South African Journal of Botany 160 (2023) 147–156

Contents lists available at ScienceDirect

South African Journal of Botany

journal homepage: www.elsevier.com/locate/sajb

An analysis and environmental interpretations of wood charcoal from the Later Stone Age deposit at Klasies River cave 1, Tsitsikamma Coast

B. Zwane[a,b,*], M. Bamford[b], Y. van Wijk[c], S. Wurz[d,e]

[a] Palaeoecology Laboratory, Botany Department, African Center for Coastal Palaeoscience, Nelson Mandela University, Gqeberha, South Africa
[b] Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa
[c] Anthropology Department, Rhodes University, Grahamstown, South Africa
[d] School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa
[e] Centre for Early Sapience Behaviour, University of Bergen, Bergen, Norway

ARTICLE INFO

Article History:
Received 20 March 2023
Revised 20 June 2023
Accepted 29 June 2023
Available online 8 July 2023

Edited by: Dr J. Manning

Keywords:
Environment
Late holocene
Charcoal
Tsitsikamma coast
Wood anatomy
Klasies river main site
Later Stone Age

ABSTRACT

In this article, we present the results for an analysis of charcoal remains from Klasies River main site cave 1. The analysis was done to understand the environmental conditions of the Tsitsikamma Coast during the late Holocene, approximately 2300 cal BP. A high-resolution reflective light microscope (Olympus BX51) with up to 500X magnification was used to analyse the microanatomy of archaeological and comparative wood charcoal, as well as following standard Anthracology procedures. Common woody species from the contemporary Klasies River landscape along with many others from other parts of southern Africa were used to identify archaeological charcoal samples to species. The vascular structures of archaeological and contemporary woody species from Klasies River were also measured and compared so that wood Vulnerability Indices could be calculated. Two species, *Protorhus longifolia* and *Hibiscus* cf. *tiliaceus,* from the archaeological charcoal assemblage indicate that environmental conditions in the Tsitsikamma Coast are no longer suited for their growth. These species currently grow in the east coastal areas and minimally in the eastern highlands of southern Africa where they tolerate a warm climatic setting. Overall, the taxonomic results indicate that more than 80% of the 17 archaeological species identified here are adapted to year-round and summer rainfall conditions. This is in contrast with the present environmental setting at Klasies River that includes, predominantly, species that prefer year-round and winter rainfall with fewer summer rainfall adapted species. A comparison of the vascular structure of the archaeological woody species against that of contemporary species indicates that the archaeological Klasies River landscape received relatively higher rainfall levels in the Late Holocene than it does presently. We conclude that the Klasies River landscape, located in the year-round rainfall region of southern Africa, supported differing amounts of winter and summer rainfall-adapted woody vegetation through time. During the late Holocene, c. 2300 cal BP, environmental or climatic conditions were more favourable for summer rainfall-adapted woody species to thrive better than at present. The same woody vegetation was also less adapted to aridity than that found in the area today.

1. Introduction

Environmental reconstructions made through botanical remains rank amongst the most reliable ways of understanding past environments and climates, and archaeological charcoal has been used extensively in this regard. Southern African charcoal studies have successfully applied Anthracology methods to interpret past environments that are dated from the late Pleistocene to the Holocene period (for example, Prior and Price-Williams, 1985; Scholtz, 1986; Tusenius, 1986, 1989; February, 1992, 1993, 1994, 2000; Shackleton and Prins, 1992; Esterhuysen, and Mitchell, 1996; Cartwright and Parkington, 1997; Allott, 2006; Cartwright, 2013; Chikumbirike, 2014; Lennox and Bamford, 2014; Bamford, 2015; Lennox et al., 2015; House and Bamford, 2019; Puech et al., 2021; Zwane and Bamford, 2021a; 2021b, 2022; House et al., 2022; Lennox et al., 2022). These, along with other environmental proxies, provide information about the conditions that prevailed over the subcontinent in the past Nami (Mitchell, 2005). This environmental data is relevant to archaeology because it provides context against which archaeological material was deposited as well as a background to better understand the relationship between Stone Age societies and their ecological settings.

---

* Corresponding author.
E-mail addresses: s227621018@mandela.ac.za (B. Zwane), marion.bamford@wits.ac.za (M. Bamford), vanwijkyvette41@gmail.com (Y. van Wijk), sarah.wurz@wits.ac.za (S. Wurz).

https://doi.org/10.1016/j.sajb.2023.06.059

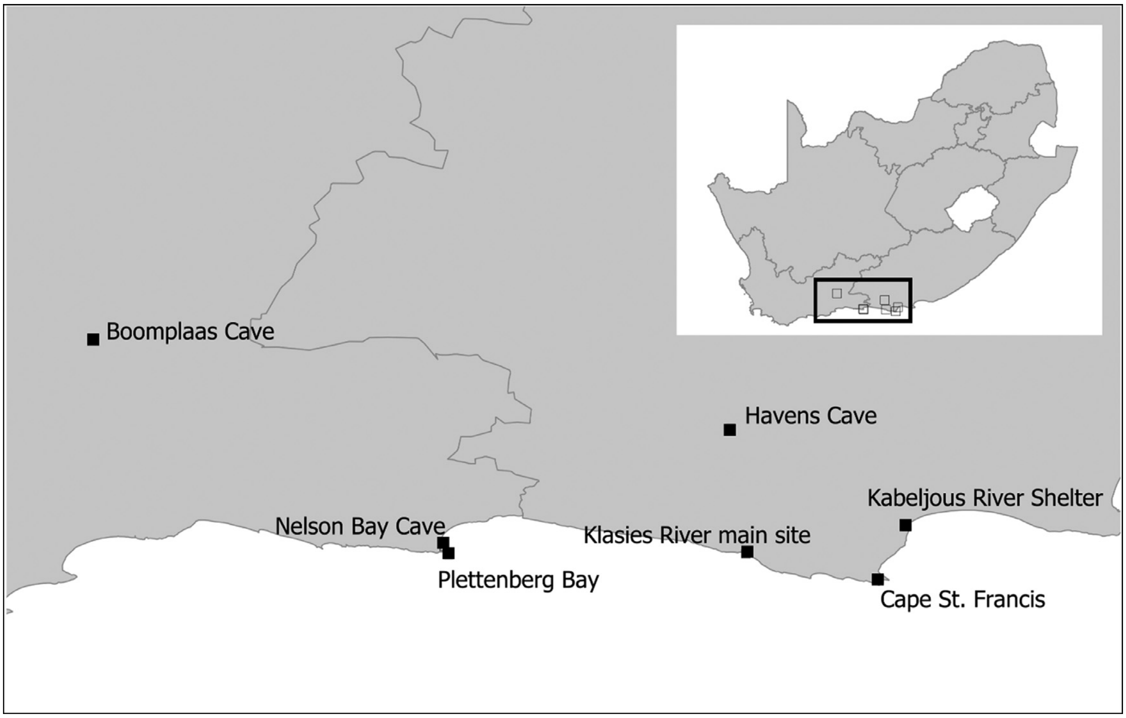

Fig. 1. The location of Klasies River main site along with some neighbouring archaeological sites in the southern Cape coast, Tsitsikamma Coast.

The Later Stone Age (LSA) archaeological deposits at Klasies River main site (KRM) cave 1 preserves human remains, evidence of foraging strategies, technologies and palaeoenvironments associated with the late Holocene societies of the southern Cape (Singer and Wymer, 1982; Binneman 1995). Singer and Wymer (1982: 120) originally excavated this deposit and associated the cultural remains of the inhabitants of the cave to Strandloper activity. Binneman (1995; 2001) classified the LSA stone tool industries at KRM cave 1 as the Kabeljous Industry that was also identified at other sites in the general area, for example at the Cape St. Francis coastal sites as well as Nelson Bay Cave, Havens Cave, Boomplaas Cave, and Kabeljous River Mouth Shelters (Fig. 1) (Binneman, 1995; 2001; 2006/2007). In the latest revisions of the Stone Age sequence of South Africa and Lesotho, Lombard et al. (2012; 2022) classified this industry under the fifth phase of the Later Stone Age techno-complex called the ‘final Later Stone Age’. This phase, dated between 100 and 4000 years ago, is characterised by the absence of ceramics, and much variability in a hunter-gatherer economy (Lombard et al., 2012, 2022).

New research is currently being undertaken to increase the knowledge about the Stone Age societies who visited the site as well as to understand the environmental background against which the cultural material was deposited in the main site (Wurz, 2016; Wurz et al., 2018; 2022). The late Holocene environment is investigated here using charcoal remains from the Upper Midden of the Later Stone Age deposit that was excavated by Wurz in 2017. This is done to increase the understanding of the environmental context that was previously inferred from shellfish remains (Binneman, 1995; Mosweu, 2016) and soil sediments (Butzer, 1978). The Upper Midden is currently dated between 2451 – 1932 cal BP and a probable mean of 2300 cal BP is used for the charcoal data in this report (Nami et al., 2016: 4). The results contribute towards understanding the relationship between the late Holocene environment in the southern Cape and the behaviour of coastal societies who visited the site. These will also form a late Holocene environmental proxy data that can be compared with other environmental proxies from other sites

In the southern Cape, environmental studies indicate that the late Holocene is associated with fluctuating sea levels and atmospheric conditions that brought variable moisture and temperatures over the landscape (Chase and Meadows, 2007; Chase et al., 2018). This study uses woody vegetation to reconstruct the late Holocene (c. 2300 cal BP) environment. The woody vegetation set from the present landscape was used as a point of reference against which to understand the conditions that occurred during the late Holocene KRM landscape. The taxa as well as the vascular structure of the two woody vegetation sets (archaeological vs contemporary) are compared to describe the late Holocene environment.

1.1. Site setting

KRM is located at 34°6′S, 24°24′E within the south-east facing cliffs that overlook the Indian Ocean on the Tsitsikamma Coast. The Tsitsikamma Coast extends for c. 150 km from east to west between Cape St Francis and Plettenberg Bay and is situated 10 km south of the Tsitsikamma Mountain range. The area is densely vegetated with plants belonging to the Thicket, Afrotemperate Forest, Coastal vegetation as well as the Fynbos Biome (Van Wijk et al., 2017; Lombard and Van Aardt, 2023). These biomes, collectively, include grasses, sedges, geophytes, ferns, herbs, climbers, shrubs and tall trees (Van Wijk et al., 2017). At KRM, woody vegetation dominates the landscape in species richness and distribution, i.e. out of 268 species currently identified around the site, approximately 46% are described in literature as shrub and tree species (Van Wijk et al., 2017). These grow on the shallow marine soil types that are derived from the Nanaga formation of the Cenozoic Algoa quarzitic sandstone within the Cape Supergroup (Mucina and Rutherford, 2006; Van Wijk et al., 2017). At KRM this sandstone occurs as sand dunes with deeply incised valleys and gorges (Thamm and Johnson, 2006; Marker and Holmes, 2010).

The Tsitsikamma Coast is situated within the region of overlap between the tropical and temperate climate systems and experiences a mesothermal climate (Butzer, 1978; Tyson and Preston-Whyte, 2000). The southern Cape coast falls under the Year-round Rainfall Zone (YRZ) with a rainfall pattern that is in phase with both that of the Summer Rainfall Zone (SRZ), associated with the tropical climate, as well as Winter Rainfall Zone (WRZ) associated with the temperate climate, and has no extended dry season. The Mean Annual Precipitation (MAP) on the Tsitsikamma Coast is 845 mm and the Mean Annual Potential Evaporation (MAPE) is 1680 mm (Mucina and Rutherford, 2006). These are accompanied by mean annual temperatures of 15.5°C.

The geographical location of KRM, on the southern Cape coast, subjects this area (and the vegetation within) to a coastal climate that is influenced by the ocean surface temperatures (Mucina and Rutherford, 2006). The Agulhas Current, originating from the Indian Ocean, distributes warm ocean surface temperatures along the east and southern Cape coasts and creates variable coastal habitats. The vegetation on this landscape is adapted to many environmental conditions including the climate, geology, topography, aspect, and wind patterns. In addition to these, the vegetation is adapted to micro-climatic conditions that are related, especially, to the exposure of the area to salt laden southerly winds (Van Wijk et al., 2017). Today, the indigenous vegetation occurs with some non-native or imported vegetation species that were planted on the landscape for commercial purposes.

2. Materials and methods

2.1. Comparative wood collection from the modern Klasies River landscape

A botanical survey was conducted in the surrounding areas of KRM to sample common indigenous woody species for comparative analysis. The context of the comparative species was noted and recorded over six smaller sections of approximately 250 m^2 (Fig. 2). Wood samples were identified taxonomically through their leaf vouchers by Y. van Wijk. The leaf vouchers of the identified species were then pressed and stored at the Evolutionary Studies Institute Herbarium, University of the Witwatersrand. The woods from the vouchers of each species were analysed at the University of the Witwatersrand.

Modern wood samples were dried through exposure to sunlight for 7 days and then further dried in an oven at 50°C for 24 h. Cut lengths (~ 5 cm) of woods were wrapped in aluminium foil to reduce oxygen levels, labelled and carbonised in a Lenton muffle furnace for 2.5 h at 350°C to produce charcoal. The new charcoal samples of each comparative species were fractured, and their microstructure studied. These were analysed under reflective light objectives of a light microscope (Olympus BX51) at 50X, 100X, 200X and 500X magnification and photographed with an Olympus Digital camera and Olympus 'Analysis' Image Software. The software package includes 'Extended Focal Image' (EFI) function that can create microphotographs of the wood specimens while adjusting the level of focus.

2.2. Archaeological charcoal from the Later Stone Age deposit in cave 1

An excavation for archaeological charcoal was done in cave 1 of Klasies River main site under the directorship of S. Wurz. A grid of 50×50 cm^2 was set over the shell midden part of the Witness Baulk following Deacon's 1984 grid system (Wurz et al., 2018). The squares that were excavated for the data of this study are located towards the north end of the cave, corresponding to the LSA deposit. Three squares (A15, B15 and B16) were opened in 2017 over the Upper Midden area. The squares are all located north of the 1 m^2 trench excavated by Binneman in 1995. Charcoal was recovered mostly in situ from each layer (spits) over the three squares and from the mesh (3 mm and 2 mm) that was used to sieve the excavated deposit. As with the comparative charcoal, archaeological charcoals were taken to the laboratory and studied using reflective light microscope that was fitted with objectives of up to 500X magnification and an image analysing software described above.

2.3. Taxonomic identification

The microstructure of archaeological charcoal remains was studied in detail along the Transverse Section (TS), Radial Longitudinal Section (RLS) and the Tangential Longitudinal Section (TLS) following the wood identification protocols promoted by the International

Fig. 2. The area, around Klasies River main site, that was surveyed for comparative wood samples. Wood samples for comparative analysis were sampled consecutively from Areas 1 to 5 as well as in the Milkwood Forest. The blue-dotted line demarcates the approximate limit of access to the landscape within all "Areas" that were sampled, due to the steep terrain.

Association for Wood Anatomists (IAWA) (Wheeler *at al.*, 2007; Baas and Wheeler, 2011). Useful elements of the anatomical microstructure of woods, such as vascular cell structure, tracheids, hard tissue cells (fibres), soft tissue cells (parenchyma) and wood ray cells, along with miscellaneous microfeatures were studied and described for each charcoal fragment. The microanatomical descriptions of these charcoal samples were compared with those of known wood species for a taxonomic identification.

Archaeological charcoal was identified using, mainly, the comparative species from the contemporary Klasies River landscape. In addition to this collection, numerous charcoal collections created during charcoal studies in southern Africa were consulted for the comparative analysis of archaeological charcoal in this study. These include comparative charcoal collections from the vicinity of Tloutle Rock Shelter and Rose Cottage Cave (Esterhuysen and Mitchell, 1996); Sibudu Cave (Allott, 2006); Bonawe, Colwinton and Ravenscraig Rock Shelters (Tusenius, 1986); Boomplaas Cave (Scholtz, 1986); Great Zimbabwe (Chikumbirike, 2014) as well as published descriptions of woody species from around Diepkloof Rock Shelter (Cartwright, 2013) and Elands' Bay Cave (Cartwright and Parkington, 1997; Cartwright et al., 2014).

A collection of fresh wood micrographs created for woody species from all over southern Africa and published by Kromhout (1975) was also referred to for comparative analysis in this study. An online 'InsideWood' wood and charcoal database (http://insidewood.lib.ncsu.edu/) with descriptions and micrographs of woody species collected throughout the world was also consulted for taxonomic identification of archaeological wood in this study. The taxa of archaeological charcoal were used to describe or interpret the past conditions by extrapolating the environmental conditions currently tolerated by the species (or their relatives) to the archaeological landscape. These conditions are documented in literature (Palgrave, 1980; Germishuizen and Meyer, 2003; Pooley, 2006; Venter, 2012; Van Wyk and van Wyk, 2013) as well as on the South African National Biodiversity Institute's online catalogue of southern African plants (pza.sanbi.org).

2.4. Analysis of the vascular structure

In addition, the vegetation of the late Holocene landscape around KRM was interpreted using the vascular structure of charcoal samples. The variation in the vascular structure of any wood species owes its origin, to some degree, to environmental parameters such as rainfall amounts (Creber and Chaloner, 1984; February 1992). The conductors of water- wood vessels - retain the microanatomical adaptations of the given plant to the amounts of water that was uptaken at various points of development (Carlquist, 1977). Studies such as those conducted by Scholtz (1986) and February (1992; 1993; 1994; 2000) suggest that a relationship between rainfall and vessel characteristics of southern African woody plants exists. This relationship is understood simply as: with increasing rainfall, vessel diameter increases while vessel frequency decreases (February 1992: 27). According to Carlquist (1977), the ratio of these vessel attributes (vessel diameter divided by the vessel frequency) otherwise known as the wood 'Vulnerability Index' (VI) provides a way to assess water availability for an individual plant.

The anatomical structure of charcoal fragments from two charcoal assemblages, contemporary vs. archaeological (c. 2300 cal BP), were compared using the VI calculated following Carlquist's (1977) method. This method determined that a lower wood VI indicates the wood's ability to withstand water stressful conditions. This means that the higher the VI of a plant, the more vulnerable it is to water scarcity. This index is an indicator of whether the plant is adapted to mesic or non-mesic conditions and can thus be used to suggest the abundance of water or moisture in their respective growth sites.

A VI below 1 indicates "Redundancy" in a plant and signifies the woody plant's ability to withstand conditions of water stress (Carlquist 1977: 891). This means that species with VI below 1 have better chances of surviving harsh or erratic climatic conditions such as drought and freezing. A VI between 1 and 2.5, on the other hand, indicates 'Mesomorphy' in any woody species. Mesomorphic plants are adapted to abundant water. This approach was used to compare the vulnerability of woods to understand the water scarcity and relative abundance of rainfall on the Klasies River landscape at present vs. c. 2300 cal BP.

3. Results

3.1. Taxonomic results

3.1.1. The comparative charred wood collection

Seventy comparative wood and leaf vouchers were identified and collected within the 1.5 km vicinity of KRM (Fig. 2). These vouchers belong to 50 of approximately 122 different woody species identified by the botanists in the contemporary KRM landscape between 2013 and 2015 (Van Wijk et al., 2017; 2019). Some of the common woody species sampled for this study include *Sideroxylon inerme, Nuxia floribunda, Ficus burtt-dayvi, Pterocelastrus tricuspidatus, Tarchonanthus littoralis, Diospyros dichrophylla, Searsia crenata* and *S. glauca*.

During the field survey for comparative woody species, it was noted that the microclimate on the contemporary Klasies River landscape has an influence on the growth of woody plants. For example, the shrubs and trees on the south-facing slopes at Klasies River are sculpted to a similar height by strong, salt laden onshore winds blowing landwards from the Indian Ocean. However, on the north-facing slopes they grow noticeably taller and un-sculpted. When analysed under the microscope, the longitudinal walls of most of the species were dominated by much fibre material that often impeded the visibility of ray cells. These fibres were also noted and described as generally thick for most comparative species from the transverse plane. The presence of fibres is consistent with general observations made during field survey that there are constant strong winds in the area. The functional role of fibres (hard tissue) in a plant is to reinforce the rigidity of a plant (Wheeler and Baas, 1991). Under conditions like those of the contemporary Klasies River landscape, woody vegetation is adapted to withstand windy conditions through increased fibre tissue, although this phenomenon needs further investigation.

3.2. The archaeological charcoal collection

The woody vegetation subset of the archaeological Klasies River landscape contains 60 different woody species identified from 911 charcoal remains. These represent 60 different wood types collected by the inhabitants of the cave c. 2300 cal BP and deposited in the Upper Midden of the LSA deposit. Seventeen of the 60 species were taxonomically identified. Fourteen of the 17 taxa are described in literature as trees, while four are described as either tall or dwarf shrubs (Table 1).

The archaeological taxa identified in this study are namely: *Loxostylis alata, S. lancea, Metalasia* cf. *muricata, T.* cf. *littoralis, N.* cf. *floribunda, Mystroxylon aethiopicum, P. tricuspidatus, Platylophus trifoliatus, D. dichrophylla, D. whyteana, Erica* cf. *glandulosa* subsp. *fourcadei, Grewia occidentalis, Podocarpus* cf. *latifolius, Zanthoxylum davyi* and *S. inerme*. Ten of these species were identified in the contemporary Klasies River landscape by Van Wijk et al. (2017). Seven of the species identified from archaeological charcoal are Fynbos species, and seven are coastal vegetation.

Ten species are thicket vegetation and fourteen species are classified as Afrotemperate forest species (Table 1). Fifteen of all 18 species that were identified in an archaeological assemblage occur on the Tsitsikamma Coast and at KRM today (van Wyk and van Wyk, 2013) and ten of them were identified in the contemporary KRM landscape by Van Wijk et al. (2017). The identified LSA woody species tolerate a

Table 1
The list of identified species along with the environmental conditions associated with their contemporary distribution. SRZ= Summer Rainfall Zone, WRZ= Winter Rainfall Zone and YRZ= Year-round Rainfall Zone.

Family	Genus and species	Frost tolerance (pza.sanbi.org)	Habitat (van Wyk and van Wyk 2013) (pza.sanbi.org) (Palgrave 1980)	Distribution of species according to Germishuizen & Meyer (2003) and van Wyk & van Wyk (2013) using rainfall zones mapped by Chase & Meadows (2007)			Vegetation types according to Mucina and Rutherford (2006) C= coastal vegetation, *F*= Afrotemperate Forest, fy= fynbos and *T*= thicket
				SRZ	YRZ	WRZ	
Anacardiaceae	*Loxostylis alata* (tree)	Light frost	Forest & riverine	x	x		T, fy
Anacardiaceae	*Protorhus longifolia* (tree)	Mild frost	Forest & riverine	x	x		F
Anacardiaceae	*Searsia lancea* (tree)	Some frost	Wide range	x	x		F, T
Asteraceae	*Metalasia* cf. *muricata* (shrub)	Tolerant	Along streams	x	x	x	T, C, fy
Asteraceae	*Tarchonanthus* cf. *littoralis* (tree)	Some frost	Dune & riverine	x	x	x	F, T, C, fy
Buddlejaceae	*Nuxia* cf. *floribunda* (tree)	Sensitive	Forest & stream	x	x		F
Celastraceae	*Mystroxylon aethiopicum* (tree)	Some frost	Riverine	x	x		F, T, C
Celastraceae	*Pterocelastrus tricuspidatus* (tree)	Tolerant	Forest	x	x	x	F, T, C, fy
Cunoniaceae	*Platylophus trifoliatus* (tree)	Sensitive	Wet habitats		x	x	F
Ebenaceae	*Diospyros whyteana* (shrub)	Some frost	Scrub & forest	x	x	x	F, T
Ericaceae	*Erica* cf. *glandulosa* subsp. *fourcadei* (shrub)	Sensitive	Coastal dune		x		fy
Malvaceae	*Grewia occidentalis* (tree)	Light frost	Forest	x	x	x	F, T, C
Malvaceae	*Hibiscus* cf. *tiliaceus* (tree)	Sensitive	Riverine	x	x		F
Podocarpaceae	*Podocarpus* cf. *latifolius* (tree)	Light frost	Forest	x	x	x	F
Rutaceae	*Zanthoxylum davyi* (tree)	?	Montane forest	x	x		F
Sapotaceae	*Sideroxylon inerme* (tree)	Tolerant	Dune forest & thicket	x	x	x	F, T, C, fy
Thymelaceae	*Passerina* sp. (shrub)	?	?	?	?	?	?

wide range of habitats. However, most species prefer to grow in areas or habitats with similar environmental traits. Most species (n = 12) can tolerate frost while only four are sensitive to it (Table 1).

Species such as *S. lancea, D. whyteana, G. occidentalis, P.* cf. *latifolius* and *S. inerme* currently occur under both tropical and temperate climates and their distribution does not indicate tolerance of any specific climatic regime. However, while tolerant of more than one climate *D. whyteana, G. occidentalis, P.* cf. *latifolius* and *S. inerme* grow mostly over areas that receive high amounts of precipitation under both climatic regimes. This is true for, especially, three species *D. whyteana, G. occidentalis* and *P. latifolius* whose current distribution ranges from low lying coastal (southern and eastern) regions to high altitude areas of southern Africa (Germishuizen and Meyer, 2003; van Wyk and van Wyk, 2013).

Six species, *M. muricata, Pterocelastrus tricuspidatus, T.* cf. *littoralis,* L. *alata, M. aethiopicum* and *Erica* cf. *glandulosa* subsp. *fourcadei* tolerate mild climate conditions (van Wyk and van Wyk, 2013). This is evidenced by their distributions that lie mostly over the southern Cape, although these species occur in the YRZ, WRZ and the SRZ (Germishuizen and Meyer, 2003; van Wyk and van Wyk, 2013). Five species were found to be widely distributed in the SRZ of southern Africa, excluding the dry inland areas of this zone. The distribution of these species begins from the low-lying southern Cape coast up to the east coast and high-altitude parts of the eastern escarpment. These are *Zanthoxylum davyi, Nuxia* cf. *floribunda, Protorhus longifolia* and *Hibiscus* cf. *tiliaceus* (van Wyk and van Wyk, 2013). *Protorhus longifolia* and *H.* cf. *tiliaceus* do not currently occur on the Tsitsikamma Coast where KRM is located (Germishuizen and Meyer, 2003; van Wyk and van Wyk, 2013). One species, *Platylophus trifoliatus,* is distributed now from the Tsitsikamma Coast to the coastal areas of the west coast. The distribution of this species suggests that *P. trifoliatus* is adapted to a temperate climate associated with only winter rainfall. Finally, one archaeological sample was identified to genus level as *Passerina* sp. So, without a species designation no inferences on its distribution could be made.

The woody species identified in this study occur, predominantly, in the YRZ (n = 17) followed by SRZ (n = 15). Only nine species are currently distributed in the WRZ. This suggests that the KRM region experienced more pronounced summer rainfall conditions around 2300 cal BP than winter rainfall conditions. More than 80% of the species (n = 15) identified in the archaeological assemblage currently occur in the SRZ, whereas less than 60% (n = 8) occur in the WRZ (Table 1). The contemporary KRM, just like the late Holocene landscape, is dominated by woody species that tolerate a year-round rainfall, but the present landscape has woody species that prefer a temperate climate (environment) rather than tropical climate (Van Wijk et al. (2017)).

The presence of *P. longifolia* and *H.* cf. *tiliaceus* in the archaeological charcoal assemblage of the study suggests that during the late Holocene they grew close to KRM and could be collected by inhabitants according to the Principle of Least Effort (Shackleton and Prins, 1992). Fig. 3 shows the microanatomy of the two species based on the archaeological wood charcoal samples from KRM. These species, however, do not occur near Tsitsikamma today (Fig. 4). Their current non-occurrence around KRM could be due to many factors, ranging from anthropogenic activity to environmental change along the southern Cape coast, since the late Holocene. The Tsitsikamma Coast has in recent years been favoured for farming, forestry and tourism which have significantly altered the natural landscape. This recent large-scale anthropogenic activity in the area may be responsible for the absence of *P. longifolia* and *H.* cf. *tiliaceus.*

Alternatively, extreme conditions such as wildfires and droughts are currently experienced along the southern Cape (Fitchett et al., 2016) and may limit the distribution of *P. longifolia* and *H.* cf. *tiliaceus* to just outside the Tsitsikamma Coast. In should be noted that the two species cannot tolerate extremely dry conditions (pza.sanbi.org). Frost and drought are often related and *P. longifolia* can only tolerate mild frost whereas *H. tiliaceus* cannot grow under any frost conditions. Both species, instead, prefer to grow in areas with plenty of water (Pooley, 2006). Their current distribution pattern suggests that both species are adapted to high amounts of rainfall that occur during summer (van Wyk and van Wyk, 2013). It is possible, therefore, that the late Holocene environment at Klasies River featured more pronounced tropical climatic conditions that were better suited for the growth of these two species.

3.3. Results for the analysis of the vascular structure

The Vulnerability Index (VI) of the comparative wood species from the contemporary KRM landscape in this study ranged between

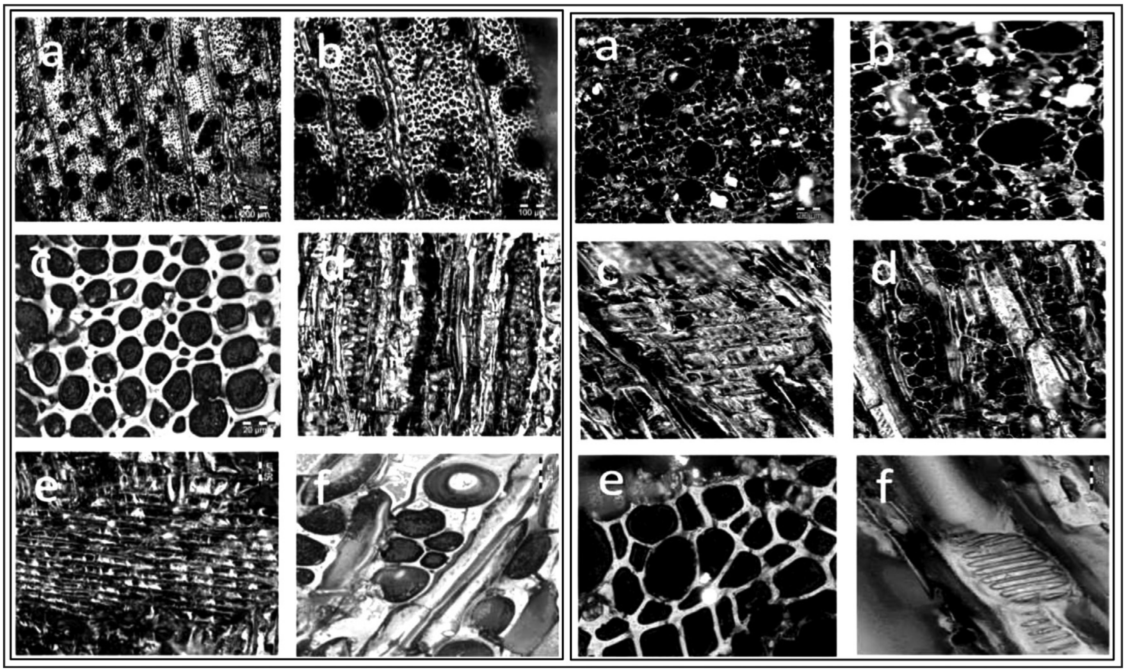

Fig. 3. The charcoal micrograph set of *Hibiscus* cf. *tiliaceus* (left, a-f) showing (a) solitary vessel arrangement; (b) the diameter of the vessel lumina; (c) fibre thickness/ lumina of fibre; (d) the triserriate ray cells; (e) the square and procumbent rays and (f) septate fibres. The scale bars (a)= 200 μm, (b)= 100 μm, (d)&(e)= 50 μm and (c) &(f)= 20 μm. The charcoal micrograph set of *Protorhus longifolia* (right a-f) showing (a) the solitary vessel arrangement; (b) the diameter of vessel lumina; (c) procumbent and square ray cells; (d) biserriate rays and simple perforation plates; (e) fibre thickness and (f) the scalariform perforation plates with 8–9 bars. The scale bars on (a)= 200 μm, (b)= 100 μm, (c)&(d)= 50 μm and (e) &(f)= 20 μm.

0.09 and 1.24 and had an average of 0.35 (Fig. 5). Only two species, *N. floribunda* and *F. burtt-davyi* with the VI of 1.24 and 1.18 respectively, have VI outside the safety range (i.e. above 1.00). The wood anatomy of species growing at the KRM landscape today is generally adapted to withstand water stressful environmental conditions. The archaeological charcoal collection, on the other hand, had VI with an average of 1.21. The values of these indices ranged between 0.03 and 7.23. Although the VI of the archaeological species had an average score that is outside the safety range (i.e. 1.21 is above 1.00), approximately 69% (n = 40) of the fragments have values within the safety range (Fig. 6). Thirteen species had a VI between 1 and 2.5, whereas five species had VI beyond the 'Mesomorphy' range, i.e. above 2.5. This implies that 31% (n = 18) of the woody species that grew at KRM around 2300 cal BP were not adapted to water stressed conditions and would have been vulnerable to environmental conditions such as drought and freezing conditions.

The VI of woody species of the contemporary (comparative taxa) and archaeological charcoal "types" is demonstrated in Figs. 5 and 6 respectively. Figure six shows the VI of all charcoal "types" (representing different taxa) including "types" that were not assigned taxonomic names. Approximately 96% (n = 46) of the contemporary comparative species are adapted to grow under water-scarce conditions while only 4% (n = 2) are characteristic of mesomorphic woody plants. Likewise, 69% of archaeological species (n = 40) appear to be 'Redundant' or adapted to conditions of water-stress. However, the archaeological assemblage has a higher proportion of species that are more vulnerable to water-scarce conditions (n = 18) compared to the present landscape (n = 2). This implies that archaeological woody vegetation at Klasies River, generally, featured species that did not tolerate aridity or drought-like environmental conditions.

The results of this study have shown that there may be a difference between the environment of the present vs. the 2300 cal BP

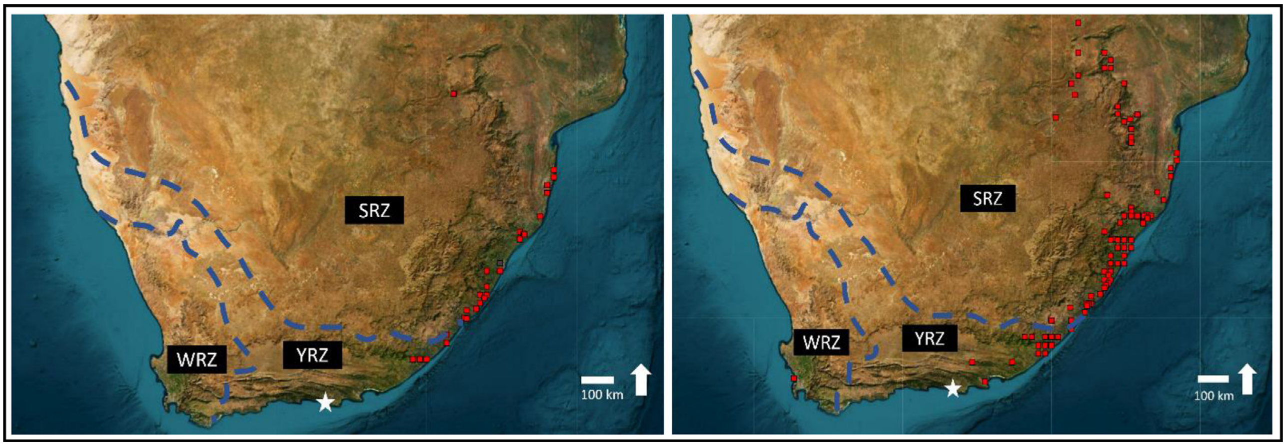

Fig. 4. The current distribution of *Hibiscus* cf. *tiliaceus* (left) and *Protorhus longifolia* (right) in southern Africa represented by red dots. The blue-dotted line defines the estimated boundaries of the Summer Rainfall Zone (SRZ), Winter Rainfall Zone (WRZ) and the Year-round Rainfall Zone (YRZ) after Chase and Meadows' (2007) map. The location of Klasies River main site is indicated by a star. Maps are modified from http://posa.sanbi.org/sanbi/Explore.

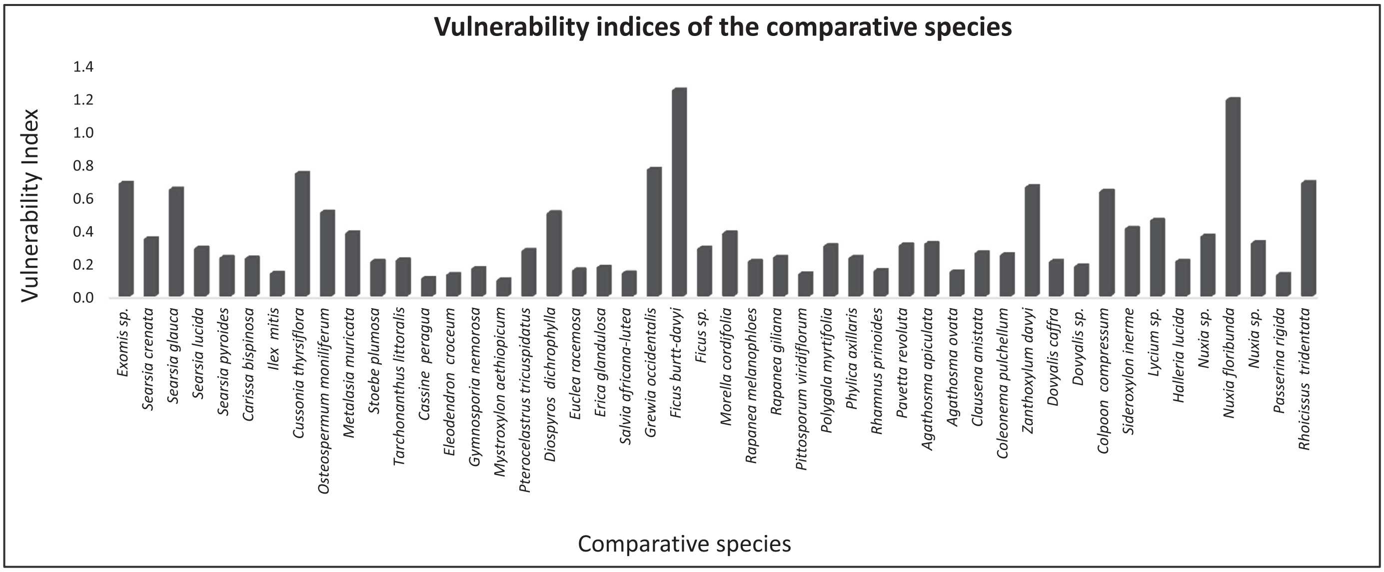

Fig. 5. The ‘Vulnerability indices’ of fragments from the collection of comparative species. Species are listed according to the alphabetical order of the family names.

KRM landscape. The taxonomic results indicate that, although there is combined influence of the tropical and temperate climate and a year-round rainfall pattern on the Tsitsikamma Coast, the effects of each of these regimes today compared to 2300 cal BP is notably different. The presence of two species, *P. longifolia* and *H.* cf. *tiliaceus* suggests that it is possible that the late Holocene landscape at KRM experienced a greater influence of tropical climatic conditions and that the current climatic setting, which is accompanied by more winter rainfall (Fitchett et al., 2016: 2), is no longer suited for the growth of these species. Furthermore, the seemingly tropical influence over the 2300 cal BP landscape at Klasies was accompanied by conditions of less aridity than the present time.

3.4. Regional comparison

3.4.1. The late Holocene environment at Klasies River

An accumulation of sediments with LSA cultural remains is associated with the mid and late Holocene period at KRM (Butzer 1978; Singer and Wymer, 1982; Binneman 1995). Two occupational sequences, in form of two middens (Lower and Upper Midden) were deposited from the mid to late Holocene and an occupational break separates these deposits. Butzer (1978: 147) reports that during the deposition of the Lower Midden (Layers KRM1–4 to KRM1–12) around 4825 – 4000 BP the sea was near the present level (Fig. 7). From 4650 BP, there was a marked decrease in sea level over the south-east coast of southern Africa (Ramsay, 1995). Evidence of sea level fluctuations documented from marine sources in the east, west and southern Cape coast, thereafter, suggest generally increasing sea levels between 3000 BP and 2000 BP followed by minor fluctuations before the present mean sea level was established (Miller et al., 1995; Ramsay, 1995; Baxter and Meadows, 1999; Strachan et al., 2014). For example, a rise in sea levels of between +2 to +1.5 m AMSL occurred on the east coast between 4000 and 2450 BP (Ramsay, 1995).

Butzer (1978: 146) reports *a* + 2 to +4 m AMSL sea level rise at Klasies River around 2450 BP (Fig. 6). This sudden change in sea level was associated with storm surges and resulted in the erosion of a significant portion of the Lower Midden (Butzer, 1978: 147). The Upper Midden layers (Layers KRM1–3 to KRM1–1), dated to 2300 cal BP,

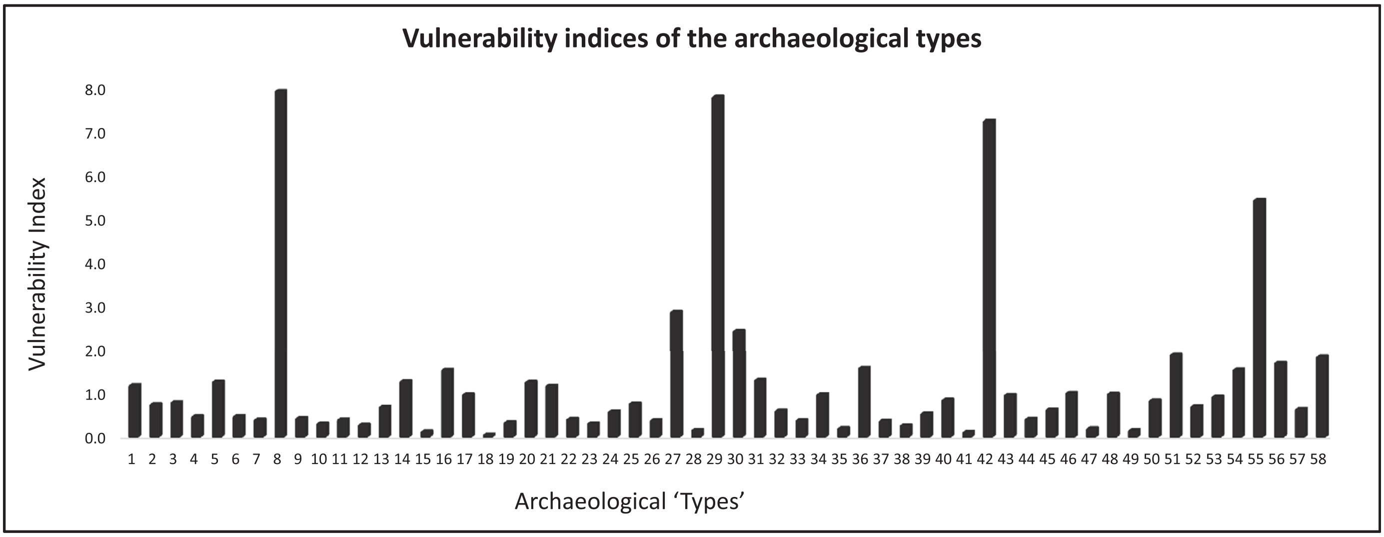

Fig. 6. The ‘Vulnerability indices’ of charcoal fragments from the archaeological charcoal assemblage. Species are listed according to the numerical order of their ‘Type’ numbers.

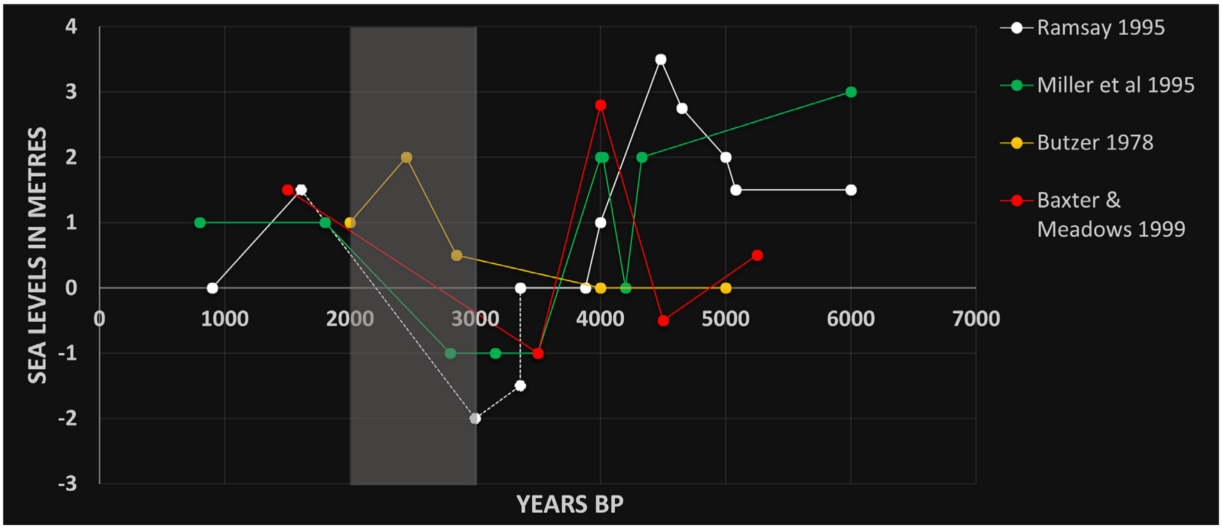

Fig. 7. Southern African sea level fluctuations from the mid to late Holocene period inferred from marine data from Klasies River (Butzer 1978), the south-east coast (Ramsay 1995) and south-west coast (Miller et al., 1995; Baxter and Meadows 1999). Only data with uncalibrated dates is included in this fluctuation curve.

are on top of the partly eroded Lower Midden layers (Butzer, 1978; Nami et al., 2016). The charcoal investigated in this study dates to this period when sea levels off the coast at Klasies River were approaching (dropping to) near present levels (Fig. 7) (Butzer, 1978).

Binneman (1995) and Mosweu (2016) report that throughout the LSA, inhabitants of KRM cave 1 collected more warm water-adapted shellfish species than cold water species. *Perna perna* and *Scutellastra tabularis* shellfish remains, species that are indicative of warm ocean waters, were deposited in the Upper Midden of the LSA deposit in cave 1 (Binneman, 1995: 120; Mosweu, 2016: 41). This suggests that marine conditions during the Late Holocene period, i.e. 2300 cal BP, were similar to the present warm Indian Ocean sea-surface temperatures and, based on the results of this study, warmer tropical, less arid climatic conditions influenced a significant part of the terrestrial condition at KRM.

3.5. The late Holocene environment along the southern Cape coast

The southern Cape, located entirely in the YRZ, receives winter and summer rainfall. In the beginning of the late Holocene (4 000 to 3 000 cal BP), mesic, warm environmental conditions associated with the establishment of the year-round rainfall regime replaced the mid-Holocene arid conditions (Chase and Meadows, 2007). During the late Holocene, stronger seasonality is reported at different periods in the southern Cape Coast (Kirsten, 2014). Bateman et al. (2011) suggest that the late Holocene sand dune sedimentation caused by the westerly winds along the Wilderness Embayment area, 160 km west of KRM, indicate the presence of predominantly winter conditions between 3700 and 2400 cal years BP. Deacon (1995: 123), on the other hand, suggests that the remarkably high amounts of δ^{13}C in the stalagmite from Boomplaas Cave, Cango valley, indicate the presence of high, summer temperatures between 3000 and 2000 BP in that part of the YRZ, although these would have been lower than those of the mid-Holocene Altithermal. Deacon (1995) argues that during this time, the dominance of summer precipitation (and higher temperatures) around Cango Valley favoured the growth of summer adapted C_4 grasses over C_3 grasses.

An analysis of soil sediments from the Groenvlei Lake, located c. 150 km west of Klasies River, indicate that the surrounding environment of the lake underwent rapid changes caused by sea level fluctuation (Wundsch et al., 2016). A dry phase (associated with winter rainfall seasonality) is reported in the period between 4200 and 2700 cal BP; during which two short-lived episodes of heavy rainfall occurred between c.3760- 3690 cal BP and 2910- 2820 cal BP. According to this study, it was only after the transition into the wet phase from 2710 cal BP onwards that the Groenvlei Lake, presently located in a YRZ, was influenced by summer rainfall seasonality. This summer rainfall, wet phase was marked by a transition of the lake from a marine-influenced to a freshwater system.

In another study in the Wilderness Embayment, late Holocene conditions were interpreted from pollen and diatom data from Eilandvlei Lake (du Plessis, 2015). They suggested that a dry phase occurred from 3800 to 3600 cal years BP. This phase was followed by a wet break, associated with winter rainfall, which prevailed until 3200 cal years BP. Thereafter a period from 3200 to 2500 cal years BP is correlated with summer rainfall in the surroundings of the lake (du Plessis, 2015). At Norga Peat site, George (located c. 200 km west of KRM), pollen assemblages from the site were analysed to understand the changes in the regional environment and climate in the last 4000 years (Scholtz, 1986). From 4000 to 2600 years BP, warmer, moister climatic conditions supported the spread of forest vegetation in the area. Drier (and perhaps colder) conditions were then suggested by the contraction of the forest and are dated between 2600 and 1400 BP.

4. Conclusion

Environmental data interpreted from marine resources along the southern Cape coast generally indicate that sea levels rose rapidly from below the present datum in the beginning of the late Holocene (Miller et al., 1995; Ramsay, 1995; Baxter and Meadows, 1999; Strachan et al., 2014). During this time, a warm period corresponding with wet, summer conditions was present in the southern Cape from at least 2710 cal BP (Wundsch et al., 2016). Scholtz (1986) places this period around 2600 BP, while du Plessis (2015) and Chase and Meadows (2007) locate it at 2500 cal BP. The presence of summer rainfall conditions is indicated by the occurrence of summer rainfall-adapted woody species that do not grow along the Tsitsikamma Coast at present. Similar to the conditions interpreted from the diatom data from Eilandvlei Lake (du Plessis 2015) and pollen assemblages from Norga Peat site (Scholtz, 1986), these conditions along the Tsitsikamma Coast were accompanied by an episode of less aridity.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to specially acknowledge the help of Ms. Madelon Tusenius who gave suggestions on the charcoal identification in this project. The project was funded by National Research Foundation (NRF) through Prof. Emeritus Lyn Wadley (University of the Witwatersrand) as well as by the Palaeontological Scientific Trust (PAST) grant (awarded to BZ for her MSc) in the year 2017. We also thank the constructive insights of the anonymous reviewer who reviewed this article.

References

Allott, L.F., 2006. Archaeological charcoal as a window on palaeovegetation and wood-use during the Middle Stone Age at Sibudu Cave. South African Humanities 18 (1), 173–201.

Baas, P., Wheeler, E.A., 2011. Wood Anatomy and Climate change. In: Hodkinson, T.R., Jones, M.B., Waldren, S., Parnell, J.A.N. (Eds.), Climate Change, Ecology and Systematics. (eds) Cambridge University Press, Cambridge, pp. 142–155.

Bamford, M.K., 2015. Charcoal from pre-Holocene Stratum 5, Wonderwerk Cave, South Africa. Palaeoecology of Africa 33, 153–174.

Bateman, M.D., Carr, A.S., Dunajko, A.C., Holmes, P.J., Roberts, D.L., McLaren, S.J., Bryant, R.G., Marker, M.E., Murray-Wallace, C.V., 2011. The evolution of coastal barrier systems: a case study of the Middle-Late Pleistocene Wilderness barriers. South Africa. Quat. Sci. Rev. 30 (1–2), 63–81.

Baxter, A.J., Meadows, M.E., 1999. Evidence for Holocene sea-level change at Verlorenvlei, Western Cape, South Africa. Quaternary International 56, 65–72.

Binneman, J., 1995. Symbolic Construction of Communities During the Holocene Later Stone Age in the South-Eastern Cape. University of the Witwatersrand, Johannesburg. Unpublished PhD thesis.

Binneman, J., 2001. An introduction to the Later Stone Age research project along the south-Eastern Cape coast. Southern African Field Archaeology 10, 72–87.

Binneman, J., 2006. Archaeological research along the south-Eastern Cape coast part 2: caves and rock shelters: Kabeljous River Shelter 1 and associated stone tool industries. Southern African Field Archaeology 15 and 16 57–74.

Butzer, K.W., 1978. Sediment stratigraphy of the Middle Stone Age sequence at Klasies River Mouth, Tsitsikamma Coast, South Africa. S. Afr. Archaeol. Bull. 33 (128), 141–151.

Carlquist, S., 1977. Ecological factors in wood evolution: a floristic approach. Am. J. Bot. 64 (7), 887–896.

Cartwright, C., 2013. Identifying the woody resources of Diepkloof Rock Shelter (South Africa) using scanning electron microscopy of the MSA wood charcoal assemblages. J. Archaeol. Sci. 40, 3463e–3474e.

Cartwright, C., Parkington, J., 1997. The wood charcoal assemblages from Elands Bay Cave, southwestern Cape: principles, procedures and preliminary interpretation. South African Archaeological Bulletin 52 (165), 59–72.

Cartwright, C., Parkington, J., Cowling, R., 2014. Understanding Late and Terminal Pleistocene Vegetation Change in the Western Cape, South Africa. In: Stevens, C.J., Nixon, S., Murray, M.A., Fuller, D.Q. (Eds.), Archaeology of African Plant Use. (eds) California Left, Coast Press, pp. 59–72.

Chase, B.M., Meadows, M.E., 2007. Late Quaternary dynamics of southern Africa's Winter-Rainfall Zone. Earth-Science Reviews 84, 103–138.

Chase, B.M., Faith, J.T., Mackay, A., Chevalier, M., Carr, A.S., Boom, A., Lim, S., Reimer, P.J., 2018. Climatic controls on Later Stone Age human adaptation in Africa's southern Cape. J. Hum. Evol. 114, 35–44.

Chikumbirike, J., 2014. Archaeological and Palaeoecological Implications of Charcoal Assemblages Dated to the Holocene from Great Zimbabwe and Its Hinterland. University of the Witwatersrand, Johannesburg. Unpublished PhD thesis.

Creber, G.T., Chaloner, W.D., 1984. Influence of environmental factors on the wood structure of living and fossil trees. The Botanical Review 50, 357–448.

Deacon, H.J. 1995. Two Late Pleistocene-Holocene Archaeological Depositories from the Southern Cape, South Africa. South African Archaeological Bulletin 50: 121–131.

Du Plessis, N. 2015. 4000 Years of Environmental and Climate Change At Eilandvlei: A Palynological Investigation into the Late Holocene Palaeoenvironment of the Wilderness Embayment. Unpublished MSc thesis. Cape Town: University of Cape Town.

Esterhuysen, A.B., Mitchell, P., 1996. Palaeoenvironmental and archaeological implications of charcoal assemblages of Holocene sites in western Lesotho, southern Africa. Palaeoecology of southern Africa and the surrounding islands 24, 203–232.

February, E., 1992. Archaeological charcoals as indicators of vegetation change and human fuel choice in the Late Holocene at Elands Bay, Western Cape Province, South Africa. J. Archaeol. Sci. 19, 347–354.

February, E.C., 1993. Sensitivity of xylem vessel size and frequency to rainfall and temperature: implications for palaeontology. Palaeontologia Africana 30, 91–95.

February, E.C., 1994. Rainfall reconstruction using wood charcoal from two archaeological sites in South Africa. Quat. Res. 42, 100–107.

February, E.C., 2000. Archaeological charcoal and dendrochronology to reconstruct past environments of southern Africa. S. Afr. J. Sci. 96, 111–116.

Fitchett, J.M., Grant, B., Hoogendoorn, G., 2016. Climate change threats to two low-lying South African coastal towns: risks and perceptions. S. Afr. J. Sci.. https://doi.org/10.17159/sajs.2016/20150262.

Germishuizen, G., Meyer, N.L., 2003. Plants of Southern Africa: An annotated Checklist, Strelitzia 14, (eds) South African National Biodiversity Institute, Pretoria.

House, A., Bamford, M.K., 2019. Investigating the utilisation of woody plant species at an Early Iron Age site in KwaZulu-Natal, South Africa, by means of identifying archaeological charcoal. Archaeol. Anthropol. Sci. 11, 6737–6750.

House, A., Bamford, M., Chikumbirike, J., 2022. Charcoal from Holocene deposits at Wonderwerk Cave, South Africa: a source of palaeoclimate information. Quaternary International 614 (20), 73–83.

Kirsten, K., 2014. Late Holocene Diatom Community Responses to Climate Variability Along the Southern Cape Coastal Plain, South Africa. Unpublished PhD Thesis. University of Cape Town, Cape Town.

Kromhout, C.P., 1975. 'n Sleutel vir die mikroskopiese uitkenning van die vernaamste in-heemse houtsoorte van Suid Afrika. South African Department of Forestry 50, 79–171.

Lennox, S.J., Bamford, M., 2014. Use of wood anatomy to identify poisonous plants: charcoal of Spirostachys africana. S. Afr. J. Sci. 111 (3/4), 1–9.

Lennox, S.J., Wadley, L., Bamford, M., 2015. Charcoal analysis from 49 000-year-old hearths at Sibudu: implications for wood uses and the KwaZulu-Natal environment. South African Archaeological Bulletin 70 (201), 36–52.

Lennox, S., Backwell, L., d'Errico, F., Wadley, L., 2022. A vegetation record based on charcoal analysis from border cave. KwaZulu-Natal, South Africa, ~227 000 to ~44 000 years ago. Quat. Sci. Rev. 293, 107676.

Lombard, M., Wadley, L., Deacon, J., Wurz, S., Parsons, I., Mohapi, M., Swart, J., Mitchell, P., 2012. South African and Lesotho Stone Age sequence updated. South African Archaeological Bulletin, 67, pp. 123–144.

Lombard, M., Bradfield, J., Caruana, M., Makhubela, T., Dusseldorp, G., Kramers, J., Wurz, S., 2022. The South African Stone Age Sequence updated (II). South African Archaeological Bulletin 77 (217), 176–212.

Lombard, M., van Aardt, A., 2023. Method for generating foodplant fitness landscapes: with a foodplant checklist for southern Africa and its application to Klasies River Main Site. J. Archaeol. Sci. 149, 105707.

Marker, M.E., Holmes, P.J., 2010. The geomorphology of the coastal platform in the southern Cape. South Afr. Geographic. J. 92 (2), 105–116.

Miller, D.E., Yates, R.J., Jerardino, A., Pakington, J.E., 1995. Late holocene coastal change in the southwestern cape, South Africa. Quat. Int. 29/30, 3–10.

Mitchell, P., 2005. Why Hunter-Gatherer archaeology matters: a personal perspective on the Renaissance and Renewal in southern African Later Stone Age research. South African Archaeological Bulletin 60 (182), 64–71.

Mosweu, K., 2016. The Environment and Coastal Adaptation During the Late Holocene (4800–2500 BP.) at Klasies River Main site, Southern Cape. Unpublished Honours Project. University of the Witwatersrand, Johannesburg.

Mucina, L., Rutherford, M.C., 2006. The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.

Nami, H.G., de la Peña, P., Vásquez, C.A., Feathers, J., Wurz, S., 2016. Palaeomagnetic Results and New Dates of Sedimentary Deposits from Klasies River Cave 1, South Africa. South African Journal of Science. doi.org/10.17159/sajs.2016/20160051.

Palgrave, K.C., 1980. Trees of Southern Africa. Struik Publications, Cape Town.

Pooley, E., 2006. Forest Plants: In the Forest and in the Garden. The Flora Publications Trust, Durban.

Prior, J., Price-Williams, D., 1985. An investigation of climatic change in the Holocene Epoch using archaeological charcoal from Swaziland, Southern Africa. J. Archaeol. Sci. 12, 457–475.

Puech, E., Bamford, M., Porraz, G., Val, A., Théry-Parisot, I., 2021. Evaluating sampling methods in charcoal-rich layers and high diversity environment: a case study from the Later Stone Age of Bushman Rock Shelter, South Africa. Quaternary International 593–594 (November 2020), 36–49.

Ramsay, P.J., 1995. 9 000 years of sea level change along the southern African coastline. Quaternary International 31, 71–75.

Scholtz, A., 1986. Palynological and Palaeobotanical Studies in the Southern Cape. University of Stellenbosch, Stellenbosch. Unpublished Phd thesis.

Shackleton, C., Prins, F., 1992. Charcoal analysis and the "Principle of Least Effort"- A conceptual model. J. Archaeol. Sci. 19, 631–637.

Singer, R., Wymer, J., 1982. The Middle Stone Age at Klasies River Mouth in South Africa. University of Chicago Press, Chicago.

Strachan, K.L., Finch, J.M., Hill, T., Barnett, R.L., 2014. A late Holocene sea level curve for the east coast of South Africa. S. Afr. J. Sci. 110n.1-2, 1–9.

Thamm, A.G., Johnson, M.R., 2006. The Cape Supergroup. (eds) In: Johnson, M.R., Anhaeusser, C.R., Thomas, R.J. (Eds.), The Geology of South Africa. The Geological Society of South Africa, Johannesburg, pp. 443–460.

Tusenius, M., 1986. The Study of Charcoal from Some Southern African archaeological Contexts. University of Stellenbosch, Unpublished M.A. thesis, Stellenbosch.

Tusenius, M., 1989. Charcoal Analytical Studies in the North-Eastern Cape. South African Archaeological Society: Godwin Series 6, 77–83.

Tyson, P.D., Preston-Whyte, R.A., 2000. The Weather and Climate of Southern Africa. Oxford University Press, Cape Town.

Van Wijk, Y., Tusenius, M.L., Rust, R., Cowling, R.M., Wurz, S., 2017. Modern vegetation in the Klasies River cultural landscape. Plant. Ecol. Evol. 150 (1), 13–34.

Van Wijk, Y.E., Rust, R., Uithaler, E.M., Wurz, S., 2019. Ethnobotanical research at Klasies River linking past, present, and future. Ethnobotany Res. Appl. 18, 1–24.

Van Wyk, B., van Wyk, P., 2013. Field Guide to Trees of Southern Africa. Struik Nature, Cape Town.

Venter, E., 2012. Trees of the Garden Route: Mosselbay to Storms River. Briza Publications, Pretoria.

Wheeler, E.A., Baas, P., 1991. A survey of the fossil record for Dicotiledonous wood and its significance for evolutionary and ecological wood anatomy. International Association for Wood Anatomists Bulletin 12 (3), 275–332.

Wheeler, E.A., Baas, P., Gasson, P.E., 2007. IAWA list of microscopic features for hardwood identification. International Association for Wood Anatomists Bulletin 10, 219–332.

Wundsch, M., Haberzettl, T., Kirsten, K.L., Kasper, T., Zabel, M., Dietze, E., Baade, J., Daut, G., Meschner, S., Meadows, M.E., Mäusbacher, R., 2016. Sea level and climate change at the southern Cape coast, South Africa, during the past 4.2 kyr. Palaeogeography, Palaeoclimate, Palaeoecology 446, 295–307.

Wurz, S., 2016. New Investigations at Klasies River main site. The Digging Stick 33 (3), 7–10.

Wurz, S., Bentsen, S.E., Reynard, J., Van Pletzen-Vos, L., Brenner, M., Mentzer, S., Pickering, R., Green, H., 2018. Connections, culture and environments around 100 000 years ago at Klasies River main site. Quaternary International 495, 102–115.

Wurz, S., Pickering, R., Mentzer, S.M., 2022. U-Th dating, taphonomy, and taxonomy of shell middens at Klasies River main site indicate stable and systematic coastal exploitation by MIS 5c-d. Frontiers in Earth Science 10, 1001370.

Zwane, B., Bamford, M., 2021. A reconstruction of woody vegetation, environment and wood use at Sibudu Cave, South Africa, based on charcoal that is dated between 73 and 72 ka. Quaternary International 593–594 (August 2021)95—103.

Zwane, B., Bamford, M., 2021. Wood Charcoal from Border Cave's Member 1RGBS: evidence for the Environment and Plant Use During MIS 5. African Archaeological Review 38, 657–674.

Zwane, B., Bamford, M., 2022. Possible avenues for archaeological charcoal studies in southern Africa? Preliminary studies using charcoal remains from Sibudu and Border caves. South African Archaeological Bulletin 77 (216), 48–56.