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The age and position of the southern boundary of prehistoric Polynesian dispersal

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ABSTRACT

Prehistoric Polynesian voyaging into high latitudes with landfall in Antarctica remains a widely credited proposition. We examine it through archaeological and environmental evidence from the Subantarctic region of the southwest Pacific, focussing upon an extensive archaeological site at Sandy Bay on Enderby Island. Combining a new set of radiocarbon ages with former, older, ages we show that the site is now within the same rapid expansion phase in which South Polynesia was first colonised. Radiocarbon ages across the site indicate a single continuous settlement, probably of some decades. Consideration of limiting factors in Subantarctic settlement, including of seafaring capability and critical resources, suggests that the site was about as far south as prehistoric habitation could be sustained and was probably vacated at the onset of the Little Ice age (LIA) in the late 14th century. An absence of prehistoric remains on islands further south also suggests that Polynesian exploration reached a boundary 2000 km short of Antarctica. The southern case is discussed briefly in the wider context of Polynesian expansion.

Keywords: Polynesian expansion, radiocarbon dating, settlement limitations, subantarctic

RÉSUMÉ

Les voyages polynésiens préhistoriques vers les hautes latitudes avec atterrissage en Antarctique restent une proposition largement reconnue. Nous l'examinons à travers des preuves archéologiques et environnementales provenant de la région subantarctique du sud-ouest du Pacifique, en nous concentrant sur un vaste site archéologique à Sandy Bay sur l'île Enderby. En combinant un nouvel ensemble d'âges au radiocarbone avec des âges antérieurs, plus anciens, nous montrons que le site se trouve désormais dans la même phase d'expansion rapide dans laquelle la Polynésie du Sud a été colonisée pour la première fois. Les âges au radiocarbone sur l'ensemble du site indiquent un seul établissement continu, probablement de plusieurs décennies. La prise en compte des facteurs limitants du peuplement subantarctique, notamment la capacité de navigation et les ressources critiques, suggère que le site se trouvait à peu près aussi au sud que l'habitation préhistorique pouvait être soutenue et qu'il a probablement été libéré au début du Petit Âge Glaciaire (LIA) à la fin du XIVe siècle. L'absence de vestiges préhistoriques sur les îles plus au sud suggère également que l'exploration polynésienne a atteint une frontière située à 2 000 km de l'Antarctique. Le cas méridional est brièvement discuté dans le contexte plus large de l'expansion polynésienne.

Mots-clés: Expansion polynésienne, subantarctique, datation au radiocarbone, limites de peuplement

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INTRODUCTION

The longest maritime migrations in global prehistory were those by Polynesians whose range, according to the distribution of characteristic archaeological remains, extended 10,000 km west-east (Nukuoro to Easter Island), and 8000 km north-south (Hawaii to New Zealand). In addition, longstanding hypotheses, prompted by inference of unusually sophisticated Polynesian voyaging capability (e.g., Finney, 2003; Howe, 2006; Irwin et al., 2023; but see Anderson, 2024, 2024a, 2024b; Goodwin et al., 2014) suggest extension of seafaring to the continental margins of the Pacific Ocean. Polynesian contact with the Americas has been argued from comparative linguistics, artefact typology and prehistoric DNA (e.g., Jones et al., 2011; Ramirez-Aliaga, 2023), while a similarly venerable hypothesis, based upon transcribed oral traditions (Walter & Moeka'a 2000), has asserted Polynesian discovery of continental Antarctica (Best, 1918; Buck, 1954; Smith, 1899, 1918). That idea continues to be credited in modern narratives of polar history (Chaplow, 2016; Headland, 1989; Ihimaera, 2023; Maddison, 2020; Martin, 1996; O'Reilly, 2017; Soper, 2018; Wehi et al., 2021a, 2021b) and in New Zealand Government policy statements (2021: 5):

> New Zealand has a long association with Antarctica and the Southern Ocean. Early exploration by the Polynesian navigator, Ui-te-Rangiora, in a fleet of waka tiwai ("hollowed-out logs"), revealed an area of ice floes and icebergs in the vastness of the Southern Ocean which he called Te Tai-uka-a-pia ("sea foaming like arrowroot").

Recent questioning of that interpretation of traditions (Anderson et al., 2021; Stevens et al., 2022) suggests; however, that the extent of prehistoric voyaging in high latitudes is open to question.

In addressing the issue here, we leave aside traditional history and discuss the material basis of Polynesian voyaging in the Southern Ocean which extends from the Subtropical Front to the Antarctic coast (48–68° South in the New Zealand region). The only means of doing so is through consideration of archaeological and related evidence of Polynesian habitation in the Subantarctic islands of the southwest Pacific (Figure 1). Such evidence has been found in the Snares and Auckland Islands, with the only recorded early Polynesian occupation site at Sandy Bay on Enderby Island, the northernmost of the Aucklands archipelago. The site extends about 250 m along the Sandy Bay foredune and seems to be at least 20 m wide, covering an area of 0.5 ha (Figure 2). It is the focus of discussion here, although our data arise from no more than 15 m^2 (0.3%) of archaeologically excavated area. Opportunities to excavate have been severely limited because the Auckland Islands are in a remote UNESCO World Heritage Area in which shore-based activity is seldom permitted.

Nevertheless, a substantial set of radiocarbon ages has accumulated from different parts of the site through brief fieldwork episodes between 1998 and 2020. The latest material has provided an opportunity to take a novel radiocarbon dating approach that seeks to minimize the problem of inbuilt age in charcoal samples. Those data and recalibrated radiocarbon dates from earlier investigations (Anderson & O'Regan 1999; Anderson, 2005, 2009) are included in a Bayesian analysis of site chronology. The new results allow us to refine the timing of settlement with greater confidence, examine its potential duration and make inferences about maritime mobility to and beyond this southernmost Polynesian colony.

It is argued that the Sandy Bay site was a colonising settlement and the factors involved in its location are discussed, notably those of seafaring technology and sailing conditions, and of climatic limitations upon key aspects of extended habitation. We propose that a deteriorating climate in the Little Ice Age (LIA) led to an early cessation of settlement and conclude that pre-European Polynesians probably did not make landfall south of the Auckland Islands (51° S). From that perspective we comment briefly upon the broader issue of continental contact in early Polynesian voyaging.

SUBANTARCTIC ISLANDS AND ARCHAEOLOGY

East Polynesian passages into high latitudes might have originated from any of the marginal islands in the subtropical zone – Rapa, Mangareva, the Pitcairn group, Easter Island – but there were no islands south of them in which evidence of voyaging landfalls could be found. It is only by way of New Zealand (34–47°S), and the Subantarctic Islands (47–56°S), that Polynesian exploration could be traced materially to within 1400 km of the Antarctic continent.

The Subantarctic region is defined in oceanic terms as lying south of the Subtropical Front (Figure 1) which curves eastward around the South Island immediately below Stewart Island and the Chatham Islands (Behrens et al., 2021). As those islands are usually less than 100 km north of the Subtropical Front, and both were inhabited continuously by Polynesians from about AD 1250–1300, they would have been the most probable sources of Subantarctic voyaging.

It is likely that Polynesian exploration, to the extent that it occurred, proceeded by incremental expansion southward, as was the pattern of historical discovery by European voyaging: the Bounty group in 1788, Snares in 1791, then the Antipodes 1800, Auckland Islands 1806, and Campbell then Macquarie islands in 1810 (McNab, 1909; Peat, 2003). All the Subantarctic islands (Figure 1) had useful resources for seafarers; landing and shelter in most cases and seal and seabird breeding populations, but they vary in climate, vegetation, size and accessibility (McGlone, 2002). The most accessible from mainland New Zealand are the steep, tree- and shrub-covered Snares (3.3 km^2), 200 km from the South Island (100 km from Stewart Island). A basalt adze of early Maori type, has been recovered near the only secure landing place (Anderson & O'Regan, 2000) suggesting some occupation, if only fleeting.

FIGURE 1. *Left*: Subantarctic Islands and Subtropical Front. *Right*: Auckland Islands places examined for signs of prehistoric activity.

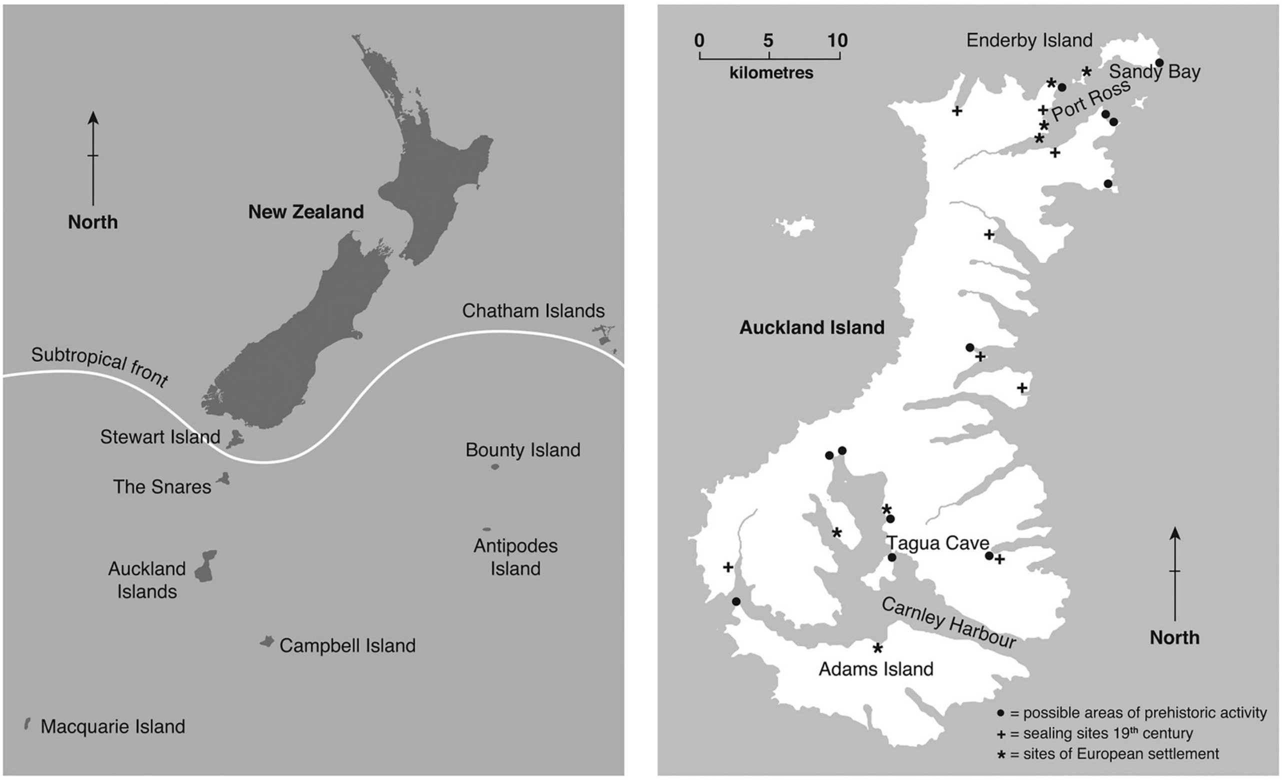
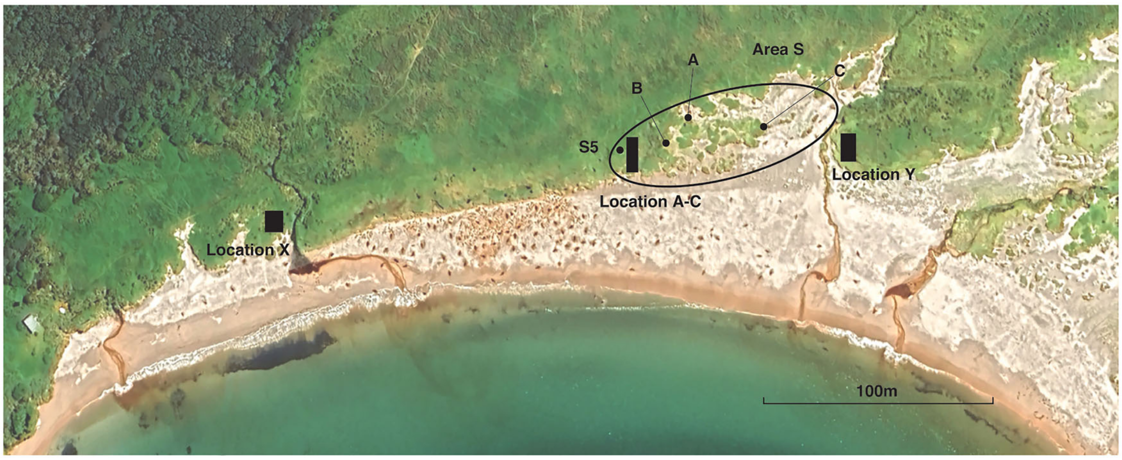


FIGURE 2. Fieldwork localities at Sandy Bay: Locations X, A–C, Y and features S5, A, B, C in Area S. Brown specks on the beach and dunes are sea lion adults and pups.



A further 275 km south are the Auckland Islands. By far the largest Subantarctic group (625 km^2), they have the southernmost forest in the western Pacific, primarily of southern rata (*Metrosideros umbellata*). There are landbirds such as ducks, parakeets, rails, and snipe (Tennyson, 2019), but the main avian taxa are albatrosses, penguins, and shearwaters. The Auckland Islands are also important breeding grounds for Hooker's sea lions and New Zealand fur seals. On Enderby Island, the northernmost of the group, Maori artefacts had been recovered from eroding dunes at Sandy Bay as early as 1903, but as they could have come from a Maori settlement there in 1842–1856 (Shand, 1893), the existence of pre-European occupation was not established until the first archaeological exploration in 1998 (Anderson & O'Regan, 2000).

No indications of pre-European Polynesian contact have been reported from any of the other Subantarctic islands. The tiny Bounty group (1.4 km^2), 500 km from the Chathams, has poor landing and almost no vegetation. The high Antipodes Islands (21 km^2), covered in tussock, fern and megaherbs were potentially habitable but they are 870 km southeast of the South Island without intervening islands and 700 km south of the Chathams. Campbell Island, 275 km south of the Auckland Islands, is large (113 km^2) with deep inlets and it supports dwarf *Dracophyllum* forest and scrub, with tussock grasses and megaherb communities above 200 m elevation and in exposed coastal areas. Despite considerable palaeoecological and archaeological research, no pre-European sites or materials have been discovered on it (McGlone et al., 2007; Prickett et al., 2011).

Remote Macquarie Island (128 km^2), 600 km from the Auckland Islands and 700 km from Campbell Island, is covered in grassland and megaherbs. On shore, 'several pieces of wreck of a large vessel… apparently very old' were suggested in 1811 by their observer, Captain Smith, as remains of the missing ships of La Pérouse (McNab, 1909: 176). They have been presumed subsequently as Polynesian (e.g., Murray, 2019), but on no cited evidence. Investigation of sea caves, suitable as shelter, recorded no signs of pre-European habitation (Harris et al., 2010) and no artefacts or structures of Polynesian type have been reported from the island.

The Sandy Bay site is wholly dominant in the archaeological landscape of the Auckland Islands. Small patches of shell and bone in exposed sections along the western shore of Friday Passage in Port Ross are possibly, but not clearly, cultural (Anderson, 2009). Otherwise, field inspection of sedimentary shoreline deposits on the Auckland Islands (Figure 1), with coring and spade pits at localities of potential occupation around Carnley Harbour and Port Ross, and in inlets along the east coast, located no other prehistoric sites (Anderson, 2009). Ground inspection of coastal caves and open sites used by 19th century sealers, and of European settlement sites, also failed to record any pre-European material (Prickett, 2009). In addition, archaeological excavations in the largest habitable cave reported on Auckland Island, at Tagua Bay, Carnley Harbour, disclosed evidence of its frequent use from the early nineteenth century onward, but nothing of prehistoric provenance (Anderson, 2009). Patches of marine shell upon the bedrock contained no cultural remains and produced a marine shell radiocarbon age, Wk-14330, (with $\Delta R = 140 \pm 80$), of 340 BC – AD 100 (Anderson, 2009). The shell might have been deposited during the late Holocene sea-level high stand. Similarly, Holocene pollen and charcoal records from the Auckland Islands contain no indication of anthropogenic disturbance before European contact (McGlone et al., 2000, 2010; Wilmshurst et al., 2015; Wood et al., 2016).

These investigations suggest that Polynesian settlement had limited distribution in the Subantarctic. It seems to have been confined to the Snares and Auckland Islands and, in the latter, is recorded only on and near Enderby Island. The Sandy Bay site is relatively extensive and, despite restricted archaeological investigation, exhibits some functional variation in its layout. Dense bone midden is encountered near the western edge of the site, the most sheltered part, and more patchy distribution of middens and ovens to the east. No evidence of dwellings has been recorded, but they might have existed on higher ground in forest behind the site where there was less exposure to weather and fewer sea-lions. Those breed on the beach at Sandy Bay (Figure 2) and often wander inland.

The nature of the Sandy Bay site is open to several possible interpretations. At one extreme, it could have been a place of repeated brief occupations over an extended period, and at the other, it could have been a settlement occupied continuously by a reproducing group over a period of decades or longer. The proposition of repeated visits implies that voyaging occurred frequently in the Subantarctic (and possibly beyond) but, if that happened, it is not represented by expected evidence of landfalls elsewhere in the region. The question then is whether the evidence at Sandy Bay fits an episodic pattern of visits to the same place, or the establishment of a single, extensive settlement indicative of a relatively large colonising group. The key approach to distinguishing the better fit is by reappraising existing radiocarbon ages in the light of newly-acquired dates from Sandy Bay which we present here. The Sandy Bay site presents some unusual challenges to sampling and interpretation which we resolve with Bayesian age modelling.

RADIOCARBON DATING OF THE SANDY BAY ARCHAEOLOGICAL SITE

The first evidence of a prehistoric site, found in 1998, was at Location A-C (Anderson, 2005, 2009) at Sandy Bay (Figure 2) where there was an eroding Polynesian oven (*umu* which used heated stones) with lenses of charcoal indicating repeated use, and nearby patches of bone midden and charcoal. Radiocarbon ages were obtained (Anderson, 2005) on charcoal from a shrub (*Dracophyllum longifolium*), the shortest-lived material in the samples. *Dracophyllum*, however, lives typically for 70–80 years, but can reach at least 240 years (Bestic et al., 2005). The results were varied, ranging at 95% from AD 1036–1289 (ANU-11085) in the upper section of the oven to AD 1283–1431 (ANU-11087) in the lower section (both at 95.4% confidence interval or 'CI'). Those results were reversed stratigraphically, although both overlap in an expected thirteenth century age range (Table 1).

Excavation in 2003 of a midden area (Location X) yielded abundant bone midden, mainly of seals and sea birds, evidence of introduced dogs (*Canis familiaris*) and remains of tool manufacture in basalt and chert (Anderson, 2005, 2009). From beneath a discontinuous palaeosol (Figure 3), charcoal samples (all *D. longifolium*) were taken from spits 4 and 5 (10 cm spits at 30–40 and 40–50 cm of a 50 cm thick single cultural layer). The deepest sample (spit 5) is *Dracophyllum* charcoal dated AD 1260–1400 (Wk-13651). Immediately above it (spit 4) the date was AD 1280–1410 (Wk-13652), whereas ANU-12038 had dated unidentified charcoal from the same sample to AD

Table 1. Chronometric data for Auckland Islands pre-European archaeological sites, including previously published ages.

Sample	Location	Provenance	Context	Material	Species	%C	Lab. No.	CRA ^{14}C yr BP	AD	Field season
Location A, Midden site										
AUKSB-04	Location A: Midden site	Loc.A/1	Layer 1	Charcoal	*Dracophyllum longifolium*		ANU-11088	780 ± 60	1183–1391	1998
Location Y, Midden site, historic period										
AUKSB-05	Location Y: Midden site	Loc.Y/1	Layer 1	Charcoal	*Dracophyllum longifolium*		ANU-11089	190 ± 60	1661–modern	1998
Location C, Oven site, spits 1-2 cultural										
AUKSB-01	Location C: Oven site	Loc.C/C6/1	Square 6 layer 1, spit 1	Charcoal	*Dracophyllum longifolium*		ANU-11085	840 ± 60	1049–1381	1998
AUKSB-03	Location C: Oven site	Loc.C/C4/2	Square 4 layer 1, spit 2	Charcoal	*Dracophyllum longifolium*		ANU-11087	620 ± 60	1294–1439	1998
AUKSB-02	Location C: Oven site	Loc.C/C4/2	Square 4 layer 1, spit 2	Charcoal	*Dracophyllum longifolium, Metrosideros umbellata*		ANU-11086	660 ± 70	1275–1436	1998
EI-1	Location C: Oven site	Loc.C/Section	Layer 1, spit 2	Charcoal	*Dracophyllum longifolium*		ANU-11238†	770 ± 70	1183–1395	1998
EI-2	Location C: Oven site	Loc.C/C4/2	Square 4 layer 1, spit 2	Charcoal	*Metrosideros umbellata*		ANU-11236A†	800 ± 50	1184–1382	1998
Location X, Occupation site, spits 1-2 cultural and European										
SAB-05	Location X: Occupation site	AB1/2/1	Square 1, layer 2, spit 1	Shell	*Cellana strigilis*		Wk-13431*	581 ± 42	1915–1950+	2003
SAB-22	Location X: Occupation site	AB1/2/1	Square 1, layer 2, spit 1	Shell	*Cellana strigilis*		Wk-13431B*	628 ± 24	1720–1950+	2003
SAB-22a	Location X: Occupation site	AC1/2/1	Square 1, layer 2, spit 1	Shell	*Aulacomya maoriana*		Wk-13427	661 ± 42	1694–modern	2003
SAB-20	Location X: Occupation site	T/pit DD	Test pit	Shell	*Venerupis largillierti*		Wk-13426	676 ± 30	1691–modern	2003
Location X, Occupation site, spits 3-5 cultural and prehistoric										
SAB 22b	Location X: Occupation site	AA1/2/3	Square 1, layer 2, spit 3	Shell	*Mytilus galloprovincialis*		Wk-13428*	1093 ± 48	1293–1560	2003

(*Continued*)

Table 1. (Continued)

Sample	Location	Provenance	Context	Material	Species	%C	Lab. No.	CRA ^{14}C yr BP	AD	Field season
SAB-10	Location X: Occupation site	AA1/2/3	Square 1, layer 2, spit 3	Shell	*Mytilus galloprovincialis*		Wk-13428A*	1126 ± 43	1283–1519	2003
SAB-04	Location X: Occupation site	AA1/2/3	Square 1, layer 2, spit 3	Shell	*Mytilus galloprovincialis*		Wk-13428B*	1173 ± 24	1267–1470	2003
AB2/2/4	Location X: Occupation site	AB2/2/4	Square 2, layer 2, spit 4	Charcoal	*D. longifolium, Coprosma sp.*		Wk-13652	658 ± 47	1289–1410	2003
SAB 03b	Location X: Occupation site	AA1/2/4	Square 1, layer 2, spit 4	Charcoal	*Unidentified*		ANU-12038	1030 ± 70	898–1213	2003
SAB-23a	Location X: Occupation site	AB2/2/4	Square 2, layer 2, spit 4	Shell	*Mytilus galloprovincialis*		Wk-13429A*	1115 ± 43	1288–1528	2003
SAB-23	Location X: Occupation site	AB2/2/4	Square 2, layer 2, spit 4	Shell	*Mytilus galloprovincialis*		Wk-13429*	1174 ± 43	1246–1481	2003
SAB 23b	Location X: Occupation site	AB2/2/4	Square 2, layer 2, spit 4	Shell	*Mytilus galloprovincialis*		Wk-13429B*	1203 ± 25	1237–1450	2003
AA1/2/5	Location X: Occupation site	AA1/2/4	Square 1, layer 2, spit 4	Shell	*Aulacomya maoriana*		ANU-12039†	1280 ± 60	1105–1430	2003
SAB-03	Location X: Occupation site	AA1/2/4	Square 1, layer 2, spit 4	Bird bone	*Puffinus griseus*		Wk-13440†	1289 ± 43	1125–1411	2003
SAB-21	Location X: Occupation site	AA1/2/5	Square 1, layer 2, spit 5	Charcoal	*Dracophyllum longifolium*		Wk-13651	701 ± 46	1280–1396	2003
Location S, Midden site										
SAB-02	Location S: Midden site	S5/1/2	Square 5, layer 1, spit 2	Charcoal	*Dracophyllum longifolium*		Wk-13653*	720 ± 43	1271–1395	2003
SAB-02b	Location S: Midden site	S5/1/2	Square 5, layer 1, spit 2	Charcoal	*Dracophyllum longifolium*		Wk-13653B*	749 ± 20	1273–1383	2003
SAB-01	Location S: Midden site	S5/1/2	Square 5, layer 1, spit 2	Shell	*Aulacomya maoriana*		ANU-12035†	1200 ± 70	1179–1490	2003
SAB-11	Location S: Midden site	S5/1/2	Square 5, layer 1, spit 2	Bird bone	*Puffinus griseus*		Wk-13441†	1216 ± 43	1209–1455	2003

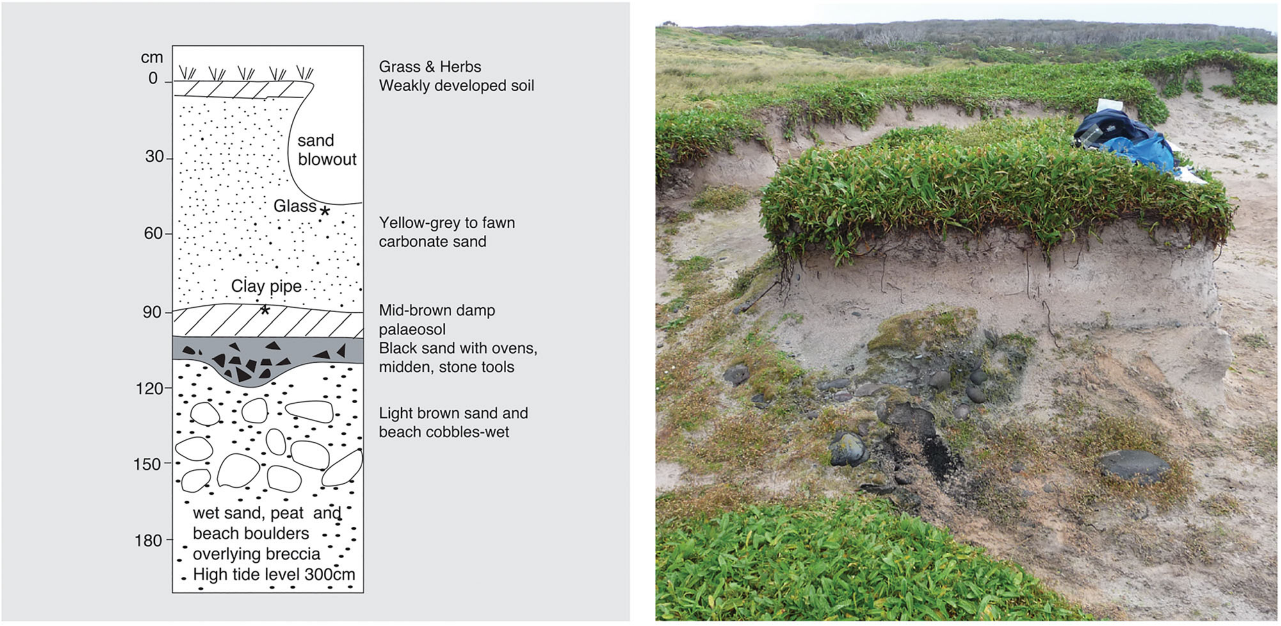
(*Continued*)

Table 1. (Continued)

Sample	Location	Provenance	Context	Material	Species	%C	Lab. No.	CRA ^{14}C yr BP	AD	Field season
Area S ovens A&B										
EI A.5	Area S, oven A	Dune exposures		Charcoal	Unidentified	75	UNSW-43*	667 ± 20	1298–1396	2020
EI A.2	Area S, oven A	Dune exposures		Charcoal	Unidentified	77	UNSW-40*	817 ± 20	1222–1280	2020
EI A.1	Area S, oven A	Dune exposures		Charcoal	Unidentified	75	UNSW-38*	839 ± 20	1215–1277	2020
EI A.1	Area S, oven A	Dune exposures		Charcoal	Unidentified	75	UNSW-39*	852 ± 20	1186–1275	2020
EI A.6	Area S, oven A	Dune exposures		Charcoal	Unidentified	74	UNSW-44*	897 ± 20	1155–1226	2020
EI A.3	Area S, oven A	Dune exposures		Charcoal	Unidentified	74	UNSW-41*	945 ± 20	1046–1214	2020
EI A.4	Area S, oven A	Dune exposures		Charcoal	Unidentified	70	UNSW-42*	1083 ± 20	988–1028	2020
EI B.2	Area S, oven B	Dune exposures		Charcoal	Unidentified	73	UNSW-46*	685 ± 20	1292–1393	2020
EI B.4	Area S, oven B	Dune exposures		Charcoal	Unidentified	72	UNSW-48*	693 ± 20	1290–1392	2020
EI B.5	Area S, oven B	Dune exposures		Charcoal	Unidentified	75	UNSW-49*	768 ± 20	1229–1380	2020
EI B.6	Area S, oven B	Dune exposures		Charcoal	Unidentified	71	UNSW-50*	903 ± 20	1153–1225	2020
EI B.1	Area S, oven B	Dune exposures		Charcoal	Unidentified	73	UNSW-45*	967 ± 20	1035–1180	2020
EI B.3	Area S, oven B	Dune exposures		Charcoal	Unidentified	70	UNSW-47*	989 ± 20	1030–1153	2020
Tagua Cave, Carnley Harbour										
SAB-24	Tagua cave, Carnley Harbour	T/pit 1/2/1		Shell	*Venerupis largillierti*		Wk-13430	2555 ± 39	305 BC–AD 71	2003

Note: Calibrated dates are noted at 95.4% CI. Duplicate results (same laboratory, type and provenance) shown by * and replicate results by † (same provenance, different types and laboratories).

FIGURE 3. *Left*: Generalised section of stratigraphy at Location X (additional plans and sections in Anderson, 2009). *Right*: Eroding oven feature A in Area S.



887–1126. There was no intact charcoal higher in the layer, but spits 1 and 2 dated late 17th to 20th centuries on marine shell samples ($\Delta R = 140 \pm 80$), while spit 3 marine shell (Wk-13428, 13428a) dated in the same range as the charcoal samples from spits 4 and 5 (Anderson, 2005: Table 1). A midden patch at point S5, adjacent to Location A-C, dated on *Dracophyllum* charcoal to AD 1250–1400 (Wk-13653), and more of that sample was dated to the same age in 2019 (Table 1).

New radiocarbon ages

More archaeological material has been exposed recently in Sandy Bay by aerial deflation of dunes and the activity of sea lions. Three additional occupation areas were recorded near the eastern margin of the prehistoric site (Area S, Figure 2) and the exposed material was sampled in 2020 (Anderson, 2021). Each area (e.g., Figure 3), was centred upon a large fire pit packed with ovenstones and all were lying in an extensive deflation surface upon which flaked stone and bone midden was observed. Most of that material is finely comminated, probably through continual breakage and abrasion by sea lion movement. As it will have included bone from sea lion and seabird regurgitation no bone samples were recovered for radiocarbon dating. Samples of charcoal were obtained from each of the three ovens to determine how this part of the site area was related to the central area (Location A-C) and the midden (Location X) dated previously. In doing so, multiple samples were dated for each feature to establish, and seek to circumvent, potential errors introduced by the inbuilt age of old wood.

Radiocarbon dating methods

Charcoal samples extracted from oven features A, B and C within Area S (Figure 1), were sampled for radiocarbon dating at the Chronos 14Carbon-Cycle Facility. Given the likely presence of charcoal with inbuilt age in each sample bag, six subsamples (single entities) were selected for radiocarbon dating, with one identified as a twig (UNSW-49). Producing multiple results for each feature tested the chronological range for each case and identified the youngest age. The resulting 18 samples were chemically pre-treated and measured following protocols noted in Turney et al. (2021).

Radiocarbon calibration was undertaken using SHCal20 and Marine20 (Hogg et al., 2020; Heaton et al., 2020) in OxCal 4.4 (Bronk Ramsey, 2009a). Although not in situ, we calculated ΔR value of -67 ± 75 based on 'paired' terrestrial-marine samples from Location S (Midden site) found within the same spit. The calculation was done through calib.org (Reimer & Reimer, 2017), using ANU-12035 (marine shell) and the average age of Wk-13653* and Wk-13653B* (duplicates; see below for method used). Given the known spatio-temporal variations in ΔR values (Alves et al., 2018), this value was applied to all marine samples as specific to the location and period studied. Due to the relative proximity and availability of ΔR data; however, an averaged value of 4 ± 74 for the Chatham Islands was also used for sensitivity testing (see SI). This was calculated using values from pre-bomb (AD 1950) samples in Sikes et al. (2000) and Petchey et al. (2008) within calib.org.

Bayesian age modelling was done through OxCal 4.4, using chronometric data and known stratigraphic information for each archaeological site/feature (Bronk

Ramsey, 2009a). Given the potential presence of inbuilt age in charcoal samples, the 'Charcoal' outlier model (Bronk Ramsey, 2009b) was applied. This samples solutions from the younger end of radiocarbon likelihoods and thus makes inbuilt age a prior. 'General' and 'SSimple' outlier models were applied to all other dates, and each was given a 5% prior probability of being an outlier. Given that inbuilt age in charcoal samples is not a certainty, we performed sensitivity testing by using 'General' and 'SSimple' outlier models (see SI). Results showed no significant difference, affording further confidence in the modelling. For duplicate measurements, averaging was done using the 'R_Combine' command in OxCal, following Ward and Wilson (1978). All modelled/calibrated estimates are noted at 68.3% credible or confidence intervals (CI) and rounded to the nearest 5 years.

Radiocarbon dating results

Results of 14C dating on charcoal samples collected from oven features A and B within Area S are shown in Table 1. Results from oven feature C were within the historical period and are not included here. Table 1, otherwise, includes all previously published radiocarbon dates for Enderby Island archaeological features. The variation in ages for each feature most likely reflects inbuilt age, with the youngest measurements within each feature – UNSW-43 (667 ± 20 BP) for oven A and UNSW-46 (685 ± 20 BP) for oven B – probably the most accurate reflection of the age at which the ovens were made and used (ovens dug in unstable sand need to be used immediately). These dates were used in the statistical analysis. Interestingly, the only twig that was identified (UNSW-49; 768 ± 20 BP) is not the youngest measurement for oven B (>2 sigma out of range). This suggests that although long-lived species are present, bark or outer rings might have been charred/sampled. Consequently, while the 'Charcoal' outlier model is useful, it is somewhat inflexible, as it assumes inbuilt age, which is not always a certainty. Therefore, employing a 'General' outlier model – which accounts for ages that might be erroneously old or young – and performing sensitivity testing to determine the impact of different outlier models, as done in this study, is a reasonable and worthwhile approach.

Bayesian age modelling results place the start of human occupation at Location S (Midden site), X (Occupation site) and C (Oven site) at AD 1160–1375, 1275–1375 and 1270–1385, respectively (see Figures 5, S1, and S2). When combined with dates representing the remaining archaeological features at Enderby Island – UNSW-43 (Area S, oven A), UNSW-46 (Area S, oven B), and ANU-11088 (Location A, midden site), a single-phase model estimates the commencement of Polynesian occupation at AD 1250–1320 (or 1185–1365 cal BP at 95.4% CI; Figures 4 and S4).

These results show with greatest probability that the Sandy Bay site was not occupied until relatively late amongst the various assays, most likely in the early fourteenth century and that the early phase ended in approximately AD 1370–1520 (or AD 1335–1700 at 95.4% CI; estimate based on the end of spit 3 in Location X, see Figure 5; with no overlap between the two ranges, per Figure S3). The estimated duration of the occupation represented by spits 5 to 3 in layer 2 of Location X (Table 1) is up to 275 (95.4%) or 105 years (68.3% CI), with an estimated calendrical range of CE 1230–1605 (95.4% CI) or 1310–1445 (68.3% CI). The transitions between each spit are statistically comparable, so a hiatus is unlikely. The possibility that some material from the late (historical) occupation represented at Location X by layer 2, spits 1 and 2, was introduced into spit 3 cannot be excluded (Anderson, 2009) Consequently the most secure estimate of the duration of initial occupation comes from spits 4 and 5 alone. These indicate a combined range of up to 130 (95.4%) or 45 years (68.3% CI).

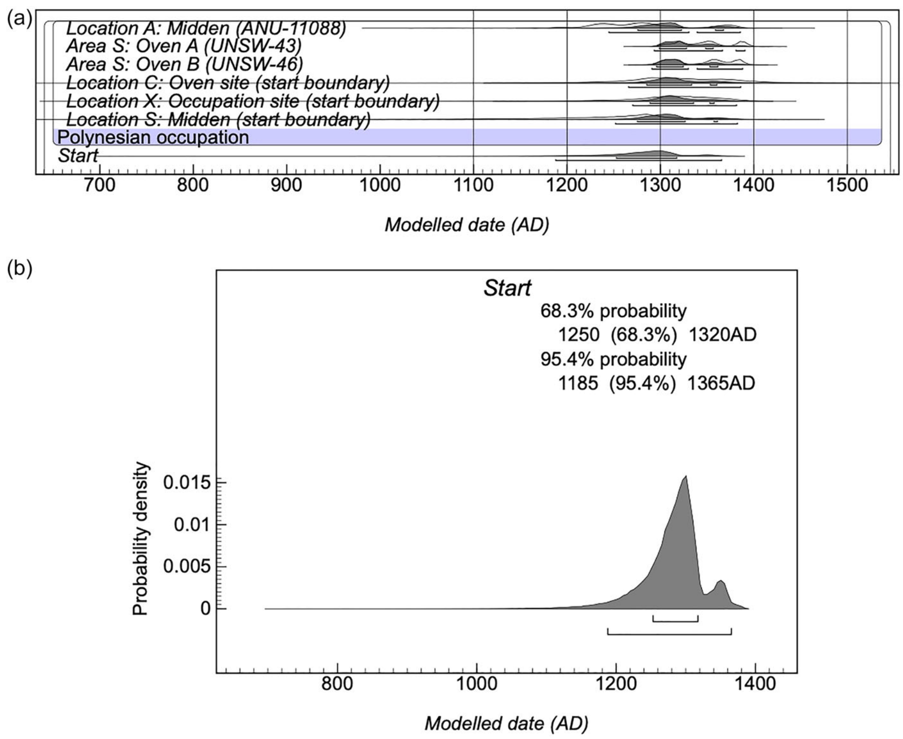
The data do not allow a more precise estimate of early settlement duration within those ranges. In favour of relatively brief occupation within the estimated ranges is the absence of recorded human impact on the adjacent forest, as reflected in pollen coring on the edge of the site (Wood et al., 2016), the relatively thin cultural layer and the absence of stone hearths, posthole patterns or other signs of housing, or of human burial – although any or all of these might emerge with more extensive investigation. Conversely, the relatively large site area and indications of functional variation in it suggest more than brief occupation and this is supported by some faunal data. Sea lion bones are most abundant in the lower part of the Location X midden with fur seal bones more prominent in the upper part. Smith (2009) argued that fur seals, which breed elsewhere on Enderby Island, might have become more heavily harvested as the local sea lion population was depleted. That inference, and the extinction of several land birds prior to European arrival (Tennyson, 2019) suggest some time depth of residence, while scarcity of material identified as originating in mainland New Zealand might reflect little or no contact after discovery.

Bayesian analysis of the radiocarbon ages for an East Polynesian site at Emily Bay on Norfolk Island suggested a similar duration of 100–200 years and that is conjectured from radiocarbon ages for the colonising site on Raoul Island (Anderson et al., 2001). An occupation span of some decades up to about a century has been suggested for early Maori 'transient villages' in mainland southern New Zealand (e.g., Anderson & Smith, 1996; Higham et al., 1999), and the duration for Sandy Bay probably falls within the lower part of that range. Occupation did not occur there again until the 18th to 20th centuries (represented by Location Y (ANU-11089), the uppermost spits of the cultural layer at Location X on marine shell (Wk-13427, Wk-13431), Testpit DD and Oven feature C in area S.

LIMITATIONS IN SUBANTARCTIC POLYNESIAN MOBILITY AND SETTLEMENT

The Subantarctic climate (classified as Subpolar Oceanic) was probably the most significant factor in shaping

FIGURE 4. **(a)** Bayesian age model for the start of human occupation at Enderby Island, at AD 1250–1320 (or 1185–1365 cal BP at 95.4% CI); (b) including distributions from all current archaeological sites/features. Bars beneath the distribution denote 68.3 and 95.4% CI.

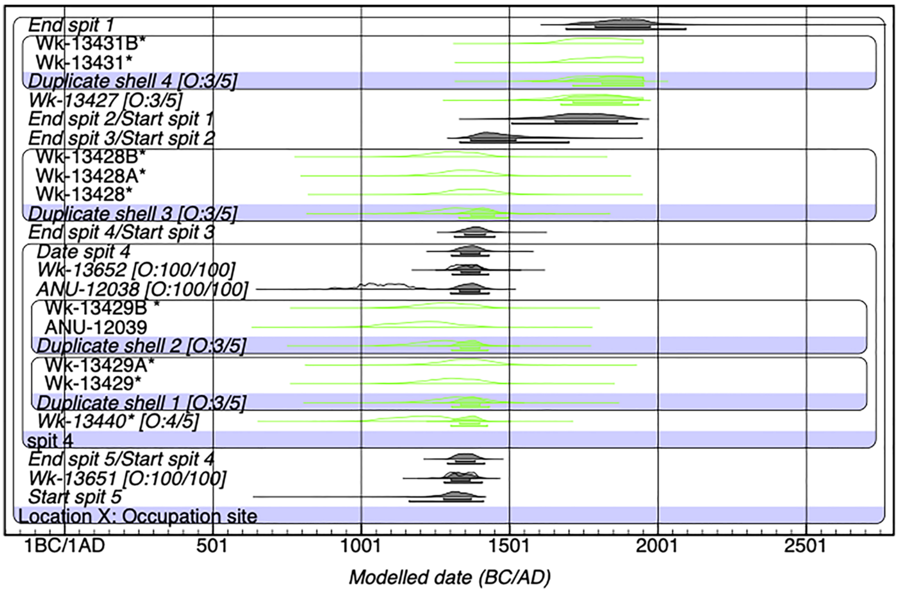


settlement distribution in the high latitudes. It impacted initially and critically upon journeys by sea. Modelling of human heat loss at sea for Polynesian voyaging from Tahiti to New Zealand illustrates the problem. The New Zealand passage has a heat loss rate three to five times that for sailing in the tropics. Even in summer this translates into requiring about 1000 kcal extra per person, per day in food consumption (Montenegro et al., 2023) to reach northern New Zealand (34°S). Sailing down to 50° South would have generated much higher demands again as, even in normal conditions, Southern Ocean seas are cold, high and breaking. Crew would have been continually drenched and bailing almost constant in open boats. Reaching the Antipodes from the Chathams by canoe cannot have been much easier, and it would have been impossible in Moriori rafts, as those became waterlogged within a few hours at sea. Furthermore, the Maori sailing rig prior to the 1820s had no windward capacity and was vulnerable to catastrophic failure in strong winds (Anderson, 2022a). Mid-latitude westerlies, averaging 39 km/h, generate 100 Newtons (N) of load per square metre of sail, which is four times the load from tradewinds (22 km/h average). Gales of 75 km/h, common in the Southern Ocean, generate 240 N and would present overwhelming force to Polynesian sails (Montenegro et al., 2023).

Opportunities to sail between New Zealand and the Auckland Islands, with reasonable expectation of success, must have been few but the sailing route had some advantages otherwise scarce in the region. In exceptionally clear conditions, the Snares are just visible from the southern mountains of Stewart Island and sailing south from the Snares was more likely to reach the Auckland Islands than any others in the Subantarctic. Once obtained, that knowledge could have increased the margin of voyaging safety by breaking a journey into three potential stages: From Bluff by the east coast of Stewart Island to South Cape (130 km), South Cape to the Snares (100 km) and Snares to Enderby (275 km) between each of which it was possible to shelter and wait for suitable weather. Summer winds alternate mainly between southwest and northeast, providing potential passages before the wind in either direction. There is tradition of such voyages. In May 1998 during a tribal (Ngai Tahu) voyage around Stewart Island the elder, Harold Ashwell, explained (to A. Anderson, *pers.comm*) that in the early 1800s when our ancestors went down to the muttonbird islands in March, the women and children were put ashore to do the muttonbirding and the men would then sometimes carry on down to the Snares and Auckland Islands after seals, returning in May. They had by then acquired European sealing boats which, at about 9 m long with sail and oars, were considerably more seaworthy than Maori canoes.

Living in the Auckland Islands was challenging for Polynesians in the 1840s (Anderson, 2007, 2023) and doubtless also in the thirteenth century when climatic conditions were similar to those today. There are about 1000 h of sunshine per year, a mean annual temperature of 8°C (monthly range 5–11°C), annual rainfall of

FIGURE 5. Bayesian age model for Location X (Occupation site; Model 'A'), with the start of human occupation estimated at AD 1275–1375 (68.3% credible interval). Outlier analysis output is noted as 'O:posterior probability/prior probability'. Note that the 'Charcoal' outlier model places a 100% prior outlier probability. Green distributions are ages calibrated using the Marine20 curve (vs. SHCal20 in grey).



1500–2000 mm falling on 300 days a year, and persistent westerly winds strongest in summer with an average monthly windspeed of 32 km/h (Meteoblue 2024). These are difficult conditions for habitation, but they were worse further south, with mean annual temperatures of 6°C for Campbell Island and 5°C for Macquarie Island plus higher windspeeds. It is possible to develop some cold tolerance which, for example, can boost blood flow to fingers, but strong winds produce substantial windchill and water conducts heat away from the body 25 times faster than dry air, so the prevailing rainy, windy conditions imply low day-to-day comfort levels, especially as Maori appear not to have developed closed clothing, hats or footwear. Living on Campbell Island would have been noticeably less comfortable again in colder conditions with windspeeds in excess of 63 km/h on 3 days out of four (DeLisle 1965; Phillips, 2012). The restriction of a base settlement to Enderby Island was, it can be conjectured, a strategic decision indicating an understanding that living conditions were less favourable in the southern part of the archipelago. Polynesians had abundant experience to draw upon in balancing colonisation choices to optimise access to resource environments while seeking to maintain demographic relations with wider kin. Sandy Bay was the closest point of access to their kin that geography allowed.

The location, in fact, could not have been improved upon in the Auckland Islands. There was unparalleled access to a large harbour and islands in Port Ross and to both western and eastern coasts of the main island. Enderby Island lies in a rain shadow from Auckland Island and has a drier, sunnier climate than anywhere else in the group (Peat, 2003). The Sandy Bay beach, sheltered from the ocean swell and to some extent from prevailing westerly winds, was suited to launching and recovery of canoes and its stabilised sand dunes provided a well-drained site for occupation and various native herbs on relatively alkaline soils in a landscape otherwise dominated by acidic peat. Several freshwater streams crossed the dunes and rata-dominated forest reaching almost to the shore extended up the slope behind the dunes (Wood et al., 2016).

In addition, tool-quality basalt, essential for making adzes and other tools, and hydrothermal laminated chert sources, are thought to occur in the basalt cliffs of Enderby Island, although particular sources have yet to be discovered (Anderson, 2009). Most immediately attractive, may have been the sea lion colony at Sandy Bay where 95% of sea lions in the Auckland Islands breed today. The dominance of sea lion amongst mammalian bone in the Sandy Bay midden, including bone from pups, indicates that a similar breeding colony existed in the thirteenth century (Smith, 2009). Choosing the prime settlement site in the archipelago suggests an intention to attempt colonisation, or at least to determine the wisdom of doing so. It is assumed that the settler group comprised families, and it is known that they brought dogs from evidence of characteristic chew marks on seal bones (Anderson, 2005).

Timber was almost certainly a critical requirement. Cooking and heating fires could use brushwood, but construction of dwellings and, above all, construction and repair of canoes, needed access to forest timber. Travel around the Auckland Islands required sea-going canoes and they constituted the fundamental lifeline to mainland New Zealand. Without canoes isolation was total and final – unless a canoe arrived from outside. It is probably significant that prehistoric subantarctic settlement occurred exclusively in the Auckland Islands, the only group to have forest timber. As rata trunks are seldom straight and the timber is very dense and tough, woodworking would have been difficult but an inescapable necessity. Canoe timber was probably sought where it grew tallest and straightest in the most sheltered inlets of Port Ross rather than at Sandy Bay.

Another essential resource was fibre for canoe sails, rigging and hull fastenings, amongst other important uses such as in house construction, clothing, fishing lines and nets. It seems, however, that there was no flax (*Phormium* spp.) on the Auckland Islands until it was introduced in the European era (Smissen & Heenan, 2010), and then it was of types with weak fibre (Walls, 2009). Its early absence might reflect the scarcity of return voyaging to mainland New Zealand. There were makeshift alternatives such as seal skin or inner bark from trees, but an absence of flax must have made life even more difficult. Seal skin clothing was in use by Maori in the Auckland Islands settlement of 1842–1856 and that was very likely the case in the thirteenth century.

The end of settlement

Sandy Bay was settled most probably in the early fourteenth century, in a period of mild conditions and perhaps during a relatively dry interval at that time (Petchey & Schmid, 2020; Bunbury et al., 2022). By the late fourteenth century, however, the LIA began in southern New Zealand with 'trough' climatic conditions (negative Southern Oscillation Index (SOI) and Southern Annular Mode, SAM), prevailing southerly winds and colder, cloudier and wetter weather than earlier (Roop, 2015). The intensity peak of the circumpolar westerlies, formerly around 60° South, moved north to 40–50° South, where it persisted for much of the ensuing 500 years (Koffman et al., 2014; Perren et al., 2020; Renwick & Thompson, 2006). In other words, harsher conditions that had existed south of the Auckland Islands moved north, bringing climatic deterioration to Enderby Island and possibly Subantarctic conditions to Stewart Island and the Chathams. The scale of those is not easily specified but if the Sandy Bay settlement was already at the southern boundary of habitation feasibility, then its residents would have had nowhere to go but back to mainland New Zealand.

The Maori and Moriori occupation of Enderby Island and Port Ross in 1842–1856 is consistent with this hypothesis. Although near the end of the LIA phase, the difficulty of producing or procuring food supplies, together with isolation from their parent communities, led to progressive abandonment with most of the population retreating to Stewart Island. A contemporary European settlement, seeking to develop farming in Port Ross, also failed (Anderson, 2007). In these circumstances, it seems unlikely that fourteenth-century Polynesians, who inhabited only the northernmost island, had explored the more southerly Subantarctic islands, much less reached Antarctica. We argue that the southern boundary of Polynesian colonisation, set by difficulties of climate, seafaring, construction resources, and social isolation, was at Enderby Island (50° S) in the early fourteenth century and retreated thereafter to Stewart Island (47° S), until after European re-discovery of the Auckland Island in 1806.

CONCLUSIONS

The new estimate of AD 1250–1320 for commencement of Polynesian settlement on Enderby Island, replaces the former settlement model in which the oldest age was AD 1190–1258 (Anderson, 2009) and, in doing so, brings initial Subantarctic colonisation into line with ages for the same colonizing horizon in mainland New Zealand and for the other outlying groups of South Polynesia colonised from it: the Kermadecs, Norfolk Island and probably the Chatham Islands (Anderson, 2000, Anderson et al., 2001; Wilmshurst et al. 2008, 2011). It is necessary to note that estimates of initial colonisation ages for these have been derived in different ways, but South Polynesian colonisation overall appears as a single dispersal phase which found mainland New Zealand and all the other islands within 800 km of it during a period too short to subdivide convincingly by radiocarbon dating. A phase of early, rapid, range expansion is also observed archaeologically in the Marquesas (Rolett & Dye, 2024) and possibly more widely in East Polynesia (Wilmshurst et al., 2011).

Chronological concurrence of radiocarbon ages from across the relatively extensive Sandy Bay site suggests a short and continuous occupation, perhaps by a migrant group of several families, which inhabited the site for some decades, as concluded for early residential sites elsewhere in New Zealand (Anderson & Smith, 1996). The Enderby inhabitants exploited abundant reserves of breeding seals and seabirds, fished (Walter, 2009) mainly for Ice-cod (*Paranotothenia microlepidota*), and made adzes and other tools from local fine-grained basalt and volcanic chert, and fish-hooks from seal ivory (Anderson, 2009). The most limiting material resources for Polynesians in the Subantarctic were doubtless timber, especially for the canoes upon which they relied critically for subsistence and travel, and flax for fibre. The existence of prehistoric settlement only on the Auckland Islands which were the only Subantarctic archipelago with forest timber is probably not coincidental. Despite there being two potential source islands for venturing into the Subantarctic, Stewart Island and the Chathams, it seems to have occurred only from the former and perhaps only once.

The limited extent of Polynesian seafaring in the region and the substantial improbability of Antarctic discovery, prompts a brief review of key arguments for Polynesian continental contact more broadly, especially with the Americas (Green, 2005; Jones et al. 2011). Pacific dispersal of the Andean sweet potato (kumara, *Ipomoea batatas*) is usually attributed to Polynesian return voyaging but recent analysis of Amerindian voyaging technology and history (Anderson, 2022b; Danel & Arango, 2023) makes an equal and opposite case for Amerindian agency. This is supported by evidence of ancient Amerindian DNA in eastern Polynesian populations (e.g., Ioannidis et al., 2020), but apparently not the reverse. Whether kumara transmission was by either or both Polynesians and Amerindians, or not cultural at all (Temmen et al., 2022) remains moot.

Purported signs of Polynesian influence in Californian Indian languages (Klar & Jones, 2005) have been widely argued but they are refuted in detail by Meroz (2013). Most significantly, a long debate about whether domestic chicken (*Gallus gallus domesticus*) from Polynesia is represented in pre-Columbian levels of Arenal 1, a site in coastal southern Chile (Jones et al. 2011; Storey & Matisoo-Smith, 2014; Thompson et al., 2014), has now concluded with demonstration that the bones were not from chicken but rather from a native South American wild fowl, the tinamou, *Nothoprocta perdicaria* (Buhring et al., 2024). Dismissing the chicken argument eliminates the only specific case of material transmission from Polynesia to the Americas.

In fact, there is only one instance currently in which Polynesian expansion can be demonstrated materially, and with reasonable confidence, as reaching continental margins prehistorically. It is an East Polynesian adze of Norfolk Island basalt recovered from an archaeological site in coastal Australia, 1400 km distant (White et al., 2014). That this transfer occurred at the point where Polynesians and other people in Remote Oceania came closest to the continents and left material remains (Rowland & Kerkhove, 2022), and where the continent was also downwind from Polynesia, are facts which serve only to emphasize the absence of such evidence elsewhere. The broader Pacific issue is, no doubt, some distance from consensus but taking the distribution of material evidence as the most reliable guide to the extent of prehistoric migration, as we do, makes a strong case for the southern boundary of Polynesian expansion at or about the latitude of the Auckland Islands.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Supporting Information