Stack embedded and loose populations are not significantly different (P=1.000), confirming conclusions from Table 5 and visual inspection of the cumulative frequency plot (Figure 6). The small sample size of the West Stack (embedded) population (N=27) means that its standard error (Table 5) is relatively large compared with other populations. This will reduce the discrimination of tests of significance involving this population.

(b) There is no significant difference between the West Stack (embedded) population and the Moyjil late Holocene Aboriginal midden and the two seabird middens (Point Avoid and Golden Island Lookout). It is, however, highly significantly different from the Cape Duquesne early Holocene Aboriginal midden.

(c) The West Stack (loose) distribution is not significantly different from the Golden Island Lookout bird midden distribution. The loose opercula distribution is, however, very highly significantly different from that of the Point Avoid bird midden (chiefly due to the absence of larger opercula from the latter).

(d) The Moyjil late Holocene Aboriginal midden is not significantly different from the Moyjil LIG and Breakwater Island beach deposits.

(e) The Cape Duquesne early Holocene Aboriginal midden is very highly similar (P=1.000) to the Goose Lagoon LIG beach deposit. Both (d) and (e) support the conclusion of Sherwood et al. (2016) that it may not be possible to distinguish Aboriginal middens from natural shell beds based on *L. undulata* size selectivity alone (noting that other taphonomic properties such as water rounding are diagnostic).

(f) The Breakwater Island beach deposit distribution is not significantly different from that of the Moyjil LIG beds. Both of these are at least significantly different from the Goose Lagoon LIG and Thunder Point modern beach distributions.

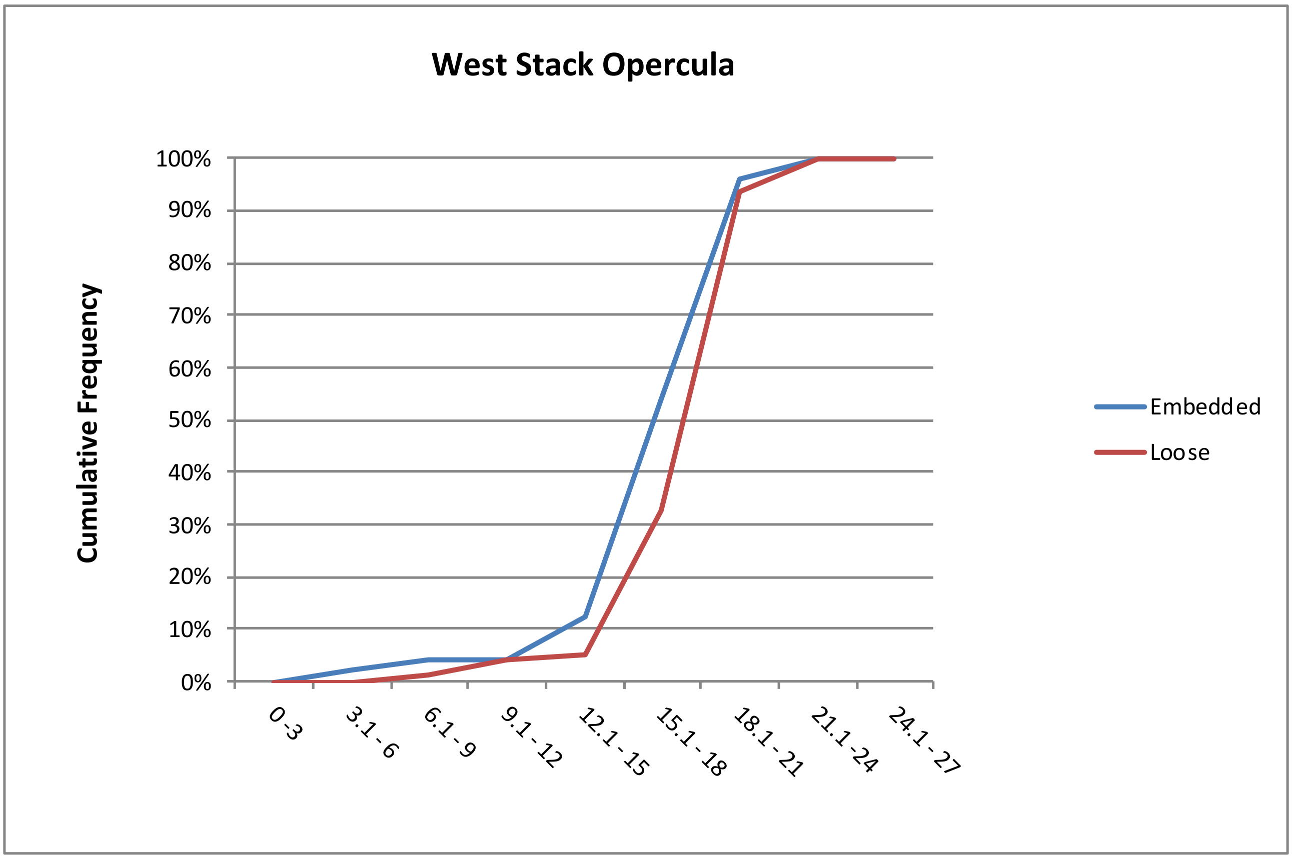


Figure 6: Cumulative frequency plots for 'embedded' (*in situ*) and 'loose' (non-*in situ*) *Lunella undulata* opercula lengths (mm) from West Stack and unit Q2.

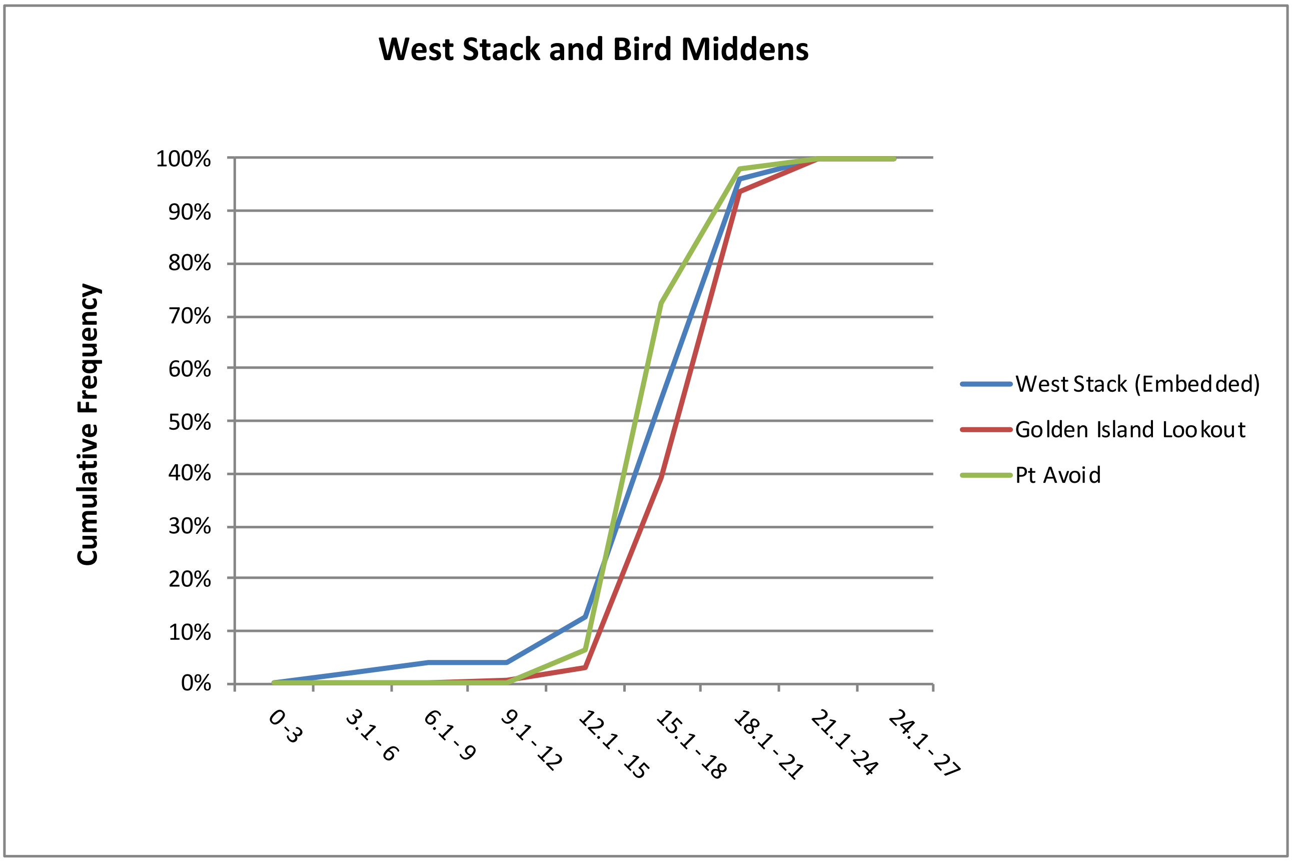


Figure 7: Comparison of the West Stack (embedded) and Pacific Gull midden *Lunella undulata* opercula size distributions.

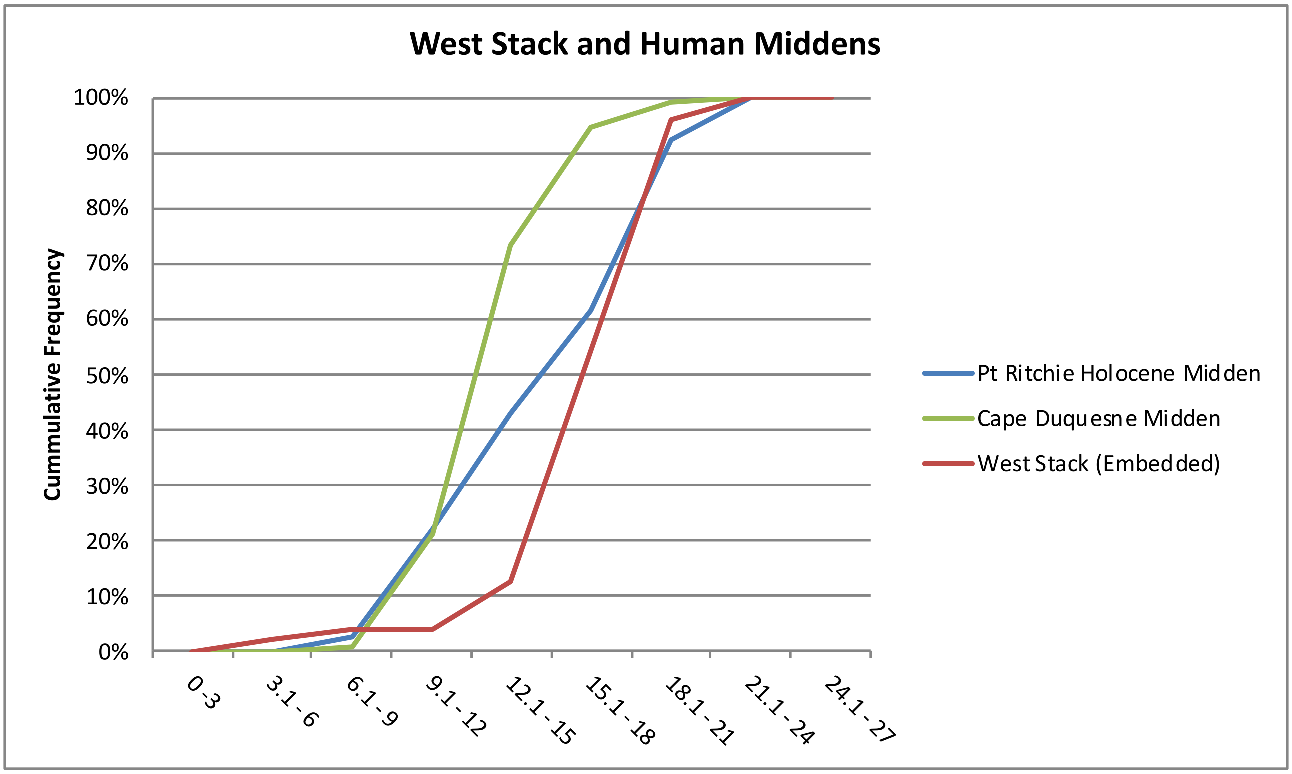


Figure 8: Size distributions of *Lunella undulata* opercula from West Stack (embedded) and Aboriginal middens.

Conclusions based on the ANOVA analysis. The West Stack opercula have a size distribution skewed towards higher size ranges. This result is independent of whether embedded opercula or loose opercula are considered. These two populations are not significantly different. The West Stack (embedded) shell distributions resemble most closely those of the Golden Island Lookout and Point Avoid modern seabird middens and the Moyjil late Holocene Aboriginal midden. The West Stack (loose) distribution is very highly significantly different from those of both Aboriginal middens as well as those of the four natural shell beds (from Breakwater Island, Moyjil and Goose Lagoon). It is not significantly different from the Golden Island Lookout bird midden distribution but highly significantly different from the Point Avoid bird midden distribution. Definitive conclusions on whether the embedded shells have an Aboriginal or seabird origin is not possible based on these analyses.

The size distributions of the two seabird middens are at least highly significantly different from those of the four beach shell deposits. This further supports the conclusion of Sherwood et al. (2016) that size distribution may be useful in distinguishing these two types of shell beds.

Confounding this analysis is the fact that shell beds created by similar means may have significantly different distributions. This was found for the two seabird middens, the four natural beach deposits and the two Aboriginal middens. This complicates interpretations of studies where a shell bed of known origin is used as a basis for comparison with one of unknown origin. Furthermore, shell beds of different origins may have indistinguishable size distributions. Distributions for the late Holocene Aboriginal midden and LIG natural shell beds at Moyjil are not significantly different. The size distribution of the early Holocene Aboriginal midden at Cape Duquesne is not significantly different from that of the natural Goose Lagoon LIG shell bed.

Sherwood et al. (2016) have discussed the various factors that may affect the size distributions measured:

- In the case of natural shell beds, the size of assembled shell specimens of the same species is dependent on both the nature of the source population and the energy available to transport the shells. The smaller sizes present at Goose Lagoon and Thunder Point compared with the Breakwater Island and Moyjil LIG populations may be due to a lower energy depositional environment of the former or some ecological factor which reduced the size of adults in their vicinity.
- Aboriginal and seabird middens would be expected to show a bias towards larger specimens because of the greater food value of larger animals. The two seabird middens demonstrate larger opercula sizes, although the Point Avoid bird midden had relatively few large opercula (>20 mm) even though its mean length was comparable to those of the Golden Island Lookout bird midden (Table 5). While it also appears to be the case

for the Moyjil late Holocene Aboriginal midden, it is not apparent in the data for the Cape Duquesne early Holocene Aboriginal midden (Table 5). During field measurements of the Moyjil Holocene midden some quite small shells of *L. undulata* and other marine species were observed, thus supporting the data here and the inference that collecting may not have focused on larger animals but included a range of size classes. It is also possible that ecological factors meant that large animals were less abundant at Cape Duquesne when that midden was created 10,000 years ago.

- Researcher collection bias, favouring larger more visible specimens, may also skew size distribution studies. All researchers (Tom Richards, John Sherwood and Ian McNiven) were aware of this issue and deliberately sought to measure all observable specimens on West Stack, the South Australian seabird middens, the LIG shell beds and the Holocene Aboriginal middens. In the case of previous sampling at Goose Lagoon (by JS), careful searching was undertaken for specimens for dating, the relative scarcity of specimens resulting in a decision to collect all available on the surface of the deposit. Loose opercula collected from West Stack by Gill and JS may not have been as thorough; however, consistency between the 'embedded' and 'loose' size distributions suggests sampling bias is not likely to have been significant.

Geomorphic and other considerations

Hearty et al. (2007) have provided a global model for LIG (Marine Isotope Stage 5e) sea-level fluctuation between 119 and 130 ka. Sea level rose to above present by 130 ka, followed by a period of stability at +2–3 m until about 125 ka. After a brief fall, sea level returned to +3–4 m between 122 and 124 ka and then rose rapidly to 6–9 m at 120 ka before falling rapidly below present sea level after 119 ka.

This model is consistent with the multiple notches at various elevations between 2 m and 6 m observed at Moyjil, as well other locations in south-west Victoria. A sea level of 6–9 m would have overtopped Gsα on West Stack and the headland (elevations 7.8–9.5 m AHD) particularly during storm events, stripping soils and any vegetation. These seas may have contributed to the pit erosion on WsS. It is unlikely that vegetation would develop on the exposed calcrete bench of Gsα until sometime after sea level began its retreat post 120 ka.

Sand exposed by a retreating sea was blown over the headland forming unit Q2 sometime after the sea level maximum (post 120 ka) consistent with its OSL age. Marine shells were continually added to the growing sand sheet. Eventually the sea was too distant for shells and sand to be transported to the headland. This model would apply equally well to Aboriginal people or seabirds as the agents of shell transport. If seabirds are responsible, collecting would only persist while a suitable shallow reef was close to the headland. The birds are unlikely to fly more than a few hundred metres inland in search of anvil rocks. Those seen at the Eyre Peninsula (by JS) were all within 50 m of high water. Aboriginal people are known to have carried shellfish further inland, with midden deposits recorded up 16 km from the nearest coast (e.g. Godfrey 1989: 68; Lauer 1979: 47; Luebbers 1978: 105, 301; McNiven 1985: 20). As such, the requirement for a coast in close proximity to Moyjil is less stringent if Aboriginal people were responsible for the shell deposit. The window of time for occupation of Moyjil in terms of sea levels and distance from the coast would be wider.

There are some observations which are difficult to account for with either the Aboriginal or bird predator model. If West Stack was used as an anvil rock by seabirds, the absence of shells on the broken slab which fell to the east is unusual. The virtual absence of shells on the headland's Gsα is also difficult to reconcile with this model. Carey et al. (2018) have proposed that the West Stack shell deposit has resulted from a seismically induced slurry flow across a now eroded bridge connecting the surface of West Stack to the headland's Gsα. If this is the case the source of the shells may remain buried beneath the unit Q2 sands opposite West Stack or was lost with collapse of the bridge post 120 ka.

CONCLUSIONS

The central question addressed in this research was whether the Moyjil shell deposit could be shown to be attributable to Aboriginal or seabird agency based on evidence provided by its shells. Overall, our comparative analyses produced a mixed set of results. Taphonomic characteristics of the West Stack (loose) opercula do not resemble those found in beach (modern and LIG), Aboriginal, or seabird middens and are attributed to post-depositional changes that have modified their original properties. Size distributions of *L. undulata* opercula from West Stack and *L. undulata* shells from the headland's unit Q2 provide strong evidence of preferential selection of larger individuals. This size bias and the overwhelming absence of water rounding features in the shells or fragments provides strong evidence for the deposit being a midden, as proposed by Nair and Sherwood (2007).

The most common marine species present at Moyjil are also common constituents of both Aboriginal and Pacific Gull middens, and this characteristic is thus non-discriminatory. The loose opercula recovered from West Stack show similar size distribution to the embedded opercula, suggesting a common origin consistent with their location and taphonomy. Together, the size distributions of West Stack (embedded and loose) opercula show greater similarity to the two modern Pacific Gull middens than the two Aboriginal middens. The low frequency of small (<10 mm) opercula embedded in West Stack is more characteristic of Aboriginal middens. This small size class was totally absent from the two seabird middens. Thus, while none of the lines of evidence pursued are able to definitively associate the West Stack shell deposit with either Pacific Gull or Aboriginal shellfishing practices, on balance the shell evidence marginally favours the bird midden hypothesis.

The conclusion that the West Stack shell deposits has slightly more features in common with Pacific Gull middens compared to Aboriginal middens is qualified in several ways. First, the West Stack (embedded) sample size is small (N=27) and the standard error of the mean is larger than for other populations studied. This reduces the sensitivity of the analysis to detection of differences in distribution. Second, the size distribution may reflect population characteristics of the sites as much as size selection. The low abundance of large individuals (>20 mm) at the Point Avoid bird midden (Table 5) may be an example of ecological factors influencing the size structure of a population. Third, if the West Stack midden was formed by Aboriginal people during the LIG, these people may have been amongst the first to exploit local shellfish beds. As such, they would have had a 'first finder' advantage, exploiting *L. undulata* stocks richer in large individuals (see Erlandson et al. 2011; Klein & Steele 2013; Mannino & Thomas 2002). Fourth, human and Pacific Gull behaviour may have changed over the *ca* 100 ka between the LIG and Holocene high sea levels that resulted in a coast near to Moyjil. As such, while the evidence is not conclusive regarding an Aboriginal or sea-bird origin, it is also true that neither origin can be discounted based on available shell evidence.

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