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Direct radiocarbon dating of fish otoliths from mulloway (*Argyrosomus japonicus*) and black bream (*Acanthopagrus butcheri*) from Long Point, Coorong, South Australia

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Abstract

Accelerator Mass Spectrometry (AMS) radiocarbon dates (n=20) determined on fish otoliths from mulloway (*Argyrosomus japonicus*) and black bream (*Acanthopagrus butcheri*) are reported from five sites at Long Point, Coorong, South Australia. The dates range from 2938–2529 to 326–1 cal. BP, extending the known period of occupation of Long Point. Previous dating at the sites indicated intensive occupation of the area from 2455–2134 cal. BP. Results provide a detailed local chronology for the region, contributing to a more comprehensive understanding of Aboriginal use of Ngarrindjeri lands and waters. This study validates the use of fish otoliths for radiocarbon dating and reveals how dating different materials can result in different midden chronologies.

Keywords: AMS radiocarbon dating, otolith, midden, Coorong

Introduction

The Coorong is a shallow saline lagoon, >100 km in length, at the terminus of the largest river in Australia, the Murray. This water body is separated from the Southern Ocean by a narrow strip of sand-dunes and with Lakes Alexandrina and Albert located at its northern extremity (Figure 1). In its natural state, prior to European alteration and the construction of barrages, the Coorong estuary comprised fresh, brackish and saline environments influenced by both marine and freshwater (river) inflow. Increased human regulation of the Murray has resulted in significantly increased salinity ranges, with hypersaline conditions existing in some areas of the Coorong (Jones et al. 2002; Scheltinga et al. 2006). Together, the Coorong and Lower Lakes support 78 species of fish, including mulloway, *Argyrosomus japonicus*, and black bream, *Acanthopagrus butcheri* (Geddes 2000).

A. japonicus is a large predatory teleost fish belonging to the Sciaenid family. It is a fast growing, relatively long-lived species, attaining a maximum age of 41 years and size of ~1800 mm (Ferguson et al. 2014; Scott et al. 1974). Juveniles inhabit estuarine environments, and adults typically aggregate around estuary mouths during the summer months, attracted by freshwater outflows and an abundance of food (Ferguson et al. 2014). *A. butcheri,* a member of the Sparidae family, is common in river mouths and estuaries where it prefers overhanging banks, snags and dead trees on the bottom of low salinity pools (Norriss et al. 2002). It is a slow growing, relatively long-lived species, reaching a maximum age of 29 years and length of 400 mm (Cashmore et al. 2000).

For thousands of years the area of the Lower Lakes and Coorong in South Australia (SA) has comprised the traditional *ruwe* (Country) of the Ngarrindjeri people (Ngarrindjeri Tendi et al.

2007). At the time of European invasion, 1836, it is reputed to have been among the most densely populated areas in Australia owing to the richness of natural resources (Jenkin 1979; Taplin 1879). Archaeological research in the area has documented hundreds of middens, testament to thousands of years of Ngarrindjeri resource use and occupation in the region (Luebbers 1978,1981,1982; St George 2009; St George et al. 2013; Wallis 2007a, 2007b; Wallis and Disspain 2008; Wilson et al. 2012). Luebbers (1978, 1981, 1982) suggested that the Coorong experienced an intensive settlement phase from 2000 BP–AD 1840s. St George et al. (2013) supported this hypothesis with 29 radiocarbon dates (charcoal and shell) from sites at Long Point, which suggested continued use from 2500 cal. BP to the recent past.

Temporal shifts in fish populations in the Lower Lakes and Coorong are expected to provide important information about fluctuating Aboriginal subsistence with archaeological otoliths a useful environmental proxy (Disspain et al. 2016; Scartascini et al. 2016). However, these studies were originally temporally constrained by the use of dates on associated materials (shell and charcoal) from the same sites (Disspain et al. 2011; Disspain et al. 2012). Despite a strong preference for using shell or charcoal samples for radiocarbon dating in archaeology, fish otoliths have been successfully dated in numerous studies (e.g., Favier Dubois and Scartascini 2012; Hufthammer et al. 2010; Scartascini and Volpedo 2013). Here we present the results of direct radiocarbon dating of Long Point otoliths, and compare them with charcoal and shell dates reported by St George et al. (2013).

Methods

In 2008 four middens in the Long Point area of the northern Coorong were excavated: LP4, LP9, LP11 and LP16 (Figure 1) (see St George 2009; St George et al. 2013; Wallis and Disspain 2008, for details). Additional surface material was collected from a deflated cultural lens in a sand dune blowout (LP8). All four middens were excavated to culturally sterile sediment using arbitrary 5 cm spits (unless otherwise dictated by a stratigraphic change). The excavated materials from each spit were weighed and passed through 7 mm and 3 mm nested sieves, with the retained sieve residues examined to recover cultural materials. A total of 23 otoliths from *A. japonicus* and *A. butcheri* were recovered from the aforementioned five sites. Of these, 20 were selected for radiocarbon dating; two samples (otoliths LP09 and LP19) were not dated because they were small fragments that could not be identified to species (Disspain et al. 2011), while one sample (otolith LP23) was identified within the assemblage after the radiocarbon dating samples were sent to the laboratory.

Approximately 10 mg of material was removed from the margin of each otolith with a Dremel® rotary tool and stored in a clean glass vial. At the Australian National University Radiocarbon Dating Laboratory, samples were ground to a powder, transferred to evacuated (<10^{-3}Torr) Vacutainer® tubes and acidified with phosphoric acid (0.5 ml, 85%, 80ºC) until the reaction was complete. The CO_2 generated was collected and purified cryogenically before reaction with H_2 over an iron catalyst at 570ºC. Water was removed during the reaction by Mg $(ClO_4)_2$. The graphite was pressed into a target and analysed for ^{14}C using a Single Stage Accelerator Mass Spectrometer (Fallon et al. 2010). Radiocarbon values were calibrated using CALIB (v7.0.2) program (Stuiver and Reimer 1993), using the Marine13 calibration dataset (Reimer et al. 2013) with a ΔR value of 61±104 as calculated for the nearby Gulf St Vincent (Ulm 2006). Although it has been shown that the life histories of the fish include periods of fresh, marine and mixed environment habitation (Disspain et al. 2011), $\delta^{13}C$ values (Table I) average -2.0 (range -5.9–1.9), close to the value of marine water of 0.0±2 reported by Stuiver and Polach (1977). If there was more freshwater influence, the reservoir age would probably be less, meaning that the calibrated ages here are probably a minimum age. Calibrated age ranges are reported at two-sigma.

Results

The radiocarbon dates obtained from the fish otoliths from Long Point range from 2938–2529 to 326–1 cal. BP (Table I). Two distinct clusters of dates are evident, one from ca 500 cal. BP to present, and another ca 2000 cal. BP (Figure 2). From site LP4, only one otolith (otolith LP01) was recovered; this originated from approximately 16–20 cm below the surface, and was dated to 523–280 cal. BP. Eleven otoliths from site LP9 were dated, with maximum age of 2295–1917 cal. BP (otolith LP02), and a minimum of 401–47 cal. BP (otolith LP10). From site LP16, two otoliths (otoliths LP16 and LP17) were recovered from the same spit (21–25 cm below surface), and dated to 566–291 cal. BP and 601–314 cal. BP, respectively. Dating of the otoliths recovered from site LP11 showed it to have the longest span of occupation, from 2938–2529 (otolith LP20) to 326–1 cal. BP (otolith LP18). The two otoliths from the LP8 surface scatter site both returned similar dates, 468–134 cal. BP (otolith LP14) and 442–70 cal. BP (otolith LP15).

The majority of otolith dates are within ca 300 years of the original associated charcoal and shell dates from the same provenance (Table I, Figure 2). Considering the complexity of shell midden taphonomy and the small size of otoliths and charcoal fragments this consistency is surprising. Two anomalies/inversions were observed. Otolith LP11 from site LP9, Square AD, Spit 1 was directly dated to 1864–1515 cal. BP, while the associated charcoal date from the same provenance was dated as modern (St George et al. 2013). A charcoal sample from Spit 4 (20 cm below surface) of the same test pit was dated to 1816–1569 cal BP (S-ANU6620) (St

George et al. 2013). This is possibly due to site disturbance or reworking of the top 20 cm of sediment. The other inverted date was that of otolith LP20 (2938–2529 cal. BP), from the LP11 test pit (Square B, Spit 2). This sample was stratigraphically positioned above a shell sample (site LP11, Square B, Spit 3), which was associated with the lowest cultural material from the test pit and dated to 930–671 cal. BP (S-ANU6632) (St George et al. 2013). This anomaly may be the result of bioturbation, where the shell or otolith may have moved within the site matrix.

Discussion

Based on the new radiocarbon chronology established from the Long Point otoliths, occupation at the sites, while still confined to the late Holocene, may extend several hundred years earlier than was indicated by shell and charcoal dates (St George et al. 2013). Unfortunately, no otolith samples were excavated from the same provenance as the oldest associated material date (LP9/Y/10 2455–2134 cal. BP ANU6618 2340±55 BP; (St George et al. 2013) to provide a direct comparison between materials in that excavation unit. All previous dates fell after the range of these values, while in this study, one otolith – otolith LP20 – from site LP11 was dated to 2938–2529 cal. BP. Conservatively, at two-sigma, this otolith is between 74 and 804 years older than the oldest charcoal/shell date; this value is broad owing to the lack of a local marine reservoir correction value. The regional value used had wide error margins, resulting in a broad calibrated age-range. Mulloway can live in a wide range of salinities; subsequently, if a fish had inhabited a freshwater environment for the majority of its life, the reservoir correction value would differ from that of a fish that had inhabited a predominantly marine environment. As such, these dates could be more precisely defined through the use of trace elemental analysis to investigate the ambient salinity experienced by each individual fish throughout its life. One outlying date may not provide sufficient evidence to confidently extend the antiquity of the site. Considering that another otolith (otolith LP21) from the same spit was dated to 1265–951 cal. BP, taphonomic site processes may contribute to this inconsistency, and further dating of samples from this square could help to confirm this finding. Should this otolith be a remnant of anthropogenic activities, as opposed to non-anthropogenic activities (such as mass fish death or deposition by a prey species), its presence in the site could indicate that this location was occupied during the initial coastal settlement phase (4500–2000 BP) of the suggested phases of occupation in the region (Luebbers 1978, 1981, 1982).

The pattern of date clusters, one at <500 cal. BP and another ca 2000 cal. BP, differs from the pattern evident in the charcoal and shell dates as presented in Figure 3 (St George et al. 2013), which spread consistently over the period of occupation. These clusters could be artefacts of taphonomic site processes and preservation, or an indication of processing methods whereby fish were processed and discarded away from the midden sites from 500 cal. BP to 1500 cal. BP. Fish bone in general was recovered from the Long Point sites in relatively small quantities, especially when compared with shellfish, which has been attributed to the deliberate targeting of shellfish at this particular location (St George 2009). This is despite numerous ethnographic sources asserting that Ngarrindjeri diets traditionally consisted mainly of fish (Beveridge 1882; Hawdon 1952; Krefft 1865; Sturt 1982), a view reiterated today by community members (Ngarrindjeri Tendi et al. 2007). As such, it is possible that these clusters of dates reflect times when there was a more focused effort on fishing at these sites, but without a larger sample size, the exact cause cannot be determined.

The provision of direct ages for the otoliths has implications for previous analyses conducted on these samples (Disspain 2009; Disspain et al. 2011). Fish otoliths were assigned dates either from radiocarbon dating of charcoal or shell from the same excavation unit or, if no dates were available, by using an age range from nearest available excavation units. Initially, otolith LP13

(*Acanthopagrus butcheri*) had been assigned an uncalibrated, inverted date of 190±40 (Disspain et al. 2011). After further dating was carried out, the age of the otolith was estimated to fall between 1822 cal. BP and a modern date (St George et al. 2013). This study has produced a direct date for otolith LP13 of 2067–1687 cal. BP. The scarcity of otoliths from *A. butcheri* at Long Point, combined with the samples' estimated recent ages (Table I), had previously been assumed to indicate that they did not preserve well within the site (Disspain 2009). The new results indicate that otoliths of *A. butcheri* are in fact capable of surviving significantly long periods of time in archaeological deposits, and alternate causes for the scarcity of specimens may be preferential targeting of the larger species, *A. japonicas*, either through capture or sampling of midden material.

Changes in fish age and size through time were previously examined using only ages determined on associated materials (Disspain 2009). After reanalysing the trends over time using direct dates, we determine that, despite a number of direct dates being significantly different to the original associated dates, the overall patterns that were reported essentially remain the same. This indicates that associated dates are useful when examining broad-scale patterns in data, but when more precise information is required, direct dating is preferable.

Conclusion

Direct radiocarbon dating of fish otoliths from midden sites at Long Point may extend the period of Aboriginal occupation of the area by 483–395 years from previous dating projects. The addition of otolith AMS radiocarbon dates to the archaeological information for the sites has refined previous research results that originally relied on associated dates of charcoal and shell with the same provenance. We recommend comprehensive direct dating, targeting multiple material types in order to investigate anomalies and site disturbance inherent within midden excavations. Further dating studies could establish the extent to which contamination exists through replication of radiocarbon dates for independent samples. Cross dating otoliths with other material types (shell or charcoal) is expected to provide important data, enabling regional ΔR values to be determined. In combination, the data provide us with a growing level of insight into broad patterns of human-environment relationships in the region.

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Table I: Radiocarbon ages for fish otoliths from Long Point based on direct dating of otoliths and dating of charcoal or shell material (St George et al. 2013). * indicates no radiocarbon determination was available from the same excavation unit, and an age range was assigned based on the nearest available ages.

										St George et al. (2013)		
Otolith Code	Lab Number	Site	Square	Spit	Depth Below Surface (cm)	Species	δ13C	14C Age (BP)	Calibrated Age (cal. BP)	Lab Number	Material	Cal. Years BP
LP01	S-ANU-16706	LP4	AK14	4	16–20	*A. japonicus*	-3.9±0.6	845±30	523–280	S-ANU-6614	Charcoal	321–modern
LP02	S-ANU-16707	LP9	Y	2	6–10	*A. japonicus*	-1.0±0.4	2510±30	2295–1917	S-ANU-6617	Charcoal	<1951–2306*
LP03	S-ANU-16709	LP9	Y	2	6–10	*A. japonicus*	1.2±0.4	2140±30	1848–1486	S-ANU-6617	Charcoal	<1951–2306*
LP04	S-ANU-16710	LP9	Y	5	21–25	*A. japonicus*	1.9±1.0	2155±35	1864–1501	S-ANU-6617	Charcoal	2306–1951
LP05	S-ANU-16711	LP9	Y	5	21–25	*A. japonicus*	-5.4±0.9	2310±35	2171–2161	S-ANU-6617	Charcoal	2306–1951
LP06	S-ANU-16712	LP9	AD	4	16–20	*A. japonicus*	-4.9±0.4	2395±30	2146–1768	S-ANU-6620	Charcoal	1816–1569
LP07	S-ANU-16713	LP9	AD	4	16–20	*A. japonicus*	-2.7±0.4	2125±30	1829–1456	S-ANU-6620	Charcoal	1816–1569
LP08	S-ANU-16714	LP9	AD	5	21–25	*A. japonicus*	-1.1±0.5	2490±30	2283–1894	S-ANU-6620 and S-ANU-6621	Charcoal	1569–2121*
LP10	S-ANU-16716	LP9	AD	1	0–5	*A. butcheri*	-0.8±0.4	655±30	401–47	S-ANU-6619	Charcoal	Modern
LP11	S-ANU-16717	LP9	AD	1	0–5	*A. japonicus*	-0.8±0.5	2165±30	1864–1515	S-ANU-6619	Charcoal	Modern
LP12	S-ANU-16718	LP9	AY12	12	56–60	*A. japonicus*	-0.7±0.4	2400±30	2151–1772	S-ANU-6623 and S-ANU-6625	Charcoal	1822–modern*
LP13	S-ANU-16719	LP9	AY12	11	51–55	*A. butcheri*	-5.9±0.4	2325±30	2067–1687	S-ANU-6623 and S-ANU-6625	Charcoal	1822–modern*
LP14	S-ANU-16720	LP8	E1	M1	Surface	*A. japonicus*	0.9±0.5	730±30	468–134	Wk-21217	Shell	276–modern
LP15	S-ANU-16721	LP8	E1	M2	Surface	*A. japonicus*	-2.1±0.3	690±30	442–70	Wk-21217	Shell	276–modern
LP16	S-ANU-16723	LP16	L8	5	21–25	*A. japonicus*	-5.0±0.6	890±30	566–291	S-ANU6627	Charcoal	491–298
LP17	S-ANU-16724	LP16	L8	5	21–25	*A. japonicus*	-0.6±0.4	910±30	601–314	S-ANU6627	Charcoal	491–298
LP18	S-ANU-16725	LP11	A	4	16–20	*A. japonicus*	-1.0±0.5	620±30	326–1	S-ANU6629	Charcoal	490–318
LP20	S-ANU-16726	LP11	B	2	6–10	*A. japonicus*	-1.8±0.5	3035±35	2938–2529	S-ANU 6632	Shell	<930–671*
LP21	S-ANU-16727	LP11	B	2	6–10	*A. japonicus*	-4.5±0.6	1620±35	1265–951	S-ANU 6632	Shell	<930–671*
LP22	S-ANU-16729	LP11	C	5	21–25	*A. japonicus*	-2.3±1.1	725±35	471–124	S-ANU6633	Charcoal	499–322

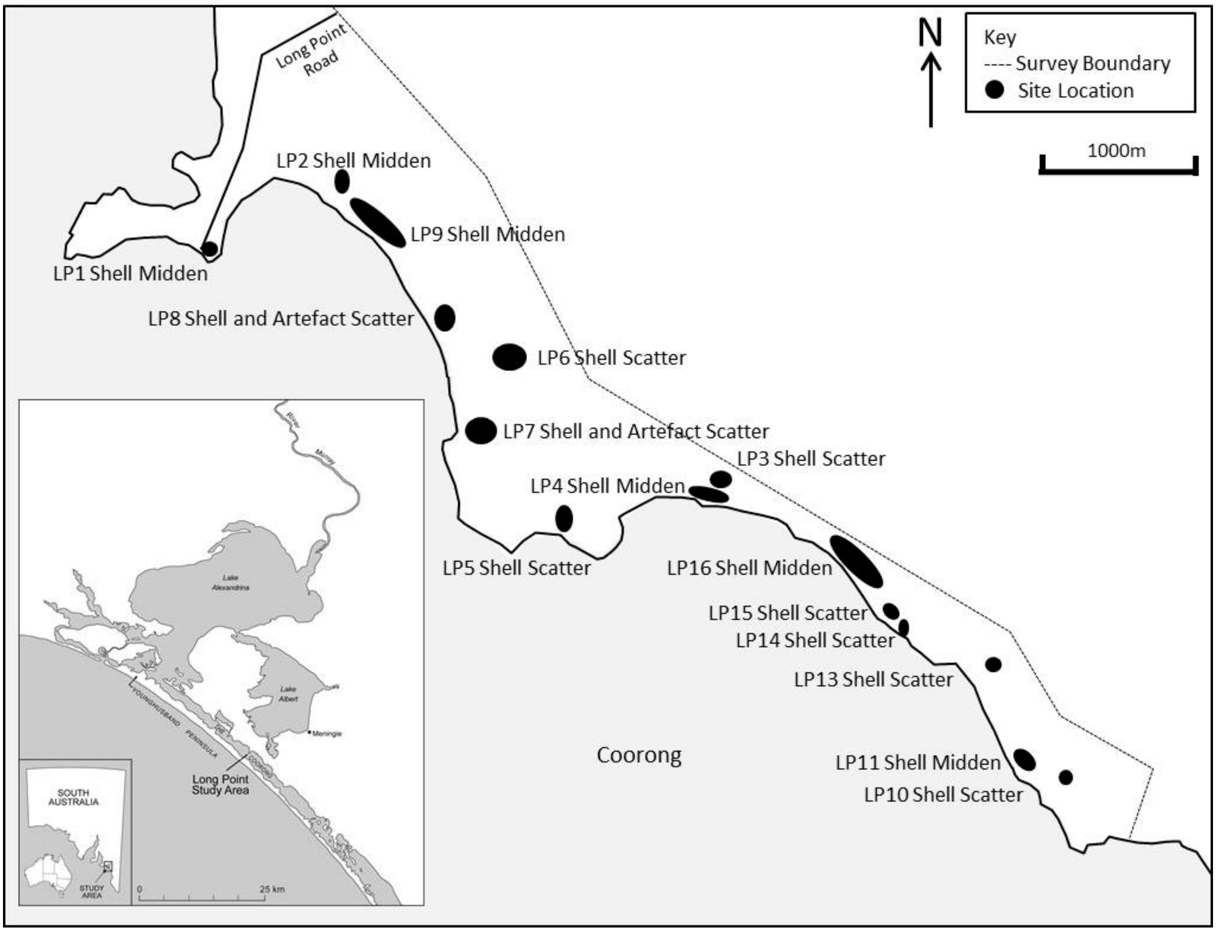

Figure 1: Map of Long Point showing the location and general extent of recorded sites.

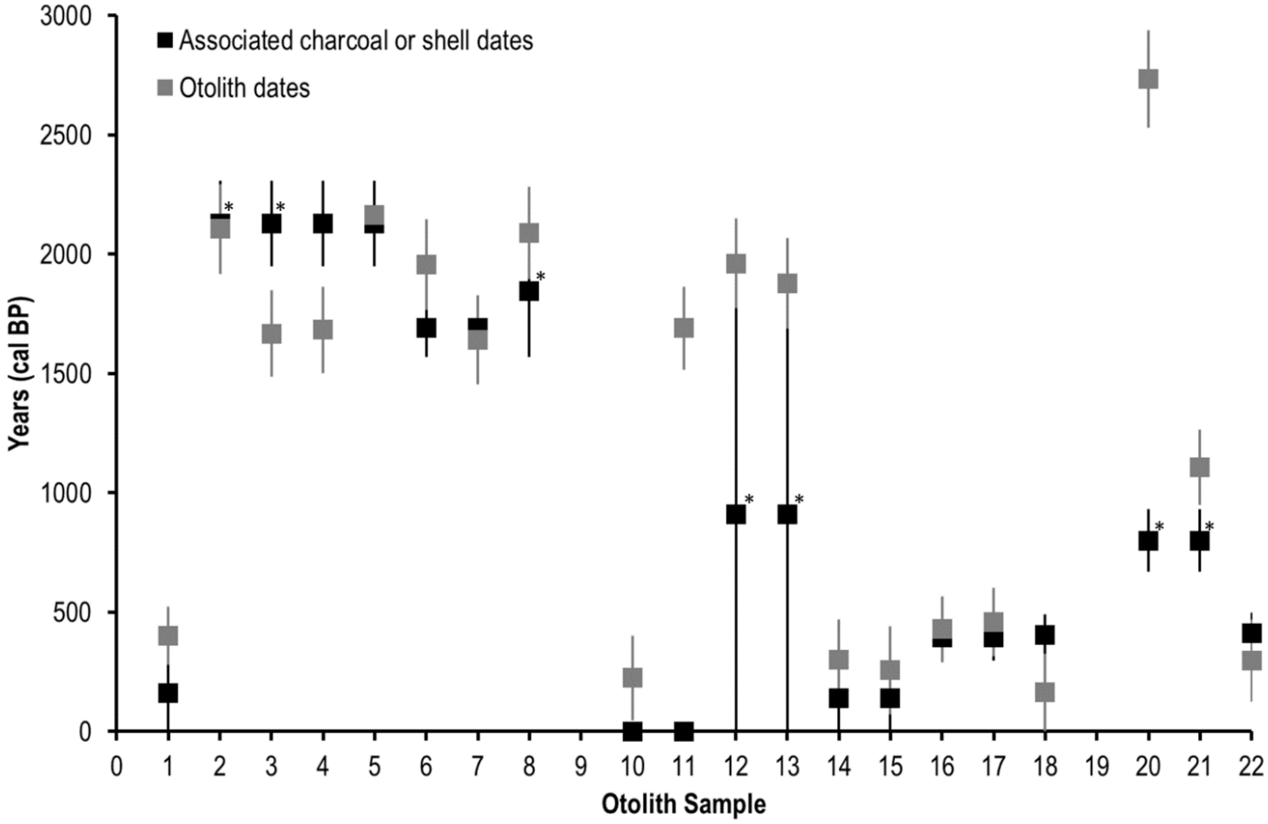

Figure 2: Direct otolith dates compared with associated charcoal or shell dates (St George et al. 2013) from Long Point. * indicates no radiocarbon determination was available from the same excavation unit, and an age range was assigned based on the nearest available ages. Note that otoliths LP09 and LP19 were not dated.

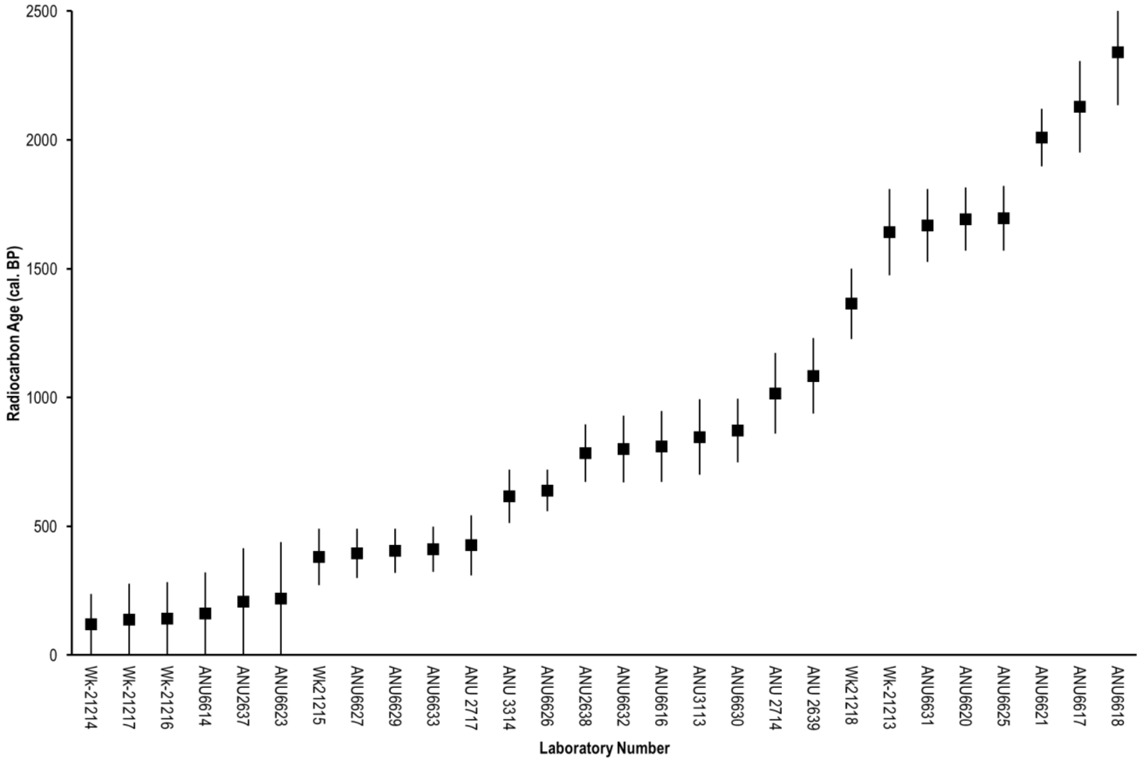

Figure 3: All radiocarbon dates from charcoal or shell at Long Point as presented in St George et al. (2013).