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Stable carbon and nitrogen isotopes as indicators of sedentism and territoriality in late Holocene South Australia

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ABSTRACT

Previous research has presented hypotheses concerning the presence of widespread Aboriginal sedentism in coastal and riverine South Australia during the past 5000 years. These hypotheses were based on biological distance data (metric and non-metric), isotopic analyses at the inland Roonka Flat site and the emergence of large, well-defined cemeteries throughout the region. Stable carbon and nitrogen isotope data for a large burial population at the Swanport archaeological site in the lower Murray River Basin of South Australia, near the coastal river mouth, provide additional evidence for the presence of hunter–gatherer sedentism and territoriality during the late Holocene. Stable isotope research provides a powerful method to examine subsistence-settlement systems and social relations in prehistoric populations.

Keywords: carbon isotopes, nitrogen isotopes, sedentism, territoriality, hunter–gatherers, Australia.

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INTRODUCTION

The first international conference on hunter–gatherers in 1966, the *Man the Hunter* Conference, demonstrated that hunter–gatherers exhibited extreme diversity in relation to subsistence practises, technology and social organisation. Sedentary and semisedentary hunter–gatherer societies with specialised food procurement and storage technologies and stratified social systems were reported for various regions of the world (Lee & DeVore 1968). This emphasis on hunter–gatherer diversity challenged previously held notions concerning widespread nomadism, seasonal movements and technological and social simplicity among foraging societies.

In regions of the world with reliable water sources associated with abundant wild plant and animal foods, hunter–gatherer economies could support settled village lifeways without the adoption of agriculture. The development of new food extraction techniques or the intensification of existing subsistence strategies to improve the yields of wild foods, combined with food preservation and storage methods, allowed hunter–gatherers to accumulate food surpluses. These surpluses were used to even out the distribution of wild foods over the year, thus providing reliable long-term food sources that allowed the development of permanent and semipermanent villages. Social networks and exchange systems provided additional mechanisms to reduce risks associated with long-term variability in food availability (David *et al*. 2006; Gamble 2008; King 1978; Lourandos 1985, 1988; Matson & Coupland 2009; Pate 2006; Price & Brown 1985).

The dominance of hunter–gatherer lifeways in pre-contact Australia provides a unique opportunity for archaeologists to address adaptive diversity among hunter–gatherers across a large continental area (Lourandos 1997; Mulvaney & Kamminga 1999; Williams & Hunn 1986). Historical and ethnographic documents suggest that the lower Murray region of South Australia was one of the most densely settled Aboriginal areas of Australia prior to European contact (Eyre 1845, II: 317; Lawrence 1968; Taplin 1874, 1879; Tindale 1974). Consequently, south-eastern South Australia provides an important natural laboratory in which to investigate sedentism and social complexity among ancient hunter–gatherers.

There are detailed historical and ethnographic accounts relating to the socio-economically complex Ngarrindjeri nation who occupied the lower Murray region of South Australia. The Ngarrindjeri nation consisted of a number of territorial clans that occupied a large triangular area of coastal and riverine land, stretching from just above Murray Bridge in the north to Encounter Bay in the south-west and Kingston in the south-east. This region includes the coastal Coorong, the Murray River mouth and the lower Murray River in the vicinity of the Swanport archaeological site (Bell 1998, 2001; Berndt & Berndt 1993; Hemming *et al*. 1989; Jenkin 1979; Salgado 1994; Taplin 1874, 1879; Tindale 1974).

Taplin (1879: 34) concluded that there were 18 independent territorial clans, or *Lakalinyeri*, that constituted the Ngarrindjeri confederacy or nation. Each territorial clan was administered by a group of 10–12 men or elders referred to as the *Tendi*. The *Tendi* from each clan collectively elected the *Rupulli*, or the head of the entire Ngarrindjeri confederacy. This centralised and hierarchical government was employed to administer the laws and traditions of the Ngarrindjeri confederacy. These historical accounts provide additional support for increased sedentism and social complexity in the resource-rich region along the lower Murray River.

Archaeology provides the means to test hypotheses regarding the time depth of these complex hunter–gatherer social systems (cf. Thomas 1973). Bioarchaeology is a specialised area of archaeology that employs studies of human skeletal remains to address behavioural questions about past social systems. The chemical composition of bones and teeth from human skeletal remains associated with archaeological sites offers an independent means of examining past social relations and landscape use (Bentley *et al*. 2005; Budd *et al*. 2003, 2004; Katzenberg 2000; Pate 1997, 2008a, 2008b; Sealy *et al*. 1995). Chemical signatures associated with geological substrates and hydrologies of particular habitats are passed up marine and terrestrial food webs and are ultimately recorded in the tissues of human consumers. Consequently, chemical differences in bones and teeth may be related to past residence in environmental zones with distinct chemical signatures. As bone collagen has a slow biochemical turnover rate compared to other human tissues, it has been employed to address long-term dietary averages in past human populations (Pate 1994; Sealy *et al*. 1995). Stable isotope analyses of human tissues are providing archaeologists with a powerful tool to reconstruct past economic and social systems.

Previous stable isotope research at the inland Roonka Flat archaeological site, in the lower Murray River Basin of South Australia (Pate 1995, 1997, 1998a, 1998b), suggested that there was limited movement of people and foods between coastal and interior riverine habitats throughout the late Holocene. It was argued that the isotopic data provided strong support for the presence of sedentism and territoriality among hunter–gatherer populations inhabiting the resource-rich riverine region. Additional evidence for increased sedentism in the riverine zone during the past 5000 years was derived from palaeopathological and biological distance analysis (cranial non-metric and metric traits) of human skeletal remains and archaeological surveys reporting the emergence of large cemeteries along the river banks (Littleton 1999; Littleton & Allen 2007; Pardoe 1988, 1994, 1995; Pate 2006; Pretty & Kricun 1989; Prokopec 1979; Webb 1995).

The Roonka Flat site is located near Blanchetown, South Australia, approximately 120 km north of the coastal river mouth at Lake Alexandrina. Rescue excavations conducted by the South Australian Museum at Roonka Flat between 1968 and 1977 produced one of the largest, best provenanced pre-European contact Aboriginal burial populations in Australia. The excavations resulted in the recovery of over 150 interments with dates spanning the Holocene, c. 10000 BP – AD 1840 (Pate *et al*. 1998a; Pretty 1977, 1986). In order to address the extent of Aboriginal sedentism in the lower Murray River region during the late Holocene prior to European contact, further stable isotope analyses of human skeletal remains from areas located closer to the coast are required. In order to provide additional isotopic data to test the hypothesis that late Holocene Aboriginal populations in the lower Murray River region were largely sedentary and territorial, this paper reports stable carbon and nitrogen isotope results for the near-coastal Swanport skeletal sample. It builds upon a small pilot study at Swanport conducted by Hobson and Collier in the 1980s (Collier & Hobson 1987; Hobson & Collier 1984).

As stable isotope data provide a valuable means of demonstrating restricted human mobility across landscapes, they may be employed to provide evidence for sedentary behaviour within various geographical zones. In relation to Swanport, isotopic evidence for sedentism would provide data to support arguments for a greater time depth for the territorial behaviour that has been reported for this region in historical and ethnographic accounts.

The Swanport site is located near Murray Bridge, South Australia, approximately 20 km north of the coastal river mouth at Lake Alexandrina (Figure 1). In 1911, the Swanport burial ground was rediscovered by the Crown Lands Department of South Australia during levee bank construction. Human interments were located in a red sandy layer underlying a layer of dark sandy midden deposits. The remains of over 135 individuals were rescued from the site (Owen 2004; Pretty 1977; Stirling 1911). After Roonka, Swanport provides the largest sample of ancient Aboriginal skeletal remains for any one archaeological site in the lower Murray River region of South Australia. On the basis of initial radiocarbon determinations on six individuals (Pate *et al*. 2003), the Swanport burials date from c. 2790 ± 40 BP (OZF 393) to 420 ± 40 BP (OZF 395).

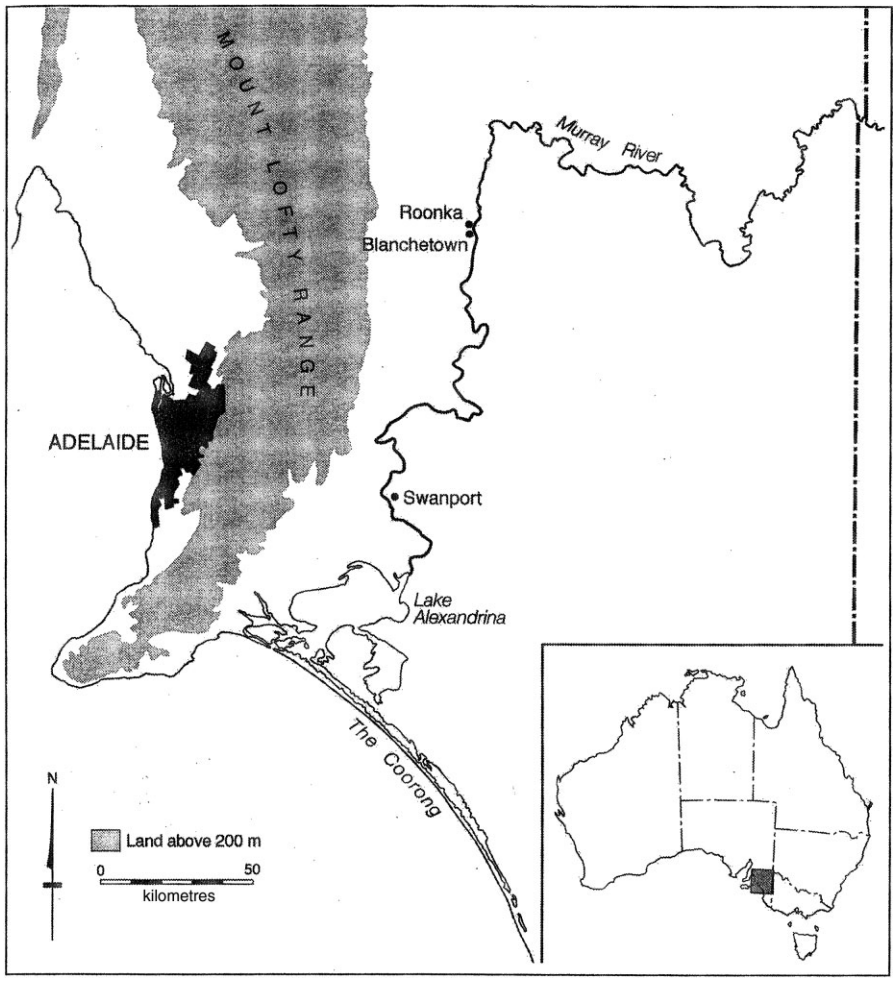
MATERIALS AND METHODS

Stable isotopes and the lower Murray environment

The lower Murray River Basin of South Australia provides a suitable natural laboratory in which to test hypotheses regarding sedentism and territoriality in late Holocene hunter–gatherer populations employing stable isotope analyses. Discrete biogeographical zones including the South-East Coast, Coastal Murray River Mouth, Inland Murray River and Arid Desert Interior have been identified using stable carbon and nitrogen isotope analyses of marine and terrestrial fauna with known diets (Pate & Anson 2008; Pate & Noble 2000; Pate & Schoeninger 1993; Pate *et al*. 1998b).

In relation to this research addressing past Aboriginal diet, landscape use and mobility patterns in the region

Figure 1. The location of the Swanport archaeological site, lower Murray River, South Australia in relation to the Roonka archaeological site and the coastal Coorong region.



adjacent to the coastal Murray River mouth in the vicinity of the Swanport archaeological site, the South-East Coast provided access to marine and C_3-based terrestrial foods; the Coastal Murray River Mouth provided access to marine and C_3-based terrestrial foods, including freshwater fish and shellfish; and the inland Murray River provided access to C_3-based terrestrial foods, including freshwater fish and shellfish. Access to distant C_4-based terrestrial foods from the Arid Desert interior (450 km) and the northern tropical coast of Australia (2500 km) are not expected due to their great distances from the south-eastern coast of South Australia.

Bone collagen stable isotope values for key Australian mammals with distinct diets provide baseline data for the examination of dietary variability and landscape use in ancient human populations. The arboreal koala (*Phascolarctos cinereus*), with a specialised eucalypt leaf diet, provides an example of a C_3 herbivore, while the northern tropical antilopine wallaroo (*Macropus antilopinus*) represents a C_4 herbivorous diet (Dawson 1989; Hume 1982; Sanson 1982). The sea lion (*Neophoca cinerea*) provides an example of an upper trophic level marine carnivore (Ridgway & Harrison 1981). Mean isotopic values for these Australian mammals are presented in Table 1 and Figure 2. Because past human mobility patterns and the scale of mobility in south-eastern South Australia will be related to the use of distinct environmental zones, hypotheses concerning restricted mobility and territoriality in the vicinity of the Swanport site can be addressed employing these key faunal standards in association with knowledge about isotopic variability in the region provided by past research.

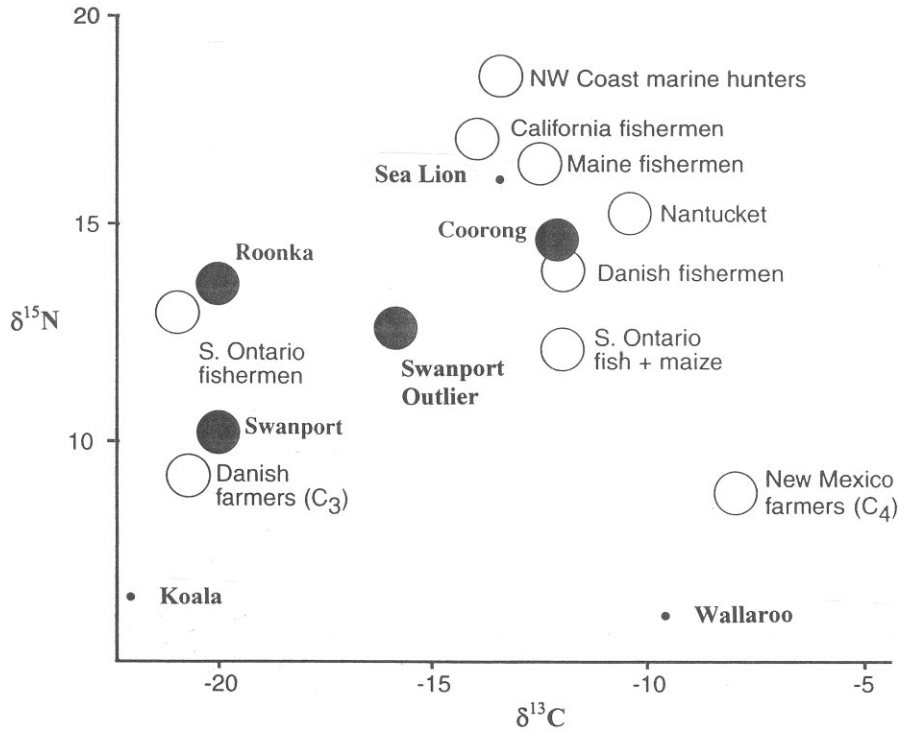
Hattersley (1983) reports the geographical distribution of C_3 and C_4 grasses in Australia in relation to climatic zones. The southern temperate coast is dominated by C_3 grasses, while the abundance of C_4 grasses increases towards the north, and they become dominant in the arid desert interior and tropical northern regions of Australia (Hattersley 1983; Murphy & Bowman 2007). As the southern coast of South Australia is a C_3 environment, both stable carbon and nitrogen isotope values can be used to distinguish marine versus terrestrial dietary inputs in this region. Furthermore, $\delta^{15}N$ values become more

Table 1. A summary of bone collagen stable carbon and nitrogen isotope values for Australian mammals with distinct diets.

Site/location	***n***	**$\delta^{13}C$ (‰)**		**$\delta^{15}N$ (‰)**	
		$X \pm SD$	Range	$X \pm SD$	Range
Koala (C_3 herbivore)	3	–22.6 ± 0.4	–23.1, –22.4	2.5 ± 0.8	1.4, 3.3
Antilopine wallaroo (C_4 herbivore)	3	–9.8 ± 0.4	–10.2, –9.4	2.0 ± 1.1	1.0, 3.2
Sea lion (marine carnivore)	3	–13.5 ± 0.3	–13.8, –13.2	15.9 ± 0.4	15.4, 16.2

Collection sites:
Kangaroo Island, South Australia: koala (*Phascolarctos cinereus*), sea lion (*Neophoca cinerea*).
Colless Creek, Queensland: antilopine wallaroo (*Macropus antilopinus*).

Figure 2. Mean bone collagen stable carbon and nitrogen isotopic values for human skeletal remains from the Swanport, Coorong, and Roonka Flat archaeological sites and Australian faunal controls in comparison to those for prehistoric human samples from other regions of the world (adapted from Little & Schoeninger 1995; Schoeninger *et al*. 1983).



positive in fauna inhabiting semi-arid and arid interior habitats where C_4 grasses are more prevalent (cf. Ambrose 1991; Anson 1997; Heaton *et al*. 1986; Pate & Anson 2008; Schwarcz *et al*. 1999; Sealy *et al*. 1987).

Finally, pollen evidence from south-eastern wetlands (Dodson 1974, 1975, 1977) and stable isotope analyses of kangaroo bones from stratified rock shelters in the lower Murray River Basin (Roberts *et al*. 1999) indicate that the climate was relatively stable during the past 5000 years.

Thus, isotopic values distinguishing modern biogeographical zones in South Australia should also be reflected throughout the late Holocene.

Laboratory methods

Age at death and sex for individual skeletons in the Swanport sample were determined using standard morphological methods. Age estimates were made employing tooth eruption sequences, stages of epiphyseal closure/cranial suture closure and erosion of pubic symphysis. Sex determinations involved the employment of sexual dimorphism associated with the skull, pelvis and long bones (Bass 2005; Buikstra & Ubelaker 1994; Owen 2004; White 2000).

In relation to laboratory methods, small cortical bone samples weighing between 1 and 1.5 g were obtained from 121 individuals from the Swanport skeletal collection at

the South Australian Museum (Owen 2004). Cortical bone was obtained from fragments of the shafts of long bones and the bone used varied according to the availability of fragments for each skeleton. The sample consisted of 55 adult females, 49 adult males and 17 individuals that could not be accurately sexed (consisting of nine juveniles aged 10–18 years and eight adults greater than 20 years). In addition, 27 adult skeletons from the coastal Coorong region were sampled to provide isotopic data for a population with access to marine foods.

Whole bone chunks were scraped clean with a scalpel and demineralized in a dilute 2% HCl solution (Sealy 1986). Extracts were soaked and washed thoroughly in distilled water following treatment. The remaining organic component was oven dried at 35°C and ground in a Retsch mixer mill. Stable carbon and nitrogen isotope values were determined by mass spectrometry at the CSIRO Land and Water laboratories in Adelaide, South Australia using a Europa Scientific ANCA-SL system. Carbon and nitrogen concentrations were determined using an ANCA-SL elemental analyser coupled to a Geo 20-20 IRMS. Isotope ratios are expressed as delta (δ) values in parts per thousand (‰) relative to the PDB and atmospheric nitrogen (AIR) standards. Analytical precision was better than ± 0.1‰ for carbon and ± 0.3‰ for nitrogen. The δ values were placed on the VPDB scale using a two-point calibration method (Coplen *et al*. 2006). A number of samples were repeated during the mass spectrometry process to ensure accuracy. Where repeat testing was conducted, the values were averaged.

Atomic C:N ratios in modern collagen were employed to determine the presence of acceptable collagen in archaeological extracts in relation to stable isotope analysis. These acceptable atomic C:N ratios were developed by extracting collagen from large samples of modern mammals and measuring their C:N ratios. Results include atomic C:N ranges of 2.9–3.6 for 172 mammals (DeNiro 1985) and 2.8–3.5 for 79 mammals (Ambrose 1990). Atomic C:N ratios were calculated according to the following equation: atomic C:N = (14/12) × (wt% C:N). The wt% C:N ratios for the Swanport sample ranged from 2.5 to 2.8 and the atomic C:N ratios from 2.9 to 3.3.

RESULTS

When the isotopic data for individual skeletons from Swanport were plotted on a graph with bone collagen $\delta^{13}C$ values on the *x*-axis and $\delta^{15}N$ values on the *y*-axis, two distinct clusters emerged (Owen 2004: 237). One cluster (the primary Swanport population) included 110 individuals and the other cluster (the Swanport outlier) represented 11 individuals (Figure 3).

The majority of the individuals interred at Swanport (110/121) have stable isotope values indicating dependence on local terrestrial foods derived from the Murray River and adjacent plains (e.g. C_3 plant foods, freshwater fish and shellfish, and terrestrial animals feeding on C_3-based foods). However, in contrast to the primary Swanport population, the 11 individuals (seven adult males, three

Figure 3. Bone collagen stable carbon and nitrogen isotopic values for individual human skeletons from the Swanport archaeological site, South Australia after 1.5‰ correction to $\delta^{13}C$ values (Bada *et al*. 1990; Marino & McElroy 1991; Peng & Freyer 1986) in relation to changes to modern atmospheric CO_2 (adapted from Owen 2004: 237). Individuals in the Swanport Outlier cluster are labelled "Marine".

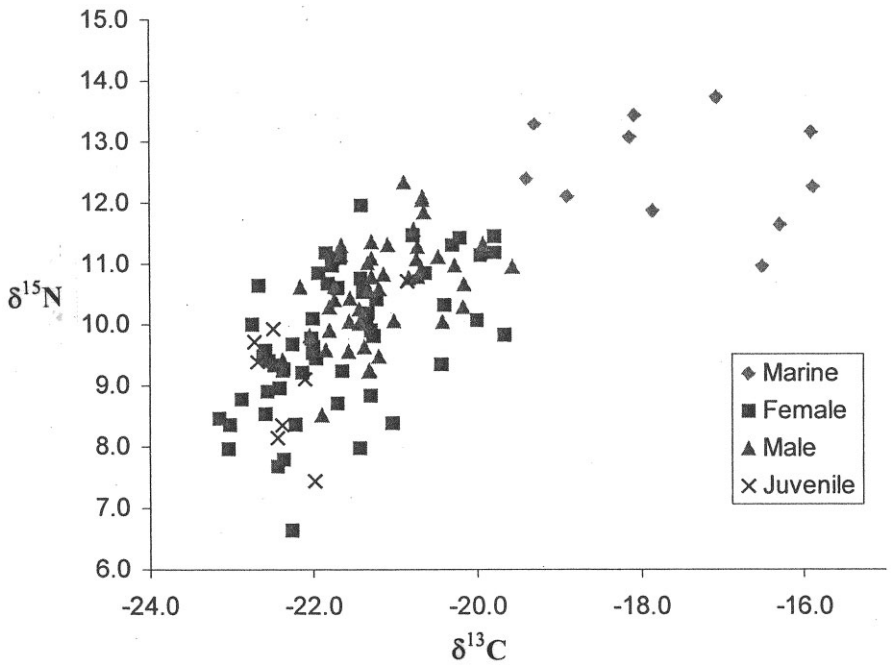


Table 2. A summary of bone collagen stable carbon and nitrogen isotope values for late Holocene Aboriginal skeletal remains from the lower Murray River basin, South Australia.

Site/location	*n*	δ^{13}C (‰)		δ^{15}N (‰)	
		X ± SD	Range	*X* ± SD	Range
Coorong (Coastal Marine)	27	–11.7 ± 1.2	–13.2, –9.6	14.7 ± 2.6	11.2, 22.2
Swanport outlier (Coastal River Mouth)	11	–16.1 ± 1.3	–17.9, –14.4	12.5 ± 0.9	11.0, 13.7
Swanport (Inland Riverine)	110	–20.0 ± 0.8	–21.6, –18.1	10.1 ± 1.1	6.6, 12.3
Roonka Flat (Inland Riverine)	32	–20.1 ± 1.2	–22.9, –18.4	13.4 ± 1.2	10.9, 16.0

adult females and one subadult) included in the Swanport outlier displayed isotopic signatures indicative of diets with significant quantities of marine foods. Furthermore, stable nitrogen isotopes suggest that these individuals consumed lower trophic level marine shellfish and fish, as opposed to higher trophic level fish and marine mammals. In contrast, previously published data for ancient Aboriginal skeletal remains from the coastal Coorong region to the south of Swanport (Pate *et al*. 2002) show carbon isotope values indicative of marine-based diets and elevated nitrogen isotope values suggesting consumption of higher trophic level marine foods. Mean isotopic values for the Swanport outlier are intermediate between those for the main Swanport and the Coorong populations (Table 2 and Figure 3).

The mean stable carbon isotope value for the main Swanport sample (–20.0 ± 0.8‰, $n = 110$) is virtually identical to that for the Roonka Flat population (–20.1 ± 1.2‰, $n = 32$). However, the Roonka Flat sample and the Swanport outlier ($n = 11$) both show higher stable nitrogen isotope values compared to the main Swanport sample.

In the larger Swanport sample, on average, males show more positive δ^{13}C and δ^{15}N values than do females, whereas males and females in the Swanport outlier have similar stable carbon and nitrogen isotope values. Subadult δ^{13}C and δ^{15}N values in the main Swanport sample are significantly more negative than those of the adult females (Table 3). In contrast, subadults (newborn to 14 years old) at the Roonka Flat site have bone collagen δ^{15}N values that are more positive than both adult males and adult females.

Table 3. Stable carbon and nitrogen isotope results for Swanport and Roonka by age and sex (sex could not be determined for nine juveniles and eight adults at Swanport and seven juveniles and children at Roonka).

	n	δ^{13}C *X* ± SD (‰)	δ^{15}N *X* ± SD (‰)
Swanport			
Adult males	42	–19.7 ± 0.7	10.5 ± 0.9
Adult females	52	–20.2 ± 0.9	9.8 ± 1.2
Adult – indeterminate sex	8	–19.8 ± 0.9	10.8 ± 0.6
Subadults – juveniles	8	–20.7 ± 0.6	9.1 ± 1.1
Swanport outlier			
Adult males	7	–16.3 ± 1.2	12.5 ± 1.0
Adult females	3	–16.1 ± 1.6	12.8 ± 0.6
Subadults – juveniles	1	–14.4	12.3
Roonka flat			
Adult males	14	–19.7 ± 1.0	13.3 ± 1.2
Adult females	11	–20.4 ± 1.3	13.2 ± 1.4
Subadults	7	–20.6 ± 0.9	13.7 ± 1.2

DISCUSSION

The stable isotope results indicate that the majority of the Swanport population had diets focused on local C_3-based food sources. In general, these data suggest that neither food nor people were moving between Swanport and the nearby coast to the south, or the semi-arid inland region to the north. Thus, as at Roonka Flat, the isotopic data at Swanport provide strong support for the existence of sedentary lifeways and territorial social systems during the late Holocene.

Isotopic values for the 11 Swanport outliers suggest residence in the adjacent coastal Murray River mouth region or some other coastal region during the majority of their lifetimes. Whereas the Coorong population appears to have relied mostly on marine foods, individuals in the Swanport outlier show isotopic values suggesting relatively equal contributions from marine and C_3-based terrestrial foods.

As the Swanport outlier population consists of adult males, adult females and a subadult, there is not an evident pattern that could be related to marriage exchanges or other social mechanisms related to sex and age. Elevated stable nitrogen isotope values in the Swanport outlier and the Roonka Flat population are related to the consumption of marine foods (Swanport) and the inclusion of δ^{15}N-enriched foods from the surrounding semi-arid terrestrial habitat (Roonka). Whereas there is an overlap of bone collagen δ^{15}N values between the Swanport outlier and the Roonka Flat population, they can be distinguished on the basis of δ^{13}C values due to the consumption of marine foods by individuals within the Swanport outlier and a focus on terrestrial foods at Roonka.

In the main Swanport sample, mean stable isotope values for both carbon and nitrogen indicate that there were significant dietary differences between adult males, adult females and subadults. Elevated δ^{15}N values in adult males at Swanport indicate that they consumed more

terrestrial foods from higher trophic levels (e.g. large freshwater fish and terrestrial animals) than did adult females and subadults. Subadult diets at Swanport included greater quantities of foods from lower trophic levels (e.g. freshwater shellfish and plant foods) and adult females were intermediate.

Although stable carbon isotope values for adult males, adult females and subadults are remarkably similar for the larger Swanport sample and the Roonka Flat population, nitrogen isotope values indicate that on average adult males and adult females at Roonka were feeding at the same trophic level, unlike the Swanport inhabitants. Additionally, subadults at Roonka were feeding at the highest trophic level, while subadults at Swanport were feeding at the lowest trophic level. In contrast to Swanport, where the subadult sample represents the 10–18 year age group, a majority of the subadults at Roonka were in the newborn to 3 year age range. Accordingly, the 0.5‰ δ^{15}N-enrichment observed in Roonka subadults versus adult females is most likely related to the trophic effect associated with breastfeeding (Schurr 1997; Tuross & Fogel 1994).

In summation, a range of techniques involving chemical and physical analyses of human skeletal remains are providing independent evidence that the territorial social relations existing along the lower Murray River and adjacent coastal region in South Australia at the time of European contact (Berndt & Berndt 1993; Jenkin 1979; Pate 2006; Peterson 1976; Tindale 1974) have ancient roots. Current evidence suggests that these "exclusive" social relations and territoriality emerged in the lower Murray sometime between 5000 and 3000 years BP (Pardoe 1994, 1995; Pate 2006). The isotopic data from Swanport complement previously published data for Roonka Flat by providing evidence for sedentism and territoriality in late Holocene South Australia in a riverine habitat located downstream and adjacent to the resource-rich coastal river mouth.

The South Australian research provides important comparative data for similar archaeological studies in other global regions. Stable carbon and nitrogen isotope results for prehistoric skeletal populations in South Africa associated with coastal and inland burial grounds (Sealy & van der Merwe 1985, 1986, 1988) also provide evidence for the existence of sedentism and territoriality, with limited seasonal mobility between coastal and inland regions during the late Holocene.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this paper at the publisher's website:

Appendix A. Stable carbon and nitrogen isotope data for the Swanport archaeological site.