University of Reading

Prehistoric avian, mammalian and *H.sapiens* footprint-tracks from intertidal sediments as evidence of human palaeoecology

PhD in Archaeology

Department of Archaeology

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Declaration:

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged

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Abstract

Footprint-tracks can provide information about the footprint maker, including the species, age, sex, and height. Combined with other datasets, this can contribute to our interpretation of animal exploitation, population dynamics, seasonality and site usage. The study focuses on the Late Mesolithic intertidal site of Goldcliff East, Severn Estuary.

The formation of human footprints upon clayey silt sediment was studied. 177 participants were involved, aged between 3 and 72 years old. The relationship between footprint length, footprint width, age, sex, stature and weight was explored. The formation and identifying features of the footprints of 21 species of bird were also investigated.

856 Mesolithic footprint-tracks were recorded between 2001-2017. 342 were human, 270 bird and 67 mammal. A further 177 were possibly human, poorly eroded mammal or localised sediment disturbance. Eight species of bird were identified in this assemblage; 46% were common crane (*Grus grus*). The footprint-track trails of nine people were identified and combined with a further 12 from Scales' (2006) study.

Stature equations suggest that the average height of an adult was 166.5cm. Sex could only be determined as male in footprint-track trails with footprints over 30cm. It was not possible to identify a difference in foot length between adult females and children over 10 years old.

Footprints from Site M, N and S were made by humans walking north-east, and south-west, taking them towards and away from Goldcliff Island and a palaeochannel. 29% of the footprint-track trails were made by children. Archaeological and ethnographic evidence is presented alongside the footprint data, with the conclusion that Site N was used as a 'pathway' by children and possibly adult females to walk to a fishing area. Some of these children may have been aged 4 years or younger, suggesting that children played an active role in their society.

This thesis is dedicated to my grandparents Michael Milne, David Barr, Sylvia Barr and Patricia Milne

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Chapter 1

1.1 Introduction

The foot is an amazing mechanism, allowing us to walk, run, dance and jump. The foot also leaves a physical record of our presence on the landscape that we have walked upon, in the form of a footprint. When out walking in woodland you may see signs of dogs chasing rabbits or children chasing birds, on a sandy beach you may see the footprints of children playing. These footprints all tell a story, they are a snapshot of one moment. This is true of footprints made during prehistory as well as those that we see today, and it is the formation of a footprint, and what it can tell us about the maker, that this study is interested in.

Footprints at archaeological sites were once seen as curiosities, barely mentioned in site reports, and undergoing very little analysis. In recent years archaeologists and forensic scientists have begun to appreciate the worth of a footprint, with research suggesting a person's footprint size can reveal their height, weight, sex, age, gait and speed of movement. Footprints can also suggest something about the habitat or season, with avian and mammalian footprints enabling the identification of species, and inferences to be made about group composition, behaviours and seasonality. The focus of this study will be the Late Mesolithic footprint-tracks from Goldcliff East, Severn Estuary, Wales.

Although footprints are now considered to be an informative archaeological source, there is still a discrepancy in how the data is analysed and reported. Footprints are often considered as two-dimensional artefacts when in reality they are three-dimensional. Human footprints are assigned far greater importance than mammalian and avian footprints; avian footprints in particular are still neglected within archaeology. This study seeks to rectify the lack of consideration given to avian footprints whilst also emphasising the importance of human footprints as a way to understand the invisible people of the past, primarily children.

1.2 Key questions

- Which techniques are most effective at accurately recording footprints in the intertidal zone?
- Can experimental work create a dataset that contributes to the interpretation of prehistoric footprint data and their formation processes?
- Can patterns of movement be established from prehistoric footprints?
- What can footprints tell us about the life of a hunter-gatherer?
- Do children's footprints make up a large percentage of the archaeological assemblage?

- Does the footprint data suggest the seasonality of either human activity or animal/bird presence on the site?

1.3 Key aims

- To identify prehistoric species present on the intertidal zones via footprints and faunal remains
- To develop methods to quickly and accurately record footprint-tracks, specifically whilst working in the short tidal window in the low intertidal zone
- To undertake experimental work exploring the formation of footprints on estuarine substrate, the variations in size that may occur from one individual depending on sediment conditions and walking/running speed and to what extent the age of an individual can be established from footprint evidence
- To analyse patterns of movement to determine if humans appeared to be walking in the same direction, which may indicate a settlement area or a concentration of resources
- To determine if the patterns of movement on given sites change over time
- To determine the percentage of children present on study sites and what they may have been doing in this environment

1.4 Structure of the thesis

Part 1 will introduce the study of ichnology and consider the literature currently available regarding the study of footprints in both archaeological and modern settings. An introduction to the study area of the Severn Estuary with reference to the later Quaternary stratigraphy is also presented, with specific references to footprint sites found on the intertidal zone, and a focus on the main Mesolithic footprint-track site of interest, Goldcliff East.

Part 2 focuses on the methodologies adopted and developed in this research. Focus is given to the criteria required for identifying and recording human footprint-tracks. The anatomical structure of avian and mammalian feet, and the ways to identify and record these is also addressed. The chapter then addresses the formation of a footprint-track and specific footprint-track terminology that will be used throughout the study. Field recording methods and post-excavation methodology is provided. The chapter ends on a discussion of the advantages and disadvantages of utilising two techniques to record prehistoric footprint-tracks on the intertidal zone: optical laser scanning and multi-image photogrammetry.

Part 3 provides the results of this study, in the form of 4 chapters. Chapter 5 deals with an experiment which collected modern human footprint data from footprint trails made in clayey silt sediment. The purpose of this chapter was to understand to what extent a persons age, sex and stature can be established from their footprint trail. The findings of this chapter are then applied to Chapter 6, the results of the Late Mesolithic footprint-tracks from Goldcliff East. In this chapter the ratio of children to adult is established, as well as the statures, ages and speed of movement. Occasionally a male can be identified. Chapter 7 addresses both experimental work regarding the formation of avian footprint-tracks, and how this knowledge can be applied to the Goldcliff East footprint assemblage. The species of bird present at Mesolithic Goldcliff is presented, with reference to changes in migration behaviour and seasonality. Chapter 8 deals with the particle size of the laminated bands walked upon by humans and birds, and the seasonal implications of this data.

Part 4 provides a detailed discussion in Chapter 9, dealing with the avian, mammalian and human footprint-tracks at Goldcliff, and what they suggest about seasonality, population demographic, and the role of children in hunter-gatherer society. Chapter 10 provides a discussion regarding public engagement and impact on the Gwent Levels, Wales, with particular emphasis on the need for different sectors to collaborate to ensure the survival of intertidal archaeological sites. Chapter 11 ends the thesis by providing conclusions regarding the initial aims and questions posed in Chapter 1, as well as a consideration of the limitations of this study and suggestions for future research.

Chapter 2

The Significance of Footprint-tracks

Footprint Introduction

> 'there was exactly the very print of a foot, toes, heel, and every part of a foot; how it came thither, I knew not, nor could in the least imagine'
>
> Daniel Defoe, 1719, *Robinson Crusoe*

Throughout history humans have used footprints to understand the world around them. Folklore surrounding the phenomena of fossil footprints can be found across the globe, and attributed to giants, fairies, saints, 'cavemen' and gods (Mayor and Sarjeant 2001). Fiction is also inundated with reference to footprints; from Defoe's 'Robinson Crusoe' to Sir A.C. Doyle's 'Sherlock Holmes', footprints add a level of intrigue and mystery. Footprints can also be an indication of achievement, when we think of the success of the 1960's NASA moon landing the human achievement was not just the act of landing on the moon, rather it was the creation of footprints on the moon as a sign that humans had achieved this feat.

2.1 Ichnology

Ichnology is the study of animal traces and derives from the Greek word for track, *Ichnos.* These are the marks that have been left by an organism in sediment. Ichnology includes a wide variety of trace fossils including footprints, claw marks, tooth marks, burrows and coprolites to name a few. In this study it is the trace fossils of footprints that are of interest.

The study of footprint-tracks is still considered 'new' and because of this it is sometimes underappreciated as archaeological evidence. Footprint-tracks from humans, mammals and birds have been found at sites across the globe. This chapter will discuss some of these footprint-track sites and the key findings and contributions these sites have made, specifically to the study of population demographics. The sites discussed are just a sample due to the large number of sites with footprint-track evidence. At the time of writing, the author is aware of 91 footprint-track sites (Table 2.1). The table is not a comprehensive list of sites; there may be many more unreported sites or reports that have not been widely published. 71 (77%) of the sites in Table 2.1 have been discovered in the past 30 years. Although animal and avian footprint-tracks are found during many different geological periods, hominin sites are by far the most reported. 71 (77%) of these sites have evidence of human footprint-tracks. 49 (54%) footprint-track sites are from Europe, 29 (32%) of which are from the UK. Research at these sites has been focused on mammals as well as humans, demonstrating that Europe is leading the world in palaeoichnological research. Footprint-tracks are of interest as they are a record of human behaviour, such as human ecology, population demographic, subsistence strategies, seasonality and social behaviours.

Footprints are also studied by physical anthropologists. A portion of this chapter will discuss the anatomy of a foot, as well as previous investigations into what footprints can tell us about the person who made them, specifically their stature, weight, gait, sex and any deformities to the foot. The application of these techniques within forensic science is also considered, with emphasis on the work by Louise Robins, who worked with both archaeological and forensic footprints.

The chapter will end on a review of the Mesolithic skeletal evidence, as well as evidence of avian bones and mammal bones from prehistoric Britain. It is essential to consider the bone remains from humans and animals when dealing with footprint-tracks as these two sources are complementary.

Site	**Age**	**Species of footprint-track maker**	**Key references**
Pliocene			
Laetoli, Tanzania	3.66ma	Human and a large variety of mammals and bird	Leakey & Hay 1979
Lower Pleistocene			
Lowermost Bed II, Olduvai Gorge, Tanzania	1.75ma	Hippopotamus	Ashley 2003
Ileret, Kenya	1.5ma	Human	Bennet *et al.* 2009; Dingwall *et al.* 2013
Koobi Fora, Kenya	1.4ma	Human and large mammal - hippopotamus	Behrensmeyer & Laporte 1981; Bennet *et al.* 2009
Happisburgh, UK	0.78-1.0ma	Human	Ashton *et al.* 2014

Gombre II-2, Melka Kunture, Ethiopia	0.7ma	Human, ungulate, mammal, bird	Altamura *et al*. 2018
Mid Pleistocene			
Swanscombe, UK	c 420ka BP	Mammal - elephant, rhinoceros, cervid and bovid	Davis and Walker 1996
Terra Amata, France	c 400ka BP	Human	De Lumley 1966; Miskovski 1967
Roccamonifina, Italy	345ka BP	Human	Mietto *et al*. 2003; Avanzini *et al*. 2008
Late Pleistocene			
Nahoon point, South Africa	c 124±4ka BP	Human, bird, mammal	Roberts 2008; Mountain 1966
Langebaan, South Africa	c 120ka BP	Human	Roberts 2008; Roberts & Berger 1997
Vartop cave, Romania	62ka BP	Human	Onac *et al*. 2005
Theopetra cave, Greece	48ka BP	Human	Facorellis *et al*. 2001; Bennet and Morse 2014
Toluquilla, Valsequillo, Mexico	c 40ka BP	Human, dog, big cat, ungulate such as small deer, camels and bovids	Huddart *et al*. 2008
Ciur-Izbuc cave, Romania	36.5ka BP	Human	Webb *et al*. 2014
Chauvet cave, France	c 26ka BP	Human, bear and wolf	Clottes 2003; Harrington 1999; Garcia 1999
Willandra, Australia	23-19ka BP	Human, avian, kangaroo	Webb *et al*. 2006
Chusang, Tibet	20ka BP	Human	Zhang and Li 2002
Lascaux, France	17ka BP	Human	Barriere & Sahly 1964; Renfrew and Morley 2009
Ojo Guarena, Burgos, Spain	15.6ka BP	Human	Marcos 2001
MonteVerde II, Chile	c 14.6ka BP	Human, mammal, shorebird	Dillehay 1989, 1997; Meltzer *et al*. 1997
Tana della Basura, Italy	12ka BP	Human and bear	Chiapella 1952; Pales 1955, 1960

Fontanet cave, France	13-14ka BP	Human and dog	Delteil *et al*. 1972; Clottes 1975; Bahn & Vertut 1988
Niaux, France	12.8ka BP	Human	Breuil and Cartailhac 1907; Pales 1976; Clottes 1984
El Abadiya, Egypt	12.4ka BP	Wild cattle and hartebeest	Vermeersch *et al*. 2000
Buenos Aires Provine, Argentina	12ka BP	Human, bear, ungulate, cervids, rodent, birds	Aramayo & Bianco 2009
Pehuen, Pampean Plain, Argentina	12ka BP	Human, large and medium sized mammals and shore birds	Bayón *et al.* 2011
Engare Sero, Tanzinia	5760 ±30 BP - 19.1±3.1ka	Human	Richmond *et al*. 2011; Liutkus-Pierce *et al*. 2016
Calvert Island, British Columbia	11.2ka BP	Human	McLaren *et al*. 2018
Lake Bogoria, Kenya	Late Pleistocene, uncertain date	Human	Scott *et al*. 2008
Holocene **Europe**			
Grotte de Cabrerets, Pech Merle, France	10ka BP	Human	Begouen 1927; Vallois 1931
Demirköprü, Turkey	9ka BP	Human	Barnaby 1975; Ozansoy 1969; Westaway *et al*. 2004
Grotte Ald'ene, France	8.2ka -7.79ka BP	Human	Casteret 1948; Ambert *et al*. 2000
Druridge Bay, UK	7ka BP	Human, red deer, auroch	Waddington 2010
Istanbul metro, Turkey	6500-6000 BC	Human	Polat 2013
Low Hauxley, UK	6296-6160 BP	Human, red deer, auroch	Eadie & Waddington 2013
Lydstep II, UK	6150±120BP - 5300±100BP	Human and mammal	Murphy *et al.* 2014; Jones 2010
Goldcliff East, UK	c 5500-5200 cal BC	Human, deer, auroch, bird	Bell 1995; Scales 2006, 2007

Goldcliff East, UK	3130±70 BP (1610-1200 cal BC)	Cattle and ovicaprid	Barr and Bell 2016
Sefton coast, UK	5400-3200 cal BC; c 2000 cal BC; c 400 cal BC	Human, avian, deer, auroch and canine	Cowell *et al.* 1993; Roberts *et al.* 1996; Huddart *et al.* 1999a,b
Uskmouth, UK	c 5245 cal BC	Human,auroch, deer and bird	Aldhouse-Green *et al.* 1992
Femern Baelt Tunnel, Denmark	c 5ka BP	Human	Museum Lolland-Falster 2014
Seaton Carew, UK	Mesolithic – Neolithic transition. Date not given	Possible red deer, elk or young cattle	Rowe 2015
Magor Pill, UK	4500 cal BC	Human, auroch, deer and bird	Aldhouse-Green *et al.* 1992
Westward Ho!, UK	c 4000 cal BC	Red deer	Balaam *et al.* 1987
Port Eynon, UK	7ka BP	Human	Cardiff University News 2017
Oldbury, UK	3096-2135 cal BC	Auroch, red deer, cattle	Allen 1998a; Barr & Bell 2016
Gwithian, UK	3.8ka – 2.9ka BP	Cattle and ovi-caprid	Walker & Bell 2013
Kenfig, UK	3700-2200 cal BC	Human	Bennet *et al.* 2010
Peterstone, UK	Neolithic/Early Bronze Age	Auroch, red deer, domestic cattle	Bell 2013
Ullunda, Sweden	1400-1200 BC	Horse	Price 1995
Nola, Italy	3780 BP	Human	Mastrolorenzo *et al.* 2006
Lodbjerg dune system, Jutland, Denmark	3265 BP	Ungulate, canine, horse, ovi-caprid	Milan *et al.* 2006
Avellino, Italy	1830 cal BC	Human	Livadie 2002; di Vito *et al.* 2009
Jeju island, Korea	1750 cal BC	Human, mammoth, carnivores, birds	Kim *et al.* 2010, Sohn *et al.* 2015
Cold Harbour Pill, UK	2900-2520 BP	Human, auroch, cattle	Whittle 1989
Goldcliff West, UK	2460±35 cal BP	Cattle and possible deer or ovicaprid	Bell *et al.* 2000

Shaugh Moor, UK	1590 ±80 to 1390 ±90 BC	Cattle, sheep, horse, badger	Fowler 1981; Smith *et al* 1981
Borth, UK	c 2000-1000 cal BC	Human, cattle, ovi-caprid and possibly bear	Meek 2012
Must Farm, UK	900-800 BC	Human, cattle and possibly other mammals	Knight 2009
Greenmoor Arch, UK	525-195 cal BC	Cattle	Locock 1999
Redwick, UK	1691-1401 Cal BC	Human, ungulate, pig, possible horse	Bell 2013; Barr & Bell 2016
Rumney Great Wharf, UK		Cattle and sheep	Allen 1996
Rhyl, UK	5640-5360 cal BC	Deer, auroch and possible human	Bell 2007
Flagfen/ Fengate, UK	1350 - 950 BC	Cattle	Pryor 1998
Prestatyn, UK	Currently uncertain	Deer, ovi-caprid and bird	Bell 2007
Point of Ayr, UK	Currently uncertain	Deer, ovi-caprid and bird	Bell 2007
Kolhorn, Netherlands	Neolithic, date uncertain	Cattle	Bakels & Zeiler 2005
Tempranas cave, Spain	Currently uncertain	Human	Noval Fonseca 2007
Holme-next-the Sea, UK	2400-2030 cal BC	Cattle footprints	Brennand *et al.* 2003; Bell 2013
Holocene Americas			
Cuatro Ciénegas, Mexico	10,500 - 7,240 BP	Human, ungulate and webbeed avian	Felstead *et al.* 2014
La Olla, Argentina	6200-5500 cal BC	Human	Bayón *et al*. 2012
Oro Grande, California	6,190-5,700 BP	Human	Rector *et al.* 1984
Monte Hermoso, Argentina	5900 cal BC	Human, mammal and shore bird	Bayón *et al.* 2012
Third unnamed, Tennessee	5,210-4,830 cal BP	Human	Crothers *et al.* 2002

Unknown or unnamed Cave, Kentucky	3.6ka BP	Human	Crothers *et al.* 2002
Jaguar Cave, Tennessee	3000 cal BC	Human, jaguar	Willey *et al*. 2005, 2009
Mojave River, California	c 3000 BC	Human and mammal	Rector 1979; Rector *et al*. 1983
Salts Cave, Kentucky	1400-270 cal BC	Human	Watson 1969
Fisher Ridge Cave, Tennessee	2.7 -3.200 BP	Human	Watson 1982; Willey *et al*. 2005
Mud glyph, Tennessee	1.5ka BP	Human	Watson 1986
El Salvador, Mexico	0.2-0.8ka	Human	Haberland & Grebe 1957
Pocket Cave, Arizona	1.5ka BP	Human	Willey *et al*. 2005
Sequoyah Caverns, Alabama	0.64 -0.5ka BP	Human	Sneed 1984
Lon Odell Cave, Missouri	0.6ka BP	Human	Beard 1997
Footprint Cave, Virginia	0.4ka BP	Human	Crothers 1997; Willey *et al*. 2005
Kīlauea, Hawaii	0.2ka	Human	Jagger 1921, 1934
Holocene Africa			
El Azrag, Mauritania	9ka	Human	Mafart 2006
Acahualincia, Lake Managua, Nicaragua	c 4800 cal BC	Human, deer, birds, opposum	Bryan 1973; Lockley *et al.* (2009); Schmincke *et al*. 2009, 2010
Walvis Bay, Nambia	450-1450 AD	Human, ovi-caprid	Kinahan 1996; Morse *et al*. 2013
Namib Sand Sea, Namibia	320 ±40 BP	Human, cattle, sheep, goat, giraffe, elephant, bird	Morse *et al*. 2013
Holocene Australia and Asia			

Fowlers Bay, Australia	6ka BP	Human, kangaroo, wallaby, emu	Belperio & Fotheringham 1990
Gunma, Japan	0.8 -1.6ka BP	Horse	Inoue & Sakaguchi 1997

Table 2.1. List of world-wide footprint-track sites.

The above list is not definitive as there may be many more sites that have not been reported on, especially regarding mammalian and avian footprint-tracks. Dating footprint-tracks is notoriously difficult and not always attempted, so often footprint dates have to be assumed utilising associated archaeology or geology. Within this study calibrated dates are included when they are available; when they were not included in the original publication the laboratory number for the sample is included. This decision was made as the calibration curve is updated every few years, and the writer did not want to quote dates that did not correspond directly with the calibrated dates from the original research.

2.1.1 Palaeoichnology

The first published account of ichnology detailed preserved vertebrate footprints, investigated by Reverend Henry Duncan in 1827 (Pemberton *et al*. 2008). The footprints that he found, the Corncockle Muir footprints, were discovered in Scotland and underwent various different taxonomic classifications as experts argued about what the footprint-tracks represented. In 1842 Richard Owen classified the prints as *Testudo duncani,* incorrectly believing that they were a spoor of turtles. Reverend Buckland performed a neoichnological study, observing the tracks created by modern crocodiles and tortoises and the prints that they created, the conclusion being that the marks found on the sandstone of Scotland were created by the feet of ancient tortoises (Pemberton *et al*. 2008). Reverend Buckland’s neoichnological study was the start of this form of experimental ichnology, where modern animals were used as an analogue in understanding the footprints of the past. Although two-hundred years have passed since then, this technique is still highly relevant.

Since 1970 the discipline of ichnology has expanded, with hundreds of footprints being reported. This does not mean that before this time people were not finding these imprints, they may simply have been ignoring or misinterpreting them. In 1802 three-toed footprints about 12 inches in length were discovered in Massachusetts (Rose 2005). Local scholars were encouraged to identify the makers of the marks; it was decided that they had been made by ‘Noahs raven’. This was actually one of the first recorded cases of a dinosaur footprint being discovered, the prints being made not by a bird but by a large crocodile-like reptile. Cases involving the misinterpretation of footprints are not unusual, which suggests the need for experimental work which will aid in the identification of species (Rose 2005).

The discovery of the ‘Noahs raven’ reptilian footprints was just the start of multiple years of reptile and dinosaur footprint discoveries (Hitchcock 1858; Lockley *et al.* 1992; Romano and Whyte 2003). Dinosaur footprints gained interest from both academics and the public (Thulborn and Wade 1979, 1989). Archaeologists have one major advantage in the study of fossil footprints, this advantage is that in many situations the animal species that made the footprint may exist somewhere in the world, even if it is a different sub-species. This allows for comparative work in archaeology using known species, as opposed to the mainly extinct species that are studied by palaeontologists.

The discovery of preserved mammalian and avian footprint-tracks are just as significant as preserved hominin tracks as they can provide a wealth of palaeoenvironmental information regarding the diversity of the species in an area, and the environment in which they were living. Footprint-tracks can often reveal species density when the bone assemblage is missing, this allows the species present in the area to be considered even if the conditions were not suitable for bone preservation.

2.1.2 Laetoli: The rise of ichnological interest

There have been multiple sites worldwide where mammalian, hominin and avian footprint-tracks have been recorded; the most archaeologically famous is the site of Laetoli, Tanzinia. Mammal footprint-tracks were recorded in this area in 1976. Footprint-tracks subsequently discovered in the same area in 1978, made by a fully bipedal hominid, were dated by Potassium-Argon dating which indicated that they were made 3.66ma (Leakey 1984). The animals and hominids were all walking in an area of wet volcanic ash, subsequent falling volcanic ash cemented the footprints and preserved them in consolidated ash (tuff). They are exposed when splits form along the bedding plain (Hay 1987).

70 hominid footprint-tracks were recorded (Leakey and Harris 1987), forming trails up to 27m long, made by three bipedal individuals walking parallel to one another, though with a shorter gait than *Homo sapiens* (Charteris *et al.* 1981). The three trails were thought to have been made by an adult male, adult female and a child, with G1 being a probable child (120cm; 3’11”), G2 the male (180cm; 5’10”) and G3 the adult female (140cm; 4’7”), and were possibly representative of a family group (Leakey and Harris 1987).

Approximately 150m away from the trails made by G1, G2 and G3, a new site (Site S) revealed two further footprint-track trails made by two bipedal individuals (S1 and S2), S1 is thought to be male (168cm; 5’6”), and S2 female (149cm; 4’10”) (Masao *et al*. 2016). The footprint-tracks correspond to the same footprint-tuff G1-G3 were preserved in and were also parallel to them, which suggests that they were contemporaneous.

Extensive research has been performed investigating the human bipedal biomechanics, and the possibility that the footprints from Laetoli were created by apes with bent-knee-bent-hip bipedal stances, or the *Homo sapiens* method of walking with extended limb biomechanics (Raichlen *et al.* 2010). Bent-knee-bent-hip gaits have a much deeper toe depth in comparison to the extended limb gait of humans. The Laetoli prints demonstrate very shallow toe depths, suggesting they were made by straight legged individuals rather than those that walked with bent-knee-bent-hip, indicating that by the Plio-Pleistocene hominids had evolved to walk with extended limbs (Raichlen *et al*. 2010). The Laetoli footprint-tracks are generally thought to have been made by *Australopithecus afarensis*.

As well as hominin footprint-tracks, 529 mammal and bird footprint-tracks were recorded at Site S, with bovid dominating the record. The bird and mammal footprint-track record from Laetoli suggests a palaeoenvironment with dry bushland, woodland, open grassland and riverine forest, with the large amount of bovid suggestive of rainy season migration (Masao *et al*. 2016).

Due to erosion and the risk of physical removal of the prints, the area had to be re-covered fairly soon after the 1970’s excavation. Casts of the footprints were taken before this occurred for further study, so the analysis of Laetoli footprints in subsequent years has been from the casts rather than the original footprint-tracks. It is important to be aware of this when considering the Laetoli data, as it is possible that some casts may not accurately capture the footprint dimensions appropriately. To provide further information for all those who would be unable to access the footprints, researchers also created three-dimensional contour mapping by performing very basic photogrammetry on the casts (Raichlen *et al*. 2010). Recent work by Masao *et al*. (2016) has created accurate multi-image photogrammetry records directly from the Site S footprint-tracks (Figure 2.1).

Figure 2.1 Laetoli footprint-tracks S1 and S2 recorded using Structure for Motion technique (Masao et al. 2016)

2.1.3 Palaeolithic Ichnology

Footprint-track site locations during the Lower Palaeolithic are almost entirely found in Africa (Table 2.1), in muds buried by volcanic tuff. The footprint-track site at Happisburgh is not only found in a different sedimentary context to the African sites, but this site was found on the coast of Norfolk, England. Continuous erosion of cliffs and the movement of modern beach deposits exposed a series of laminated banded sands and silts which infill channels, these banded laminations are generally flat, however one area, about 12m^2, was covered in hollows and disturbances to the laminae. These laminations were above gravels that contained flint artefacts (Ashton *et al.* 2014). There were 152 hollows in the laminated sediments which could have been footprint-tracks, none of which were of a length or width to suggest animal instead of human. The depth of the hollows suggests that soft-stiff mud was being walked upon. Twelve of the footprint-tracks were complete outlines of the foot, allowing for accurate measurements which enabled stature, possible age and weight to be suggested. These twelve footprint-tracks were thought to be from five individuals, ranging in stature between 0.93m (3’0”) to 173cm (5’8”) (Ashton *et al*. 2014). Only three of the footprint-tracks are thought to have come from full-grown adults, the other nine were likely from children. The footprint-track assemblage at Happisburgh suggests that adults and children were out foraging together on the mudflats, there was no age division of labour. The Happisburgh deposits are thought to date between 0.78-1ma (Parfitt *et al*. 2010), this site changes what was previously known about the record of human occupation in northern Europe, occurring at least 350,000 years earlier than previously thought

(Ashton *et al*. 2014). The age of the site and the overall foot size and stature of the Happisburgh individuals is most similar to estimates of *Homo antecessor* (Ashton *et al*. 2014; Pablos *et al*. 2012).

The Happisburgh footprint-tracks were recorded using multi-image photogrammetry (Figure 2.2) and laser scanning, although the footprint surface was rapidly eroding the use of these techniques enabled prompt recording of the features with the metric dimensions able to be analysed and re-examined at a later date (Ashton *et al*. 2014). The fieldwork at Happisburgh is the first ichnolological study to utilise a variety of techniques designed for rapid and accurate digital recording on intertidal zones. These techniques demonstrate the potential of creating data that can be made easily accessible to researchers worldwide.

Figure 2.2 Multi-image photogrammetry model of a footprint-track from Happisburgh (image by Sarah Duffy)

The 'Devils footsteps' in Roccamonfina, Italy, are hominin footprints preserved within the ash from a volcanic eruption. Dating using 40AR/39AR gives a date of 345ka BP (Mietto *et al.* 2003; Avanzini *et al*. 2008), which led Scaillet *et al*. (2008) to suggest that the species responsible for the footprints were *Homo heidelbergensis*. Three trails containing up to 56 footprint-tracks were recorded, all narrow, with a mean footprint size of 20cm, a pace of 60cm and a stride of 120cm. These individuals were fully bipedal, but with a stature of no more than 135cm (4'5"), though they are thought to be adult (Mietto *et al.* 2003). The footprint-tracks were created on an elevated surface, on a slope of about 80°; there was evidence of one individual slipping on this elevation, as there were handprints on the surface as well as footprints. The slope may affect the appearance of the footprints as opposed to footprints created on a flat surface, which could lead to a misinterpretation of stature data if relying upon the gait alone. Plans, photographs and diagrams were made to record these footprints, although there is little detail about the precise method utilised for recording.

Many footprint-tracks from the Palaeolithic are difficult to date due to poor preservation, or not being dated or recorded thoroughly when first discovered, resulting in loss of data. Ciur-Izbuc Cave, Romania, is an example of this; the footprint-tracks were first discovered in 1965. They were made in clay/silt sediment on the cave floor, the sediments were possibly transported there through water flow such as flooding (Webb *et al.* 2014). There were approximately 400 human footprint-tracks in the Ciur-Izbuc cave, excavators marked 230 of these with metal flags inserted into the soft sediment by the footprint-tracks. Although recording began it was never fully completed; Rişcutia and Rişcutia (1970) published information about 188 of the footprint-tracks that had been measured and cast, however the subsequent data about the remaining 212 footprint-tracks was lost (Webb *et al*. 2014). Archaeologists returned in 2012 to attempt to carry on recording, although by this point vast amounts of data had been lost due to people entering the cave and walking upon the footprint-tracks. Webb *et al.* (2014) radiocarbon dated the site from bear bone fragments to 36.5ka cal BP (Poz54805), and created stature estimates for the individuals recorded by Rişcutia and Rişcutia (1970), with one tall male evident (188cm, 6’2”). It is thought that six or seven individuals made the footprints in this cave and would have been in the cave less than 10 minutes as there are very few footprint-tracks compared to the size of the cave. This may indicate the entrance to the cave collapsed soon after the footprint-tracks were made (Webb *et al.* 2014).

Children are prominent in the footprint-track record, which is significant as they are often invisible within archaeological datasets. The site of Gombore II-2, Melka Kunture, Ethiopia is rich in archaeological data, with evidence of butchery and flint knapping activities (Chavaillon and Piperno 2004), as well as preserved footprint-tracks (Altamura *et al*. 2018). The footprint-tracks were made upon silty substrate at the edge of a water source; this body of water would have periodically flooded the footprint area, depositing fine-grained sediment upon which new footprint-tracks were then made. The site was then preserved by an ash flow surge dated to 0.7ma (Morgan *et al*. 2012). Footprint-tracks were made by a variety of species including gazelle, hippopotamus, and birds (Altamura *et al*. 2018). 11 possible human footprint-tracks were recorded in this area, two were adults over 18 years old, the rest were children all estimated to be aged three or younger, with three footprint-tracks thought to belong to infants under 12 months old. Altamura *et al*. (2018) tentatively suggest that the footprint-track evidence at this site indicate that children were present during knapping and butchery activities and may even have handled the tools so that they could learn important skills.

Theopetra Cave, Greece, dated 48ka BP, contained footprint-track evidence of children, made in clay at the bottom of the cave. The footprint-tracks were made by four juveniles aged between four and seven years old (Facorellis *et al*. 2001), indicating that these children may have had a specific purpose in these liminal areas, either due to their small size and ability to get further into a cave to get at specific resources, for ritual reasons, or to play. Fontanet cave, France contains cave art near the front of the cave dated to 13-14ka BP, and further back into the cave are foot, knee and handprints made by a child who appeared to have been chasing a puppy or a fox across the clay floor (Delteil *et al.* 1972; Clottes 1975; Bahn & Vertut 1988). The abundance of juvenile footprint-tracks is seen throughout the Palaeolithic, from a variety of different contexts. The children of prehistory appear to have been involved in activities, being given responsibilities from a young age as well as being allowed to play.

The increase in the recognition and recordings of Palaeolithic footprint-track sites has resulted in the utilisation of unconventional methods to better understand prehistoric individuals. At Willandra Lakes, Australia, Webb *et al*. (2006) recorded 123 human footprint-tracks made by approximately eight individuals from a group of children, sub-adults and adults. Subsequently approximately 700 footprint-tracks from a variety of species have been recorded, 400 of which have been identified as humans who formed 23 trails (Webb *et al.* 2006; Webb 2007). The footprint-tracks were exposed in laminated calcareous silts, on a 700m^2 hardpan ‘pavement’ near the shoreline of a lake basin, they had been buried and preserved by Aeolian sand. The footprint-tracks were dated by Optically Stimulated Luminescence to 23-19ka BP (Webb *et al*. 2006; Webb 2007). Although these footprints are from the Palaeolithic, the advantages of a site such as Willandra Lakes is that Australian Aborigines still live near the area; they are generally unshod and so their anatomy has not been altered artificially by shoes. A large study involving measuring the footprints of 478 central Australian Aborigines was performed by Campbell *et al*. (1936). With these dimensions Webb *et al*. (2006) interpreted the prehistoric data and were able to make suggestions about the presence of children and adults, and the statures of individuals. One individual, T1, had an estimated stature of 1.98±0.15m (6’5”), another individual, T8, had an estimated stature of 1.94±0.15m (6’4”) and had a pace that suggested they were running at approximately 20 km/hr (Webb *et al*. 2006). The lakes were most likely being utilised by the hominins to hunt terrestrial game such as kangaroo, lake birds, to fish and to gather food (Webb *et al*. 2006).

The Willandra Lakes evidence demonstrates the importance of experimental work with modern human footprints, enabling footprints to be assigned stature using scientific methods rather than assumptions. Although Webb *et al*. (2006) provide a thorough analysis of the footprint-tracks, they do not specify the way in which they recorded the footprints or any exclusion factors, such as excluding measurements from indistinct shapes. They also work on the assumption that the foot to stature correlation is universal among humans, whereas the correlation does in fact seem to be influenced by geographical origins among *H.sapiens* (Chapter 2, Table 2.2).

2.1.4 Mesolithic Ichnology

Mesolithic footprint-tracks are predominately recorded in Europe, with intertidal zones in Britain being the main sites for this ichnological research (Table 2.1). At Low Hauxley and Druridge, Northumberland, footprint-tracks from Mesolithic adult and juvenile *H.sapiens*, and cloven-hoofed animals such as auroch and red deer have been recorded on exposed intertidal peat beds overlain with sand (Eadie and Waddington 2013). At Low Hauxley the peat where there have been 269 possible footprint-tracks identified was dated to 6296 ±34 BP (OxA-22735; 5330–5210 cal BC; Eadie and Waddington 2013). This peat was located below a Bronze Age cemetery.

90 of the footprint-tracks were identified as possible human, and 88 possible animal footprint-tracks. A further 91 depressions were identified as disturbance to the peat but were too indistinct to identify. The human footprint-tracks are relatively short, the smallest is 8cm in length, and the longest 22cm, indicating children and possibly adult females made the footprint-tracks, small adult males may have made some of the larger footprints. It is suggested that due to the lack of toe impressions preserved and the ‘smooth’ edges of the footprint-tracks that these individuals were shod (Figure 2.3; Eadie and Waddington 2013). This may be the case, however it is also conceivable that the peat had experienced erosion and any anatomical detail has been smoothed, or that the surface was relatively soft when originally walked upon preventing detailed preservation. The footprint-tracks are noted as being ‘smudged’ and having evidence of ‘dragging’, which again may be caused by a taphonomic process or is evidence that the supposed footprint-tracks seen in the peat are not from the actual footprint level. Figure 2.3 is the image provided of the human footprint-tracks from this site, the author would argue that although it is possible that these individuals were all shod, the smooth appearance of the peat and the edges of the footprint-tracks is more suggestive of erosion of the peat rather than evidence of footwear. Cloven footprint-tracks were mainly from red deer, though wild boar and auroch were also present within the assemblage (Eadie and Waddington 2013). There has not been a huge amount of research dedicated to these footprint-tracks, they are only briefly addressed in the site report and there is no information regarding how they were recorded. Although mentioned briefly, the recognition of footprint-tracks at this site is important. The

recording of all the lengths allows for this group of individuals to be identified as predominantly children and adult women, who may have been hunting, gathering or fishing in the area.

Figure 2.3 Human footprint-track trail at Low Hauxley made upon intertidal peat (Eadie and Waddington 2013; Figure 7)

The west coast of Britain, specifically the intertidal zone of the Severn Estuary, is particularly rich in Mesolithic footprint-track sites (Aldhouse-Green *et al*. 1992; Bell 1995; Scales 2006, 2007). These sites will be discussed in Chapter 3, as Goldcliff East is found in this area and is the main site of interest to this study, and is relatable to the other Mesolithic intertidal sites on the Severn Estuary.

2.1.5 Ichnology from the Early Farmers

Britain is rich in footprint-track evidence from the Neolithic, with intertidal sites being particularly informative. Footprint-tracks from *H.sapiens* and many species of animals have been recorded at Merseyside, which is located on the west coast of England in a wetland area.

These footprint-tracks are found preserved in silt laminations, interspersed with sand and are above the mid Holocene marine-clays (Roberts and Worsely 2008, p 30). The palaeoenvironmental history and the Holocene coastal sequence of the Merseyside coastland has been extensively investigated by Tooley (1970; 1974; Pye and Neal 1993), though the importance of Formby Point was not fully appreciated until 1989. In 1989 Gordon Roberts observed footprint-tracks of a variety of species which he began to systematically record (Roberts 2014). It was these footprint-tracks that began to attract archaeological attention to Formby Point (Huddart *et al*. 1999a,b; Roberts *et al*. 1996; Roberts and Worsley 2008). Since 1989 an archive of over three thousand photographs has been built from the evidence that spans over 4km of the shoreline. Measurements of the footprint lengths, widths, and when there was a trail the stride length and pacing have also been recorded (Figure 2.4; Roberts *et al*. 1996). Plaster casts of some of the footprint-tracks were made from well-preserved prints, some have been laser-scanned and contour plots were made (Bennet *et al*. 2010).

Gordon Roberts was active daily at Formby Point until 2006 (Roberts 2014), and was an enthusiast of the archaeology until his death in 2016. He was not a professional archaeologist, however he was diligent in monitoring the coastline and was able to see features that had previously gone unnoticed. Roberts involved a number of environmental scientists in working on the sequence at Formby. Although there have been several articles written on the Merseyside footprint-tracks (Cowell *et al*. 1993; Huddart *et al*. 1999a; Roberts *et al*. 1996), these have all been preliminary and interim reports rather than a detailed publication of the footprint-tracks or the dating evidence.

Bovid hoofprints were the first footprint-tracks recognised at Formby, from the Iron Age context. These were radiocarbon dated to 2510±120 ^{14}C BP using the wood within the peat stratum where the footprint-tracks were found (Tooley 1970, 1974). The dating of the footprint-tracks observed by Roberts is rather more complicated. The footprints occur in two main horizons, the lower horizon was OSL dated and the upper horizons were radiocarbon dated. Dates established through OSL were from sediment samples taken from near the ‘stepped’ strata where both red deer and human footprints were noted (Roberts and Worsley 2008, p 38). The sample taken from the sediment of minus 30cm deep was dated to 6650±700 years BP, whereas the sample from minus 10cm deep was dated to 5750±600 years BP (Roberts and Worsley 2008, p 38). Another date was also established through radiocarbon dating, obtained from red deer antlers discovered in the same strata as red deer hoof prints, dated to 4450±45 ^{14}C BP (OxA-9130), suggesting a Late Mesolithic/Early Neolithic date (Roberts and Worsley 2008). From the upper horizon three dates were obtained for the footprints from the wood in the peat, 3230±80 ^{14}C BP (Pye and Neal 1993), 3333±83 ^{14}C BP and 3649±109 ^{14}C BP (Gonzalez *et al*. 1996). Further radiocarbon dates were established by dating *Alnus* roots that were growing into the surface of the footprints, these were dated to 3575±45 ^{14}C BP suggesting that the area continued to be walked upon throughout the Bronze Age until the Iron Age (Roberts and Worsley 2008, p 38). Due to a lack of organic material in many of the higher and lower stratigraphic layers the dates are not entirely reliable and the date sequence is not completely clear, although the radiocarbon dates do suggest they are at least Neolithic/Early Bronze Age in date and some may be of Mesolithic date (Huddart *et al.* 1999a; Roberts & Worsley 2008).

Since 1990 there have been 219 human footprint-track trails recorded at Formby Point, 179 of these have been well preserved, enabling the stature, gait, speed of movement, sex, and age of the individual to be calculated (Roberts and Worsley 2008). These individuals were generally unshod, though there were some with a shod appearance suggesting they were wearing footwear similar to moccasins. Analysis of 75 of the footprint-track trails by Roberts (1995) suggested that those made by adult females would have had an average stature of 145cm (4’9”) and adult males 166cm (5’5”), though the majority of footprint-track trails were made by children, with certain prints suggesting that they were playing (Roberts and Worsley 2008, p 36).

The foot health and certain anatomical features of individuals were also suggested to have been captured in the footprint-tracks of four individuals (Figure 2.5; Roberts 2009). A plaster cast taken of one footprint indicated that the metatarsals had collapsed but the *peroneus longus* and the *tibialis posterior* tendons had thickened to substitute for an abnormality, though the individual had still managed to walk with a normal gait (Roberts 2009; Roberts and Worsley 2008). Roberts (2009) also reported a footprint, which was identified as that of an adolescent female, which indicated that the individual had an awkward gait, putting a large amount of weight on the heels rather than the balls of the feet; the feet were arched with the toes curled under to maintain grip in the mud. There have been multiple suggestions as to the reasons the individual was walking in this manner, one suggestion being that she was heavily pregnant and was walking awkwardly due to the weight of her child, another may be that she was a healthy individual who was simply returning with some type of basket full of heavy items after a fruitful day of gathering. The final explanation Roberts (2009) gave for the appearance of the footprints was a pathological one; that the curvature of the feet may be an indication of *pes cavus*, which may be caused by certain medical conditions such as diabetes or Friedreich’s ataxia. The extent of detail noted in these footprints is impressive, though unfortunately further analysis and interpretation of these footprints by others has proven difficult due to lack of published detailed photographic evidence of more than two footprint-track for each of the four individuals.

Figure 2.4 Example of a well-preserved human footprint-track trail at Formby (photograph courtesy of Gordon Roberts)

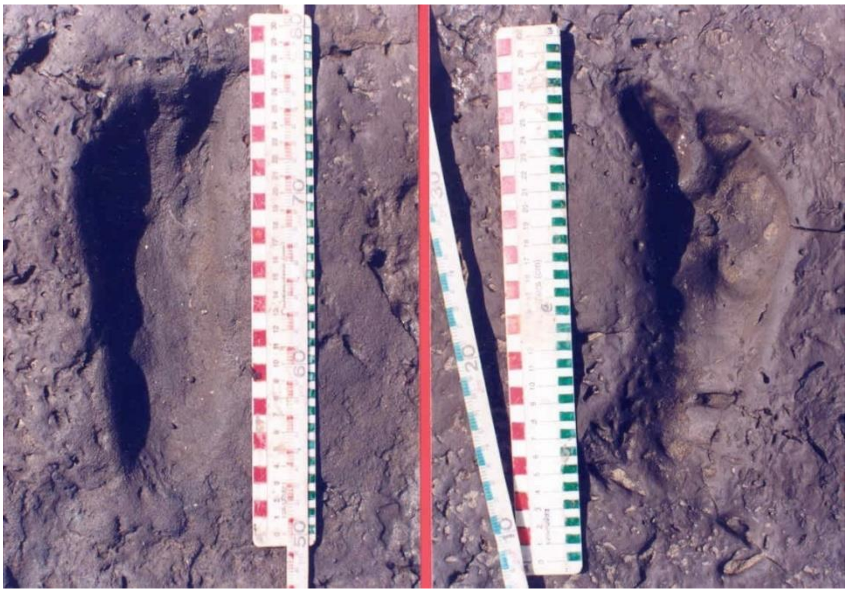


Figure 2.5 Left and right footprint-tracks from Formby Point. The deformed appearance of the footprint may be due to ectrodactyly (split foot malformation). (Photograph courtesy of Gordon Roberts)

There are a variety of mammal footprint-tracks at Formby, including roe and red deer, wild boar, aurochs, and multiple wading birds, as well as oystercatcher and crane (Figure 2.6). The adult male *H.sapiens* footprint-tracks are often associated with red deer which is suggestive of hunting activity (Figure 2.7; Roberts and Worsley 2008, p 31). Domestic animals can also be seen in the footprint-track record, represented by cattle, ovicaprid, horse and possible dog. Although there is no specification of the exact number of mammal and avian footprint-tracks, Robert and Worsely (2008, p 31) state that oystercatcher were the most numerous.

Figure 2.6 Footprint-tracks of a crane, probably more than one bird (Photograph courtesy of Gordon Roberts)

Figure 2.7 Footprint-track trail at Formby of an adult human intercepting the tracks of a red deer, possibly indicating hunting activity (Photograph courtesy of Gordon Roberts)

The humans and animals at Formby would have been walking over mudflats that were subjected to marine influence (Gonzalez *et al*. 1997), the distinctive lack of artefacts associated with the footprint-tracks indicates that these people were utilising the mudflats for activities, probably hunting, gathering and fishing. It is likely that the lack of artefacts is an indication that these people came from an occupation area or settlement that was further inland, in a drier environment (Roberts and Worsley 2008, p 33). The formation of the footprints from Merseyside suggests multiple site visitations with children heavily involved with activity on the saltmarsh. The importance of children within hunter-gatherer-fisher society will be discussed fully in Chapter 9.

Neolithic intertidal footprint sites are found across Britain, with a concentration in Wales and the south-west of England on the Severn Estuary. Many of the footprints made in Wales during the Neolithic are from cattle and red deer. These animals could easily trample a surface which can cause distortion to the sediment but do not always create well preserved prints, instead there are many poor-quality prints that offer little information and may not always be recognised for what they are. On many Severn Estuary sites, especially between Goldcliff and Magor Pill, peat was forming throughout the Neolithic so footprints will not be found in laminated sediments (Bell 2013, Figure 2.2, p 15). There is a need to target sites on the Severn Estuary, where Neolithic sediment may be preserved, for evidence of Neolithic activity, as this evidence is so rich at Formby Point.

As well as the large number of footprint-tracks from Formby, human, deer and cattle footprints at Kenfig, Wales were exposed on intertidal peat dated between 3700-3200 cal BC and recorded using optical laser-scanning (Bennet *et al*. 2010). At Oldbury, South Gloucestershire 13 cattle footprint-tracks were recorded from the surface of a thin peat shelf at the point where silts were encroaching on the peat at a horizon (Allen 1998a; Barr and Bell 2016). Red deer footprint-tracks were also noted at Oldbury, it is thought that they date to the Late Neolithic between 3096-2135 cal BC. The footprint-tracks at Oldbury were traced by Rachel Scales in 2003 (Barr and Bell 2016). Footprint-tracks of auroch and deer were found in laminated silts cut by palaeochannels at Peterstone, these produced radiocarbon dates from late Neolithic/initial Bronze Age to middle Bronze Age (Bell 2013, p 175). At Lydstep II, Wales, the footprint-tracks of adult and juvenile human and red deer were noted in the surface of peat deposits (Figure 2.8; Jones 2010). Though not dated directly, the site of Lydstep I is thought to be of a similar date to the footprint-tracks, between 4230-3400 cal BC (Murphy *et al*. 2014). Within the site of Lydstep pig remains and 36 flints were also recorded, with microliths coming from the shoulder of the pig. The flints are of Late Mesolithic type (Leach 1918, p 50), and the pig dated to the Mesolithic 5300±100 BP (OxA-1412; 4345-3950 cal. BC; Murphy *et al*. 2014).

The evidence of domesticated animals within the footprint-track record allows us to view the shift in subsistence practices, from one that was hunter-gatherer based to one that incorporates farming. Although the Lydstep pig may be the remains of an unsuccessful Mesolithic hunt (David 2007, p 119; Bell 2007, p 328), as the date is from the Mesolithic/Neolithic transition it has also been suggested that the pig may be an escaped domesticated animal (Lewis 1992; Schulting 2000, p 30). Footprint-track evidence indicates that cattle were being grazed upon the saltmarsh environment, which was shared with wild auroch and deer. Although these sites are not noted as vast, or the footprint-tracks of particularly good preservation, the presence of human, domesticated cattle, wild deer and auroch indicates that people were beginning to use the saltmarsh as part of their husbandry practices. The 13 footprint-tracks from Oldbury were all from full grown cattle, indicating a possible focus on meat production or using the animals for traction, though the sample is small so caution must be applied to any inferences drawn from this dataset (Barr and Bell 2016).

Figure 2.8 A child stood barefoot next to probable Neolithic child footprint-tracks preserved in intertidal peat at Lydstep (Phototograph by Dyfed Archaeological Trust)

At the site of the Femern Bælt Tunnel excavation in Denmark footprint-tracks thought to have been made by two individuals have been noted alongside a system of fishing weirs (Lolland-Falster Museum 2014). These footprint-tracks were preserved in a silted seabed, and were made approximately 5,000 years ago. It is thought that the individuals waded out to the fishing weirs in an attempt to safeguard the weirs or fishing baskets before a flood. This process covered the prints with sand, preserving both the footprints and the fishing weirs they were attempting to protect. Investigation of the weirs indicated that they were being repeatedly repaired and moved. The finding of Neolithic human footprint-tracks alongside fishing weirs gives an insight into these individuals' subsistence practices, with fishing being of evident importance to these Neolithic people.

The Femern Bælt Tunnel footprint-tracks are significant, however the way they were recorded demonstrates the need for a universal method of footprint-track recording. The outline of the footprint-tracks was scoured out by excavators, although the line that the person created does not match up entirely with the actual outline and makes it difficult to view the original size and shape (Figure 2.9). Developing a universal recording method accessible to archaeologists worldwide would clear up the issue.

Figure 2.9 Femern Bælt Tunnel footprint-track, recorded by scouring out a rough outline. This recording technique is an example of the need of a universal method for prehistoric intertidal footprint-track recording (Photograph Museum Lolland-Falster)

2.1.6 Bronze Age Ichnology

The majority of Bronze Age sites have been recorded in Britain and Europe, though the Americas also have sites of significance (Table 2.1). British sites are again predominately discovered on the intertidal zone of the Severn Estuary and surrounding areas. Finds include cattle and sheep footprint-tracks found at Rumney Great Wharf from within soft muds that had formed within palaeochannels from the Upper Wentlooge Formation (Allen 1996), and cattle and ovi-caprid footprint-tracks from silts between the Fourth and Fifth peats at Cold Harbour Pill (Bell 2013, p 154). Charcoal from Cold Harbour Pill was radiocarbon dated by Whittle (1989, Figure 7) to 2900 ±60 BP (Car-991; 1289-920 cal BC). The footprint-tracks were made between this date and the date provided by radiocarbon dating a post, 2520 ±60 BP (Swan-241; 800-416 cal BC; Bell 2013, Table 8.1, p 154). The Bronze Age footprint-tracks are often primarily that of domesticated livestock (Table 2.1), and can indicate husbandry practices undertaken by the people who lived in the area.

The site of Goldcliff East on the Bronze Age peat shelf has preserved the footprint-tracks of domesticated cattle and ovi-caprid. 25 footprint-tracks were recorded, 12 from ovi-caprid, six from bovids, and seven that were too poorly preserved to accurately identify (Barr 2012; Barr and Bell 2016). The footprints were made on the surface of the middle Wentlooge peat where reed peat is dated 3130±70BP (CAR-644; 1610-1200 cal BC; Bell 2007). They were on the edge of a silt filled palaeochannel, the footprints were made in peat and then filled by blue-grey silt (Barr and Bell 2016). Nine of the footprint-tracks were very small; comparison with modern analogues has suggested these were made by neonatal animals, though there was also evidence of adults and possible large males (Barr and Bell 2016). The herd and flock composition of this small footprint-track sample suggests that this was a breeding herd and flock, evidenced by the footprint-tracks made by neonates and females; this composition is indicative of dairy production as the juvenile animals would have stimulated lactation in the adult females (Balasse and Tresset 2002; Copley *et al*. 2005a,b; O'Connor 2000). If we assume that the cattle and ovicaprids of prehistory birth during the spring period then we can also infer that these animals were present on site during the spring/summer months (Barr 2012; Barr and Bell 2016). The tidal regime would have prevented the saltmarsh environment of Goldcliff from being exploited year-round, as during winter the tide is higher, this tidal inundation constantly replenishes minerals and organic material meaning that the saltmarshes provide especially good grazing when accessible (Bell 2013). It would also have been a spatially extensive grazing resource in the past. The evidence suggests a community exploiting the environment for safe and healthy grazing of their breeding livestock, with the saltmarshes preventing foot rot and liver disease, problems which arise from livestock grazing on damp pastures (Fulford *et al*. 1994). This would result in the provision of milk, meat, traction and wool for the saltmarsh farmers (Barr and Bell 2016).

Evidence for the exploitation of intertidal wetlands is also indicated by the human and domesticated animal footprint-tracks made in peat at Redwick, Gwent, Wales. The peat is on the surface of the middle Wentlooge peat where raised bog is covered by thin sedge peat, the top of this peat is dated 1691-1401 Cal BC (Beta-181453; 3250±70BP; Bell 2013, Table 8.1), and there is a transition to saltmarsh silts in this area. The footprints were in peat and filled with silt in curvilinear depressions around slight peat hummocks; these footprints occurred around buildings and in palaeochannels, the buildings were dated to 1500-1000 cal BC (Bell 2013, Table 8.1). There were 243 footprint-tracks recorded at Redwick, from around buildings and in palaeochannels. The assemblage was dominated by *Bos*, making up 71% of the assemblage, ovicaprid make up a further 16%. Four domesticated pig footprint-tracks were also recorded, along with one possible horse, and ten mostly poorly preserved human footprint-tracks (Bell 2013, Table 7.1, p 151). Of the ten human footprint-tracks, one was well preserved and considered to be likely to have come from a five/six year old, five were from children under 11 years old, and two were adults. Two others were too indistinct to assign age.

Further investigation of the footprint-tracks at Redwick was undertaken by Barr and Bell (2016), where they reassessed the data and possible footprint-tracks that may have been considered too small or indistinct to have been included in Bell's (2013) interpretation. Reanalysis of a possible 290 footprint-tracks suggested an assemblage containing ovicaprid (22%), bovid (45%), red deer (<1%), pig (<2%), human (3%), and 28% too poor to enable identification of species. 20 of the ovicaprid footprint-tracks were made by animals aged three months and under, 15 of which were under a month of age. 24 of the bovid footprint-tracks were made by individuals aged under two months. This assemblage again suggests a dairying community, as there is a large percentage of both young and mature animals (Barr and Bell 2016). The footprint-tracks of human children may indicate the engagement of juveniles within specific activities, such as raising livestock or assisting with milking.

Like the footprints found at the Femern Bælt Tunnel excavation in Denmark (Lolland-Falster Museum 2014), the footprints at Redwick were recorded in association with artefacts, including buildings. These buildings and associated artefacts demonstrate the behaviour of Bronze Age people and the way they were interacting between animals and the landscape (Bell 2013). Animals were being kept in buildings with partitions, interpreted as animal stalls. The rearing of animals was occurring in the same area in which the Bronze Age people were living, indicating a close relationship between humans and animals. The structures were not permanent, with Bell (2013) suggesting that people were moving seasonally with their herds or flocks, and were far less sedentary than previously thought. Prehistoric footprint-track research often deals primarily with just the footprints themselves; however, Bell (2013) has demonstrated the strength that this form of archaeological data can bring to the interpretation of a site as a whole.

Although there are many coastal sites in Wales that are important to footprint-track research, there are other areas in Britain where footprint-tracks have been recorded, although in many cases not in the same volume or detail that are found in Wales**.** This is likely to be due to differences in preservation at these sites and differences in the extent of study in this area, so archaeologists are perhaps not always trained to spot a footprint-track in sediment. Excavation at Gwithian, Cornwall (3,800 to 2,900 BP) revealed Bronze Age cattle and ovicaprid footprint-tracks (Walker and Bell 2013), and at Shaugh Moor, Bronze Age cattle, ovi-caprid, deer and badger footprints were recorded (Smith *et al*. 1981). The Shaugh Moor footprint-tracks were from a ditch of a Bronze Age reeve system (1590 ±80 BC to 1390 ±90 BC), and provide evidence for animal husbandry in the associated reeve (Fowler 1981; Smith *et al*. 1981).

The discovery and significance of this form of archaeological data is often treated as an afterthought; the footprint-tracks from Shaugh Moor for example were never fully analysed or published, perhaps because researchers at the time did not know what to do with them.

2.1.7 Other iconological sites

The only recorded ichnological site in Japan is from the site of Shiroi, Gunma, from the Late Kofun period, around the 6th century AD (Inoue and Sakaguchi 1997). Excavation of the site covered 50,000m^{2,} with around 40,000 horse hoofprints preserved in this area. The site is located on a river terrace; the horse hoofprints were made on the land surface and then preserved when a volcano erupted, covering the site in between 50cm and 120cm of volcanic pumice. At the site there was also evidence of farmland, though this was not in use when the volcano erupted. The hoofprints from Shiroi allowed ancient horse species in Japan to be better understood, with the size of some of the prints indicating that foals younger than one years old were at the site. A medium sized breed of horse, a Mongolian type or similar, made all of the footprint-tracks; these footprint-tracks therefore assisted in establishing the origin of Japanese horses and the route humans may have taken to get them (Inoue and Sakaguchi 1997). The footprint-track evidence from Shiroi suggests that at the time of the volcanic eruption the area was being used to graze medium-sized horses, some of which were raising foals, and so needed the safety of a pastureland to nurse their young.

2.1.8 American Cave Sites

Footprint-tracks from the American Late Archaic Period, approximately 4,500 years ago, are found in a variety of cave sites (Table 2.1). Jaguar Cave, Tennessee, contained a clay cave floor with 274 human footprint-tracks, made by approximately nine individuals who were male, with some possible females (Watson *et al*. 2005; Willey *et al.* 2005; 2009). Carbon found on the roof, caused by the use of torches within the cave was radiocarbon dated to *c*3000 cal BC (Watson *et al*. 2005). As well as human footprint-tracks found within the cave there is evidence of jaguars (*Panthera onca*). Between 35,000 and 10,000 years ago jaguars became trapped within the cave and created multiple footprint-tracks, skeletal remains from this species were also in the cave and is the caves namesake (Watson *et al.* 2005). Further fragmented skeletal remains were also discovered in the cave from a variety of species including mastodon (*mammut americanum*), dire wolf (*Canis dirus*), horse (*Equus*), tapir (*Tapirus*) and camel (*Camelops*), indicating these animals may have lived in the cave, or their remains were dragged in by other animals (Watson *et al*. 2005). This site is of importance because it has been extensively studied over multiple years. Footprint-tracks preserved in cave sites have an advantage over open-air sites as they are not subject to the elements and temperatures generally do not fluctuate, preventing damage and erosion. Watson *et al*. (2005) focused upon the methods of recording footprint-tracks, as many of the footprints are in hard to access areas. The continuous recording over multiple years and reduced threat of erosion has resulted in strong archaeological results, with the sex and stature of the nine individuals determined from footprint-track trails (Watson *et al*. 2005).

2.1.9 Footprints on Roman Tiles

Roman brick and tiles presented ideal situations to capture footprints, as when walked upon a wet tile or brick substrate creates an excellent surface for the preservation of footprints. These footprints may assist in an understanding of life in the area, such as if domesticated or wild animals were most prevalent. Roman sites within Britain often exhibit footprints preserved in this manner (Brodribb 1979; Cram 1984; Elliot 1991; Wall 1985), although the detail of these prints is often lacking in reports and does not include thorough analysis. Cram and Fulford (1979) carried out a more detailed analysis of footprints found upon the tiles at Silchester Roman Town; this footprint material indicated a variety of species including sheep/goat, dog, horse and human, suggesting a town where animals were used for husbandry purposes, and had access to areas where tiles were made. Reanalysis of the Silchester tiles from the forum-basilica, Insula IX and the collection held by Reading Museum was undertaken by Sara Machin as part of her doctoral thesis regarding the ceramic building material of Silchester (S. Machin per comms. 21/02/2018). The dating of this material was considered difficult due to the lack of material from dateable structures, however the fabrics of the Nero stamped tiles give *a terminus post quem* date of AD54, which is early in the Roman occupation of Britain. A total of 394 footprints were identified on the tiles; 82 ungulates, as well as 282 other animals including human, cat, weasel and dog. 30 avian footprints were also identified, from species including heron, crane, crow, owl and chicken. The ungulate assemblage contained a large amount of neonate and juvenile cattle and ovicaprid; eight were calves aged four months and under, and eight were ovicaprid aged five months or under. Adults were also in the assemblage, indicating the breeding of animals was occurring near to the tilery (Grant 2004, p 380), so dairy production may have been a focus.

It must be remembered that just because a tile has a footprint on it, this does not automatically reflect the species preference or behaviours of individuals in the sites in which they are found. Ceramics and tiles are portable objects and could easily have been made in a different town or country and do not directly imply that the footprint maker was present at the site of interest. Tiles/bricks are therefore not a reliable source of footprint-track information for the identification of species preference.

As of the Roman period, footprints on tiles and other surfaces become far more common on archaeological sites, however they are omitted from this study due to the vast amount of material which will not be relevant to this report.

2.1.10 Conclusion of footprints in archaeology

This section has discussed a variety of footprint-track sites from across the world, from a range of contexts, to illustrate the widespread nature of this fascinating evidence. There is no methodology used universally for footprint-track recording, or for the interpretation of the data, and at each site there are lessons to be learnt from the way in which footprint-tracks were recorded.

The main goal within human footprint-track research tends to be to expand our knowledge of the people who made them. The stature, sex, age, gait, direction of travel and speed of movement are all of interest. As archaeologists we view each footprint-track trail individually so that we can learn something about the track-maker, but we must also consider their footprint-tracks in relation to those made by other humans and animals, as well as other archaeology. Bell’s (2013) work on the site of Redwick, Wales demonstrated the importance of considering footprint-tracks within a site as a whole, as this may indicate specific behaviours or an age or sex based division of labour.

There is usually at least one juvenile footprint-track found in association with multiple other footprint-tracks at sites, indicating the importance of the young within human populations. Identifying children from footprint-tracks allows us to form an understanding of the activities and behaviours of a community, so it is essential to attempt to discover the ages of individuals through footprint analysis. Many footprint-tracks made by children in prehistory are from very young individuals, some possibly as young as one year old (Altamura *et al*. 2018), which suggests that children were active members of the community from a young age.

The age of mammals as established from footprint-track evidence is generally not dealt with in the literature, though species are often mentioned. This gap in the literature needs to be addressed as seasonality and animal husbandry may be understood by the appearance of juveniles or specific species. The same lack of thorough analysis is true for avian footprint-tracks, with species and numbers of footprint-tracks not often given.

There is a comparatively sparse footprint-track data from the Iron Age (Table 2.1), there may be a multitude of reasons for this. One reason may be that the sites favoured for habitation during the Iron Age may not have provided the correct environment or sediment for track preservation, or it may be that as Iron Age sites are so rich in archaeological data, footprints may be found and recorded but not mentioned in detail during the write-up of the site. It may also be that the footprint-tracks are not even recognised as archaeologically important or recorded. At the site of Goldcliff West, Wales, Bell *et al*. (2000, p 118) identified cattle footprints that were identified in association with Iron Age Building's 6 and 2. These footprints were identified during the recording of the buildings, and also retrospectively. The archaeologists who identified these footprints had knowledge of ichnology so was likely more aware of what to look for.

Footprints may not always be discovered in plan; in an excavation it is reasonable to assume that it is just as likely to discover a footprint in section. There has not yet been a study into the ability to recognise and identify footprint-tracks in section. The failure to recognise footprint-tracks will result in the loss of this data, with footprint-track sites still being relatively rare it is especially important during any fieldwork to consider that a turbated area may be the result of animal trampling, and should be recorded thoroughly (Chapter 4).

2.2 Physical Anthropology

2.2.1 Anatomical Structure of *Homo sapiens* feet

This section will review the anatomical structure of *Homo sapiens* feet, the way that they function and growth and development. For the anatomical structure of bird and mammal feet see Chapter 4.

The human foot is extremely complex, with 26 bones and 33 joints (Figure 2.10). Its function is to provide support, mobility and balance for the body. The complexity of the foot is enhanced further when considering the large amount of layered muscles present (McMinn *et al*. 1993). There are three structural components to the foot, the forefoot, midfoot and hindfoot. The five toes are composed of phalanges and their connecting long bones called metatarsals. The hallux, often referred to as the big toe, or first toe, articulates with the head of the first metatarsophalangeal joint, the tip of the hallux is large and bulbous (McMinn *et al*. 1993). The other toes shall be referred to as toe two, three, four and five, two being the toe next to the hallux and five being the smallest, lateral toe. All have three bones and two joints; the metatarsal phalangeal joint connects the metatarsals and phalanges to the ball of the foot. These toes make up the forefoot, which bears half of the body's weight on the ball of the foot, shifting and correcting the balance as required (White and Folkens 2005, p 262). The midfoot is the shock absorber for the foot, and is made up of five tarsal bones which create the arch of the foot. These bones connect to the forefoot and hindfoot by muscles and the *plantar fascia* ligament (McMinn *et al*. 1993). The curving arch of the foot, which is developed during childhood (Scheuer and Black 2004, p 404), occurs between the heel and ball; the arch is a defining characteristic as it indicates which side of the body the limb that made the footprint came from, the toes also indicate this. Connected to the midfoot by muscles and ligaments is the hindfoot, this is composed of three joints that link the midfoot to the talus (ankle). The calcaneus, or heel bone, is the largest bone in the foot that joins the talus, forming the subtalar joint (McMinn *et al*. 1993). The bottom of the heel bone is protected from damage by a thick layer of fat tissue. The top of the talus connects to the distal ends of the tibia and fibula, forming a hinge to allow the foot to have rotational movement (White and Folkens 2005, p 292).

The human foot has many unique characteristics which enable identification; the foot is much longer than it is wide, with a swollen ball, prominent heel, strong curving arch and five toes, the first of which is very large. These characteristics aid in identifying a hominin footprint when it is poorly preserved (Figure 2.11).

The feet of prehistoric humans, many of which were constantly unshod, may retain the outline of the neonatal foot, as they have not been deformed by restrictive or ill-fitting footwear. Leather shoes for example greatly restrict the spread of the toes, and if worn throughout childhood will result in a far narrower foot than somebody who is habitually unshod (Tuttle *et al*. 1990; Musiba *et al*. 1997; Roberts 2004). The appearance of a constantly unshod foot has certain characteristics, such as the toes fanning out from the midfoot; the medial longitudinal arch of the foot is also greatly strengthened in people who are constantly unshod (Tuttle 2008). These characteristics are important to be aware of, as it is possible that many prehistoric populations went unshod.

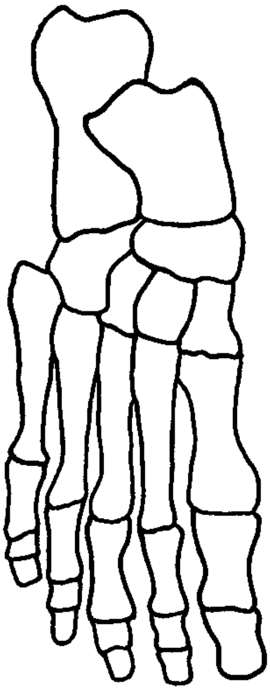


Figure 2.10 Anatomical drawing of bones in the right foot

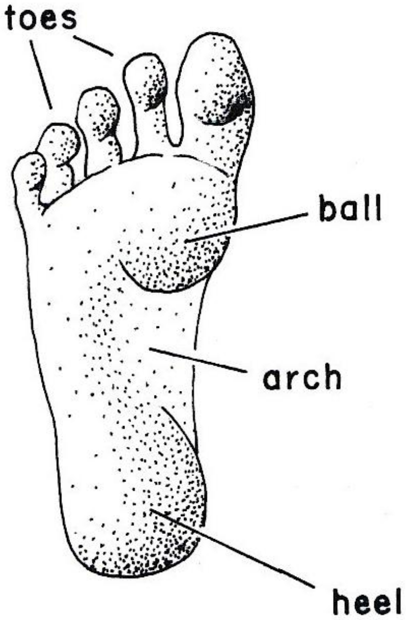


Figure 2.11 descriptive scheme of the parts of a human foot (Allen et al. 2003, Figure 6e)

Another key consideration is growth rate (Figure 2.12). A neonate will have a foot that is long and slender with no evidence of longitudinal arches. The foot of a neonate is approximately 8cm in length, and 34% of its adult size (Scheuer and Black 2004, p 403). Between the ages of 12 and 18 months old the foot will have achieved half the length of its overall mature size and by two years the longitudinal arches will have descended. From two until five years there is a significant decrease in growth rate. The sexes experience a slight difference in growth rate; from five to twelve years in females and five to fourteen years in males, the foot experiences growth of approximately 0.9cm per year in length. The rate of growth then decreases again, with females experiencing decreased growth after 12 years of age, and males at 14 years. 95% of mature length will be achieved by the female foot by the age of 12-13 years, and by 15 years in males (Scheuer and Black 2004, p 404). Females will usually have achieved their maximum growth by the age of 14 years, with males slightly older at 16 years; this coincides in both sexes with the end of epiphyseal growth. The stages of growth of the human foot may assist in the identification of the ages present in prehistoric samples, there is also evidently a problem with regards to maturity. A sub-adult will have achieved their maximum foot length by 14 years if female, this size will then remain unchanged later in life so determining which is made by a sub-adult and which is made by a mature adult will be virtually impossible.

Changes to foot morphology can easily occur, as the bones are physiologically plastic. An example for this is China's historical practice of binding young girls' feet, which occurred between the ages of four and eight years old (Klenerman and Wood 2006). By approximately 14 years of age the child's feet would have reached full maturity, if binding had occurred constantly over the possible ten years, the effects of binding would create permanent deformities in the foot and would have hugely influenced the gait of the individual, these deformities were further worsened if the child's feet were not only bound but also broken. Foot binding in children takes advantage of the increased plasticity of children's bones compared to that of adults.

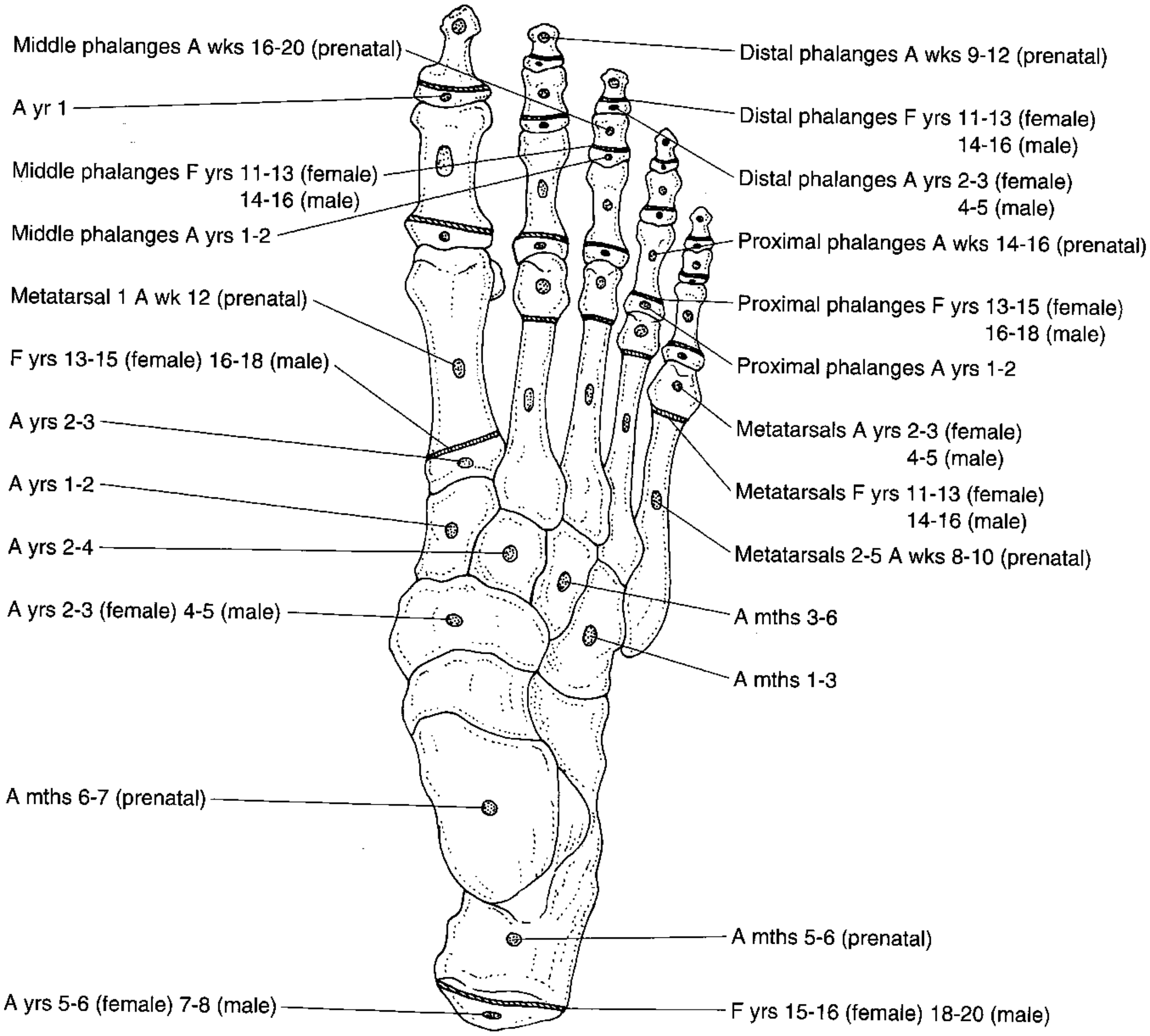


Figure 2.12 Appearance (A) and Fusion (F) times of the ossification centres of the foot (Scheuer & Black 2004, Figure 11.41)

2.2.2 Stature

The morphology of the human foot varies between individuals, from the way that the bones are aligned, to the way that muscles and connective tissues are attached (Barker and Scheuer 1998). Stature can be determined from a footprint as the length of a human foot is on average 15% of a person's overall stature, although this percentage can range from 14%-17% (Giles and Vallandigham 1991; Gordon and Buikstra 1992). Due to this, multiple techniques have been created to ascertain the most scientifically sound method of using footprints to estimate stature.

The estimation of stature is problematic as there are marked differences in footprint morphology within regions and continentally, which means that a single formula cannot be considered representative of all people. This has resulted in an array of formulas dealing with multiple populations (Table 2.2). Prehistoric people may be rather different in stature to modern populations, in these situations European Mesolithic skeletal remains and the statures indicated by these must be considered to assess the stature of individuals from footprints.

Source	**Regression Equation**	**SEE**	**Sample**
Abledu *et al.* 2016	4.63×*T*1+51.64	6.75	50 female students from Eastern Ghana, aged 18-30
Atamturk & Duyar 2008	5.295xFL+38.903	5.142	263 females and 253 males from Ankara, Turkey, aged 17.6-82.9 years
Bennet & Morse 2014	0.00581X+0.186	0.0578	200 students and administrative staff from the University of Bournemouth
Dingwall *et al.* 2013	74.47+3.72 x FPL	5.4	19 male, 19 female Daasanach, Kenya
Fawzy & Kamal 2010	91.88 + 3.1 × T_1R (right)	3.55	50 Egyptian men aged 18 - 25
Fawzy & Kamal 2010	88.34 + 3.25 × T_1L (left)	3.63	50 Egyptian men aged 18 - 25
Geetha *et al*. 2015	81.978 +.294 x foot length	6.91	100 females aged 20-30 from Kasargod District of Northern Kerala
Geetha *et al*. 2015	98.51 +.242 x foot length	5.375	100 males aged 20-30 from Kasargod District of Northern Kerala
Hairunnisa & Moorthy 2015	43.170 + 5.247PLT1	4.064	160 males and 160 females from Iban, Malaysia, aged 18-32
Hemy *et al.* 2013	79.838+3.597 (FL) (left)	5.065	90 male staff and students from University of Western Australia aged 19-68
Hemy *et al*. 2013	78.913+3.642 (FL) (right)	5.105	90 male staff and students from University of Western Australia aged 19-68
Hemy *et al.* 2013	56.375+4.365 (FL) (left)	4.777	110 female staff and students from the University of Western Australia, aged 18-63
Hemy *et al.* 2013	56.476+ 4.364 (FL) (right)	4.841	110 female staff and students from the University of Western Australia, aged 18-63
Krishan 2008a	3.689 × T-1 length + 84.013 (left)	not provided	1040 adult male Gujjars aged 18-30
Krishan 2008a	3.510 × T-1 length + 87.214 (right)	not provided	1040 adult male Gujjars aged 18-30
Krishan *et al*. 2012	03.744 + 5.037 + 2.064 (Age)	5.0412	154 North Indian males aged 13 - 18
Krishan *et al.* 2011	69.544 + 3.99 LFL	4.38	123 male students from Rajputs, aged 17-20
Krishan *et al.* 2011	69.028 + 4.01 RFL	4.44	123 male students from Rajputs, aged 17-20
Krishan *et al.* 2011	74.82 + 3.58 LFL	3.53	123 female students from Rajputs, aged 17-20

Krishan *et al.* 2011	73.88 + 3.61 RFL	3.5	123 female students from Rajputs, aged 17-20
Moorthy *et al*. 2014a	113.117 + 2.450 PLT1 (left)	3.812	1020 adult Indian Tamils males, aged 19 to 42
Moorthy *et al.* 2014a	112.148 + 2.499 PRT1 (right)	3.812	1020 adult Indian Tamils males, aged 19 to 42
Moorthy et al 2014b	52.489+4.939 PLT1	4.563	100 male, 100 female adult Chinease staff and students of Universiti Sains Malaysia
Pales 1976	3.641 (max foot length)+72.92 (right)	4.35	Not stated
Pales 1976	4.229 (max foot length) +56.49	3.58	Not stated
Singh *et al.* 2013	2.967 x2 + 88.235	not provided	250 females who visited Lady Hardinge Medical College, New Delhi , aged 18-23
Uhrova *et al.* 2015	84.09+3.64 (right)	4.56	120 males from Slovakia, aged 18-24
Uhrova *et al*. 2015	86.32+3.55 (left)	4.55	120 males from Slovakia, aged 18-24
Uhrova *et al.* 2015	71.45+3.98 (right)	4.81	130 females from Slovakia, aged 18-24
Uhrova *et al.* 2015	73.64+3.89 (left)	4.82	130 females from Slovakia, aged 18-24

Table 2.2 A small sample of literature providing regression equations to estimate stature, including the sample size and additional data such as age and sex. The Standard Error of Estimate is also given for each equation.

A further consideration when estimating the stature of prehistoric footprints is that the sex of an individual will affect the size of the foot. Females are generally smaller than males in both stature and footprint size. Many anthropological and forensic studies of the footprint often focus entirely on males (Table 2.3), with less consideration of females (Table 2.4). The author is unaware of any data that provides regression equations for the relationship between stature and footprint size of children, though Scales (2006) performed an experiment with UK primary school children aged four to eleven years and found that the children’s foot length was an average of 15.6% of height.

Indian populations are the most studied, with Asia and the Middle East being areas where footprint studies are dominant. Europe is particularly weak in producing stature estimates from footprint evidence, with only one major study in the United Kingdom (Reel *et al*. 2012), although the study involved British people who had family origins outside of Europe, again such as India and the Middle East. The reason for this large disparity is due to geographical differences. In general footprint research is performed in countries where many of the residents habitually go unshod, whereas in Europe and the Americas people are usually shod. The development of stature estimates from a footprint primarily has a forensic focus, therefore areas where people are likely to leave footprints when committing a crime are more in need of certain forensic techniques than countries where people are generally shod when committing crimes, footprint research in these countries are not as necessary forensically speaking. This is also the reason behind the lack of stature estimates for children from their footprint-tracks, as they are generally not investigated for criminal activity, so there has been no need to develop techniques to identify children. This may be true forensically, however archaeologically there is a need to develop stature estimates from children’s footprints, as so many are being discovered.

Population	**Average male stature**	**Average left foot length**	**Average right foot length**	**Source**
Turkey	174.39 ± 7.21	26.04 ± 1.36	26 ± 1.34	Ozden *et al.* 2005
Turkey	174.19 ± 5.73	25.57 ± 1.15	26.6 ± 1.11	Zeybeck *et al.* 2008
Turkey	172.37 ± 7.33	25.84 ± 1.26	-	Atamturk & Duyar 2008
Khamyangs, India	163.73 ± 0.53	24.30 ± 0.1	24.23 ± 0.1	Singh & Phookan 1993
Turungs, India	166.57 ± 0.95	24.71 ± 0.11	24.76 ± 0.11	Singh & Phookan 1993
Aitons, India	163.5 ± 0.54	24.16 ± 0.1	24.21 ± 0.1	Singh & Phookan 1993
Khamtis, India	163.07 ± 0.81	24.44 ± 0.14	24.39 ± 0.15	Singh & Phookan 1993
Gujjars, India	172.73 ± 0.5	24.05 ± 3.23	24.13 ± 3.26	Krishan 2008a
Rajputs, India	168.24 ± 6.5	24.7 ± 1.21	24.72 ± 1.19	Krishan & Sharma 2007
Mangalore, India	174.6 ± 5.3	24.3 ± 1.4	24.1 ± 1.3	Kanchan *et al.* 2012
Jat Sikhs, Punjab	169.88 ± 5.85	25.657 ± 1.198	25.512 ± 1.199	Jasuja *et al.* 1991
Egypt	-	25.31 ± 1.21	24.82 ± 1.26	Fawzy & Kamal 2010
Australia	178.47 ± 7.08	27.42 ± 1.38	27.348 ± 1.36	Hemy *et al.* 2013
UK	176.90 ± 5.98	-	25.472 ± 1.933	Reel *et al.* 2012
Nigeria	168.45 ± 7.63	25.42 ± 1.12	25.39 ± 1.14	Saxena 1984
Malaysian China	171.5 ± 5.5	23.81 ± 0.9	23.86 ± 0.9	Moorthy *et al.* 2014a
USA	174.516 ± 6.610	27.776 ± 1.301	26.766 ± 1.301	Giles & Vallandigham 1991

Table 2.3 Male stature estimates and average foot length from a variety of population studies

Population	Average female stature	Average left foot length	Average right foot length	Source
Turkey	160.94 ± 6.31	23.30 ± 1.07	23.26 ± 1.07	Ozden *et al*. 2005
Turkey	161.69 ± 5.19	23.07 ± 0.9	23.04 ± 0.9	Zeybeck *et al*. 2008
Turkey	157.39 ± 6.53	23.45 ± 1.07	-	Atamturk & Duyar 2008
Rajputs, India	155.72 ± 5.18	22.60 ± 1.06	22.65 ± 1.06	Krishan & Sharma 2007
Mangalore, India	156.9 ± 6.2	22.5 ± 0.9	22.1 ± 0.9	Kanchan *et al*. 2012b
Australia	163.67 ± 7.14	24.58 ± 1.22	24.56 ± 1.21	Hemy *et al*. 2013
UK	163.43 ± 6.73	-	25.427 ± 1.933	Reel *et al*. 2012
Malaysian China	158.2 ± 4.9	21.68 ± 1	21.63 ± 0.9	Moorthy *et al*. 2014a
USA	162.951 ± 6.520	24.318 ± 1.251	24.318 ± 1.251	Giles & Vallandighan 1991

Table 2.4 female stature estimates and average foot length from a variety of population studies

2.2.3 Gait

Although stature is generally established by taking the heel to toe measurement of a footprint, the gait of an individual can also be indicative of their stature. The gait of an individual is unique, dependent on the movement of the lower limbs in relation to the pelvic girdle. As a person increases their walking speed to jogging or running, their step length also increases. A person will have a ‘normal’ walking pattern specifically suited to their individual movement; the problem with relying solely on this is that stride length is variable depending on the speed of an individual, and can be altered by a change in weight, creating a different gait to the ‘norm’ (Charteris *et al*. 1981; Jasuja 1993; Jasuja *et al*. 1997). This change of stride length may be recognisable within a footprint trail.

2.2.4 Weight

The weight of an individual can affect the appearance of footprints; this can be utilized to make inferences about the overall size of an individual or indicate if the person was carrying a load. Robbins (1986) proposed that body weight could be predicted from a person’s footprint; building upon Robbins’ experiment, Krishan (2008b) established that a person holding 5kg of weight in each hand would exhibit no variation in footprint size, however with 20kg in each hand, the length and the breadth of the footprint greatly increases (Krishan 2008b). This is particularly important to note, as it suggests that large weight held in the hands can significantly change the footprint outline (Atamturk and Duyar 2008). If a person was carrying something they may have the appearance of wider feet, this would have nothing to do with the persons actual body weight as suggested by Robbins (1986) but rather the amount of weight being directly exerted onto the body.

2.2.5 Sex

It has been suggested that it is possible to establish the sex of an individual through the appearance and morphology of the footprint (Robbins 1985); the accurate scientific application of these methods is ambiguous (Zeybeck *et al*. 2008). Multiple experiments have revealed that differences in foot length within a single community are clear, with variations caused by climate, nutrition, pathology and overall health (Saxena 1984; Jasuja *et al*. 1991; Gordon and Buikstra 1992; Krishan *et al*. 2007). Singh and Phookan (1993) studied the males from four different ethnic groups and found that these groups did exhibit a high correlation between stature, foot size and sex. Ozden *et al*. (2005) established an insignificant relation between the stature and foot breadth of females; this is expected, as in multiple studies it is the foot length that is significant, and the width of a foot is influenced by multiple factors, such as restrictive footwear, nutrition, genetics and climate, unrelated with either stature or sex (Jasuja *et al*. 1991; Gordon and Buikstra 1992; Krishan 2007). A formula was developed by Zeybeck *et al*. (2008) to estimate the stature and sex of an individual via footprint marks, with over 90% accuracy. The sample size was relatively small, involving 238 individuals who were attending school or university in Turkey. This suggests that although it may be possible to establish the sex of an individual from a specific population, this is not always the case. It is important to consider that very large footprints will most likely be male, but small footprints are not necessarily female; these could be small adult males or juveniles of either sex.

2.2.6 Footprint Characteristics

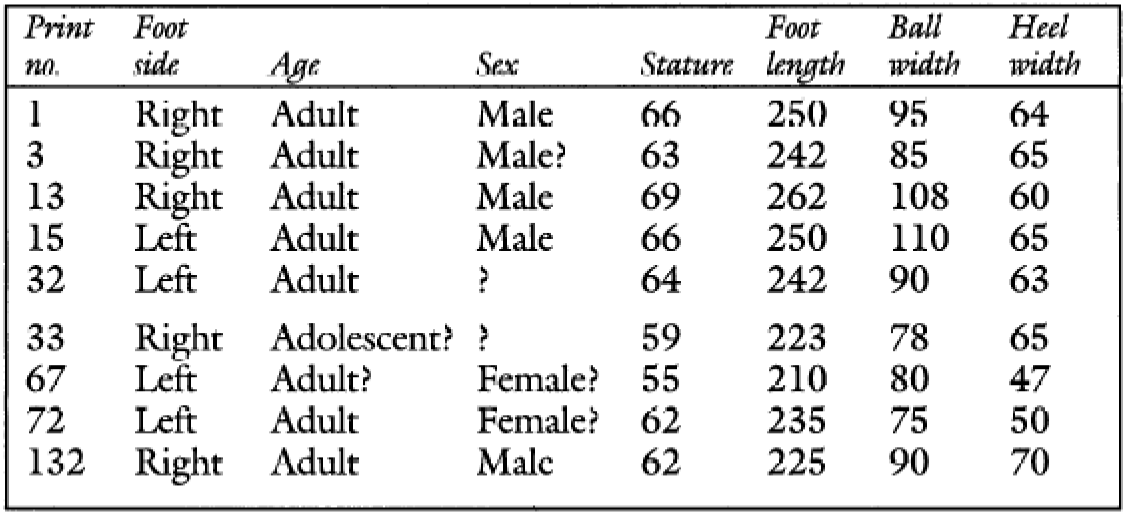
A footprint may also reveal pathological information or defining characteristics, such as corns, pits or creases. Flatfoot, for example, is a condition where the instep region of the plantar surface is in more contact with the ground than a normal foot, this is caused by the collapse or absence of the arch of the foot; the degree of flat-footedness is variable and unique to each sufferer. If an individual with flatfoot has created a footprint-track it should be relatively straightforward to accurately identify the footprints created by that one individual (Krishan 2007).

The presence and size of phalanges can also assist in the identification of an individual. When a footprint is created it is normally the phalanx from the hallux that leaves an impression, with the phalanges from the second to fifth toe not always creating any impression (Krishan 2007). The use of forensic podiatry in a criminal investigation can result in reliable results. Archaeologists can utilise the techniques created for forensic podiatry when analysing prehistoric footprint-tracks to understand the foot health of individuals, as the methods are easily transferable if detail is preserved, and obvious pathologies can be noticed in footprint trails.

2.2.7 Forensic Science

Louise Robbins (1985, 1986) was considered a ‘footprint expert’ in Canada and America and was heavily involved in analysing not only forensic footprints, but also footprint-tracks discovered on many archaeological sites, including Laetoli and American cave sites. Robbins (1978, 1985) claimed that she could accurately identify someone’s stature, weight, sex and even ethnicity from a footprint.

Robbins was involved in analysing footprint-tracks from sites such as Mammoth cave in Kentucky (Watson 1969; Robbins 1974), and Jaguar Cave, Tennessee (Watson *et al.* 2005). Robbins analysed 202 footprint-track impressions from Jaguar Cave and established from the morphologies that these were made by nine individuals. She was then able to calculate age, sex and stature of the people who made the footprint-tracks (Table 2.5). Full analysis of Jaguar Cave was published once Robbins had died, with several other techniques used with Robbins’ theories to estimate the stature of the individuals as accurately as possible (Giles and Vallandigham 1991; Jasuja *et al*. 1991; Singh and Pookham 1993).



Print no.	Foot side	Age	Sex	Stature	Foot length	Ball width	Heel width
1	Right	Adult	Male	66	250	95	64
3	Right	Adult	Male?	63	242	85	65
13	Right	Adult	Male	69	262	108	60
15	Left	Adult	Male	66	250	110	65
32	Left	Adult	?	64	242	90	63
33	Right	Adolescent?	?	59	223	78	65
67	Left	Adult?	Female?	55	210	80	47
72	Left	Adult	Female?	62	235	75	50
132	Right	Adult	Male	62	225	90	70

Table 2.5 Preliminary classification of the Jaguar Cave individuals by Louise Robbins (Robbins et al. 1981). Stature is given in inches (Watson et al. 2005; Table 3)

Robbins' confidence and reputation within the court room meant that her theories and methods were used by the prosecution without questioning, with multiple people being convicted of murder and ending up on death-row through her testimony. A case in Canada (*The Queen vs. Nielson & Stolar*, Winnipeg, 1982) appears to be one of the turning points for forensic podiatry and forensic anthropology regarding footprint interpretation, as scientific opinions and methods were questioned and challenged. The case involved bloody footprints discovered on a paving slab at the scene of a murder. Robbins was working on the prosecution and had said that these footprints were made by the accused. Robbins (1978) used her own method of determining stature, assessing that the footprints were made by somebody of the accused's height. Robbins' stature estimation only had a 36% accuracy rate, inappropriate to be relied upon so heavily in a homicide investigation, or indeed any scientific investigation at all (Tuttle 2008). It was not until after Robbins death in 1987 that the American Academy of Forensic Scientists met to discuss the scientific integrity of her footprint methodology. Her methods were denounced by 135 experts in forensics and law.

Although footprints can provide important information, they should always be treated with caution. Equations should be of high statistical value, and subjected to vigorous testing in multiple situations. It is important to consider the lessons learnt from Robbins, as although the data assessed in this thesis shall be primarily prehistoric, the methods used must be of high scientific merit. Robbins has proven that it is easy to rely too entirely upon footprint data and that it is simple to create poor statistical results through over-interpretation. Robbins' thorough recording and analysis of prehistoric footprint-tracks has sadly lost its value among researchers due to the lack of integrity of her modern forensic work (Tuttle 2008).

Bennet and Morse (2014) provide extensive analysis of the worth of footprint-tracks, both within prehistory and in forensic settings, whilst also considering the limits of inferences from a footprint-track. They place emphasis on solid scientific recording and analysis, with a focus upon Palaeolithic human footprints and the anatomical evolution of humans. This approach to footprint-tracks analysis is more appropriate as it avoids over-interpreting prehistoric footprint-track data. Footprints should be analysed in a critical and questioning approach, rather than relying on an unchallenged ‘expert’ view or method. A further way to avoid over-interpreting prehistoric footprints is to consider other sources, such as bone and environmental data, to avoid creating scientifically unsound interpretations.

2.3 Prehistoric *Homo sapiens* bones from Britain

The following sections will present data from the skeletal remains of Mesolithic humans and mammals. The bones from species of bird found throughout prehistory will also be discussed. As bones are complementary to footprints it is important to understand the information we already have available within the skeletal record, as this data can strengthen our analysis of footprints.

Human bones have been found in a variety of Mesolithic contexts across Britain. The Mendip Hills and southwest England have multiple remains of potential Mesolithic date. Aveline’s Hole, Somerset, contained the remains of approximately 50 individuals; although originally assigned an Upper Palaeolithic age, further radiocarbon dating suggested that the individuals were from the Early Mesolithic, dated 9115±110 BP (BM-471; 8460 cal BC) to 8740 ±100 BP (OxA-1070; 8140cal BC; Schulting and Wysocki 2002; Schulting 2005). Badgers Hole, Somerset, contained remains from two young people (Oakley 1971), dated 9360±100 (OxA-1459) to 9060±130 (OxA-679; Hedges *et al*. 1989, 1991). Gough’s cave, Somerset, also contained Mesolithic skeletal remains of ‘Cheddar man’ of similar date to the aforementioned sites, 9100±100BP (OxA-814) to 9080±150 (BM-525; Hedges *et al*. 1989). These similarities may be suggestive of the general use of the caves of Somerset, primarily for burial. Totty Pot, Somerset, contained 60 skeletal elements, from six or seven humans. One of the individuals may have been as young as two years old, a further child was aged three to six, and an older child of about 10 was also part of the assemblage. As well as children there were three or four adults. AMS dating on the remains indicated that two individuals were Mesolithic in date, 8245±45 (OxA-16457; 7445-7080 cal BC) to 8180±70 (BM-2973; 7450-7050 cal BC), there were also Neolithic and Bronze Age individuals (Schulting *et al.* 2010). Somerset is rich in prehistoric archaeology; across the River Severn in Wales prehistoric people were also prominent.

Throughout Wales there are a variety of cave sites where prehistoric remains have been recovered ranging from Palaeolithic to Iron Age. Foxhole cave, Gower peninsula, Glamorgan contained the remains of at least six humans, dated 6785±50 uncal BC (OxA-8316; 5730-5560 cal BC; Schulting 2005; Schulting *et al*. 2013). There are five sites on Caldey Island, Pembrokeshire that contain skeletal remains of prehistoric humans, in particular the site of Ogof yr ychen contained skeletal remains of at least five individuals, dated between 8760±55 BP (OxA-10616; 7170 cal BC) to 7020±100 (OxA-2574; 5640 cal BC; Schulting and Richards 2002b). These sites may represent intentional burial or may be the result of 'sediment traps' (Davies 1989; Schulting and Richards 2002b). The presence of multiple Mesolithic 'burial' sites in Wales, as well as the occurrence of human footprint-tracks, suggests a landscape that was being fully exploited by the people of prehistory, actively used in life and for their dead.

In Oronsay, Western Scotland, bones have been preserved well, an uncommon occurrence in the Hebrides. These bones are often found within the context of middens rather than caves. The remains at Cnoc Coig, Oronsay, Argyllshire, were from at least six individuals, potentially more, whilst Priory midden, Oronsay, Argyllshire, contained one hand phalanx (Mellars 1987). The Cnoc Coig midden remains were radiocarbon dated (Bronk Ramsey *et al*. 2000), providing three Mesolithic dates, 5740±65 (OxA-8004), 5495±55 (OxA-8014) and 5615±45 (OxA-8019). The hand phalanx was indirectly dated by charcoal discovered within the shell midden, which was radiocarbon dated to 5870±50 BP (Q-3001; Mellars 1987). Midden deposits are not uncommon and appear throughout history and prehistory, particularly during the Mesolithic where it seems that people exploited the sea for their subsistence (Smith 1992).

These sites are just a small selection of prehistoric sites across Britain; access to prehistoric skeletal remains enables the prehistoric human diet to be understood, and in cases where the necessary bones are preserved, the stature, age and sex (Chapter 9, Table 9.7). It is important to understand the stature of people from different time periods, as shorter people may be the norm during certain periods and may be easily mistaken for children, so it is necessary to understand the population specifics. To estimate stature certain bones do need to be recovered in a well-preserved state; human bones from the Mesolithic are a relatively uncommon find as it is, even more uncommon is the preservation of the long bones required for stature estimates.

2.4 Mammalian bones from Mesolithic Britain

During prehistory there were a variety of changes in the composition of the fauna of Britain. Palaeolithic fauna were generally large, with animals such as mammoth, rhinoceros, oxen, wild horse, reindeer, giant deer and red deer. The warmer environment of the Mesolithic resulted in denser forested areas, meaning that the habitat was not as well suited to larger mammals that were adapted to live on tundra. The Mesolithic site of Star Carr, Yorkshire, dated 9670 ±100BP (OxA-4577; 9300-8700 cal BC) to 9060 ±220BP (OxA-4450; 8800-7500 cal BC; Dark *et al.* 2006), was abundant in faunal remains including worked bone and antler (Clark 1954). The bones of red deer, elk, and auroch occurred frequently in the Star Carr material (Table 2.6; Clark 1954; Legge and Rowley-Conwy 1998). The early Mesolithic sites at Thatcham, near Newbury, Berkshire, radiocarbon dated 9200±90 BP (OxA-2848; 8636-8261 cal BC; Hedges *et al.* 1994), contained bones from red and roe deer, there was also wild pig bones (Carter 2001). Interestingly unlike Star Carr very few auroch remains were found at this site (King 1962).

Although the percentages of Mesolithic fauna represented within an assemblage differs, with sites often omitting certain taxa, red deer, roe deer, auroch and wild pig bones occur continuously from early until late Mesolithic. Red deer bones make up over a third of all large mammal bones recorded from nine British Mesolithic sites (Table 2.6), indicating a possible preference for this mammal, or that they were a dominant species during the Mesolithic period. Familiarity with common British Mesolithic species enables more accurate identification of footprint-tracks as each species has identifiable footprint characteristics.

After the Mesolithic, the domestication of many animals occurred, shown in prehistoric assemblages more abundant in domestic cattle, domestic pig, and sheep/goat, rather than large fauna such as auroch. Southern Britain has the greatest number of both Neolithic and early Bronze Age animal bone assemblages (Serjeantson 2011). Central Britain contains less than 20 assemblages (Albarella and Pirnie 2008), with even fewer assemblages in Northern England (Dobney ND). Other than the domestic animals, the fauna of Britain would still have been fairly similar to the Mesolithic, apart from the notable extinctions of the large species, such as the extinction of elk and horse during the early Mesolithic, and aurochs in the middle Bronze Age. It is important to understand the fauna that may have been present at a footprint site, to allow the footprints to be appropriately analysed.

Site	Red deer	Roe deer	Pig	Auroch	Elk	Wolf	Otter	Grey seal	Cetacean	Total number of bones identifiable
Star Carr	541	103	22	174	247	0	0	0	0	**1087**
Thatcham	60	19	91	13	6	0	0	0	0	**189**
Wawcott	15	5	23	21	11	0	0	0	0	**75**
Morton Fife	7	1	1	3	0	0	0	0	0	**12**
Westward Ho!	5	3	1	10	0	0	0	0	0	**19**
Cherhill	20	16	65	18	0	0	0	0	0	**119**
Goldcliff East	52	10	17	29	0	0	0	0	0	**108**
Goldcliff West	87	4	27	0	0	4	7	0	0	**129**
Cnoc Coig	84	0	68	0	0	0	152	449	8	**761**
Total	871	161	315	268	264	4	159	449	8	**2499**

Table 2.6 Total number of bones identifiable from large mammal species from different Mesolithic sites. Star Carr assemblage based on Legge and Rowley-Conwy (1988), Thatcham assemblage based on Wymer (1962), Wawcott Sites XV, XXX based on Carter (1975), Morton Fife based on Coles (1971), Westward Ho! assemblage based on Grigson (1978), Cherhill based on Evans et al. (1983; Grigson 1978), Goldcliff West assemblage based on Coard (2000), Goldcliff East assemblage based on Scales (2007), Cnoc Coig based on Grigson (1978).

2.5 Prehistoric avian bones

Across Britain bird bones have been discovered in many different environments, these bones strengthen our interpretation of bird footprint-tracks as a different data assemblage, and can aid our understanding of birds that are likely to be found on intertidal zones during prehistory. Sites from south-west Britain are of interest as they are rich in avian wetland species and are geographically near the sites considered within this thesis (Table 2.7). Tornewton Cave, south Devon, contained bird remains from the Wolstonian Glaciation, one of the earliest sites in

Britain where bird remains have been recovered (Harrison 1980a; Sutcliffe and Zeuner 1962; Sutcliffe and Kowalski 1976). The stratum stages were named after the fauna most frequently discovered, with the Wolverine (*Gulo gulo*) stratum being the earliest stage, followed by the Brown Bear (*Ursus arctos*) and Otter (*Cyrnaonyx antiqua*) stratum. The Wolverine stratum exhibited palaeoenvironmental evidence in the soil and stalagmites, indicating a period of extreme cold, whereas the Brown Bear stratum displayed evidence of a warmer environment, similar to the Ipswichian glaciation (Harrison 1987a). Interestingly the Otter stratum displayed environmental evidence and faunal species that seemed to be from both the Wolstonian and Ipswichian glaciation. All three stratum contained remains of white stork (*Ciconia ciconia*). This is of particular significance as, assuming the stork were governed by the same distribution factors that affect them today, primarily temperature and summer migration, it would suggest that during these periods there was a continental climate, potentially with summer temperature highs of c.16.7◦c (Harrison 1980a; Sutcliffe and Zeuner 1962; Sutcliffe and Kowalski 1976). Within the cave there were other bird remains that indicated a wetland environment at certain stages; the remains of brent goose (*Branta bernicla*) and goosander (*Mergus merganser*) were found in the Otter strata, the latter was also found in the Wolverine strata. Common shelduck (*Tadorna tadorna*), a current resident of the British Isles, was recovered from all strata (Harrison 1987a). It is thought that these bird remains are likely to have ended up in the cave through predation; the remains therefore present an assemblage bias in exhibiting the species that could be most easily caught or were most favoured, however these species do provide valuable information about possible prehistoric birds that may be found elsewhere.

Tornewton cave contained a further stratum from the Ipswichian interglacial, this stratum mainly contained Spotted Hyena (*Crocuta crocuta*) remains, indicating a warm climate. Many of the remains found in the Hyena stratum were similar to the strata below such as brent goose, common shelduck, and ruddy shelduck (*Tadorna ferruginea*) (Lydekker 1891). Wigeon (*Anas Penelope*) were also recovered, again indicating a wetland environment (Harrison 1987a).

Bacon Hole, a cave in the Gower Peninsula, south Wales, contained a variety of faunal remains; although the majority are from mammals, birds were recovered. Two bird species were using the cave to roost, shown through bones with incomplete ossification and hence juvenile in age (Harrison 1977; Stringer 1975, 1977; Stringer *et al*. 1986). The species represented are razorbill (*Alca torda*) and cory's shearwater (*Calonectris diomedea*). The cave also contained evidence of other birds, two of which are species that still inhabit wetland and intertidal zones, dunlin (*Calidris alpina*) and turnstone (*Arenaria interpres*). Towards the end of the Ipswichian interglacial period, a time of cooling, the remains of bean goose (*Anser fabalis*) and golden plover (*Pluvialias apricaria*) were also recovered from the strata (Harrison 1987a). These birds need open areas and grassland to survive rather than woodland, so assumptions can be made about the surrounding environment. Minchin Hole, a cave also in the Gower Peninsula, south Wales, had remains from the wetland species of razorbill and dunlin, however in comparison to Bacon Hole, this cave was lacking in diversity (Sutcliffe and Bowen 1973; Sutcliffe 1981; Sutcliffe and Currant 1984).

There have also been a variety of species found within the Devensian glaciation contexts, these species were generally arctic or tundra breeding-types indicating the colder environment. Bewick's swan (*Cygnus bewickii*) remains were recovered from Cat's Hole, a cave again found on the Gower peninsula (Allen and Rutter 1948), and white-fronted goose (*Anser albifrons*) remains were recovered from Kent's Cavern, south Devon, and Soldier's Hole, Somerset. The remains of greylag goose (*Anser anser*) were also found at Soldier's Hole (Kennard 1945; Campbell and Simpson 1971; Parry 1929, 1931; Bramwell 1960). Further evidence for wetland birds was discovered at Tornewton Cave in the Reindeer stratum, these birds were teal (*Anas crecca*). The environmental evidence in this area suggests a temperate zone in the southern borders of Britain, however the remains of common shelduck from Brixham Cave, south Devon, is indicative of mild conditions (Prestwich 1874). There are multiple caves within the south-west with evidence for a variety of wetland bird species, many of which are seen in Britain today.

The end of the Devensian glaciation period consists of sites which exhibit the remains of a bird species which were adapted to the cold, but also adapted to grazing on grassland that was becoming readily available. Whooper swan bones (*Cygnus Cygnus*) recovered in Gough's Cave, Somerset, are an example of a migratory bird that still returns to the estuaries and wetlands of Britain in the winter (Jacobi 1986; Harrison 1980b, 1986). Mallard (*Anas platyrhynchos*), teal and wigeon have also been recovered from Soldier's Hole; these avian species are a common sight across Britain today. Other bird remains include barnacle goose (*Branta leucopsis*) from Chelm's Combe, Somerset, and smew (*Mergus albellus*) from Bridged Pot cave shelter, Somerset. Smew and barnacle geese are migratory birds, wintering in Britain. Smew currently return almost exclusively to the Severn Estuary and surrounding areas such as Somerset, the remains of smew were found in Somerset, indicating that this preference has remained unchanged (Balch 1928; Harrison 1987a).

The Holocene period in Britain is represented by a multitude of sites with a variety of avian species, many of which could have lived in estuarine or wetland environments. Port Eyon Cave, on the Gower Peninsula, south Wales, is a particularly important site as it contains faunal remains from between c.9,000-6,000 BP (Harrison 1987a). This site contained waterfowl and seabird remains, such as white-fronted goose, barnacle goose, mallard, wigeon and common shelduck, which are suggested to have been deposited by a large predatory bird. Very few wading birds have been found at Port Eyon Cave; though turnstone, golden plover (*Pluvialis apricaria*) and grey plover (*Pluvialis squatarola*) have been recorded. These birds are still common wetland waders in the Severn Estuary. The remains of bones with incomplete ossification, juvenile in age, have also been recovered at this site for great black-backed gull (*Larus marinus*), guillemot (*Uria aalge*), little auk (*Alle alle*), puffin (*Fratercula arctica*) and razorbill (*Alca torda*); these birds are also still found in Britain and many are migratory, spending time in Britain during either the summer or winter.

A further important site that contains a variety of avian remains is Glastonbury Lake Settlement, with an approximate date of 150 BC-50 AD (Andrews 1899; Bulleid and Gray 1911-1917; Harrison 1980b). The bones of Dalmatian pelican (*Pelecanus crispus*) have been recovered in this settlement, these birds nest in marshy areas and keep to marsh and estuarine areas, avoiding humans where possible. The remains of these birds suggest that during this period the species was migrating to Britain; they no-longer do, choosing other warmer areas in Europe. The remains of mallard, wigeon, pochard (*Aythya ferina*), bittern (*Botaurus stellaris*), and tufted duck (*Aythya fuligula*) were also recorded. Common crane (*Grus grus*) remains were recovered at Glastonbury Lake Settlement, Meare Lake Settlement, Somerset and Woodbury Settlement, Devon (Harrison 1980a). A larger crane species was also discovered at the aforementioned lake settlements in Somerset.

The range of wetland and wading avian remains found across the south-west of Britain is vast, revealing a change in species as the climate and environment also changed. There are species that suggest that migratory patterns and behaviours of certain species have changed; when attempting to determine Mesolithic species from footprint-track evidence modern birds of the British Isles, birds from across the world and birds that are now extinct must all be considered.

Key to Table 2.7

Wolstonian 200000-120000BP
Tornewton Cave, south Devon (Site1)

Ipswichian 120000-110000BP
Bacon Hole, Gower Peninsula, Wales (Site 2)
Minchin Hole, Gower Peninsula, Wales (Site 3)
Tornewton Cave, south Devon (Site 4)

Devensian 100000-11000BP
Soldier’s Hole, Cheddar Gorge, Somerset (Site 5)
Tornewton Cave, south Devon (Site 6)
Kent’s Cavern, Devon (Site 7)
Cat’s Hole, Gower Peninsula, Wales (Site 8)
Brixham Cave, Brixham, Devon (Site 9)
Gough’s Cave, Cheddar Gorge, Somerset (Site 10)
Chelm’s Combe Rock Shelter, Cheddar, Somerset (Site 11)
Bridged pot cave shelter, Ebbor Gorge, Somerset (Site 12)

Mesolithic 10000-5500BP
Port Eyon Cave, Gower Peninsula, Wales (Site 13)

Neolithic 5500-4000BP
Hazelton North, Gloustershire (Site 14)
Durrington Walls (Site 15)
Mount Pleasant (Site 16)

Bronze Age 4000-3200BP
Twyford Down (Site 17)

Iron Age 3200BP-43AD

Glastonbury Lake Settlement, Somerset (Site 18)
Meare Lake Settlement, Somerset (Site 19)
Woodbury Settlement, Devon (Site 20)

Site number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Barnacle Goose (*Branta leucopsis*)											X		X							
Bean Goose (*Anser fabalis*)		X																		
Bewick's Swan (*Cygnus bewickii*)								X												
Bittern (*Botaurus stellaris*)																			X	
Black-throated Diver (*Gavia arctia*)													X							
Brent Goose (*Branta bernicla*)	X			X																
Common Crane (*Grus grus*)																			X	X
Common Scoter (*Melanitta nigra*)													X							
Common Shelduck (*Tadorna tadorna*)	X			X					X				X							
Cormorant *(Phalacrocorax carbo)*																X				
Cory's Shearwater (*Calonectris diomedea*)		X																		
Dalmatian Pelican (*Pelecanus crispus*)																			X	
Duck (*Anas anas*) sub-species unidetified																		X		
Dunlin (*Calidris alpina*)		X	X																	
extinct European Crane (*Grus primigenia*)																			X	
Gannet (*Morus bassanus*)													X							
Golden Plover (*Pluvialias apricaria*)		X											X							
Goosander (*Mergus merganser*)	X																			
Great Black-backed Gull (*Larus marinus*)													X							
Grey Plover (*Pluvialis squatarola*)													X							
Greylag Goose (*Anser anser*)					X									X			X			
Guillemot (*Uria aalge*)													X							
Little Auk (*Alle alle*)													X							
Long-tailed duck (*Clangula hyemalis*)													X							
Mallard (*Anas platyrhynchos*)					X								X		X				X	
Manx Shearwater (*Puffinus puffinus*)													X							
Pochard (*Aythya ferina*)																			X	
Puffin (*Fratercula arctica*)													X							
Razorbill (*Alca torda*)		X	X										X							
Ruddy Shelduck (*Tadorna ferruginea*)				X																
Shag (*Phalacrocorax aristotelis)*													X							
Smew (*Mergus albellus*)												X	X							
Teal (*Anas crecca*)					X	X												X		
Tufted duck (*Aythya fuligula*)																			X	
Turnstone (*Arenaria interpres*)		X											X							
Velvet Scoter (*Melanitta fusca*)													X							
White Stork (*Ciconia ciconia*)	X			X																
White-fronted Goose (*Anser albifrons*)					X		X						X							
Whooper Swan (*Cygnus Cygnus*)										X										
Wigeon (*Anas Penelope*)				X	X								X						X	
Total number of species identified	4	6	2	5	5	1	1	1	1	1	1	1	21	1	1	1	1	2	8	1

Table 2.7 Species of avian remains from South West Britain from a variety of sites and time periods. View above key for the sites represented by the site number and the time period of the finds. This list draws heavily on Harrison (1987a). X indicates their presence

As well as understanding the possible species of the past it is also important to understand the present bird species that visit the Severn Estuary and Great Britain, as migration behaviours and residents of Britain may have changed since prehistory. Table 2.8 records the avian species that have been noted on the Severn Estuary since 1952 (Severn Side Birds 2018), the seasons that they are present and in certain cases, their rarity. By understanding the large range of birds that may frequent the intertidal zone, and comparing it to the avian skeletal record of nearby prehistoric sites (Table 2.7) a picture of the prehistoric birds that visited the Severn Estuary begins to be established. Mesolithic Port Eyon is contemporary in date to Goldcliff and approximately 70 miles from Goldcliff Island. A consideration of the species within this area may assist in understanding the birds that may have been present on the Severn Estuary during the Mesolithic period. Of the 21 avian species from Port Eyon, 12 are currently still found on the Severn Estuary. Three of the 12 are year-round residents and the other nine visit the Severn Estuary during different seasons throughout the year. Four of the species represented in the bones at Port Eyon are from birds that are seen on the Severn Estuary, but are considered rare. Barnacle goose and little auk can be seen during the winter, and razorbill during the summer; less than 100 of these birds are noted each year. Great-blacked gull were not on the Severn Estuary bird list (Severn Side Birds 2018), however the RSPB note that one or two pairs may be sighted there each year. The final five species are all birds that have not been sighted on the Severn Estuary since 1952, but they are still seen in other areas of Britain. Black-throated divers are residents of the British coastline and can be seen at Port Eyon (Hume 2002), there is also a summer migratory population that can be found across the coastlines of Britain. Gannet are also not listed on the Severn Estuary bird list; they are a relatively rare bird due to their small breeding populations, some of which are in Pembrokeshire. Long-tailed duck still winter on British coastlines, especially at Orkney, though they do not winter on the Severn Estuary. Puffins are residents of north Scotland, though summer breeders fly to west Wales and Ireland. Velvet Scoters are also found in small numbers in winter on the British coastlines (Hume 2002).

Within footprint-track studies, a consideration of the species in prehistory and the environments and habitats these species require can be a useful resource when establishing a footprint-track maker. Avian footprint-tracks are often overlooked or only briefly mentioned in site reports, full analysis would enhance our understanding of Mesolithic birds, as the bone record is not extensive.

2.6 Summary

The Mesolithic period in Britain is relatively sparse in terms of sites that contain human, bird and mammal bones, though those we do have are informative and assist in our understanding of the species. This information can complement footprint-track data and assist in the way we interpret a site. A brief discussion of the bird bones in prehistoric Britain was presented within this chapter to assist in understanding why certain species were focused upon during the experiment in Chapter 7. The bones of Mesolithic humans and animals are also of importance in using as a complimentary dataset when observing the prehistoric footprints.

Species	Present year round	Present in spring	Present in summer	Present in autumn	Present in winter	Rare on the estuary (<100 noted yearly)	Extremely rare on the estuary (<10 noted yearly)
American golden plover (*Pluvialis dominica*)					X		X
American wigeon (*Anas americana*)					X	X	
Arctic tern (*Sterna paradisaea*)		X	X				
Artic skua (*Stercorarius parasiticus*)		X	X	X			
Avocet (*Recurvirostra avosetta*)		X		X	X	X	
Baird's sandpiper (*Calidris bairdii*)			X	X			X
Barnacle goose (*Branta leucopsis*)					X	X	
Bar-tailed godwit (*Limosa lapponica*)			X	X	X		
Bean goose (Anser fabalis)					X		X
Bewick's swan (Cygnus columbianus)				X			
Black tern (*Chlidonias niger*)		X	X				
Black-headed gull (*Chroicocephalus ridibundus*)	X						
Black-tailed godwit (*Limosa limosa*)		X		X	X		
Bonaparte's gull (*Chroicocephalus philadelphia*)			X	X		X	
Brent goose (*Branta bernicla*)					X		
Broad-billed sandpiper (*Limicola falcinellus*)		X					X
Buff-breasted sandpiper (*Tryngites subruficollis*)			X	X			X
Cattle egret (*Bubulcus ibis*)		X		X			X
Common crane (*Grus grus*)		X			X		X
Common gull (*Larus canus*)					X		
Common sandpiper (*Actitis hypoleucos*)		X	X				
Common scoter (*Melanitta nigra*)				X	X		
Common shelduck (*Tadorna tadorna*)	X						
Common snipe (*Gallinago gallinago*)				X	X		
Common tern (*Sterna hirundo*)		X	X				
Coot (*Fulica atra*)	X						
Curlew (*Numenius arquata*)			X	X	X		
Curlew sandpiper (*Calidris ferruginea*)			X	X			
Dotterel (*Charadrius morinellus*)			X	X			X

Table 2.8 Avian species that have been seen on the Severn Estuary since 1952, including the season they can be seen and their rarity (data gathered from Severnside birds systematic list). X indicates their presence

Species	Present year round	Present in spring	Present in summer	Present in autumn	Present in winter	Rare on the estuary (<100 noted yearly)	Extremely rare on the estuary (<10 noted yearly)
Dunlin (*Calidris alpina*)					X		
Eider (*Somateria mollissima*)					X		
European teal (*Anas crecca*)			X	X			
Franklin's Gull (*Leucophaeus pipixcan*)			X				X
Fulmar (*Fulmarus glacialis*)			X	X			
Gadwall (*Anas strepera*)	X						
Garganey (*Anas querquedula*)			X			X	
Glaucous gull (*Larus hyperboreus)*					X	X	
Glossy ibis (*Plegadis falcinellus*)		X					X
Golden plover (*Pluvialis apricaria*)		X		X	X		
Goldeneye (*Bucephala clangula*)					X		
Goosander (*Mergus merganser*)					X		
Great bittern (*Botaurus stellaris*)					X		
Great crested grebe (*Podiceps cristatus*)	X						
Great northern diver (*Gavia immer*)					X		X
Great skua (*Catharacta skua*)		X					
Great white egret (*Ardea alba*)		X	X	X	X		X
Green sandpiper (*Tringa ochropus*)		X	X	X			
Greenshank (*Tringa nebularia*)		X			X		
Green-winged teal (*Anas carolinensis*)					X		X
Grey heron (*Ardea cinerea*)	X						
Grey plover (*Pluvialis squatarola*)		X		X			
Greylag goose (*Anser anser*)	X					X	
Guillemot (*Uria aalge)*			X	X			
Herring gull (*Larus argentatus*)					X		
Iceland gull (*Larus glaucoides*)					X	X	
Jack snipe (*Lymnocryptes minimus*)				X	X		
Kentish plover (*Charadrius alexandrinus*)			X	X			X
Kittiwake (*Rissa tridactyla*)					X		
Knot (*Calidris canutus*)					X		

Table 2.8 continued

Species	**Present year round**	**Present in spring**	**Present in summer**	**Present in autumn**	**Present in winter**	**Rare on the estuary (<100 noted yearly)**	**Extremely rare on the estuary (<10 noted yearly)**
Lapwing (*Vanellus vanellus*)	X						
Little auk (*Alle alle*)					X	X	
Little egret (*Egretta garzetta*)		X	X				
Little grebe (*Tachybaptus ruficollis*)	X						
Little gull (*Hydrocoloeus minutus*)		X		X	X		
Little stint (*Calidris minuta*)		X	X	X			
Little tern (*Sternula albifrons*)		X	X			X	
Long-billed dowitcher (*Limnodromus scolopaceus*)				X			X
Long-tailed skua (*Stercorarius longicaudus*)		X		X		X	
Mallard duck (*Anas platyrhynchos*)	X						
Manx shearwater (*Puffinus puffinus*)			X				
Meadow pipits (*Anthus pratensis*)				X	X		
Mediterranean gull (Larus melanocephalus)		X					
Moorhen (*Gallinula chloropus*)	X						
Mute swan (*Cygnus olor*)	X						X
Night heron (*Nycticorax nycticorax*)		X					X
Northern gannet (*Sula bassana*)			X	X			
Oystercatcher (*Haematopus ostralegus*)	X						
Pectoral sandpipers (*Calidris melanotos*)		X	X	X			X
Pink-footed goose (*Anser brachyrhynchus*)					X		X
Pintail (*Anas acuta*)					X		
Pochard (*Aythya ferina*)					X		
Pomarine skua (*Stercorarius pomarinus*)		X				X	
Purple heron (*Ardea purpurea*)		X					X
Purple sandpiper (*Calidris maritima*)					X		X
Razorbill (*Alca torda)*			X	X		X	
Red-breasted goose (*Branta ruficollis*)					X		X
Red-breasted merganser (*Mergus serrator*)					X		X
Red-crested pochard (*Netta rufina*)					X	X	
Red-necked phalarope (*Phalaropus lobatus*)			X	X			X

Table 2.8 continued

Species	**Present year round**	**Present in spring**	**Present in summer**	**Present in autumn**	**Present in winter**	**Rare on the estuary (<100 noted yearly)**	**Extremely rare on the estuary (<10 noted yearly)**
Red-throated diver (*Gavia stellata*)			X				X
Reed bunting (*Emberiza schoeniclus*)				X	X		
Ring-billed gull (*Larus delawarensis*)			X				X
Ringed plover (*Charadrius hiaticula*)	X						
Roseate tern (*Sterna dougallii*)			X	X			X
Ruddy duck (*Oxyura jamaicensis*)		X		X	X	X	
Ruff (*Philomachus pugnax*)				X	X	X	
Sabine’s Gull (*Xema sabini*)				X			X
Sand martin (*Riparia riparia*)		X		X			
Sanderling (*Calidris alba*)		X			X		
Scaup (*Aythya marila*)					X		
Semipalmated sandpiper (*Calidris pusilla*)			X	X			X
Shag (*Phalacrocorax aristotelis*)			X	X			
Shoveler (*Anas clypeata*)	X						
Smew (*Mergus albellus*)					X		X
Snow goose (*Chen caerulescens*)					X		X
Spoonbill (*Platalea leucorodia*)		X	X	X	X	X	
Spotted redshank (*Tringa erythropus*)					X		
Stone curlew (*Burhinus oedicnemus*)		X	X				X
Temmincks stint (*Calidris temminckii*)		X	X	X			X
Temminck's stint (*Calidris temminckii*)			X	X			X
Terek sandpiper (*Xenus cinereus*)				X			X
Tufted ducks (*Aythya fuligula*)	X						
Tundra swan (*Cygnus columbianus*)					X	X	
Turnstone (*Arenaria interpres*)		X			X		
Water rail (*Rallus aquaticus*)	X						
Whimbrel (*Numenius phaeopus*)		X			X		
Whiskered tern (*Chlidonias hybrida*)		X				X	
White stork (*Ciconia ciconia*)		X	X				X
White-fronted goose (*Anser albifrons*)				X			
White-rumped sandpiper (*Calidris fuscicollis*)			X	X			X
White-tailed lapwing (*Vanellus leucurus*)			X			X	
Whooper swan (*Cygnus cygnus*)		X		X	X		X
Wigeon (*Anas penelope*)					X		
Yellow-legged gull (*Larus michahellis*)					X		

Table 2.8 continued

Chapter 3

Later Quaternary Stratigraphy of the Severn Estuary Levels

3.1 Introduction

The Severn Estuary is located on the south-west coast of Britain, which is rich in sites of high archaeological and palaeoenviromental importance, and is a Site of Special Scientific Interest, a Special Protection Area, and a Special Area of Conservation. The Severn River is the longest river in Great Britain, with the second highest tidal range in the world, reaching a maximum of 14.8m at Avonmouth (Admiralty Tide Tables 2015). This tidal range has created an ecosystem unique to the United Kingdom, with mud and sand flats, estuaries, saltmarsh pastures and lagoons providing a habitat for a variety of birds, mammals and fish (The Wildlife Trust, Avon 2017).

The preservation of palaeoenvironmental evidence is rich in intertidal areas (Davidson 2002). Changes to sea levels over time has enabled excellent preservation, with a variety of archaeology preserved in the waterlogged environments of the Flandrian sediments. These sediments form part of a complex sequence of sediment formation through terrestrial regression and marine transgression during the Late Quaternary (Allen 1997, 2001a). Fluctuating sea levels through multiple time periods have resulted in a variety of terrestrial, riverine and estuarine land surfaces, enhanced by the twice daily rising and falling tide, the biweekly spring tide cycle, the equinox cycles and tides related to astronomical events, floods and storms (Bell and Neumann 1997).

The embanked shore of the estuary of today differs from that of prehistory. During the last Ipswichian interglacial period sea levels were higher than they currently are, possibly 5-10m above current sea level, with gravels and sands deposited upon the Pre-Ipswichian dissected bedrock (Jones 2002a). The following glaciation (Devensian) resulted in a significant drop in sea levels, approximately 120m below present sea level, exposing a greater land mass (Murphy 2002).

At the end of the glaciation (9500 cal BC) sea levels were at most 35m below present levels (Murphy 2002), sea levels rose again in Britain, as melting of the ice (glacio-eustasy) occurred (Tooley 1974). The amount of water released by glacio-eustasy resulted in a large amount of water entering the oceans, submerging low-lying coastland, peat beds and forests (Jones 2002b). The sequence of the Holocene stratigraphy formed over the last 8000 years (Figure 3.1; Table 3.1), has at its base basal peat that overlays a Holocene soil above Pleistocene bedrock (Allen 2000b).

The Holocene prehistoric sediment sequence found upon the Severn Estuary is the Wentlooge Formation, named after the Wentlooge Level in Gwent (Allen and Rae 1987). The sediments in the Wentlooge Series are predominantly uniform grey clayey silts (Rippon 1997). The Wentlooge Formation is found beneath the Severn Levels, with Holocene sediments covering an area of *c*.840km^2, and 10-15m in total thickness (Allen 2005). Evidence of footprint-tracks can be found in these Holocene sediments.

Due to rapid periods of sea level rise experienced during the Holocene, the basal gravel and peats were overlain with lower estuarine silts, clays, and with sand in certain areas. These estuarine silt layers represent marine phases extending further inland, whereas the alternating peat phases contain the remains of reed marshes, fen carr, woodland and raised bog. These extended further out to areas that are now covered by water, with different phases representing climate and sea level changes (Nayling 2002).

The number of peat sequences varies, although as many as five peat bed sequences may occur (Allen 2000b), with the development of the peat occurring from 6770 ±70 BP (Beta-60761; 5740-5490 cal BC; Bell 2007, Table 2.1). The thickest Holocene peat is a clearly defined feature of the intertidal zone, formed from reed peat overlain by wood peat and raised bog during the middle Wentlooge (Figure 3.2 and Figure 3.3). Peat provides archaeologists with excellent dating opportunities; when footprint-tracks are recorded on this surface dates can be ascertained for these.

The Upper Wentlooge estuarine silts and peats are late Holocene in date and many meters thick, with sea levels fluctuating between approximately five meters of the current tidal height (Allen 2000b; Nayling 2002; Tooley 1974). The Wentlooge Formation represents the remains of a wetland environment, consisting of salt marshes and intertidal silt mudflats during the marine phase, and reed marshes, woodland and peat bogs in the terrestrial phase.

Other silt formation stages occur above the Wentlooge Formation, on areas of the Severn Estuary where there is still an active saltmarsh. These are the Rumney, Northwick and Awre Formations and represent areas of saltmarsh retreat and advancement during the last millennia (Allen and Rae 1987; Allen 1987; 1997; Allen 2001a). The Rumney Formation is split into lower (medieval) and upper (early modern) and underlies the highest saltmarsh, whilst the Awre Formation is late 19th century in date and underlies the salt marshes at an intermediate level. The Northwick Formation is mid-20th century in date and is found beneath the lowest lying saltmarsh (Allen 2001a).

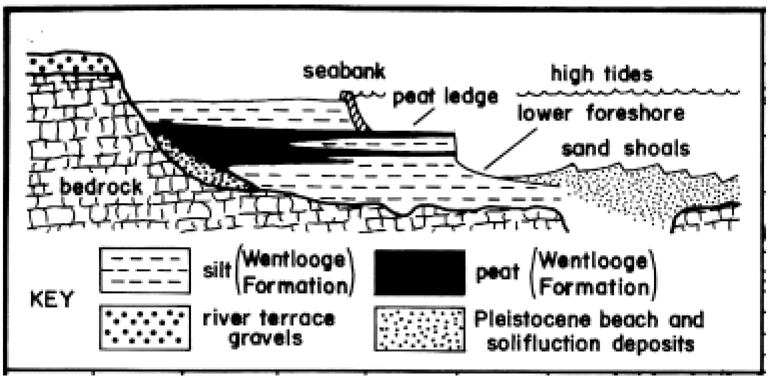


Figure 3.1 Schematic geomorphology and stratigraphy from the Severn Estuary showing the Wentlooge formation (Allen 2000b).

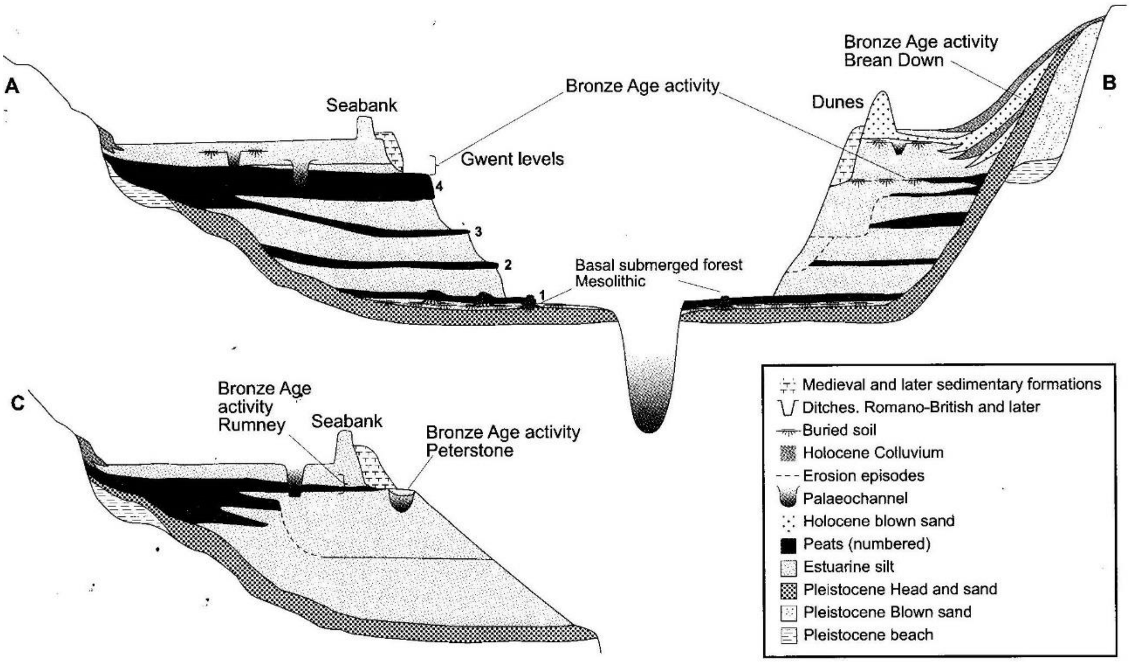


Figure 3.2 Simplified sediment sequence of the Severn Estuary (graphics S. Lucas; Bell 2013, Figure 1.4)

Figure 3.3 Example of the clayey silt interspersed with peat seen in the Wentlooge Formation, photographed at Goldcliff East near Site A

Unit	**Sediments**	**Sedimentary formation period**	**Calibrated date**	**Evidence of footprint-tracks from sites on the Severn Estuary**
xv	Grey silts beneath lowest lying marsh	Northwick (mid-20th century) formation		Human at Tites Point, Arlingham and Strand Cattle at Rodley Sheep at Goldcliff and Rodley
xiii	Grey silts	Awre (late 19th century) formation		Human at Frampton-on-Severn. Cattle at Horse Pill, Frampton-on-Severn, Awre and Rodley. Sheep at Tites Point
xiv	Texturally banded pale brown grading up to grey silts	upper (early modern) Rumney Formation		Human, cattle and sheep at Pill House, Tidenham Human and cattle at Plusterwine, Woolaston
xii	Texturally banded pale brown grading up to grey silts	lower (Medieval) Rumney formation		Cattle and sheep at Frampton-on-Severn
xi	Minerogenic estuarine sediments	upper Wentlooge		Human, cattle and horse at Redwick Human and cattle at Beachley Cattle at Rumney great wharf Cattle and deer at Oldbury mud flats Possible horse at Goldcliff
x	Thin reed peat	upper Wentlooge		Cattle at Cold Harbour Pill
ix	Minerogenic estuarine sediments	upper Wentlooge		
viii(f)	Reed peat	middle Wentlooge	1610-1200 cal BC	Sheep/goat and cattle at Goldcliff East Human and mammal at Redwick Auroch and deer at Peterstone

viii (e)	Raised bog peat	middle Wentlooge	3970-3650 to 1940-1530 cal BC	Neolithic human, cattle and deer at Oldbury flats
viii (d)	Reed and sedge peat	middle Wentlooge	4350-3990 to 3970-3650 cal BC	
viii (c)	Upper Submerged Oak Forest	middle Wentlooge		
viii (b)	Alder carr-woodland	middle Wentlooge		
viii (a)	Reed peat	middle Wentlooge	5050-4610 to 4910-4500 cal BC	Human and dog/ wolf at Magor
vii	Minerogenic estuarine sediments, banded	lower Wentlooge	10,000 BP – c 4600 Cal BC	Mammal, bird and human at Goldcliff East Human and ungulate at Uskmouth Auroch, deer, wolf/ dog and bird at Magor Pill Auroch and deer at Redwick
vi	Thin peat containing some trees of Lower Submerged Forest	Mid-Holocene		
v (c)	Thin estuarine sediment	Mid-Holocene		
v (b)	Lower Submerged Oak Forest	Mid-Holocene	6179-5826 ±4 BC	
v (a)	Old Land Surface	Mid-Holocene	5490-5330 cal BC	Ungulate footprint-tracks at Site J, Goldcliff East
iv	Stony Head containing Trias Red Marl	Devensian		

iii	Sandy pebbly Head containing Lias limestone	Devensian		
ii	Sandy pebbly Ipswichian beach cemented as sandrock locally	Ipswichian		
i	Bottom			

Table 3.1 Geological sequence of sediment formation from the Severn Estuary, outlining the main Pleistocene and Holocene sedimentary units, including contexts where footprint-tracks have been recorded. Table compiled from the work of Bell (2007, Table 2.1) and Allen (1997). The mid-Holocene sediments represent dry land sediments at Goldcliff Island, whereas the lower Wentlooge sediments represent the sediment sequence within the wetland and estuarine environment across the Severn Estuary.

3.2 Banded Sediments

Estuarine sediments of the lower Wentlooge Formation are characterised by banding of silts exposed on the margins of the estuary (Figure 3.4; Bell *et al*. 2003). The banding occurs in three stratigraphic contexts. The unbroken deposition of silt and sand creates banded layers which form a sequence of ‘couplets’, these occur in the lower and middle Wentlooge Formation, with the banding only occurring upon the middle and upper parts of the silt beds (Allen 2004). A further context for banded silts is seen in palaeochannels, where many of the former tidal creeks are infilled with silts. The third context for banded sediments occurs when silts are accumulated above erosion surfaces after regime change. A further fourth context may occur in minor settings and is caused when sediment is laterally added to a landmass, which can be seen at the Holocene deposits at Goldcliff, where there are silt deposits that are gently dipped (Figure 3.5).

Prehistoric footprint-tracks can be found on banded silts between the basal mid-Holocene and middle Wentlooge peats. The banded laminae have been observed to be on a submillimetre to millimetre scale (Allen 2004), and are visually distinctive, with the fine textured clayey silt overlain by sandy silt (Figure 3.6). Textural models studying sediment deposition on a modern estuarine environment suggest that seasonally changing windiness and temperature of the water effect the deposition of the silts, which can vary in grain-size and thickness of the laminated band (Allen and Haslett 2006). Seasonal changes to water temperature cause variation in the grain size of particles held in suspension in the water, as temperature effects viscosity (Allen 2004). During the winter months waters are more viscous and hold larger particles in suspension, as opposed to the warmer summer waters which are less viscous and hold finer grained particles (Allen 2004; Dark and Allen 2005). The modern water body of the Severn Estuary has high turbidity, with spring neap and semi-annual tidal patterns having a differing effect on the deposition of fine-grained sediments (Allen 2004).

Fine-grained bands were found to contain a higher concentration of pollen opposed to coarse-grained bands; pollen in the fine-grained bands was made up of a higher proportion of late spring and summer flowering plants (Allen 2004). Pollen deposited on coarse-grained sediments came from pollen that was suspended in the estuarine water and from rivers, whereas in the fine-grained sediment pollen was deposited via the atmosphere (Table 3.2).

Textural differences indicate that there are a variety of factors that influence the deposition of different sized particles. The evidence suggests that laminations containing sediment made up of coarse-grained particles and a limited amount of plant pollen were deposited during the winter months, whereas the fine-grained, pollen rich sediment was lain down during the late spring and summer months (Dark & Allen 2005).

This seasonal distinction between coarse-grained and fine-grained banding is of importance within this study as the particle size of the banding may indicate the season in which animals were present (Chapter 8).

Figure 3.4 Lower Wentlooge Formation banded estuarine silt sediment cliff in section, at Site C/E (photograph courtesy of T. Walker)

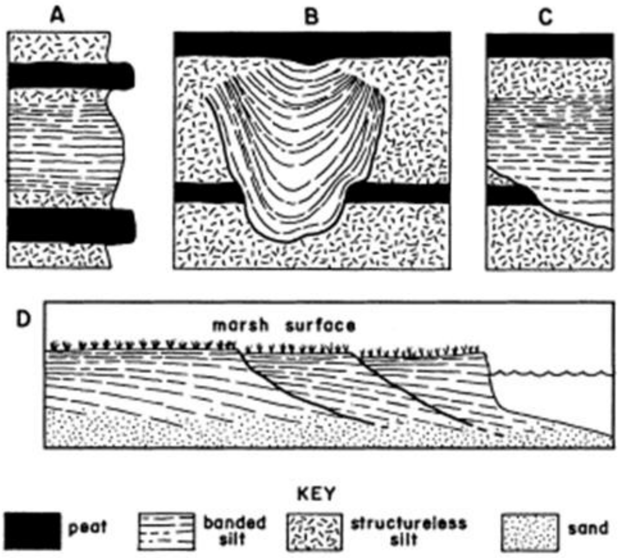


Figure 3.5 Schematic representation of the stratigraphic contexts of banded silts in the Severn Estuary Levels. (A) Continuously deposited sequence. (B) Palaeochannels. (C) Above erosion surface. (D) Laterally accreted (above an erosion surface). No explicit scales are given, but the sequences represented are of the order of one to a few metres in thickness. (Allen 2004, Figure 2)

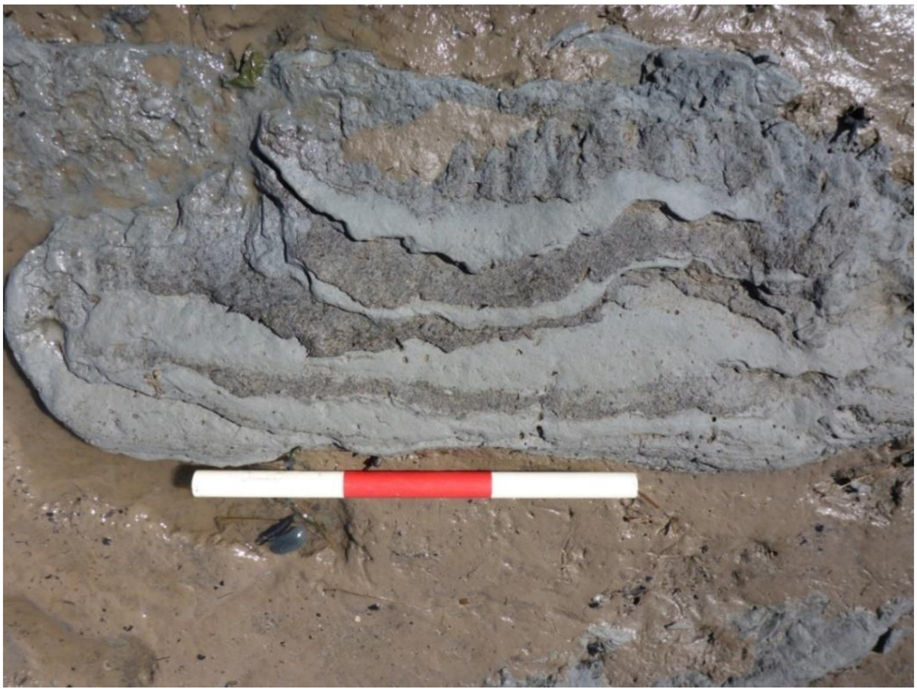
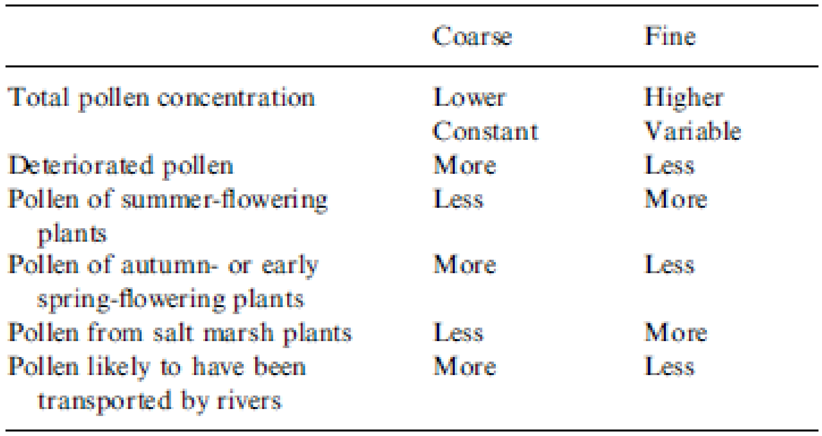


Figure 3.6 Banded sediment demonstrating the coarse-grained winter sediment as opposed to the fine-grained summer sediments, in plan view. Scale 30cm



	Coarse	Fine
Total pollen concentration	Lower Constant	Higher Variable
Deteriorated pollen	More	Less
Pollen of summer-flowering plants	Less	More
Pollen of autumn- or early spring-flowering plants	More	Less
Pollen from salt marsh plants	Less	More
Pollen likely to have been transported by rivers	More	Less

Table 3.2 Summary of overall differences between coarse and fine band

(Dark and Allen 2005, Table 6)

3.3 Footprint-track sites in the Severn Estuary

The Mesolithic sea-level was different to today; certain areas of land that were once accessible have now been transgressed by the sea. The changes in sea-level resulted in a drowned landscape and a waterlogged environment which is excellent for the preservation of artefacts, especially organic materials. Footprint-tracks of Holocene humans, birds and mammals have been preserved in this drowned landscape, these are mainly recorded on laminated silts of the lower Wentlooge Formation. Due to the tidal range, these submerged sites are uncovered several times a year, which allows archaeologists to access the foreshore.

The Mesolithic site at Goldcliff East is the focus of this thesis due to the frequency in which preserved prehistoric footprint-tracks have been found, however there are a variety of sites from multiple time periods on the Severn Estuary with evidence of footprint-tracks (Table 3.1). Sites surrounding Goldcliff East were visited during the fieldwork for this investigation (Figure 3.7, Figure 3.8), however thick mud and sandbanks covered these areas. There has also been extensive erosion since the footprint-tracks were originally recorded around 20 years ago, completely changing the landscape and burying or destroying many sediments where prehistoric footprint-tracks were preserved.

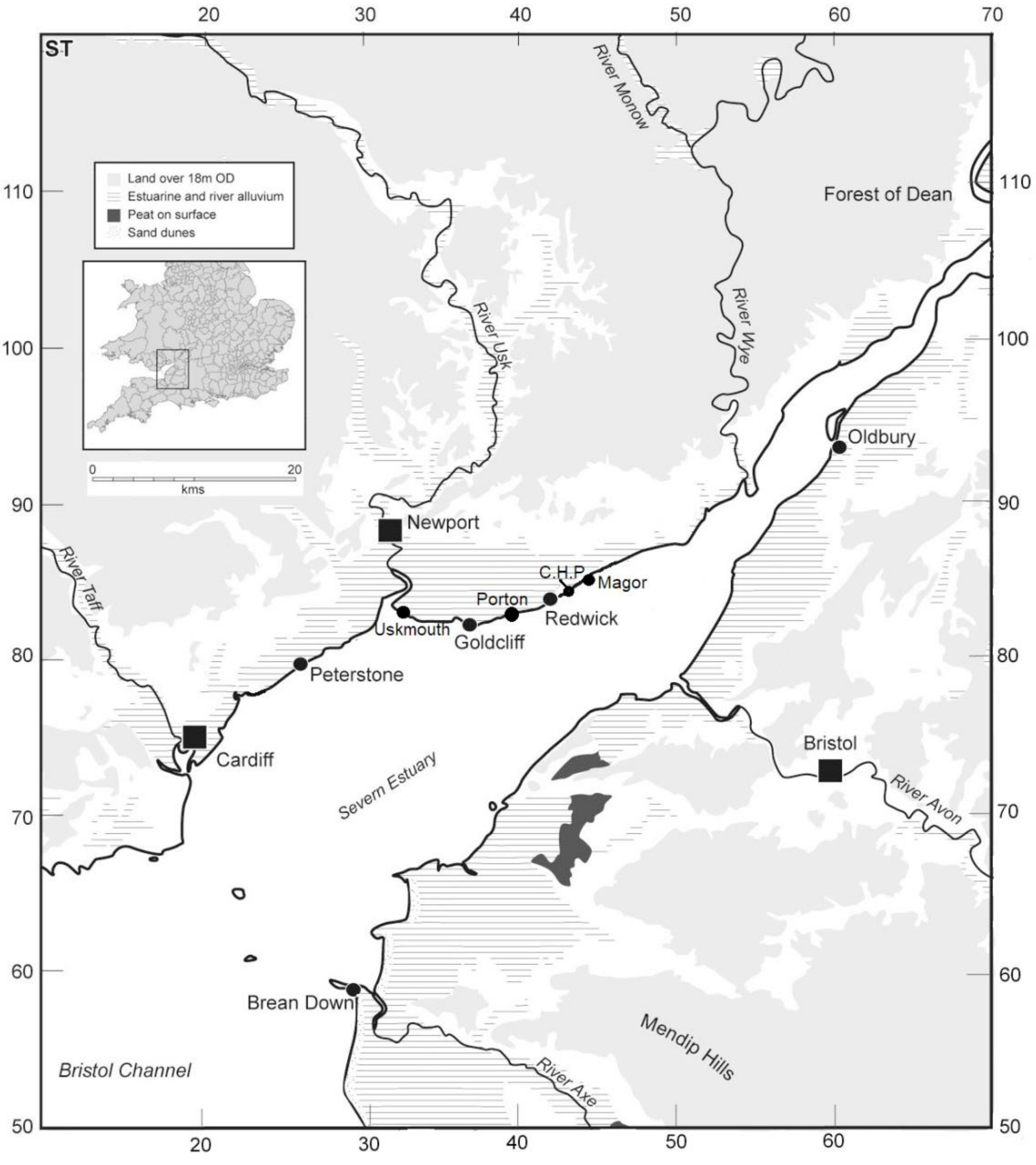


Figure 3.7 Map of the Severn Estuary and the site of Mesolithic, Bronze Age and Neolithic footprint-tracks found in close proximity to Goldcliff. Note that C.H.P is Cold Harbour Pill. (Graphic M. Matthews and adapted by author)

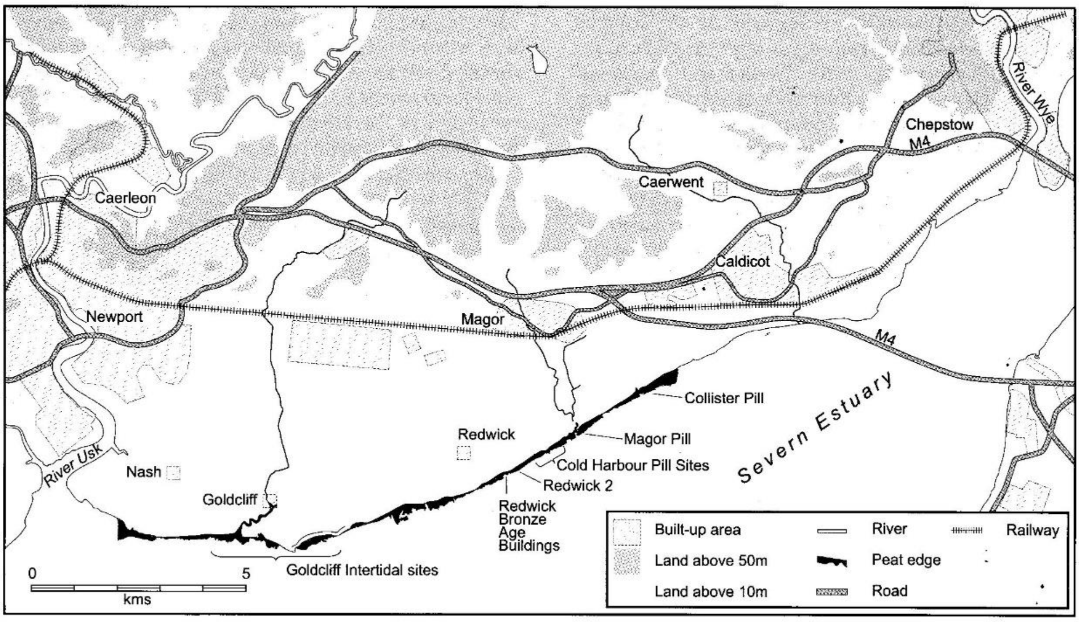


Figure 3.8 Map of the Prehistoric sites near Goldcliff (graphic M. Matthews; Bell 2013, Figure 2.1)

3.3.1 Magor Pill

Magor Pill is located between the sites of Cold Harbour Pill and Chapelthump, 1km in length across the intertidal zone. Previous survey at the site revealed an area rich in both history and prehistory. Trails of human footprint-tracks were recorded on the lower Wentlooge formation, made on silty clay laminations sealed by peat, with the peats slightly below the footprint-tracks dated to 5720 ± 80 BP (OxA-2626, 4780-4360 cal BC; Aldhouse-Green e*t al*. 1992). The trails were made by two barefoot individuals travelling together; one was an adult, likely a male due to the approximate height of 200cm (6’6”), the other trail was smaller and likely to have been made by a child. These individuals were travelling in the direction of a large palaeochannel (Aldhouse-Green *et al*. 1992). Near to this trail a further adult footprint-track trail was recorded, also heading towards a palaeochannel. A dog/wolf footprint-track was recorded within the laminated silts that infilled the channel, as well as auroch and deer footprint-tracks from a number of laminated silts from the lower Wentlooge Formation (Allen 1987). When the site was revisited by Bell *et al*. (2000, p 290) further possible human footprint-tracks were noted, as well as avian footprints, one of which was identified as a probable crane. The mudflats would have provided the people of Magor Pill with an open hunting ground, where ungulates could be targeted, as well as an area that would provide resources from the sea. The juvenile walking with the adult male suggests that young children were actively involved in activities, possibly including hunting and fishing.

As well as footprint-tracks, several artefacts were recorded at Magor. An unstratified Neolithic polished rhyolite axe was found on muds near the middle Wentlooge peats (Green 1989). A possible hearth was discovered on raised bog peat, approximately 150m east of Magor Pill's eastern palaeochannel; a brushwood trackway was also in this area, these were likely Bronze Age in date due to being on the peat surface, though they may have been Iron Age (Neumann 2000, p 307). Iron Age finds were recorded in the upper part of the fill in a channel at Magor, and include Iron Age pottery such as a bucket-shaped pot which was dated to the 3rd-1st century BC (Whittle *et al*.1989), and Late Iron Age calcite tempered ware from other areas of Magor Pill (Allen 1998b). Further finds in the channel upper silt recorded by Whittle *et al*. (1989) include animal bones and a wooden peg. Pottery from the Roman and Medieval period was also recorded at Magor, as was a medieval boat and medieval-modern fishtraps (Bell and Neumann 1997, p 5; Nayling 1998). This site demonstrates how intertidal zones provide a palimpsest of archaeology due to the exploitation of wetland environments.

Although previously rich in data, during this study the site was covered by a large sand bank with little exposure of laminated silts or peats.

3.3.2 Cold Harbour Pill

The site of Cold Harbour Pill is relatively small, covering *c*.400m of the intertidal zone, and is situated between Redwick and Magor. Cold Harbour Pill has evidence of prehistoric footprint-tracks, with a possible cattle hoofprint documented by Whittle *et al*. (1989) on the middle Wentlooge Formation. Further cattle footprint-tracks were recorded from peat on the bank of a palaeochannel which had a consolidated grey clay fill, the footprint-tracks were marked out by areas of grey clay on the peat. Further investigation of the palaeochannel found a line of round wood verticals and a woven structure which is thought to be from a fishing structure (Figure 3.9), possibly a fence-like structure which contained woven baskets (Neumann 2000, p 309). The wooden structure was radiocarbon dated to 2520 ± 60 BP (SWAN-241, 790-530 cal BC; Neumann 2000, p 306), meaning the cattle footprint-tracks and the wooden structure were early Iron Age in date.

A trackway was reported by Locock (1998) and was found on the peaty clay layer above the main peat shelf, with the peat sealed by a second thinner peat layer (Neumann 2000, p 289). Within the raised peat bog at Cold Harbour Pill, found within a depression, two concentrated areas of charcoal were observed, radiocarbon dated to 2900 ± 60 BP (Car-991, 1300-920 cal BC; Whittle *et al*. 1989). Associated with the charcoal were fragments of pottery, pointed stakes and fire-cracked flints. Another area containing charcoal was located 360m west of Cold Harbour Pill, and was also found to contain evidence of stakes (Neumann 2000, p 300).

During this study there were no footprint-tracks or any other archaeological data discovered at Cold Harbour Pill, though this was likely due to mud and a large sandbank covering most of the area.

Figure 3.9 Palaeochannel at Cold Harbour Pill containing a wooden structure which was possibly for fishing. Scale 0.3m (Bell et al. 2000, Figure 16.20)

3.3.3 Redwick

Redwick is a site in the intertidal zone of approximately 700m in length. This area has been studied thoroughly and exhibits archaeological evidence from a variety of time periods. On the lower Wentlooge Formation the footprint-tracks of adults and juveniles were recorded on laminated silts, as were those of deer and cattle, which were likely auroch (Figure 3.10). On the middle Wentlooge Formation cattle footprint-tracks were recorded within heavily trampled muds within a paleochannel (Allen 1997). Further footprint-tracks are on the surface of middle Wentlooge peat, are filled with silt and are around peat hummocks where four Bronze Age rectangular buildings have been recorded, these have been dated to 1500-100 cal BC (Bell 2013, p 155). Evidence for the exploitation of intertidal wetlands is indicated by the human and domesticated animal footprint-tracks made upon the peat shelf; these occur in curvilinear depressions around the buildings (Figure 3.11 and Figure 3.12).

Redwick contained a prevalence of cattle and sheep/goat in the footprint-track record, made up of juveniles and full-grown adults (Table 3.3). The composition of neonates and adults in the assemblage indicates a breeding herd made up of lactating females and their young, which is a herd/flock composition that is suggestive of dairy production (Barr and Bell 2016; Balasse and Tresset 2002; Copley *et al*. 2005a,b; O'Connor 2000). Sheep would provide the added benefit of wool when they were at a young age.

Only a small number of artefacts were associated with the buildings, which indicates that it is unlikely that these buildings were used throughout the year, though random repairs to the buildings indicate re-use (Pearson 2013, p 88). The recovery of skeletal remains from a juvenile calf, as well as the footprint-track evidence, indicates that the saltmarshes were being exploited by humans during the warmer months to graze their animals on nutrient-rich saltmarsh, and as a safe place for livestock to birth and nurse their young (Britton *et al.* 2008). The artefact and footprint-track evidence from Redwick suggests seasonal use by pastoralists during the Bronze Age (Bell 2013, p 161).

Within this study Redwick was re-visited, however there were not any newly discovered footprint-tracks that could be included in this study, though the previous work on these Bronze Age footprint-tracks does demonstrate how informative footprints can be.

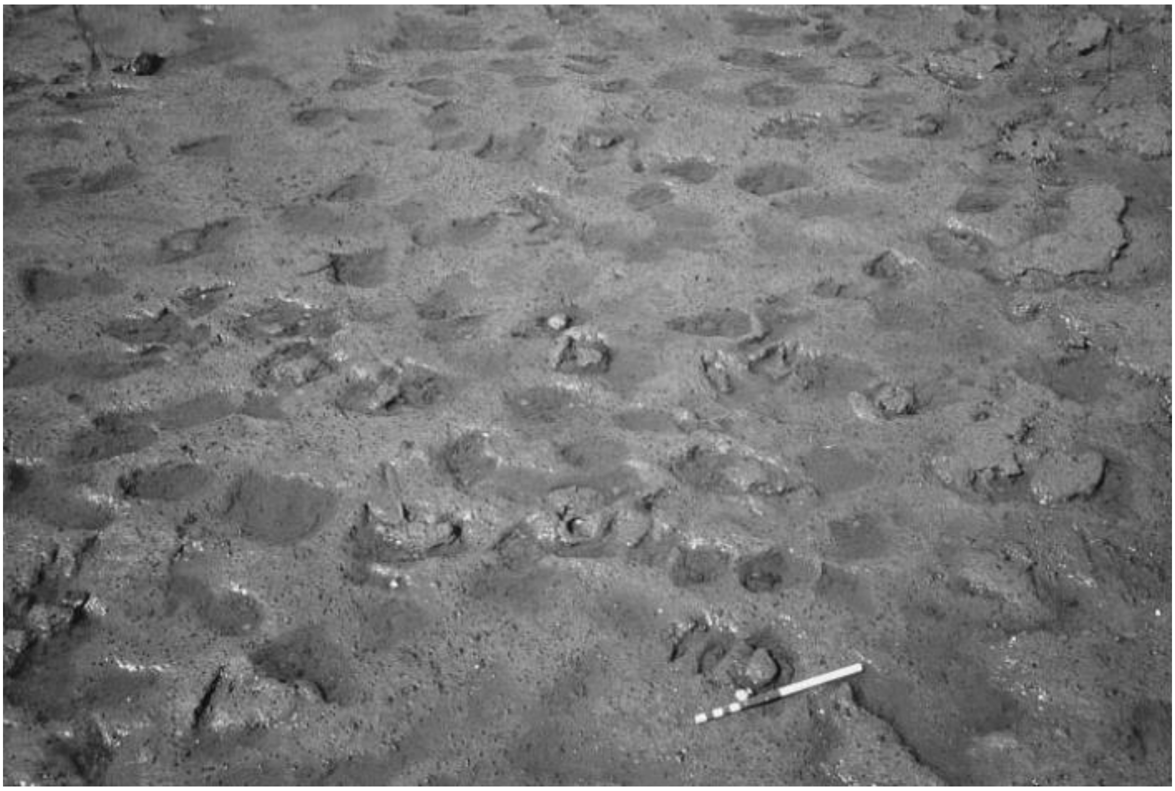


Figure 3.10 Laminated surface trampled by deer, likely red deer, and auroch/cattle on the lower Wentlooge formation, Redwick. Scale 0.2m (Allen 1997)

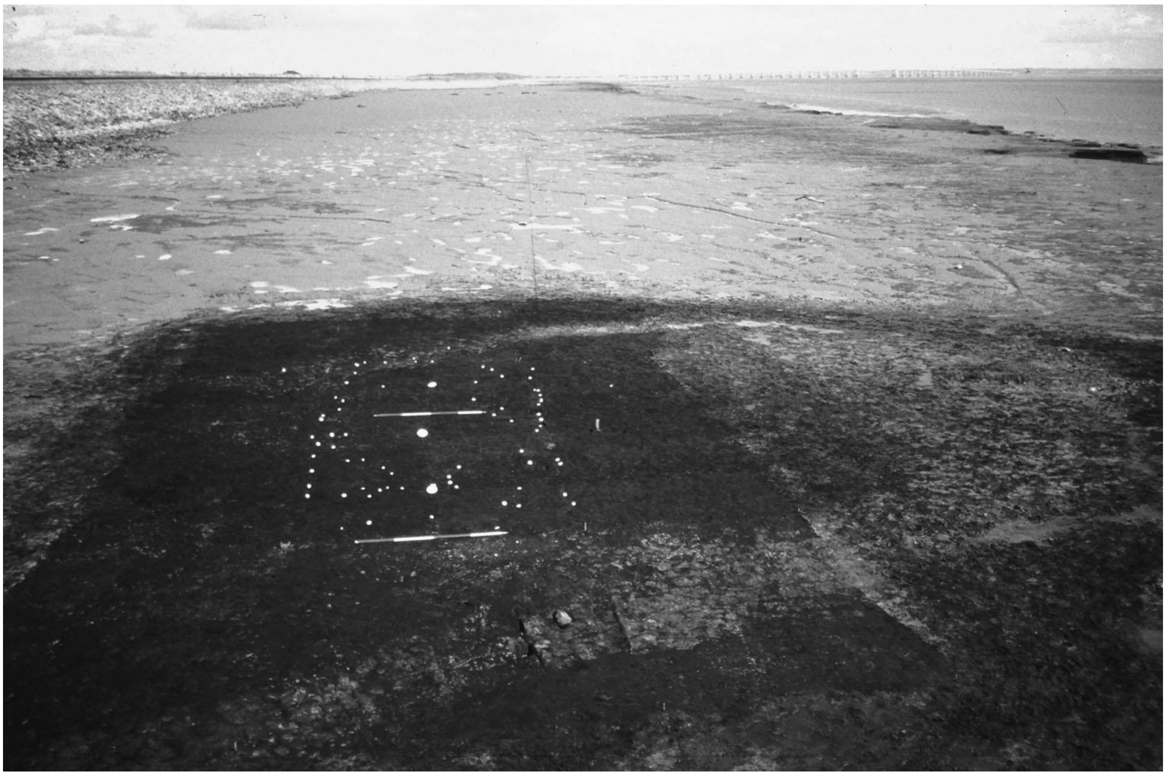


Figure 3.11 Bronze Age buildings at Redwick flanked by curvilinear depression footprint-tracks, scale 2 m (photograph by E. Sacre; Barr and Bell 2016, Figure 2)

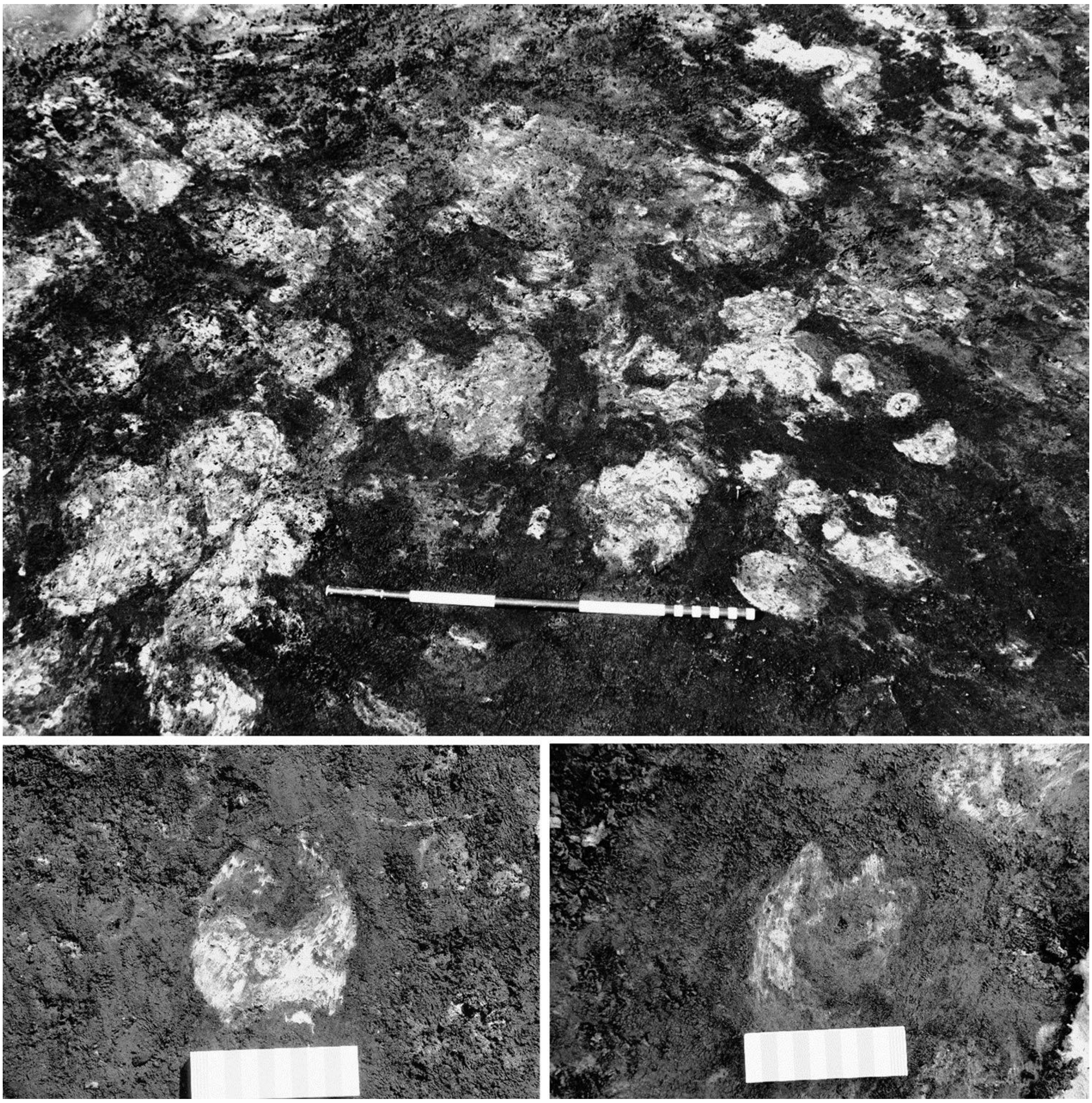
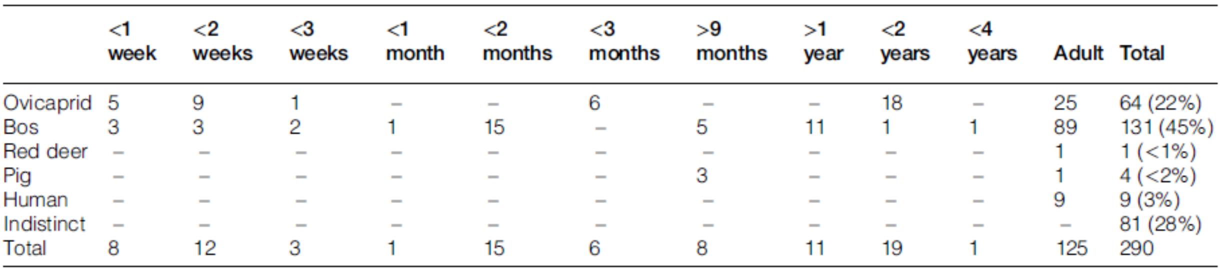


Figure 3.12. Trampled surface at Redwick where ungulate footprints were recorded (photograph E. Sacre; Barr and Bell 2016, Figure 4)



	<1 week	<2 weeks	<3 weeks	<1 month	<2 months	<3 months	>9 months	>1 year	<2 years	<4 years	Adult	Total
Ovicaprid	5	9	1	–	–	6	–	–	18	–	25	64 (22%)
Bos	3	3	2	1	15	–	5	11	1	1	89	131 (45%)
Red deer	–	–	–	–	–	–	–	–	–	–	1	1 (<1%)
Pig	–	–	–	–	–	–	3	–	–	–	1	4 (<2%)
Human	–	–	–	–	–	–	–	–	–	–	9	9 (3%)
Indistinct	–	–	–	–	–	–	–	–	–	–	–	81 (28%)
Total	8	12	3	1	15	6	8	11	19	1	125	290

Table 3.3 Species and ages of footprints made at Redwick, recorded by Bell (2013) from 1999-2001 (Barr and Bell 2016, Table 2)

3.3.4 Porton

Porton is located on the Severn Estuary between Goldcliff East and Redwick (Figure 3.7); both of which demonstrate large amounts of activity during prehistory. Compared to the other estuarine areas discussed, Porton has a sparser archaeological assemblage, with occasional hoofprints of deer and auroch noted. A Mesolithic tranchet axe, a Bronze Age spearhead, fishtraps, a trackway and reed matting have been recovered (Bell *et al*. 2000), a large palaeochannel has also been noted in this area (Bell & Neumann 1997).

During this study Porton was covered in areas of deep and dangerous mud and sand banks preventing access to much of the site, though two poorly preserved human footprint-tracks were recorded on 20.04.15. These footprints were found in laminated silts at ST41583 83257, on the edge of a large curving palaeochannel. The date of these footprint-tracks has not yet been established.

The footprints were recorded as per the methodology (Chapter 4), though the multi-image photogrammetry model was of poor quality due to the constant changes in cloud cover and sunlight when recording, which resulted in a large amount of artefact being present within the model (Figure 3.13). The footprint-tracks are better seen in a standard photograph (Figure 3.14).

There were two human footprint-tracks exposed on the laminated sediment, numbered 2015:10 and 2015:11. The footprint-tracks were parallel to each other, and were undertraces/overtraces. Footprint-track 2015:10 was 28cm long and 11cm wide, footprint-track 2015:11 was 26cm long and 10cm wide. The toes of the footprint-tracks were not clear, nor was it clear if they were made by the same individual or two people walking next to each other. The shape of the footprint-tracks, with an evident ball of the foot and heel, did suggest that they were orientated 76° east of north. This is evidently a new human footprint-track area, however the poor quality of the footprint-tracks prevents thorough analysis.

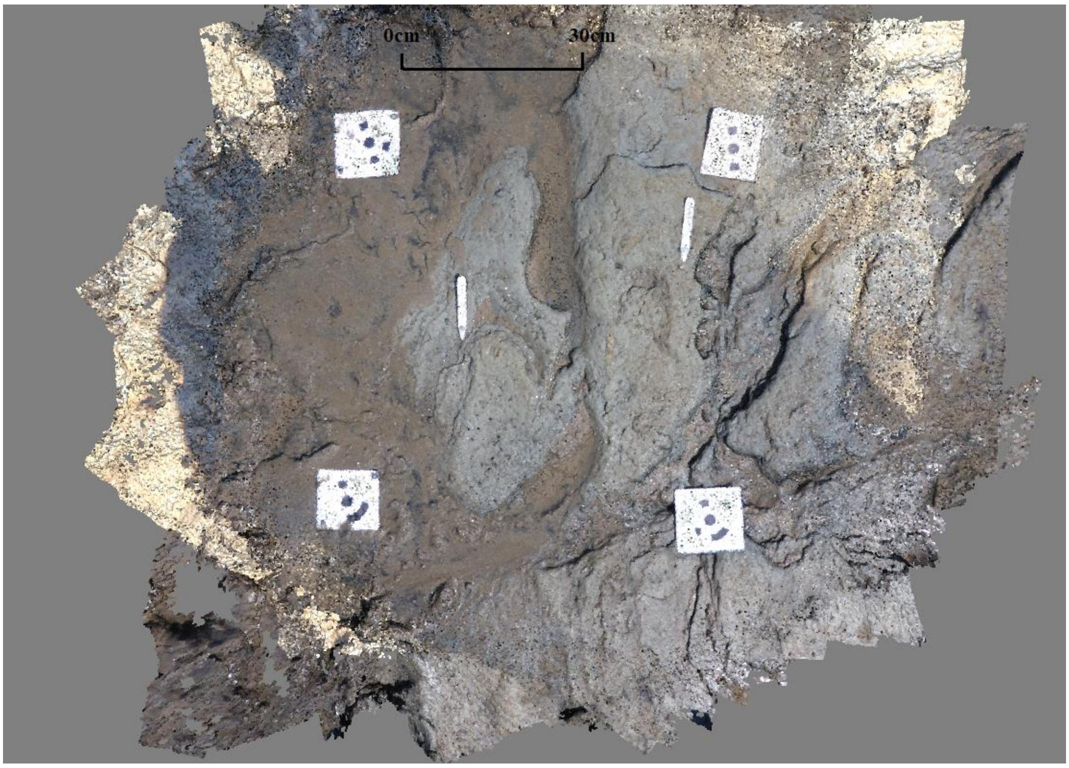


Figure 3.13 Multi-image photogrammetry model made of footprint-tracks 2015:10 and 2015:11. The model is relatively poor quality due to missing data

Figure 3.14 Standard photograph of footprint-track 2015:10 and 2015:11

3.3.5 Uskmouth

The intertidal site of Uskmouth is located on mudflats within the Newport wetlands, near the RSPB Newport Wetlands visitor centre, Newport, Wales, immediately east of the mouth of the River Usk. Approximately 2km long, in this area there has previously been a variety of archaeology recorded. Perhaps the most significant of the Uskmouth finds is three human footprint-track trails made by two probable adults and a child, all of whom were unshod, and were recorded on the lower Wentlooge Formation from minerogenic sediments (Aldhouse-Green *et al*. 1992). The lowermost peat overlaying the footprint-tracks was dated to 6140±100 BP (OxA-3307, 5240-4940 Cal BC; Aldhouse-Green *et al*. 1992). An antler mattock was found near to the footprint-tracks, and radiocarbon dated to 6180±80 BP (OxA-4574, 5260-500 Cal BC; Aldhouse-Green and Housley 1993). The footprint-track trails were travelling in a direction that was diagonal to the current shoreline. One of the footprint-tracks was block-lifted so that the silt could be examined by X-raying thin slices, and the shaft of the footprint was found to be 40-60mm deep, indicating that when the footprints were formed the silt was relatively firm.

Probable auroch footprint-tracks were recorded from the silts of the lower Wentlooge formation, as were deer, which were found to be more plentiful than auroch footprint-tracks. The deer footprint-tracks were found on silts at a variety of laminated levels, and were well-formed, indicating that the sediment was likely firm and dry when walked upon (Allen 1997).

The appearance of human and animal footprint-tracks from the minerogenic lower Wentlooge Formation sediments indicates that the Mesolithic people of Uskmouth were exploiting the saltmarshes (Aldhouse-Green *et al*. 1992). Footprint-track evidence also suggests deer were abundant and possibly being hunted. The antler mattock found in association to the footprint-tracks may have been dropped by individuals as they were hunting or gathering on the saltmarshes.

From the middle Wentlooge Formation a complete articulated aurochsen skeleton was recovered from marine clay (4660±70 BP, Car-1096, 3640-3130 Cal BC; Whittle and Green 1988), though it is thought that this animal did not die because of human activity (Neumann 2000, p 290).

Uskmouth was visited during this study, however mud and a large sandbank had been deposited making the discovery of footprint-tracks incredibly difficult. Although large areas of laminations were clearly trampled by ungulates and a small number of deer footprint-tracks were recorded this site had poor exposure.

3.3.6 Goldcliff

The site of Goldcliff is located 9km south-east of Newport, Monmouthshire. A projection into the estuary marks the site of a former island, once approximately 1km in length and 450m in width. About three quarters of the island has been eroded (Figure 3.15), with the Ipswichian interglacial beach around the island defining its former extent (Allen 2000b). The island is currently occupied by the buildings of Hill Farm and Goldcliff Fishery, and was formerly the site of Goldcliff Priory.

The intertidal zone at Goldcliff can be divided into the area that is west of the former island, which will be referred to as Goldcliff West, and east of the former island, referred to as Goldcliff East. Both the areas west and east of the island are rich in archaeology.

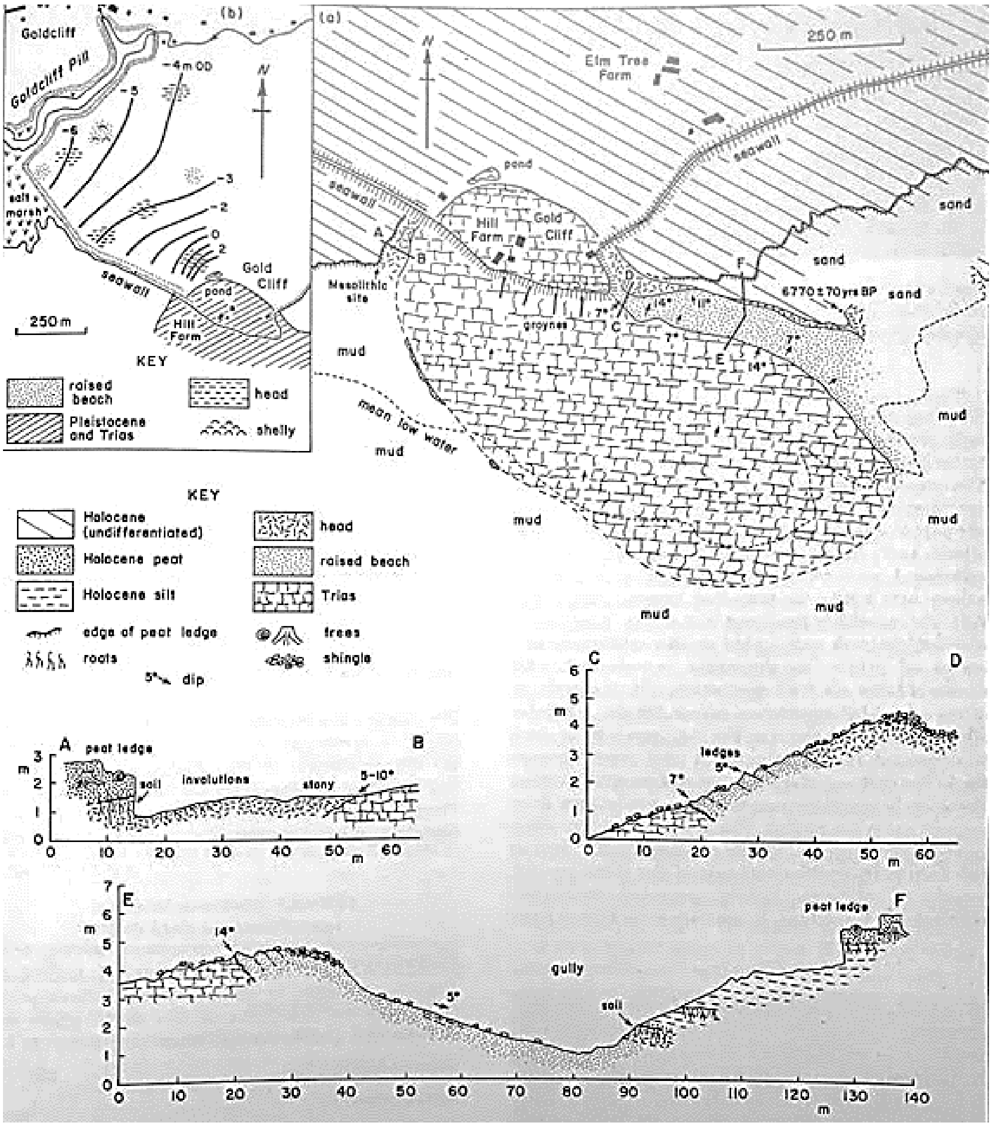


Figure 3.15 Geology of Goldcliff 'island' (a) geological map (b) contours and composition of the sub-Holocene surface between Goldcliff and Goldcliff Pill (Allen 2000b, Figure 2.1)

3.3.7 Goldcliff West

The first prehistoric evidence from Goldcliff West was discovered in 1987 by Derek Upton and Bob Trett, who observed a layer of charcoal, as well as flint flakes below the lower peat shelf of the lower Wentlooge Formation (Parkhouse 1991, p 14). Further recording of this site in 1989 was carried out by Malcom Lillie (Bell 2000, p 33). Excavation between 1992-1994 found a Mesolithic site within 10-20m of the edge of the bedrock from the original projection of Goldcliff Island and demonstrated that this site, which shall now be referred to as Site W, was on an old land surface (Figure 3.16). A radiocarbon date for this site comes from a cut deer bone (6760±80 BP, 5750-5470 Cal BC; Barton and Bell 2000, p 58). An area of the Mesolithic land surface at Site W had a concentration of charcoal which was possibly the remains of an unlined flat hearth (Barton and Bell 2000, p 61). The charcoal was radiocarbon dated to 6430±80 BP (GU-2759; 5440-5280 cal BC; Bell 2000, p 33), meaning the Mesolithic activity at this site ranged from c 5600 Cal BC to 5200 Cal BC (Barton and Bell 2000, p 58).

1650 artefacts were recorded at Site W, many were flint debitage and unidentifiable bone fragments. A limited amount of geological raw material was found within the assemblages; flint, chert, tuff and quartz, which took the form of flakes, blades, bladelets, chips, cores, rejuvenation flakes, retouched tools, axes, adzes and unidentified waste, these were regarded as late-Mesolithic types (Allen 2000b). The Mesolithic faunal assemblage from Goldcliff West was dominated by red deer remains (63%), 20% of skeletal remains were that of pig, 5% were otter, 3% roe deer, 3% wolf, 2% bird, 2% microvertebrates and 1% fish (Coard 2000, Table 4.2). The size of eel and smelt from this assemblage indicate they were netted during the autumn/winter months (Ingrem 2000, p 54). Winter seasonality was also suggested by ageing wild pig mandibles, where it was thought that they died aged 6-7 months, indicating that they were killed during the winter period if assuming that they were born in the late spring/early summer (Coard 2000, p 52). It was suggested that Site W was an impermanent settlement that was only used for a short amount of time, possibly during the winter or spring (Barton and Bell 2000, p 63).

The middle Wentlooge formation at Goldcliff West contained evidence of two stratified human skulls. The skulls, Goldcliff 1214 (3095±40 BP, OxA-7744; 1450-1260 Cal BC; Bell 2000, p 67) and Goldcliff 1990 find 497, were analysed and Goldcliff 1214 was found to be that of an adult, whereas Goldcliff 1990 find 497 was an adolescent or a young adult. To the west an almost clean clayey silt surface between the peat shelf and Site W was observed, where there were traces of a small wooden structure (Bell *et al.* 2000, p 74). The structure was made up of two planks with holes in them, as well as roundwood and brushwood. The structure extended 1.65m in length, and radiocarbon dating on a piece of cut roundwood (3443) dated the artefact to 2720±70 BP (CAR-1434; 1040-790 cal BC; Bell *et al*. 2000, p 76). This suggests that the boat planks were from the Bronze Age and had been reused to possibly create a small trackway to assist in walking across a palaeochannel, or to provide a base to support boats being hauled up from larger palaeochannels (Bell *et al*. 2000, p 82).

To the west of Goldcliff Pill, eight rectangular structures with probable reed flooring were discovered on intertidal peats. Of these eight, five were well preserved and appeared to have been roofed buildings (Bell *et al*. 2000, p 83). Radiocarbon dating of one of the post 127 (2120± 90 BP; GU-2912), wattle 919 (2100± 60 BP; CAR-1346; 360 cal BC- 20 cal AD), and the reed layer (2200±70 BP; CAR-1347; 400-100 cal BC), suggest the structures were Iron Age (Bell *et al.* 2000, p 92). Trackways were found in association to the buildings, with some leading towards the buildings and others leading out into the estuary, possibly for fishing, fowling or boat landing purposes. The trackways on the peat shelf were radiocarbon dated to between 400 cal BC and 100 cal BC (Bell *et al*. 2000, Figure 10.21). On the edge of a palaeochannel by Building 6 and 8 there was extensive evidence of animal trampling between the peat edge and the overlying upper Wentlooge clay. The area contained footprint-tracks that were clearly cattle, with cattle head biting lice and dung beetles also present in the palaeochannel (Bell *et al*. 2000, p 281; Smith *et al*. 2000, p 259).

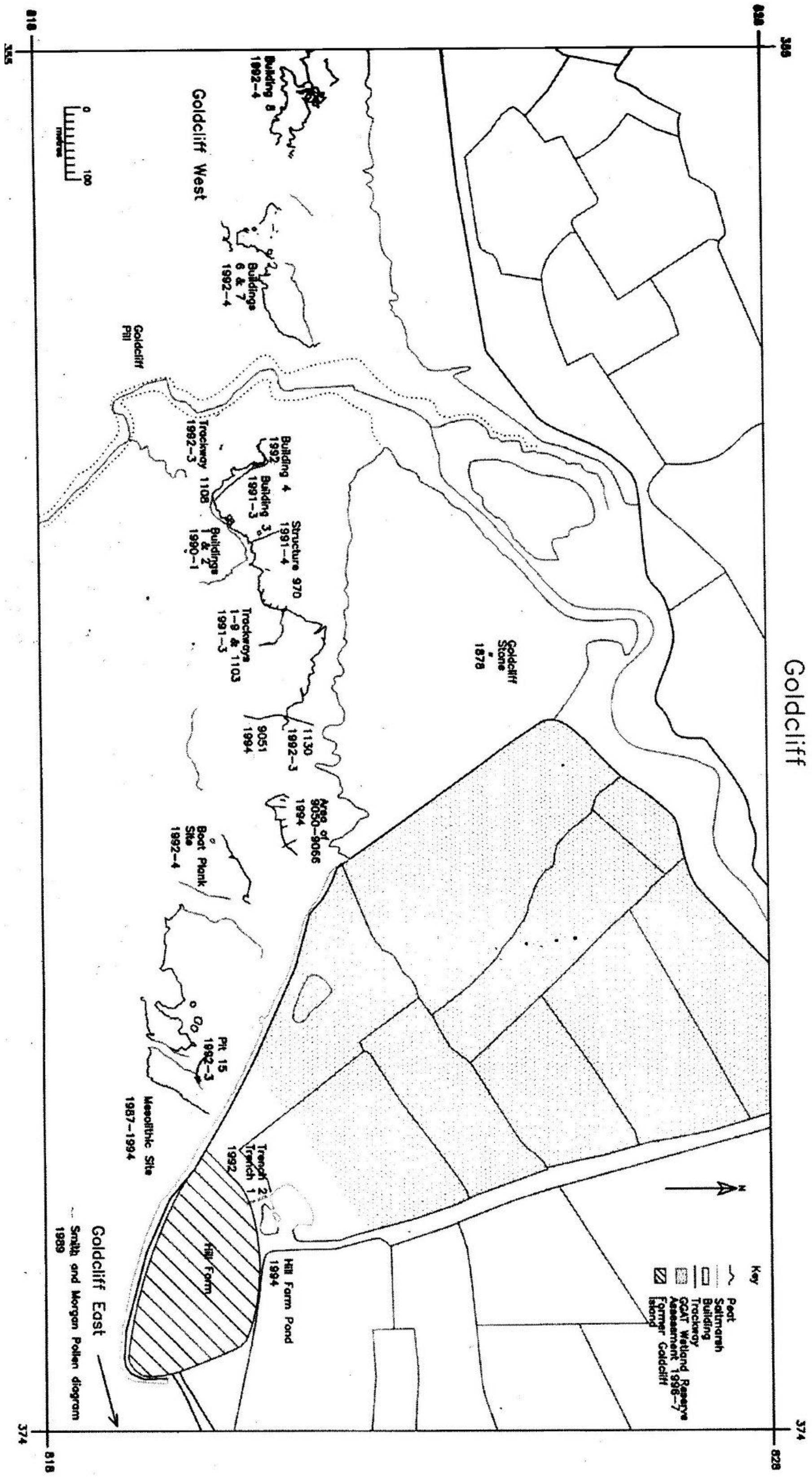


Figure 3.16 Map of Goldcliff West showing main sites investigated from 1987 to 1994 (drawing by B Taylor; Bell 2000, Figure 1.3)

3.3.8 Goldcliff East

Goldcliff East is found east of Goldcliff Island (Figure 3.17). It is an excellent area for viewing a ‘snapshot’ of British prehistory and history. Although the area is less than a kilometre in length, it is an area rich in finds. Four Early Upper Palaeolithic flint artefacts have been found unstratified on the lower foreshore, as has a Mesolithic tranchet axe, Romano-British and Medieval sherd scatters and fishtraps (Bell & Neumann 1997).

Bronze Age footprint-tracks, recorded in 2011 and 2012 by the author, were on the surface of the middle Wentlooge peat and were near to Site F (Figure 3.15), the reed peat has been dated to 3130±70 BP (CAR-644; 1610-1200 cal BC; Bell 2007, Table 2.1). The footprint-tracks were made in the peat on the edge of a palaeochannel, which had been infilled with silt (Barr and Bell 2016). There were 25 footprint-tracks recorded in the palaeochannel, only ovicaprid and bovids were identified within this assemblage. Like those recorded from the Redwick assemblage, there was a variety of juveniles as well as older animals (Table 3.4), with ovicaprids and their young making up 48% of this small assemblage. The presence of young animals suggests grazing on the saltmarshes in late spring or early summer, as some of the young were less than two weeks old. This is suggestive of dairying as a predominant husbandry practice, as there were few adult males but multiple adult females represented within the footprint-track assemblage. These females would be lactating to feed their young, and exploiting the saltmarshes for the nutrient-rich grazing and safety from predators (Barr and Bell 2016). These footprint-tracks are the only evidence of Bronze Age activity in the intertidal zone at Goldcliff East.

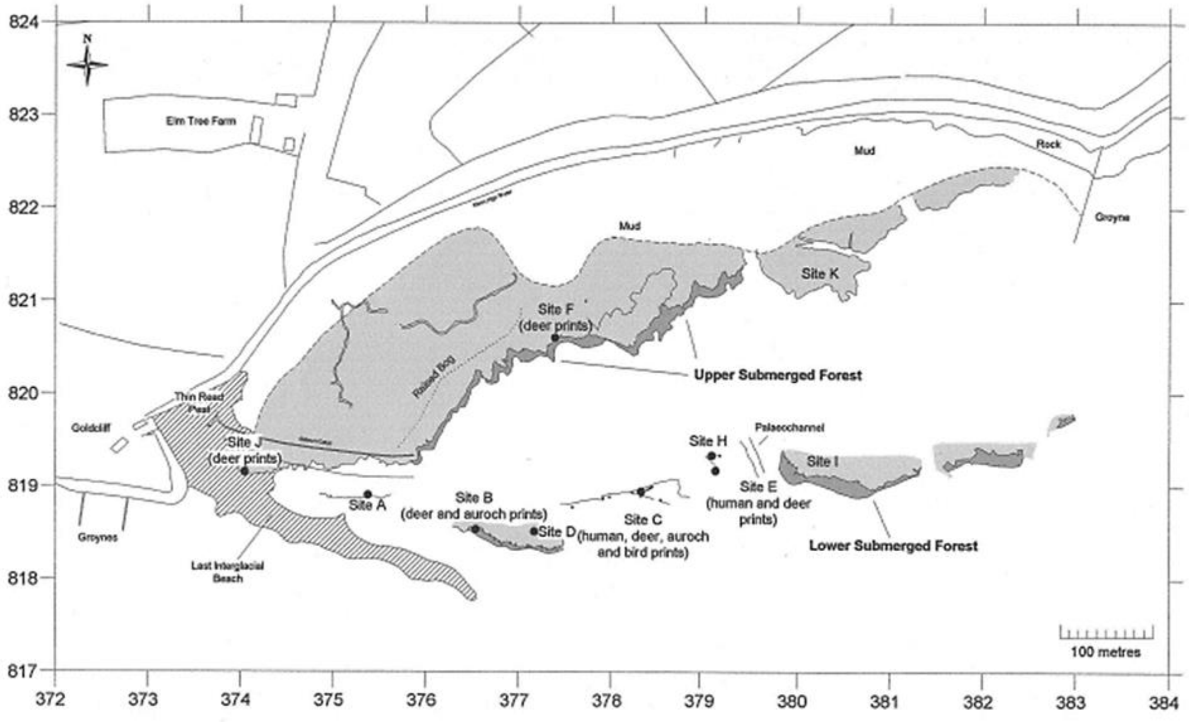


Figure 3.17 Map of Goldcliff East showing the main sites investigated during 2001-2003 (graphic S. Buckeley; Bell 2007, Figure 2.3)

	<2 weeks	<1 month	>9 months	<2 years	Adult	Possible male	Total
Ovicaprid	5	3	–	2	1	1	12 (48%)
Bos	1	–	2	–	2	1	6 (24%)
Indistinct	–	–	–	–	–	–	7 (28%)
Total	6	3	2	2	3	2	25

Table 3.4 The species and ages of footprint-tracks recorded from middle Wentlooge peat at Goldcliff East, data gathered in 2011 and 2012 by the author

The lower Wentlooge Formation at Goldcliff East is rich in archaeology from the Mesolithic period. The foreshore is now almost constantly covered by water but would have been easily accessed by prehistoric populations due to lower sea level. These sites were preserved by burial under peats and silts as the water level rose, and were subsequently uncovered due to erosion and movement of the sediments due to strong winds and tides.

Before the fieldwork period of 2014, there had been multiple sites recorded at Goldcliff East. A summary of the excavated lower Wentlooge sites most important to this body of work are given below.

3.3.8.1 Site J

An Old Land Surface, developed on the Pleistocene Head, contained many of the Mesolithic activity sites at Goldcliff East. One of these is Site J, which is exposed at *c*.1.5m OD (Bell 2007, p 65). Site J is 120m west of Site A (Figure 3.17), on the most western point of the Upper Peat and Submerged Forest. It is much higher in the tidal frame than the other Mesolithic sites which meant that excavation could occur during the neap and the spring tides. Excavation showed that Site J lay at the interface between a wetland environment and the island edge, which resulted in environmental and organic artefacts being preserved next to dryland (Bell 2007, 63).

The Mesolithic activity area in the Old Land Surface (Context 328) was sealed by the peat sequence (Figure 3.18), and provided two wood artefacts that were successfully radiocarbon dated to 5934±39 BP (OxA-15549, 4940-4710 Cal BC; Bell 2007, Table 8.2) and 5930±37 BP (OxA-15550, 4910-4710 Cal BC; Bell 2007, Table 8.2). This is when most activity was occurring at this site, though it may have started earlier and finished later on a smaller scale (Bell 2007, p 74). Dates have been obtained from the peat sequence sealing the Mesolithic activity area, including reed peat from the bottom of Pit J, radiocarbon dated to 5730±33 BP (OxA-13934, 4690-4490 Cal BC; Bell 2007, Table 8.2), and peat dated to 5061±21 BP (OxA-12355, 3950-3790 Cal BC; Bell 2007, Table 8.2). The later date was from peat at 1.77m OD and was the latest dated peat. The radiocarbon dates throughout the peat sequence showed that the wood peat took approximately 900 years to form (Bell 2007, p 72). Wiggle match dating on a tree ring from the Upper Submerged Forest showed that the forest died at about 4239±16 Cal BC (Bell 2007, Table 8.2), this indicates that over about 1000 years Site J went from a dryland site which was replaced by saltmarsh and then succeeded by peat.

Due to the sealed Mesolithic land surface, artefacts from Site J have been plentiful and well-dated, with lithics, bone, charcoal, worked wood, shell and heat-fractured stone within the assemblage. In the north-west of Site J there was evidence of animal butchery and skin processing of red deer and auroch. 32 bones of red deer were recorded, the elements indicated that complete red deer carcasses were being processed in this area (Scales 2007b, p 160). Auroch were also being butchered but their horns and skins were taken from Site J to another area, there were 25 auroch bones recorded from this area (Scales 2007b, p 161). The bones of wild pig and roe deer were also found on the Old Land Surface, though in a smaller amount, 11 wild pig and six roe deer. The bones of red deer had evidence of scraping and fine cut marks. There was also a bone (7595) that was used as an awl and evidence of bone scrapers (Bell 2007, p 135), indicating probable use in butchery and hide processing.

Heat-fractured stones were abundant at Site J, with 233 from context 328, these had multiple fractures caused by heated stones cooling rapidly. One of the main stone types was quartzites, a stone likely imported to the site due to its thermal properties (Allen 2007, p 124). It is possible that these stones were being heated for food processing, cooking the meat of the animals butchered nearby.

There was a concentration of artefacts at the centre of Site J, and it is argued by Bell (2007, p 82) that as these artefacts were found in a circular area of approximately 3m, it may be an indication of a small shelter, possibly like a tent, where some of the knapping took place. Site J exhibited evidence for knapping, with 13 microliths recorded. There was also a crescent microlith (4527) with impact evidence, an artefact (9210) with microwear evidence for cutting something relatively soft, such as meat, and scrapers. These lithics are indicative of the processing of animal carcasses and compliment the skeletal faunal assemblage.

At the base of the peat sequence (Context 327) was an area with the appearance of animal trampling, these could be seen best at the base of the peat where the animals had trampled this into the underlying estuarine sediment (Bell 2007, p 82). 21 ungulate footprint-tracks were recorded from this trampled area and the Old Land Surface. These footprints would have been made at the edge of the island, where the reed peat was softer, causing the animals to sink in slightly to the sediment below. Of these 21 footprint-tracks, Scales (2007a, p 156) identified seven adult red deer, as well as three probable stags. A further three footprint-tracks were small and may have been made by roe deer or juvenile red deer.

Site J represents a Mesolithic area where a variety of activities were being undertaken, including the hunting of ungulates and the processing of carcasses, cooking with heated stones, knapping flints, woodworking and possibly processing other foods such as plants. This is a site that experienced successive reoccupation, and it is argued by Bell (2007, p 230) that the evidence may indicate a base camp.

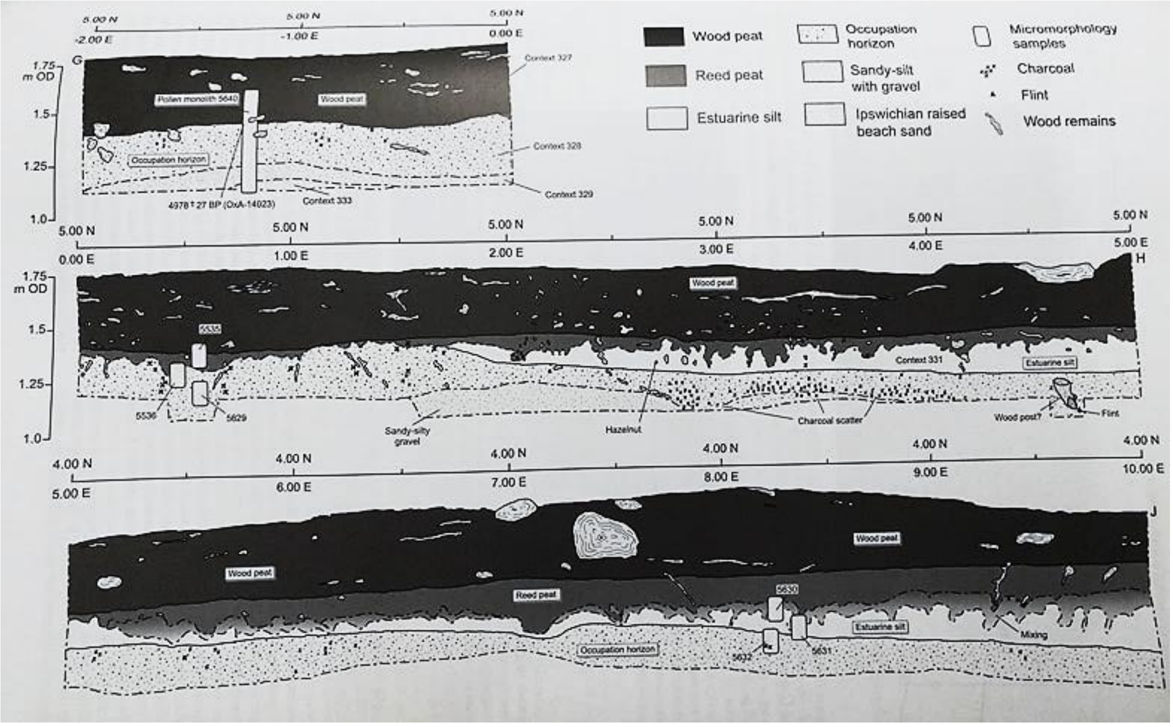


Figure 3.18 Site J, the east/west stratigraphic sequence on north face of 2003 excavation (graphic J. Bezant and S. Buckley; Bell 2007, Figure 6.9)

3.3.8.2 Site A

Site A is 120m west of Site B and 120m east of the present projection of Goldcliff Island, it is 80m north of the Ipswichian beach that marks the extent of the former island and is approximately 20m south of the Upper Peat Shelf (Bell 2007, p 57). This site was originally recorded in 2001, uncovered due to an area that had been washed clean of mud by the tide, containing a charcoal-rich band in the sediment which was observed to contain worked lithics and bone. A 1m^2 pit was excavated to investigate the stratigraphy and the occupation surface was found to be between -2.4 and -2.5m OD. The area dips to the south at 5°, as does the Old Land Surface. This 5° slope is thought to be the sediment dipping away from the edge of the former island (Bell 2007, p 57). Site A had only one artefact that could provide dating evidence, a charred hazelnut, which was dated to 6629±38 BP (OxA-13928; 5630-5480 cal BC; Bell 2007, p 58). Site A is 1.05m above Site B, with activity at this site occurring between 100-300 years after the latest activity that took place on Site B and Site D (Bell 2007, p 58).

There were relatively limited organic artefacts and pollen preserved at Site A, this is thought to be due to activity taking place decades before the site was buried by estuarine sediments. Lithics were found throughout Site A, mainly struck flints, cores and retouched flint types. 70 microliths were found, with over half of these broken (Barton 2007). The area that had the densest amount of lithic scatter had very few large bones, most of the bones were recorded west of the concentration of lithics. 13 of the bones were deer, five had cut-marks, and two of these were near the lithic concentration. The results of sieving indicated that the highest concentration of calcined bones was from the same area as the lithic concentration (Bell 2007, p 61). The bone assemblage indicated that red deer made up half of the skeletal remains, three bones were from auroch, six from wild pig and three from roe deer (Scales 2007b, p 160). Fish bones were found in a high concentration at Site A, with 502 identified specimens from 12 different species (Ingrem 2007, Table 13.3). As well as fishbones, fish scales were found via sieving, and were in a concentrated area (Bell 2007, p 61).

An ungulate footprint-track, similar in size to red deer, was recorded at Site A and was made on the estuarine sediment of the lower Wentlooge Formation (Scales 2007a, p 155). It had splayed toes which indicated that the animal was running. The silt that the ungulate footprint-track was made in contained a small amount of charcoal but no other artefacts. The silt sediment unit was north of the site, sealed by the Upper Peat and the Submerged Forest, meaning that the ungulate footprint-track was made during the Mesolithic.

The activities represented by the artefacts indicate that Site A was an area used for flint knapping, cooking, fish processing and drying fish. Mammal bones were found at this site, as well as the splayed footprint-tracks of red deer. Food preparation is implied by the quantity of calcined fish bones, which may suggest smoking or cooking activities, as well as other bone evidence; food consumption was also indicated by charred hazelnut. It is possible that the activities of Site A were centred around a hearth, evidenced by the charcoal and calcined bones. Bell (2007, p 62) suggests that the artefacts are dense in certain areas but areas of activity end abruptly due to a physical barrier preventing the artefact dispersal, possibly the wall of a shelter, though no post holes or stakeholes were recorded.

3.3.8.3 Site B

Site B is located on the western exposure of the Lower Peat at *c*-3.5m OD and was first recorded in 2001, where it was observed that artefacts such as calcined bones, could be seen on the eroding peat surface. Mesolithic activity on this site took place on dry land close to the advancing shoreline (Bell 2007, p 37).

There were a total of 45 lithic pieces recorded at Site B, with two microliths, one with a notched piece, flint flakes and a core. A scraper, a hammerstone and a retouched piece were also found (Bell 2007, p 42). This assemblage indicates that knapping may have taken place on a very small scale. It was found that every tool and micro-debitage came from the minerogenic sediment rather than the peat, except for one microlith and three pieces of heat-fractured micro-debitage. Notable finds from the Old Land Surface included a shaped sandstone plaque which had been used as a pounder, a boulder used as a hammerstone and heat-fractured stones (Bell 2007, p 42). An axe/adze was found on unstratified on the gravel bank 5.7m west of Site B (Barton 2007, p 113).

There were 65 bone fragments recorded within the peat. Sieving of context 320 revealed a further 270 fragments, as well as four fish bones (Bell 2007, p 42). Of the bone assemblage, seven fragments were identified as red deer, one auroch, and one roe deer (Scales 2007b, p 160). Charcoal was abundant and corresponded with calcined bones, it is thought that at the time of the peat, the area may have been used for the preparation of red deer carcasses, with the scraper indicating hides were being processed (Bell 2007, p 42). Charred hazelnuts were found at Site B, as was one piece of worked wood, which had the appearance of the rounded end of a spatula. The charred hazelnuts were recorded from the minerogenic soil and were dated to 7002±35 BP (OxA-13927; 5990-5790 cal BC; Bell 2007, p 45).

Context 319, on the surface of the peat, was cleaned, and small oval depressions were observed, all 8cm or smaller. Two of these had the appearance of ungulate footprint-tracks, likely to be from red deer due to the size. Further excavation of Site B uncovered four more red deer footprint-tracks on the peat, as well as an auroch. Two red deer footprint-tracks were recorded at the base of the overlying estuarine sediment, and a red deer footprint-track was found at the interface between the estuarine sediment and the peat (Scales 2007a, p 154).

The artefacts at Site B indicate a focus on butchery, cooking and hide processing and limited flint knapping. The footprint-track evidence of red deer may suggest the animals were being hunted within the area before being butchered. Finds were relatively few and indicate an area that was not the focus of a large amount of activity over a long period, this was a site used briefly for a small amount of activity (Bell 2007, p 45).

3.3.8.4 Site D

Site D is 50m east of Site B and is on the westerly exposure of the Lower Submerged Forest, with the peat surface at -4m OD. The base of the peat was dated to 6790±38BP (OxA-12359; 5740-5630 cal BC; Bell 2007, p 47), and the top of the peat was dated to 6726±33 BP (OxA-12358; 5720-5560 cal BC; Bell 2007, p 47). There have been a small number of artefacts recorded at Site D; charcoal, a flint flake and one debitage chip. There were also four fragments of heat-fractured stone, a fragment of charred hazelnut and human intestinal parasites (Bell 2007 pp 45-47; Dark 2007, p 170). One ungulate footprint-track was recorded at Site D, likely that of a deer (Bell 2007, p 47). It is thought that Site D represents an area that was at the side-line of a main activity area, and the appearance of human intestinal parasites may suggest that this area was being used away from camp as a place to defecate. The small number of artefacts may have been deposited in the area by humans or mammals moving them unintentionally; the deer footprint compliments this theory (Bell 2007, p 47).

3.3.8.5 Mesolithic footprint-tracks from Sites C, E and H

During 2001-2004 footprint-tracks were discovered upon laminated banded sediments, these were assigned the site identification of Site C, Site E and Site H. These sites were low in the tidal frame at -3.1m to -4.4m OD (Bell 2007, p 48). The footprint-tracks were preserved in estuarine sediments which overlay the Lower Peat at Sites B, D and I, when the Submerged Forest and Lower Peat was inundated *c* 5650 cal BC (Bell 2007, p 49). The estuarine sediment was then sealed by the formation of the Upper Peat and Submerged Forest, which formed *c* 4700 cal BC. The Lower peat is divided into two by erosion of a later palaeochannel which is 240m wide (Figure 3.15) Within this there are a number of other intersecting channels representing various stages in the migration of the palaeochannel. The footprints recorded on Sites C, E and H are in the laminated sediments which fill this channel. The footprints recorded in the present thesis on sites M, N, O, R and S and the wood structure at Site T are all within this palaeochannel feature. The palaeochannel is capped by the main peat and is of later Mesolithic date.

Within the banded laminated estuarine sediments there was little artefactual evidence, though unstratified lithics and an antler mattock-hammer were recorded near the footprint sites. No flint artefacts have been recorded in the banded laminations (Bell 2007, p 53). At Site E, 15m east of a footprint area a wood artefact (13302) was found stratified within the banded sediments c.20cm below the footprint-tracks (Bell 2007, p 50). Some pieces of probably worked roundwood (Context 332) were found in one of the palaeochannels (Bell 2007, Figure 4.2).

During 2001-2004 extensive laminated banded sediment areas were exposed, and footprint-tracks could be observed upon these laminations, this was named Site C. The main area of Site C is 35m by 11m and consists of a series of low cliffs running north-east to south-west, exposing the laminated bands (Bell 2007, p 52). This area was recorded during 2001, footprint-tracks were present on a variety of laminations, and they had to be recorded rapidly as they were found 11 days before the end of fieldwork. They were recorded via planning and only footprint-tracks that had been exposed were recorded, rather than excavating any of the area (Bell *et al*. 2001). The footprint-tracks in this area were poorly preserved and partly eroded but were thought to have been lain down over a period of about 16 years, evidenced from the laminations they were on (Bell 2007, p 52). During fieldwork in 2001 there were 61 footprint-tracks recorded, 35 from humans, 13 from birds and 18 from red deer (Bell *et al*. 2002).

Rachel Scales became involved in the footprint-track recording at Goldcliff East in 2002-2004. During this fieldwork several new areas in Site C were exposed (Figure 3.19 and Figure 3.20). 10-14m south of the 2001 footprint-track site, at -4.09 to -4.2m OD 24 footprint-tracks were recorded. These were made by a child and a bird (Bell 2007, p 52). Two further human footprint-tracks were recorded on a lamination approximately 4m north of this site. To the west of the 2001 footprint-track area, at -3.6m OD there was further exposure, with 32 large avian footprint-tracks recorded over a 3m by 1.5m area. 8m north of these avian footprint-tracks, but on the same lamination, at 3.3m OD, large avian footprint-tracks were noted. Three child footprint-tracks, as well as the tracks of auroch were exposed, as were the footprint-tracks of a small bird. Three laminations above these were two further human footprint-tracks, and one lamination above these was a poorly preserved footprint-track of a human (Bell 2007, p 52). Scales revisited the area of the 2001 investigation and found further human and bird footprint-tracks; 177 human footprint-tracks, mostly from children, were recorded from a single lamination. In 2004 a further two footprint-tracks made by children, and 27 avian footprint-tracks, were all recorded from laminations near the large assemblage of footprint-tracks.

A further area of interest, Site E, was exposed 50m east of Site C, on an east/west erosion cliff. The erosion cliff exposed footprint-tracks in the laminations. Finger-tip excavation was attempted in this area to see if the footprint-track trails could be followed, this involved gently peeling away laminations using only the fingertips (Scales 2006). An area 6m by 3.5m was successfully excavated with fingertip excavation (6113), where it was evident that at least four prehistoric humans had walked across the sediment at -3.9m OD, making 33 footprint-tracks (Figure 3.21). There were also four deer prints in this area (Bell 2007, p 55). Fingertip excavation also uncovered seven human footprint-tracks and six deer from Area 6161.

16m north of Site E a further laminated surface was exposed between -3.14 and 3.38m OD, here a trail of 16 human footprint-tracks was observed. This site was named Site H, and the footprint-tracks were recorded via tracing (Bell 2007, p 55).

3.4 Summary

A further Mesolithic activity site, B2, has been identified since the work of Bell (2007). It is evident from the number of sites at Goldcliff East that during the Mesolithic this was an often-exploited area.

The work of Bell (2007) and Scales (2006) demonstrates that the minerogenic estuarine sediments of the Lower Wentlooge have preserved the footprint-tracks of humans, mammals and birds. Footprint-track evidence provides archaeologists with the opportunity to make suggestions about age composition and the activities being undertaken in a specific area. The stratigraphy of the Severn Estuary is complex, however it is this complex pattern of terrestrial regression and marine transgression during the Late Quaternary that has resulted in the preservation of organic material and artefacts, as well as the preservation of human, mammalian and avian footprint-tracks from a variety of different contexts and a range of prehistoric and historic periods. The sediments of the Severn Estuary need to be monitored as more finds and sites are likely to be exposed through erosion.

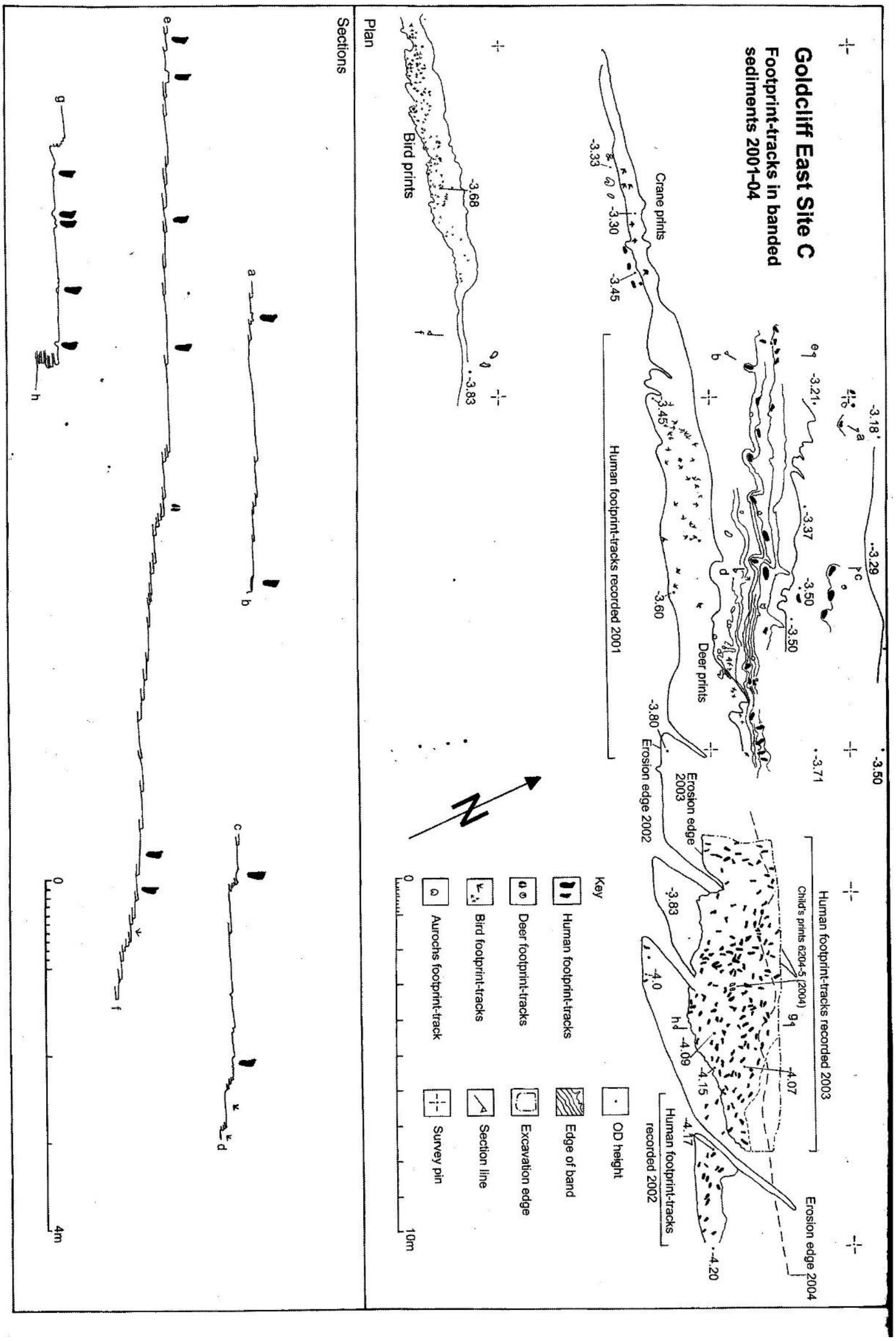


Figure 3.19 Plan of Site C showing footprint-tracks exposed on laminated bands, recorded between 2001-2004 (drawing M. Bell and R. Scales; Bell 2007, Figure 4.3)

Figure 3.20 Excavation of Site C, in 2003 (photo E. Sacre; Bell 2007, Figure 12.9)

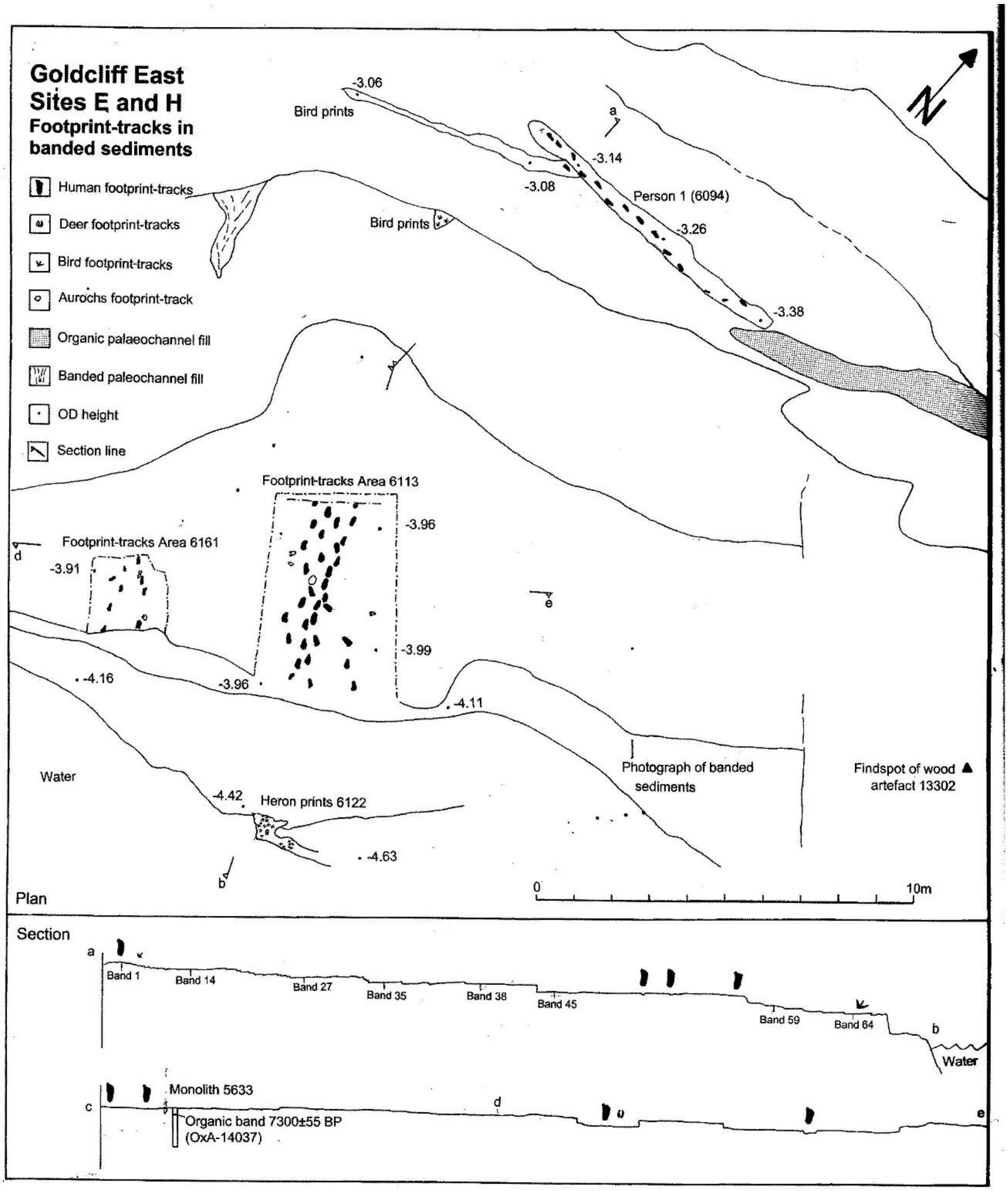


Figure 3.21 Plan of Goldcliff East, Site E and H footprint-tracks in banded sediments, exposed between 2002 and 2003 (drawing M. Bell and R. Scales; Bell 2007, Figure 4.5)

Chapter 4

Anatomy of the foot, footprint terminology and methodologies developed for footprint recording

4.1 Introduction

The methods developed by both archaeologists and palaeontologists for the recording of footprint-tracks are important to consider when dealing with footprints found in liminal areas, such as intertidal zones. Archaeologists have borrowed many recording techniques developed for the recording of dinosaur footprints (Thulborn and Wade 1979, 1989), as many of these sites are in remote, difficult to access areas, a problem also encountered by intertidal archaeologists. To address these problems palaeoichnologists have created techniques to safely record the footprints without damaging them. Bates *et al*. (2008a,b) experimented with creating three-dimensional geometric models using Light Detection and Ranging (LiDAR), creating point-clouds from these scans (Figure 4.1), with the conclusion that LiDAR can record accurately and rapidly with very little use of complicated software. Three-dimensional models of dinosaur footprints have also been experimented with by Bates *et al*. (2006) using long-range active sensors. Short-range scanners were experimented with by Adams *et al*. (2009) and Wilson *et al*. (2009). Photogrammetric recording of dinosaur footprint-tracks was explored by Matthews and Breithaupt (2001) and Remondino *et al*. (2010). These palaeontological techniques have been tested and refined by archaeologists, ensuring that they can also be utilised for the more delicate task of recording smaller footprint-tracks.

Traditional photogrammetric recording of footprint-tracks was applied at Laetoli, this technique involved hard-copy images that were overlapped, and then contour maps were generated from the data (Day and Wickens 1980). It was not until recently, however, that technology has allowed for high-quality three-dimensional recording of footprint-tracks. Bennet *et al*. (2013) experimented with both high-resolution optical laser-scanners and digital photogrammetry, and created a range of methodologies for these different approaches.

Laser scanning technology is beginning to be used regularly when recording prehistoric footprints, with Raichlen *et al*.'s (2010) experiment indicating that the gait and weight of an individual can be well represented by the morphology and depressions of the footprint, which can be easily picked up by laser scanning equipment. At the site of Valsequillo, Mexico, possible footprint-tracks were scanned with a close-quarter optical laser (Gonzalez *et al*. 2006), though these have since been rejected as human footprint-tracks (Morse *et al*. 2010). Casts of footprints from sites such as Laetoli have also been scanned, to allow the data to be digitally available to researchers (Raichlen *et al*. 2010; Meldrum *et al*. 2011).

Multi-image photogrammetry has been successfully utilised to record British intertidal footprint-track sites (Figure 4.2; Ashton *et al*. 2014; Bennett *et al*. 2010), as well as other footprint sites such as the Ileret footprint-tracks (Hatala *et al*. 2013). The footprint-tracks of Happisburgh are of interest as they are at an intertidal site where erosion is rapid and the constraints of the tide make fast and effective recording essential, similar in a way to Goldcliff East. At Happisburgh multi-image photogrammetry and laser scanning were both attempted, however multi-image photogrammetry was most effective as erosion affected the morphology of the footprint-tracks when attempting to record with laser scanning on a subsequent visit, meaning the footprint features were poorly defined and as such did not provide high-quality data (Ashton *et al*. 2014).

The use of digital technologies enriches the Heritage 3D project, allowing archaeological evidence which is difficult to access and preserve to be easily viewed by the public, and to be studied by others in future when the archaeological data has been eroded (Barber and Mills 2011). Further work is required to establish the best techniques and equipment for recording in a demanding environment, such as the intertidal zone of the Severn Estuary. Ichnology is very much a multi-disciplinary practice and one that is ever evolving as the demands in the field become more apparent.

The nature of working with any preserved footprint site is that the environment and the type of archaeology must be considered. The intertidal environment is an area where one is constantly working with ephemeral features; the tide, coastal currents, weather and erosion may be the cause of the initial discovery, but it is these forces that will culminate in the destruction of footprints. A methodology that works under the principles of ‘record and rescue’ must be considered to enable evidence from highly erodible substrates to be captured, though this method may not be appropriate for footprints on less erodible substrates, where more detailed excavation can occur. Bennett *et al.* (2013) explored the variables relevant to the conservation of footprint-tracks from soft sediments, with the Severn Estuary considered as a record and rescue site due to the high rates of erosion (Figure 4.3).

As well as considering the substrate walked upon, it is also important to consider the anatomy of the foot and how it moves during footprint formation.

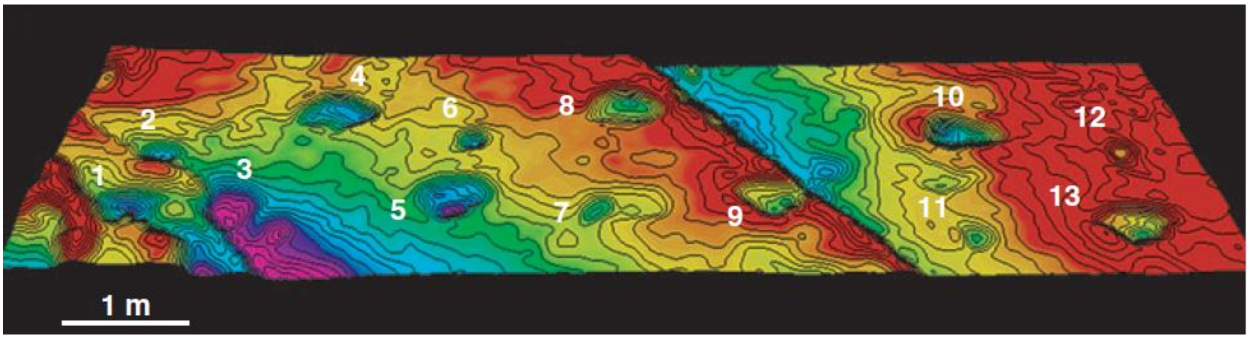


Figure 4.1. LiDAR models of the succession of tracks making up the footprint trail from Fumanya, Barcelona (Bates et al. 2008)

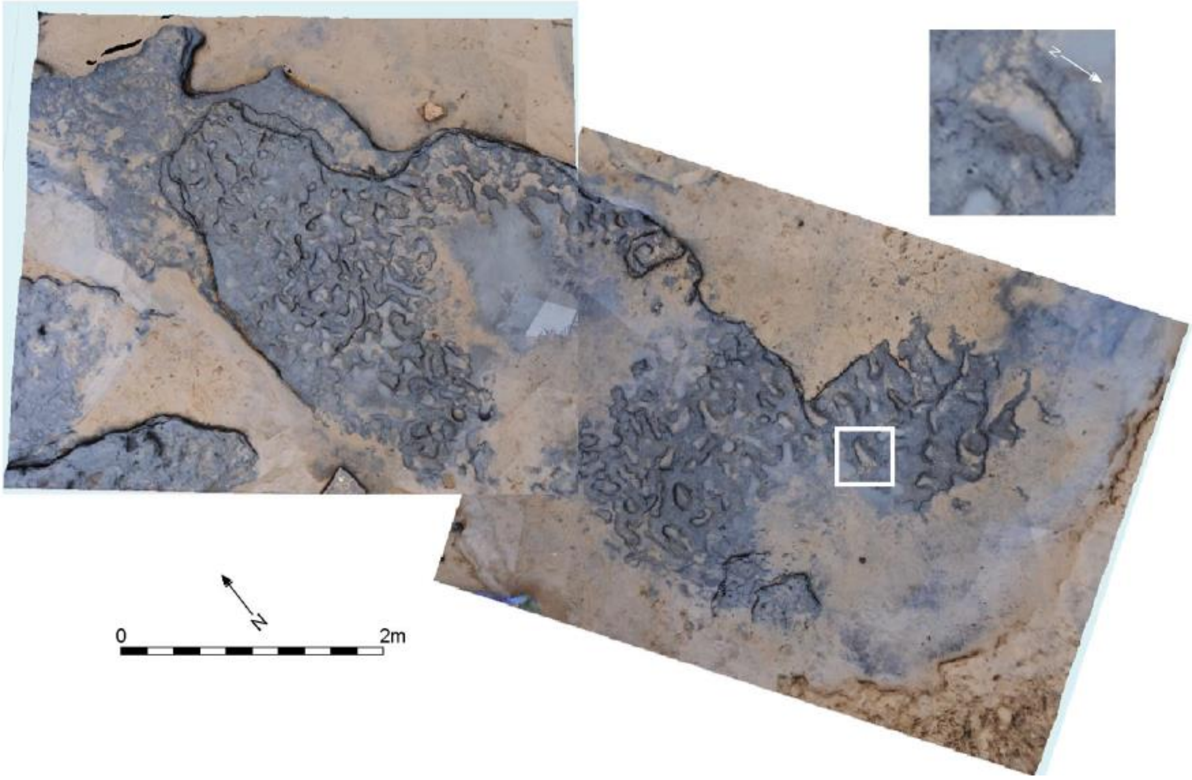


Figure 4.2 Vertical image of Area A at Happisburgh, model produced by photogrammetric survey (Ashton et al. 2014)

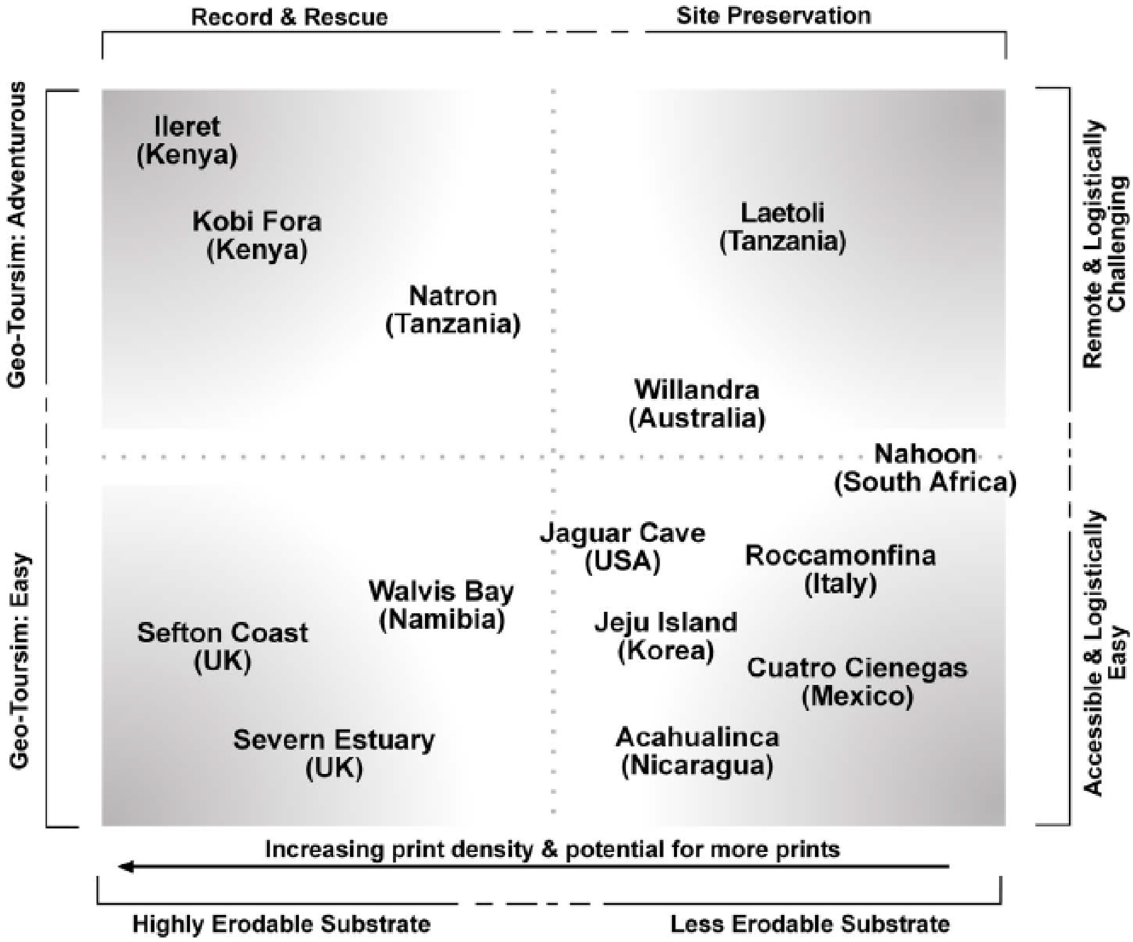


Figure 4.3 Matrix of variables relevant to the conservation of hominin/human footprint sites with emphasis on soft sediment sites (Bennett et al. 2013)

4.2 Human footprint identification criteria and measurement recording

The recognition of human footprint-tracks can be difficult, especially in situations where the formation or preservation of the prints is poor and clear anatomical features are lacking. There has been controversy regarding the identification of footprint-track trails at some archaeological sites. The Laetoli footprint-tracks, for instance, were debated as some prints were unclear and thought to be either bipedal human or Pliocene bear (Leakey 1978; Tuttle 1984, 1987, 2008).

Morse *et al*. (2010) undertook a thorough study into the best methods of identifying a human footprint, and established that it must show both the basic anatomy of a foot and the way a human foot functions, such as plantar pressure and depth measurements. Within their research they considered the possible footprint-tracks from Valsequillo and found them to be far broader than expected in human tracks, and were therefore established to not be prehistoric hominin, rather they were damage made on sediments by modern vehicles. It was through the process of identifiable anatomical features and three-dimensional digital elevation data that this was established.

A similar list of human footprint identification criteria was required to identify footprint-tracks at Goldcliff East, this was primarily achieved through the identification of at least one anatomical feature (Figure 4.4). The anatomy of the human foot is discussed in Chapter 2.2.1. The appearance of a left-right-left footprint-track trail was also an identifying factor, though there were few obvious left-right trails recorded within this study. The Goldcliff East footprint-tracks provide an extra challenge in identification, as they are often overtraces/undertraces and so the function of the foot, the depth of the print and the way the footprint was formed cannot always be seen. In many situations there must be reliance upon anatomy alone to identify a human footprint.

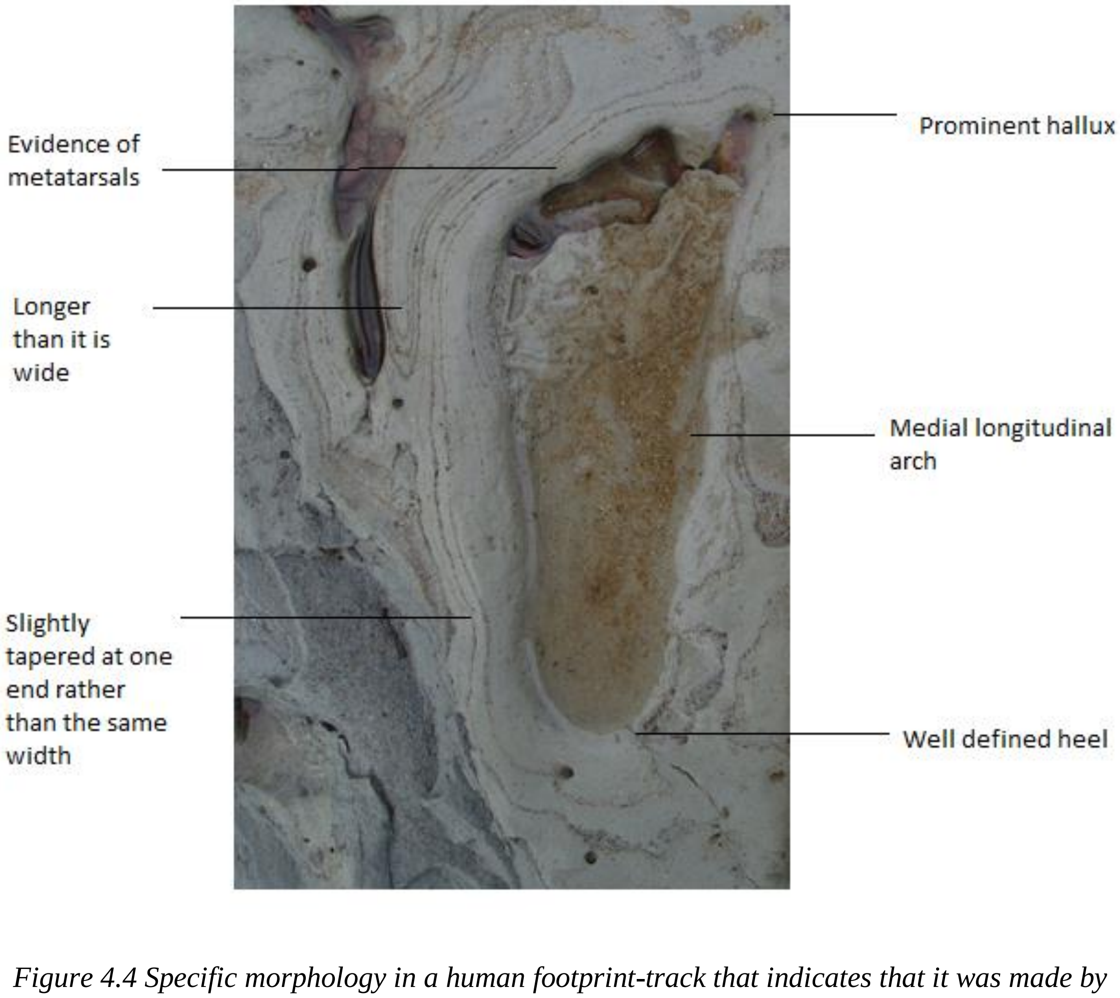


Figure 4.4 Specific morphology in a human footprint-track that indicates that it was made by humans (photographed by M. Bell, annotated by author)

Once a footprint has been identified as human, measurements of the footprint need to be made. The length and width are of the most interest, though length is agreed to be the most important measurement (Robbins 1985; Gunn 1991). There is debate about which part of the foot length should be measured, with the second toe thought to be most precise (Fawzy & Kamal 2010; Kulthanan *et al*. 2004; Reel *et al*. 2010, 2012). It was decided by the writer that in the case of the Mesolithic footprint-tracks at Goldcliff East it was most appropriate to measure from the tip of the hallux, through the medial longitudinal arch and to the pterion (Figure 4.5), as the hallux is one of the most prominent anatomical landmarks seen within the Goldcliff data set (Figure 4.4), the other toes are not always identifiable. The width of the footprint was measured from the widest point at the ball of the foot.

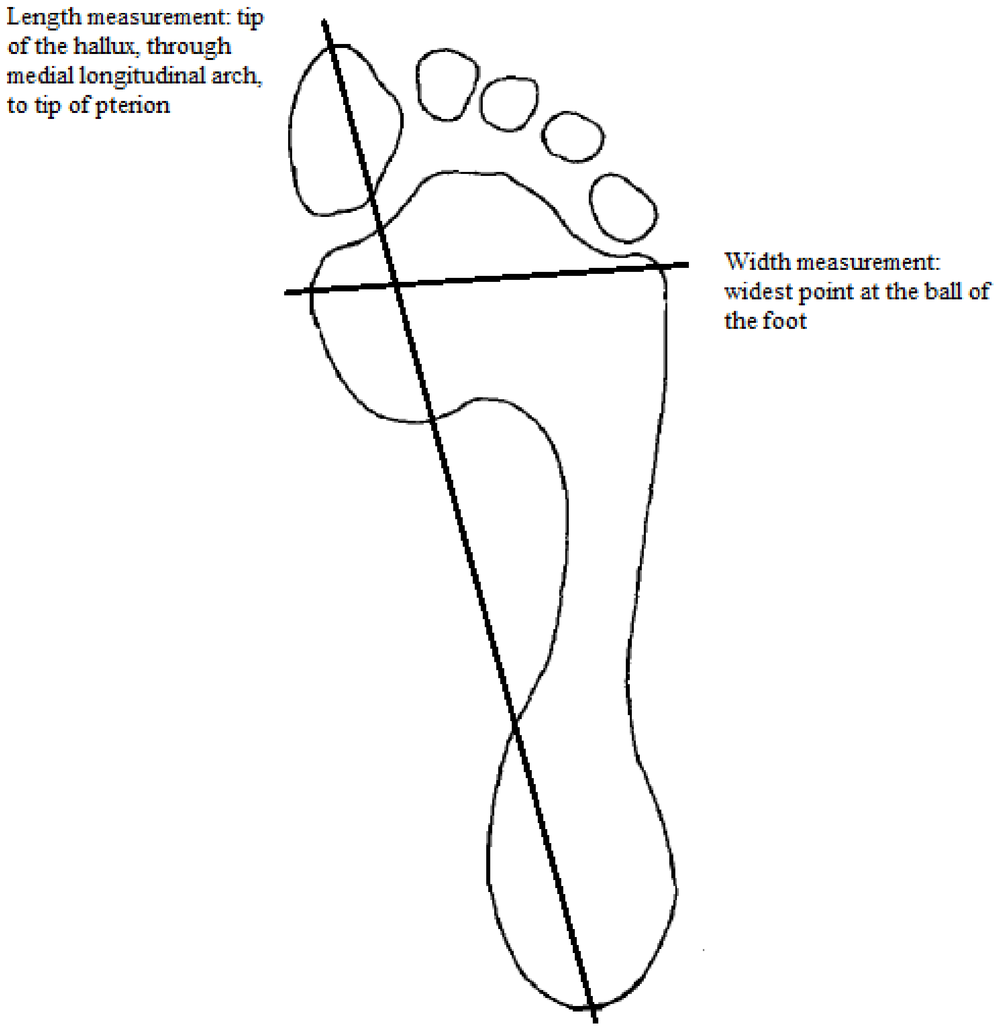


Figure 4.5 Method of measuring the length and width of a footprint utilised within this experiment

Footprint-track trails provide the most convincing evidence of human activity. A trail of footprints can assist in understanding the direction someone was walking in and the length of their stride which can lead to inferences about stature and gait. Pace was measured between the top of the hallux of a foot and the hallux of the foot behind them or in front of them in the trail, eg. left-right-left (Figure 4.6). Stride was recorded from the end of the hallux of a left foot to the end of the hallux of the next left foot in the trail, the same was measured for the right side.

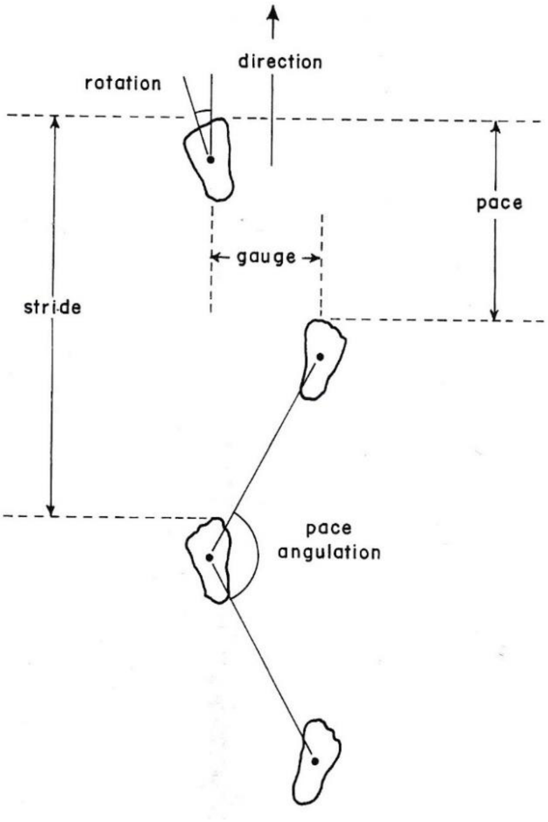


Figure 4.6 Descriptive scheme of trails (Allen et al. 2003; Figure 2)

4.3 Anatomical structure of avian feet and footprint identification and recording

On the ground, a bird may create footprints by hopping, walking or running, this movement creates distinctive footprint patterns. A hop will create paired footprints, walking creates footprint-tracks in a zigzag pattern or sometimes in a straight line, running causes the stride length to widen (Bang and Dahlstrom 1974). Birds have four toes, in anisodactyl three are usually forward facing and one is usually back facing (Figure 4.7). At the centre of the toes is the sole of the foot (Brown *et al.* 1987). The back facing toe is often referred to as the first toe, and may be positioned further up the foot meaning it does not meet the ground (Bang and Dahlstrom 1974). Each toe generally has a fleshy protrusion just before the pectinated claws; this is referred to as a tubercle and is more pronounced in certain species (Brown *et al*. 1987). The shape of an animal's foot can greatly assist in species identification, as it is reflected in the footprint. Wading birds will have long, slender, widely spread toes which have been adapted to ensure easy movement along soft sediments. Waders which belong to the *Charadriiformes* order, such as oystercatchers, usually have a small 1st toe although large 1st toes are not unheard of. Herons have a particularly long 1st toe to enable them to grip branches in arboreal areas as well as the thin well spread toes which allows them to wade easily in wet sediment (Liebenberg 1990). Birds that swim, such as ducks, geese, and swans, have enlarged feet with a thin membrane spread between each toe causing webbed feet, allowing the toes to be spread and pulled together to allow aerodynamic swimming; these are palmate species (Baker 2013). Some bird feet are specially adapted to enable the exploitation of multiple habitats, such as both coastland and woodland, cranes, storks and plovers all have this adaptation (Liebenberg 1990). Others, such as coots, have large fleshy protrusions to assist in both wading and swimming (Brown *et al*. 1987). It is considered a difficult task to identify the individual species of a bird from a footprint. Bang and Dahlstrom (1974) noted that there are many points to consider; first the size of the track in general, the length, size and shape of the first toe, and the length of the central toe. The angle between the two outer toes, their length and width should also be considered, as should any evidence of webbing. The final identifying factor, suggested by Brown *et al*. (1987), is if the track displays any evidence of symmetry, this requires the 1st and 3rd toe, and as the 1st toe is not always present this can be a problem. Any clear asymmetry can be a clear diagnostic feature when attempting to identify a species.

Avian footprints within this study were recorded and the species identified by considering the length, width and number of toes of a footprint (Figure 4.8). The symmetry between the 1st and 3rd toe was considered. The angle between the 2nd and 4th toes was noted, as was any webbing that was present.

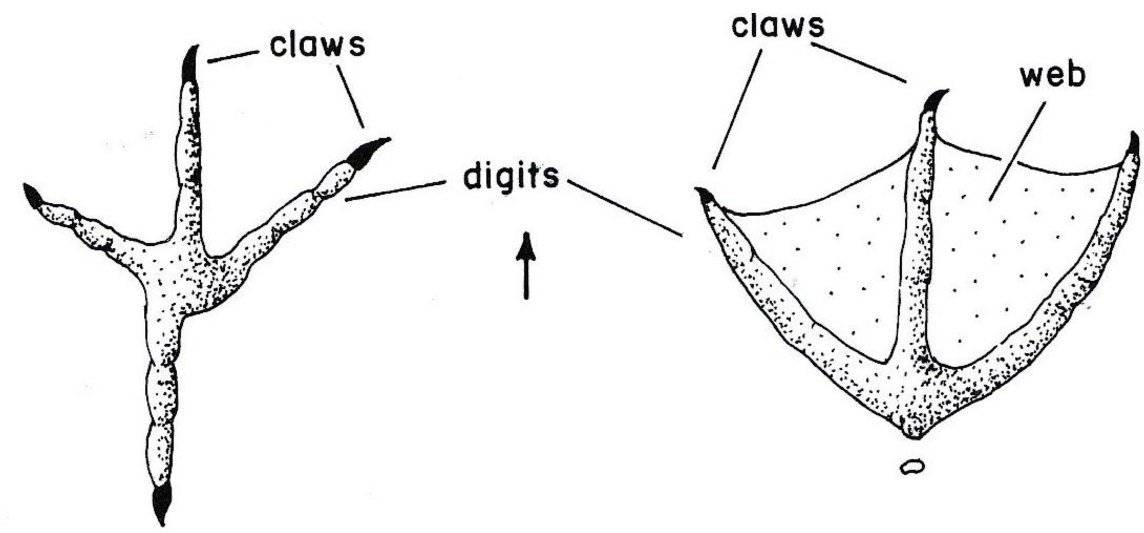


Figure 4.7 Descriptive schemes for avian footprint identification (after Allen et al. 2003; Figure 6)

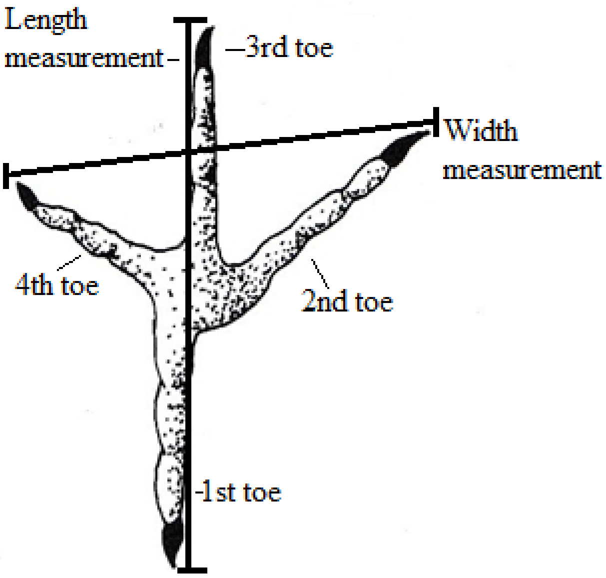


Figure 4.8 Avian footprint identification and required measurements for recording (Drawing by J.R.L. Allen, annotated by author)

A further consideration regarding bird footprints is the trails that they leave. Different species have specific ways of walking, and many species have certain habitats that they will populate, these preferences as well as their behaviours may also assist in identification. Birds have three main gaits, walking, running and hopping (Brown *et al*. 1987). At a walking pace tracks generally appear in a straight line or astride the mid line, though they can also be slightly straddled; this is usually seen in webbed birds (Figure 4.9). When running the stride length increases and accessory marks, such as toe or tail drag may be seen. As speed increases the straddle of the mid line tends to decrease and footprints may be seen in single file. Hopping will be obvious when footprints are presented in pairs, usually opposite each other and close to the midline. Although this is the basic trend seen in avian footprints, it should be remembered that each species unique behaviour will affect the way they move and their footprint formation. To accurately identify an avian footprint, it is helpful to have an idea of what species are generally in the area to help narrow down identification.

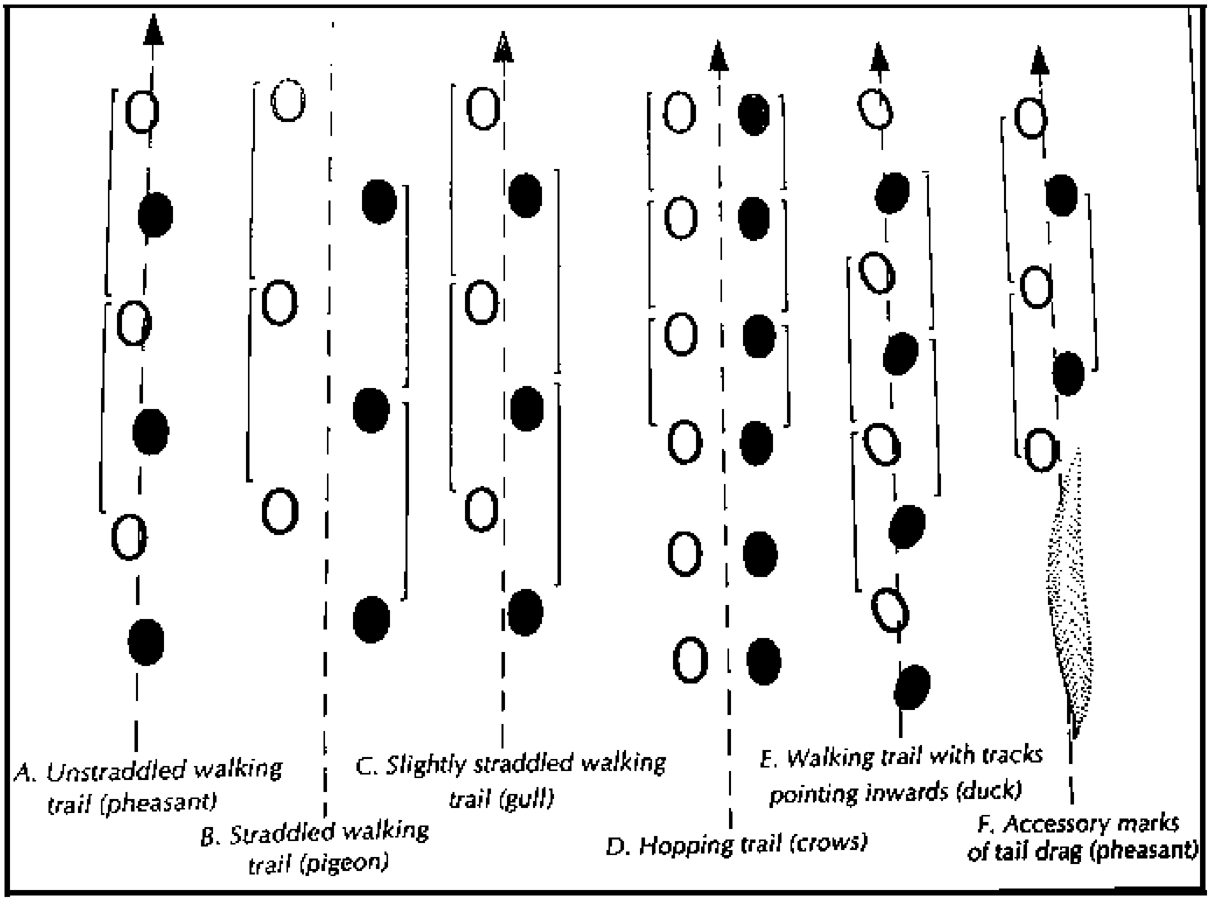


Figure 4.9 Trail morphology from a variety of avian species walking and hopping (Brown et al. 1987)

4.4 Anatomical features of mammal feet and footprint identification recording

The following discussion of footprint morphology deals primarily with some of the mammal species that would have been present in the British Isles throughout the Holocene, although the approach shall draw upon worldwide work performed on animal tracks and tracking. The measurements of all mammal footprints should consider the length and width; however the overall morphology is more of an identifying feature than size alone. For all footprints the length should be measured from the longest part of the foot and the width from the widest.

4.4.1 Cloven Hoof

Cloven hooves are very recognisable. The foot is made up of four toes, the third and fourth toes are central and will be well-developed, the second and fifth toes (dew claws), will be smaller and rounder, the second toe is positioned medially and the fifth toe is positioned laterally on the body (Lawrence and Brown 1967). The first toe is no longer present in cloven hoofed animals (Lawrence and Brown 1967). The location of the dew claw is species dependent; in species such as cattle, deer, sheep and goat they will be positioned so high up the leg that they rarely meet the ground, unless the sediment is extremely deep. In other situations, such as with pigs, the dew claw may be seen in a footprint, which may aid in species identification (Bang and Dahlstrom 1974). Toes three and four are generally symmetrical in shape, with different species displaying different levels of symmetry. In most cases it will be these two toes that create the recognisable footprint.

The cloven hoof is made of a wall (or plate) and a sole (Figure 4.10). The wall of the hoof creates the smooth upper sides, extending slightly beyond the sole to form a sharp edge which can be seen in the footprint. Often it may be the sharp wall edges that are the only part of the foot that creates an imprint, especially upon hard ground (Bang and Dahlstrom 1974). The sole is on the underside of the foot; behind the sole is the toe pad. The toe pad is again a feature that is species specific, taking up certain proportions of the foot and specific shapes. In red deer, for example, the toe pad will appear as a rounded depression, whereas in roe deer the toe pad extends over almost the entire hoof, with only a small amount of sole (Lawrence and Brown 1967).

The shape and size of the footprint may also be an indication of the species, with tracks made by the forefoot being larger than the hindfoot. This is due to the forefoot generally creating splayed tracks, even if being created on hard substrate, whereas the hindfoot is less splayed (Bang & Dahlstrom 1974). There are a variety of identifiable features that may be seen in the footprint-track to aid in establishing the species (Figure 4.11).

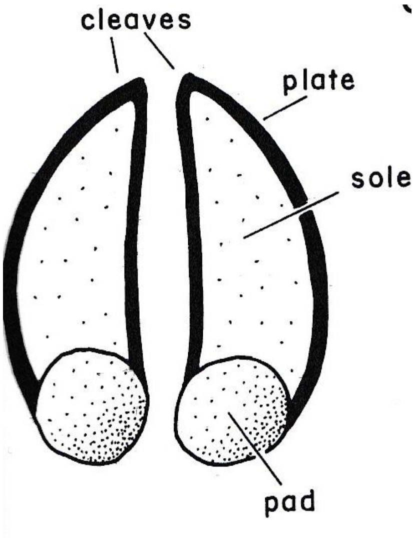


Figure 4.10 Descriptive schemes for cloven hoofed animals (Allen et al. 2003; Figure 6)

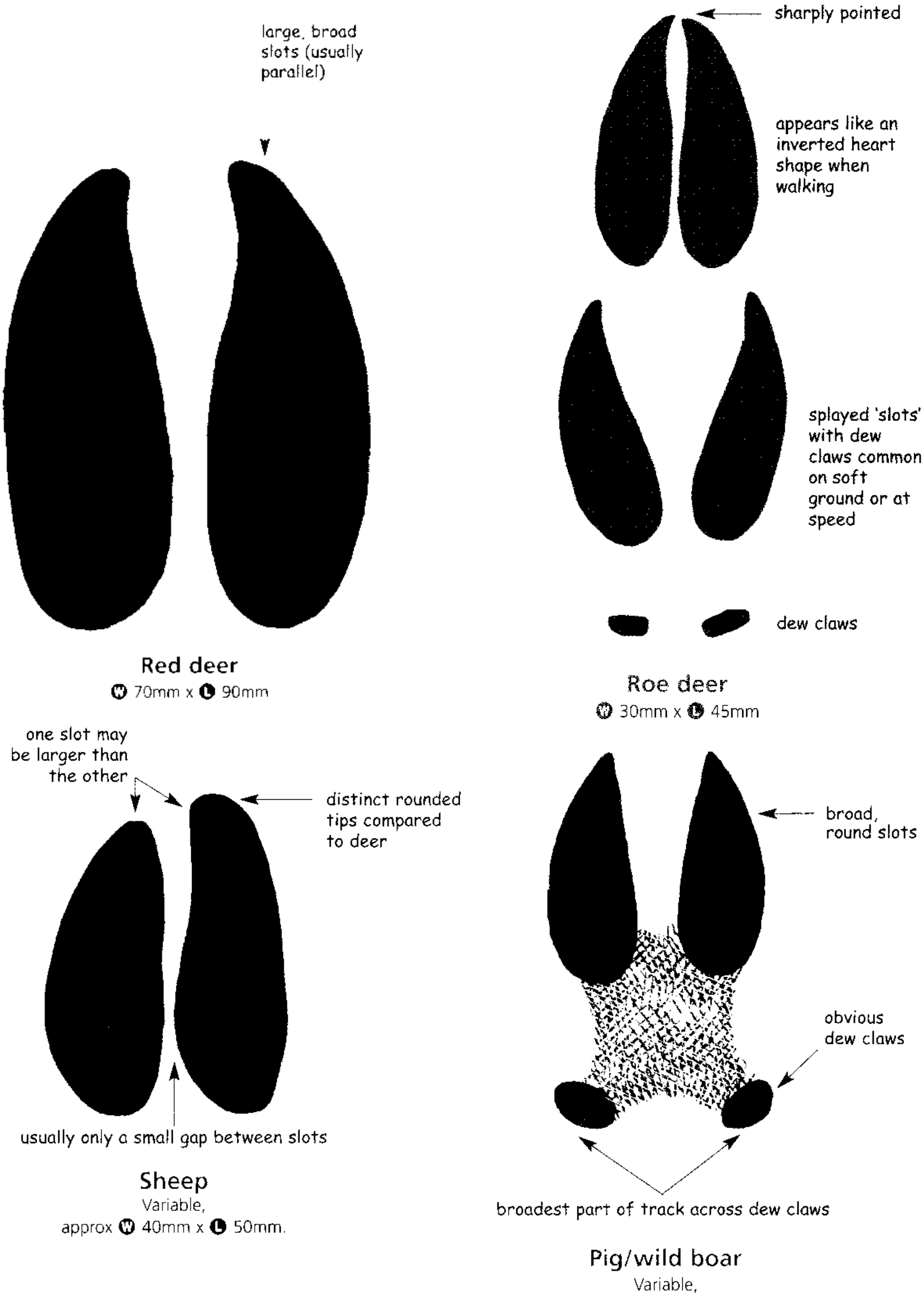


Figure 4.11 The different identifiable features seen within cloven hoofed animal footprints, and approximate sizes of the prints (not to scale; Bullion 2014)

4.4.2 Horses

Although horses are hoofed animals they have evolved differently to ungulates, as they walk on one toe. Horses walk upon their third toe, on a singular large hoof on every leg. The hoof is almost circular in shape, and like cloven hoofed animals, it is made up of a wall and a toe pad (frog). Horse footprints are distinctively circular (Figure 4.12).

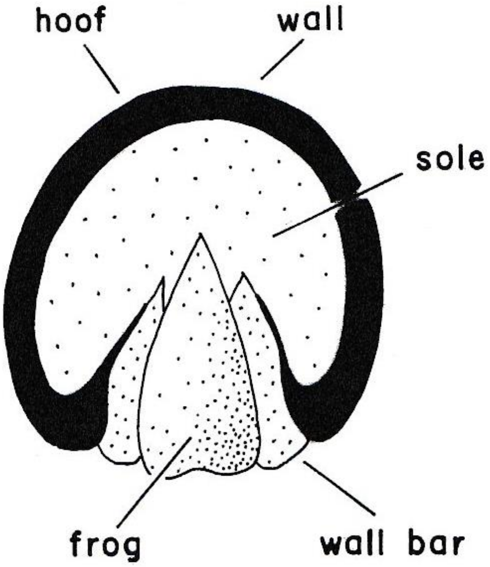


Figure 4.12 Descriptive scheme for horse footprint (Allen et al. 2003; Figure 6)

4.4.3 Paws and Claws

Animals that have paws and/or claws, such as canids, felines, bears, and mustelids, generally have five well-developed toes of different lengths (Bang and Dahlstrom 1974). The toes are numbered from one to five for identification purposes, with toe one being the shortest inner anterior toe, the longest toe is toe three. Knowing which toe is anterior allows the foot to be sided. Often the first toe creates a faint impression or does not create an imprint at all; in this case the shortest toe will be the outer toe, again allowing the foot to be sided. Animals that are digitigrade, such as felines and canids, walk on their toes leaving paw prints and claw prints in the footprint. In these animals, under every toe tip there is a pad, behind the toe tip pad are the intermediate pads. In many species, such as wolves, dogs, foxes and cats the intermediate pads are fused making a large toe pad (Figure 4.13). Some animals, such as otters, also have proximal pads (Figure 4.14); these features can be used for species identification as it is often the pad rather than the claw that will leave an imprint (Bang and Dahlstrom 1974). Canid and feline tracks are common examples of footprints created by digitigrade animals, meaning animals that leave more of a pad impression than a claw impression. The trail of an animal with paws/claws can also assist in identification; foxes for example walk in a straight trail, whereas dogs leave an erratic trail (Bullion 2014). There are a variety of identifiable features that may be seen in a footprint to aid in establishing species.

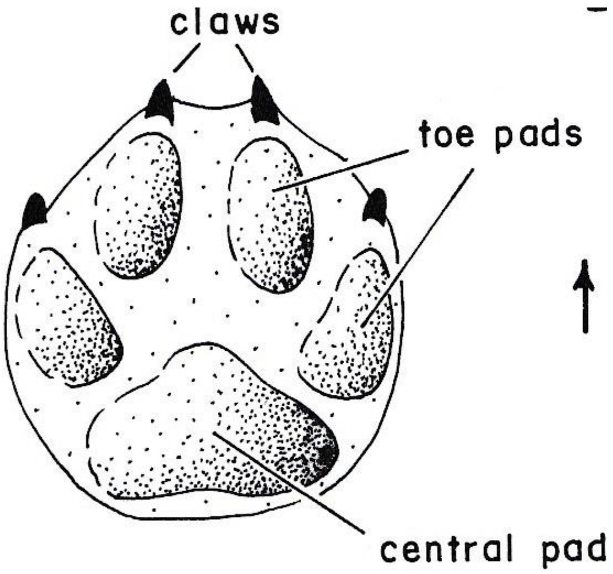


Figure 4.13 Descriptive scheme of dog footprint features (Allen et al. 2003; Figure 6)

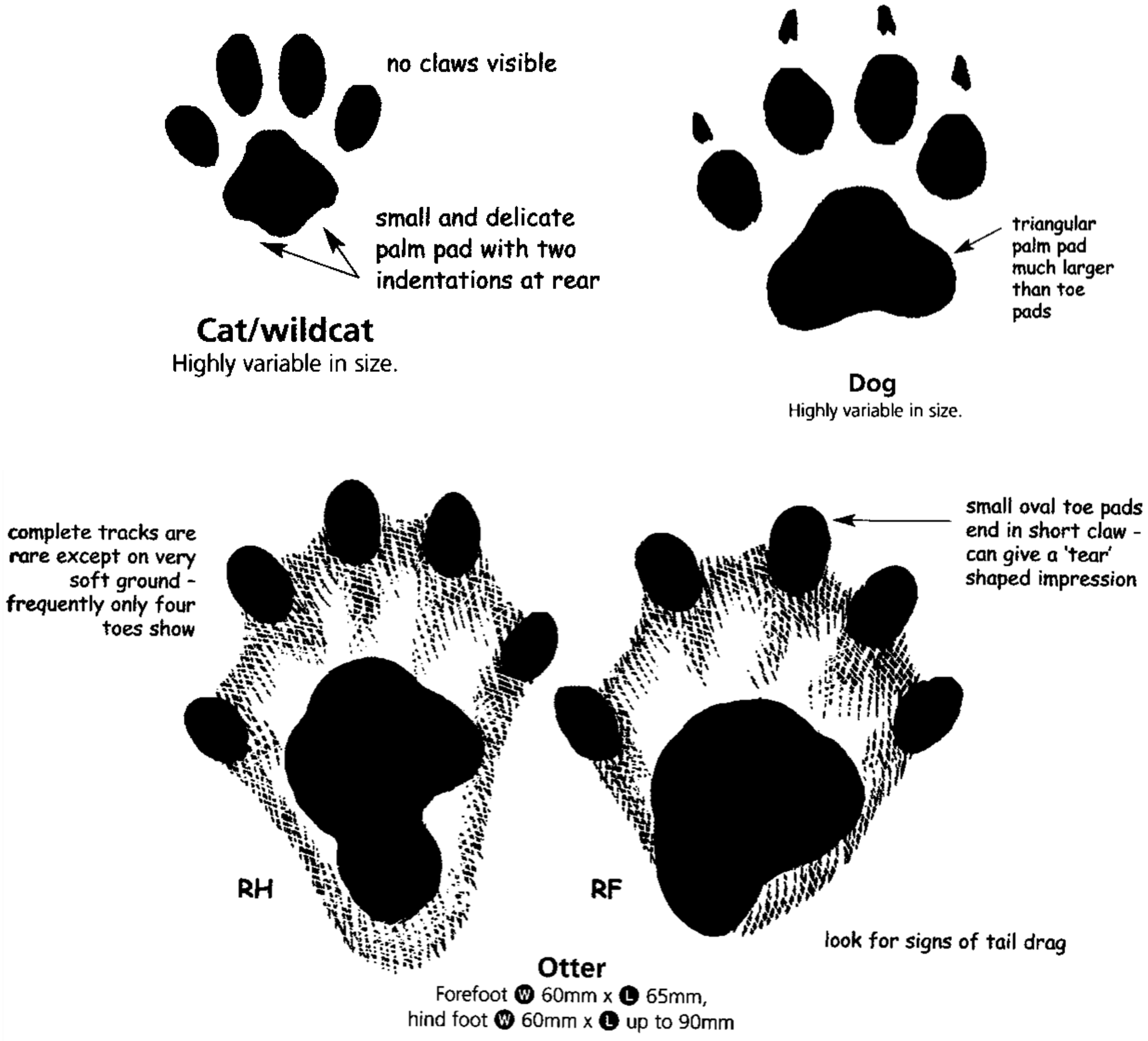


Figure 4.14 The different identifiable features seen within footprints of animals with paws/claws, and approximate sizes of the footprints, not to scale. (Buillion 2014)

4.5 Formation of a footprint

The way in which a footprint is formed must be understood to appreciate the value of a footprint, in particular the formation process in different sediments, or when moisture content is variable (Figure 4.18). In recent years experiments have been undertaken to enable an understanding of the formation process, and the effects of different substrate plasticity and water content, to demonstrate the ways in which a footprint is formed and becomes fossilised (Allen 1997; Marty *et al*. 2009).

Moisture content is an influencing factor in footprint formation, no matter what the sediment walked upon. Moist or slightly damp sediment is the most effective at maintaining a footprints morphology so that they may be preserved, whereas dry sediment creates poorly formed footprints (Scrivner and Bottjer 1986). In situations where moisture content is too high, such as when there is wet clay or silt, the sediment fails to hold any footprint shape, and it is only when footprints have been made on slightly drier clay or silt that the track can be observed (Marty *et al*. 2009).

Intertidal footprints are ephemeral; erosion is continuous as they are in a high energy environment, often only episodically exposed during large storms. Footprint-track evidence is preserved in contexts which are low energy, which results in fine-grained sediment depositions. In some incidences footprint-tracks are preserved with exceptional detail. The nature of the sediments within the Wentlooge Formation, with alternating silts and peats, is a further factor influencing the creation of footprint-tracks (Chapter 3). Whilst walking upon estuarine mud it is easy to sink through the soft surface and impact upon the more stable peat/clay/buried soil sediments below. It has been noted by Scales (2006) that prehistoric individuals also impacted the sediment in this way, although this phenomenon may create difficulties in identifying the species of the footprint-track maker.

When a footprint-track is found on the intertidal zone the key question to consider is if they are in consolidated sediments which were distorted when they were made but are now consolidated and firm, or if the footprint is in unconsolidated mud and likely to be of very recent origin. If the footprints are in consolidated sediment they are likely to be archaeological and worthy of recording.

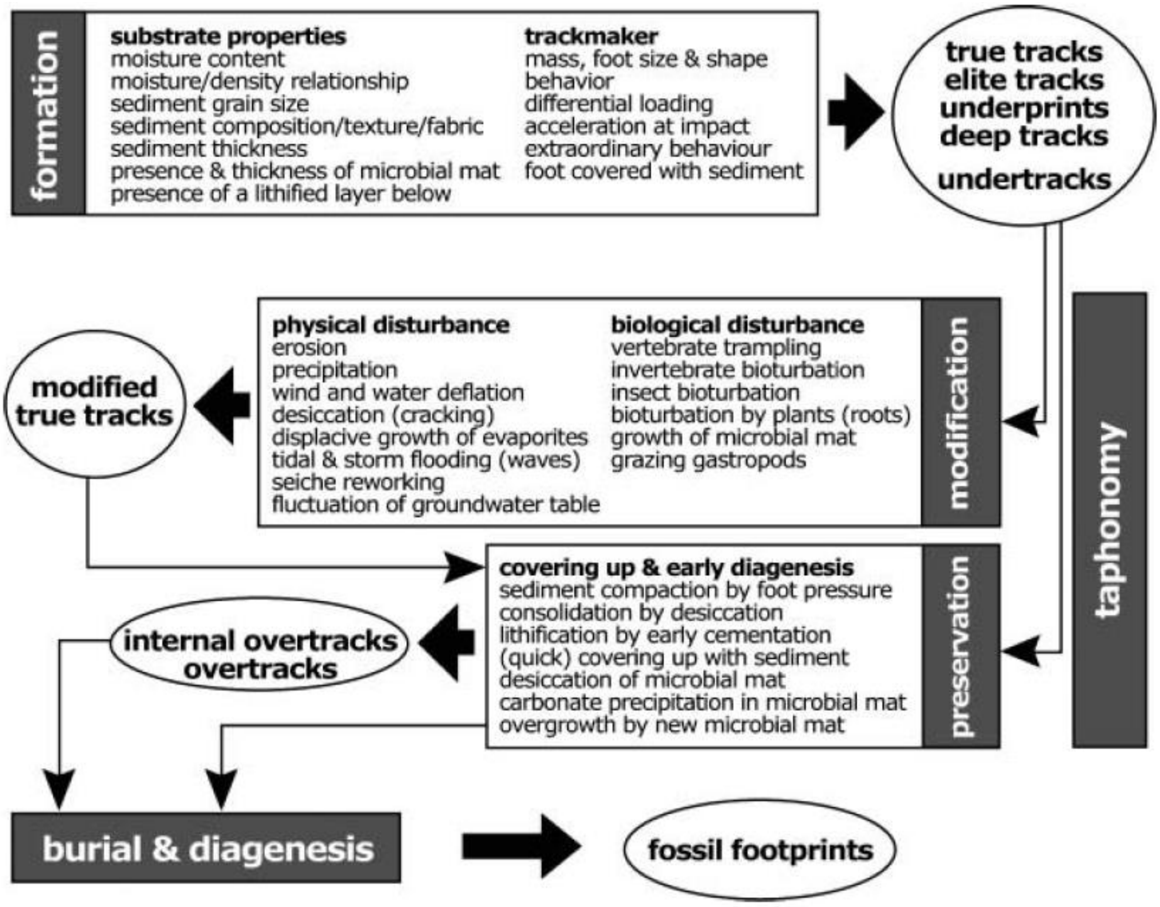


Figure 4.15 Processes acting during footprint formation (Marty et al. 2009). Note that they use the terminology 'true track' instead of 'footprint'

4.6 Footprint Terminology

Allen (1997) created descriptive terms for the different parts of a footprint and extensively studied footprint formation processes, with particular emphasis on the formation processes on the Severn Estuary (Allen 1997; Allen *et al*. 2003). The terminolgy applied by Allen (1997) is used within the current study. For a track to be created, the limb and foot cuts or deforms the sediment, creating a vertical shaft (Figure 4.16), as it is put down and then withdrawn (Allen 1997). When walking the force applied through a limb is gradual, whereas when an animal is running the force is far quicker and more violent (Leutscher 1960; Bang and Dahlstrom 1974). These forces can be seen in the footprint and can assist in understanding the speed that the animal was moving.

Footprint-track: A footprint-track is the trace of the foot created by an encounter between the substrate and each individual limb of the animal.

Footprint: The footprint is the place of contact between the foot and the surface; providing the right preservation details have been maintained the anatomical form of the foot may be viewed. It is found at the bottom of the shaft.

Shaft: The shaft is created by the limb and foot cutting or deforming the sediment. The shaft depth is variable depending on the sediment consistency, it can be shallow and only slightly deeper than wide or it may be deeper than it is wide.

Overtrace: An overtrace will form in the shaft of the footprint when the correct sediment conditions allow a lamination plug to build up or a microbial mat to grow (Hitchcock 1858; Marty *et al*. 2009) (Figure 4.17). An overtrace can be identified by the slight difference in sediment cololour or type to that of the surrounding sediment. The overtrace may be longer and wider than a footprint.

Undertrace: An undertrace may form when the foot compresses but does not penetrate the sediment, this may cause a stack of the print. The sediment, when split, may reveal a horizon of footprints, the deeper the print the less detailed it becomes (Lockley 1991; Hitchcock 1858; Marty *et al*. 2009). It can be dificult to distinguish between an overtrace and an undertrace.

Interdigital ridges: The toes of the foot are separated by grooved areas, represented in footprint-tracks as interdigital ridges.

Marginal ridges: Marginal ridges are caused by a deformation of the substrate, creating raised areas where radial and circumferential fractures may be evident (Figure 4.18).

Drag/Skim/Skid Marks: Drag, skim and skid marks can be produced by an animal as it either places its foot into or removes its foot from the sediment. Drag marks are generally caused by the toes or claws scraping the anterior edge of the track (Smith 1993). Skim marks are usually created by part of the bent foot skimming slightly across the surface before penetrating deeper into sediment (Leakey 1987). Skid marks are created when the whole of the foot skids on the soft sediment layer before the whole foot enters the deeper sediment (Stuart 1982).

Trail: A trail is a sequence of footprint-tracks which have been made by one individual’s limbs coming into contact with the substrate. It is a trail that can reveal information about the direction they were moving in, stride length, pace length, and rotation. The characteristics of a trail can also aid in identifying the species that created the footprint-tracks even if preservation is poor. Humans have a bipedal gait which is easy to see even in the most poorly preserved prints. Different species of birds also have specific patterns of walking, again this would be reflected in the trail. Ducks for example tend to walk in their mating pairs, side by side.

Stride length: One complete cycle of the limb, stride length involves the same foot, e.g. measuring the distance between the left toes to the successive left toes.

Pace length: The pace length is the measurement between one limb's footprint and its' opposite, e.g. measuring the distance between the left and right toes.

Rotation: A footprint may assist in understanding the general direction of movement by looking at the rotation of each footprint. The footprint may be turned inwards or outwards which suggests direction of travel.

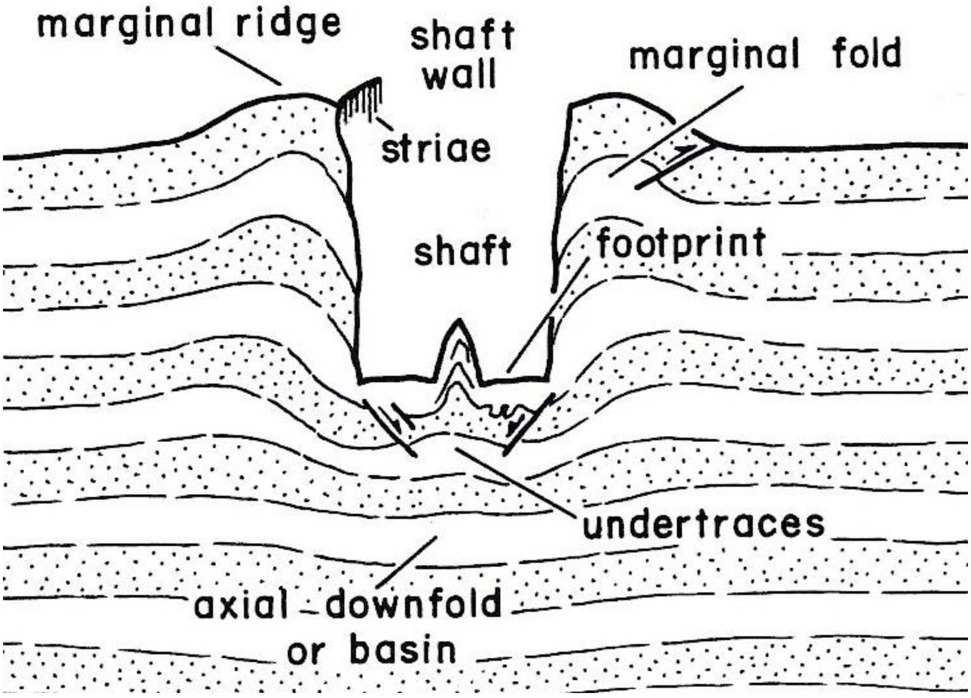


Figure 4.16 Vertical section of a footprint-track made by a toe-toed track maker and description of the different features that make a footprint-track (Allen et al. 2003; Figure 5a)

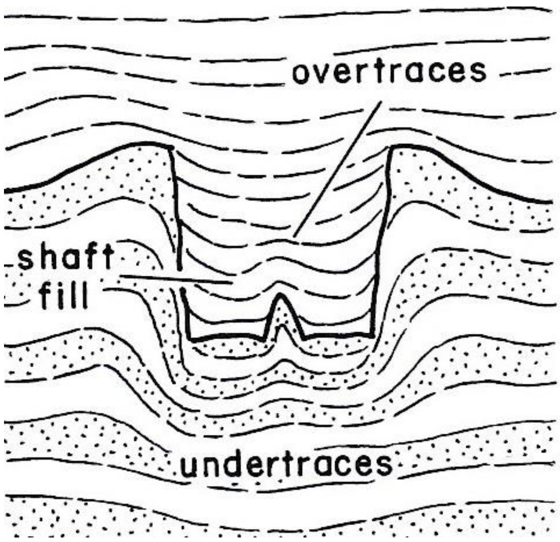


Figure 4.17 Example of how an overtrace and undertrace footprint-track is formed, vertical section of a footprint-track made by a two-toed trackmaker (Allen et al. 2003; Figure 5c)

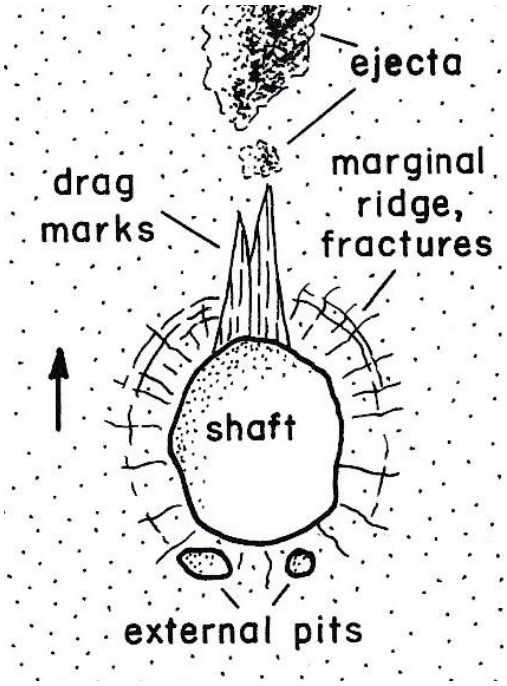


Figure 4.18 Vertical section of a footprint-track (Allen et al. 2003; Figure 5b)

4.7 Field Recording Methods

The methodology and footprint-track terminology established by Allen *et al*. (2003) and Scales (2006) provided a base from which to work and adapt; this methodology was modified to include thorough recording of mammalian and avian footprint-tracks, as well as modernised by utilising Bennet *et al*'s (2013) methods for accurate recording.

In this methodological section the full range of techniques utilised during the fieldwork period 2014-2017 are outlined. The narrow tidal window, differences in preservation and the locations of each footprint area meant that it was not possible to employ the full range of techniques in every occasion. Each period of fieldwork had a clear set of objectives as to which techniques were expected to be used and in what sequence. The priority was to ensure that any well-preserved footprint-tracks were fully recorded in the time available and that the potential of new technology for the rapid recording of footprint-tracks was developed. A guide to recording prehistoric footprint-tracks from intertidal zones was written by the author and supplied to The Coastal and Intertidal Zone Archaeological Network and is available online for anybody to access (Appendix 1.1).

4.7.1 Preparing for fieldwork

In advance of coastal fieldwork, the tide table ‘Easy tide’ and ‘Admiralty Tide Tables’ were consulted. ‘Easy tide’ is a government website which predicts tides for the week ahead, whilst the ‘Admiralty Tide Tables’ provide a more approximate time for tides throughout the year. The likely time of exposure of the area was established depending on the site location and its OD height in relation to the tidal frame.

Before heading out onto a coastal site it is important to have a clear plan of action and a list of delegated tasks that need to be achieved during exposure. It is important to have all equipment with you, as every moment counts. Creating a list of all possible equipment that may be required in any eventuality ensures that the footprint-track exposure is used to upmost advantage. The footprint areas at Goldcliff are exposed during only a short tidal frame. The OD height at which footprints occur range from about -3m OD (top of Site C) down to -5.31m (Site S). The highest footprint sites will be exposed for about 2 hours at the best during spring tides and the lowest (Site N and S) only for about 1.5 hours. Under average muddy conditions much of this time will be spent locating footprints and washing off mud and sand before recording can start.

A health and safety risk assessment was prepared for fieldwork.

Permission to enter the intertidal zone at Goldcliff East was given by Natural Resource Wales and arrangements for each visit were made with the wardens of the nature reserve within which the sites lie.

4.7.2 Cleaning

Due to the unpredictability of estuarine conditions, each visit required a different level of cleaning; after a large storm the footprint-tracks will often have the best exposure, whereas when the water is calm the mud will generally remain over the site, covering the footprint-tracks from view (Scales 2006).

At the Mesolithic site of Goldcliff East, the laminations are fragile and must not be cleaned with excessive force, such as by using trowels or spades as this would cause damage (Scales 2007a, p 140). It is most effective to use water to gently clean the area; one approach was to use buckets of seawater to wash off small areas, this mimics erosion caused by the tide rather than using tools which may harm the fragile laminae. The use of buckets depends on the presence of a nearby body of water and a slope which does not have sand which will simply wash onto what you are trying to clean. Another approach was using a pressure washer on a low setting to remove the top mud if there is a large area that needs to be cleaned, and then using buckets full of water to gently rinse off any mud on exposed or singular footprints. The use of a pressure washer was experimented with during this research, however it was found that the machine was easily clogged with silt and therefore time was wasted attempting to rectify this issue. In a cleaner environment the pressure washer would work well at gently exposing footprints; in the Severn Estuary there was frequently too much silt within the water source. A further issue was getting the heavy machine across rocky ground down to the footprint area without damaging laminations where footprint-tracks may have been preserved.

The Middle Bronze Age peat at Goldcliff East is sturdier than the Mesolithic silt laminations, and can be cleaned by gently trowelling in one direction so as not to distort the features (Barr 2012; Barr and Bell 2016).

4.7.3 Planning, photography, measurements and descriptions

Each site discovered at Goldcliff East was marked out by 1m long steel pins, this allowed the activity along the foreshore to be continually recorded and revisited even when the footprint-tracks have been eroded away.

After cleaning, each footprint-track was assigned a footprint number and a waterproof tag with the footprint number written on using a waterproof pen, the tag was then inserted into the sediment next to the footprint. The footprint-track was then photographed using standard photography. The photograph included the label with the footprint number, a scale bar and a north point established with a compass. Recording with standard photography ensures that there is still a digital document if time does not allow for appropriate recording.

The location of a footprint-track should be established using Differential Global Positioning Systems (differential GPS), which works out the location using signals transmitted by satellites obtained from terrestrial stations (Historic England 2015). This system can have 1cm accuracy and is portable, which is an advantage on the intertidal zone. During the present research the Differential GPS was not always available for use and on several visits the equipment did not function correctly. Consequently, accurate Differential GPS data is only available for some areas, although in most cases it was possible to revisit sites later and obtain accurate locational information. The disadvantage of this technology is that it is expensive and generally owned by specialist organisations such as universities. A handheld Global Positioning Systems (GPS) has accuracy of about 3-6m, however it is relatively cheap technology so is a good substitute when a differential GPS is unavailable.

A description of the footprint-tracks was recorded, which included the number in the area, the possible species, evidence of trail, association to other footprint areas, association to certain topography and any unusual features. The rotation of the footprint-track was recorded using a handheld compass, to identify the direction of movement.

After the written description, the measurements of the footprint-track were then documented. The full length and width were measured, though it was not always possible to discern all the features. In human footprints, where possible, length of the foot was recorded from the tip of the hallux, through the medial arch and to the pterion. The width was measured at the widest point, from the forefoot.

A plan of the area was created using a planning grid square scaled at 1:20 or using the pins inserted during previous investigations, a note of each footprint number was included in the plan.

4.7.4 Multi-image photogrammetry in the intertidal zone

The use of multi-image photogrammetry in this experiment involved prepared targets set up on the sediment near the footprint-tracks as ground control points (GCP). The GCP's positions were recorded using handheld GPS or differential GPS depending on availability. The distance between each GCP was measured and a brief plan was created to enable the area to be analysed if the differential GPS failed, which was a problem experienced multiple times during the fieldwork period.

A 10cm scale was placed by the footprint for size reference. The images were taken by hand, as the unstable and uneven sediments were not appropriate for mounting tripods and they caused damage to the laminations. Taking the photographs by hand rather than using a tripod was a time-effective method (Rüther *et al*. 2012). Multiple images of the footprint-tracks were taken, at a different position for each image, using a fixed angle, full framed camera, with a fixed angle lens (Bennet *et al*. 2013; De Reu *et al*. 2013), ensuring at least a third overlap of the frame for each photograph and from as many angles as possible. The zoom and flash features were not utilised, and all images were shot in RAW. This experiment utilised a Nikon D600 SLR camera with a 50mm lens. This camera has 24.3 megapixels and a wide ISO sensitivity range of ISO 100 to 6400. Two 120gb memory cards were in the camera at one time and a spare was carried.

4.7.5 Laser scanner

A Faro Scanner Freestyle^{3D} was utilised in this experiment. It is a small machine, weighing less than 1kg (Faro technologies 2017), making it ideal to transport onto the intertidal zone. This machine was designed to allow scanning in a variety of versatile sites and hard to access areas. Ground control points were placed around the footprint-tracks; it was not necessary to measure the distance between these as the scanner has accuracy of 1mm and is calibrated before each recording. A surface tablet and Faro laser scanner software prompted the user through each stage of the laser recording process.

Within the current study laser scanning was utilised during fieldwork on 18th May 2015, however no data of quality was gathered due to issues with recording with this technology, this will be discussed in Section 4.9.

4.7.6 Casting

Casting greatly compliments standard photography; where two-dimensional images can create an issue in defining the morphology of the footprints, casts provide a physical replica of the footprint that can be removed from the site and studied in a laboratory and perhaps later used for museum display. Footprint-tracks of a good preservation quality were cast to gain a further understanding as to the contours and morphology of the print. Dental alginate was used to cast with as it was found to work well within the Severn Estuary environment (Scales 2006). Dental alginate has a setting time of two minutes and most of the footprint-tracks were on the very lowest area of the foreshore with the shortest exposure time. Footprint-tracks were fully recorded using photography, measurements and photogrammetry before casting. The footprint track was surrounded by a plastic frame to retain the alginate. The mixture was made up as directed by each product’s specification, using fresh (not salt) water, which was poured into the cleaned footprint-track once it has gained the correct consistency. Once dry the cast was lifted out. Dental alginate is flexible and lifts out the footprint easily, though like all casting methods it can still cause damage to the laminations. Dental alginate can only be stored for a short period, once off-site the prints were recast in a longer lasting material, Plaster of Paris.

4.7.7 Block-lifting

The method of block-lifting footprint-tracks was taken from Scales (2006), and its effectiveness experimented with during this study. A 30cm trench was dug around footprint-track 2014:308, at Site M5a. An aluminium reinforced metal sheet was then used to cut into the sediment underneath the block so that the sediment containing the footprint-track could be removed from its original context. The block lifted was approximately 30cm deep. Before removal the footprint was carefully bound round the edges using packing material and masking tape. This was done with care so as not to crack the silt. The block-lifted sediment was then removed from the laminations and carried off the intertidal zone.

4.7.8 Sediment samples

Sediment samples were taken from the same lamination as a random selection of footprint-tracks. The focus was on the precise surface upon which the footprint itself had been made, though samples were also taken from the lamination below. The exact walked upon lamination was not always clear as most of the footprint-tracks were overtraces/undertraces rather than obvious footprints. The sediment samples were taken in an intact block of about 5 grams, no thicker than the lamination in question, and put into a sample bag. The bags were clearly marked with the footprint number and its precise relation to the footprint (eg. surface of footprint, sediment filling footprint, lamination under footprint). The sample was used for laser granulometry to understand the particle sizes of the sediments. The method and results of this analysis is discussed in Chapter 8.

4.7.9 Optically stimulated luminescence dating

There have been a range of methods and techniques developed for archaeological dating (Walker 2005), many of which can be applied to date footprint-tracks (Figure 4.19). Pleistocene footprint-tracks from contexts older than approximately 50ka BP are often dated via the footprint's relation to volcanic context, using Potassium-Argon, with the site of Laetoli being an example of this (Leakey 1984). In contexts with bones or shells the footprint can be dated via Uranium Series. From *c*. 50ka BP radiocarbon dating can be utilised to date footprint-tracks, although this method provides an accurate date, the footprint-track horizon itself may not contain material that can be radiocarbon dated, in these situations it is dated via its association to stratified artefacts that provide the radiocarbon date. An example of this is seen at Formby Point, where radiocarbon dates were obtained from red deer antlers discovered in the same strata as red deer hoof prints, dated to 4450±45 ^{14}C BP (OxA-9130; Roberts and Worsley 2008). Optically Stimulated Luminescence (OSL) is a technique that has been utilised to date several footprint-track sites such as Willandra lakes (Webb *et al*. 2006; Webb 2007), and Formby Point (Roberts and Worsley 2008, p 38), and provides dates based on the last time quartz in the sediment was exposed to light, though the range in date is far larger than that provided by radiocarbon dating (Preusser *et al*. 2008). The stratigraphic context of the site must be fully understood for this method to be appropriate, as quartz or feldspar-rich minerogenic sediments are required for this technique, and would need to be present in the footprint-track horizon for accurate dating.

There is a distinctive lack of artefacts from the footprint-track horizons at Goldcliff East. Past research has dated them in association with artefacts that have provided radiocarbon dates, such as from plant remains in organic silts between the laminations of Site E (Bell 2007, p 50), and radiocarbon dated to 7300±55 BP (OxA-14037; 6340-6030 cal BC; Bell 2007, p 223). Within the current research OSL dating of the footprint-track horizons was also attempted to compliment the radiocarbon dating from this site.

Samples for OSL sediments were taken from footprint-track 2014:310 from Site M5a, and from Site R at Goldcliff East (Chapter 6, Figure 6.23 and 6.67). The samples were labelled and the position of the samples was recorded using differential GPS. The samples were sent to the University of Gloucestershire Luminescence dating laboratory where they were analysed (Appendix 1.2).

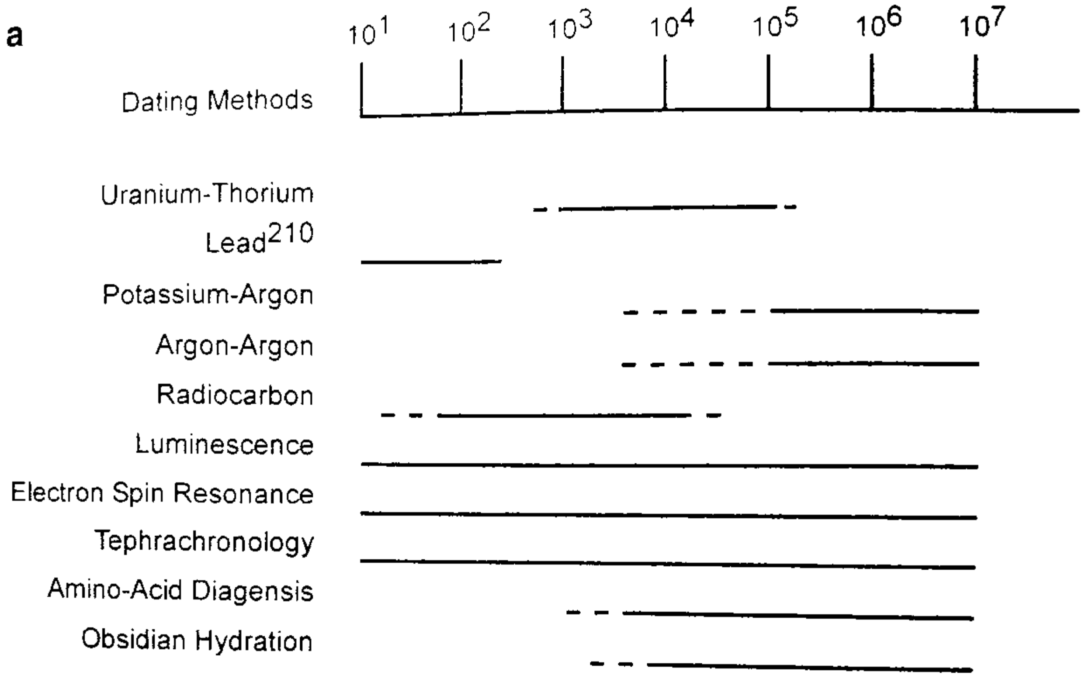


Figure 4.19 Dating methods used for fossil footprint-tracks and the time range for these techniques (Bennett and Morse 2014, Figure 2.7), each measurement of 10 represents 10,000 years, e.g. 10,000, 20,000, 30,000 etc.

4.8 Post-excavation methodology

4.8.1 Digitisation of tracings

Tracings were not used as a recording method by the author as tracings are subjective to the individual recording them, however the author considered it important to create a gazetteer of all Goldcliff East footprint-track evidence. Tracings made of footprint-tracks before digital capture techniques were utilised on the Severn Estuary were included within this study.

Tracings created in previous fieldwork, from 2010-2014 and Scales (2006), were digitised using an A0 digitiser and a computer installed with *Tablet Works* and *Adobe Illustrator*. Once *Tablet Works* has been set up and synchronised with the A0 digitiser then *Adobe Illustrator* was used to record the tracings. The tracings were affixed to the digitiser using masking tape, this ensured that the tracing did not move and both hands were free for digitising. Using the digitiser's mouse, the lines from the tracing made in the field were traced. This enabled the tracings to be digitised to scale. Although this method is not entirely accurate as the tracings may be several millimetres larger or smaller than the original tracings, it is still the most appropriate way of digitising these. The program *Adobe Illustrator* allows for further editing to the tracing if required and for lamination lines to be removed if necessary so that only the footprint-tracks remain.

4.8.2 Block-lift analysis

If a block-lift has been taken from the silt lamination it is important to investigate the footprint as soon as possible, as estuarine silt can crack easily, especially when dried out. Putting the block-lift in the freezer until you are ready to investigate may help to delay the cracking process although it is still likely to become cracked and crumbly. Immediately analysing the block-lift within a day of removing from the site is the best procedure.

It can be difficult to immediately ascertain if a footprint-track is an overtrace or an undertrace so micro-excavation can be attempted to establish this. The silt laminations in the block-lift will be fragile and will be easy to peel away with the fingertips, this technique of fingertip excavation was developed by Scales (2006). Small wooden tools are appropriate for use during micro-excavation as they are less likely to smudge any features. Carefully, first using fingertips and where necessary wooden tools, the laminations were peeled away and any noticeable features recorded, including whether the footprint was an undertrace, or an overtrace of the actual footprint.

The poorly preserved block-lifted footprint-track, 2014:308, did not reveal any underlying features when block-lifted and micro-excavated. This technique was not attempted again due to how destructive it was to the underlying laminations, and the time that was spent block-lifting and carrying the sediment back from the foreshore for very little information.

4.8.3 Footprint-track recording form

The footprint-track recording forms are modelled upon those created by Scales (2006), updated to include the different techniques used within the field (e.g. photogrammetry, casts, laser scanning etc.). Each form notes the site and area, footprint-number, and possible species as well as a variety of other considerations. Each footprint-track was recorded onto a footprint-track recording form after each day of fieldwork. A copy of the recording form is included within Appendix 1.3.

4.8.4 Multi-image photogrammetry process

The data obtained via photogrammetry produces the principle output of a point-cloud consisting of x, y and z co-ordinates. The software package *Agisoft Photoscan Professional* was used to create the point-cloud, allowing the creation of a 3D model. This program uses a combination of algorithms such as stereo-matching and Structure from Motion (SfM) (Agisoft LLC 2018). The first step of the programme is SfM, at this stage all the photographs are loaded into the software and aligned. The software allows for markers to be placed, one was placed in the centre of each of the ground-control points and the distance measured during initially recording between each marker was manually entered. The software identifies these markers as points of interest and tracks them around the movement of the image, the images are then aligned again to ensure all GCPs are in the correct area. This produces a sparse point-cloud, with the position of the cameras and the calibrations given for each image. Within *Agisoft Photoscan Professional* the sparse point-cloud can then be used to build geometry and a textured model and mesh. This resulted in a three-dimensional representation of the footprint-track, footprint-track trail or footprint area. The ability to view the full extent of the footprint-track trails and footprint areas in this way meant that the relationship between the footprint-tracks could be more fully understood and analysed.

Digital elevation models were generated within this program and then exported to ArcGIS to generate contour maps (Figure 4.20), and multi-directional hillshade models to view the topography which allowed the shape of a single footprint-track to be focused upon.

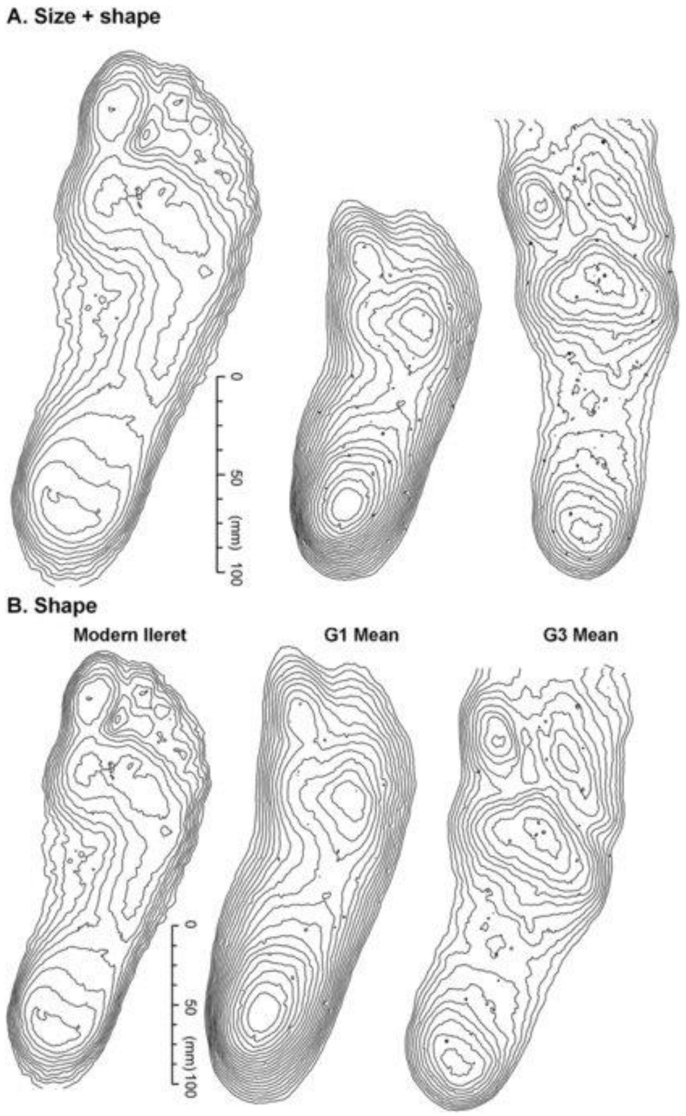


Figure 4.20 (A) Contour maps (1 mm interval) for unregistered mean tracks for habitually unshod modern feet (Daasanach, northern Kenya), Laetoli G1 Trail and G3 Trail. (B). Contoured maps for registered mean tracks for habitually unshod modern feet (Daasanach), Laetoli G1 Trail and G3 Trail (Bennet et al. 2016; Figure 4)

4.8.5 Laser scanning models

In a similar way to that of photogrammetry, a point-cloud built of x, y, z co-ordinates gathered through laser scanning may be utilised to create a 3D model. A very simple and free to use program that might be used for this is *CloudCompare* or *Meshlab*. These software packages allow the three-dimensional files to be viewed, as well as options to alter the point-cloud to show surfacing or geometry (Bennet and Morse 2014).

4.9 Comparison of techniques developed for intertidal footprint-track recording: multi-image photogrammetry versus laser scanning

A comparison between the effectiveness of an optical laser scanner and multi-image photogrammetry for footprint recording has been investigated thoroughly by Bennet *et al*. (2013; Bennet and Morse 2014). Recording conditions were very different from those experienced at Goldcliff East, so the comparison of techniques has been reassessed for use in challenging recording environments in the intertidal zone (Table 4.1). The utilisation of laser scanners on many footprint-track sites has been successful (Raichlen *et al*. 2010; Meldrum *et al*. 2011), however the use of a laser scanner on the intertidal zone very quickly became problematic. Certain requirements such as the need to recalibrate after levels of inactivity, which took a few minutes on each calibration, would not be an issue on many footprint sites, however in the intertidal zone, where tidal windows are small and opportunities to access certain areas are rare, these minutes for recalibration were problematic. The Faro Scanner Freestyle^{3D} was light, compact, and easily portable, however strong winds and bright sunlight prevented any data being accurately captured with the handheld laser scanner during the fieldwork. Due to the cost of hiring the laser scanning equipment and the uncertainty of being able to guarantee appropriate weather on days when the tide table was sufficient, laser scanning was not a technique that offered accurate, fast or reliable recording of footprints from areas where the destruction of the footprint was imminent. This is not to say that in the future laser scanning cannot be utilised or that other makes of laser scanners would not be effective, rather at the time of writing the conditions for recording on the Severn Estuary require equipment that is ruggedized, light and portable, can be used without a large power source or a tripod and is able to work in a variety of weather conditions, which the Faro Scanner Freestyle^{3D} could not. Laser Scanners are improving all the time; new models would benefit from being tested on the intertidal zone footprints to fully investigate if laser scanning in intertidal zones is practical and effective.

Multi-image photogrammetry was found to be the most effective digital recording technique in the challenging conditions of working within the intertidal zone. The cost of the hardware is low as any make of digital camera can be used. In this research a Nikon D600 SLR camera, with a 50mm lens and a 120megabite memory card was utilised, however the use of a camera phone (Nokia Lumia 735 with a 6.7-megapixel camera) was also experimented with. The camera phone did capture enough detail to create a point-cloud, though depth and texture were not as detailed and there was often a large amount of artefact surrounding the edges of the model, however in situations where someone only has a camera phone the models would still be useful. Multi-image photogrammetry was excellent for recording in the intertidal zone of the Severn Estuary, where bulky equipment is not practical and may damage the archaeology. To perform this process all that was required was a camera, memory card, and a scale, though a handheld GPS or a differential GPS is useful equipment to use alongside the recording, as are GCPs. The ability to perform this technique without a tripod is also convenient as the land surface is unstable and the laminations are soft and tripods can again cause damage. The process is relatively quick to perform, though laying down the GCPs and measuring the distances between each one can take time if the footprint-tracks are spread over a large area. The size of the area can also affect the amount of GCPs that it is possible to lay down. Within this study GCPs were generally set up in 50cm^2 or 1m^2, however this is not always possible when a trail is on several laminated bands over several meters. The software used to process the multiple images into models was *Agisoft Photoscan*. This is a costly package at approximately £2700 for a stand-alone licence, though floating and educational licenses are also available for a lower price.

4.10 Summary

There are many techniques used by ichnologists to record footprint-tracks, some of which are more sophisticated than others. Within this research the use of multi-image photogrammetry was found to be the most effective method to digitally capture the data,and allowed for the footprint-tracks to be fully viewed again when they had been processed into a 3D point cloud model. These models allowed for thorough analysis of the footprint-tracks and make it possible for the footprint-tracks to be 3D-printed from the point cloud data so that they can be exhibited in museums. Optical laser scanning is a technique that has been utilised to record footprint-track sites (Bennet and Morse 2014), however the Faro handheld laser scanner utilised within this experiment was unable to accurately record within the intertidal zone of the Severn Estuary, due to issues caused by winds, sunlight and the need for re-calibration. A ruggedized laser scanner may be more effective at recording in this environment. Although recording the footprint-tracks digitally provides strong data, there is always the possibility of inadequate data capture, or technical failure, so the writer would also suggest that traditional methods such as standard photography, the physical recording of metric measurements, and casting in dental alginate (when appropriate) should all remain methods that are utilised in intertidal footprint-track recording.

	Multi-image photogrammetry (Nikon D600)	**Laser Scanner (Faro Scanner Freestyle 3D)**
Recording Equipment	Digital camera, lens and memory card are all that is required, although Ground Control Points, scale bar and differential GPS are beneficial. A waterproof camera case prevents the estuarine conditions breaking the equipment	Laser scanner and tablet to record the data onto
Hardware requirements	Apart from the equipment needed for recording on site, a CPU with the ability to run the software and process the model is required	Apart from the laser scanner itself and the tablet there are no specific hardware requirements
Software requirements	Dependant on what is used to process the models, there are commercial and free versions available	Faro Scanner Freestyle 3D works with Faro Scene Capture and Faro Scene Process software, which are free
Cost	Low cost, any form of digital camera can be utilised including cameras in mobile phones. If utilising commercial software the cost does increase	Depends on the model, the Faro Scanner Freestyle cost approximately £750 to hire for a week, the surface tablet was included in this
Portability	Very portable, cameras are small, light and compact	Many laser scanners are not portable, the Faro Scanner Freestyle was small, portable and relatively lightweight
Potential risk to the site	Minimal, especially if a tripod is not utilised. Main damage comes from the photographers' feet whilst they attempt to capture a variety of angles	In general laser scanners would cause damage as they require tripods and scanner frames. The Faro Scanner Freestyle 3D did not need a tripod, the risk is the same as photogrammetry, with destruction from the recorders feet being the main problem
Ease of use	Relatively simple if you know how to use a digital camera	Simple, the Microsoft Surface Tablet provided all instructions on how to use the equipment
Speed of use	Relatively fast to set up and record. A 1m^2 area takes	The machine needs to be recalibrated each time it goes onto standby or is turned off between uses. Recalibration

	approximately 10 minutes to record	takes a few minutes each time. Otherwise data capture is incredibly fast, approximately 1 minute per 50cm^2
Effectiveness in the intertidal zone	Very effective, though sunlight or shadowed areas may prevent detailed data capture. Rain can slow down capture, though a waterproof camera casing prevents this being an issue	The Faro Scanner Freestyle was not effective in the strong winds and bright sunlight, the estuarine conditions prevented any data capture using this model. This machine was not effective in the intertidal zone and time was wasted.
Accuracy of capture	This is dependent on the quality and quantity of images captured, as well as the type of software used to produce the model. Deep prints can cause an issue by creating shade at the bottom of the print. Images need to be scaled accurately	Dependant on scanner make and model. Problems can be caused by shadows and deep prints. The machine needs regular calibration resulting in scans on an accurate scale
Risk of failure - Equipment	Low. Digital cameras are relatively cheap and most people involved in the fieldwork will have a digital camera, mobile phone camera, or both.	Moderate/high. Scanners are relatively delicate and can easily be damaged in the field, especially in the wet, unstable environment of the Severn Estuary where transportation is difficult
Risk of failure - Data quality	Moderate/high. Failure to capture images of good quality or coverage can result in loss of data. Due to erosion and tide times you may not be able to find the same footprint again to record	Low in theory as you can check the data quality on site. There was high risk of being unable to collect any high-quality data due to weather conditions (sunlight, shade, rain, wind).
Risk of failure - Post-processing	Moderate. Software may fail to create high-quality models. If images are high quality this can just be run again until successful	Low, as the data collected will already have been of high quality

Table 4.1 Table based on the work of Bennet et al. (2013; Table 1) and Bennet and Morse (2014; Table 2.1) investigating the advantages and disadvantages of recording footprint-tracks using multi-image photogrammetry and optical laser scanner. Author has edited the contents of the table to make it relevant to recording at Goldcliff East

Chapter 5

Inferring the age, sex and stature of an individual by utilising experimental footprint data

5.1 Introduction

The foot, a biological mechanism made of 26 bones, layers of sinew and muscles, can perform a variety of movements and enables us to control our speed and movement without a second of thought. This chapter will explore the question of the relationship between a person's height, weight and footprint length and the determination of age and sex utilising experimental footprint data. The understanding of this relationship is important within archaeological footprint research, where a footprint may be the only evidence of an individual or a community. Through understanding the footprint, we can then build a picture up of the society who made them, their social demographic and the activities they may have partaken in.

The height of an individual has a more positive relationship to foot size compared to other parts of the body, such as hand width (Krishan *et al*. 2010). It is generally agreed that an individual's foot length is between 14 to 16% of a person's stature (Toppinard 1877; Barker and Scheuer 1998). This concept has encouraged forensic scientists to investigate the potential in identifying an individual by utilising footprint evidence (Atamturk 2010; Fawzy & Kamal 2010; Giles and Vallandigham 1991, Jasuja 1991), with multiple regression equations created to estimate the stature of an individual from a footprint (Chapter 2, Table 2.2). Forensically this technique was utilised to identify criminals, disaster victims, and victims of crime (Bennet and Morse 2014), however anthropologists and archaeologists have also become interested in the potential of this form of evidence.

The bones and morphology of the foot change over time as a person grows and reaches maturity (Anderson 1956; Atamturk 2010; Hill 1958), it is in these differences in growth that the age of a person may be determined. Footprint studies tend to produce regression equations based on a specific sample, these datasets range in sample size from 38 people (Dingwall *et al*. 2013) to over 1000 (Krishan 2008a,b; Moorthy *et al*. 2014).

Regression equations to establish stature will be determined from this dataset and presented against those of other studies to observe the differences between studies that have focused on the morphology of the foot represented in the footprint, compared to the appearance of a footprint made in a sediment context.

Studies in forensic science have focused mainly upon the male sex, though studies into female footprints are becoming more frequent (Chapter 2, Table 2.2). Children are rarely considered due to the forensic purpose of most studies, though there have been a select number of studies involving children aged one and over (Anderson 1956; Bertsch *et al*. 2004; Bosch *et al.* 2010; Chen *et al.* 2011; Dowling *et al.* 2001; Grivas *et al*. 2008; Scales 2006).

There is merit in footprint data generated within forensic studies, however there are limitations when utilising these techniques within archaeology. Studies generally focus on males or females of a specific race or ethnicity or age range, University students or members of the military (Chapter 2, Table 2.2). These groups will not be representative of an entire population; members of the American military, for example, are generally in excellent health, aged between 18 and 40, and the sample used are all male and primarily Black or White (Robbins 1986). If applied to someone of Indian heritage, for example, the results for this equation would not be appropriate due to the morphological differences between different ethnicities and races (Krishan 2008a). A further consideration is general health and nutrition and any other socio-economic factors that may play a part in the growth of an individual.

The diet and lifestyle contrast between Mesolithic hunter-gatherers and modern populations may cause a difference in foot structure, and therefore the footprint. Nutritional stress can significantly affect the development of a juveniles' body, which in turn can affect the timing of puberty and the age of menarche. The delayed onset of puberty is thought to be an evolutionary response to deal with poor childhood weight gain and nutrition, preventing the child from experiencing the growth spurt of puberty until the body has the nutrients needed (Gluckman and Hanson 2006; Stearns 1992). Prehistoric humans are likely to have come under periods of food shortage or malnutrition due to the hunter-gatherer way of life, these stresses may have had an influence on the growth of the individual. An indicator of nutritional stress can be seen within the bones themselves; transverse lines of increased bone density (Harris lines) appear on long bones and are a sign of arrested development during a growth period (Harris 1933). These lines do not form unless an individual is otherwise well nourished most of the time, so are indicators of periods of shortage rather than long periods of slow starvation (Murchison *et al*. 1984; Symes 1984).

There are a host of illnesses children may suffer with if they are constantly lacking in nutrients, many of these stresses leave signs within children's bones, Harris lines are not the only indicator. Rickets, for example, occurs when there is a lack of vitamin D, calcium and phosphorus within a person's diet, vitamin D precursors are found in foods such as oily fish and eggs (Pai and Shaw 2011). In samples with juvenile remains, rickets is one of the most identifiable diseases. One of the earliest potential cases of rickets within archaeology was remains from a mid-Holocene assemblage in Southern Africa, radiocarbon dated to 4820 ± 90 BP (TO-9531), and believed to be from a child aged between 3.5 and 5 months old (Pfeiffer and

Crowder 2004). Changes in bone growth or delayed growth may be an indicator of nutritional stress. If an individual has delayed puberty until this stress is over then they may not fully correspond with modern footprint growth data, though it should be remembered that modern humans are just as likely to experience nutritional stress as hunter-gatherers. Vitamin D deficiency rickets is still a disease affecting children in the United Kingdom (Mughal 2012). The footprints of a child with rickets would not express their true stature or gait, as the weight bearing bones would be curved. Forensic podiatry is also a concern when evaluating a footprint, as there are a variety of issues related to the foot that may lead to a footprint with an unnatural appearance.

Past populations may have had different biomechanics, have varying statures or walked with a different gait to modern humans (Masao 2016). Levels of physical activity may also have influenced the shape and size of the foot, as well as if the individual was shod habitually. It has been reported that being habitually shod can change the structure and function of the foot, as well as the gait of an individual; walking barefoot results in a reduced stride length as opposed to shod individuals (Franklin *et al*. 2015). Initial vertical impact force between the foot and the surface walked upon is also reduced, and an even distribution of pressure is seen in unshod individuals. The habitual use of footwear has also been found to influence the width of a foot. Those who are habitably barefoot have wider feet (D'Août *et al*. 2009), if a prehistoric population was habitually unshod their feet would therefore be expected to be wider. Archaeological evidence suggests hominins may have started wearing protective footwear as early as 30,000 years ago (Trinkaus and Shang 2008), we therefore cannot assume that because an individual was unshod when they created a footprint that they were continuously unshod, they may in fact have just removed their footwear.

In terms of the influence of daily activity on the body, specifically the foot, the use of pedometers has broadened the understanding of the average daily activity levels of a population. Americans were found to walk an average of 5117 steps per day, Australians averaged 9695 steps per day, the Swiss averaged 9650 steps per day and the Japanese averaged 7168 steps per day (Bassett *et al.* 2010). In contrast, pedometers were attached to members of the Hazda population, who were found to undertake about 135 minutes of moderate to vigorous physical activity a day (Pontzer *et al* 2012), which is not as active as is perhaps expected of a hunter-gatherer group, though far more active than an average American. Contrarily, The Old Order Amish community undertake more exercise as a farming community than the Hazda hunter-gatherers. Amish men in a farming community took an average of 18,425 steps a day, with women doing about 14,196. Men performed an average of 7.5 hours a day of moderate to vigorous physical activity, and a further 1.5 hours a day of walking. Women took part in an average of 6 hours per day of moderate to vigorous activity and just under an hour of walking per day. Although clearly a very active community, 25% of men and 27% of women were overweight, with a body mass index between 25 and 30 (Bassett *et al*. 2004).

Considering the level of exercise among the Hazda people it is unlikely that the population were doing so much physical activity when unshod that their feet would have become much more muscular than a shod individual, as they were only engaging in 2.3 hours of moderate to vigorous physical activity a day, some of which may not have included the feet, e.g. chopping wood. Although they undertake more exercise than the average American, it is not vastly different to many communities worldwide; farming communities for instance are more active than the Hazda hunter-gatherers. This being the case, we can expect habitually unshod individuals to have wider feet, with a more even pressure distribution and a slightly shorter gait than shod individuals, however the foot may not be vastly more muscular in hunter-gatherers than other populations.

The differences in ethnicity and similar geographical populations has been explored within the forensic literature, though there are very few populations that can be an analogue to an ancient population. Campbell *et al*. (1936) investigated the relationship between the body and the footprints of 478 central Australian Aborigines. These footprints represented a population of people who were still partaking in a hunter-gatherer way of life which was perhaps like those who lived in the same area 20,000 years ago, thus making them an excellent footprint analogue. This dataset allowed the prehistoric footprints at Willandra Lakes to be analysed using an appropriate analogue (Webb *et al*. 2006). A smaller study was conducted by Dingwall *et al.* (2013) on 38 adult Daasanach individuals who lived near Lake Turkana, Kenya, where each volunteer was asked to walk and run along a 15m long trackway. Midway along the trackway a pit was dug, and sediment taken directly from the layer where prehistoric footprints at Illeret, Kenya, had been found. This provided a direct sedimentary analogue between the prehistoric footprints and modern Daasanach people, enabling the stature of the prehistoric people to be estimated (Dingwall *et al*. 2013).

Unfortunately, most of the world has a ‘modernised’ lifestyle and groups such as Aborigines are few and far between. Europe is lacking an indigenous hunter-gatherer population; therefore, footprints studied in these areas should be inclusive to provide a better range of results which may accurately represent a now non-existent population. In these situations, skeletal remains may assist in determining the average stature of a population, which can be applied to footprints to fully understand body metrics. Within Britain, skeletal remains from the Mesolithic period are scarce, and even within Europe Mesolithic skeletal remains are still relatively uncommon, though there are some bones that can be utilised for stature measurements (Schulting and Wysocki 2002; Schulting *et al*. 2010; Waldron 1989). These suggest that Mesolithic *H.sapiens* were similar in stature to humans of today, and so our footprints may be utilised to understand past populations, though we must be cautious and not over interpret the data.

5.2 Method

The purpose of this experiment was to establish if there is any relationship between a person's height, age, sex and footprint size when creating footprints on silty clay sediments. This relationship can then be applied to footprint-tracks found within archaeological contexts in similar sediments, such as Mesolithic footprint-tracks found at Goldcliff East, Severn Estuary.

Ethical approval for this experiment was granted by the University of Reading Ethics Committee in 2015 (Appendix 2.1), allowing children as young as three to take part in the experiment. The writer underwent a Disclosure and Barring Services check to allow them to work with children (Appendix 2.2).

177 male and female participants volunteered for this experiment, aged between 3 to 72 years. Most volunteers were White European (94%), though there was also Filipino (0.5%), Filipino White American (0.5%), Black British (2%), and Indian British (3%). White European were dominant by coincidence, due to the locations in which the study was performed. The ways in which ethnicity effects the size and shape of a footprint was not explored within this experiment as it was not considered to be relevant.

Of the 177 people who volunteered to take part in this study, 89 adults aged above 16 years old were involved. Of the 89 adults, 30 were male aged between 19 and 71, 59 were female aged 17 to 70. A total of 88 people aged between three and 16 years were studied for estimations of stature utilising footprint data. Of these 46 were female and 42 were male, although two males and one female withdrew from the study before any data except age and sex could be established. This sample size is relatively small; however it is large enough to allow general trends to be observed. Children aged between three to six years were one of the main focuses of this study, as there have been very few studies regarding this age group before (Anderson *et al*. 1956; Scales 2006). Of all the children, 19 were three years of age, 15 were four, seven were five, and nine were six years old. A further 38 volunteers were aged between seven and 16 years old.

Children younger than three were not considered, as before this age a child is still a 'toddler' and has a gait that does not resemble that of an adult. They tend to walk on their toes and have a gait that is broad and short, their legs also are more rotated than an adult (Anderson *et al*. 1956). Due to these factors the relationship between their footprint length and height would not be expressed in the same way as children above this age.

Volunteers were a mixture of students and staff, as well as their relatives, from the University of Reading (19%), and children and child carers from childminding groups and parent and toddler groups from Reading and the surrounding areas (62%). A final group was a large childminding group from Waterlooville, Hampshire (19%).

Only those with good foot health were involved in this study. Volunteers suffering from infections such as Athletes foot were not asked to take part in the footprint experiment, though people with recent foot breaks, a child suffering with *Plantar Fasciitis*, several women suffering with *hallux valgus*, a child with a missing toe and a seven months' pregnant woman were included within this study.

Within forensics, footprints are often recorded using ink and measurements recorded from specific landmarks (Kanchan *et al*. 2012; Krishan 2008a,b; Moorthy *et al*. 2014; Robbins 1985). A further recording technique utilising geometric morphometrics has been established as creating accurate reliable results with landmarks. This technique uses a laser foot scanner (Domjanic *et al.* 2013), however this method is not appropriate when attempting to understand the formation of footprints made within silty clay sediments, such as prehistoric footprints found on intertidal zones. Sediment is malleable and is often lacking in clear landmarks, unlike that of a static or two-dimensional ink footprint or those made on firmer sediments. This study utilised sediments taken directly from banded clay silt laminations near areas where Mesolithic footprint-tracks have been found. These laminations were obtained from an area where it was unlikely that prehistoric footprints would survive, due to the high levels of erosion and churned up sediments. In a similar approach to Dingwall *et al*. (2013), volunteers walked barefoot on these sediments. An aluminium tray, 2m in length and 1m in width, was made for this experiment (Figure 5.1). To enable footprints from a variety of people to be recorded this tray was made this size so that it was easily portable.

The tray was placed within a shallow depression with the same dimensions as the tray, providing a tight fit and preventing the tray from moving. The edges of the tray were level with the rest of the ground surface, removing the need for a step to enter the footprint tray, which would have altered gait. Estuarine sediment was added to the footprint area, this sediment was compressed as much as possible using a plastic plastering trowel, so that the whole of the tray was evenly filled by the sediment. After recording, the sediment had to be compressed and spread across the tray. Constantly spreading and compressing the sediment prevented footprints remaining preserved under the surface of the clay, which would alter the footprint data.

Figure 5.1 Footprint tray filled with estuarine silty clay

Each volunteer was assigned a number to retain anonymity. If over the age of 16 the volunteer was required to sign a consent form for their involvement, as well as read an information sheet which described the experiment (Appendix 2.3; 2.4). The parents and guardians of children between the ages of 3 and 15 signed the consent form on behalf of their children, whilst the project was explained to the children and they gave their verbal consent. They were informed that they could stop their involvement at any time.

The heights, in centimetres, and the weights, in kilograms, were recorded for every volunteer. They were then asked to walk normally through the sediment in the tray. Each was required to set their gait by starting at least four meters away from the footprint tray. As they walked the writer asked them questions such as their age, to stop them thinking about the way that they were walking.

Due to the unpredictability of working with very young children the methodology had to be flexible, simple and quick to perform. Once out of the footprint trap, the footprints were photographed and measured (Figure 5.2). Multi image photogrammetry was attempted when time allowed.

Figure 5.2

a) Female adult walking, *b)* male adult walking, *c)* male adult from *b* running, *d)* 3 year old male walking, *e)* 4 year old female walking

Measurements of length were taken from the end of the hallux to the most posterior part of the heel (pterion), passing through the medial longitudinal arch (Chapter 4, Figure 4.5). Width of the footprint was measured from the widest point, at the ball of the foot.

The stride and pace of an individual's footprint trail were also recorded to attempt to understand gait (Chapter 4, Figure 4.6). Pace was recorded between the top of the hallux of each footprint, e.g. left hallux to right hallux to left hallux. The stride was recorded from the end of the hallux of the left foot to the following left hallux, the same was repeated for the right foot.

The footprint measurements were recorded by the author, who then measured a second time to ensure a correct measurement. This eliminated incorrect measurements, where multiple individuals may have been measuring slightly different points of the foot, leading to discrepancies within the data.

The results were then analysed in Microsoft Excel and in Statistical Package for the Social Sciences software (SPSS), where linear regression equations were established. The results of this data will be presented below to establish whether footprints made in a clayey silt sediment, rather than ink tracing, can provide any evidence of the relationship between a person's footprint and their age, sex, height and weight.

5.3 Results

A key aim of this study was to establish if it was possible to identify footprints that have been made by individuals of different sexes. Table 5.1 shows the ranges of footprint sizes for males and females, both adult and children, as well as the mean value and standard deviation of population. Figure 5.3 shows a box plot for graphical representation of the ranges within the data of Table 5.1. The box plot demonstrates that within this dataset males were on average taller than females. There were two obvious exceptions to this, two male individuals who both had a stature of 155.4cm, volunteer 108 and volunteer 137. These individuals were both White British males, volunteer 108 was 47 years old, 61.4kg and with UK size 10 feet, volunteer 137 was 43, 109kg and with UK size 8 feet. These individuals were both short men, being 20cm shorter than the average British male height of 175.3cm (Office for National Statistics 2010) even in comparison to the women within this study, the shortest woman being only 4cm shorter, and 6cm shorter than the average height of British women (Office for National Statistics 2010). In both cases the foot sizes of the shortest males were still larger than the tallest woman's shoe size, wearing a UK size 7.

	Adult Male	**Adult Female**	**Male Child**	**Female Child**
Number of individuals	30	59	41	45
Mean	180.1	163.5	124.3	123.2
SD	9.4	7.3	21.3	23.6
Maximum length	196	185	175.5	173.5
Minimum length	155.4	151	92	83

Table 5.1 The heights of all participants including the mean and standard deviation

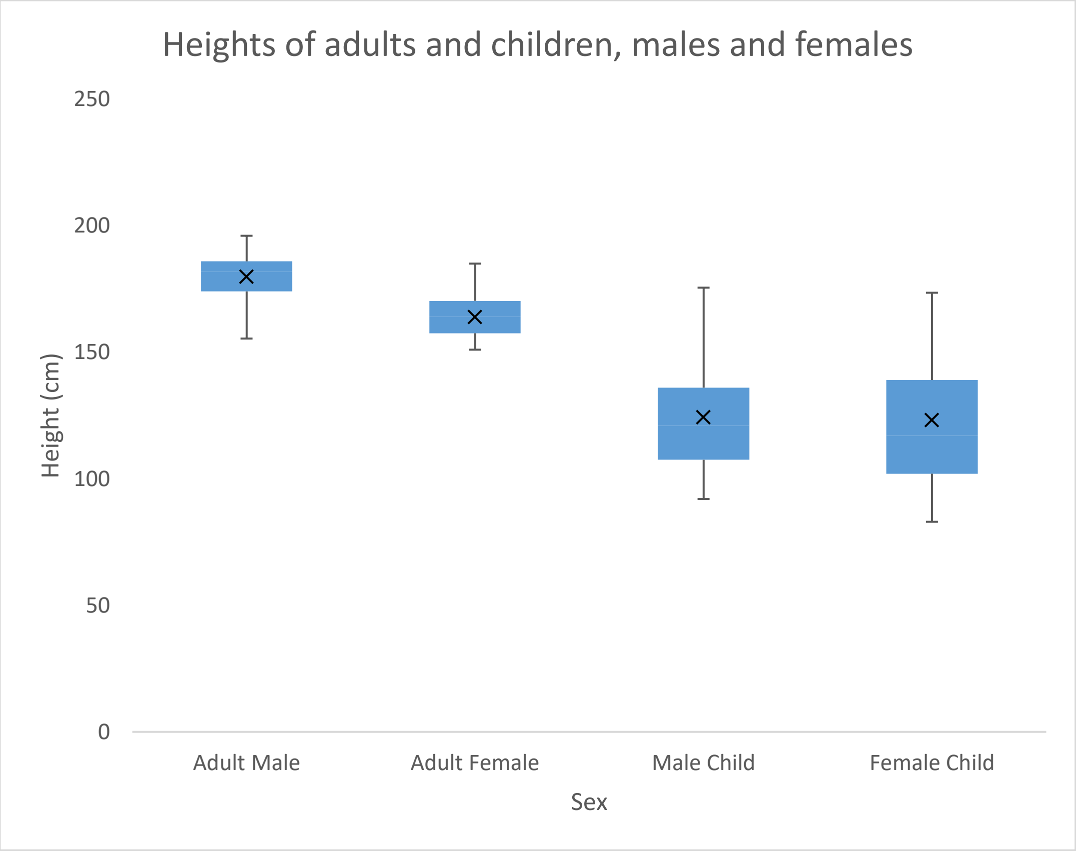


Figure 5.3 Box and whisker graph showing a visual representation of Table 5.1, the whiskers show the first quartile and third quartile, the X shows the mean value of the data

Due to the large age range of the children, and thus the resulting differences in growth rates, this box plot (Figure 5.3) shows the range in heights that children will exhibit. It is more appropriate to look for patterns in ages where growth patterns are similar, e.g. prepubescent and pubescent, rather than attempting to group all children together. An adolescent may be similar in height to an adult, a three-year-old will not be.

5.3.1 Relationship between heights and weights

Homo sapiens are less sexually dimorphic than other members of the ape family (Frayer and Wolpoff 1985). Generally, males are taller and heavier than females, though there is often a sizable overlap between males and females, as demonstrated in Figure 5.4. The shortest female was Volunteer 158, a White English individual who was 151cm tall and 40 years old. The tallest female, Volunteer 2, was also White English and was 19 years old and 185 cm tall. Volunteer 137 was the shortest male in this experiment, a 47-year-old White English male who was 155.4cm tall. Volunteer 6 was the tallest male, 20 years old, White English and measuring 196cm tall. The range in height for male and female is therefore problematic. Weight also seems to have no clear pattern in relation to height, though women are heavier for their height than men. 37 (63%) of the adult females in this experiment had given birth in the past, this may have affected the weights of these individuals due to the stresses on the body caused by pregnancy. British women are advised to gain an extra 15-25% of their current body weight during pregnancy, women from the Sub-Saharan African Maasai tribe gain around 11% extra weight during pregnancy (Brady *et al*. 2008). When walking or resting the metabolic cost is the same among Hazda hunter-gatherers and western groups, meaning they will burn calories at the same rate, it is therefore the lifestyle (such as diet and exercise) of the individual which will cause the postpartum weight loss (Pontzer *et al*. 2012). Breastfeeding may also influence postpartum weight loss. A study by Rooney and Schauberger (2002) observed the weight of 540 women throughout pregnancy and six months postpartum and found that women who had breastfed exclusively for at least 3 months had a lower body mass index than those who did not breastfeed. The women who breastfed also had a lower body mass index when re-examined 10 years later, which suggests that the initial postpartum weight loss is important for overall health and changes to the body. In a society where females breastfeed for a limited time, or where babies are bottle fed, the mothers may therefore struggle with losing the weight gained throughout pregnancy. In Britain, for instance, only 17% of mothers exclusively breastfeed for three months, by six months postpartum only 1% of mothers exclusively breastfeed (NHS Digital 2010), in contrast the !Kung of the Kalahari desert tribe breastfeed their babies until four or even five years old (Konner 1977), meaning the tribal women are more likely to have lower body mass indexes after pregnancy.

The population mean height of a female in this experiment was 164.4cm and population mean weight was 69.9kg. Female weights ranged between 47.4 kg and 107.3kg. The population mean height for males in this experiment was 179.8cm, and the population mean weight 83.7kg, with weights ranging between 61.4 kg and 126.6kg (Figure 5.4).

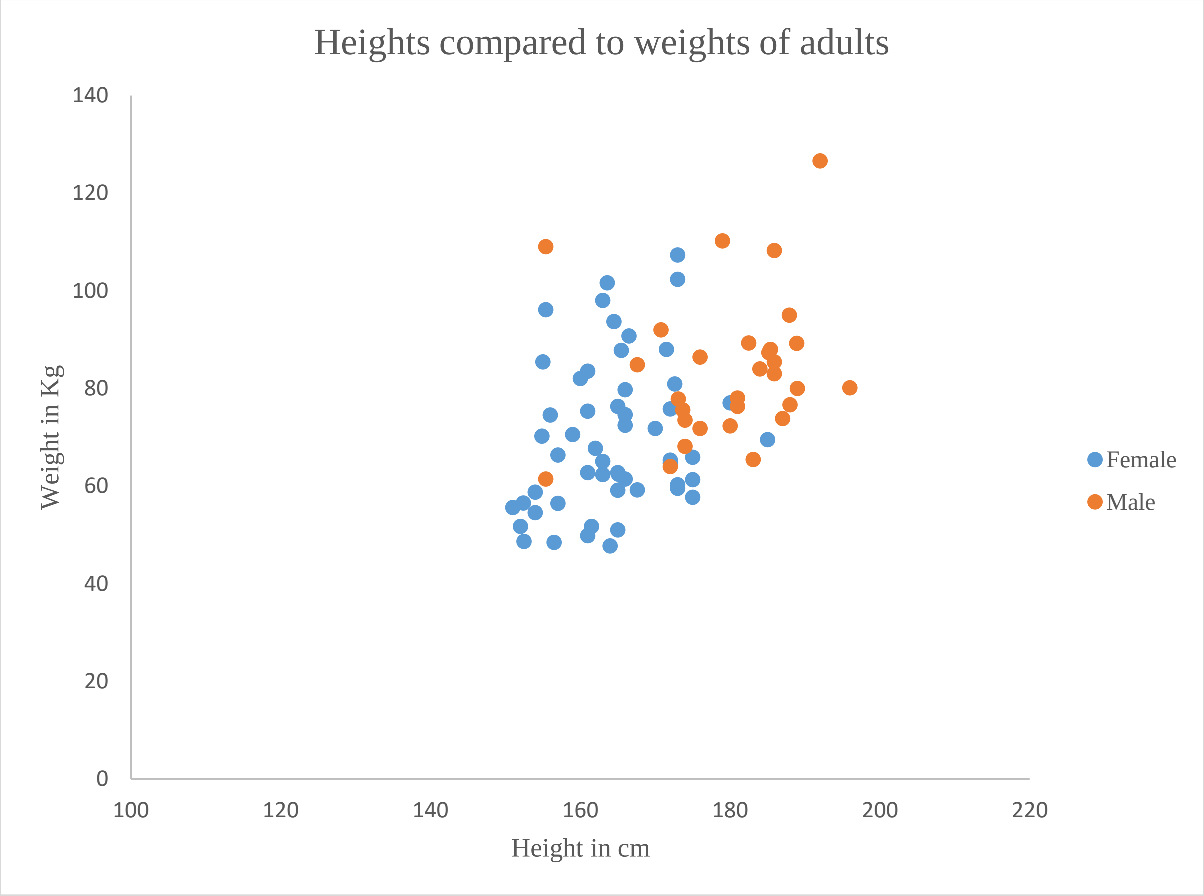


Figure 5.4 Heights and weights of adult males and females

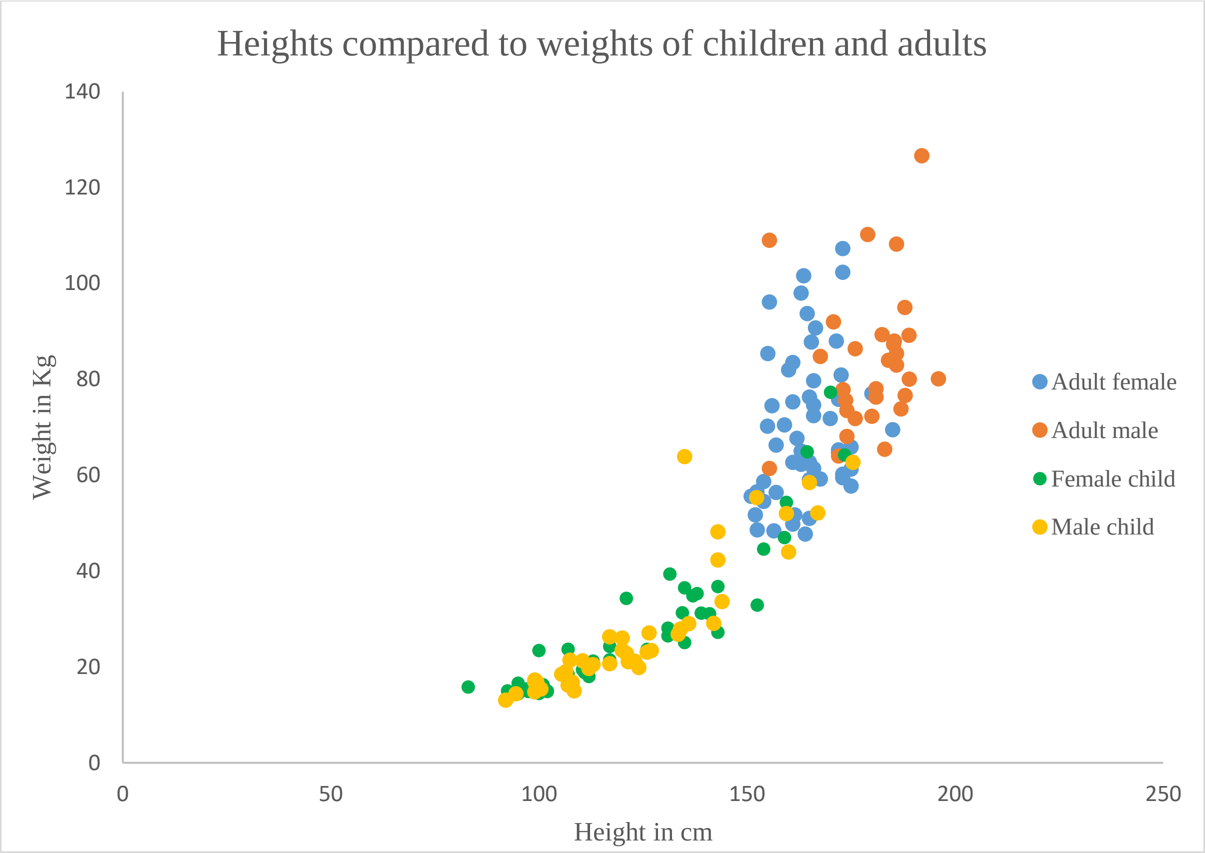


Figure 5.5 Heights and weights of every individual in the experiment from aged 3 to 71 years old

Figure 5.5 shows how variable height can be compared to weight. With young children there is a positive correlation between height and weight; during adolescence and adulthood there is a large increase in weight and that positive correlation then becomes not as evident.

Within juveniles the heights and weights of an individual will generally correspond if they are partaking in a healthy diet and sufficient exercise, with weight increasing as height increases. Comparing the volunteer children’s heights and weights against one another (Figure 5.6), there is a positive correlation that demonstrates a general trend towards an increase in weight when height is increased. The data displays a concentration of similar results in shorter children and is more sporadic in taller children. It is likely that this correlation is demonstrated by the age of the child, which will be explored throughout the next part of this chapter.

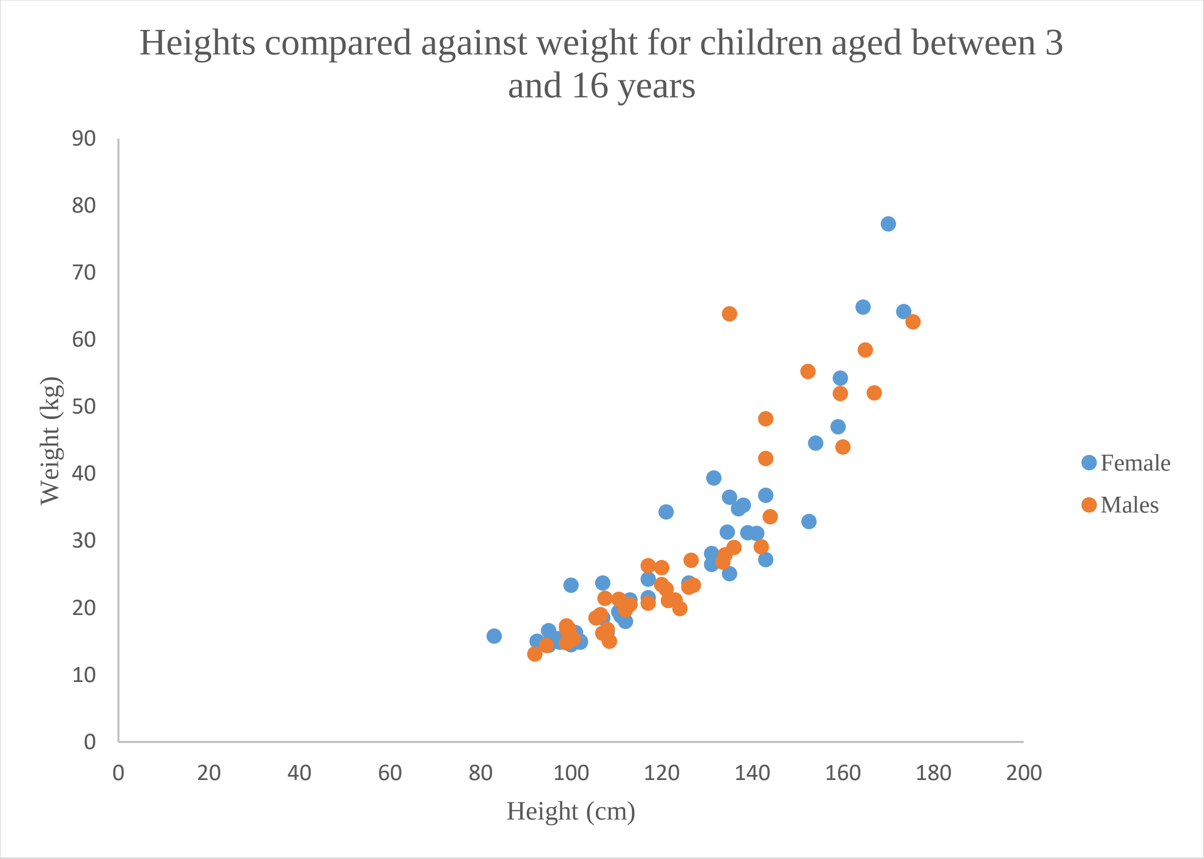


Figure 5.6 Heights compared to weights of male and female children aged between 3 to 16 years. Female R^2= 0.8164, male R^2 = 0.7902, indicating that females have a slightly more positive relationship between height and weight

The relationship between the height and the weight of a three-year-old is displayed in Figure 5.7. The smallest of the children, volunteer 17, was 83cm tall and 15.8kg and was the youngest of the children in this study, having just turned three the same week in which she partook in the experiment. Volunteer 52 was the tallest, being 112cm, though a similar weight to children up to 10cm shorter than her. Volunteer 50 was a similar height to other children her age, however she was 5.4kg heavier than volunteer 52. The data indicates that three-year-old children can differ in height by 20cm. In this study the children's birth dates were recorded; volunteer 17 was almost a year younger than volunteer 50, which is clearly reflected within the dataset.

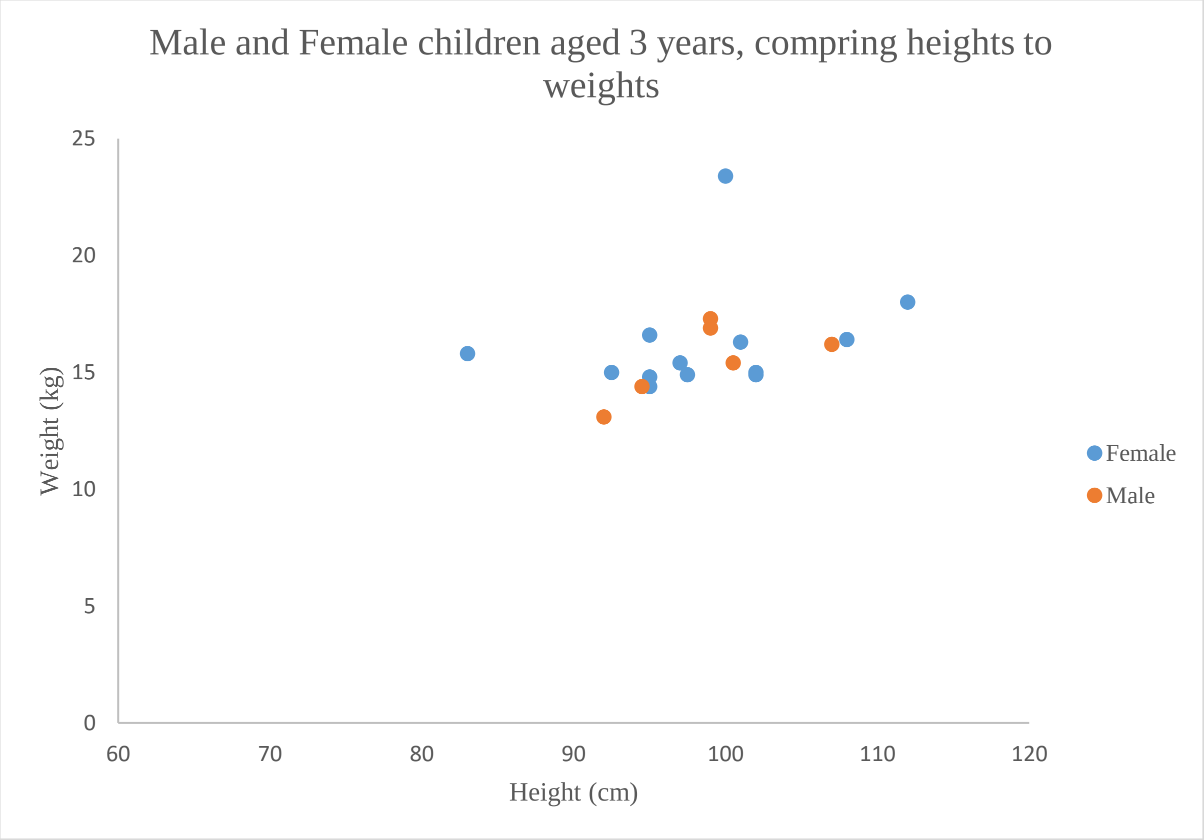


Figure 5.7 Heights compared to weights of 3-year-old males and females

Children aged four have a similar correlation between height and weight as three-year-olds (Figure 5.8). Again, there is little difference between the height and weight of males and females of this age, although there are two groupings of results for both sexes. The smaller clustering, children weighing between 14.5kg and 16.9kg, and between 99 and 101cm tall, could easily fall into the measurements of a three-year-old. As illustrated in Figure 5.9, there is clearly cross-over between age, height and weight, though there is a positive relationship between height and weight when aged three and four.

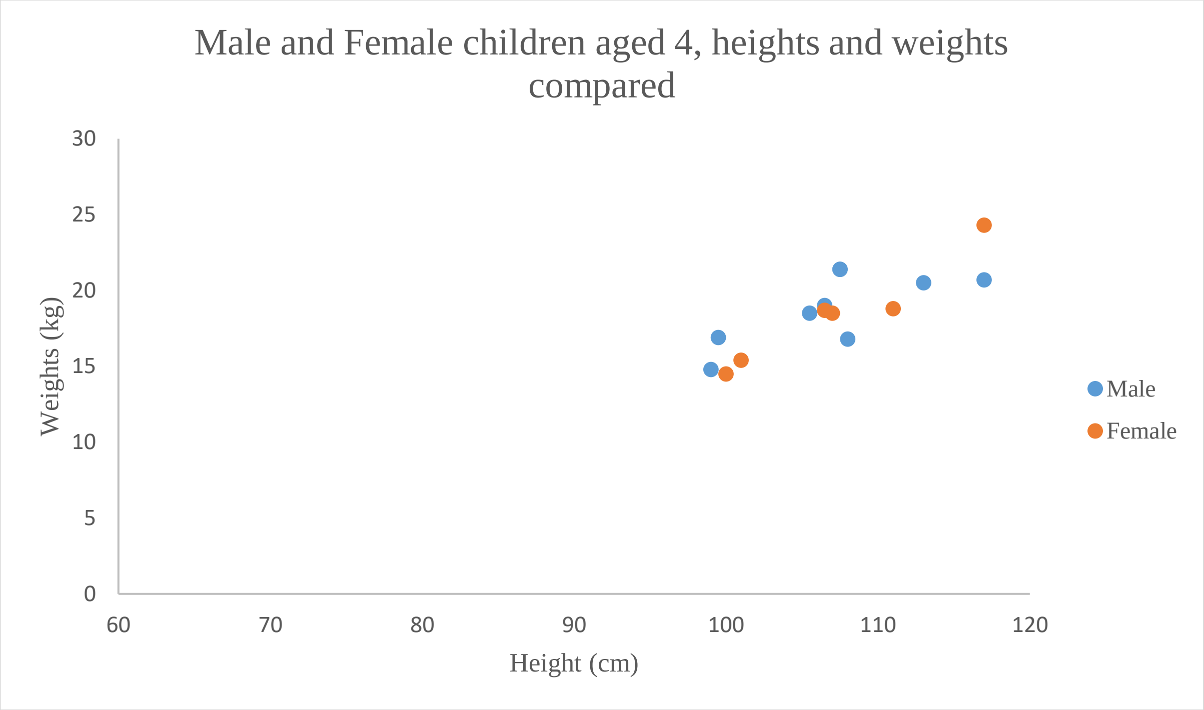


Figure 5.8 Heights compared to weights of male and female 4-year-olds

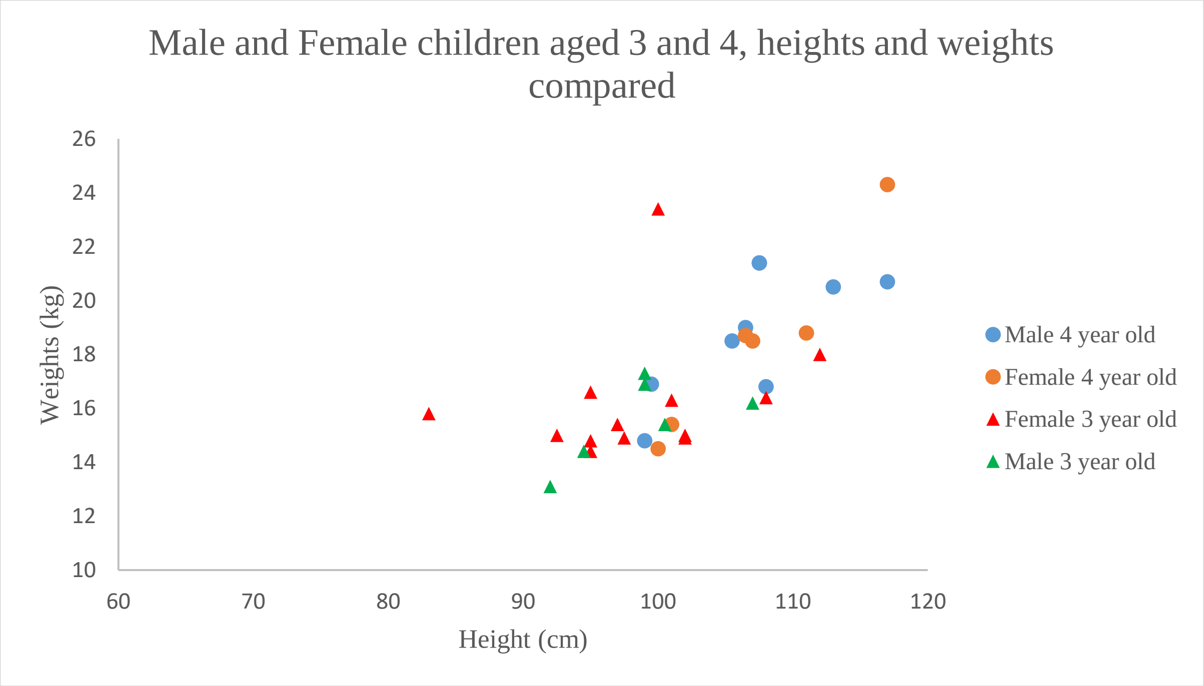


Figure 5.9 Heights compared to weights of children aged between 3 and 4, males and females

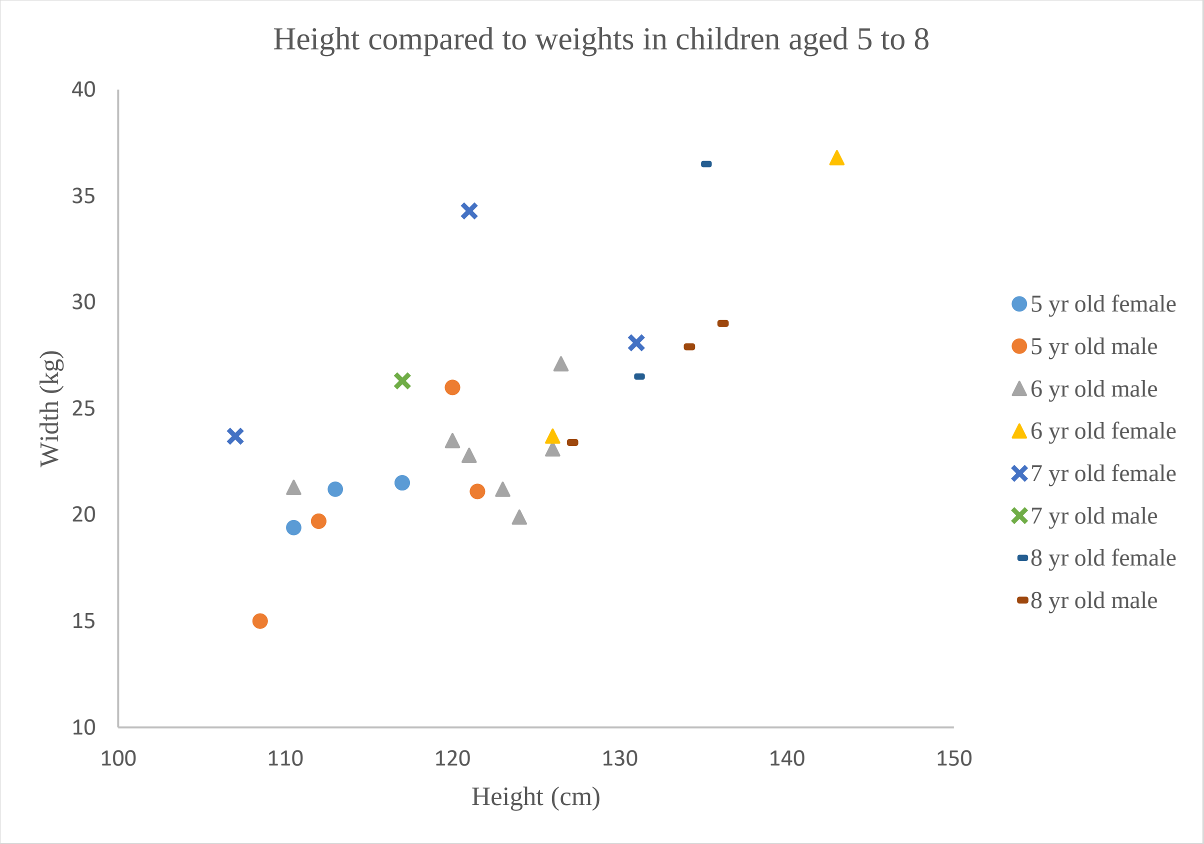


Figure 5.10 Heights and weights of children 5 to 8 years old

The relationship between height and age becomes less pronounced upon reaching six-years-old (Figure 5.10). The tallest, heaviest child was a six-year-old female, Volunteer 90, this individual was 7cm taller than an eight-year-old male. Volunteer 90 may be taller than average; she has a foot size of adult size two, similar to shoe sizes worn by children aged eight and nine. Another six-year-old, Volunteer 62, was 32.5 cm shorter than another female the same age and had a shoe size of children's size 11. The variation between these children may be an indication that the height and weight in children of a similar age is not relatable.

Comparing the height and weight of children aged between nine and 15 indicates that these factors are relatable (Figure 5.11). Females aged nine and ten cluster between 131.5cm and 142 cm, whereas nine and ten-year-old males are slightly taller ranging between 142cm and 152.3cm, though an 11-year-old male and female in this experiment were both of a similar size to a nine-year-old female. After the age of nine, once puberty and genetics start to influence an individuals' height and weight, there does not appear to be a relationship between age and height. This is particularity obvious with Volunteer 129, a female who was a month away from being 12 years old and one of the tallest children in this experiment. This child's parents were also involved in this study, the mother Volunteer 130, and father Volunteer 131. Volunteer 130 was 173cm tall, Volunteer 131 was 192cm tall, indicating that the child, Volunteer 129, was predisposed to be tall through her genetics. This child had adult size seven feet, her height, 170.1cm, weight, 77.3kg, and foot size could all easily result in her mistaken identification as a full-grown adult within the footprint record. Figure 5.11 demonstrates that in the early teenage years it is females who are generally taller at a younger age.

Some children within Figure 5.11 have medical issues which resulted in slight anomalies in the data. Volunteer 56, a 15-year-old male, experienced stunted growth due to steroid use as a child to treat asthma, this resulted in him only being 135cm tall. Volunteer 56 had a brother, Volunteer 54, a nine-year-old male who had a height of 143cm and a sister, Volunteer 57, an 11-year-old, with a height of 164.5 cm. Both did not suffer from stunted growth, and were already taller than their elder brother. In this situation volunteer 54 appears to be an incredibly short individual, however his true stature, if he had not experienced a medical issue, is likely to be taller judging by the heights of his siblings and his shoe size, a UK adult size 6.5.

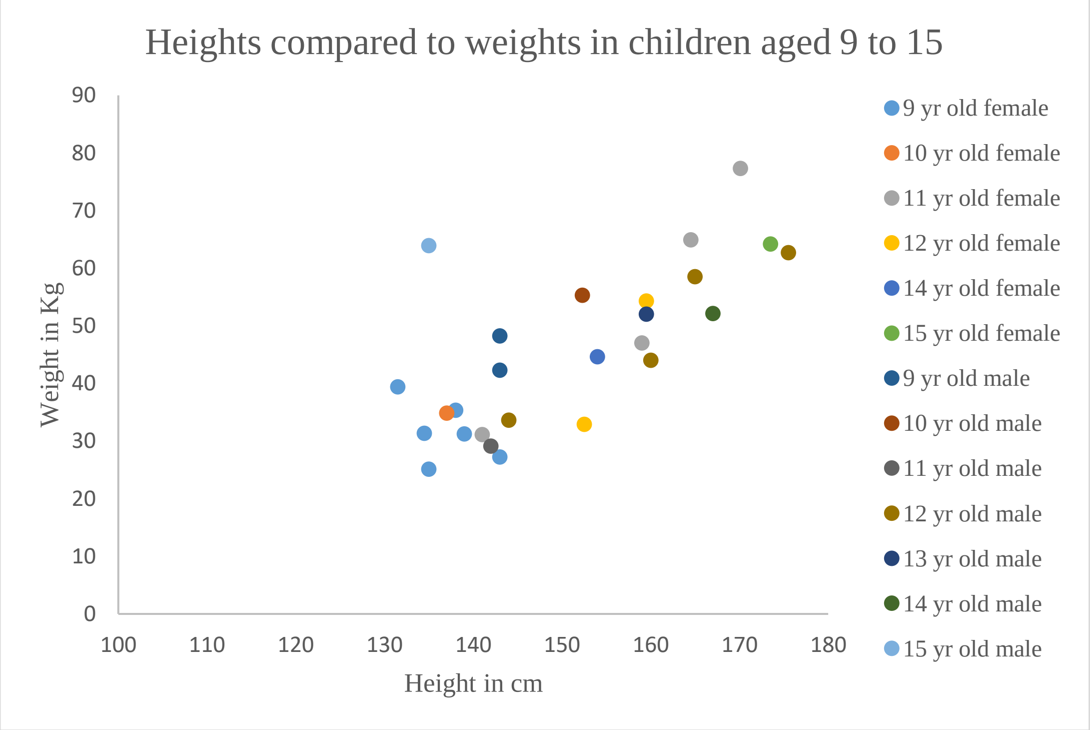


Figure 5.11 Heights compared to weights in male and female children aged between 9 and 15 years old

Although children under five years old do seem to exhibit a correlation between age, height and weight, as children start to mature their heights and weights appear to have a relationship to one another, their ages do not. Other factors such as nutrition, genetics and puberty will have a greater effect on the growth of a child than age. It is unlikely that an exact age of a child could be suggested from height and weight, however an age range could be provided to demonstrate the likely ages a child of a certain height and weight may fall into.

5.3.2 Relationship between age, sex and footprint length

There is forensic literature that suggests that identifying the age, sex, weight and even ethnicity of an individual can be determined using only a footprint (Robbins 1985, 1986), however this experimental study indicates that footprints are incredibly variable between individuals. The shoe sizes of individuals within this study were the first indication of the inaccuracy of relying on footprint sizes to pinpoint a specific age.

Age of male (years)	UK Shoe size
3	child 9
4	child 8 to child 10.5
5	child 9 to child 13
6	child 11 to adult 1.5
7	adult 1
8	child 13 to adult 4
9	adult 2 to adult 5
10	adult 2 to adult 6
11	adult 2
12	adult 4 to adult 9
13	-
14	adult 6.5
15	-
16	-
17+	adult 7.5 to adult 12.5

Table 5.2 Ages and UK shoe sizes of males in the experiment, shoe sizes were determined from asking the volunteers their shoe size

Age of female (years)	**UK Shoe size**
3	child 7 to child 9
4	child 8 to child 10.5
5	child 10 to child 11
6	Adult 1 to 2
7	child 12 to adult 1
8	adult 2
9	adult 2 to 3.5
10	adult 2
11	adult 4 to adult 7
12	adult 3.5 to adult 5
13	adult 7
14	**-**
15	adult 6.5
16	**-**
17+	adult 3 to 7

Table 5.3 Ages and UK shoe size of females in the experiment, shoe sizes were determined from asking the volunteers their shoe sizes

Male children aged as young as eight and females aged nine may have a shoe size of adult size three and over, which falls into full grown adult footprint sizes (Table 5.2 and 5.3). Males as young as 12-years-old can have shoe sizes as large as adult size nine, which is larger than all the female shoe sizes within this study and so would be assumed to have been made by a full-grown male. Young adolescent males often have shoe sizes that are similar to adult females. This can cause issues in footprint identification, in our understanding of whether an individual is a male that is still growing, or a full-grown female. Females aged eight and males aged nine can also have shoe sizes that can be as small as those of a five-year-old, indicating how variable the growth of children the same age can be. Relying only upon shoe size is therefore not a hugely accurate method in understanding the relationship between age, sex and footprint length. Shoe sizing can vary depending on the shop the shoes were purchased from and some individuals may be wearing the incorrect shoe size. A more accurate understanding on the relationship between an individual’s age, sex and footprint length can be achieved in recording the lengths of the footprints in a three-dimensional experiment, rather than static two-dimensional data achieved from recording shoe sizes.

	Adult Male left	**Adult Male right**	**Adult Female left**	**Adult Female right**
Number of footprints	53	58	112	115
Mean (cm)	27.55	27.16	24.46	24.4
SD (cm)	1.52	1.45	1.58	1.52
Maximum length (cm)	32.5	31	29.8	30
Minimum length (cm)	24.5	24	20	21

Table 5.4 Footprint lengths of males and female adults, including the mean and standard deviation

Table 5.4 shows that the male left feet within this study range from 24.5cm to 32.5cm, with a mean value of 27.55cm and a standard deviation value of 1.52. The standard deviation indicates that 66% (one standard deviation) of the footprints lie within a +/-1.52cm of the mean value of 27.55cm. This suggests that although the overall spread of lengths is wide, two thirds of male left footprints were relatively clustered around the mean value, and 1/3 of footprints represents a wider spread.

Female left feet range from 20cm to 29.8cm in length, with a mean value of 24.46cm and a standard deviation of 1.58. The right foot length in males range from 24cm to 31cm with a mean value of 27.16cm and a standard deviation of 1.45. In females the foot length ranged between 21cm and 30cm, with a mean value of 24.40cm and a standard deviation of 1.52. The data in Table 5.4 is expressed in Figure 5.12 as a box and whisker diagram. When expressed in this manner the smaller size of the female footprints compared to the males can be visualised and the tight clustering of the footprint lengths around the mean, and the relatively small standard deviations can be seen.

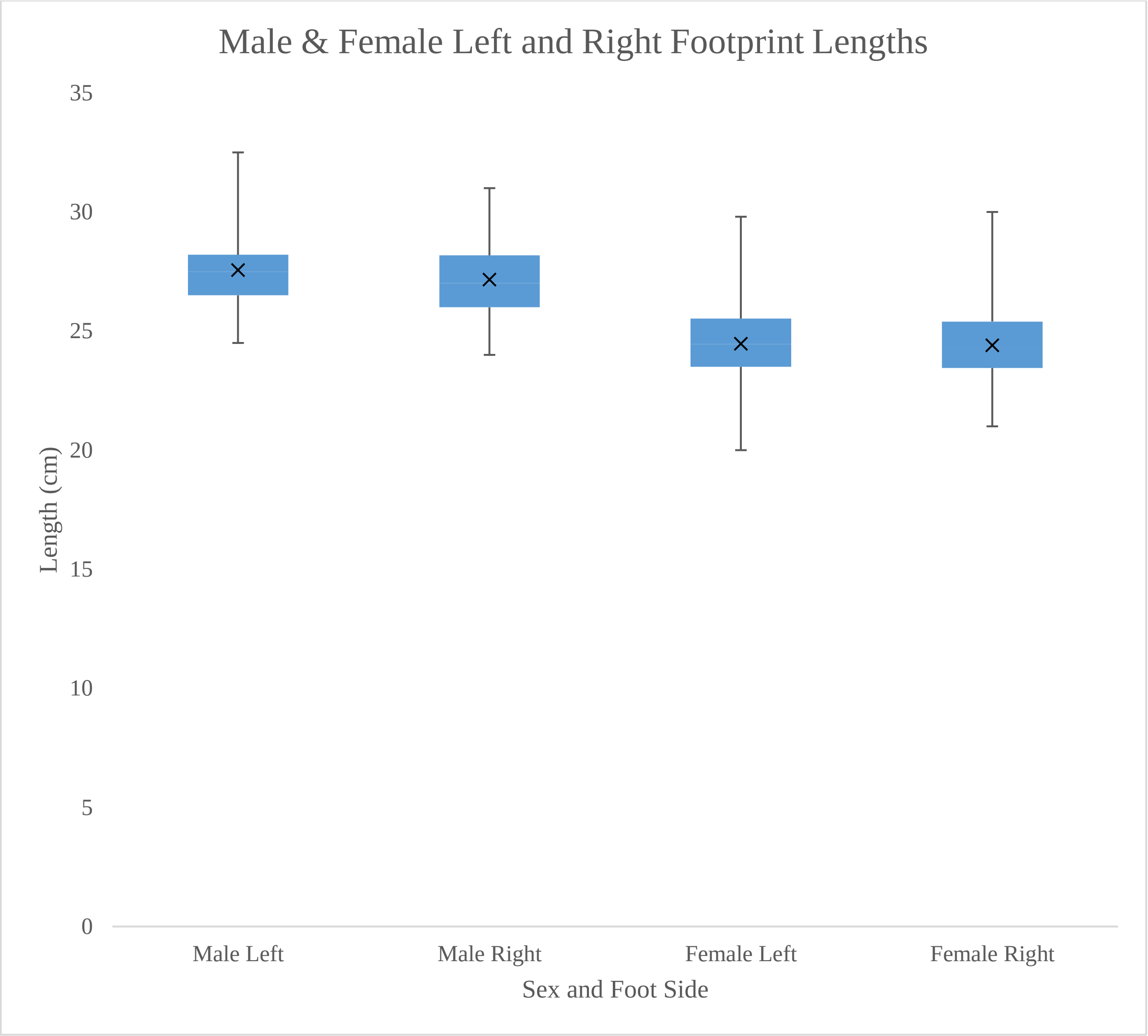


Figure 5.12 Representation of the data from Table 5.4, the whiskers show the first quartile and third quartile, the X shows the mean value of the data

Within adults there appears to be very little difference between the left and right foot sizes, contrary to previous literature (Agnihotri *et al*. 2007, Sen & Ghosh 2008, Fawzy & Kamal 2010). In both males and females the footprints from the left side are larger, however the difference in size is minimal. The average for male left foot size is 27.5cm, whereas the right is 27.1cm. In females the left foot was on average 24.46cm, the right was 24.40cm, indicating an insignificant difference between female footprints, and only a 4mm difference between the left and right footprint of males.

This approach demonstrates that, unless a footprint is very large, it will be difficult to determine whether it was created by a male or female, especially when children are also considered.

Children and adolescents can be similar in size to females, this can cause difficulties in sex identification.

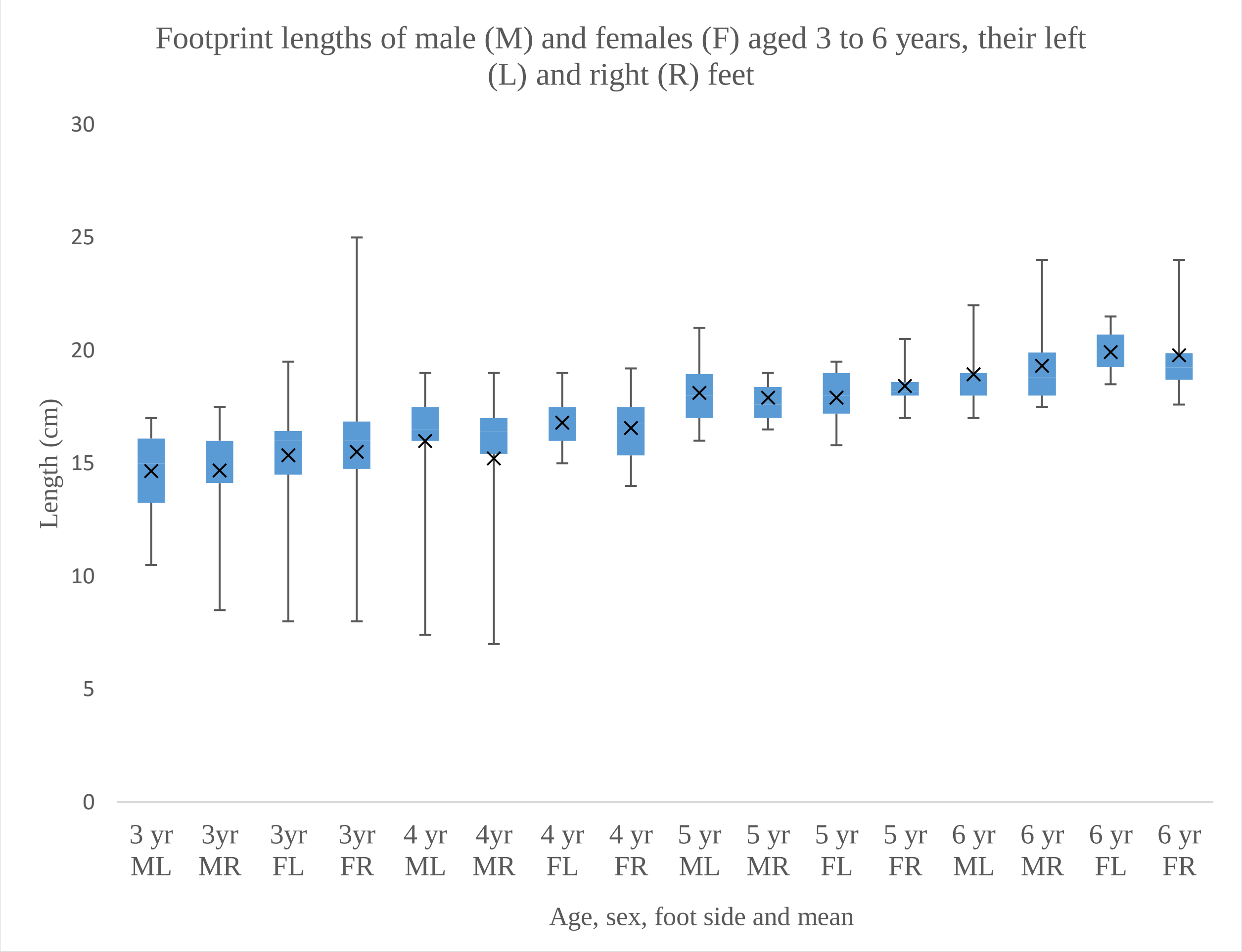


Figure 5.13 Age and sex of children aged 3 to 6 years old, plotted against footprint length. The whiskers show the first quartile and third quartile of the results, the X shows the mean value of the data

Figure 5.13 represents the general footprint size trend of children aged three to six years old, as well as the mean for these. On a box and whisker chart it becomes clear that children aged three and four are more likely to fall under the mean of these footprint lengths. Once over the age of four children have a similar footprint size in their age range. The larger whisker in the female three-year-olds right foot was caused by a single individual, volunteer 50, who was 100cm tall and weighed 23.4kg. This child was over 5kg heavier than the other children of a similar age (Figure 5.9), and the rest of volunteer 50's footprints measured between 16.5 and 18.5cm. This larger footprint was caused by slippage; although this causes the data to become skewed it was included within this graph to demonstrate just how variable footprint data can be, and the effect that slippage may have upon an individual's footprint. The width of this child's footprint was 7.5cm, far smaller than adult footprint width, indicating that footprints made by children but caused by slippage may be identifiable if the width can also be observed.

Within the three to six-year-old children's footprint lengths there is no clear foot that is predominantly larger in size, unlike in adults where adult left footprints are marginally larger.

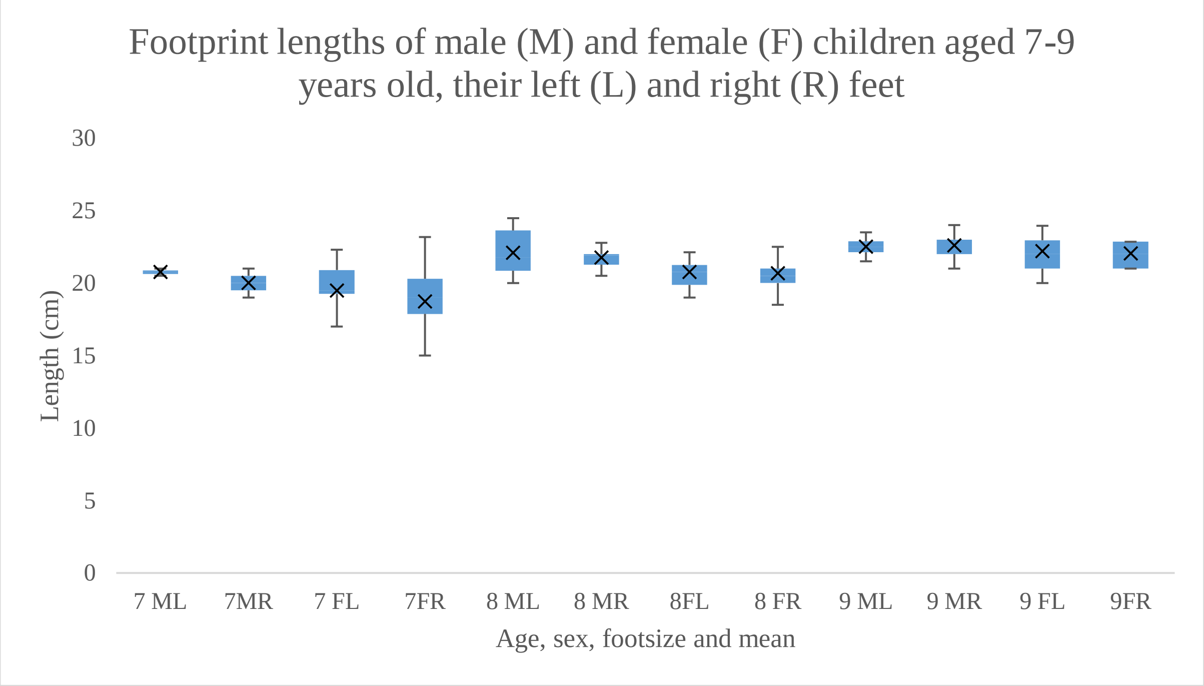


Figure 5.14 Age and sex of children aged 7 to 9, against footprint length, the whiskers show the first quartile and third quartile of the data, the X shows the mean value of the results

Figure 5.14 demonstrates that at seven years old males have an average footprint length of 20cm or more, whereas the whiskers on the seven-year-old female footprint lengths indicate that a seven-year-old can still create footprints that are small, at 15cm. Past the age of seven, both males and females have a mean footprint length of over 20cm. The data does not suggest a large difference between the size of the left and right footprints, though the mean of the left footprints in both sexes are all larger, except for a nine-year-old male where the mean of the right foot length was 0.1cm larger. The sizes of footprint lengths in children aged seven to nine have a general average size of 20cm or just slightly larger in length. As of the age of ten this trend can no longer be seen within the data (Figure 5.15).

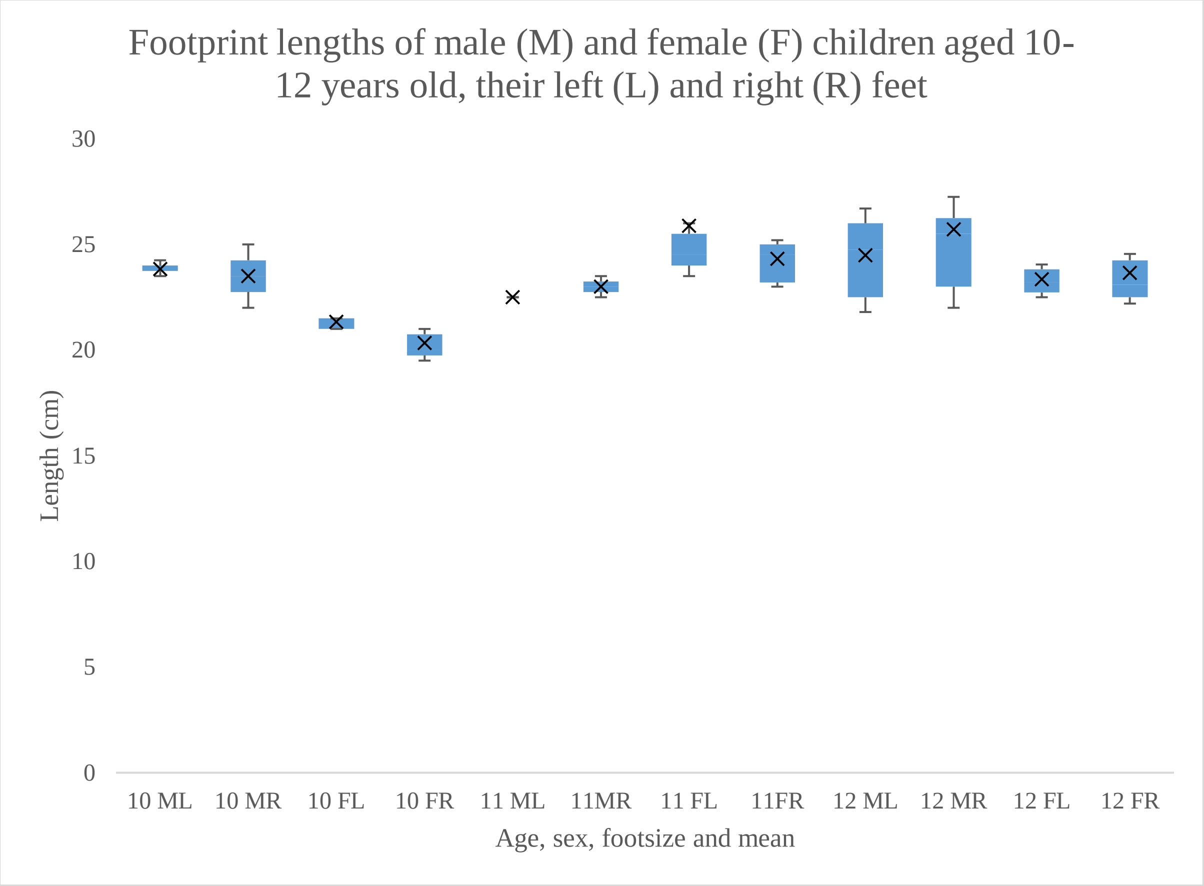


Figure 5.15 Age, sex and footprint side of children aged 10 to 12 years old, and footprint length, the whiskers show the first quartile and third quartile, the X shows the mean value of the data

Figure 5.16 indicates an increase in the average footprint length for both male and female children as of the age of ten. The smallest footprint was created by a ten-year-old female and was 19.5cm in length. This footprint was made by volunteer 169, who was 131cm in height and 28.1kg, falling within the weight and height positive correlation as seen in Figure 5.6, suggesting a relatively standard height and weight for her age. This child had relatively small footprints, at the largest 20.1cm in length. She wore a size one shoe which indicates that she had relatively small feet for her age and height. This data suggests that footprints over 20cm will have been made by an individual over the age of seven years, though there will be incidences where children have smaller than average feet for their age, making the age of ten and below a more accurate age estimation from footprint length. Above the age of 11 children begin to produce footprints larger than 25cm, these dimensions are comfortably within the lengths of many adult females. Again, there seems to be little evidence of a left or right footprint being predominately larger.

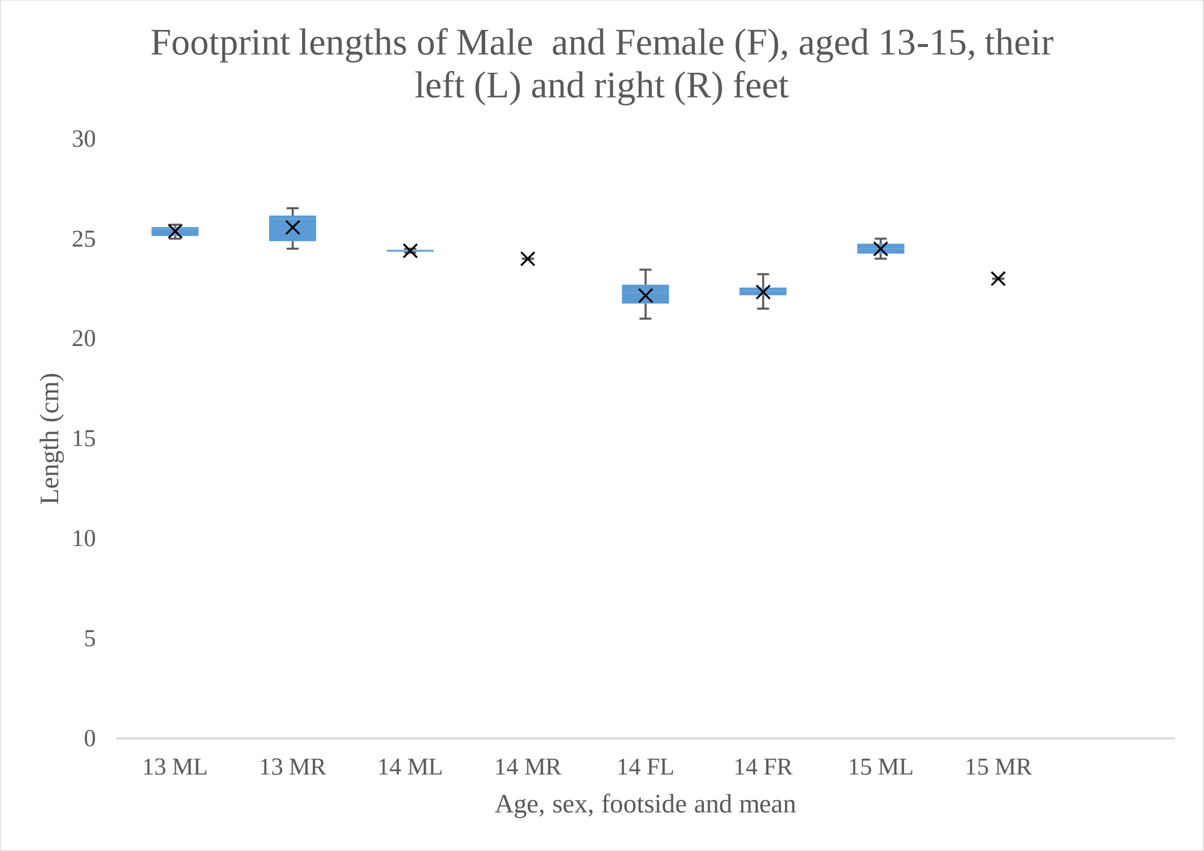


Figure 5.16 Age and sex of children from 13 to 15 years, against footprint length, the whiskers show the first quartile and third quartile, the X shows the mean value of the data

Figure 5.16 involved a small dataset, of only 28 footprints created by children aged 13 to 15 years old. At these ages puberty will have begun in all children (Kipke 1999), resulting in a strong genetic influence on the height and foot size of children. Volunteer 3, an adult female, made a footprint with a length of 20cm, though the other prints they made were 24cm in length. Volunteer 3 was 163cm in height and 65kg in weight, this is not particularly short for an adult female. This female also wore UK size six shoes, which is an above average shoe size in the UK, but her footprint lengths fell within the dimensions of children aged 13-15 years old.

This small dataset does not demonstrate a noticeable difference in size between the left and right feet. Male and female children also do not show any sexual dimorphism when young. Once puberty begins males do tend to have a slightly larger average foot size than females, these would fall within the dimensions of adult females unless very large, which demonstrates the difficulty in establishing the sex of an individual from a footprint. Females however seem to have larger footprints at a younger age, indicating that the earlier onset of puberty in females can again cause confusion between males and females.

5.3.3 Relationship between height and footprint size

The average height of males and females demonstrate that females are generally 16cm shorter than the mean height of a male (Table 5.5). Males have a mean footprint length of 27.5cm whereas females are 3cm smaller with a mean length of 24.5cm. The standard deviation of both left and right male footprints was 1.4, indicating a relatively tight clustering around the mean length. Female left footprints had a standard deviation of 1.5, their right footprint again had a standard deviation of 1.4.

	MALES	FEMALES	COMBINED
MEAN HEIGHT MEASURED (CM)	180.1	163.5	169.2
S.D.	9.4	7.3	11.3
LEFT FOOTPRINT LENGTH (MEAN)	27.6	24.5	25.6
S.D.	1.4	1.5	2.1
RIGHT FOOTPRINT LENGTH (MEAN)	27.4	24.5	25.5
S.D	1.4	1.4	1.9

Table 5.5 Mean heights and footprint lengths of males and females

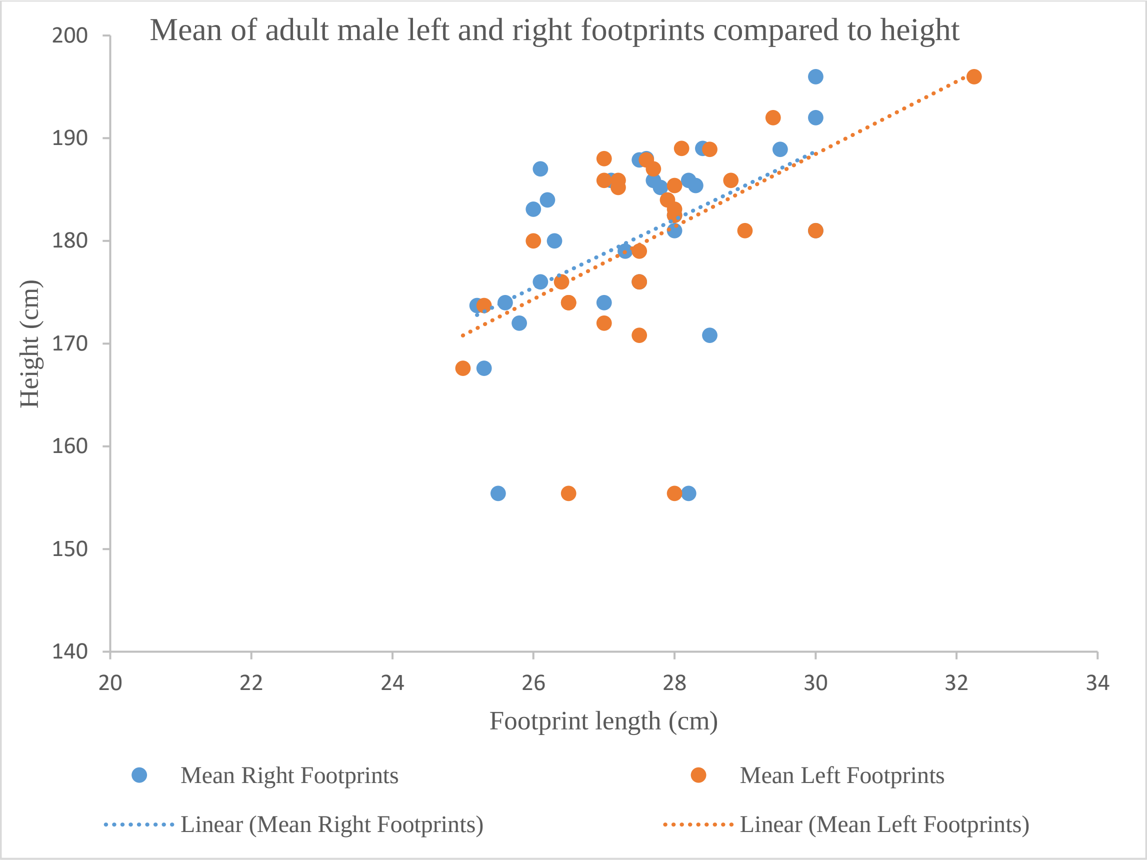


Figure 5.17 Height compared to footprint length of adult males

Figure 5.17 shows the relationship between adult male footprint lengths and height, utilising the results for both the left and right feet. The correlation coefficient of the male left foot was 0.52, the right was 0.49, these correlation strengths are both positive and indicate that there is a relationship between a male's height and footprint size. The linear trend line demonstrating the means of both left and right footprint sizes indicates that in this situation the footprint mean values were very similar, however there was a large amount of the data both above and below the mean results.

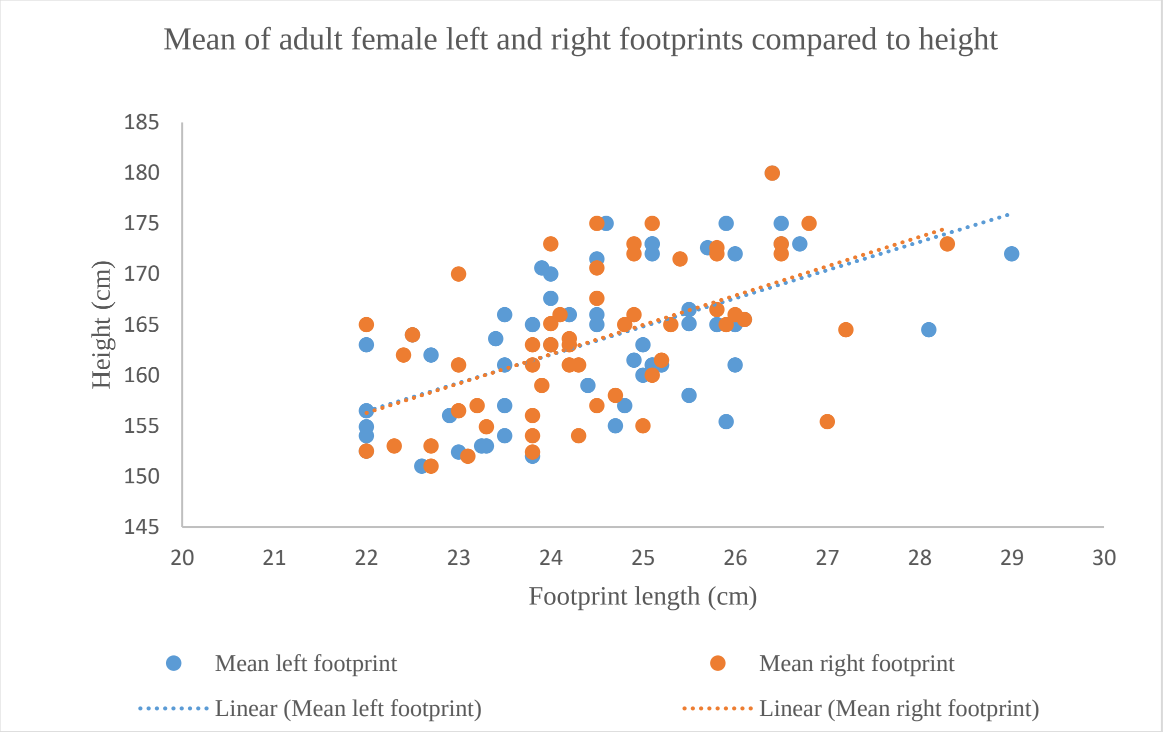


Figure 5.18 Height compared to footprint length of adult females

Figure 5.18 shows the left and right footprint lengths of females. The correlation coefficient of female left footprints was 0.58. The right foot correlation coefficient was 0.55. Again, these are correlation strengths that are positive and indicate a relationship between a females' height and footprint size. The mean of both the left and right footprint were similar, as demonstrated by the linear trend line. The similarity between the lefts and rights of full grown adult feet removes uncertainty concerning the effects that a predominately larger foot side would have on the data set.

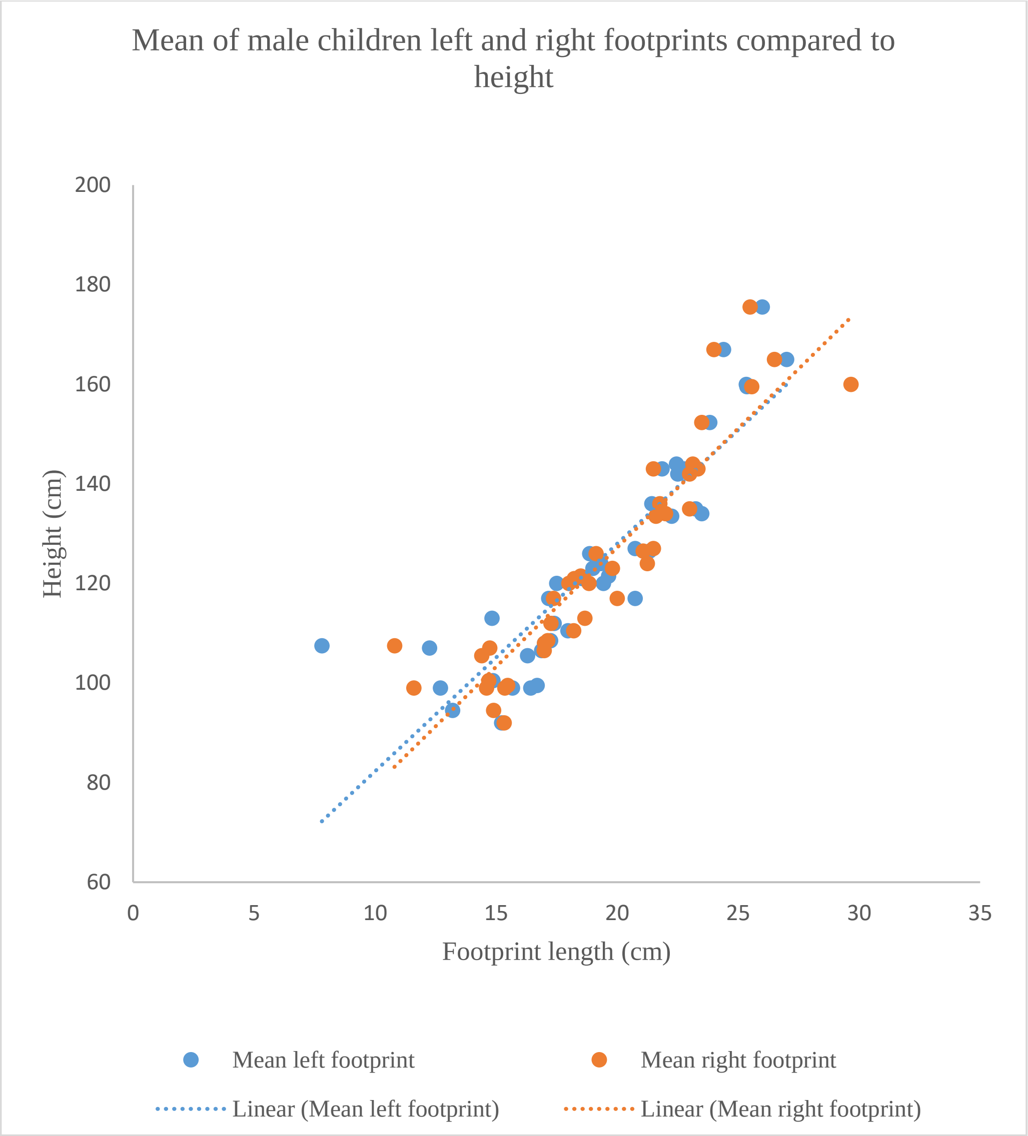


Figure 5.19 Height compared to footprint length of male children aged 3-15 years old

The correlation coefficient for the left footprints of male children was 0.88 (Figure 5.19), the right foot correlation coefficient was 0.91. The correlation coefficient for these footprints is strong, especially in the right foot. Again, young children with footprints under 25cm demonstrate a strong relationship between size of the footprint and height of the individual.

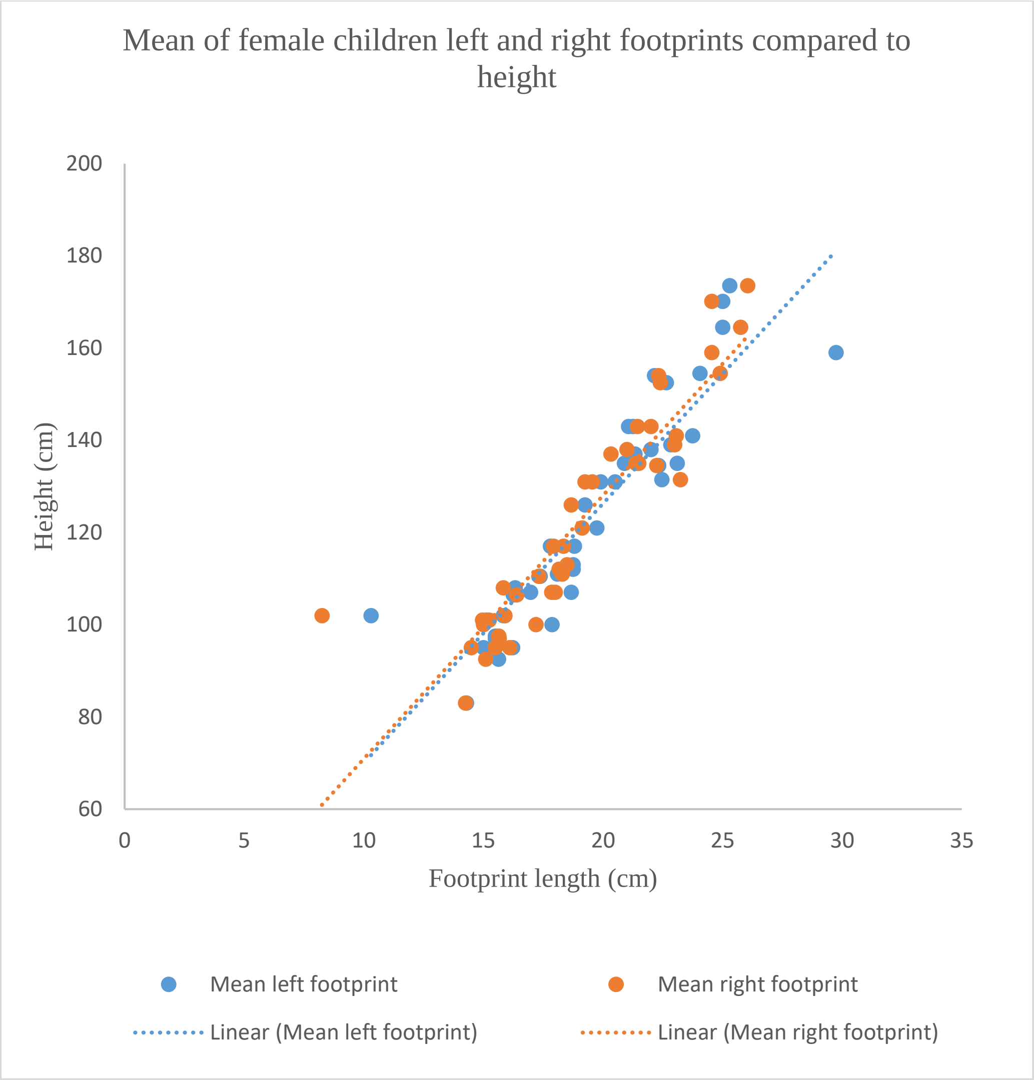


Figure 5.20 Height compared to footprint length of female children aged 3-15 years old

The correlation coefficient of the left footprint of female children was 0.91 (Figure 5.20), the right footprint coefficient was 0.91. Female children have a very strong correlation coefficient in both feet; if a child's footprint is recorded it can evidently be a good indicator of their height.

Children shorter than 150cm do appear to have a stronger correlation between their height and footprint length. A further consideration is if there is also a relationship between weight and footprint size.

5.3.4 Height, weight and footprint width relationship

It has been suggested that the width of an individual’s footprint may be indicative of weight and sex (Dingwall *et al*. 2013, Fawzy and Kamal 2010, Hemy *et al*. 2013). In this study female footprints ranged in width from 6.7cm to 12.3cm (Figure 5.21), and weights varied from 47.7kg to 107.3kg, whilst male footprints ranged in width from 8cm to 23cm, with weights ranging from 61.4kg to 126.6kg.

The heaviest individual was volunteer 131, a 50-year-old White English male, who was 192cm tall, and made footprints with a width of 11cm. This individual was over 16kg heavier than the second heaviest individual, volunteer 7 who was a 20-year-old White English male, 179cm tall and weighing 110.2 kg. This individual had a foot width of 13.25cm, 2.25 cm wider than volunteer 131 who was 16kg heavier. The average width of the male footprints within this experiment was 10.9cm in left feet and 11.3cm in right feet. This indicates that, although heavier than all individuals within this study, volunteer 131 had a footprint width of average size. Females had a mean left foot width of 9.8cm and right foot width of 9.9cm. These widths indicate a very slight difference in footprint size in males compared to females, with males being slightly wider on average than females. The variations in results and the minimal mean difference in width between males and females suggests that unless the footprint was very wide, and long in length, it is unlikely to be able to identify a male or female footprint with any scientific accuracy when utilising the widths of a footprint.

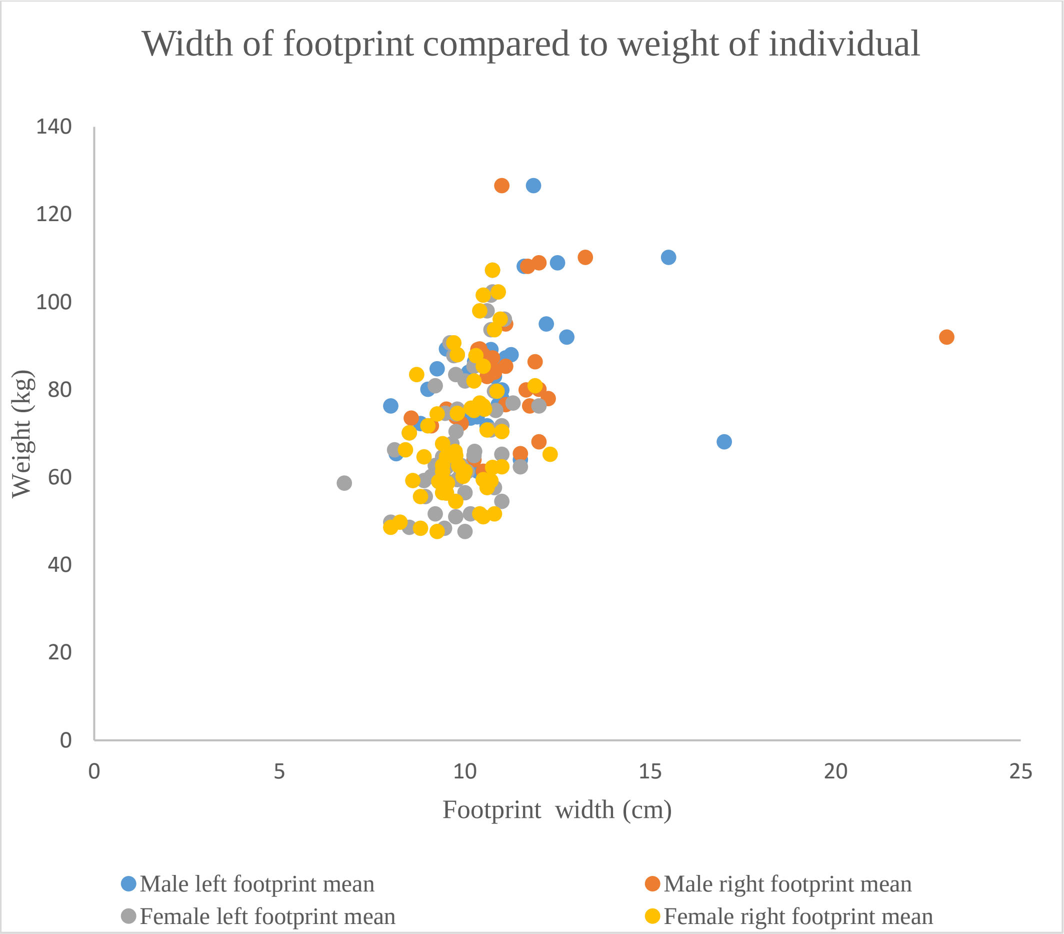


Figure 5.21 Width of footprint compared against weight of adult males and females

Figure 5.22 indicates that the width of an individual's footprint when compared to height has less of a positive relationship than the width of a footprint and weight of an individual. Although there is a clustering of tall males this relationship is not relatable to width of a footprint. The evidence suggests that footprint width cannot be used as a sex or height indicator. Male heights ranged from 155.4cm to 196cm, with footprint widths ranging from 8cm to 23cm, females were between 151cm to 180cm tall, ranging in footprint width from 6.7cm to 12.3cm. The wide male footprint, measuring 23cm, was caused by slipping on unstable, wet sediments, which caused the foot to slip sideways.

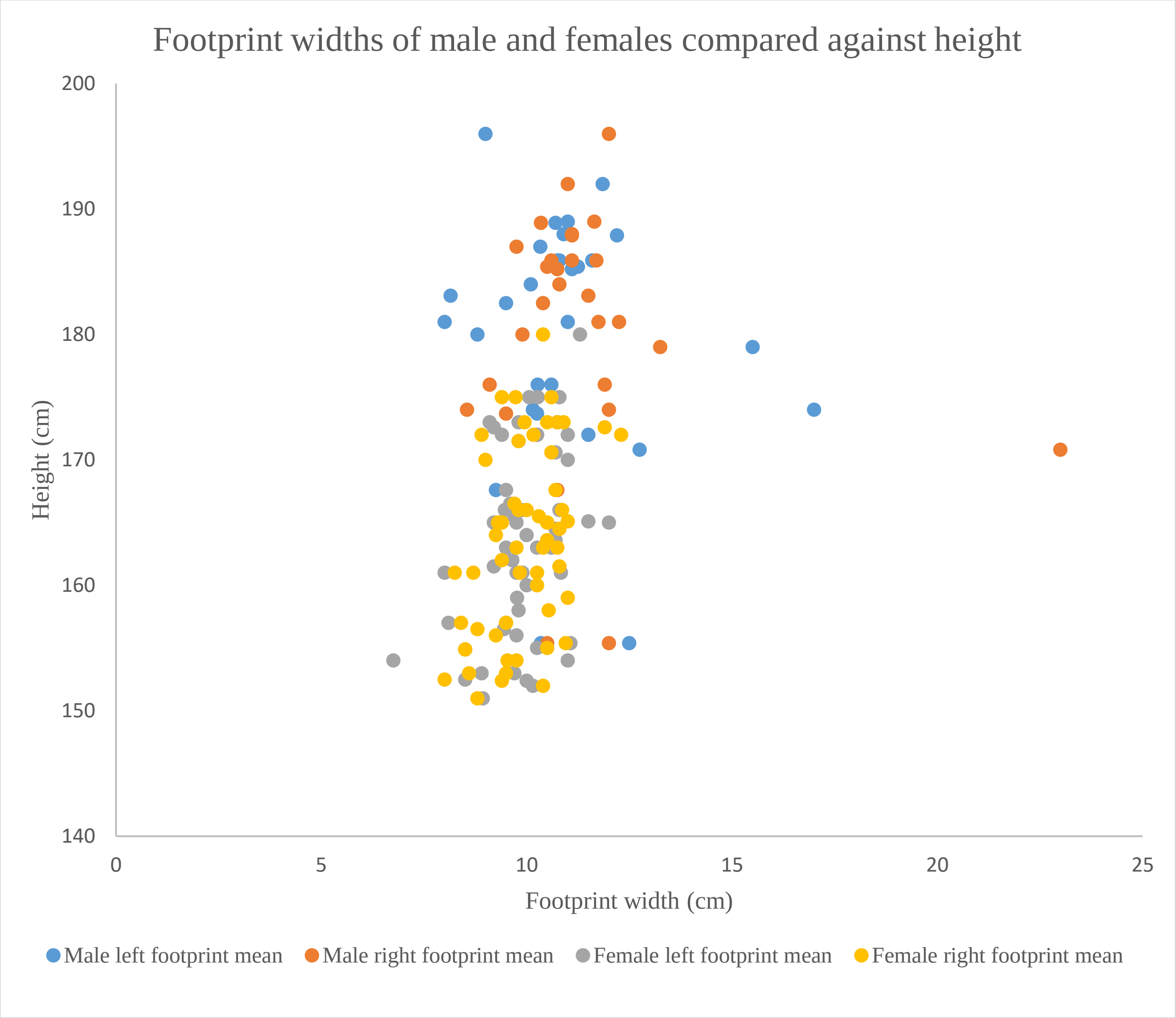


Figure 5.22 Footprint width compared against the height of adult males and females

The data indicates that height and footprint length have a positive relationship, whereas the width of a footprint is less associated to the weight of an individual. Height and footprint length can give an indication of the sex of an individual. The width of a footprint cannot be used alone as a sex or weight indicator; the data is too variable to create any equation expressing the relationship with any scientific worth. Although other studies have established that there is a relationship between weight and width when looking at ink footprints, those made in this experiment were made onto estuarine clayey silt sediments and do not exhibit the same relationship.

5.3.5 Running

Within this study footprints of running individuals were recorded from willing volunteers, to understand the differences in size of walking and running footprints. Of the adult volunteers, 22 were willing to partake in the running part of the experiment, 17 children were also willing to make footprints by running. This dataset is far smaller than the walking data, however, general trends can be observed.

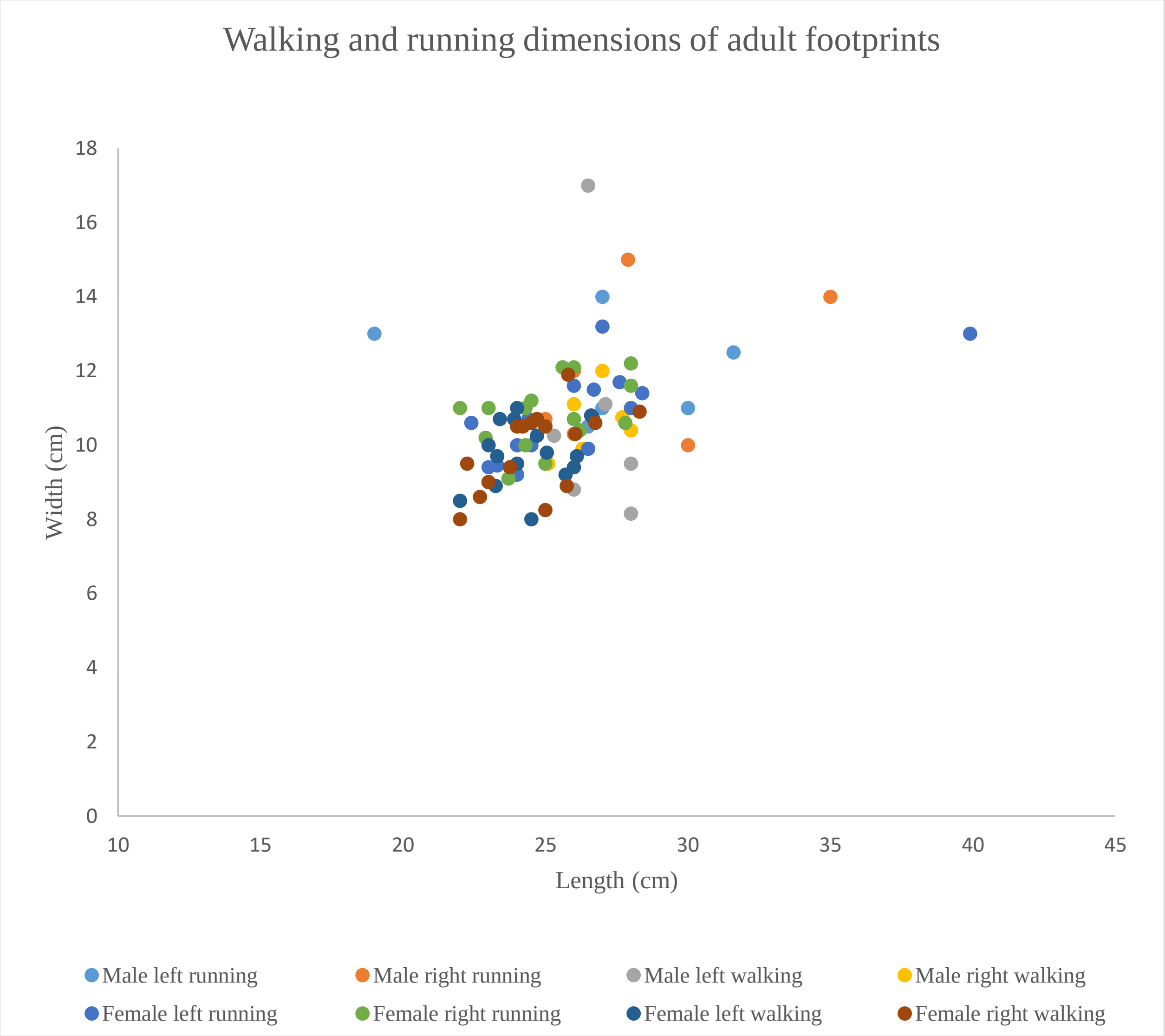


Figure 5.23 The walking footprint dimensions compared against running footprint dimensions of males and females

The range in male running footprint sizes was 19cm to 35cm in length and 10.3cm to 15cm in width. Footprints made by walking ranged from 25.1cm to 28cm in length, with widths ranging from 8.1cm to 17cm. Female running footprints ranged from 22cm to 39.9cm in length and 9cm to 13.2cm in width. Female walking footprint sizes ranged from 22 to 25.8cm with widths ranging from 8cm to 11.9cm. This small dataset suggests that running may cause the footprint to become longer and wider, though very slightly so (Figure 5.23). It is only when viewing a trail of footprints, where the pace and stride is seen, can any real understanding of the speed an individual was travelling be established.

5.3.6 Gait estimations utilising footprint data

A further use for footprint-tracks may be in establishing the travelling speed of an individual**.** An increase in stride length can be considered to indicate an increase in speed (Bennet and Morse 2014, p 154), the gait of an individual can also be utilised as an identification factor. An individual who is 165cm will have a shorter stride length than an individual who is 185cm, this will be the pattern in both walking and running. If walking together, the shorter person would have to take more strides than the taller individual, as well as speeding up their pace to keep up, this would be reflected within the footprint record.

Alexander (1976, 1984) theorised that the speed of a verterbrate had a relationship with the strides taken, and that there could be an equation to express this to establish gait, as gait is expressed by stride length. Alexander (1984) collected footprint data from a beach-based experiment involving children and adults, and developed a statistical power law which could then be used to estimate the speed of an individual:

$$\lambda/h \sim= 2.3\ [v^2/(gh)]^{0.3}$$

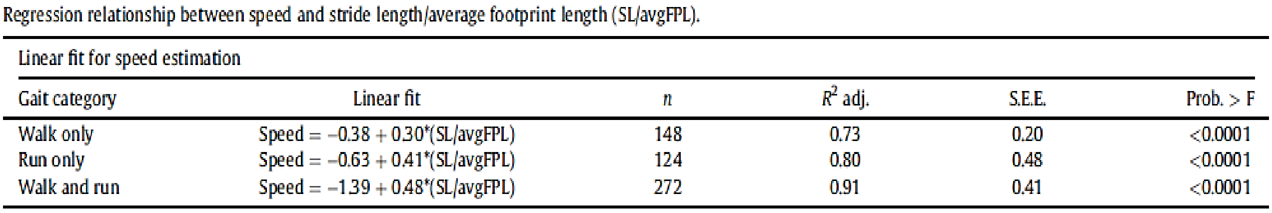
Within this equation, v represents the locomotory speed, g is the the accelerator of freefall and h is the height between the hip and the ground. Λ represents the relative stride length.

Absolute speed is then calculated with a function of λ and h:

$$v = 0.25\ g^{0.5}\lambda^{1.67}h^{-1.17}.$$

When a vertebrae transitions between walking to running the λ/h ratio will exceed 2.0 (Alexander 1976).

This statistical power law was then adapted by Dingwall *et al*. (2013) and applied to the Daasanach population (Figure 5.24). These equations were tested on the experimental footprint data (Table 5.6), however due to a very small sample size for stride lengths of adults running, a regression equation could not be determined. Children were not included as they were omitted from the Daasanach study. The Dingwall *et al*. (2013) equation can be used when considering prehistoric footprint data to attempt to determine the speed an individual was walking.



Regression relationship between speed and stride length/average footprint length (SL/avgFPL).

Linear fit for speed estimation

Gait category	Linear fit	*n*	R^2 adj.	S.E.E.	Prob. > F
Walk only	Speed = −0.38 + 0.30*(SL/avgFPL)	148	0.73	0.20	<0.0001
Run only	Speed = −0.63 + 0.41*(SL/avgFPL)	124	0.80	0.48	<0.0001
Walk and run	Speed = −1.39 + 0.48*(SL/avgFPL)	272	0.91	0.41	<0.0001

Figure 5.24 Regression relationship between the speed, stride and footprint length, Dingwall et al. 2013.

Sex	Height (cm)	Walking (meters per second)	Running (meters per second)
Female	152.4	0.8	1.2
Male	173.7	0.6	1.23
Female	167.6	0.95	1.23
Female	173	1.05	1.1
Female	165.5	0.67	1.21
Female	153	0.8	1.11

Table 5.6 Results of experimental footprints estimated speeds using Dingwall et al. 2013 regression equation

5.4 Discussion

5.4.1 Age estimation utilising footprint length

Due to the similarities in male and female footprint lengths the argument that will be presented is that it is not forensically accurate to suggest that the sex of a child can be established through the length of a footprint. The age of an individual can be estimated from a footprint, though it is important to note that accuracy will be within a broad age range rather than a specific age due to variations in growth, genetics and nutrition (Table 5.7).

Footprint length (cm)	**Age**	**UK shoe size**
<15	4 or younger	Child 7 to child 10.5
<20	10 or younger	Child 11 to child 13
> 20	10 to adult female	Adult 1 to adult 7

Table 5.7 Age estimation utilising footprint length

Footprint length (cm)	**Sex**	**UK shoe size**
20 to 24	Adult female / pubescent child of unknown sex	3 to 5
24 to 30	Either sex	5 to 10
>30	Adult male	11 to 12.5

Table 5.8 Sex estimation utilising footprint length

Table 5.8 shows the differences in foot size expressed in both sexes. It is evident that within the footprint data there is a large overlap between males and females. In this experiment the largest shoe size a female was wearing was a UK size seven, however these individuals often had footprints similar in size to males who wore a UK size ten.

Individuals with footprints over 30cm or smaller than 15cm will be the easiest to identify, in all other cases there is a relative amount of overlap. Footprints that were 20cm or less belong to children aged under ten, which will be an indication of children from within the archaeological footprint-track record.

Footprints can also be used to establish an individual’s stature. Understanding the stature of an individual can also give an indication as to the maturity, so the likelihood of an individual being tall and near to full grown, or being a relatively young child.

5.4.2 Stature Estimation

One of the aims of this study was to understand the relationship between an individual’s height and footprint length. By carrying out the experiment within the same sediment as those created by a prehistoric population it means that the footprint formation in the substrate would be similar. Using other regression equations would produce less accurate results as the formation of a footprint is partially influenced by the substrate, moisture content and plasticity of the sediment being walked upon.

Table 5.9 provides the regression equations created by the writer for both female and male left and right footprints made within this study. These equations assist in determining the stature of an individual. All of the equations were calculated by the writer using the lengths of each footprint from the modern human data set and calculating the relationship between the footprints (independantvariable) to the stature of the person (dependant variable).

A complication can arise in archaeological datasets as the sex of an individual is unknown. In these situations, a footprint trail may assist in identifying the gait, which may indicate a male or female, and then those specific equations can be utilised. Footprints can be indistinct, where the left or right foot and the sex is not identifiable, a combined regression equation can be used to estimate the stature.

Sex and footprint side	Regression equation	Standard error of estimate
Male Left	y=82.48 + 3.53x	8.3
Male Right	y=89.24 + 3.31x	8.5
Female Left	y= 95.05 + 2.78x	6.0
Female Right	y= 92.4 + 2.90x	6.18
Combined	y= 60.3 + 4.3x	7.3

Table 5.9 Regression equation establishing heights for adult males and females, y=height, x=footprint length, to be used on footprints larger than 20cm.

This research has demonstrated that identifying the sex of children from a footprint is not accurate, there is too much variation in children of both genders to establish sex by utilising the footprint, however identifying the stature of a child from a footprint is possible. This research took into consideration children aged ten and younger, as after this point many children were of a similar height to adults and produced results with adult dimensions. Only if a footprint is under 20cm, indicating a prepubescent child, should these equations be utilised (Table 5.10).

Footprint side	Regression equation	Standard error of estimate
Child left	y = 41.32 + 4.13x	9.14
Child right	y = 36.22 + 4.42x	8.12
Combined	y= 38.82 + 4.27x	8.59

Table 5.10 Regression equation establishing heights for children, y=height, x=footprint length, to be used on children with footprint lengths under 20cm.

Other studies have created stature equations with a standard error that is less than those determined in this experiment (Chapter 2, Table 2.2), however this experiment was observing the results of three-dimensional footprint-tracks rather than footprints made on flat surfaces with ink. Ink would provide results that more accurately demonstrate the morphology of a foot. This is not specifically essential in this study; it is not the foot itself that this study was interested in, rather the footprint, which would have some differences compared to a footprint made from ink or a static footprint. Footprints are evidently more variable; a single individual can create a footprint with over 10cm variability dependent on the way the footprint was formed, which is why the standard error estimate is larger.

The regression equations that were created for males had a higher standard error than females. More participants of the male sex may have provided results that were more strongly correlated. A further consideration of the created regression equations is the subjects themselves. Most individuals in Table 2.2 were from the same geographical region, ethnicity and even occupation. Many of them were in a similar age bracket; these factors may have influenced their foot growth or morphology.

The stature equations within this study are most similar to those obtained by Fawzy and Kamal (2010) and Uhrova *et al*. (2015) for the male results, the latter a study of 120 males from Slovakia aged 18-24 and the former a study of 50 Egyptian males aged 18 – 25 (Table 5.11 and Table 5.12). Although from different geographical regions, individuals of a very similar age were studied, and similar regression equations were created to this study, where ages ranged from children above ten-years-old, up to a 71-year-old. The female regression equation in this study is different from the few female studies that have been undertaken. Krishan and Sharma (2007), for example, investigated 123 North Indian females aged 17-20 and developed stature regression equations for the left (S= 74.82 + 3.58 LFL; SEE ± 3.53) and right (S= 73.88 + 3.61 RFL; SEE ±3.50) footprints. The variation between the writers' regression equations for female footprints and other studies is likely due to the variety of females within this study, compared to the unvaried ethnic groups within other studies, who were generally those of an Asian demographic. Female footprints are studied less than males and so data is limited in comparison.

Study	**Regression equation for male left foot**	**Standard error of estimate**
Current study	y=82.48 + 3.53x	8.3
Fawzy and Kamal 2010	$88.34 + 3.25 \times T_1L$ (left)	3.63
Uhrova *et al*. 2015	86.32+3.55 (left)	4.55

Table 5.11 Regression equations most like this study for male left feet

Study	**Regression equation for male right foot**	**Standard error of estimate**
Current study	y=89.24 + 3.31x	8.5
Fawzy and Kamal 2010	91.88 + 3.1 × T_1R (right)	3.55
Uhrova *et al.* 2015	84.09+3.64 (right)	4.56

Table 5.12 Regression equations most like this study for male right feet

5.5 Limitations

As with any experimental study there are always limitations to the method. In this experiment the main limitation was the footprint tray filled with sediment taken directly from the estuary. Several footprint studies consider the depth of a footprint; this was not considered in this experiment due to the unnatural environment of the footprint tray. Although attempts were made to compress the sediment within the tray, it was sediment that had been removed from its original context and so was far less compact than the natural sediment. Although this limitation exists, this method will still be the most precise way of capturing modern footprints in a sediment where prehistoric footprint-tracks were also recorded. Dingwall *et al.* (2013) undertook a similar experiment with sediments taken directly from a specific area where footprints were discovered and they did not report issues with this technique. An advantage of the footprint tray was that it allowed footprints to be made in an appropriate sediment that was removed from an area where the public are not allowed to visit.

This study has determined that there is a relationship between an individual’s footprint dimensions and their body size. This relationship can be utilised in forensic science studies, by anthropologists and archaeologists, to make inferences about an individual when all the data that is available is a footprint or a footprint trail. An issue with relying on inferences made about certain footprints made by a specific population is that the references to these inferences will only be highly relevant to the population or ethnicity that was sampled, rather than the population. The footprints within this study were created in a specific sediment and are comparable to footprints made in similar sediments.

The individuals in footprint studies are selected from a restricted data set, including the military (Robbins 1986; Adams and Herrmann 2009), a single ethnic group (Singh and Phookan 1993; Kanchan *et al*. 2010) and specific groups such as university administrators and academic staff as utilised by Bennet & Morse (2014, p 9). The individuals in this experiment were multiple groups of volunteers, students and staff from the University of Reading, children and child carers from groups in Reading, Berkshire, and the surrounding areas, and children and child carers from a large childminding group in Waterlooville, Hampshire. This provided a more varied range of individuals but they are not representative of a population, the adult females for example were primarily mothers, a bias that would have been caused by the interaction with childminding and child care groups, rather than being representative of the female population.

5.6 Conclusion

This study supports the hypothesis that there is a relationship between a person’s height and footprint length in footprints made in clayey silt estuarine sediments, though there is not a clear relationship between footprints and weights of an individual. Footprints can give an indication of whether an individual was a juvenile or fully-grown adult, and if the full-grown person was male or female. The results indicate that the accuracy of stature regression equations are less than static footprints or those made in ink, however they still provide a strong equation which can be applied to prehistoric footprints made in similar sediments.

Female and juvenile footprints are still understudied within the forensic community, especially within Europe, and the discipline would benefit greatly from studies that are not just performed in a university setting, but with individuals from a variety of social backgrounds.

Chapter 6

Mesolithic human footprint-tracks from Goldcliff East: age, sex and stature estimates and an interpretation of results

6.1 Introduction

Fossil footprint-track sites have been extensively analysed and interpreted, with research utilising footprint-track evidence to identify an individual’s activities and health related conditions (Roberts and Worsely 2008). These interpretations can be strengthened by analysing ethnographic studies, to attempt to understand hunter-gatherer behaviour.

The site of Willandra Lakes, Australia, is of note as aborigines are still inhabiting this area, possibly engaging in some of the same behaviours as their prehistoric ancestors. Campbell *et al*. (1936) recorded data from 478 central Australian aborigines, recording the foot length and stature of these individuals. From this data Webb *et al*. (2006; 2007) created equations that could then be applied to the prehistoric Willandra Lake footprints and determined stature, age and speed of movement. In areas where there are no longer indigenous populations, ichnologists must rely upon ethnographic examples from across the globe to help interpret footprint-tracks. It must be remembered that these behaviours are likely influenced greatly by environment, habitat, availability of resources, predators, temperature and weather. These factors would also have influenced the hunter-gatherer’s way of life.

The utilisation of modern hunter-gatherer datasets does have limitations and it is important to not over-interpret the prehistoric data using modern hunter-gatherer data as an exact comparison; these people are not a group of ‘pristine survivals from the Stone Age’ (Finlayson and Warren 2010, p 28). Modern indigenous populations have adapted to living on the fringes of agricultural and industrial land and will often trade resources and work directly in farming activities, a very different way of life to that of prehistoric hunter-gatherers (Finlayson and Warren 2010, p 41). They are therefore not a direct comparison, but can assist our interpretations of archaeological evidence in providing an analogue of the different ways that hunter-gatherers may perform the same activity.

Mesolithic footprint-tracks have been found preserved at the site of Goldcliff East on the Severn Estuary, Wales in a variety of sizes.

6.2 Method

The purpose of the fieldwork on the Severn Estuary was to record prehistoric footprint-tracks and determine the species of the footprint maker. If identified as *Homo sapiens*, then the direction of movement was also recorded. Modern human footprints made within the same clayey silt sediment as the prehistoric footprints were analysed in Chapter 5 and assist in establishing the extent to which this data provides reliable evidence relating to the footprint-makers.

During fieldwork from 2014 to 2017, 62 Mesolithic human footprint-tracks from a variety of laminations and areas were recorded, with a further 20 which may have been human or ungulate. From 2010 to 2014 103 possible human footprint-tracks were recorded during fieldwork. These were identified as human due to the long, slender shape, with evidence of a prominent arch, hallux or heel of the foot. Some footprint-tracks had only the appearance of the ball or heel of the foot preserved; these could have been made by ungulates or people, therefore the morphological appearance and metric measurements must be considered.

The footprint-track data will be displayed within the specific sites in which they were found, as these were created on differing laminations, at different time periods. Fine-grained sediments allow greater accuracy in capturing the definitions of a footprint, though the examination of shallower footprints made in fine-grained sediments may result in underestimation of foot length (Webb *et al*. 2006). This can also be an issue in cases where people were likely to have been running on the balls of their feet. Of the 62 footprint-tracks recorded during the 2014-2017 period of fieldwork, all were overtraces or undertraces, though four footprint-tracks were close to the lamination where the foot had made contact with the sediment, with clear evidence of separate toe prints, medial arch, heel and ball of foot impressions. Footprint-tracks at Goldcliff East recorded by Rachel Scales (2006) are also included within this study, to attempt to understand this area over the 17 years of site monitoring and observation that has taken place. Scales (2006) noted 320 possible human footprint-tracks at Goldcliff East, reanalysis of these individuals will be included within the discussion (Chapter 9) to gather a more complete and accurate understanding of the hunter-gatherers at Goldcliff East.

The unpredictability of the intertidal zone of the Severn Estuary can see dramatic changes to a site within two tides (Figure 6.1). The shifting of sandbanks and the constant threat of erosion provides an environment where footprint-tracks need to be recorded as soon as they are discovered, almost as a form of ‘rescue’ archaeology. It is therefore essential to digitally capture them, as well as record them physically on site by planning, taking metric measurements and casting; this is the only way in which intertidal footprint sites can viably be preserved by record. These recording techniques are discussed in depth in Chapter 4.

Figure 6.1 Photograph of low tide at Goldcliff East demonstrating the challenging terrain of the intertidal zone, taken from the sea wall

This study utilised multi-image photogrammetry to ensure that the footprint-tracks made on intertidal sediments were quickly and accurately recorded, as well as the more established techniques of standard photography and metric measurements. Multi-image photogrammetry enabled precise and reliable recording, providing there were no problems with the technology or the recording conditions (Table 4.1). This data could then be used to create 3D photographic point clouds and digital elevation models, and imported into ArcGIS to apply multidirectional hillshade and view the data in a variety of ways.

The metric dimensions and multi-image photogrammetry point clouds were analysed and the results will be presented in this chapter, utilising the results from the experimental work to enable an understanding of the individuals' age, sex and height. A discussion of the palaeosociety at Goldcliff East will follow this.

6.3 Previous work on the Goldcliff East footprint-tracks

The results presented within this section were recorded during the period of 2014-2017 at Goldcliff East. The footprint-tracks recorded during the period of 2010-2014 are also briefly analysed, a full report of all the footprint-tracks recorded at Goldcliff East from 2007-2017 can be found in Appendix 3.1. The results section is broken down by site (Figure 6.2) to enable any patterns of behaviour to be noted, e.g. travel in same direction, or a concentration of child or adult footprint-tracks.

Footprint-tracks were first noted at Goldcliff East by Allen (1997) who noticed an ill-preserved human footprint-track in silts, however they were not otherwise recorded.

In 2001 an area of footprint-tracks was discovered and recorded by Bell *et al*. (2001) as part of the Mesolithic to Neolithic coastal environmental change project. Under the umbrella of that project Scales (2006; 2007a) worked on the footprint-tracks for two seasons in 2002 and 2003 developing a technique for the excavation of areas of footprint-tracks stratified within stacks of laminated sediments. In 2004 three particularly well-preserved footprints were discovered by Bell during filming for a Coast television programme,and included in Scales work.

Between 2004-2009 there were only occasional visits to the site, resulting in the photography of one or two poorly preserved footprint-tracks. During this time the area of laminated silts investigated in 2001-2004 was largely covered by a sand bar which remains at the time of writing, although small areas of laminated sediments and footprint-tracks are occasionally exposed in places.

In 2010 footprint-tracks were found in several areas seaward of the 2001-4 finds and the sandbar. From 2010-2014 there were several short seasons of 1 day to 6 days of recording. This was before the writer began research for this thesis, although the writer was involved in one season in August 2011, during which work was undertaken on Bronze Age ungulate footprints on the upper peat shelf (Barr 2012; Bell and Barr 2016).

The writer began work on the thesis in 2014 and was responsible for footprint-track research and recording in 2014-2017, the results from this period of fieldwork form the core of this thesis, but where possible evidence from the earlier periods of fieldwork is drawn upon to aid in creating a fuller picture. It should be appreciated that some records and areas are richer and more detailed than others. Sometimes a footprint-track will only be recorded by a photograph, at other times with several days of fieldwork undertaken by a team of archaeologists it was possible to create a more complete record of the area studied.

All footprint-tracks recorded within this study appeared to have been made while barefoot, rather than shod, though during Scales (2006) investigation there was one footprint-track with the appearance of footwear (trail 6161, footprint-track 7/2).

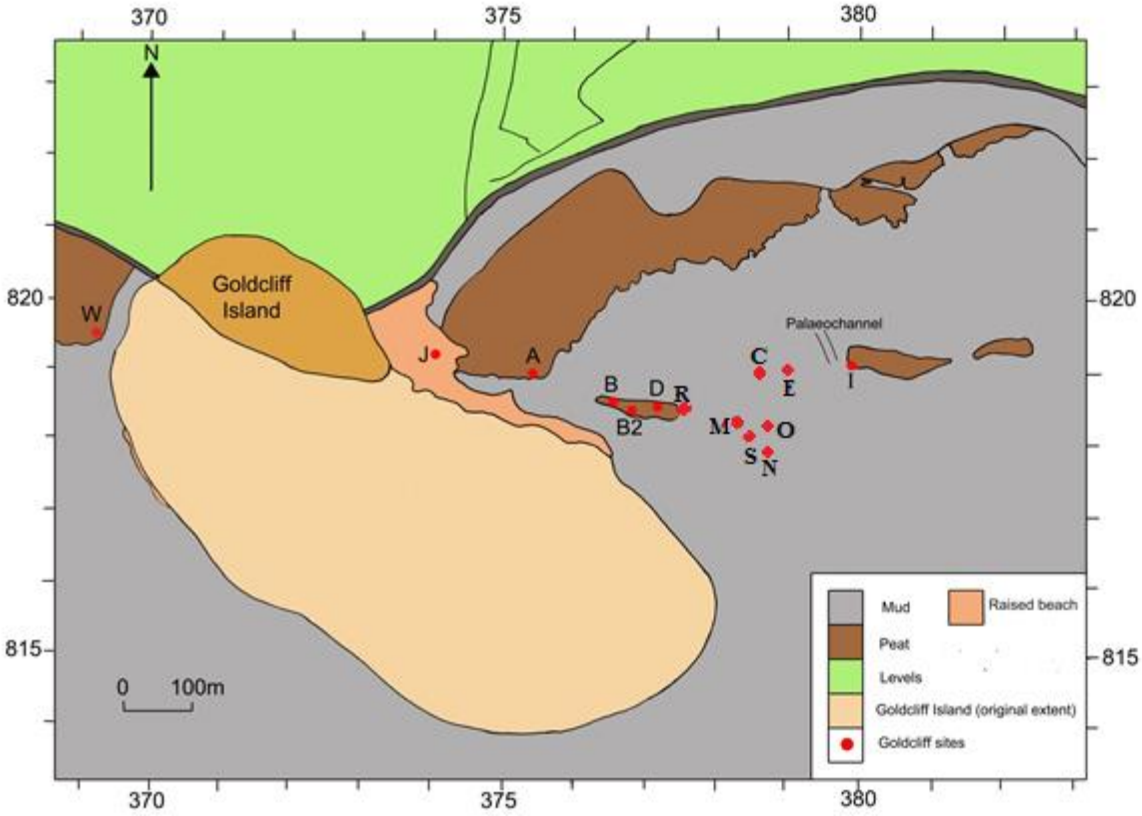


Figure 6.2 Map of the Mesolithic footprint-track sites and relationship to other occupation areas. Graphics by J. Foster and added to by writer

6.4 Are they human?

A human footprint reflects the unique anatomy of the foot, as well as the way in which an individual moved. The foot generally makes contact with the sediment at the heel first, creating a rounded impression. Pressure is then distributed throughout the foot as it makes full contact with the sediment, with the lateral side of the foot and the metatarsal heads undergoing the most pressure, as the weight is then rolled onto the ball of the foot and the head of the hallux (Elftman and Manter 1935; Vereecke *et al*. 2003). The hallux therefore is generally the deepest part of the footprint, due to the pressure it undergoes during movement. The rest of the foot's preservation in sediment is dependent upon factors including the substrate walked upon, and the orientation of the foot as it makes contact with the substrate (Vereecke *et al*. 2003).

To understand if the footprint-tracks at Goldcliff East were made by humans there were specific criteria that had to be met; this is discussed fully in Chapter 4.2 and involved characteristics such as a well-defined heel, medial longitudinal arch, deep hallux (Figure 6.3), as well as possible trails with alternating left-right footprints, which can enable identification even if the footprint detail is poorly preserved. Many of the footprint-tracks could only be tentatively identified as human due to poor preservation, though there were a few footprints that were exceptionally well-preserved (Figure 6.3). Figure 6.4 represents multi-directional hillshade models of a variety of the footprint-tracks recorded at Goldcliff East that were poorly preserved, these were derived from 3D photogrammetry models and processed within ArcGIS. The footprints within this site are fairly poor examples of human footprints; the edges lack definition, and they have undergone post-depositional erosion to varying degrees. The footprint-tracks were undertraces or overtraces so the actual footprint could not be seen, and in cases where the wall of the footprint could be observed, they generally had a sediment infill within part of the footprint.

Although most are poor examples of human footprints, the majority of those found at Goldcliff East had at least one identifiable feature, which was generally a well-rounded heel, though evidence of a medial longitudinal arch, hallux or metatarsals were also seen. The presence of several evident left-right trails also confirms that these footprints were made by humans and were not formed through natural processes.

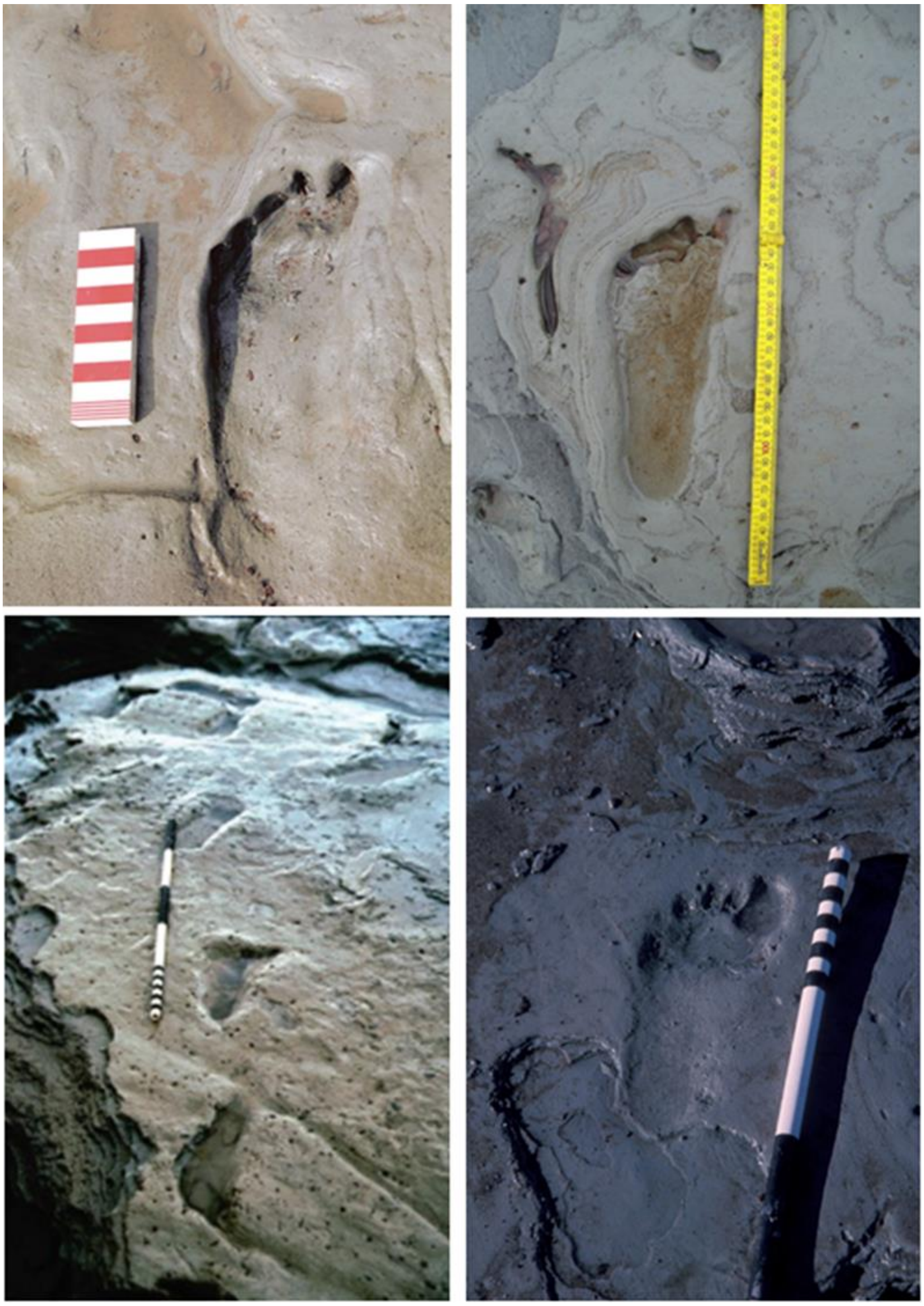


Figure 6.3 (top left) Footprint of Person 13 (6215), scale 10cm (photo E. Sacre), (top right) footprint of Person 13 (6204) (photo M. Bell), (bottom left) footprint trail, small divisions 1cm (photo E. Sacre), (bottom right) footprint of Person 6 (6160a), small divisions 1cm (photo E. Sacre). Footprint-tracks recorded by Scales (2006, 2007)

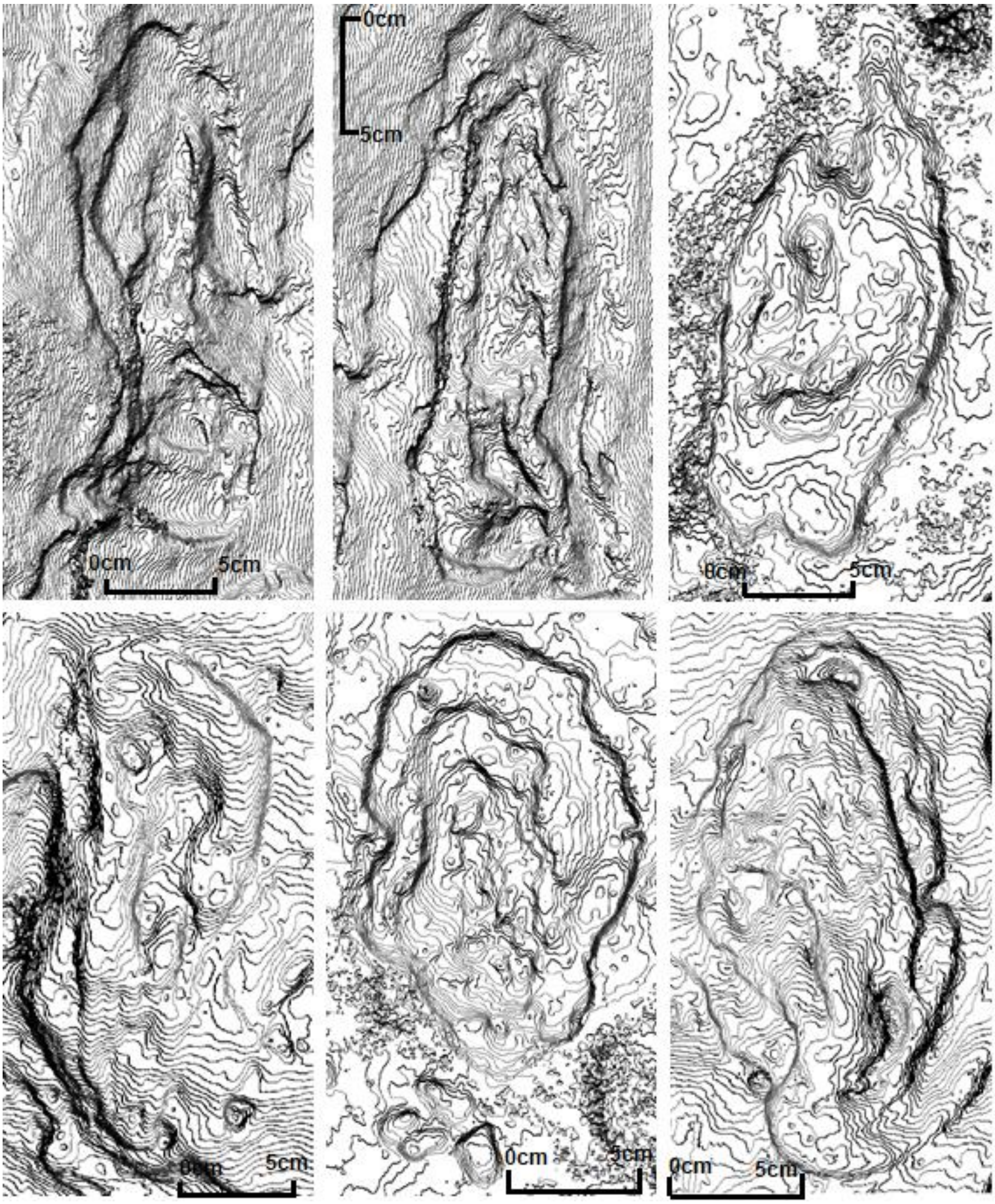


Figure 6.4 Multi-directional hillshade models of Mesolithic human footprint-tracks from Goldcliff East Site N (top left to right) footprint-track 2016:17, 2016:16, 2015:7, (Bottom left to right) footprint-track 2015:18, 2015:6, 2015:7

6.5 Resuts of Site C/E footprint-track evidence

Site C/E footprint-tracks were exposed in small areas mostly on an eroding low cliff through laminated sediments, this was the northerly (landward) of the Mesolithic footprint-track sites (Figure 6.5). Site C and E were extensively studied by Scales (2006), Site C was located on laminations between -3.6m and -4.2m OD, and Site E was at -3.9m OD (Bell 2007, Figure 4.5). During the current research a large sandbank covered these sites, and exposed areas of banded laminated sediments was small, with footprint-tracks recorded in areas that were near to the previous footprint-tracks recorded at C and E but not in the exact location. Site C/E was the highest footprint-track area and so was exposed for the longest period. The retreating tide provided a clean body of water to clean the footprint-tracks, and due to the laminated cliffs the water was easily accessible if one was on site as the tide retreated. The moving sandbank caused issues in finding and recording footprints, with areas being buried by over 15cm of sand within 24 hours of initial discovery. Although water was accessible to wash areas off, the thickness of the sand often prevented any recording, sometimes as Figure 6.5 shows it was possible to clear sand back to increase the area of footprint-track exposure.

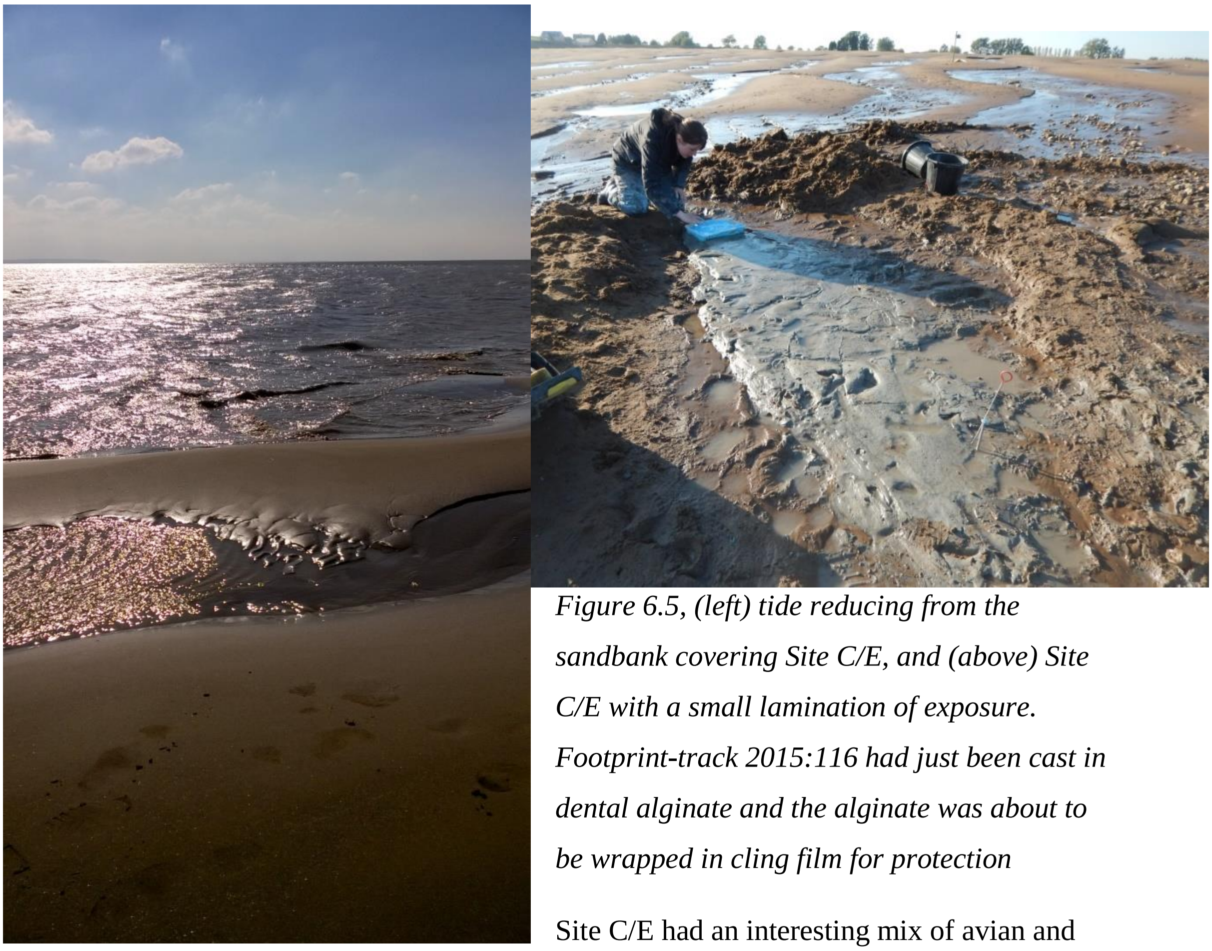


Figure 6.5, (left) tide reducing from the sandbank covering Site C/E, and (above) Site C/E with a small lamination of exposure. Footprint-track 2015:116 had just been cast in dental alginate and the alginate was about to be wrapped in cling film for protection

Site C/E had an interesting mix of avian and human footprint-tracks found on multiple laminations. This was one of the main areas investigated by Scales (2006) in 2002-4. Subsequently between 2014-2016, 18 human footprint-tracks were recorded (Table 6.1). Many of these were relatively well preserved, with anatomical features evident such as indentations from the toes, heel and arch of the foot. The footprint-tracks ranged in length from 17cm to 30cm, and in width from 5cm to 14cm. These footprint-tracks were created across multiple laminations indicating that they were lain down over several years, and were all within 30 meters of each other.

Footprint-track number	**Site**	**Length (cm)**	**Width (cm)**	**Identifying features?**	**Left or Right?**	**Direction of movement**
2015:88	C/E	20	8.5	Prominent hallux	Right	82° east

2015:89	C/E	Incomplete	8	Arch of foot	Left	340° west of north
2015:106	C/E	30	14	Prominent hallux	Left	340° west of north
2015:107	C/E	30	11	Arch of foot	Left	226° west
2015:114	C/E	26	11	Arch of foot	Right	30° north
2015:115	C/E	26	11	Arch of foot	Left	18° north
2015:116	C/E	21	10	Prominent hallux, arch and heel	Right	310° west of north
2015:117	C/E	23	10	Arch of foot	Left	290° west of north
2015:118	C/E	17	5	Arch of foot, but deep and narrow with no evidence of toes	Indistinct	Indistinct
2015:119	C/E	30	8.5	Undertrace	Indistinct	Indistinct
2015:120	C/E	Incomplete	Incomplete	Heel only	Indistinct	Indistinct
2015:122	C/E	Incomplete	Incomplete	Heel or ball of foot	Indistinct	290° west of north
2015:123	C/E	Incomplete	Incomplete	Heel or ball of foot	Indistinct	290° west of north
2015:126.2	C/E	Incomplete	8	Hallux evident but heavily eroded at the heel	Left	46° north north east
2015:127	C/E	25	9	Prominent hallux and ball of foot	Left	314° north north west
2015:129	C/E	Incomplete	8	Toes and ball of foot	Left?	46° north north east
2015:131	C/E	20	9.5	Heel	Indistinct	150° south
2016:71	C/E	18	7.5	Toes/heel	Indistinct	270° west

Table 6.1 Footprint-tracks from Site C/E recorded on multiple laminations. For further information such as grid reference locations (where available) see Appendix 3.1

6.5.1 Description: footprint-tracks 2015:88 and 2015:89

The Site C/E laminations were covered in sand at the start of the research period**,** and it was not until 28.10.2015 that any human footprint-tracks were exposed in this area. Two human footprint-tracks were identified and numbered 2015:88 and 2015:89, these were partly under water throughout recording. These footprint-tracks had a small amount of sediment infill within them. Both footprint-tracks had the appearance of undertraces. The shaft of the foot had evidently broken through layers of sediment, most likely because this sediment was soft or wet. Footprint-track 2015:88 had an interdigital ridge between the hallux and the second toe digit. Erosion was sudden and by the following day footprint-track 2015:89 had lost 6cm from the heel, originally being 19cm in length, even before this its length had been truncated by erosion. The following day this print was 13cm in length. The proximity to the lamination cliff edge and the water prevented fingertip excavation.

The rotation of footprint-track 2015:88 from footprint-track 2015:89 suggests a change in direction of movement, either to avoid something or to head in a different direction. Footprint-track 2015:89 was a left foot and would have been made first, heading 340° west of north, footprint-track 2015:88 was a right foot and was heading 82° east (Figure 6.6).

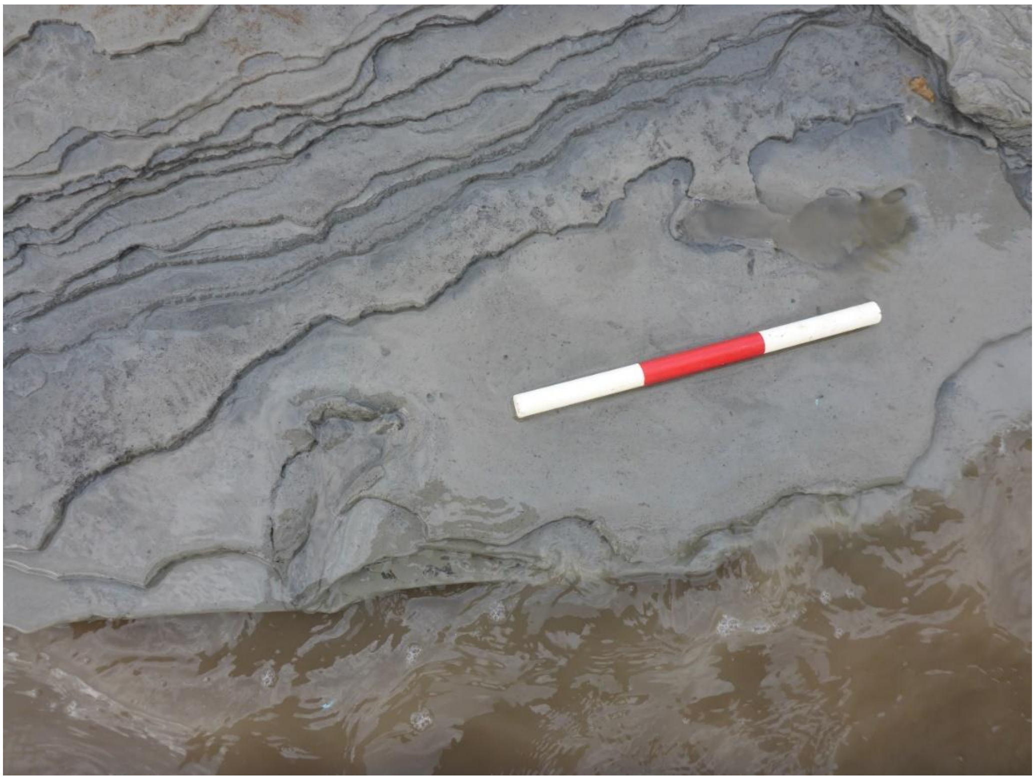


Figure 6.6 Photograph of footprint-tracks 2015:88 (top right) and 2015:89 (bottom left). Note the change in direction and difficult recording conditions. Scale 0.3m

6.5.2 Description: footprint-track 2015:106 and 2015:107

During fieldwork on 13.09.15, on the edge of a laminated cliff in Site C/E two human footprint-tracks were recorded, 2015:106 and 2015:107. These footprint-tracks were possibly undertraces as the toes were not preserved in detail. Footprint-track 2015:106 was a left footprint, with a deep hallux imprint and slight interdigital ridges between all digits (Figure 6.7). This individual was heading 340° west of north. Footprint-track 2015:107 was also a left footprint, with an interdigital ridge between the hallux and the second digit (Figure 6.8). Individual 2015:107 was orientated 226° west towards Goldcliff Island. It is possible that the same individual made both footprint-tracks, they were on the same lamination, were the same length (30cm), over 10cm in width and had prominent features (hallux, heel, arch, ball of the foot). The detail preserved in the footprint-tracks suggests that the sediment was relatively firm, though both footprint-tracks had evidence of toenail drag from the hallux which again suggests they were made by the same person.

Figure 6.7 Footprint-track 2015:106. Note North arrow was being used as a scale bar [small divisions 1cm] and is not representative of direction of north

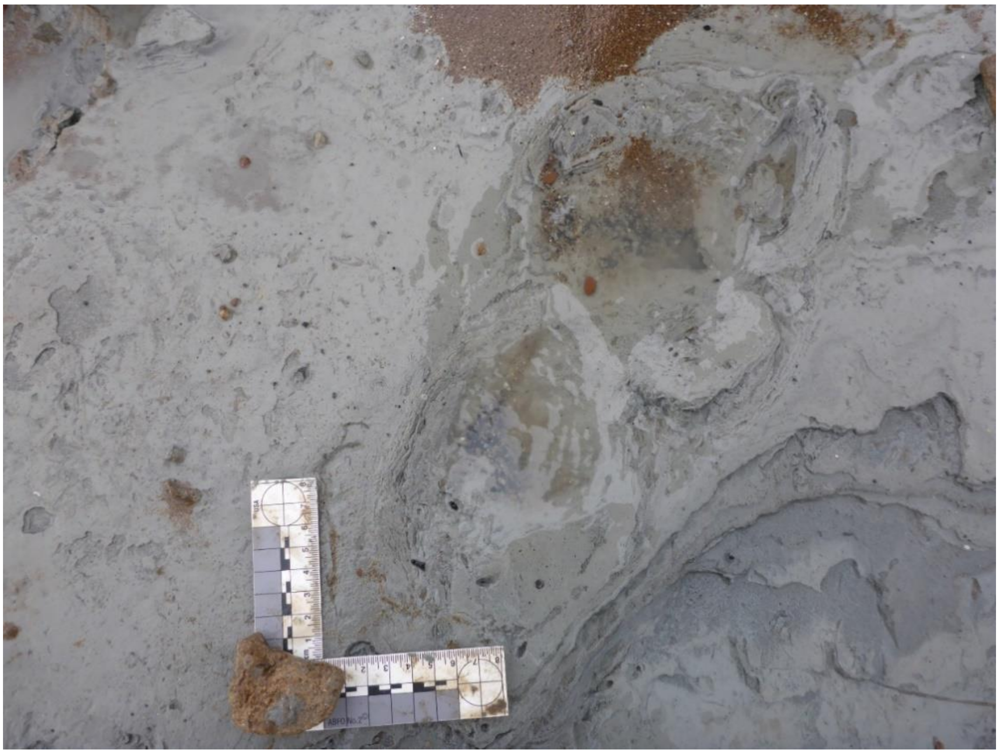


Figure 6.8 Footprint-track 2015:107, with evidence of hallux impression and toe nail drag

6.5.3 Description: footprint-track 2015: 114 and 115

Fieldwork during 28.9.2015 revealed poorly preserved human footprint-tracks on a clean lamination; these were numbered 2015:114 and 2015:115. The encroaching tide prevented anything but measurements and standard photographs of these footprint-tracks being recorded, the photographs were of poor quality however the measurements were informative and allowed pace to be established. The footprint-tracks were identified as human due to their shape, the appearance of a foot arch and possible toes indicate that 2015:114 was probably a right and 2015:115 was a left. These footprint-tracks were made on the same lamination, and were the same size; 26cm in length, 11cm in width. Footprint-track 2015:114 was heading 30° north and 2015:115 was heading 18° north, the similarities in these footprint-tracks suggest that the same individual made them.

6.5.4 Description: footprint-track 2015:116, 117, 118, 119, 120, 122, 123

Eight footprint-tracks were found on the same lamination, on 28.09.15, these were within a 3m^2 area surrounded by mobile sand, some of which could be cleared away to reveal footprint-tracks. Footprint-tracks 2015:116, 117, 118, 119, 122 and 123 were on the same lamination, 2015:120 was on a thin lamination above (approximately 3mm). This area was recorded by utilising multi-image photogrammetry, enabling point clouds and digital elevation models to be generated (Figure 6.9 and 6.10).

Footprint-track 2015:116 was a right footprint, with a heel and arch and an interdigital ridge between the hallux and second digit (Figure 6.11), sediment slightly infilled this footprint-track. Once fingertip excavation had been performed it was evident that this footprint-track was either the footprint itself or a slight undertrace, as there was not any further evidence of interdigital ridges.

Footprint-track 2015:117 was a left footprint, the heel of this footprint and an interdigital ridge between the hallux and first digit was preserved. This probable undertrace was less well-preserved/well-formed than 2015:116. The heel of the foot was prominent in this footprint-track and there was possibly slight drag or skid from the heel before the foot made full contact with the sediment. Footprint-track 2015:116's direction of movement was 310° west of north, whilst 2015:117 was orientated west of north 290°.

The other footprint-tracks in this area were less obviously human. Footprint-track 2015:118 was a very deep impression. It was long and very slender, with a small suggestion of toe indentations, though there were no interdigital ridges (Figure 6.12). This footprint-track was deep, approximately 4cm, the slenderness of the print may indicate that this is the shaft of the print rather than the actual footprint. Due to this it was unclear if this was a left or right footprint, though this footprint-track was likely heading 330° west of north.

Footprint-track 2015:119 was identified due to the localised disturbance in the lamination, however there were not enough identifying features visible to accurately identify as human, or indeed any other animal. Footprint-track 2015:120 was an undertrace, could only be seen in certain light, and was one thin lamination band above 2015:116. The direction of movement was established due to the shape of the undertrace, where the heel was identified, though the left/right foot side was not. This individual was heading 270° west.

Two further human footprint-tracks were identified in this area, though again they were very poorly preserved and were more of a disturbance to the lamination than a clear footprint-track, possibly overtraces. These footprint-tracks were assigned the identification number 2015:122 and 2015:123. They were tentatively identified as human due to the shape and probable heel. They were heading 290° west of north. These were identified the day after the other footprint-tracks had been recorded and as such are not included within the point cloud model. They were both to the west of the point cloud model.

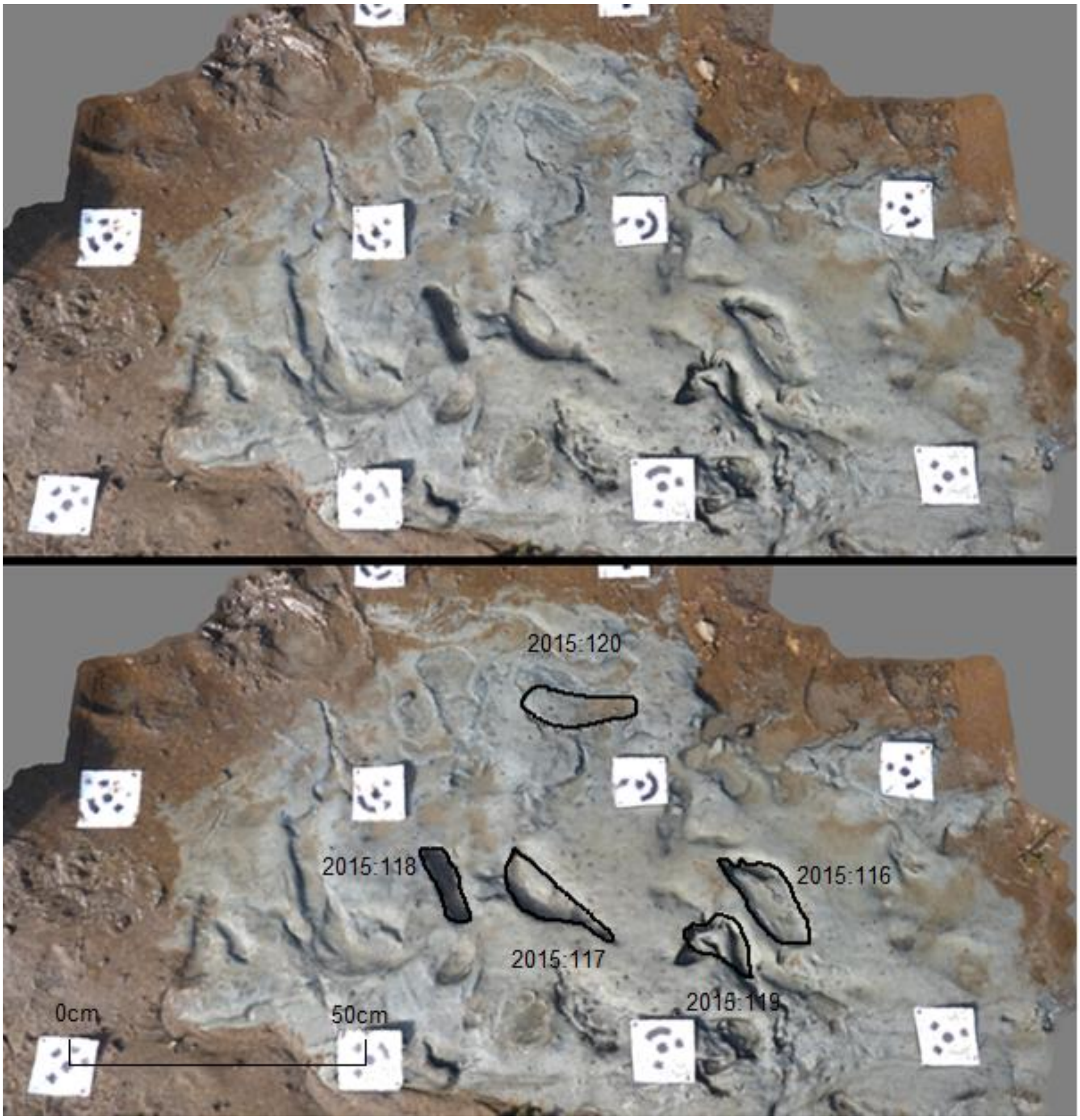


Figure 6.9 (top) Footprint-track area generated in Agisoft Photoscan Pro, utilising multi-image photogrammetry point cloud, (bottom) footprint-tracks within this area traced to provide clarity

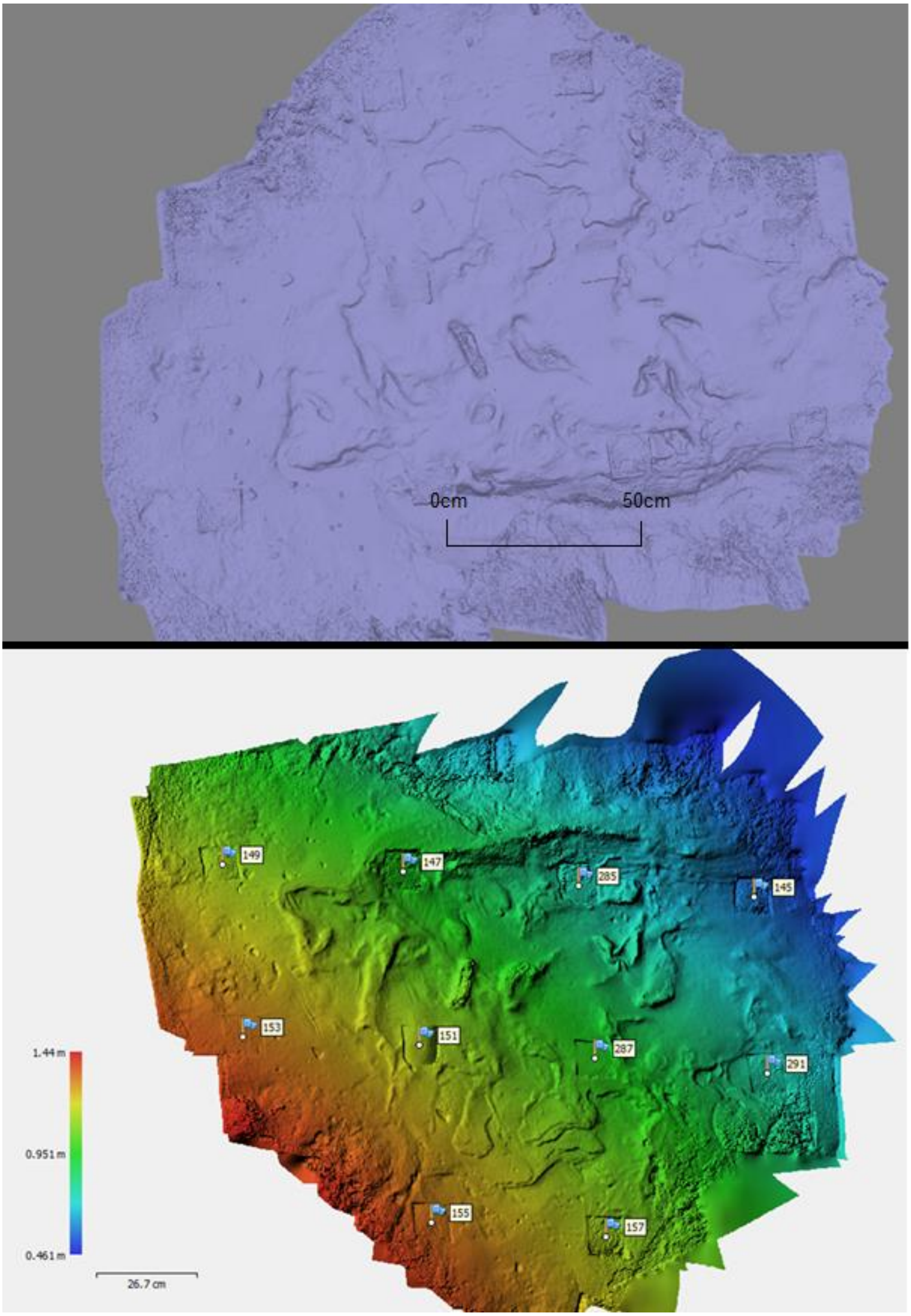


Figure 6.10 (top) Solid colour model of footprint-track area 2015:116-123 (bottom) Digital elevation model of the area, note that the scale bar does not give the actual OD height of this trail, which is -3.6m OD.

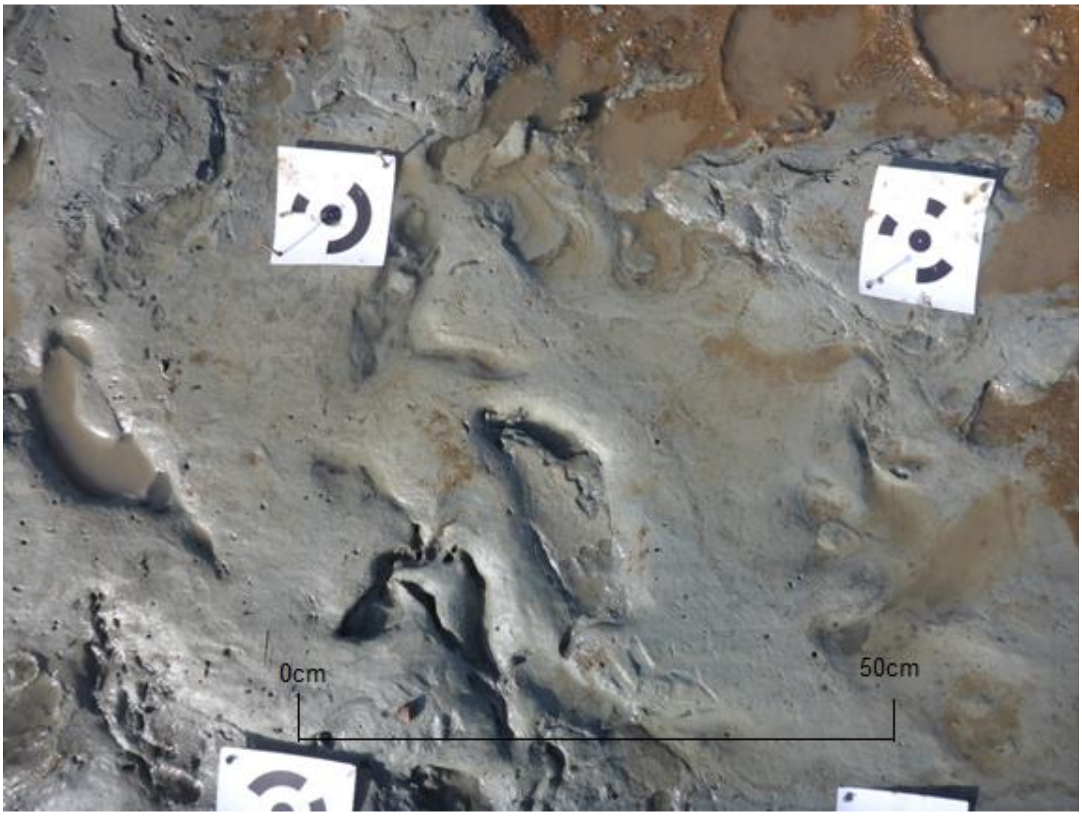


Figure 6.11 Footprint-track 2015:116 (right), 2015:117 (left) and 2015:119 (centre)

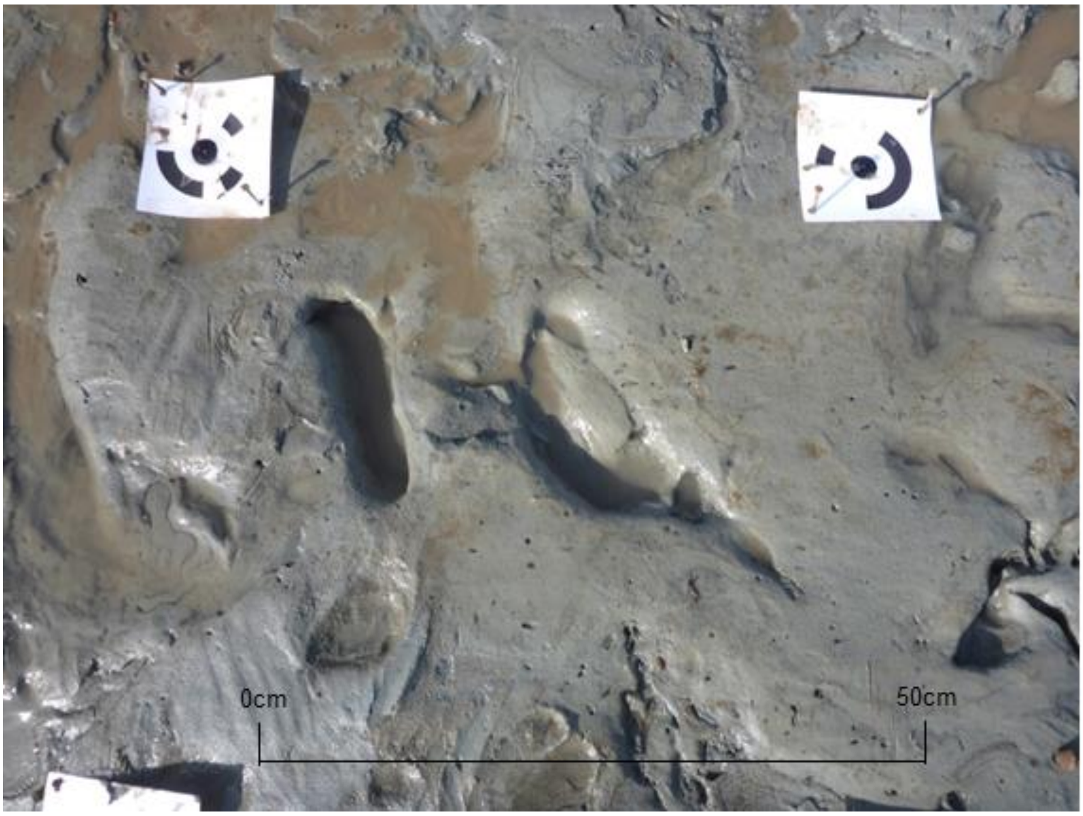


Figure 6.12 Footprint-track 2015:117 (right) and 2015:118 (left)

6.5.5 Description: footprint-track 2015:127

A small laminated area was uncovered during 27.10.2015, approximately 2m west and 3m north of avian footprints 2015:112 and 2015:113. This footprint-track, 2015:127, was from a human left foot, with a prominent hallux as the main identifying feature. No indication of any other toes was preserved, giving this footprint-track an odd shape as the hallux appears very long (Figure 6.13). This footprint-track was likely an undertrace; it was difficult to see on the lamination as it was smooth, and there was very little indentation apart from the hallux. There were not any interdigital or marginal ridges evident. This individual was heading 314° north-north-west and was 170cm from footprint-tracks 2015:116-2015:123, on what appeared to be the same lamination surface. There was also a large avian footprint (2015:127.1) on the same lamination, less than 3cm parallel to the fifth toe digit of the human footprint-track.

Figure 6.13 Footprint-track 2015:127and avian footprint-track 127.1

6.5.6 Description: footprint-track 2015:126.2

As 2015 progressed it became evident that the sandbar that originally covered Site C/E was moving. During fieldwork on 29.10.2015 Site C/E had become almost completely covered again, with just the large laminated cliffs with clean exposure. These were small areas between approximately 50cm and 1m that were exposed. A human footprint-track was uncovered at ST 37885 81905, this footprint-track had a prominent hallux and ball of the foot, but was eroded at the heel so that the true length of the footprint could not be identified. There were no interdigital ridges preserved as this was an undertrace from a left foot of an individual heading 46° north-north-east. Above this human footprint-track, on the same lamination, was avian footprint 2015:126.1, an oystercatcher.

6.5.7 Description: footprint-track 2015:131

During fieldwork on 27.11.15 one small lamination at Site C/E, approximately 1m^2, was cleaned of sand for a long enough period to identify a human footprint-track. It was unclear if this was made by a left or a right foot, however there was a prominent heel which implied that this individual was heading away from Goldcliff Island, 150° south, located at ST 37867 81891. The constant flow of water and sand prevented any clear photograph of the footprint-track or any further understanding of the way this footprint-track had formed.

6.5.8 Description: footprint-track 2016:71

A single human footprint-track, 2016:71, possibly a right foot, was discovered on a clean lamination during 16.09.16. This area was on a lamination with 2m of exposed surface, at ST 37872 81893. This is the only human footprint-track on this lamination and was an undertrace; the footprint-track was almost fully eroded, with just a slight indentation. There were no interdigital ridges or a deep hallux mark so it was difficult to determine the direction of travel, though they were moving either towards or away from Goldcliff Island, possibly travelling 270° west. Nine laminations below this human footprint-track was a single footprint-track of a wading bird, likely an oystercatcher (2016:72). This was partially obscured by the laminations above (Figure 6.14).

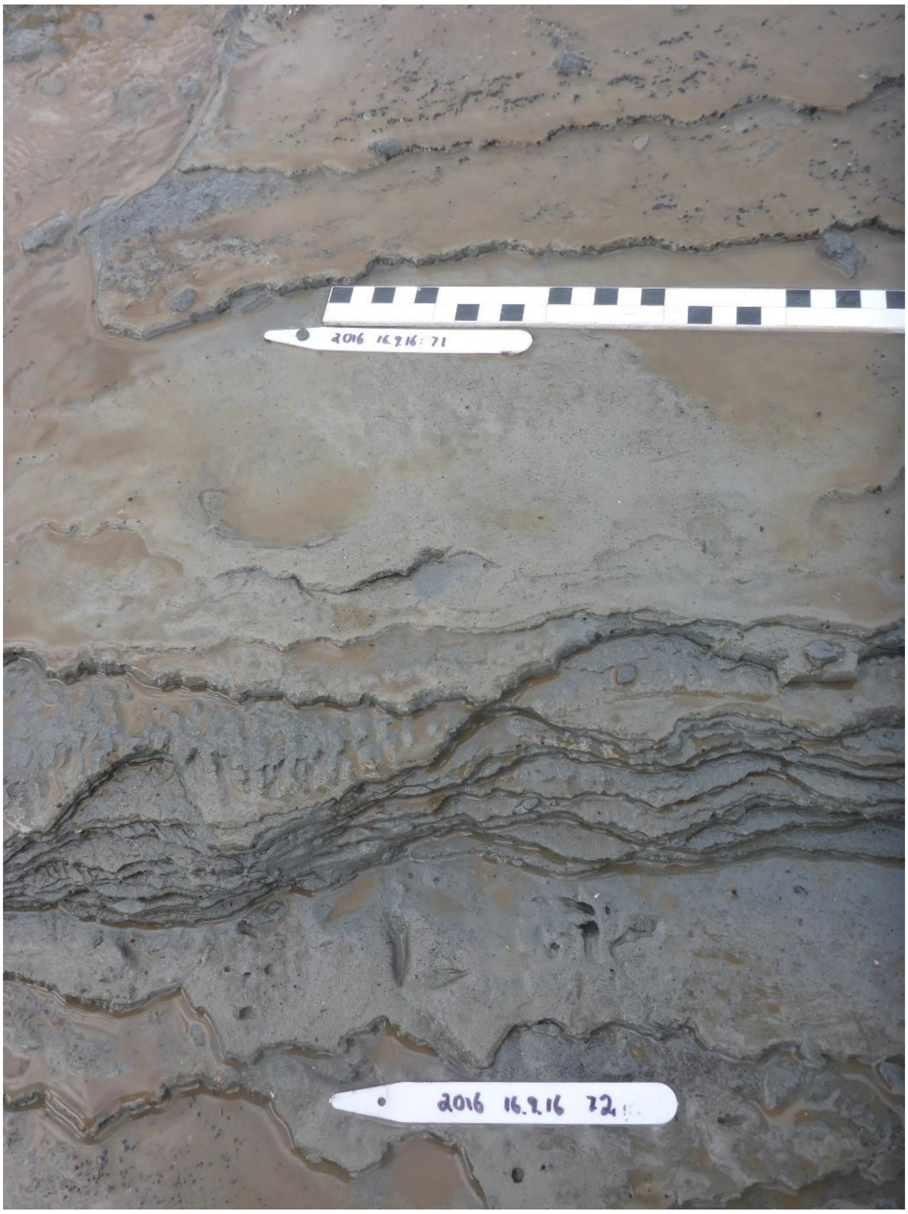


Figure 6.14 Footprint-track 2016:71 multiple laminations above 2016:72, an oystercatcher footprint-track, scale cm divisions

6.5.9 Analysis of Site C/E footprint-tracks

The experimental footprint research results (Chapter 5) enabled the footprint-tracks in Site C/E to be explored, with inferences made about age, sex, and stature. The most important part of analysis was in confirming that the footprint-tracks were human. Figure 6.15 demonstrates the lengths and widths of the human footprint-tracks recorded at Site C/E. Figure 6.16 displays these footprint-tracks against those recorded during the human footprint experiment. By comparing the lengths and widths of the footprints it is evident that the footprint-tracks from Site C/E were similar in size to both modern children and adults.

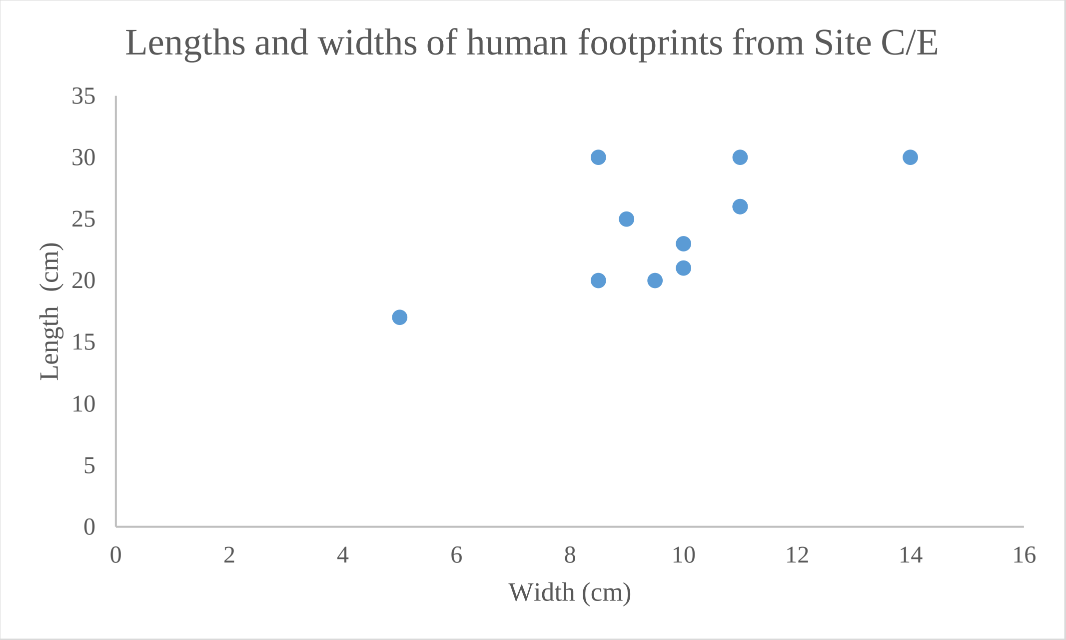


Figure 6.15 Scatter diagram of footprint-track lengths and widths from Site C/E

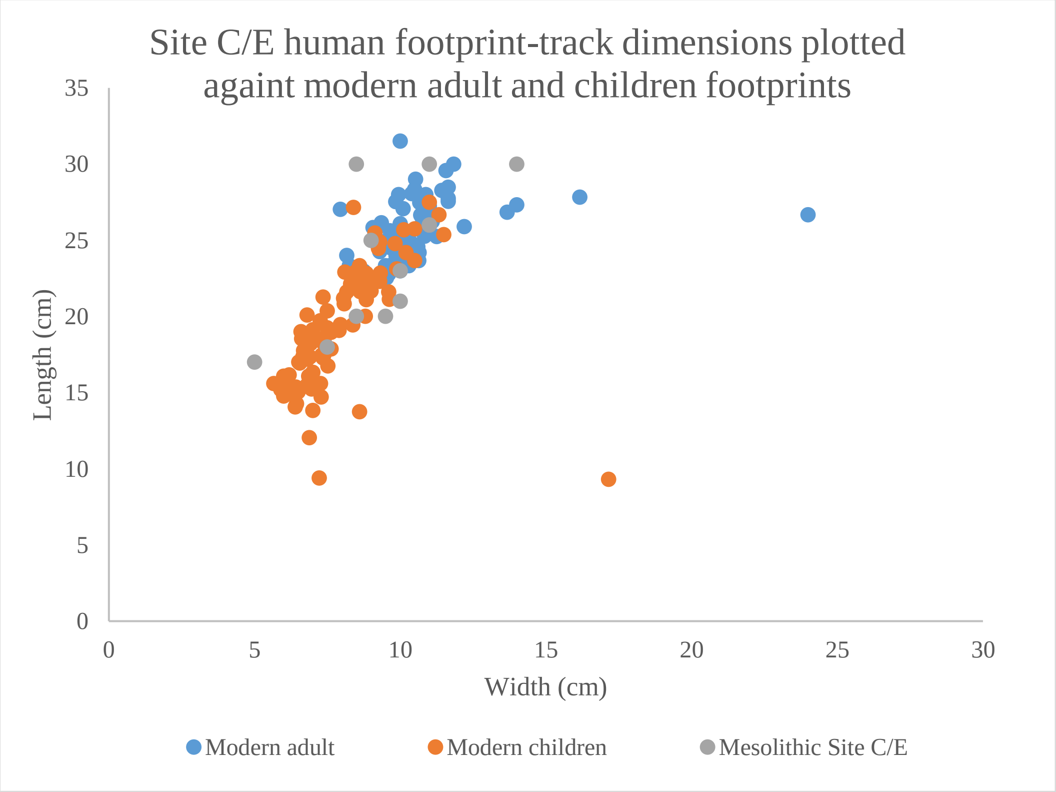


Figure 6.16 Scatter diagram comparing lengths and widths of Site C/E Mesolithic data against modern human footprints

6.5.10 Age and sex of individuals who made footprint-tracks in Site C/E

Footprint sizes are variable between individuals so do not fit a set growth pattern or shoe size, which we would expect to see if looking at the foot itself. The experimental study from Chapter 5 concluded that shoe sizing was not an accurate way to establish age, though this can assist in understanding the size of the person. The footprint is instead heavily influenced by the type of sediment walked upon, its moisture content, and the way a person walks such as the pressure they assert on specific areas of the foot.

Although shoe size information such as the ‘Clarks Shoe Size Guide’ can assist in understanding the possible shoe size of someone’s foot size, it must be remembered that humans making footprints during the Mesolithic were walking upon a soft clayey silt sediment, and they may have had robust, muscular feet, whereas the ‘Clarks’ guide was compiled from measurements from the foot itself and from a modern population who are habitually shod. This alone cannot assist in understanding the age of an individual, as there is likely to be a larger range due to the unpredictability of footprint formation. The experimental data gives a range of footprint sizes for different ages, however this range was rather broad. Table 6.2 is an edited version of the experimental results table (Chapter 5, Table 5.7), with extra age ranges added. The two extra footprint sizes, 15 to 18cm and 18 to 19cm, have a large amount of age overlap and were not included within the experimental results, the purpose of which was to be as forensically accurate as possible. In terms of the prehistoric footprint data it is not significant that there is age overlap due to the many variables that can affect the formation of a footprint. An approximate age is all that is expected from the footprint data, however this data can still indicate the presence of young children.

Adolescents aged between ten and 15 years were found to have a large range in footprint size. The smallest footprint made by an adolescent was from a ten-year-old female, 137cm tall (4’5”), 34.8kg and a size two shoe, this child had an average footprint length of 20.8cm from the six footprints that she made. The largest footprint made by a female child was made by an 11-year-old, she was 159cm (5’2”) tall and weighing 47kg, she wore a size five shoe and had an average footprint size of 27.2cm from a trail of four footprints. The largest male footprint made by a child was made by a 12-year-old, who was 160cm (5’2”) tall, 44kg and wore a size nine shoe; he had an average footprint size of 27.5cm from six footprints.

Table 6.3 shows the similarity between pubescent child and adult footprint lengths. There is overlap between adult females and children, as well as adult females and males, which makes accurate identification of adult female footprints problematic. There were however certain length footprints that were found to be more likely to belong to adult females than children or adult males. 63% of adult females from the modern footprint data had an average footprint length of 22-24cm, 56% of children aged ten to 15 years old had a similar footprint length average. No adult males made a footprint trail with an average footprint length of under 24cm. Footprints between 25cm and 26cm were problematic as 28% of children aged ten to 15 years, 32% of adult females and 32% of adult males had this average footprint length. Footprints above 27cm in length were more likely adult male as only 11% of children aged between ten to 15 years had an average footprint length of 27cm, and only 5% of adult females had an overall average footprint length of 27cm. 68% of males had an average footprint-length of 27cm or over. None of the children or adult females had an average footprint length of over 28cm.

Within the experimental study it was found that adult females were most likely to have footprints with a length of 23-25cm. The archaeological data, however, cannot be identified with absolute certainty as adult instead of child in origin as there is too much similarity in footprint size between adults and pubescent children. Large footprints can be identified as adult male. The results were from a small dataset; if a larger number of individuals was included then more patterns may have been seen concerning the difference between the length of an adult female footprint and children or adult males when walking upon clayey silt sediment. The results from this small dataset already demonstrate certain patterns in footprint sizing for females as opposed to males.

Footprint length (cm)	**Age (years)**	**UK shoe size (Clarks)**
<15	4 or younger	Children's 7.5
15 to 18	5.5 +/- 1.5	Children's 7.5 to 11.5
18 to 19	6.5 +/- 1.5	Children's 11.5 to 13
<20	10 or younger	1
21	10 +/- 1	2
> 22	Over 10 or adult female	3 to 5.5
>24	Over 10 or adult	5.5 to 10
>30	Adult male	12.5

Table 6.2 Modified version of Table 5.7, demonstrating the relationship between footprint length, age and shoe size

Footprint Length (cm)	**Percentage of children (10 -15 years old)**	**Percentage of adult female**	**Percentage of adult male**
<22	5%	0%	0%
22	22%	13%	0%
23	17%	21%	0%
24	17%	29%	0%
25	22%	21%	11%
26	6%	11%	21%
27	11%	5%	32%
28	0%	0%	21%
29	0%	0%	7%
30+	0%	0%	8%
Total	100%	100%	100%

Table 6.3 The percentage of average footprint length, data from 19 modern children aged between ten to 15 years old, compared to 57 adult female and 29 adult male. The data shows the overlap in footprint length between pubescent children, adult females and males, it also highlights the likelihood of a large footprint (over 27cm) being male.

The Mesolithic footprint-track data (Table 6.4 and Table 6.5) indicate that there were children present at Site C/E, possibly as young as four years old (2015:118). Of the 12 footprint-tracks that were well-preserved enough to observe identifiable features (hallux, arch, heel etc.), four of these were made by children aged ten or under, one was made by a child likely aged 10 +/-1 and seven of these footprint-tracks were made by pubescent children aged over ten or adults.

Footprints made by children can aid in identifying age, but there is not an accurate method to determine the sex of a child through footprints made in clayey silt sediment (Table 6.5). Attempts were made in Chapter 5 to sex children through their footprints, however results indicated that children were too variable to establish sex, with growth rates likely influenced by diet, levels of activity, and genetics. Although there is crossover between the foot sizes of adult males and females, large footed adult males can be distinguished due to the size of their footprints. The 3 footprint-tracks measuring 30cm in length are likely to have been made by males; of the modern human footprint database made up of 57 adult females only one (< 2%) individual made one footprint 30cm in size and this individual was tall, with a height of 173 cm

(5’8”) and wore a size eight shoe. This individual made three other footprints which were between 26.5cm and 26.8cm in length, suggesting slippage occurred.

Footprint-track number	**Probable age range (years)**	**Footprint-track length (cm)**	**UK Shoe Size (Clarks)**
2015:88	10 or younger	20	1
2015:106	Adult	30	12.5
2015:107	Adult	30	12.5
2015:114	Adult	26	8
2015:115	Adult	26	8
2015:116	10 +/- 1	21	2
2015:117	10 + or adult female	23	4.5
2015:118	5.5 +/- 1.5	17	Children’s 10.5
2015:119	Adult	30	12.5
2015:127	10 to adult	25	6.5
2015:131	10 or younger	20	1
2016:71	6 +/- 1.5	18	Children’s 11.5

Table 6.4 Estimated age, footprint-track length and UK shoe size of prehistoric footprint-tracks from Site C/E

Footprint-track number	Sex	Footprint-track length (cm)
2015:88	Child of either sex	20
2015:106	Adult male	30
2015:107	Adult male	30
2015:114	Adult of either sex	26
2015:115	Adult of either sex	26
2015:116	Child of either sex	21
2015:117	Pubescent child or adult female	23
2015:118	Child of either sex	17
2015:119	Adult male	30
2015:127	Pubescent child or adult	25
2015:131	Child of either sex	20
2016:71	Child of either sex	18

Table 6.5 Estimated sex of individuals from Site C/E

6.5.11 Stature estimates

Once an understanding of the age and possible sex of a prehistoric person is established, this information can then be applied to the regression equations created in Chapter 5.4.2 to understand the stature of these people. Individuals ranged in height from 111.4cm to 189.3cm (Table 6.6), this is not unexpected considering adult males and young children made some of these footprint-tracks. Three of the people were likely to have been tall, between 188.4cm and 189.3cm; males who would be considered tall within Britain today. Unfortunately, there was not a clear footprint-track trail made by these individuals so their speed of movement could not be determined. There was however speed of movement established from the footprint-tracks of a child and an adult of unknown sex.

Footprint-track number	Footprint-track length (cm)	Footprint side	Estimated stature with footprint equation (cm)	Height (feet and inches)	Standard error (cm)
2015:88	20	Right	124.6	4’1”	8.12
2015:106	30	Left	188.4	6’2”	8.3
2015:107	30	Left	188.4	6’2”	8.3
2015:114	26	Right	172.1	5’7”	7.3
2015:115	26	Left	172.1	5’7”	7.3
2015:116	21	Right	150.6	4’11”	7.3
2015:117	23	Left	159.2	5’2”	7.3
2015:118	17	indistinct	111.4	3’7”	8.59
2015:119	30	indistinct	189.3	6’2”	7.3
2015:127	25	Left	167.8	5’6”	7.3
2015:131	20	indistinct	124.2	4’0”	8.59

Table 6.6 Estimated heights of prehistoric individuals from Site C/E, the standard error relates to the heights of the individuals

6.5.12 Speed of movement

Only four footprint-tracks recorded during 2014-2017 from Site C/E were part of a clear trail. There were two footprint-tracks in two different trails, which allowed the speed of movement to be established by utilising the equations created by Dingwall *et al*. (2013).

Footprint-track number	Footprint-track length average (cm)	Stride (cm)	Walking (meters per second)	Running (meters per second)	Walking and running (meters per second)
2015: 114 to 2015: 115	26	180	1.69	2.2	1.9
2015: 116 to 2015: 117	22	84	0.77	0.93	0.4

Table 6.7 Speed of movement estimated utilising footprint-track trails from Site C/E, calculated using equations from Figure 5.25 (Dingwall et al. 2013).

Table 6.7 shows the estimated speed for two individuals. It is likely that the person who made footprint-tracks 2015:114 and 2015:115 was jogging or walking at a very quick pace. They were approximately 172.1cm (5’7”) tall and may have been either sex. The arch of the foot was the most prominent feature in these footprint-tracks. When habitually unshod people run, it is often on the forefoot or midfoot rather than the hindfoot (Perl *et al*. 2012) however these footprint-tracks displayed evidence of the arch of the foot, which suggests that the individual modified their movement due to the substrate they were stepping on, or that they were walking at a very quick pace. They would have been travelling at approximately 8km per hour (5mph); an average person at a relative walking pace travels approximately 5 to 6km per hour (3 to 4mph). It is unlikely that they were running due to the depth and footprint-track appearance, though they may have been slowly jogging on unstable sediment.

The hunter-gatherer who made footprint-tracks 2015:116 and 2015:117 was probably a pubescent child or a small adult female, with stature ranging between 150.6cm to 159.2cm (between 4’11” and 5’2”). They were not running or moving quickly, in keeping this pace they would travel only 3km per hour (2mph). This is also indicated by the deep hallux marks; when running it is unlikely that a person will curl their toes. This individual was walking at a very slow pace, the deep hallux marks, prominent heel and arch of the foot may suggest that they were carrying something heavy. They may also have been walking slowly due to the sediment, perhaps this was wet or soft resulting in a slower pace to remain stable.

6.5.13 Direction of movement

Figure 6.17 shows the location of the footprint-tracks recorded on Site C/E. During fieldwork the orientation of the footprint-tracks was noted to identify the direction in which the footprint-tracks were heading. The most common direction of movement was seen in nine (50%) footprint-tracks heading west/north-west, between 226° west and 340° west of north, towards Goldcliff Island. A further two (11%) footprint-tracks were orientated north, at 18° and 30°, three (17%) were heading east-north-east away from Goldcliff Island, at between 42° and 82°, and one (5%) was orientated south-east at 150°; this would take this person out towards the sea. Although identifiable as human footprint-tracks, three (17%) were poorly preserved and so the direction of movement for these could not be accurately established. The footprint-tracks recorded at Site C/E were moving in a northerly direction, rather than to the south, with only one footprint-track identified as orientated in a southerly direction.

The direction of movement of the footprint-tracks may provide an insight into specific resources the people were exploiting, or the different areas of activity. This may also provide an understanding of changes in patterns of behaviour over time when compared against other footprint areas.

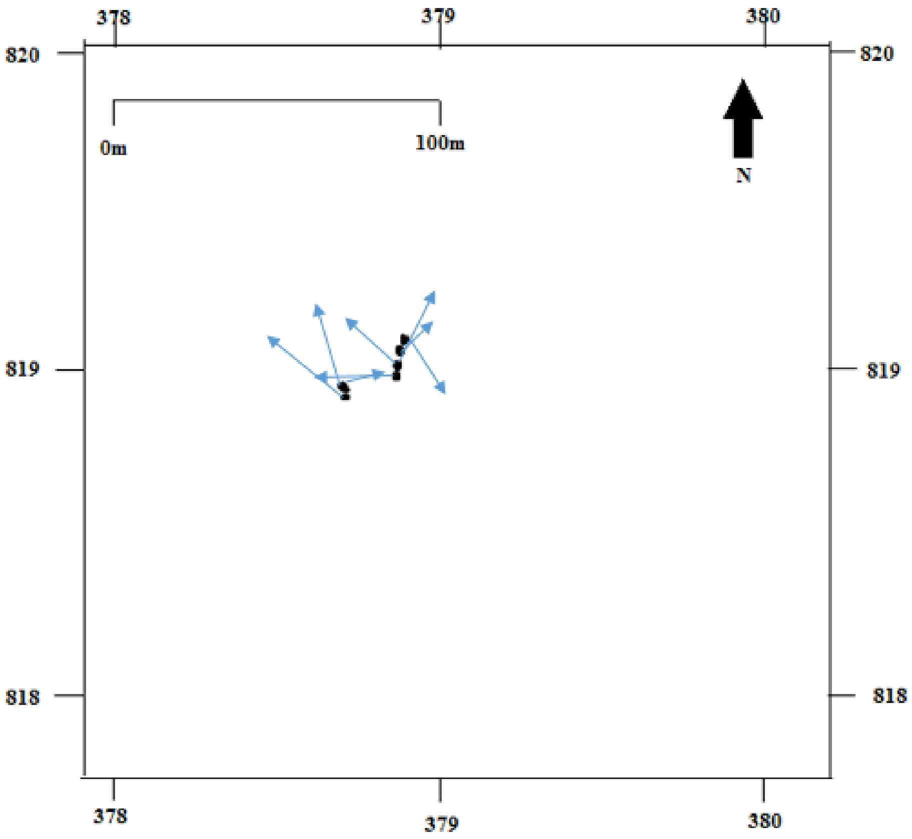


Figure 6.17 Direction of movement of the human footprint-tracks recorded during 2014-2016 from Site C/E. Black symbol represents where the footprint-tracks were discovered and the arrows indicate their direction of movement. Accuracy of location was within 3m using hand held GPS, direction was recorded with a compass

6.6 Site M footprint-tracks

Site M was discovered in 2010 and studied between 2010-2016. This area is older than Site C/E; it is further south, *c* 70m south-west, and multiple laminations lower, between -4m -4.8m OD. Due to its location, it is only exposed on low spring tides less than 0.8m chart datum. Unlike Site C/E, the formation or preservation of the footprints were poor, with overtrace/undertrace footprint-tracks being all that has been preserved in this area. Site M was eroded with linear erosion gullies separating ridges of laminated sediments with footprint-tracks exposed in plan on their surfaces (Figure 6.18). The pattern of erosion made this area easy to clean by utilising the outgoing tide (Figure 6.19), and clean areas made the localised disturbances within the laminations straightforward to see, however the footprint-tracks were poorly preserved.

Figure 6.18 Site M topography. Photograph was taken looking southwards towards the retreating tide. The two pins seen in the foreground of the picture are where footprint-track 2014:308 (to the left) and footprint-track 2014:310 (to the right) were recorded.

Figure 6.19 Professor Martin Bell using buckets of water from the retreating tide to attempt to wash the sand and mud off Site M5 laminations

6.6.1 Brief analysis of 2010-2014 fieldwork results from Site M

Sporadic fieldwork was undertaken at Goldcliff East during the period of 2010-2014, led by Professor Martin Bell with the University of Reading. Sites M and N were discovered during this fieldwork period. The footprint-tracks in this area were fairly poor, and mainly overtraces/undertraces.

Within Site M there were 55 poorly preserved footprint-tracks recorded between 2010-2016, with 12 of these recorded by the writer during 2014-2016. These 12 will be the focus of the Site M analysis as they were recorded by the author, however the other footprint-tracks will also be discussed briefly to put the whole area into context.

There were 47 footprint-tracks recorded at Site M during the period of 2010-2014. 43 were human, and there were also three areas with bird footprints and one possible ungulate. Table 6.8 presents the data for the footprint-tracks recorded during 2010-2014. These footprint-tracks were predominately recorded utilising standard photography, planning and tracing the footprint area, as well as occasional casting. The issue with tracings is that they are open to interpretation, with different people including different details; therefore it was not accurate for those who did not make the tracing to take metric measurements directly off of the tracings. They still indicate an abundance of human footprint-tracks in an area and the direction of travel for these individuals, even if the age, sex, height and speed of movement cannot be established. Figure 6.20 demonstrates the abundance of footprint-tracks in Site M, and the directions in which they were moving. Appendix 3.2 shows a plan of Site M, and its relationship to Site R, O and S. Metric measurements were recorded for only one out of the six footprint-track trails, allowing the author to estimate the age, sex, height and speed of movement of the creator of footprint-tracks 2010:1-5 (Table 6.8). This person was approximately 161.3cm tall (5’3”) and their age and sex were not identifiable, though the speed they were moving at was established as being a fast walking speed, 7.6k per hour (4.38mph). This is faster than a normal walking pace, especially in a saltmarsh environment, where the ground can be soft and uneven.

Footprint-track number	**Footprint-track length (cm)**	**Pace length (cm)**	**Stride length (cm)**	**Direction of movement**	**Part of clear trail**	**Number of footprints in trail**	**Trail number**
2010:1	28	-	-	233° west south west	yes	5	1
2010:2	23	28	-	233° west south west	yes	5	1
2010:3	36	14	-	233° west south west	yes	5	1
2010:4	23	32	60	233° west south west	yes	5	1
2010:5	20	26	40	233° west south west	yes	5	1
2010:21	21	-	-	235° south west	no	-	-
2010:22	27	-	-	235° south west	no	-	-
2010:23	24	-	-	235° south west	no	-	-
2010:24	21	-	-	235° south west	no	-	-
2010:25	21	-	-	235° south west	no	-	-
2010:26	23	-	-	235° south west	no	-	-
2010:27	26	-	-	235° south west	no	-	-
2010:28	10 (heel only)	-	-	235° south west	no	-	-
2010:29	12 (heel only)	-	-	235° south west	no	-	-
2010:30	20	-	-	235° south west	no	-	-
2010:31	-	-	-	235° south west	no	-	-

2010:46	-	-	-	270° west	no	-	-
2010:48	16	-	-	245° west south west	yes	6	2
2010:49	-	-	-	232° south west	yes	6	2
2010:50	22	-	-	232° south west	yes	6	2
2010:51	22	-	-	238° south west	yes	6	2
2010:52	28	-	-	238° south west	yes	6	2
2011:138	-	-	-	180° south	no	-	-
2011:139	-	-	-	268° west	no	-	-
2011:150	-	-	-	250° west south west	yes	6	2
2011:151	-	-	-	195° south	no	-	-
2011:152	-	-	-	190° south	no	-	-
2011:153	-	-	-	250° west south west	yes	2	3
2011:154	-	-	-	250° west south west	yes	2	3
2011:155	-	-	-	240° west south west	no	-	-
2011:156 probable ungulate	-	-	-	-	-	-	-
2011:157	-	-	-	185° south	no	-	-
2011:158	-	-	-	266° west	no	-	-
2011:159	-	-	-	210° south south west	yes	2	4
2011:160	-	-	-	210° south south west	yes	2	4
2011:162	-	-	-	230° south west	no	2	5
2011:163	-	-	-	230° south west	no	2	5

2011:160a	-	-	-	240° west south west	yes	6	6
2011:161	-	-	-	240° west south west	yes	6	6
2011:162	-	-	-	240° west south west	yes	6	6
2011:163	-	-	-	240° west south west	yes	6	6
2011:164	-	-	-	240° west south west	yes	6	6
2011:165	-	-	-	240° west south west	yes	6	6

Table 6.8 Data from footprint-tracks from Site M, recorded 2010-2014. Missing data is due to a lack of complementary metric measurement data to accompany the tracings

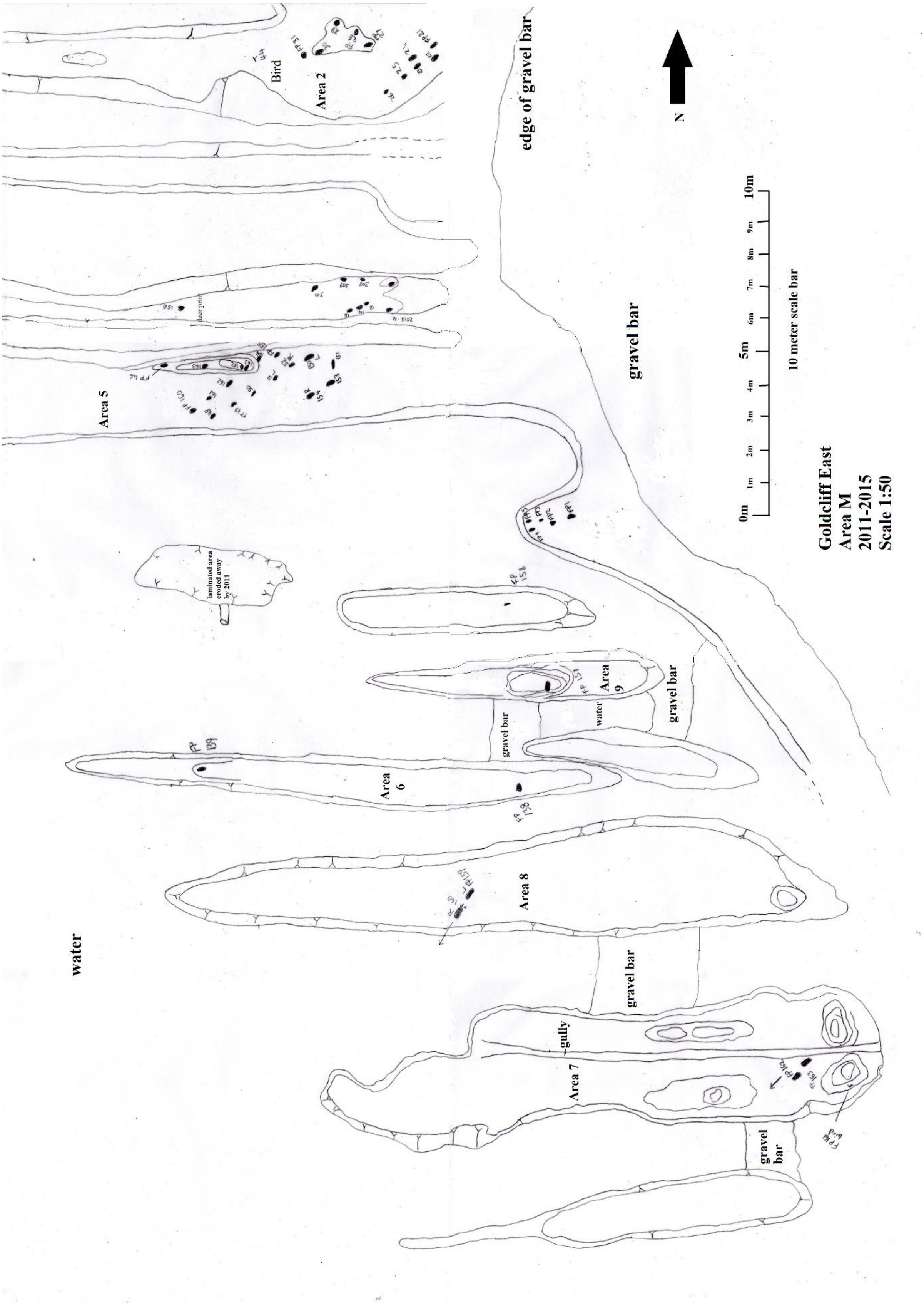


Figure 6.20 Plan of Site M, 2011-2015. Plan made by J.Foster and M.Bell and digitised by author

Footprint-track number	**Age range (years)**	**Average height (cm)**	**Average height (feet and inches)**	**Foot length average (cm)**	**British shoe size**	**Walk speed (meters per second)**	**Run speed (meters per second)**	**Direction of movement**	**No. of footprint-tracks in trail**
2010:1-5	Adult	161.3	5’3”	26	8	1.96	1.92	233° west south west	5

Table 6.9 Speed of movement of individual 2010:1-5

6.6.2 Analysis of Site M footprint-tracks 2014-2016

Although all Site M footprint-tracks were overtraces or undertraces, several had clear features of the foot still evident, such as heel or hallux, which meant they could be identified as human. Others were in clear trails formed by an obvious left-right-left-right human gait, enabling identification even when morphological features were lacking. The footprint-tracks ranged in length from 13cm to 33cm and 8cm to 14cm in width (Table 6.10). The footprint-tracks were all made on similar lamination layers and were within less than 37m of one another.

Footprint-track number	Site	Length (cm)	Width (cm)	Identifying features?	Left or Right?	Direction of movement
2014:308	M	22	10	Overtrace	Right	230° south west
2014:309	M	17.5	11	Overtrace, either a human heel or animal print	Indistinct	230° south west
2014:310	M	18	10.5	Overtrace	Left	230° south west
2015:12	M	25	16	Overtrace	Indistinct	220° south west
2015:13	M	13	8	Overtrace, heel or animal print	Indistinct	220° south west
2015:14	M	23	9	Overtrace	Indistinct	220° south west
2015:15	M	18	10	Overtrace	Indistinct	220° south west
2015:53	M	23.4	16	Overtrace, arch evident	Left	320° north north west
2015:54	M	33	14	Overtrace, arch evident	Right	320° north north west
2015:160	M	25	11	Overtrace	Left	230° south west
2015:163	M	23.5	8.5	Overtrace, clear hallux	Left	230° south west
2016:67	M	22	10.5	Overtrace	Right?	Possibly heading towards island, 230° south west

Table 6.10 Data of footprint-tracks from Site M 2014-2016

6.6.3 Description: footprint-tracks 2014:308, 309, and 310

During fieldwork in November 2014, three human footprint-tracks were recorded at Site M5a (Figure 6.20). The footprint-tracks were assigned numbers 2014:308, 2014:309 and 2014:310. They were on a similar lamination and orientated 230° south-west towards Goldcliff island. These footprint-tracks were all overtraces/undertraces. 2014:308 was the most convincing of the three footprint-tracks (Figure 6.21). Although an overtrace/undertrace it was evidently a right footprint-track, the heel was slightly more eroded that the rest of the footprint, and the arch of the footprint was also evident. There were not any interdigital ridges. Footprint-track 2014:308 was block-lifted in the field and taken back to the laboratory for micro-excavation. Footprint-track 2014:309 was an incomplete footprint-track, indicating either the ball and the toes or the heel of the foot. It was an overtrace/undertrace and was identified as human although there was not a full human footprint-track, so it may have been made by a large ungulate that crossed the human footprint trail (Figure 6.22). Footprint-track 2014:310 was an overtrace/undertrace of a left human footprint. The heel and arch of this overtrace were well formed, though there was not any evidence of a hallux or interdigital ridges (Figure 6.23). The discovery and recording of these footprint-tracks was filmed by a camera crew for a BBC Horizon documentary, ‘First Britons’.

An Optically Stimulated Luminescence sample was collected from the east end of footprint-track 2014:310 and provided a date of 8890+/- 790 years before 2017 (GL16185) (Full details in Appendix 1.2).

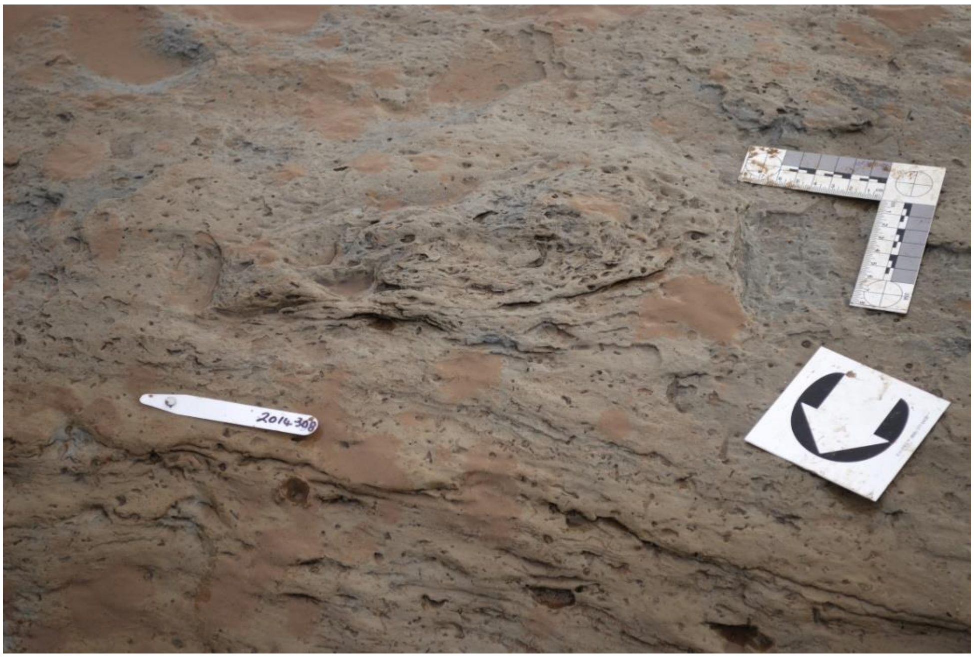


Figure 6.21 Footprint-track 2014:308

Figure 6.22 Footprint-track 2014:309

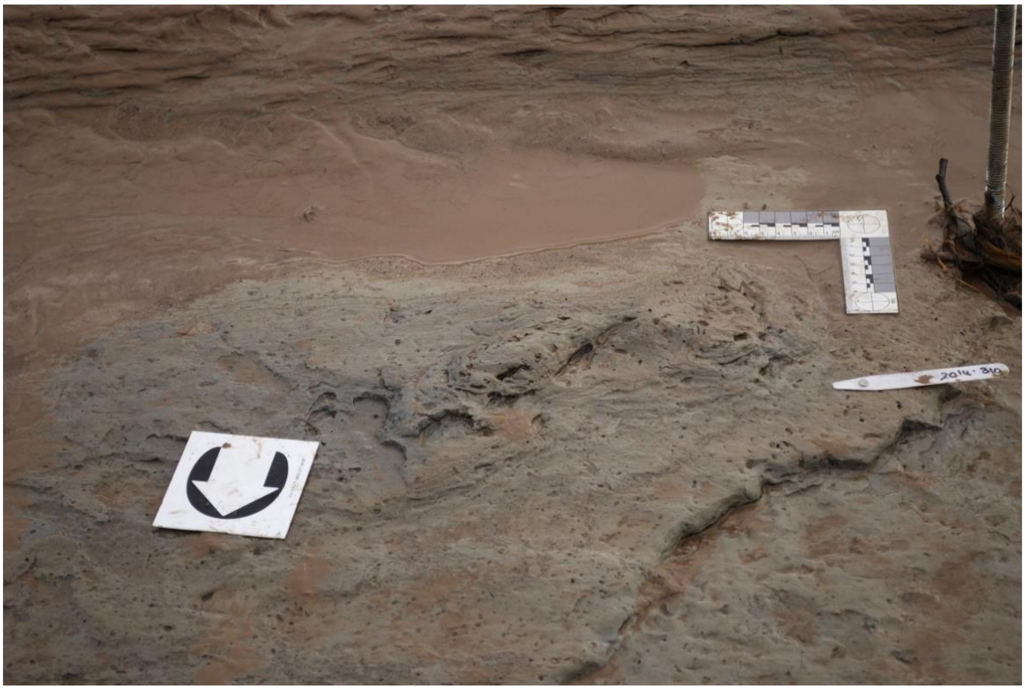


Figure 6.23 Footprint-track 2014:310

6.6.4 Description: footprint-tracks 2015:12, 13, 14 and 15

Site M5a was revisited on 19.4.15 (Figure 6.20), where four human footprint-tracks were noted, 2015:12, 2015:13, 2015:14 and 2015:15. These were found 1m south of the 2014:308-310 trail described above. All of these footprint-tracks were overtraces/undertraces. They were all on the same lamination and possibly from the same individual, moving south-west 220° towards Goldcliff Island. Footprint-track 2015:12 was a human left footprint-track, almost the entirety had eroded and it was at the same level as the surrounding lamination (Figure 6.24). It was revealed primarily through the appearance of the sediment, which was slightly darker than the surrounding lamination. The shape was that of a footprint, though there was no evidence of any interdigital or marginal ridges. This footprint-track was recorded with multi-image photogrammetry, where the features were more easily identifiable once processed; the hallux could be seen in the model (Figure 6.25 and 6.26). Attempts were also made to micro-excavate 2015:12, using wooden tools and fingertip excavation (Scales 2006). The level of the footprint could not be found, which indicates that this was likely an undertrace.

Footprint-track 2015:13 was an overtrace/undertrace of a human footprint, it may have been a left footprint but it was not well formed/preserved (Figure 6.27). There was no evidence of individual toes or interdigital ridges. The heel of the foot was at the same level as the surrounding lamination, like footprint-track 2015:12. The front of the foot was a higher level than the surrounding lamination, indicating that the front and mid part of the footprint likely went deeper into the sediment than the heel, which suggests soft sediment was walked upon.

Footprint-track 2015:14 was again a poorly formed/preserved human footprint-track (Figure 6.28). This footprint-track was similar in formation to 2015:13, with the heel at the same height as the surrounding lamination, and the mid and front foot higher than the lamination.

Footprint-track 2015:15 was the poorest of the footprint-tracks in this possible trail, poor preservation or formation meant that no identifiable features of this footprint remained and it could not be determined if it was made by a left or right foot (Figure 6.29). These footprint-tracks were most noticeable due to the disturbance caused by the footprint in the lamination, rather than footprint-track features. If they were seen in a trail they would be more convincing; although these footprint-tracks all had a similar direction of movement they were very close together, some less than 10cm apart, so cannot really be considered a trail.

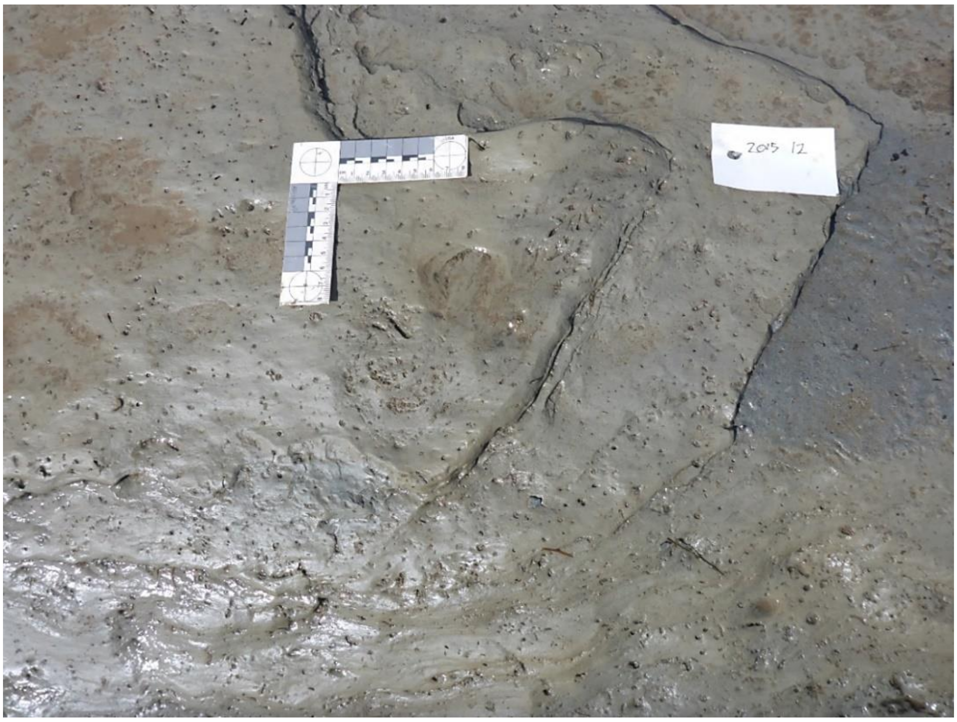


Figure 6.24 Footprint-track 2015:12

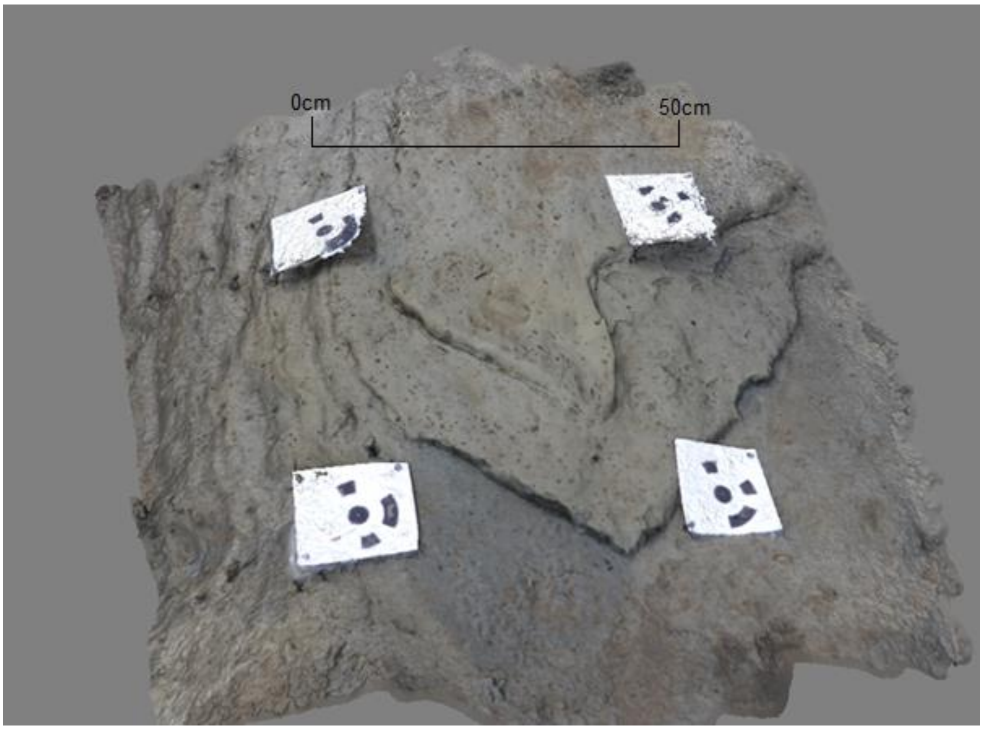


Figure 6.25 Point cloud model of footprint-track 2015:12. Note that two laminations down from the footprint-track lamination there is the distinct impact of raindrops in an area which had clearly just been exposed by a lamination breaking off just before the photo was taken

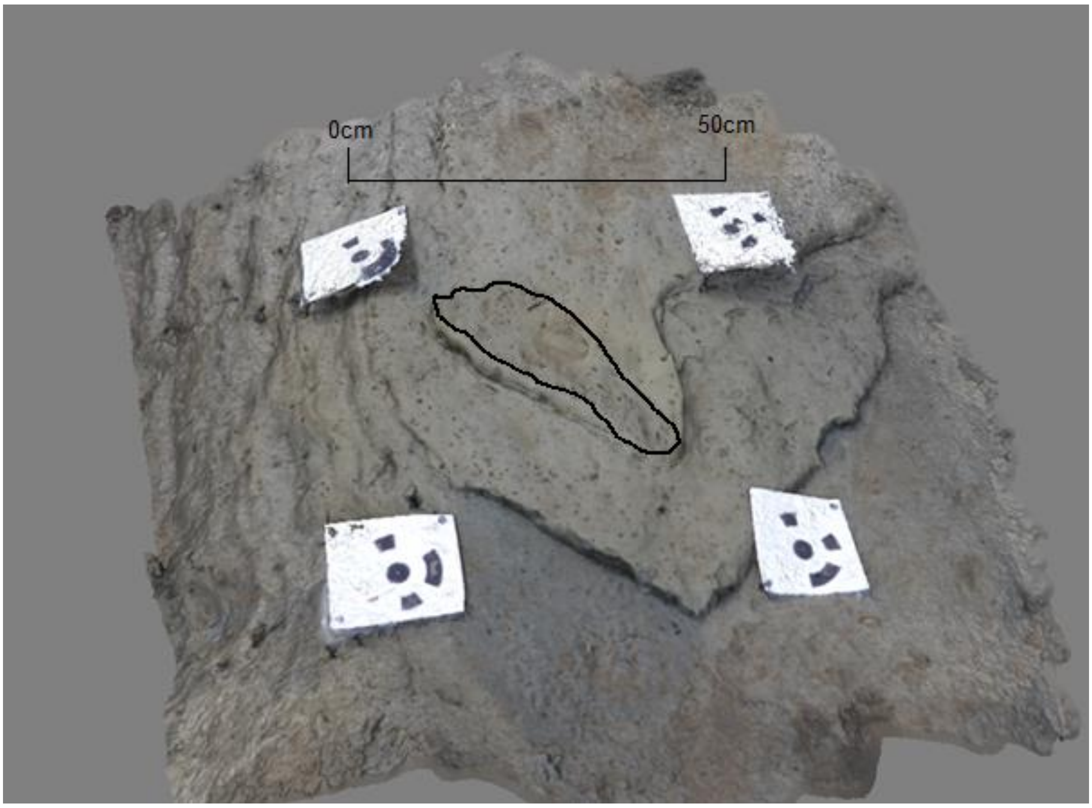


Figure 6.26 The outline of footprint-track 2015:12, this footprint-track was difficult to see in a standard photograph (Figure 6.24) but clear on the point cloud model (Figure 6.25)

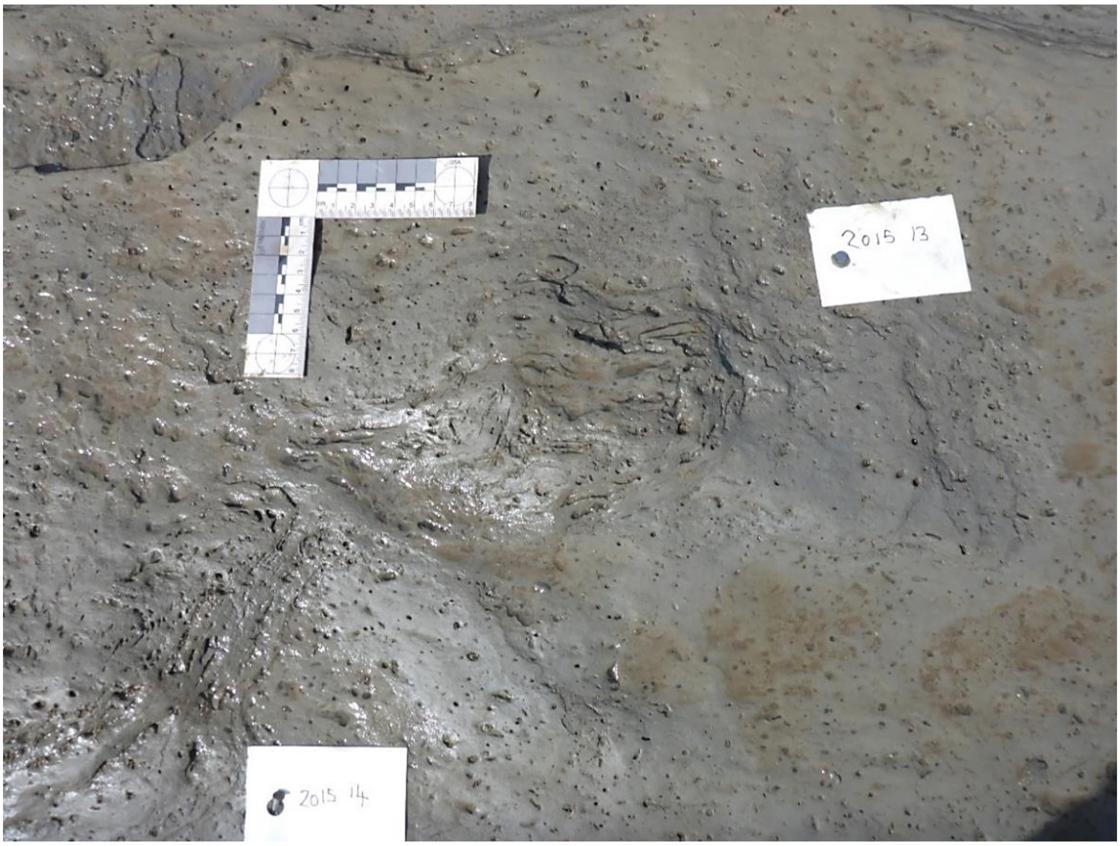


Figure 6.27 Footprint-track 2015:13

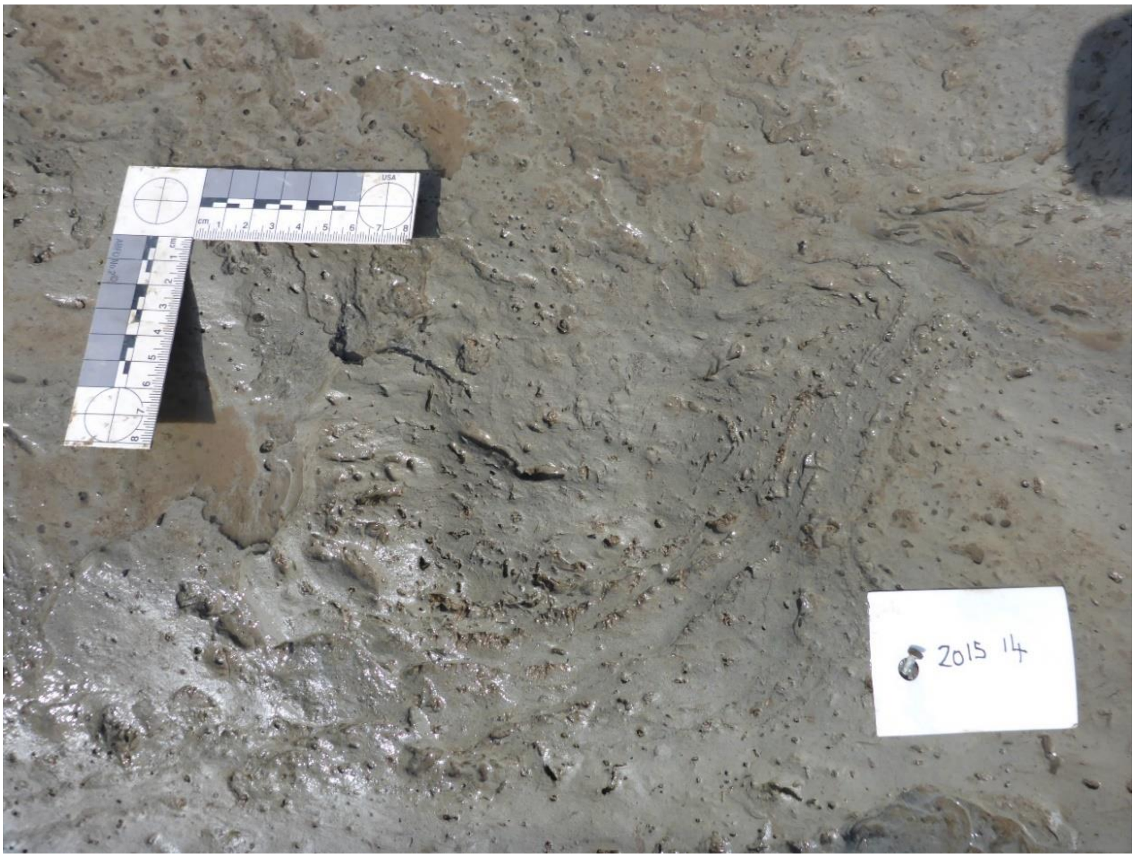


Figure 6.28 Footprint-track 2015:14

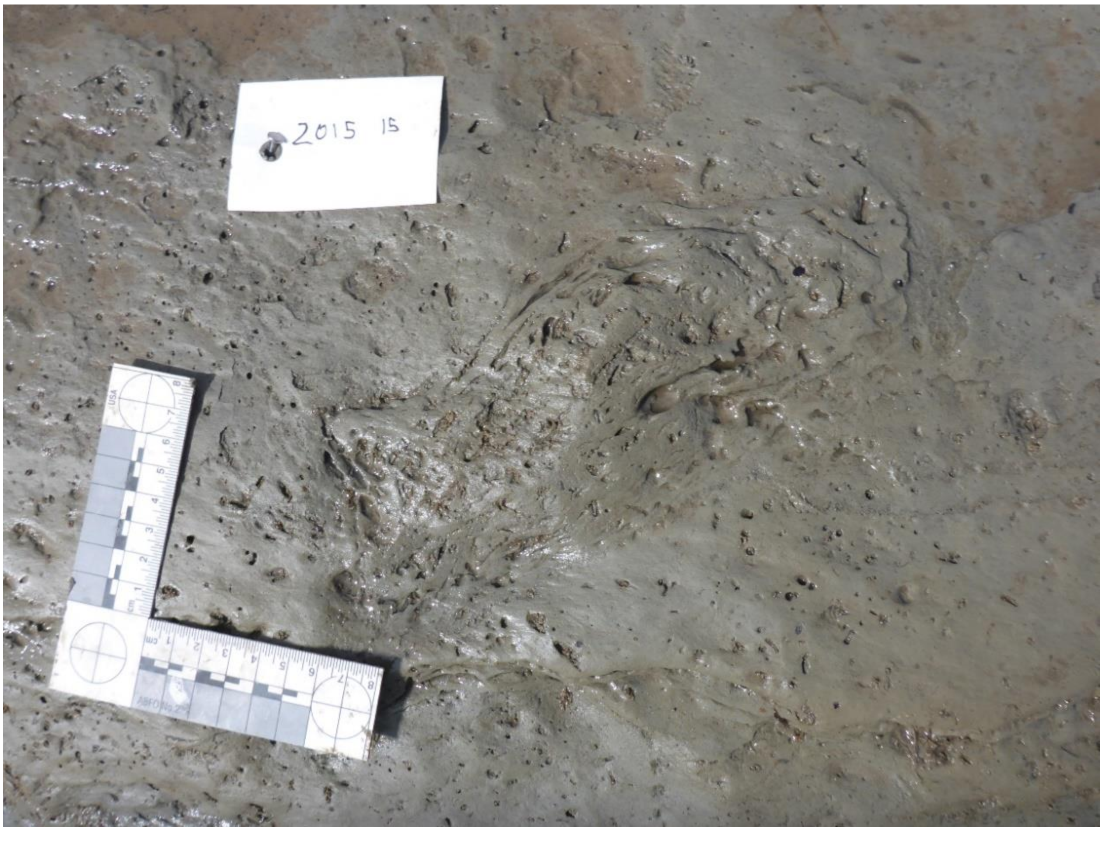


Figure 6.29 Footprint-track 2015:15

6.6.5 Description: footprint-track 2015:53 and 2015:54

Further fieldwork was undertaken on Site M5a on 18.5.15, with footprint-tracks discovered on the same laminated area, less than 50cm to the south of footprint-tracks 2014:308, 309 and 310. The new footprint-track, 2015:53, was a left human footprint-track overtrace/undertrace with a prominent foot arch, though no evidence of any toes of interdigital ridges were observed. The footprint-track had the appearance of a slight curve between the midfoot and hindfoot and may indicate a deformity or that the foot made impact with the sediment at an unusual angle, or that the person slipped (Figure 6.30). The footprint-track was facing the direction of Goldcliff island, 320° north-north-west.

Footprint-track 2015:54 was on the same lamination as 2015:53; this was an overtrace/undertrace of a possible right footprint. Though it was difficult to pick out any identifiable features it was evident which part was the forefoot and which the hindfoot (Figure 6.31). This footprint-track was formed/preserved in a similar way to footprint-track 2015:12-15, where the heel of the print was at the same level as the surrounding lamination, but the rest of the footprint-track bulged above the surrounding sediment. This footprint-track was almost parallel to footprint 2015:15. The footprint-track was angled 320° north-north-west.

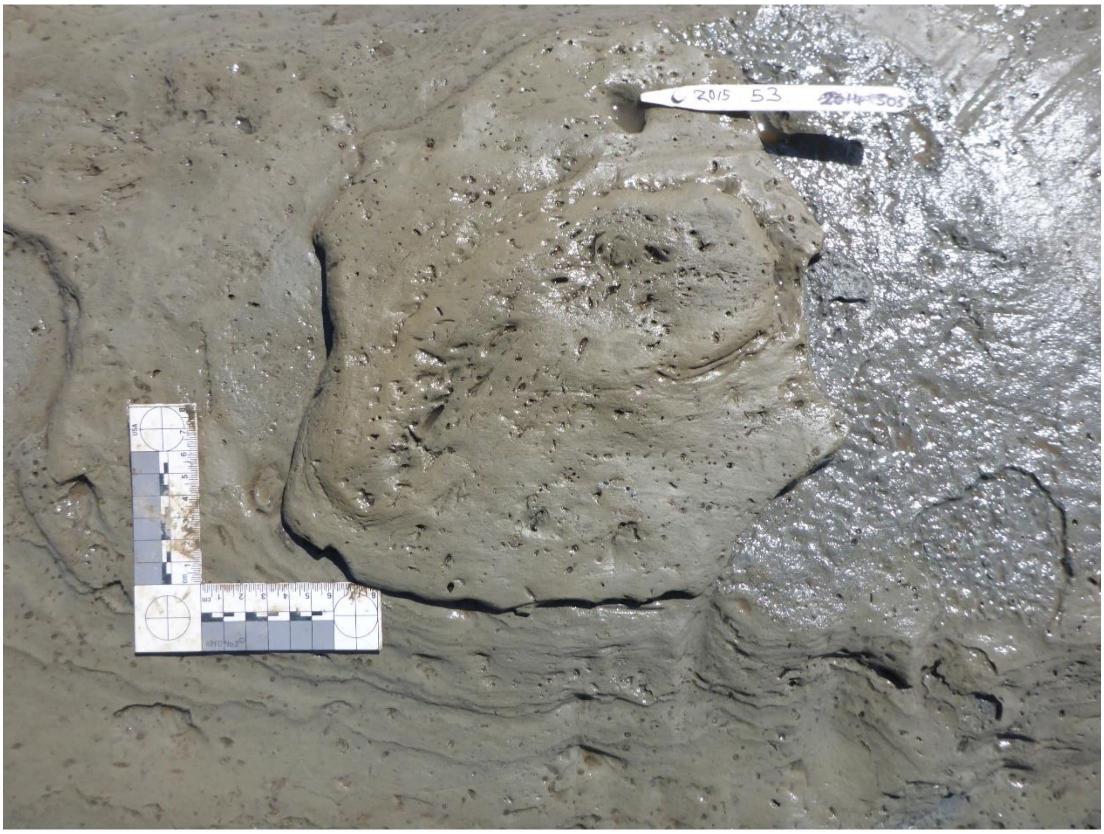


Figure 6.30 Footprint-track 2015:53

Figure 6.31 Footprint-track 2015:54

6.6.6 Description: footprint-track 2015:160 and 163

On 28.11.2015 a singular left footprint-track on a newly uncovered lamination was observed in Site M7 (Figure 6.20), this was assigned the footprint-track number 2015:160. No other footprint-tracks were observed within this area, though 2m west of 2015:160 on a thin lamination above there was another left footprint-track, evidenced from the hallux, heading 230° west towards Goldcliff Island; this was assigned the footprint-track number 2015:163. Both footprint-tracks were overtraces/undertraces. Measurements and directions of movement were recorded for the footprint-tracks, however the tide came in too rapidly to record any prominent features or take any photographs. On return this area was covered in a thick layer of sand.

6.6.7 Description: footprint-track 2016: 67

Fieldwork during 2.9.2016 uncovered three possible footprint-tracks, one was human in appearance and the others could have belonged to either a human or large ungulate. The human footprint-track was assigned the footprint-track number 2016:67 (Site M, north of planned area,

Figure 6.20), this was an overtrace/undertrace and seemed to be heading towards Goldcliff Island. Preservation was too poor to confidently identify this as a right footprint and there were not any identifiable features to assist in identification other than the overall shape and disturbance by a footprint to the lamination.

6.6.8 Analysis of Site M footprint-track data

Figure 6.32 shows the lengths and widths of the human footprint-tracks recorded at Site M, Figure 6.33 displays these footprint-tracks against the footprints recorded during the human footprint experiment (Chapter 5). By comparing the length and width of the footprint-tracks it is evident that those from Site M were similar in length to modern footprints, though they were generally wider; this is likely to be to do with the preservation of the footprints and the measuring technique. The method for footprint measuring required the widest possible point of the footprint to be measured, in situations where footprint-tracks are overtraces/undertraces they can be wider than the actual footprint. The footprint-tracks from Site M reflected similar results to contemporary humans in terms of length, and as such it is likely that the length of the footprint is a more accurate indicator due to width being influenced by formation processes and preservation.

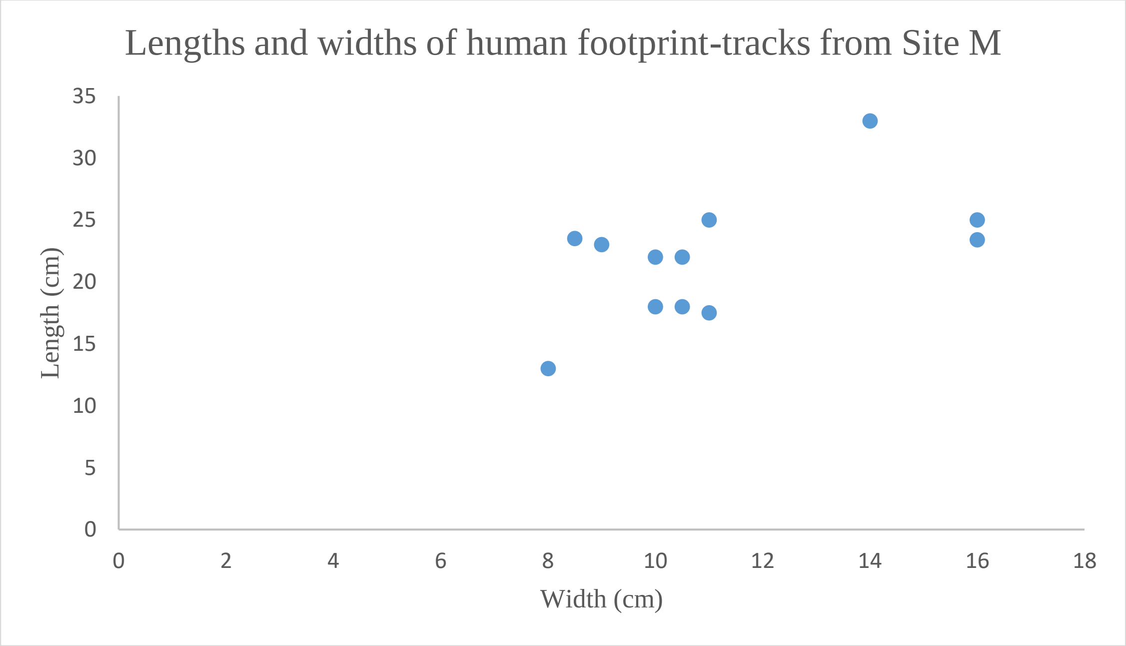


Figure 6.32 Metric measurements from Site M footprint-tracks

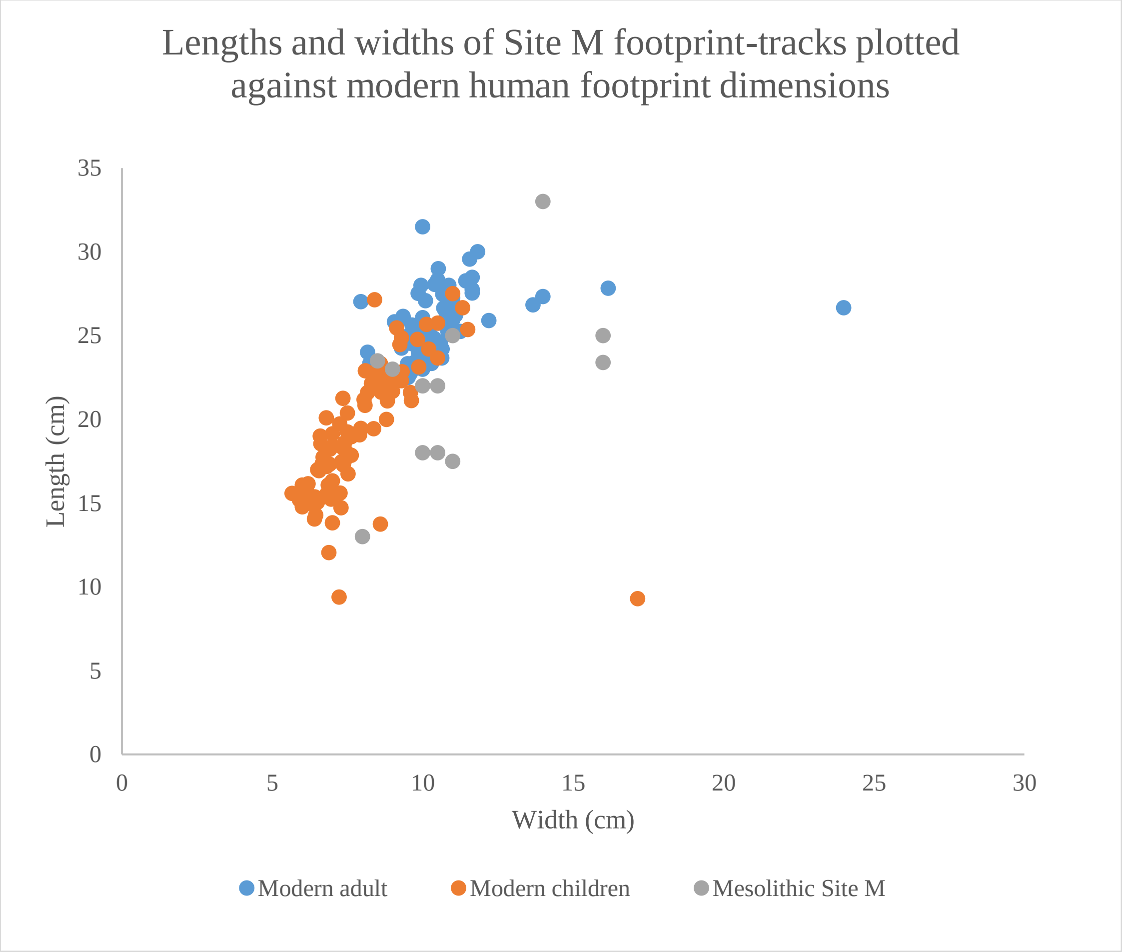


Figure 6.33 Metric footprint-track dimensions from Site M compared against modern experimental data

6.6.9 Age and sex of individuals who made footprint-tracks at Site M

The approximate age and sex of the individuals from Site M could not be established for all footprint-tracks due to preservation issues, as the full length of the footprint had not always survived (Table 6.11). The results indicate that there were children present. There were two footprint-tracks from separate areas the size of 6 +/- 1.5 year olds, seven footprint-tracks made by either pubescent children aged ten and over or adults, and one footprint-track made by a large full grown adult male (Table 6.12).

The footprint-tracks from Site M were generally small, suggestive of adult females and children, rather than adult males.

Footprint-track number	**Probable age range (years)**	**Footprint-track length (cm)**	**UK Shoe Size**
2014: 308	10+ or adult female	22	3
2014: 309	Incomplete footprint length	17.5	-
2014: 310	6 +/- 1.5	18	Children's 11.5
2015: 12	10 to adult	25	6.5
2015: 13	Incomplete footprint length	13	-
2015: 14	10+ or adult female	23	4.5
2015: 15	6 +/- 1.5	18	Children's 11.5
2015: 53	10+ or adult female	23.4	5
2015: 54	Adult male	33	15
2015: 160	10+ or adult	25	6.5
2015: 163	10+ or adult female	23.5	5
2016: 67	10+ or adult female	22	3

Table 6.11 Age range, footprint-track length and probable shoe size of Site M footprint-tracks

Footprint-track number	Sex	Footprint-track length (cm)
2014: 308	Pubescent child or adult female	22
2014:309	-	17.5
2014:310	Child of either sex	18
2015:12	Adult of either sex	25
2015:13	-	13
2015: 14	Pubescent child or adult female	23
2015:15	Child of either sex	18
2015:53	Pubescent child or adult female	23.4
2015:54	Adult male	33
2015:160	Adult of either sex	25
2015:163	Pubescent child or adult female	23.5
2016:67	Pubescent child or adult female	22

Table 6.12 Sex identification of the Site M footprint-tracks

6.6.10 Stature estimates

Estimates were made of the probable stature of the hunter-gatherers who made footprint-tracks in Site M (Table 6.13). The two children aged 6 +/- 1.5 years had a similar stature of 115.6cm (3’9”). All others were over 152cm (4’11”), the shortest of these was 154.9cm (5’0”), whilst the tallest was 198.5cm (6’6”); this individual would be considered tall in modern society, though not unusually so.

Footprint –track number	Footprint-track length (cm)	Footprint side	Estimated stature with footprint equation (cm)	Height in feet and inches	Standard error (cm)
2014:308	22	Right	154.9	5’0”	7.3
2014:309	17.5	Indistinct	Unknown as print was incomplete	-	-
2014:310	18	Left	115.6	3’9”	9.14
2015:12	25	Indistinct	167.8	5’6”	7.3
2015:13	13	Indistinct	Unknown as print was incomplete	-	-
2015:14	23	Indistinct	159.2	5’2”	7.3
2015:15	18	Indistinct	115.6	3’9”	8.59
2015:53	23.4	Left	160.1	5’3”	6
2015:54	33	Right	198.5	6’6”	8.5
2015:160	25	Left	167.8	5’6”	7.3
2015:163	23.5	Left	160.8	5’3”	6
2016:67	22	Right	156.2	5’1”	6.18

Table 6.13 Stature estimates of individuals recorded in Site M

6.6.11 Speed of movement

Speed of movement could only be established from two footprint-tracks that formed a trail, as these were the only footprint-tracks where it was clearly the same person travelling across the area (Table 6.14). There were other possible trails, however many of the footprint-tracks were indistinct so these trails cannot be accurately analysed. The maker of footprint-tracks 2015:160 and 2015:163 ranged from approximately 160cm (5’2”) to 167cm (5’5”) in height, but had a stride length of 200cm. They were travelling at approximately 10km per hour (6mph), suggesting a steady jogging speed for someone of that stature.

Footprint number	**Footprint length average (cm)**	**Stride (cm)**	**Walking (meters per second)**	**Running (meters per second)**	**Walking and running (meters per second)**
2015:160 and 2015:163	24.3	200	2	2.75	2.56

Table 6.14 Speed of movement estimated for Site M footprints

6.6.12 Site M direction of movement

The footprint-tracks recorded on Site M were predominately made by individuals heading west-south-west (Figure 6.34), of the 55 footprint-tracks recorded during 2010-2016, 45 (81%) were orientated south-west between 210° and 250°. A further three (5%) were heading west at between 266° and 270°, and two (4%) were heading 320° north-west. 4 (7%) footprint-tracks were orientated south at between 180° and 195°. There was also one individual whose orientation could not be established. The implication of the direction of movement of the footprint-tracks at Site M will be established within the discussion section of this chapter.

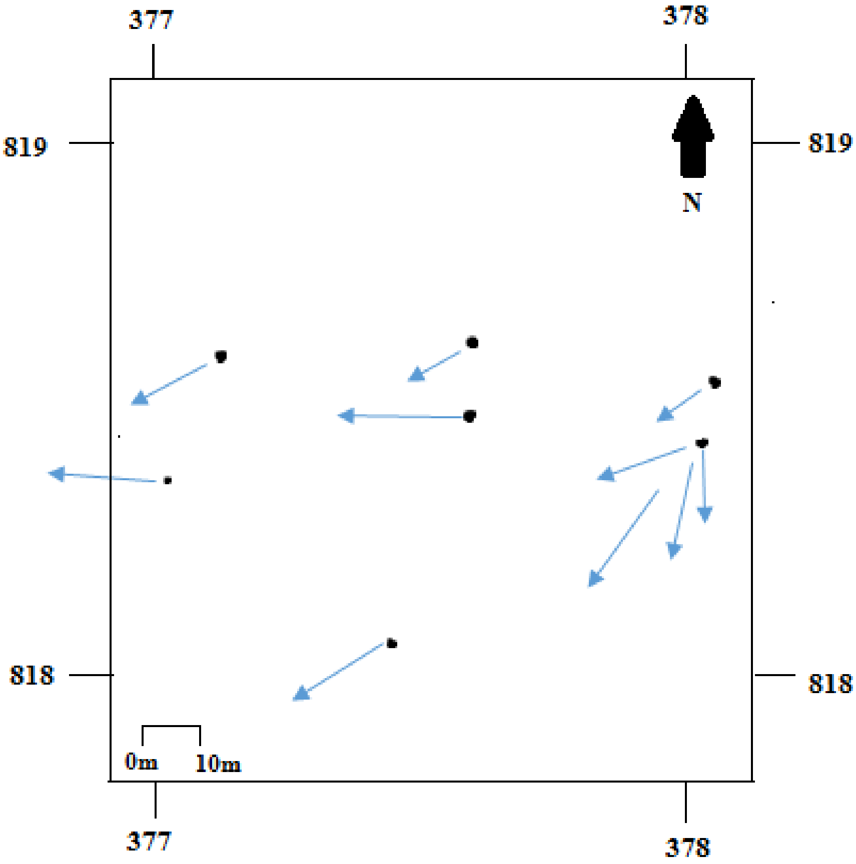


Figure 6.34 Direction of movement of footprint-tracks recorded during 2010-2016 from Site M. Black symbol represents where the footprint-tracks were discovered and the arrows indicate their direction of movement. Accuracy of location was within 3m using hand held GPS, direction was recorded with a compass

6.7 Site N footprint-tracks

Site N was located between a prominent gravel bar and an area of permanent water, even at low tide, at OD *c* -5.30m. There were areas at the edge of this gravel bar where banded laminations could be seen when the area was relatively clear of sand and mud (Figure 6.35). The preservation of footprint-tracks in this area was relatively poor, made worse by gravel drag. Site N was discovered in 2010 and studied between 2010-2016. This footprint-track area was the most southern of all the footprint areas so far recorded and was found on laminations that were covered by a gravel bar, which was occasionally shifted by the tides, allowing the underlying laminations and footprint-tracks to be observed. Due to its location, this footprint area was only accessible on the very lowest of spring tides, 0.6m chart datum or less, meaning that it was only accessible for a limited time throughout the year. The footprint-tracks from Site N were within approximately 16m by 6m of one another, but parts of this area were generally obscured by a mobile gravel spread.

Figure 6.35 Site N topography, demonstrating the closeness of the site to a large body of water as it is low in the tide table. The gullied and irregular surface of the laminations can also be seen

6.7.1 Brief analysis of 2010-2014 fieldwork results from Site N

During the 2010-2014 fieldwork, particularly between 30.8.11 and 2.9.11, footprint-tracks were found in abundance at Site N, though all were poorly formed/preserved, overtraces or undertraces and there was often little indication of anatomical detail left by the foot, e.g no evidence of toes, arches or heels. These lay within a 10x2m area, between -4.94m and -5.44m OD. There were ten human footprint-track trails that could be seen in this area, three ran north-west and seven were orientated south-east towards the sea. Unfortunately, only the western 3m of this area was traced before work was interrupted by a rapidly rising tide, since that day the area has been largely covered by mobile gravel bars. These footprint-tracks were identified as human due to the long thin shape of the footprint-tracks and the localised disturbance in the sediment. There were footprint-tracks within the sample that may have been the heel or ball of the foot preserved, or may have been ungulate in origin. Due to the time constraints of recording, the best technique at the time was to trace the footprint-tracks, to allow some idea as to the abundance, shape and appearance of any possible footprint-trails. There were three large tracings made from this footprint-track area, containing 68 possible footprint-tracks. The issue with tracings is that they are subjective. The writer did not make the tracings as they were recorded before the thesis research started, so only basic analysis of these footprint-tracks has been attempted. The exact metric dimensions of the footprint-tracks are unknown and the tracings were varied in quality, making it inaccurate to take metric measurements off a two-dimensional tracing. Despite this, these tracings are informative about the direction of movement of these individuals, whether human or ungulate. A plan of this footprint-track area, and its association to footprint-track trail 2016:50-56 can be seen in Figure 6.36. All seemingly headed in an east/south-east or north-west direction, which is similar to the footprint-tracks recorded during the 2014-2017 fieldwork. The similar direction of movement suggests these individuals were visiting a static resource on the same axis of movement, crossing Site N repeatedly, they were travelling in the direction of a palaeochannel.

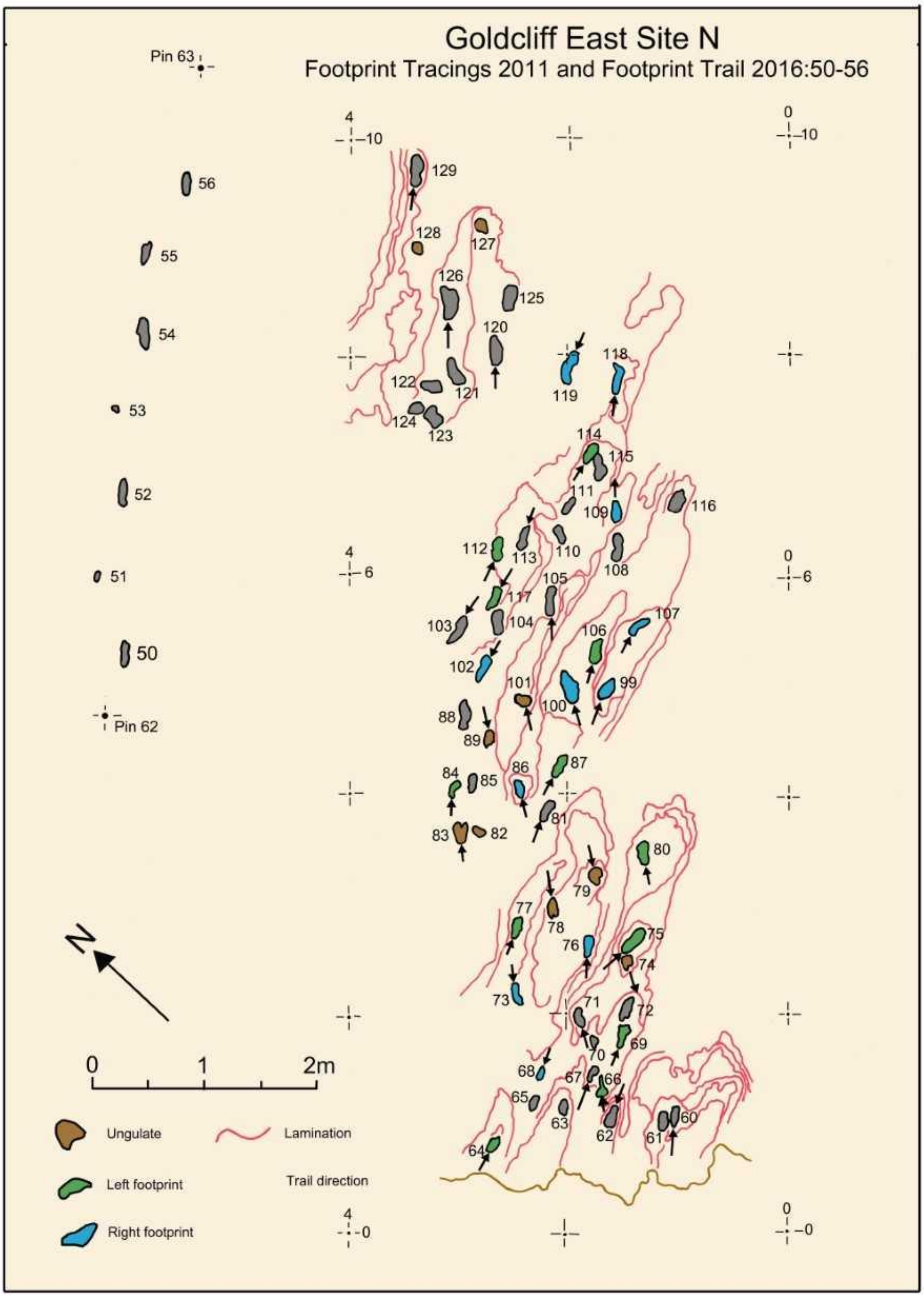


Figure 6.36 Plan of the footprint-track tracings made during 2011 fieldwork, with inclusion of the nearest footprint-track trail recorded during the current study, 2015:50-56. Plan made by M.Bell and J.Foster

6.7.2 Analysis of footprint-tracks recorded at Site N 2014-2016

Within Site N, during the thesis study period of 2014-2016, there were 35 possible human footprint-tracks recorded. Of these 35 footprint-tracks there were nine that were poorly preserved and may have been ungulate rather than human. If made by humans the appearance suggests they are likely to be the heel or ball of the foot that has remained preserved. The footprint-tracks range in length from 15cm to 33cm and 6.5cm to 15.5cm in width (Table 6.15). The footprint-tracks were made on a similar laminated surface, however the formation of the footprint-tracks, erosion from the tide and destruction from the gravel has resulted in an area full of poor examples of footprint-tracks.

Footprint-track number	Site	Length (cm)	Width (cm)	Identifying features?	Left or Right?	Direction of movement
2015:6	N	22	13.6	Overtrace	Indistinct	Indistinct
2015:7	N	21.2	10.5	Overtrace	Indistinct	Indistinct
2015:8	N	24	10.4	Overtrace	Indistinct	Indistinct
2015:9	N	16	11	Overtrace, possible human heel or animal	Indistinct	Indistinct
2015:17	N	26	13	Overtrace, arch evident	Left	60° north east
2015:18	N	25	9	Overtrace, arch evident	Right	60° north east
2015: 20	N	24	10	Overtrace, arch evident	Left	60° north east
2015:42	N	22	11	Overtrace, very unclear.	Indistinct	Indistinct
2016:15	N	26	9	Overtrace, arch and toes evident	Right	52° north east
2016: 16	N	25	9.5	Overtrace, arch, heel	Right	240° south west

				and toes evident		
2016:17	N	26	9.5	Overtrace, arch, heels and toes evident	Left	240° south west
2016:18	N	17	8	Overtrace, possible human heel or animal	Indistinct	78° east
2016:20	N	14	12.5	Overtrace, possible human heel or animal	indistinct	52° north east
2016:21	N	17	8.5	Overtrace, possible human heel or animal	Indistinct	103° east
2016:22	N	22	8	Overtrace	Left	103° east
2016:23	N	22	15.5	Overtrace, possible human heel or animal	Left	103° east
2016:24	N	21	14.5	Overtrace, possible human heel or animal	Indistinct	52° north east
2016:25	N	21.7	11.4	Overtrace, possible human heel or animal	Indistinct	52° north east
2016:26	N	26.5	9	Heel and arch evident	Right	100° east
2016:27	N	23.5	9	Overtrace, arch evident	Indistinct	65° north east

2016:28	N	21.4	8		Indistinct	65° north east
2016:29	N	15	12.5	Overtrace, more likely deer than human	Indistinct	50° north east
2016:31	N	24	8.5	Heel and arch evident	Left	78° north east
2016: 50	N	24	9	Overtrace or undertrace	Right	55° north east
2016:51	N	23	9	Deep hallux, arch of foot evident	Left	70° north east
2016:52	N	25	9	Overtrace or undertrace, arch evident	Right	50° north east
2016:53	N	24	10	Overtrace or undertrace, arch evident	Left	50° north east
2016:54	N	25	8	Overtrace or undertrace, heel evident	Indistinct	50° north east
2016:55	N	23.5	8	Overtrace or undertrace, arch evidet	Left	60° north east
2016:56	N	22	6.5	Overtrace or undertrace	Indistinct	50° north east
2016:57	N	19.5	7.5	Overtrace or	Left	55° north east

				undertrace, distinct hallux, arch and heel		
2016:58	N	22	10	Distinct hallux	Right	250° west
2016:59	N	24	10.5	Distinct long hallux	Left	70° east
2016: 60	N	23	8	Partially preserved, distinct long hallux	Left	80° east
2016:61	N	Incomplete	Incomplete	Overtrace	Indistinct	Indistinct

Table 6.15 Footprint-track data from Site N

6.7.3 Description: footprint-track 2015:6, 7, 8

During fieldwork in February 2015, four poorly preserved footprint-tracks were uncovered. At least three were human, 2015: 6, 2015:7 and 2015:8. These were identified as human from the long slender shape. Two of the footprint-tracks, 2015:6 and 2015:7, were parallel to one another. Although they were overtraces/undertraces and too poorly preserved to determine if they were made by the left or right foot, it was clear that these were human footprint-tracks (Figure 6.37 and 6.38). Footprint-track 2015:9 may have been an overtrace/undertrace of a human heel, or an ungulate footprint. The footprint-tracks caused a localised disturbance to the lamination.

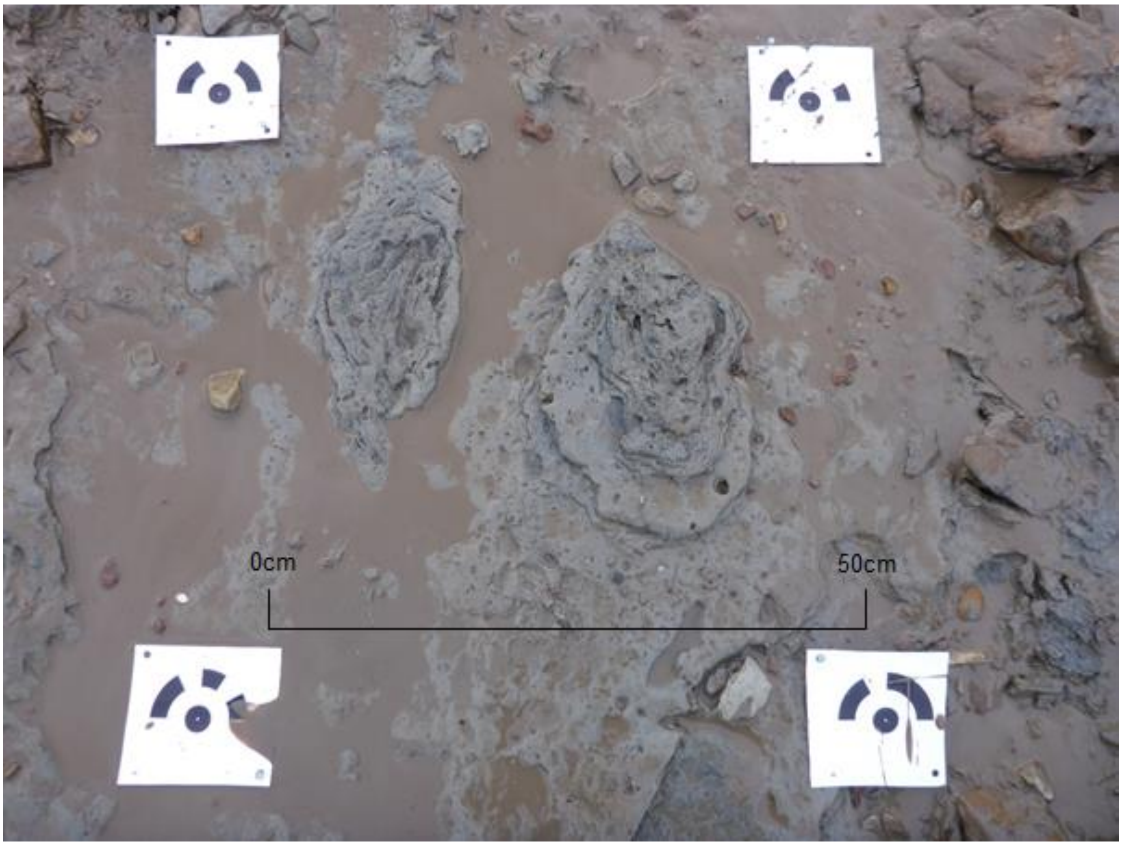


Figure 6.37 Footprint-track 2015:6 (right) and 2015:7(left)

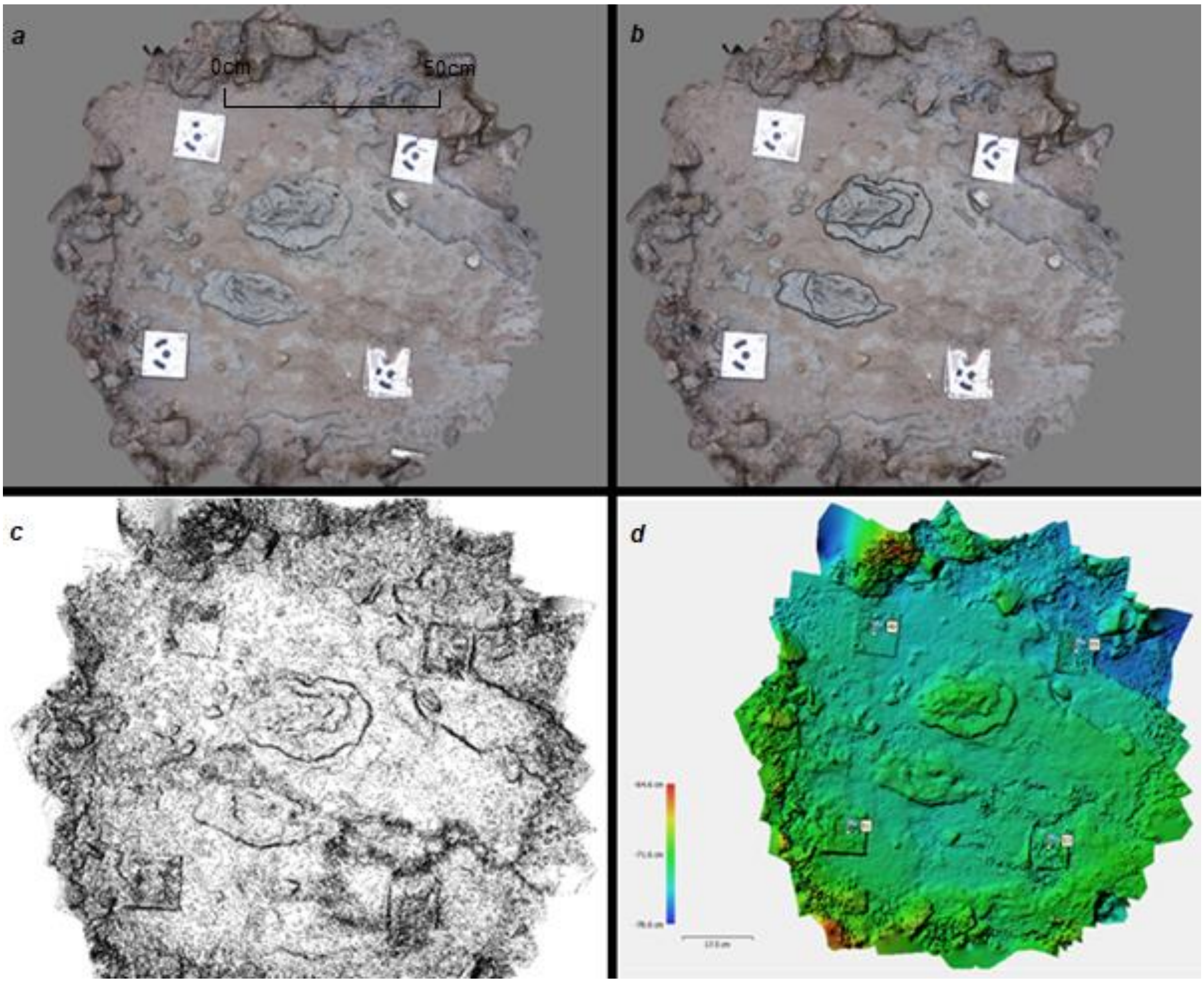


Figure 6.38 (a) Multi-image photogrammetry point cloud model of footprint-track 2015:6 and 2015:7, (b) digitised outline of the footprint-tracks, (c) multi-directional hillshade model, (d) digital elevation model. Note that the scale are not absolute OD heights, the OD height of this trail is -5m -5.14m OD

6.7.4 Description: footprint-tracks 2015:17, 18, 20

During fieldwork on 19.4.15 a trail of three human footprint-tracks, 2015:17, 2015:18 and 2015:20, was recorded utilising multi-image photogrammetry (Figure 6.39 and 6.40). The three human footprint-tracks were overtraces/undertraces and part of the same footprint-trail orientated 60° east of north. Footprint-track 2015:17 was made by a left foot (Figure 6.41), 2015:18 a right (Figure 6.42) and 2015:20 a left (Figure 6.43). Although overtraces/undertraces, some detail could be seen; 2015:17 had a hallux imprint that was on a lower lamination level than the rest of the footprint-track. Footprint-track 2015:18 had the entire morphological outline of a footprint, although without any evidence of interdigital ridges. Footprint-track 2015:20 again had the shape of a human footprint but without the interdigital ridges. It is unlikely that the person was shod, as 2015:17 had a clear hallux imprint, it is more likely that the sediment was very soft or wet when walked upon and so did not hold the detail of the toes.

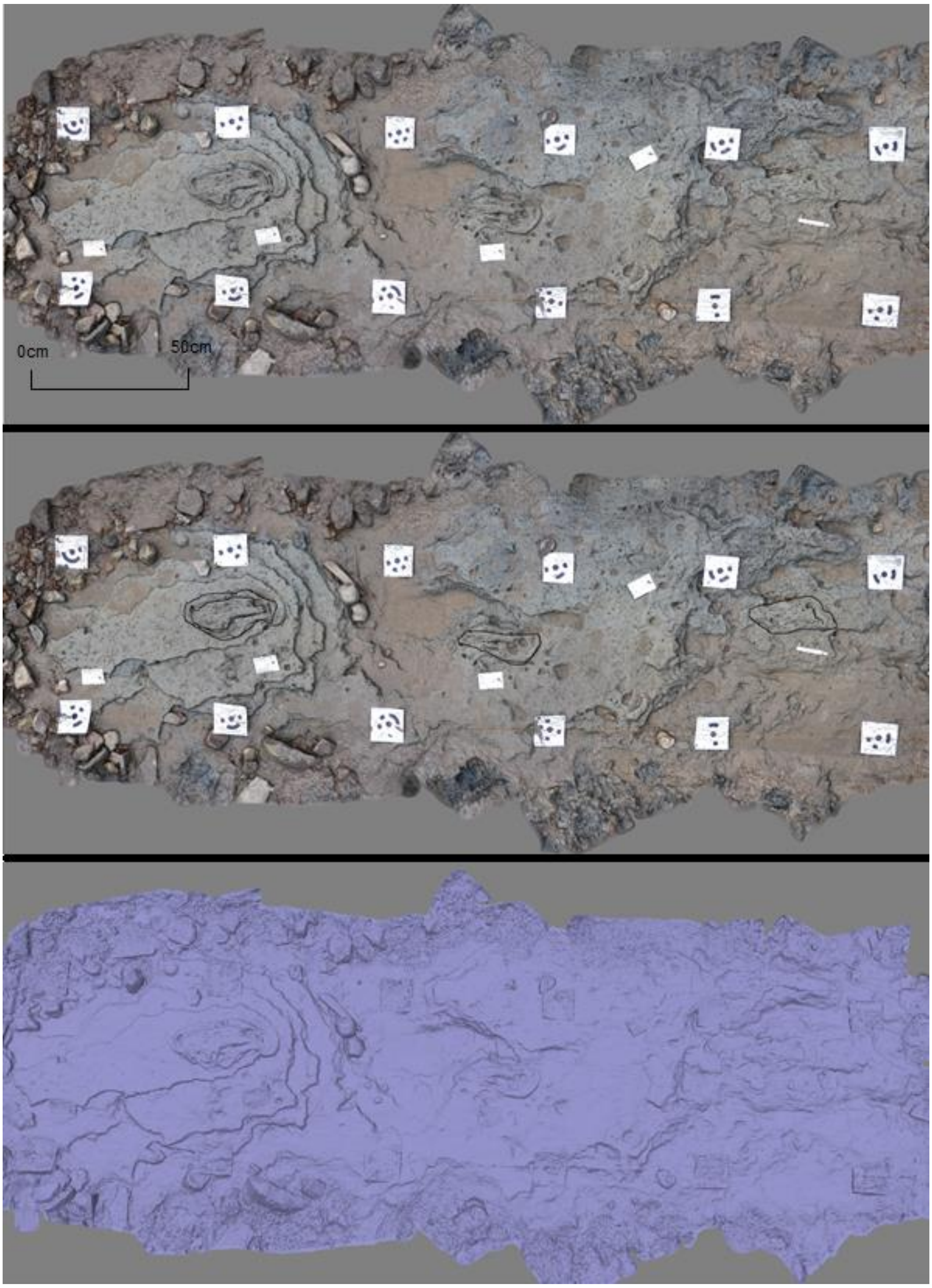


Figure 6.39 (top) Multi-image photogrammetry point cloud model of footprint-tracks, from left to right, 2015:17, 2015:18 and 2015:20, (centre) digitised outline of the footprint-tracks, (bottom) solid mesh of the model to enable the area to be viewed without interruption from shadow or colour

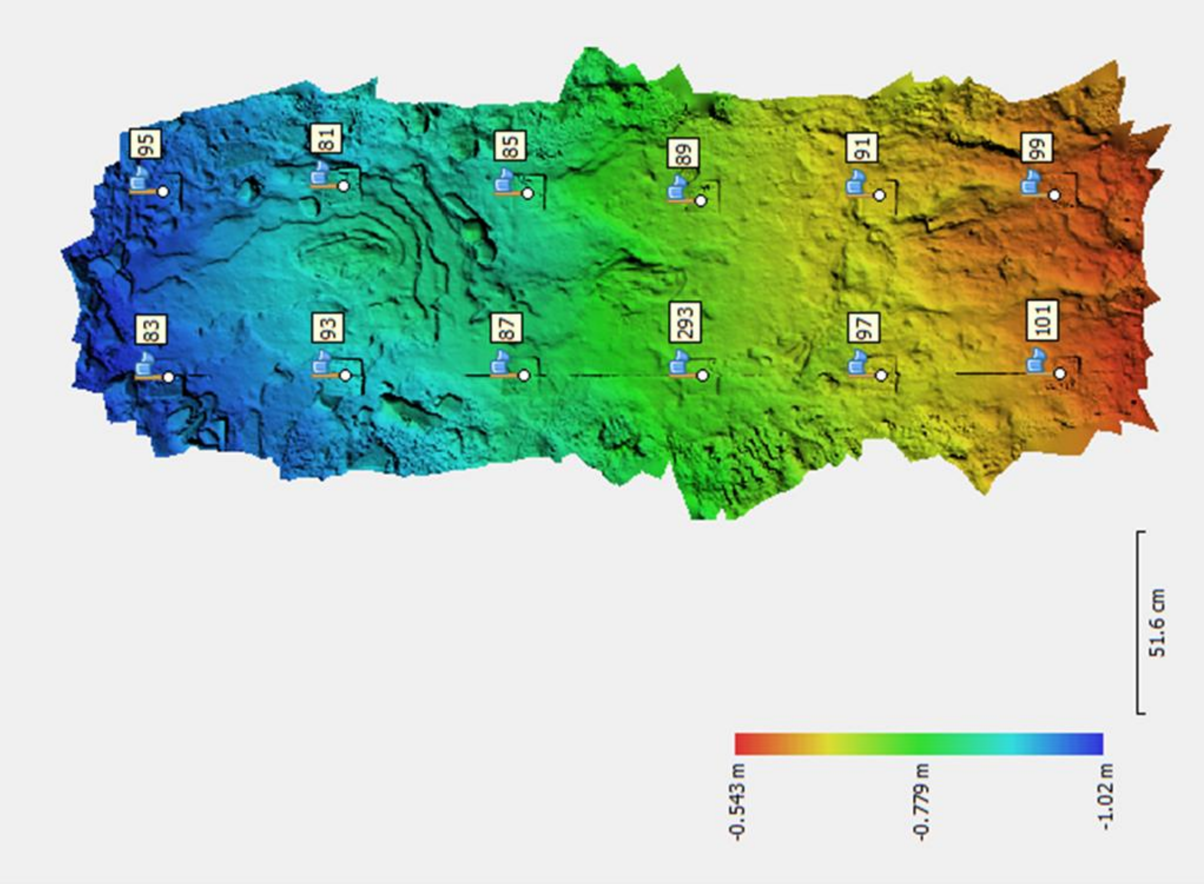


Figure 6.40 Digital elevation model of footprint-tracks, left to right, 2015: 17, 2015:18 and 2015:20. Note that the scale are not absolute OD heights, the OD height of this trail is -5m - 5.14m OD. The flagged numbers are the GCP's

Figure 6.41 Footprint-track 2015:17, scale 30cm

Figure 6.42 Footprint-track 2015:18

Figure 6.43 Footprint-track 2015:20. Scale 30cm

6.7.5 Description: footprint-tracks 2015: 42, 43, 44, 45

There was a further footprint area approximately 2m east from the human footprint-track trail 2015:17, 2015:18, 2015:20. They were numbered 2015:42, 2015:43, 2015:44 and 2015:45. Footprint-track 2015:42 was an elongated print, possibly human, though there were not any clear features such as hallux that may indicate if this was made by a left or right foot (Figure 6.44). 2015:43 was most likely an ungulate due to its large width compared to its length. This footprint-track may be human, however the lack of any defining features such as an arch, heel or toes and the overall width of the footprint-track indicates ungulate. The shape of 2015:44, without defining characteristics, again suggests ungulate, most likely deer. This may have been part of a trail including 2015:44 and 2015:45. Footprint-track 2015:45 indicates two possible deer prints, although it may be one rather eroded human footprint-track; the footprint-track width suggests red deer rather than human.

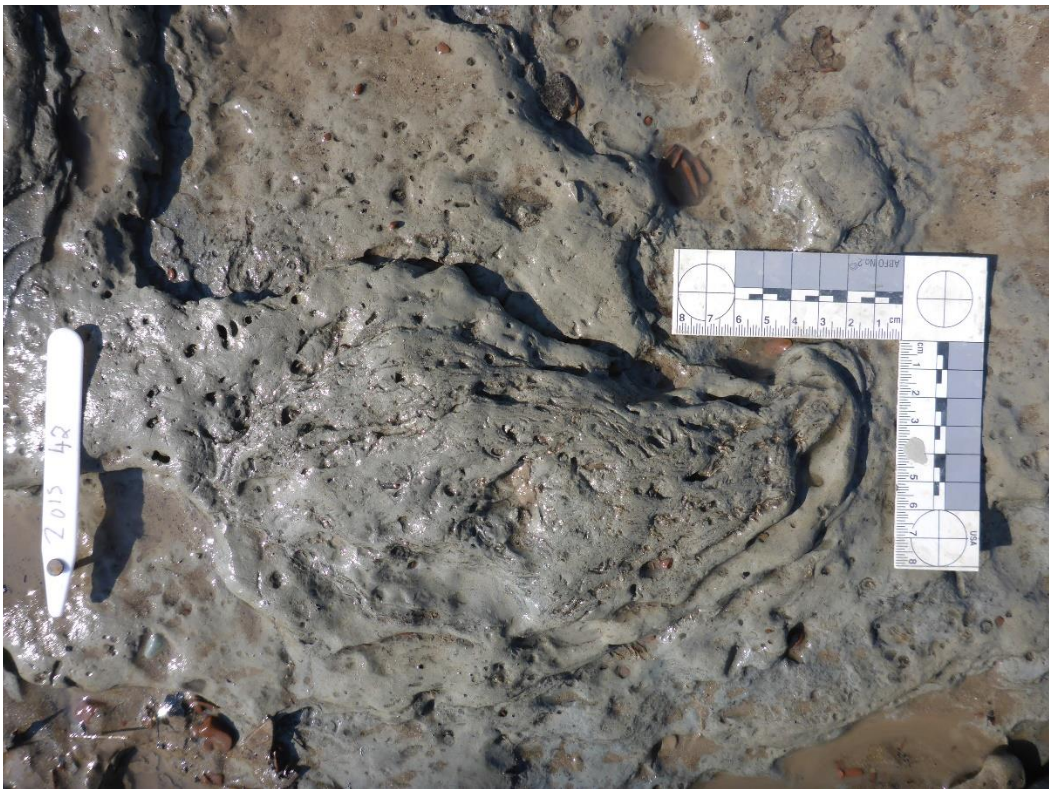


Figure 6.44 Footprint-track 2015:42. Scale 1cm divisions

6.7.6 Description: footprint-track 2016:27 2016:28

On 5.6.16 there was a favourable tide of 0.6m chart datum. At Site N two human footprint-tracks were recorded at the edge of the gravel bank, near to where footprint-tracks 2015:17, 18 and 20 were discovered. These footprint-tracks were assigned the identification numbers 2016:27 and 2016:28. These were poorly preserved and identified as human due to the slender appearance, though they were lacking in detailed features.

6.7.7 Description: footprint-tracks 2016: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,26, 29 and 31

On 6.6.16 multiple footprint-tracks were uncovered on a lamination in Site N, on the same lamination as 2016:27 and 2016:28, these were identified as 2016:15, 2016:16, 2016:17, 2016:18, 2016:19, 2016:20, 2016:21, 2016:22, 2016:23, 2016:24, 2016:25, 2016:26, 2016:29, 2016:31. This area was at -5m to -5.12m OD. The footprint-tracks were poorly preserved (Figure 6.45), though the utilisation of multi-image photogrammetry when recording the footprint-tracks allowed for a better understanding of the spacing between them, and which were human in appearance (Figure 6.46 and Figure 6.47), a plan of these footprint-tracks was also made whilst on site (Figure 6.48).

Footprint-tracks 2016:17 and 2016:16 were identifiable as human footprint-tracks, 2016:17 was made by a right foot and 2016:16 was made by a left foot, these were made by the same person (Figure 6.49). These footprint-tracks were parallel to one another, as though the individual had stopped and stood still in this area. The heels of both footprint-tracks were well defined. These footprint-tracks are likely overtraces and were beginning to erode. There was not any evidence of interdigital ridges. Footprint-track 2016:18 was also identifiable as a human right footprint-track (Figure 6.50, Figure 6.51). Although the footprint-track was a probable overtrace and there were not any interdigital ridges, there was a slight suggestion of a hallux indentation. The ball of this footprint-track and the slender width indicates it was made by a human. This footprint-track was on the same lamination as a large grey heron footprint, only 5cm away from this (2016:30).

Further footprint-tracks in this area were too poor to identify, 2016:18, 2016:19, 2016:20, 2016:25 all had the appearance of the ball of a human foot or may have been made by an ungulate, possibly deer. There were not any features preserved that allowed for an accurate species identification.

A further possible trail was identified on this lamination, again poorly preserved. This trail may have been made by humans, ungulates or a mixture of both. These footprint-tracks were lacking in any identifiable features. Footprint-tracks 2016:26 and 2016:31 were positioned on the same line of movement with a similar appearance, likely to have been made by the same individual. Footprint-tracks 2016:21, 2016:24, 2015:23, and 2016:29 were all less convincing footprint-tracks than 2016:26 and 2016:31. Footprint-track 2016:22 was made by a left human foot, with possible features of toes and the heel preserved. This footprint-track had the appearance of an undertrace and was heavily eroded. The curve of the arch enabled this to be identified as a left footprint-track.

Figure 6.45 Example of the difficulty of getting a detailed photograph of an area containing multiple footprint-tracks, and demonstrating how they relate to one another

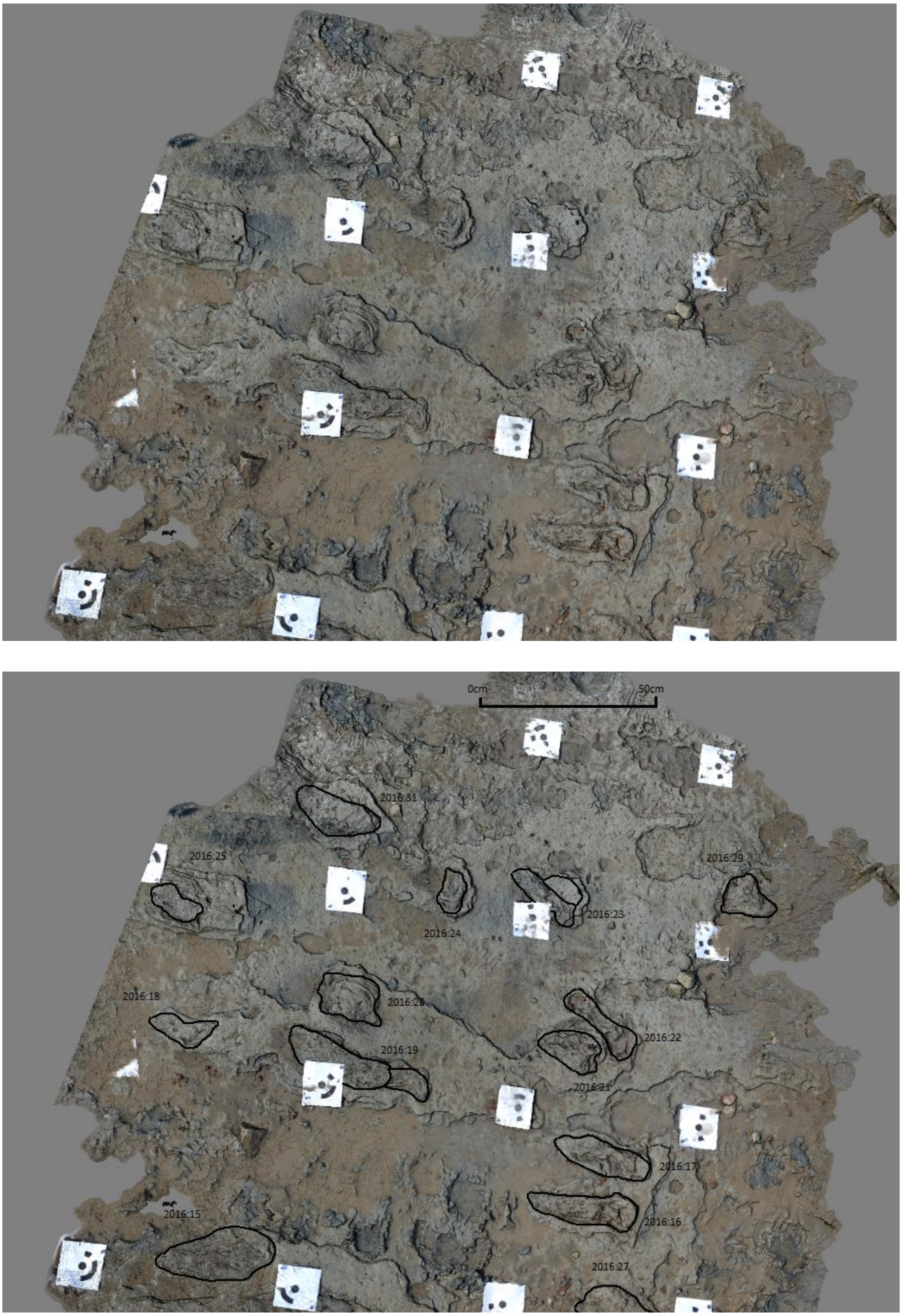


Figure 6.46 (top) Multi-image photogrammetry model of footprint-tracks 2016: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,26, 27, 29 and 31, (bottom) digitised outline of the footprints. This area is a good representation of the concentration of poor quality footprint-tracks in Site N

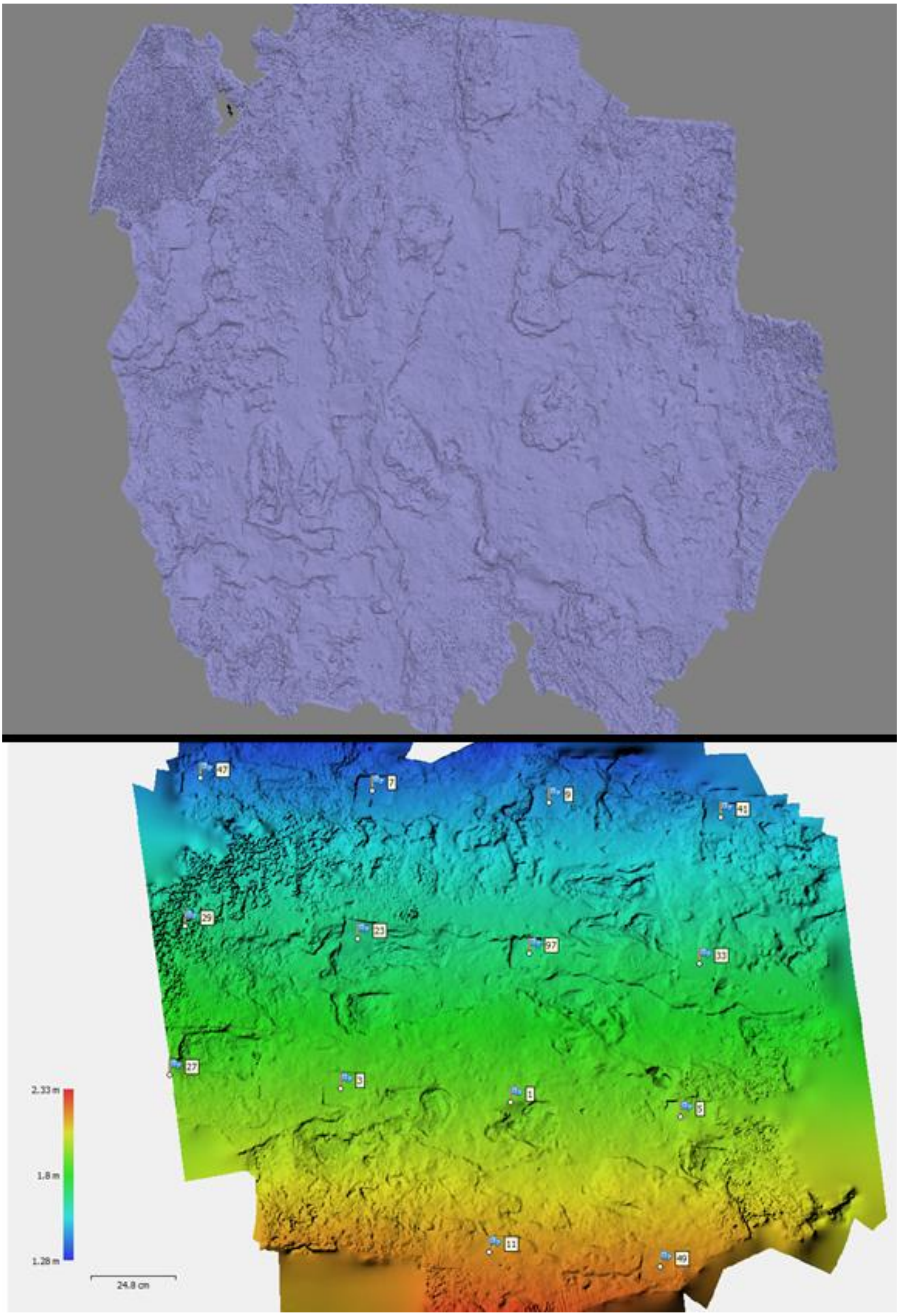


Figure 6.47 (top) Solid colour model of footprint-tracks 2016: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,26, 29 and 31, without shadows and colour variation in the sediments the footprint-tracks are difficult to see. (bottom) digital elevation model of the footprint-track area

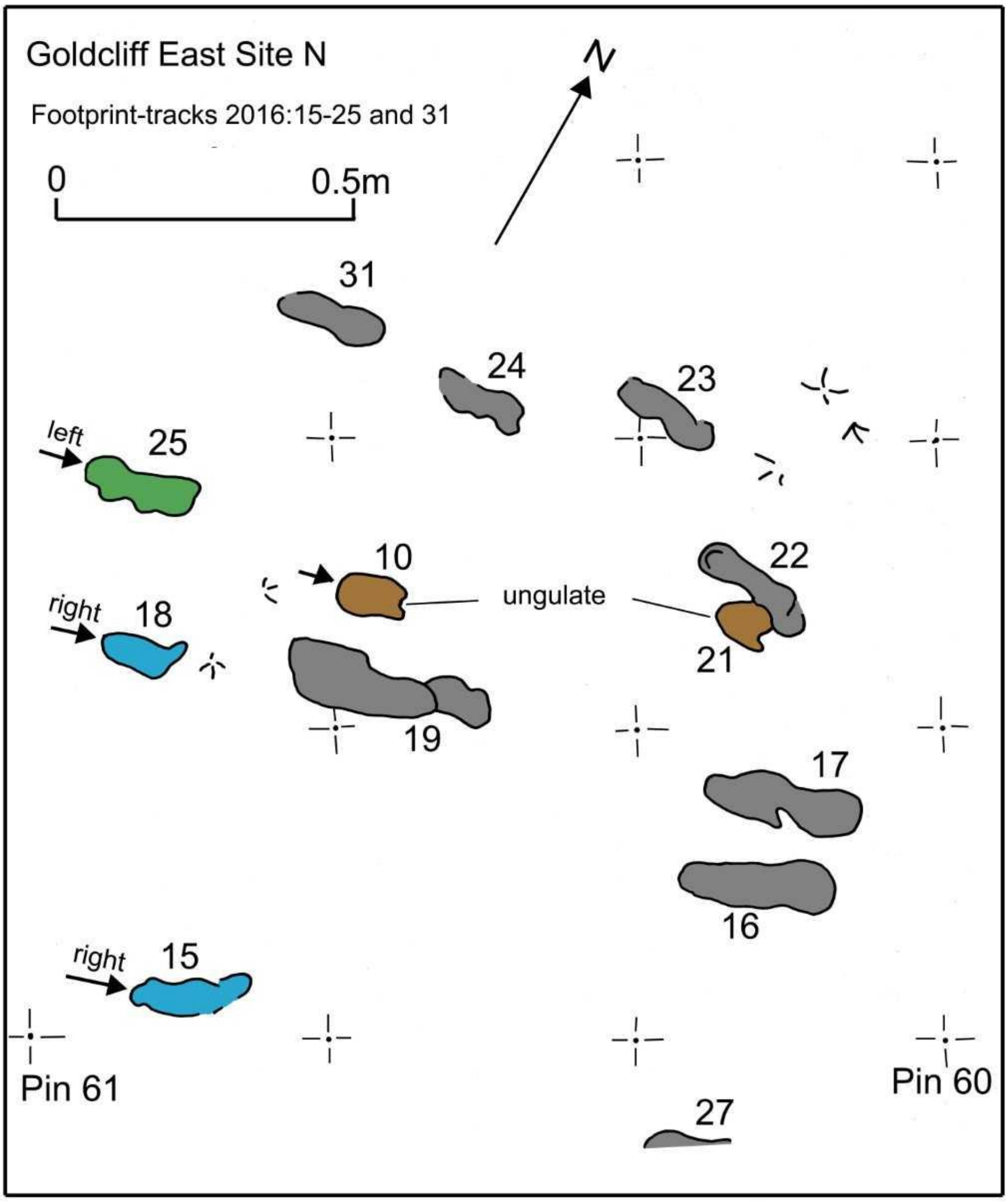


Figure 6.48 Plan of footprint-track 2016:15-25 and 2016:31 from Site N. Plan by M.Bell and J.Foster

Figure 6.49 Footprint-tracks 2016:16 (left) and 2016:17(right). Scale 10mm divisions

Figure 6.50 Footprint-track 2016:18, toes are only 5cm from a grey heron footprint (2016:30). Scale 1cm divisions

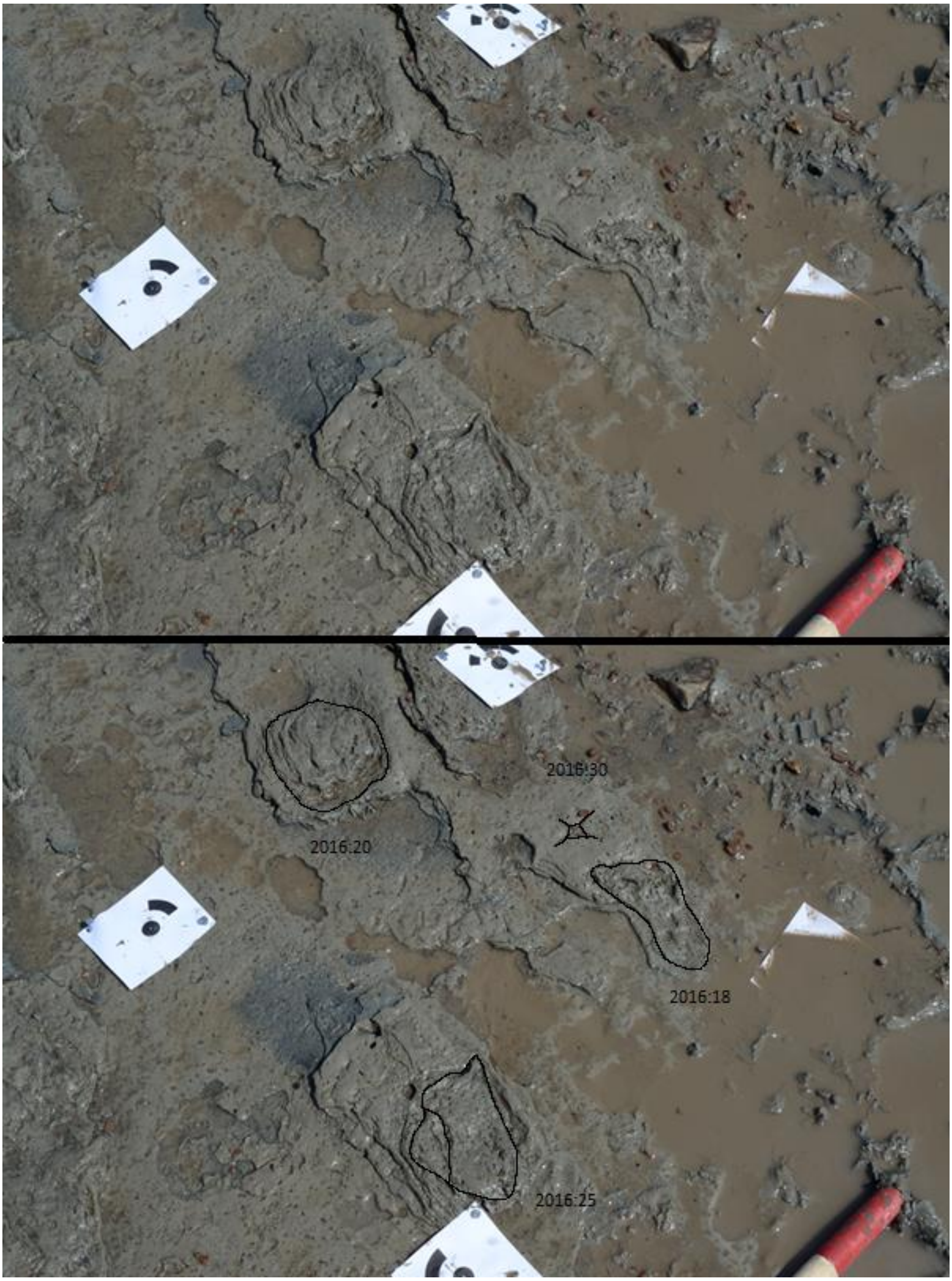


Figure 6.51 Footprint-track 2016:18, the right foot of a human, 2016:30 is a grey heron footprint, and 2016:25 and 2016:20 which may be human footprint-tracks but may also be ungulate

6.7.8 Description: footprint-track trail 2016:50 to 57

North of footprint-tracks 2016:15-2016:31, on a similar lamination layer, a further human footprint-track trail was recorded. This area was exposed in laminations from an area previously covered by the gravel bank and was 3.5m in length and 50cm in width. It was between -5.31m and -5.48m OD. There were eight possible human footprint-tracks recorded in this area, these were numbered from 2016:50 to 2016:57 and were part of the same footprint-track trail. The visible trail starts with 2016:50 and ends with 2016:57. This footprint-track trail was the most obviously human of all the trails recorded during the fieldwork period, with an obvious left-right footprint formation (Figure 6.52 and 6.53). Although there were eight footprint-tracks in this trail, the encroaching tide prevented footprint-track 2016:50, 51 and 52 from being included within the multi-image photogrammetry model. These footprint-tracks were photographed and metric measurements were made on site ensuring that some data was still recorded. A plan of this site was also made, though 2016:57 was not included due to recording time constraints (Figure 6.54).

Footprint-track 2016:50 was an overtrace of a right foot, orientated 55° north-east (Figure 6.55). The shape of the footprint-track, with possible hallux, indicates a right foot. This footprint was best observed in low lighting, in bright light the detail was unclear. Footprint-track 2016:51 was an overtrace (Figure 6.56). The majority of the footprint-track was difficult to see, however the hallux of the foot had made an imprint deeper into the sediment than the rest of the footprint-track, suggesting soft sediment was walked upon. There was no evidence of the other toes or interdigital ridges in this footprint though the arch could be observed. The footprint-track was orientated 70° north-east. Footprint-track 2016:52 again was likely to be an overtrace (Figure 6.57). This footprint-track was also discovered due to localised disturbance**s** in the sediment, with a darker, sandier sediment infill in the footprint-track. The footprint-track was made by a right foot, apparent from the arch of the foot, and was orientated 50° north-east. Footprint-track 2016:53 was an overtrace of a left footprint-track, orientated 50° north-east (Figure 6.58). As with all the footprint-tracks in this trail, this footprint-track was seen through the disturbance in the lamination and the differing colour of the sediment to the surrounding lamination. Footprint-track 2016:54 was an overtrace (Figure 6.59). Although there were not any distinct features that allowed it to be sided, its' positioning within the footprint-track trail suggests that it was made by a right foot. This footprint-track was orientated 50° north-east. Erosion was beginning to peel back the overlying sediment, revealing further evidence of a footprint below. It may be that this footprint-track trail is an overtrace that is only a few micro-laminations above the actual footprint. Footprint-track 2016:55 was made by a left foot with the arch apparent, as well as interdigital ridges and the hallux impression (Figure 6.60). This footprint-track had the appearance of an overtrace, though the sediment was no longer at the heel of the footprint, either due to erosion, or the way that the foot made contact with the sediment when the footprint was made. The orientation of this footprint was 60° north-east. Footprint-track 2016:56 was a poorly preserved footprint-track which prevented its’ identification as a left or right footprint (Figure 6.61). The positioning within the trail suggests a right footprint. There was not any evidence of toes, though the heel imprint was evident. The footprint-track was orientated 50° north-east. Footprint-track 2016:57 was the last footprint-track found within this trail. It was an overtrace of a left footprint, orientated 55° north-east. This footprint-track had a prominent arch, hallux and heel (Figure 6.62).

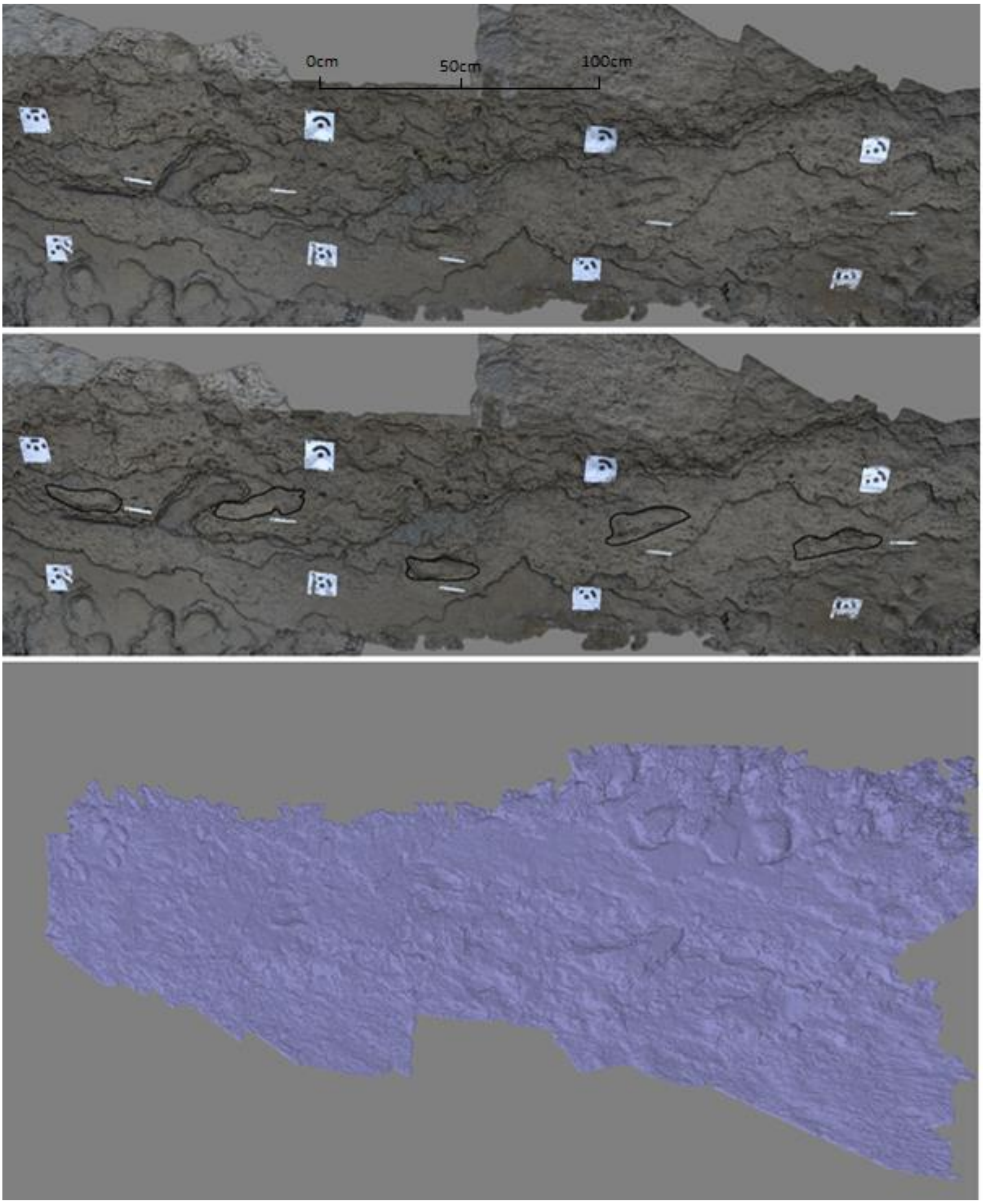


Figure 6.52 (top) Multi-image photogrammetry model of footprint-track 2016:53 to 57, the encroaching tide prevented the full trail being recorded. Footprint-track 2016:57 on left to 2016:53 on right (centre) digitised outline of the footprint-tracks, (bottom) solid model of the area, showing that light and colour play a part when attempting to locate undertrace and overtrace footprint-tracks

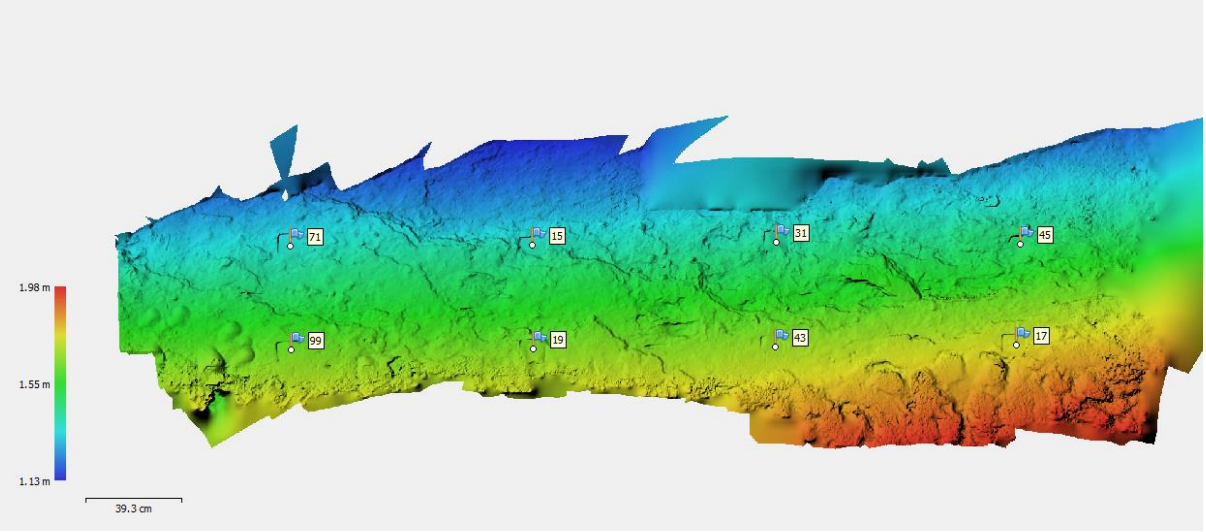


Figure 6.53 Digital elevation model of footprint-track trail, note that the coloured scale bar does not represent absolute OD, which is between -5.31 and -5.48m OD

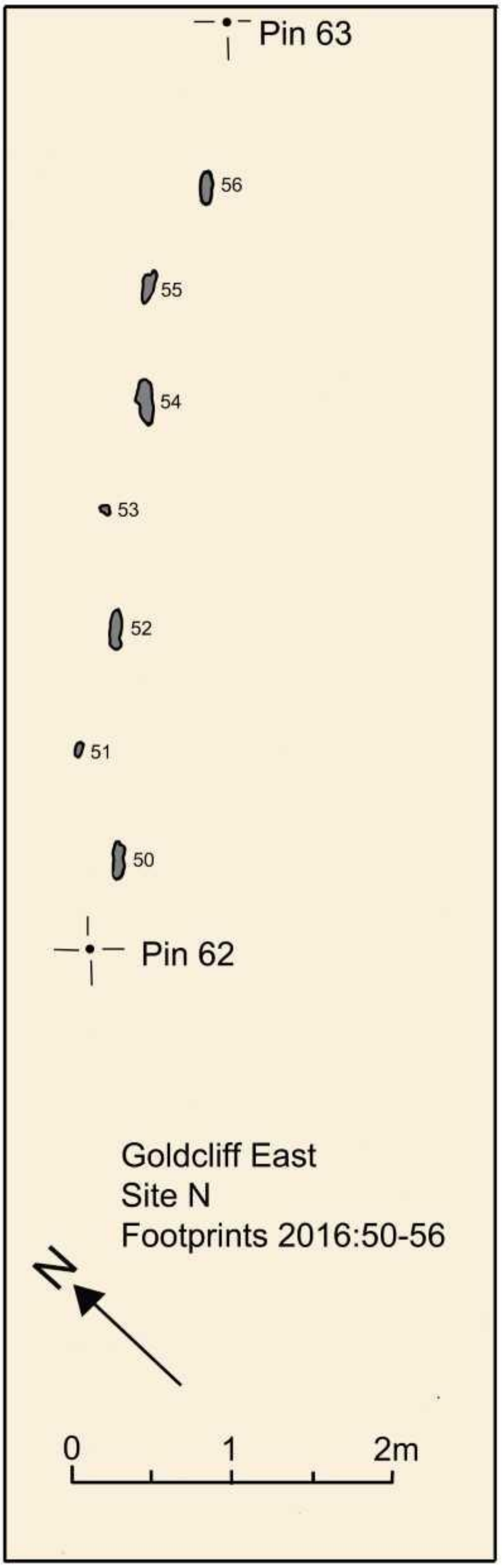


Figure 6.54 Plan of footprint-track trail 2016:50-56. Plan by M.Bell and J.Foster

Figure 6.55 Footprint-track 2016:50

Figure 6.56 Footprint-track 2016:51. Scale 10cm divisions

Figure 6.57 Footprint-track 2016:52. Scale 10cm divisions

Figure 6.58 Footprint-track 2016:53. Scale 10cm divisions

Figure 6.59 Footprint-track 2016:54. Scale 10cm divisions

Figure 6.60 Footprint-track 2016:55. Scale 10cm divisions

Figure 6.61 Footprint-track 2016:56. Scale 10cm divisions

Figure 6.62 Footprint-track 2016:57. Scale 10cm divisions

6.7.9 Analysis of Site N footprint-tracks

Figure 6.63 shows the lengths and widths of human footprint-tracks recorded at Site N, Figure 6.64 displays these footprint-tracks against the modern human analogue dataset. These scatter diagrams indicate that the footprint-tracks in Site N are similar in length and width to modern human footprints, though there were several footprints that were larger than the general clustering of widths, presumably because of the sediment composition, with the footprints having been made in wet rather than fluid mud.

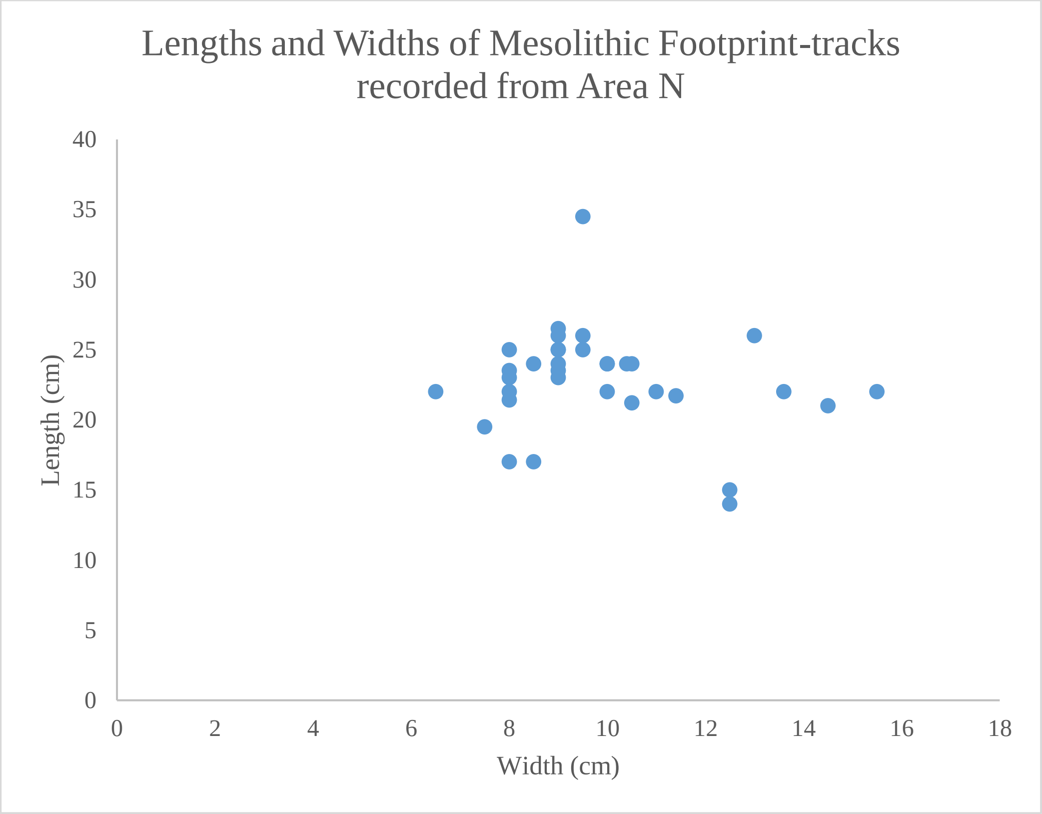


Figure 6.63 Metric dimensions of footprint-tracks from Site N

Figure 6.64 metric dimensions of footprint-track from Site N plotted against modern human footprint data

6.7.10 Age and sex of individuals at Site N

The approximate age and sex of individuals from Site N could not all be established as the footprint-tracks within this area were incomplete, generally poorly preserved, or lacking in identifiable human footprint morphology. The results indicate that children were present within this area, aged approximately 6.5 +/- 1.5 years or above (Table 6.16).

There were a variety of footprint-tracks made by pubescent children and adults. Table 6.17 demonstrates the possible sex of everyone in Site N. The children below ten could have been either sex, the 16 footprint-tracks that were made by either pubescent children or small females could also have been either sex. Although it is difficult to identify a difference in footprint size between an adult female and a pubescent child, footprint data from the modern human assemblage indicates that there are sizes that are more likely children or more likely adult female (Table 6.3). Of the 16 footprint-tracks that measured between 22cm and 24cm, indicating a child or adult female, six of the footprint-tracks were 22cm in length. Only 13% of adult females from the modern data assemblage had footprint-tracks this small, which indicates these are more likely to have been made by children. Four of the footprint-tracks had a length of 23cm, this is where most cross-over between children and adult female sizing occurs, with 17% of children (ten to 15 years) displaying this length of footprint, and 21% of modern adult females also sharing this footprint length. The final six of the footprint-tracks measuring 24cm are slightly more likely to have been made by adult females; 29% of modern adult females had this footprint length, as opposed to 17% of children aged between ten and 15 years. In determining if females were present in this area, it is likely that at least six of the 16 footprint-tracks were adult females, there is also the possibility that the footprint-tracks measuring 25cm and 26cm were made by adult females. 21% of adult females from the modern data had footprints measuring 25cm, though 22% of children aged 10-15 years also had this foot length. Only 11% of modern adult males had a footprint length as small as 25cm, indicating that the four footprint-tracks of this size were more likely made by children or adult females. Four further Mesolithic footprint-tracks were 26cm in length; the largest footprint-track recorded from Site N was 26.5cm, the size of these footprints indicate that they could have been made by pubescent children or adults of both sexes. Only 11% of modern children aged ten to 15 years had a footprint length of 27+cm, and 5% of adult females made footprints 27+cm. In comparison, 68% of modern male footprints were sized 27cm and above, indicating that although it is possible for children and adult females to make large footprint-tracks, it is far more likely that large footprint-tracks were made by males. Within Site N the lack of large footprint-tracks suggests that large adult males were unlikely to have been in this area, and that adult females, pubescent children and young children were all walking within an area 16m by 6m, the footprint-tracks made within this area were made on multiple laminations, indicating a pathway being used repeatedly by children and possibly adult females over multiple visits.

Footprint-track number	**Probable age range (years)**	**Footprint-track length (cm)**	**UK Shoe Size**
2015:6	10+ or adult female	22	3
2015:7	10 +/- 1	21.2	2
2015:8	10+ or adult female	24	5.5
2015:9	Incomplete footprint	-	-
2015:17	10+ or adult	26	8
2015:18	10+ or adult	25	6.5
2015:20	10+ or adult female	24	5.5
2015:42	10+ or adult female	22	3
2016:15	10+ or adult	26	8
2016:16	10+ or adult	25	6.5
2016:17	10+ or adult	26	8
2016:18	Incomplete, heel or animal	17	-
2016:20	Incomplete, heel or animal	14	-
2016:21	Incomplete, heel or animal	17	-
2016:22	10+ or adult female	22	3
2016:23	Incomplete, heel or animal	22	-
2016:24	Incomplete, heel or animal	21	-
2016:25	Incomplete, heel or animal	21.7	-
2016:26	10+ or adult	26.5	8.5
2016:27	10+ or adult female	23.5	5
2016:28	10 +/- 1	21.4	2.5
2016:29	Incomplete, heel or animal	15	-
2016:31	10+ or adult female	24	5.5
2016:50	10+ or adult female	24	5.5
2016:51	10+ or adult female	23	4.5
2016:52	10+ or adult	25	6.5
2016:53	10+ or adult female	24	5.5
2016:54	10+ or adult	25	6.5
2016:55	10+ or adult female	23.5	5
2016:56	10+ or adult female	22	3
2016:57	6.5 +/- 1.5	19.5	Children's 13.5

2016:58	10+ or adult female	22	3
2016:59	10+ or adult female	24	5.5
2016:60	10+ or adult female	23	4.5
2016:61	Incomplete footprint	-	-

Table 6.16 Age estimates from human footprint-tracks in Site N

Footprint-track number	**Sex**	**Length (cm)**
2015:6	Pubescent child or short adult female	22
2015:7	Child of either sex	21.2
2015:8	Pubescent child or adult female	24
2015:17	Pubescent child or adult of either sex	26
2015:18	Pubescent child or adult of either sex	25
2015:20	Pubescent child or adult of either sex	24
2015:42	Pubescent child or short adult female	22
2016:15	Pubescent child or adult of either sex	26
2016:16	Pubescent child or adult of either sex	25
2016:17	Pubescent child or adult of either sex	26
2016:18	Incomplete length, sex cannot be established	17
2016:20	Incomplete length, sex cannot be established	14
2016:21	Incomplete length, sex cannot be established	17
2016:22	Pubescent child or short adult female	22
2016:23	Incomplete length, sex cannot be established	22
2016:24	Incomplete length, sex cannot be established	21
2016:25	Incomplete length, sex cannot be established	21.7
2016:26	Pubescent child or adult of either sex	26.5
2016:27	Pubescent child or adult female	23.5
2016:28	Pubescent child or short adult female	21.4
2016:29	Incomplete length, sex cannot be established	15
2016:31	Pubescent child or adult female	24
2016:50	Pubescent child or adult female	24
2016:51	Pubescent child or adult female	23

2016:52	Pubescent child or adult of either sex	25
2016:53	Pubescent child or adult female	24
2016:54	Pubescent child or adult of either sex	25
2016:55	Pubescent child or adult female	23.5
2016:56	Pubescent child or adult female	22
2016:57	Child of either sex	19.5
2016:58	Pubescent child or adult female	22
2016:59	Pubescent child or adult female	24
2016:60	Pubescent child or adult female	23

Table 6.17 Sex estimates from Site N footprint-tracks

6.7.11 Stature estimates

The stature of individuals from Site N was estimated (Table 6.18), with results indicating that the child aged 6.5 +/- 1.5 who made footprint-track 2016:57 was the shortest person in this area, at only 121.9cm (3’11”), the 10 +/-1 year old was 151.5cm (4’11”) and the tallest individual was 174.3cm (5’8”). All others ranged in height between 154.9cm (5’0”) and 172.1cm (5’7”).

Footprint -track number	Footprint -track length (cm)	Footprint side	Estimated stature (cm)	Height (feet and inches)	Standard error
2015:6	22	Indistinct	154.9	5’0”	7.3
2015:7	21.2	Indistinct	151.5	4’11”	7.3
2015:8	24	Indistinct	163.5	5’4”	7.3
2015:17	26	Left	172.1	5’7”	7.3
2015:18	25	Right	167.8	5’6”	7.3
2015:20	24	Left	161.7	5’3”	6
2015:42	22	Indistinct	154.9	5’0”	7.3
2016:15	26	Right	172.1	5’7”	7.3
2016:16	25	Right	167.8	5’6”	7.3
2016:17	26	Left	172.1	5’7”	7.3
2016:26	26.5	Right	174.3	5’8”	7.3
2016:27	23.5	Indistinct	161.4	5’3”	7.3
2016:28	21.4	Indistinct	152.3	4’11”	7.3
2016:31	24	Left	162.2	5’3”	6
2016:50	24	Right	162	5’3”	6.18
2016:51	23	Left	158.9	5’2”	6
2016:52	25	Right	167.8	5’5”	7.3
2016:53	24	Left	161.8	5’3”	6
2016:54	25	Indistinct	167.8	5’6”	7.3
2016:55	23.5	Left	160.4	5’3”	6
2016:56	22	Indistinct	154.9	5’0”	7.3
2016:57	19.5	Left	121.9	3’11”	9.14
2016:58	22	Right	156.2	5’1”	6.18
2016:59	24	Left	164.5	5’4”	6
2016:60	23	Left	158.9	5’2”	6

Table 6.18 Stature estimates from footprint-tracks from Site N

6.7.12 Speed of movement Site N

The footprint-tracks recorded at Site N were the poorest in terms of clear footprints, however some of the best human footprint-track trails were discovered here during the fieldwork period of 2014 to 2016. There were two trails recorded in this area, one involved three footprint-tracks, 2015:17, 2015:18 and 2015:20, the other was a trail of eight footprint-tracks. These footprint-tracks were orientated in the same direction upon the same lamination, and had a clear left-right foot pacing, as well as the long and slender footprint morphology expected to be seen in a human footprint.

The individual who made the trail of footprint-tracks 2015:17, 2015:18 and 2015:20 had a footprint-track length ranging between 24cm and 26cm, with a stature between 161.7cm (5’3”) and 172.1cm (5’7”). This person had a stride of 170cm, walking at 1.66 meters per second, which equates to 6km per hour (4mph), an average walking speed for someone of that height (Table 6.19). If running they would have been travelling at 2.15 meters per second, meaning they would have been traveling at 8k per hour (5mph), a slow jogging pace. This person created footprint-tracks with a clear arch and heel, making it unlikely that they were running at a fast pace, given the estimated speed of travel it is more likely they were walking quickly along the foreshore.

The eight footprint-tracks from trail 2016:50 to 2016:57 were better preserved than many of the other footprint-tracks in this area. This trail was made by a bipedal individual, with the arches and heels of the feet evident, and a deep hallux imprint in one of the footprint-tracks. The estimated speed was calculated for each of the stride lengths (left to left, right to right) and then an average of these results was calculated to give an accurate understanding of the speed of movement. Although made by the same individual, the stride length varied between 130cm and 157cm; this meant that there was a slight difference in the speed estimates for each separate footprint. The combined average indicated a stride length of 147.6cm, meaning that they would have been travelling at 1.46 meters per second when walking, which equates to a walking speed of 5k per hour (3 miles per hour). This is a relatively average walking pace. If the individual was running they would have been covering 1.89 meters per second, which would equate to 7k per hour (4 miles per hour). This is an unrealistic speed to run as it would be an incredibly slow speed considering that the individual had an estimated stature between 154.9cm (5’0”) and 167.8cm (5’6”). This person was walking in an eastern direction. The footprint-tracks were relatively slender, between 6.5cm and 10cm, making it unlikely that they were carrying a heavy load.

Footprint-track number	**Footprint-track length average (cm)**	**Stride (cm)**	**Walking (meters per second)**	**Running (meters per second)**	**Walking and running (meters per second)**
2015:17 to 2015:20	25	170	1.66	2.15	1.87
2016:50 to 2016:52	24.5	152	1.48	1.9	1.58
2016:51 to 2016:53	23.5	155	1.59	2.07	1.77
2016:52 to 2016:54	25	157	1.5	1.94	1.62
2016:53 to 2016:55	23.7	144	1.44	1.86	1.52
2016:54 to 2016:56	23	130	1.31	1.68	1.32
Average 2016:50 to 2016:56	23.9	147.6	1.46	1.89	1.56

Table 6.19 Speed of movement of Site N individuals

6.7.13 Site N direction of movement

Analysis of the footprint-tracks (2014-2017) recorded in Site N indicates a similar direction of movement to Site M, travelling in a north-east and south-west direction (Figure 6.65). The footprint-tracks recorded between 2011-2014 were not included with this analysis as orientation of each footprint-track was not recorded during the fieldwork, though the plan from the tracings made onsite suggest that these individuals were moving east towards the sea and west, away from the sea and towards Goldcliff Island (Figure 6.65). The 2011-2017 footprint-tracks were on a similar axis suggesting that they were walking towards and away from a palaeochannel, at right-angles. The footprint-tracks were found on several laminations, implying that this small area was visited multiple times, over a period of several years.

In this area, of the 35 footprint-tracks recorded during 2014-2016, 26 were orientated north-east, between 50° and 103°, three footprint-tracks were orientated south-west, between 240° and 250°, and six footprint-tracks were not clear enough to establish orientation. 29 of the footprint-tracks were orientated on the same axis as the recently found wood structure of a possible fish trap (Site T) which lies on this axis between Site N and the edge of the island. Site N seems to be a distinct axis of movement, covering a ‘pathway’ 16m by 6m. The dip of the laminated sediments at Site N suggests that, although this is on the same axis as Site T, it is likely to be later in date and therefore the footprint-tracks probably relate to another fish trap covered by the area of water east of Site N. It is likely that this ‘pathway’ led to a fish trap from when the channel migrated further east, Site L is a site further east and very fragmentary traces of a wood structure possibly representing fragments of a fish trap was found within this palaeochannel (Bell 2007, p 50).

These people were walking at a steady pace and in a similar direction which suggests engagement in some routine activity at a static place; the fish trap evidence is consistent with this. Those concerned with looking after the hypothetical fish trap appear to have been children and women without the definite involvement of adult males.

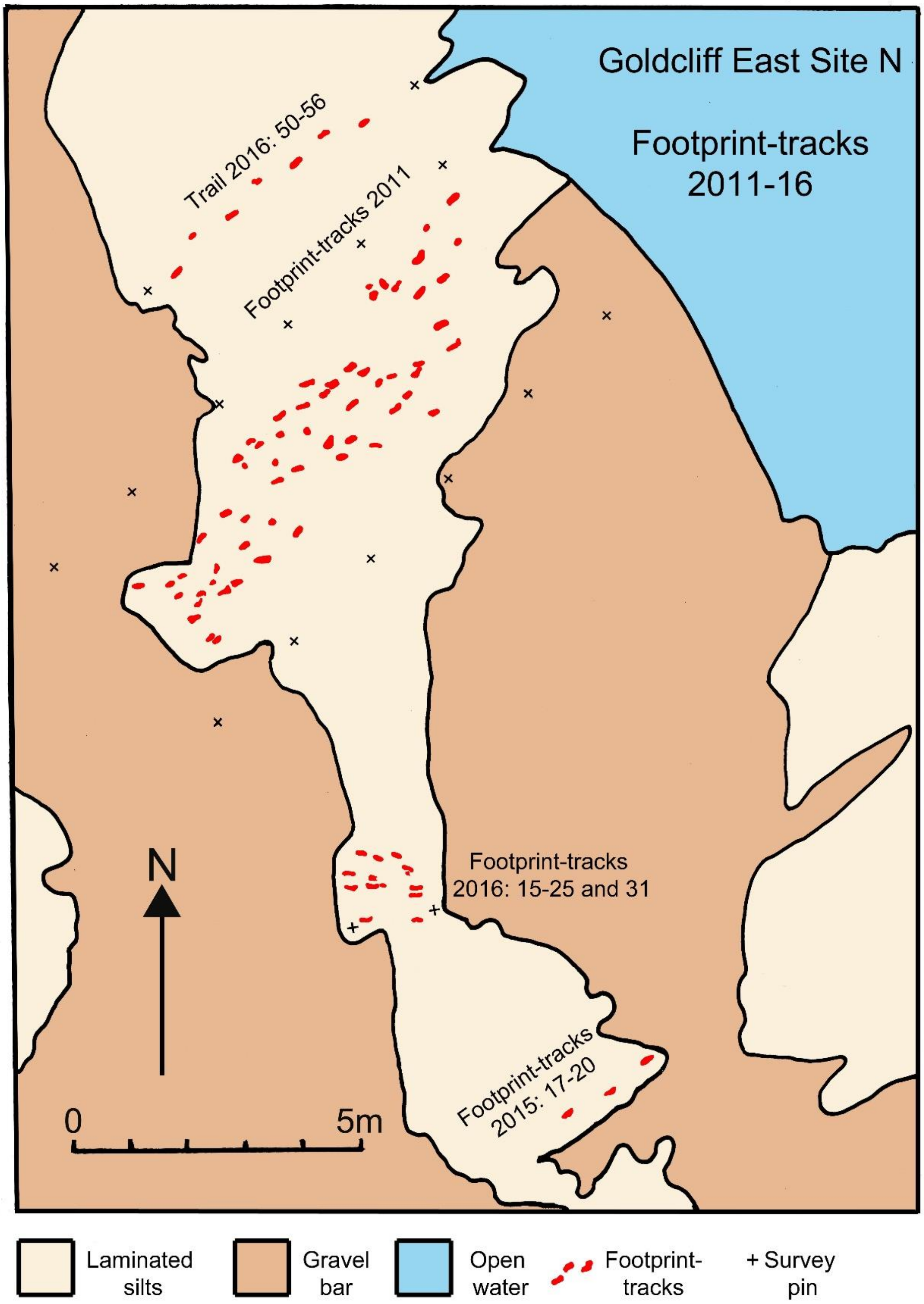


Figure 6.65 Plan showing the extent of the footprints in Site N and their direction of movement. Site recorded between 2011-2016. Plan by M.Bell and J.Foster

6.8 Site R footprint-tracks

Site R was discovered on 16.9.16, 9.5m east of the edge of a palaeochannel where it cuts the Lower Peat shelf (Figure 6.66). It is the most western of the Mesolithic human footprint areas so far recorded at Goldcliff East and was briefly exposed on laminated silts between -4.17 and -4.35m OD which are generally covered by sands and gravels. The footprint-tracks at Site R were on consolidated banded sediments exposed in plan.

Within this area eight footprint-tracks were recorded, three formed a trail of human footprint-tracks. There was also a singular human footprint-track that was not part of the trail, this was determined by observing its orientation, size and positioning. The final four footprint-tracks were possibly human heel prints, though the shape is more suggestive of ungulates.

The footprint-tracks ranged in length from 14cm to 26cm in length, and 7.5cm to 12cm in width. The footprint-tracks that were not accurately identified were still included in these results as they could possibly be human heel prints (Table 6.20).

Figure 6.66 Small exposed lamination of Site R, being recorded by the author utilising multi-image photogrammetry and ground control points (photograph by M. Bell)

Footprint-track number	Site	Length (cm)	Width (cm)	Identifying features?	Left or Right?	Direction of movement
2016:73	R	20.5	12	Overtrace/undertrace hallux and heel evident	Left	295° west
2016:74	R	19.5	10.5	Partially preserved human, or animal	Indistinct	Indistinct
2016:75	R	26	12	Overtrace/undertrace hallux and heel evident	Right	295° west
2016:76	R	24.5	10.2	Partially preserved human or animal	Indistinct	Indistinct
2016:77	R	14	10	Partially preserved human, or animal	Indistinct	Indistinct
2016:82	R	17	7.5	Clear hallux	Left	270° west
2016:83	R	-	12	Disturbed area, indistinct footprint	indistinct	Indistinct
2016: 100	R	23.2	11	Overtrace/undertrace hallux and heel evident	Left	295° west

Table 6.20 Data of footprint-tracks recorded from Site R

6.8.1 Description of footprint-tracks: 2016:73, 2016:74, 2016:75, 2016:77, 2016:82, 2016:83, 2016:100

This trail was first recorded in September 2016 and subsequent footprint-tracks were noted as part of the same trail in November 2016. Eight footprint-tracks were noted on banded laminations, with the appearance of overtraces/undertraces (Figure 6.67 and 6.68). Footprint-track 2016:100 was not included in this multi-image point cloud model as it was identified on subsequent fieldwork a month after the original trail was recorded, and the encroaching tide prevented a further model being created. Measurements, photographs and the orientation of footprint-track 2016:100 were recorded, as was the distance between 2016:100, 2016:73 and 2016:75, which formed a trail. Footprint-track 2016:100 was recorded north-west of footprint-track 2016:76.

Footprint-track 2016:73, 2016:75 and 2016:100 formed a left-right-left human footprint-track trail, they were orientated 295° west towards the present day Goldcliff Fishery, and the excavated Site B (Bell 2007, Chapter 3). Footprint-track 2016:73 was made by a left foot, with indication of interdigital ridges between the hallux and second toe. Footprint-track 2016:75 was made by a right foot, the prominent feature of this footprint-track was the wide ball of the foot (Figure 6.69). Footprint-track 2016:100 was a left foot, with evidence of a hallux and heel mark.

Footprint-track 2016:82 was a human footprint-track, with a hallux mark visible, meaning it was identifiable as being made by a left foot. This footprint-track was also an overtrace/undertrace and was not part of the human footprint-track trail of 2016:73, 2016:75 and 2016:100. It was a far smaller footprint-track, only 17cm in length, and orientated towards Goldcliff Island at 270° west.

Footprint-track 2016:74 had the appearance of an animal footprint rather than a human; it was rounded and wide rather than long and slender. Three further footprint-tracks, 2016:76, 2016:77 and 2016:83 were observed. These footprint-tracks may have been partially preserved human footprints or mammal footprints, as again they were wider than they were long and had no distinctive features. When a point cloud model had been generated from the photographs, footprint 2016:74 was seen to have the distinctive cleaves of an ungulate, it is therefore possible that these four footprints represent part of a trail made by a deer that had crossed paths with the human footprint trail at 140°, the large size and shape of the footprint-tracks suggest red deer.

Sample 2016:111, was collected from the eastern end of this trail, 20cm to the south-east of footprint-track 2016:73 (Figure 6.67). This sample was Optically Stimulated Luminescence dated to 6620+/-610 years before 2017 (GL16184) (Appendix 1.2).

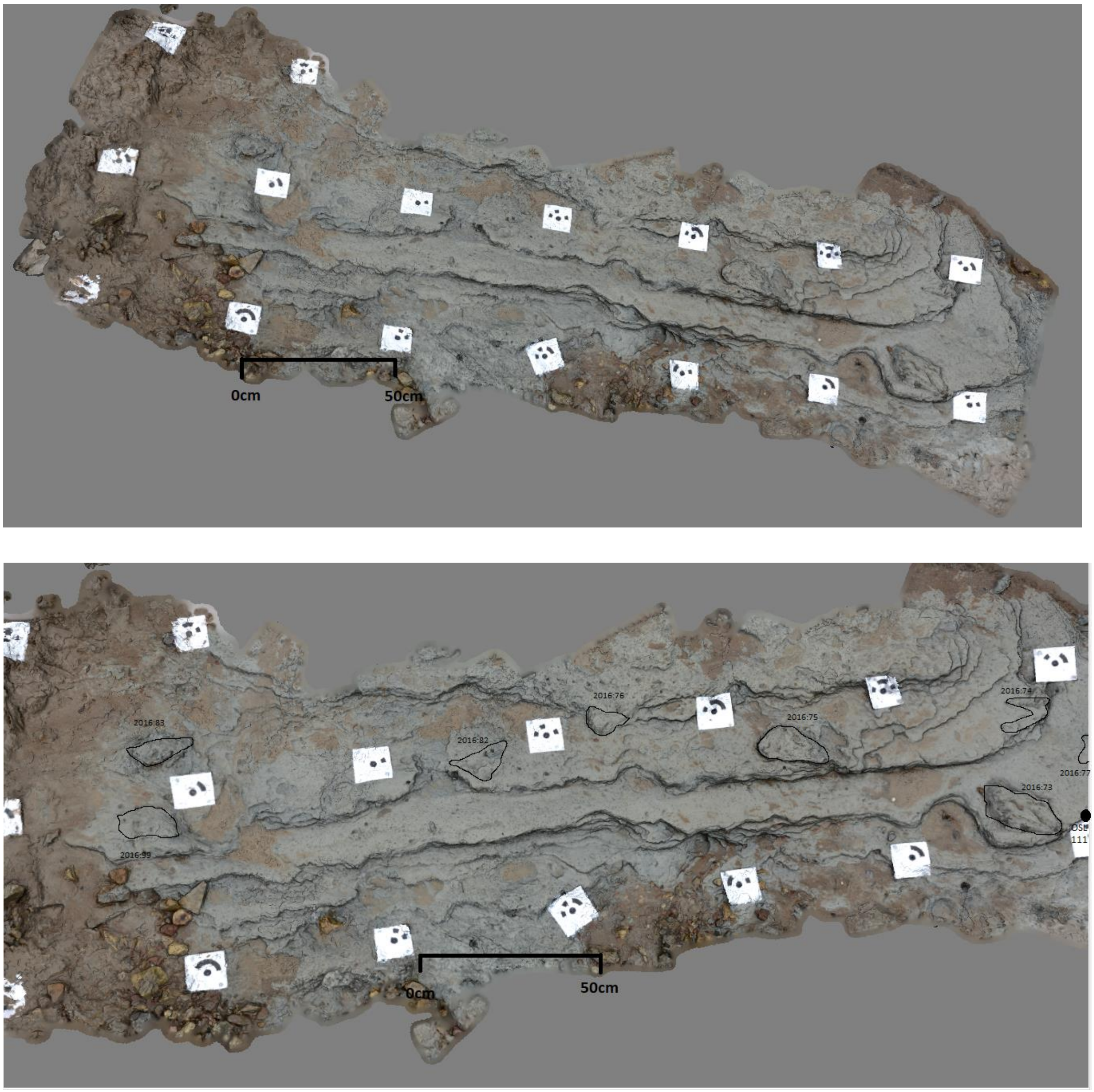


Figure 6.67 (top) Multi-image photogrammetry model of the footprint-track trail from Site R, from two different angles, with (bottom) the footprint-tracks numbered and outlines digitised, as well as approximate location of OSL sample 2016:111

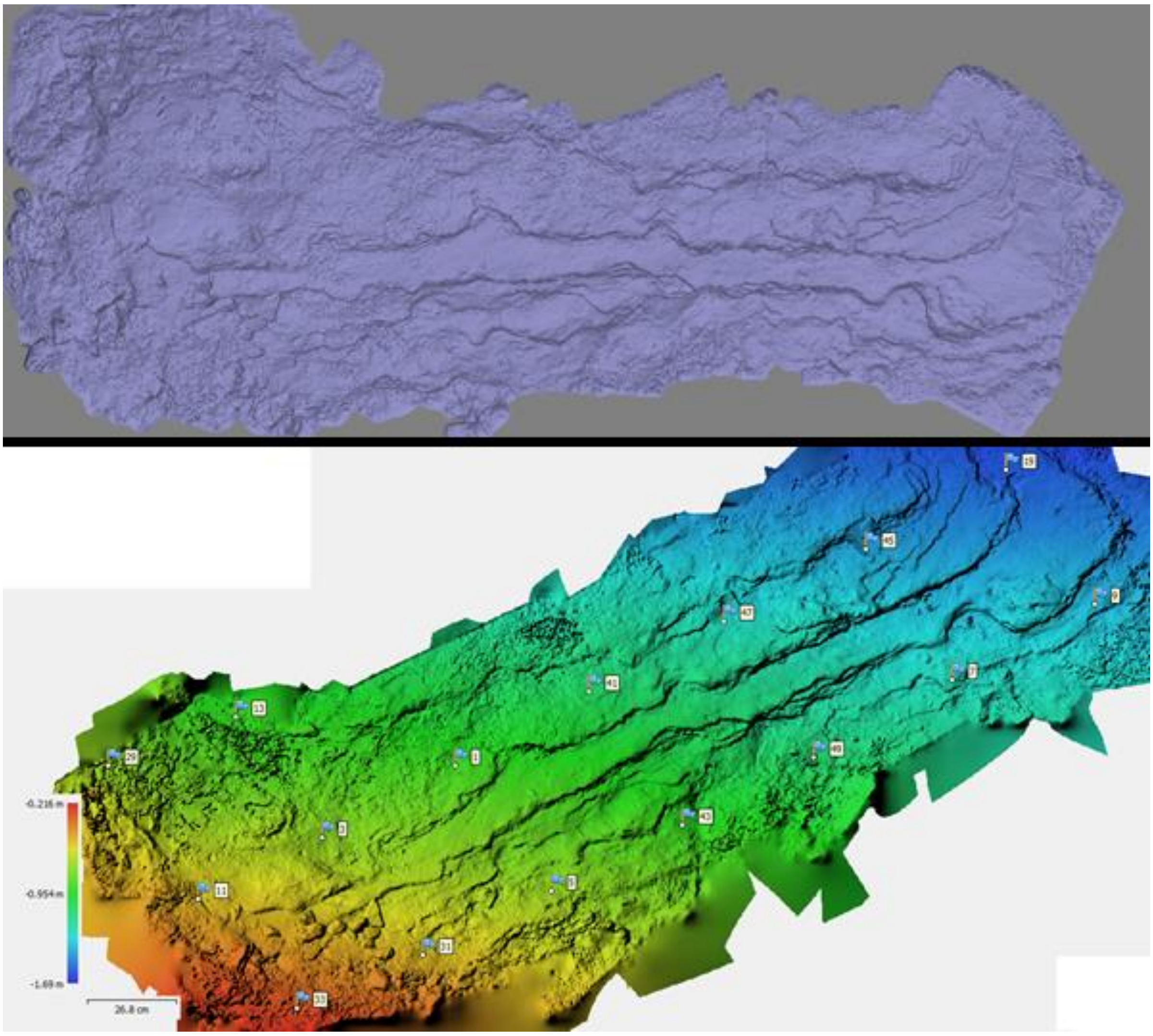


Figure 6.68 (top) Solid colour model of the area, (bottom) digital elevation model of Site R, note that scale is not the OD height of the area, which is -4.17 and -4.35m OD

Figure 6.69 Footprint-track 2016:73 (bottom right) and 2016:75 (top left)

6.8.2 Analysis of Site R footprint-tracks

Figure 6.70 demonstrates the lengths and widths of the human footprint-tracks recorded on Site R, with these results plotted against the modern footprint data discussed in Chapter 5 (Figure 6.71). There were four footprint-tracks that were not identifiable; one was disturbed and the other three were poorly formed and may have been ungulate footprints. These footprint-tracks were wider than many of the experimental footprints, this is a feature of ungulate footprints rather than human footprints, which are long and relatively slender.

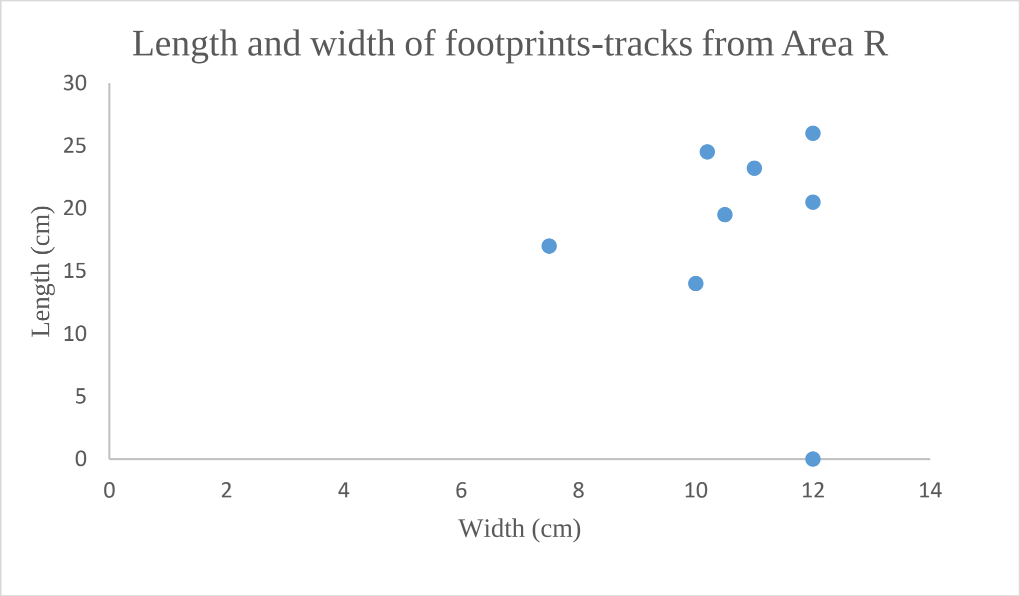


Figure 6.70 Scatter diagram representing metric dimensions of footprint-tracks from Site R

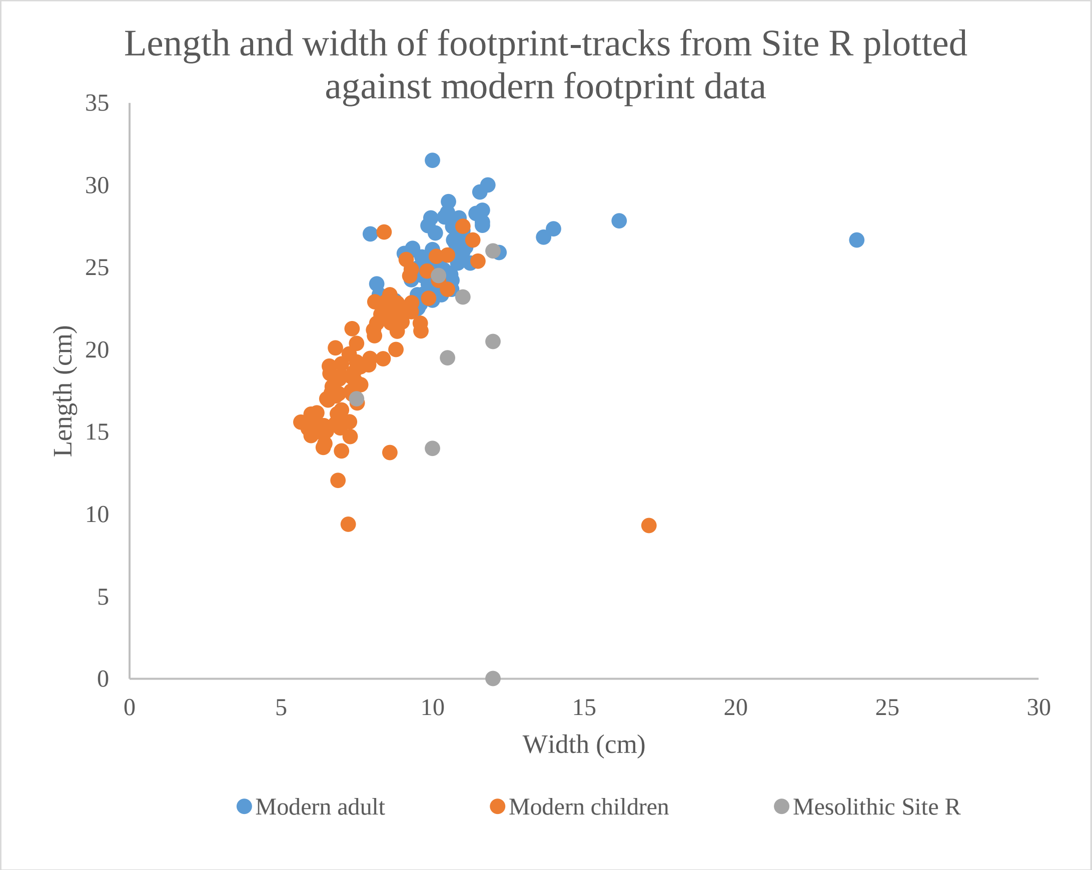


Figure 6.71 Metric dimensions of prehistoric footprint-tracks from Site R plotted against modern footprint data

6.8.3 Age and sex of individuals who made the footprint-tracks at Site R

Of the eight footprint-tracks preserved at Site R, only four of these had a morphological appearance which could accurately identify them as human footprints. The age and sex of these individuals is presented in Table 6.21 and Table 6.22. Three of the footprint-tracks, 2016:73, 2016:75 and 2016:100, formed a clear trail heading in a north-western direction. This individual created footprint-tracks that ranged in size from 20.5cm to 26cm, making an age and sex estimate problematic. At the youngest, this person would be 10 +/- 1 years old, though they may have been an adolescent or a full-grown adult. The variability in a single individual’s footprints is exemplified by this footprint-track trail. It must be remembered that these footprint-tracks were overtraces/undertraces so their lengths may be slightly over represented and as the photographs show they were quite eroded.

On the same lamination as this footprint-track trail the singular footprint-track 2016:82 was recorded. This individual was a young child, aged 5.5 +/- 1.5 years of undetermined sex.

Footprint –track number	**Probable age range (years)**	**Footprint-track length (cm)**	**UK shoe size**
2016:73	10 +/- 1	20.5	1
2016:74	Incomplete	19.5	-
2016:75	Pubescent child over 10 or adult	26	8
2016:76	Incomplete	24.5	-
2016:77	Incomplete	14	-
2016:82	5.5 +/- 1.5	17	Children’s 10.5
2016:83	Incomplete	-	-
2016:100	Pubescent child over 10 or adult	23.2	4.5

Table 6.21 Estimated age range from Site R footprint-tracks

Footprint-track number	**Sex**	**Footprint-track length (cm)**
2016:73	Child of either sex	20.5
2016:74	Incomplete	19.5
2016:75	Pubescent child or adult of either sex	26
2016:76	Incomplete	24.5
2016:77	Incomplete	14
2016:82	Child of either sex	17
2016:83	Incomplete	-
2016:100	Pubescent child of either sex or adult female	23.2

Table 6.22 Sex estimates from Site R footprint results

6.8.4 Stature estimates for Site R footprint-tracks

The stature of the individuals from Site R are represented in Table 6.23. The individual who made the footprint-track trail formed of 2016:73, 2016:75 and 2016:100 had an estimated stature between 152.0cm (4’11”) and 172.1cm (5’7”). The stature estimate standard error indicates that footprint-track 2016:73 may have been made by an individual as tall as 158.0cm (5’2”), whereas footprint 2016:75 may have been made by an individual who at the shortest was 164.8cm (5’4”) tall. The standard error for the stature estimates allows for a six-centimetre difference between the expected height for an individual who made footprints of a certain size, putting the individual at an expected stature of approximately 155.4cm (5’1”) to 164.5cm (5’4”).

Individual 2016:82 was a relatively short individual, at only 111.5cm (3’7”) indicating a young child. The estimated stature suggests that they were likely to be aged 5.5 +/- 1.5 years old, as children generally are taller than this by age 7, though they may have been shorter due to other factors such as nutrition and genetics.

Footprint number	**Footprint length (cm)**	**Footprint side**	**Estimated stature (cm)**	**Height (feet and inches)**	**Standard error**
2016 73	20.5	Left	152.0	4’11”	6
2016 75	26	Right	172.1	5’7”	7.3
2016 82	17	Left	111.5	3’7”	9.14
2016 100	23.2	Left	159.3	5’2”	6

Table 6.23 Stature estimates of individuals who made footprints in Site R

6.8.5 Speed of movement of individual on Site R

The left stride length from the individual who made footprint-tracks 2016:100 and 2016:73 was utilised to establish speed of movement (Table 6.24). This person had a stride of 136cm. If running they would have been travelling at 7km per hour (4mph), this speed would be a very slow jog. If walking they would have been travelling at 5km per hour (3mph), which is an average walking pace. Given the likely speed of movement it is probable that this person was walking. The presence of a young child on the same lamination may be an explanation for this slow speed and will be explored further within the discussion portion of this thesis.

Footprint-track number	**Footprint-track length average (cm)**	**Stride (cm)**	**Walking (meters per second)**	**Running (meters per second)**	**Walking and running (meters per second)**
2016: 100 - 2016 73 – 2016 75	21.8	136	1.49	1.9	1.6

Table 6.24 Speed of movement of individuals in Site R

6.8.6 Site R direction of movement

There has been one small footprint area so far uncovered at Site R, these individuals were all heading in a north-west direction (Figure 6.72), heading towards Goldcliff Island and Site B2. This direction of movement is different to those from Site M and N, which were generally moving on a north-east, south-west axis, but similar to some of the individuals at Site C/E.

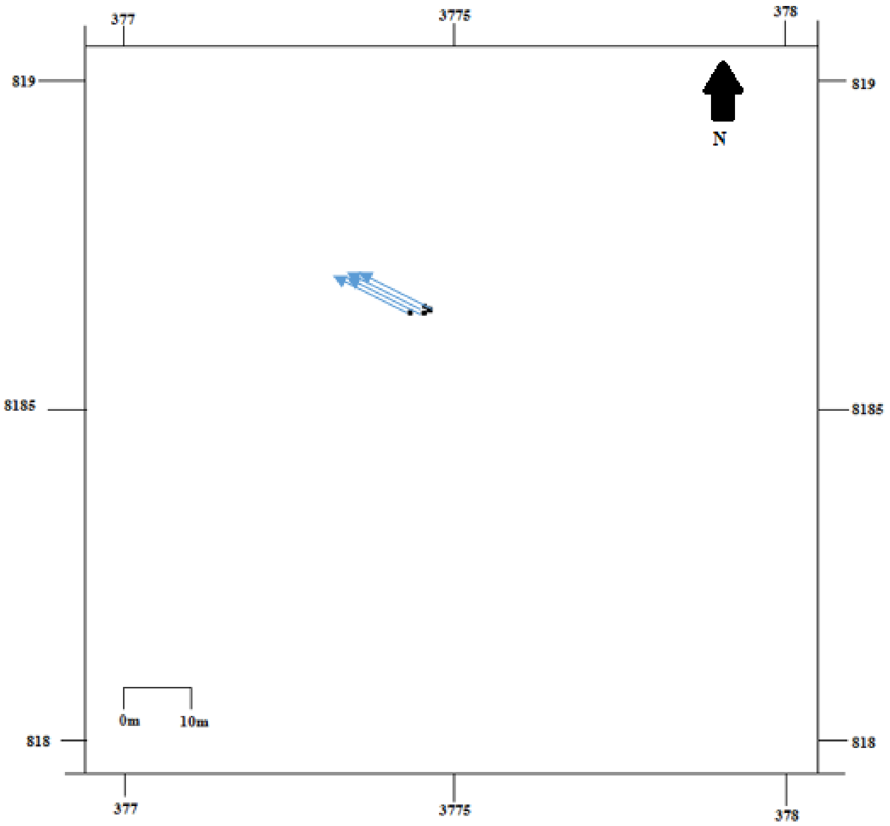


Figure 6.72 Direction of movement of Site R footprint-tracks

6.9 Site S footprint-tracks

Site S was discovered on 13.11.16. It is on laminations south of Site M, and is likely to be one of the earliest footprint areas so far recorded at Goldcliff East, as it was on lower laminations than Site M. This area is at -5.15 -5.31m OD which is a little higher than the Site N trail at -5.38 -5.59m OD, Site N is the oldest footprint-track area at Goldcliff East so far recorded as it is on the lowest laminations.

Due to the location of the laminations, it is an area that is only completely exposed during the spring tide of less than 0.6 meters above chart datum. The footprint-tracks themselves are located within a small gully through dipping laminations, which created difficulties in recording due to the constant flow of water and prevented multi-image photogrammetry being attempted (Figure 6.73). It was in a part of the site south of Site M where for more than 10 years at low tides there had been a waterfall draining an upper area of shallow water into an easterly area of permanent water. The area of this waterfall had become more eroded revealing the footprint-tracks. In August 2011 an area of bird footprints (2011:226) was recorded in the same area but on laminations 5cm to 13cm higher. The footprint-tracks from Site S were all within 2m of one another. There were nine footprint-tracks recorded within Site S, two of these footprint-tracks were poorly preserved, or possibly poorly formed in very wet sediment, only evident through an area of obvious localised disturbance by a foot on the lamination. The other seven had identifiable features enabling them to be assigned to the human species; this included hallux marks, heel and arches of the foot. They were all overtraces, though one footprint, 2016:102 had eroded so part of the possible footprint and undertrace could be observed.

The footprint-tracks ranged in length from 16.5cm to 25.2cm, with a width range of between 7cm and 9cm. These footprint-tracks were all relatively small in length and width compared to the other footprint areas (Table 6.25).

Figure 6.73 Example of the dipping gully, slopped laminations and constant water flow experienced whilst recording Site S

Footprint-track number	Site	Length (cm)	Width (cm)	Identifying features?	Left or Right?	Direction of movement
2016:102	S	25.2	9	Prominent hallux, arch and heel	Left	250° west
2016:103	S	16.5	7	Prominent arch	Left	64° north east
2016:104	S	16.5	7	Prominent arch	Right	64° north east
2016:105	S	19	8	Overtrace/undertrace	Indistinct	250° west
2016:107	S	19	9	Overtrace/undertrace, heel evident	Indistinct	64° north east
2016:108	S	16	8.2	Overtrace/ undertrace, heel evident	Indistinct	64° north east
2017:10	S	14.5	7	Toes evident	Left	308° north west
2017:11	S	13	9	Heel	Indistinct	310° north west
2017:12	S	26.8	6.8	Undertrace, arch evident	Left	260° west

Table 6.25 Data of the Site S footprints

6.9.1 Description of Site S footprints-tracks: 2016:102, 2016:103, 2016:104, 2016:105, 2016:107, 2016:108, 2017:10, 2017:11 and 2017:12

Site S is near Site M, less than 10 meters east of Site M7 (Figure 6.20). Seven footprint-tracks were recorded in this area.

Footprint-track 2016:102 was made by the left foot of a human, with all the identifying features for a human foot (hallux, toes, ball of foot, heel, arch, long and slender imprint) seen in the right light (Figure 6.74). This footprint-track was likely an undertrace, with the overtrace sediment still present on the heel of the footprint-track. This individual was orientated towards Goldcliff Island, 250° west. There were other footprint-tracks with the appearance of human footprints, though none were as detailed as 2016:102.

Footprint-track 2016:103 was possibly orientated 64° east, moving away from Goldcliff Island, however the features of the footprint are lacking, and what appears to be the heel of the footprint-track could also be eroded toes. This footprint-track is likely an undertrace and there was no evidence of any interdigital ridges.

Footprint-track 2016:104 was possibly a child footprint but direction of movement or size could not be established due to lack of preservation. There was obvious turbation in this area, this localised disturbance to the sediment was given the identification number 2016:105, however it was too unclear to accurately identify this as any kind of footprint-track.

Footprint-track 2016:107 was a probable human footprint overtrace (Figure 6.75). There were no identifying features meaning that a positive identification and orientation could not be established. Footprint-track 2016:108 was orientated 65°east, heading away from Goldcliff Island. This footprint-track was relatively indistinct and was an undertrace.

Footprint-track 2017:10, 2017:11 and 2017:12 were all identified as human as there was a clear human footprint shape to the disturbed sediment. They were likely undertraces (Figure 6.76). Footprint-track 2017:10 was a left foot with an evident arch and hallux. 2017:11 was lacking in toes or an arch so the foot side could not be established, 2017:12 was also from a left foot. In terms of orientation footprint-track 2017:10 was orientated 308° north, 2017:11 was 310° north and 2017:12 in a 260° west direction.

Figure 6.74 Human footprint-track 2016:102, note the obvious toes

Figure 6.75 Footprint-track 2016:107, scale is mm

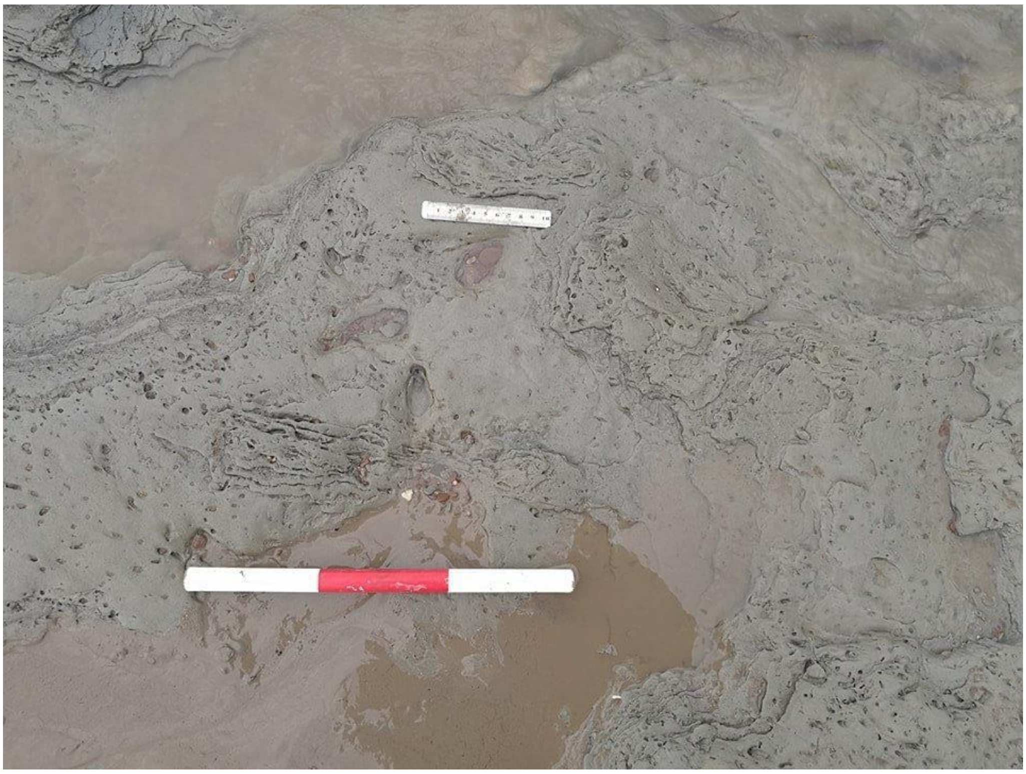


Figure 6.76 Footprint-tracks 2017:10, 2017:11 and 2017:12, scale 30cm

6.9.2 Analysis of Site S footprint-tracks

Figure 6.77 shows the lengths and widths of the possible human footprint-tracks recorded on Site S, and Figure 6.78 shows these footprint-tracks plotted against the modern human analogue. Most of these footprint-tracks were similar in length and width to those made by modern children aged under 10 years of age.

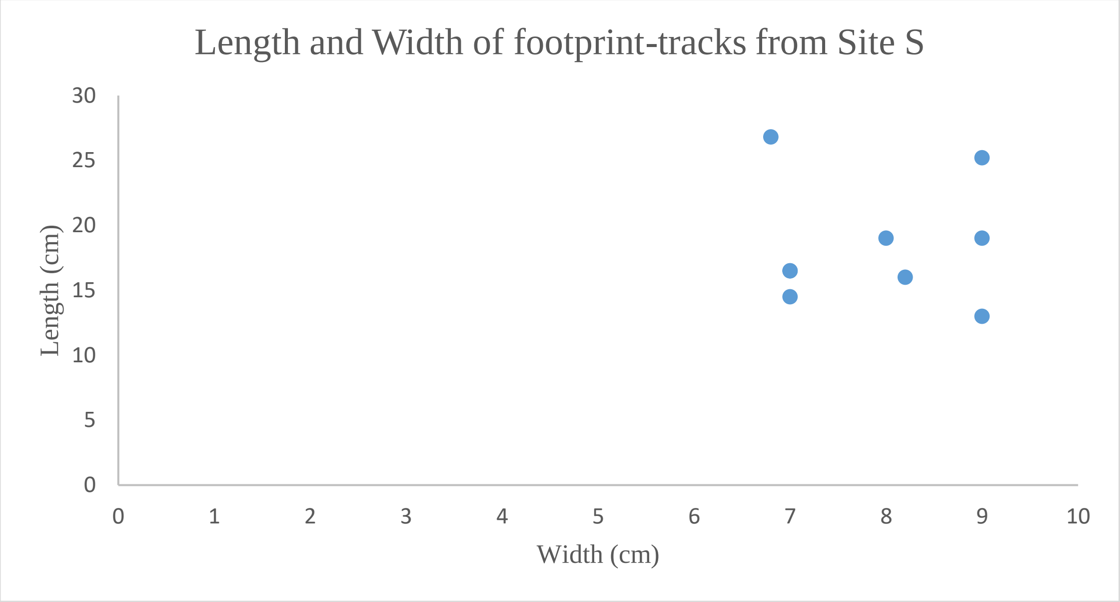


Figure 6.77 Scatter diagram plotting metric dimensions of Site S footprint-tracks

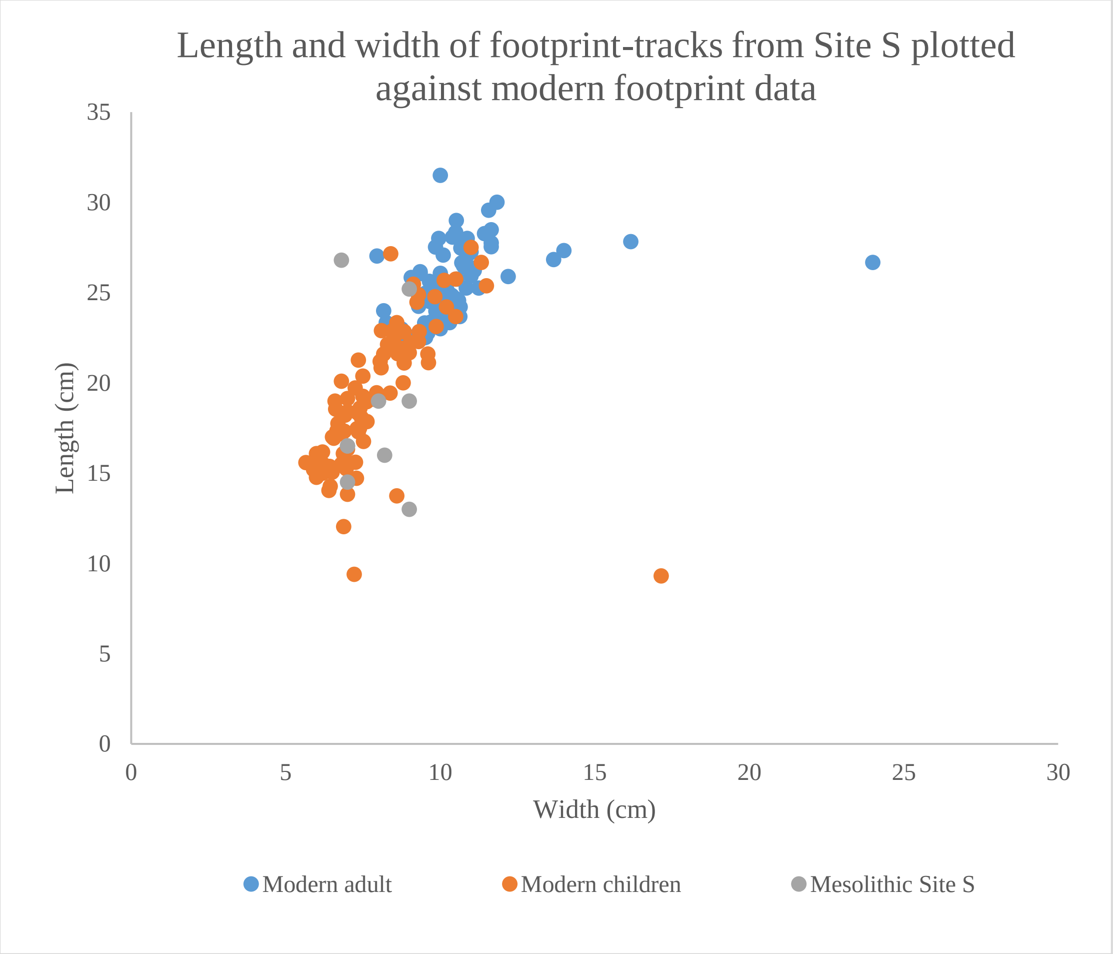


Figure 6.78 Metric dimensions of footprint-tracks from Site S plotted against modern footprint dimensions

6.9.3 Age and sex of the individuals at Site S

There were nine footprint-tracks recorded in Site S, although some were not clear, often with only a foot arch or heel evident. Two of the footprint-tracks, 2016:103 and 2016:108, were part of a trail. This area was investigated but there were not any further footprint-track trails identified, though there were other singular footprint-tracks. This individual was heading east away from Goldcliff Island. Within Site S the smallest footprint-tracks found during the 2014-2017 fieldwork were recorded. Two of the footprint-tracks, 2017:10 and 2017:11, were made by very young individuals, aged four or younger (Table 6.26). A further three footprint-tracks were made by children aged 5.5 +/- 1.5 years, and two individuals were aged 6.5 +/-1.5 years. There were a further two footprint-tracks, 2016:102 and 2017:12 that were made by larger individuals, either full grown adults or pubescent children. Due to the nature of the footprints, mainly belonging to children, sex could not be established, though 2017:12 may have been an adult male due to its large size (Table 6.27).

Footprint-track number	Probable age range (years)	Footprint-track length (cm)	UK shoe size
2016:102	10+ / adult	25.2	7
2016:103	5.5 +/- 1.5	16.5	Children’s 10
2016:104	5.5 +/- 1.5	16.5	Children’s 10
2016:105	6.5 +/- 1.5	19	Children’s 13
2016:107	6.5 +/- 1.5	19	Children’s 13
2016:108	5.5 +/- 1.5	16	Children’s 9.5
2017:10	4 or younger	14.5	Children’s 7.5
2017:11	4 or younger	13	Children’s 3.5
2017:12	10 +/ adult	26.8	8.5

Table 6.26 Possible age ranges of the individuals who made the footprint-tracks from Site S

Footprint-track number	Sex	Footprint-track length (cm)
2016:102	Pubescent child or adult	25.2
2016:103	Child of either sex	16.5
2016:104	Child of either sex	16.5
2016:105	Child of either sex	19
2016:107	Child of either sex	19
2016:108	Child of either sex	16
2017:10	Child of either sex	14.5
2017:11	Child of either sex	13
2017:12	Pubescent child or adult	26.8

Table 6.27 Possible sex of the individuals in Site S

6.9.4 Stature estimates for individuals on Site S

The statures of individuals from Site S are represented in Table 6.28 and indicate that there were young juveniles in the area as the multitude were under 121cm tall (3’11”). It is significant that these children were young, as there is very little evidence in the archaeological record of young children going about their daily lives.

Two of the individuals were 168.6cm (5’6”) and 175.5cm (5’9”) tall, this stature suggests that a possible adult male may have been present, as well as an adult female or an adolescent.

Footprint-track number	Footprint-track length (cm)	Footprint side	Estimated stature (cm)	Height (feet and inches)	Standard error
2016:102	25.2	Left	168.6	5’6”	7.3
2016:103	16.5	Left	109.5	3’7”	9.14
2016:104	16.5	Right	109.2	3’6”	8.12
2016:105	19	Indistinct	119.9	3’11”	8.59
2016:107	19	Indistinct	119.9	3’11”	8.59
2016:108	16	Indistinct	107.1	3’6”	8.59
2017:10	14.5	Left	101.2	3’3”	9.14
2017:11	13	Indistinct	94.3	3’1”	8.59
2017:12	26.8	Left	175.5	5’9”	7.3

Table 6.28 Estimated heights of the individuals in Site S

6.9.5 Speed of movement in Site S

There were four footprint-tracks within Site S that were part of a trail, each trail contained two footprint-tracks (Table 6.29). It was established that the person who made footprint-tracks 2016:108 and 2016:103 was walking 0.92 meters per second, this equates to a speed of 3km per hour (2mph). Considering the small stature of the person it is a realistic speed for them to be walking. They were not running; the footprints were fully formed in the sediment indicating full contact between the sediment and the foot.

The other footprint-track trail in this area was formed by footprint-tracks 2017:10 and 2017:11. The calculated walking speed was 0.42 meters per second, which is a speed of 1.51km per hour (0.94mph). This person was 97.8 cm tall (3’2”) so the slow speed is not unexpected. They had a possible running speed of 0.43 meters per second, almost identical to the walking speed, indicating that this juvenile was unlikely to have been moving anywhere quickly.

Footprint-track number	**Footprint-track length average**	**Stride (cm)**	**Walking (meters per second)**	**Running (meters per second)**	**Walking and running (meters per second)**
2016:108 to 2016:103	16.3	70.8	0.92	1.15	0.69
2017:10 to 2017:11	13.8	36	0.42	0.43	1.1

Table 6.29 Estimated speed of movement of the individuals from Site S

6.9.6 Site S direction of movement

There were only a small number of footprint-tracks within the assemblage at Site S, though three of the nine were orientated south-west, at between 250° and 260°. Four were orientated north-east, at 64°, and two were orientated north-west towards Goldcliff Island, at between 308° and 310°. In a similar way to those found at Site M and Site N, a predominant amount of these footprints were orientated on a south-west and north-east axis, indicating individuals who were coming from and heading to similar places (Figure 6.79).

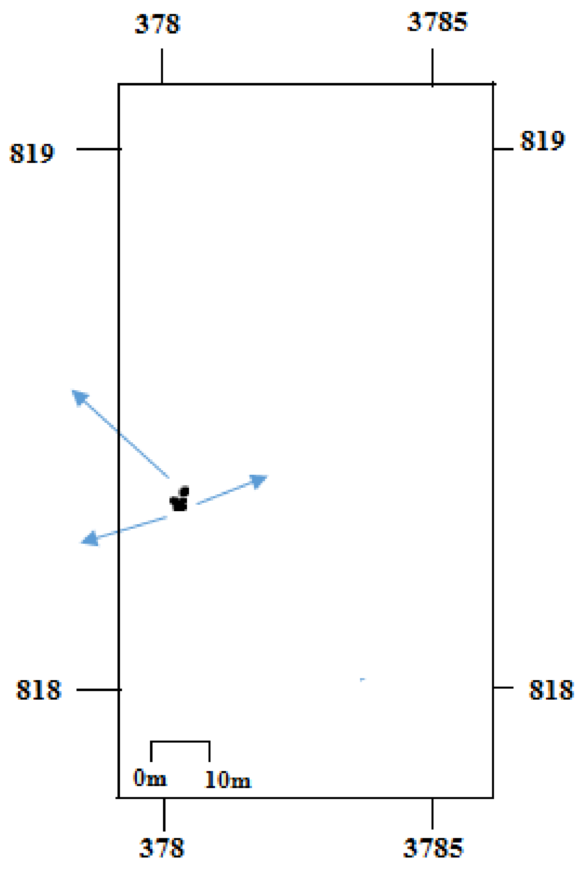


Figure 6.79 Direction of movement of Site S individuals

6.10 Footprint-tracks recorded at Goldcliff East before 2014

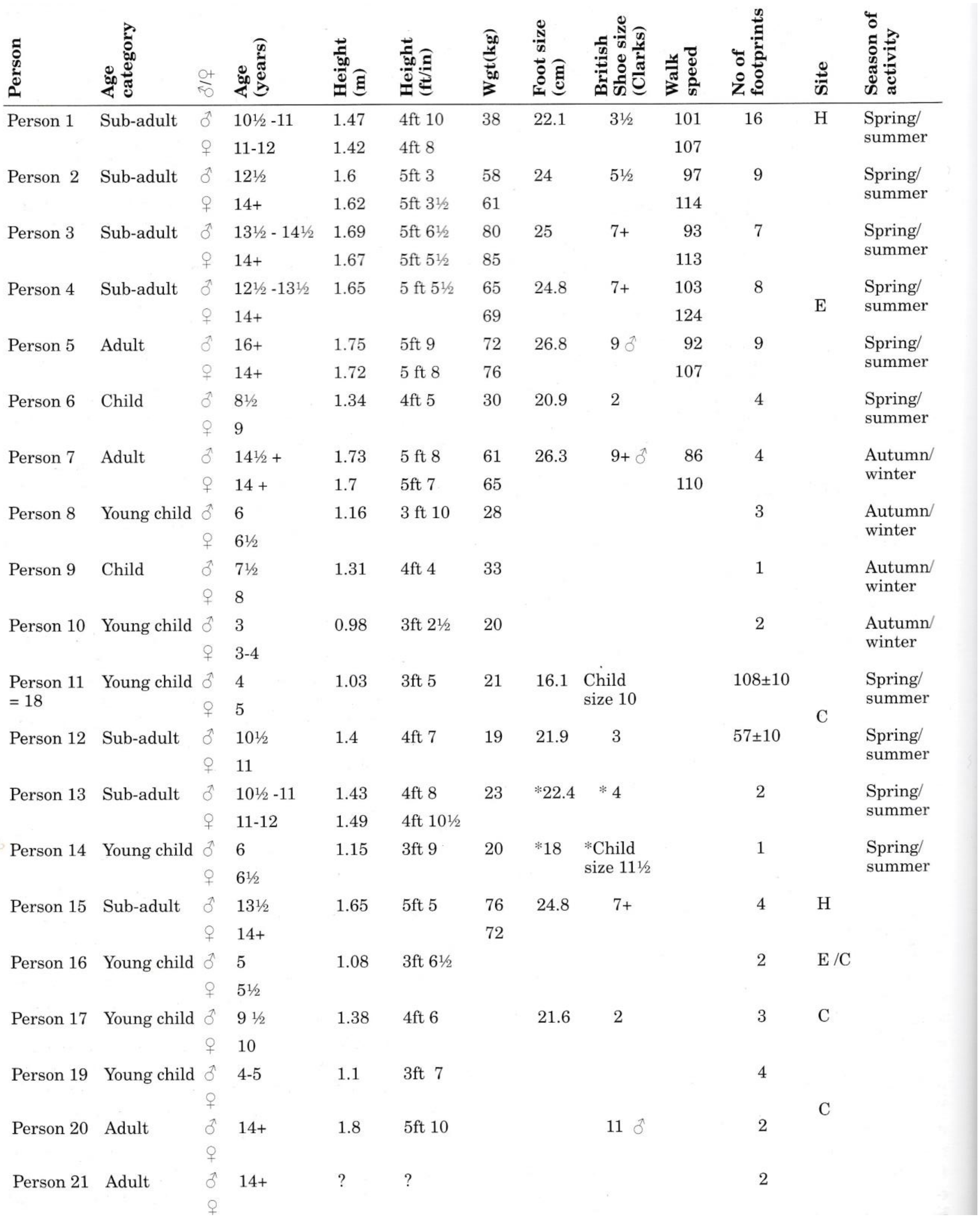
A thorough study was conducted on the human footprint-tracks recorded in 2001-2004 by Rachel Scales (2006). A summary of the human age, sex, height, weight and shoe size is provided in Table 6.30.

Scales (2006) collected age and footprint size data from 254 present day school children aged between four and eleven years old. The technique utilised to record metric data of a foot was to trace the left and right foot of each child onto paper, to achieve a footprint parameter. The experimental research in this study demonstrated that footprints made in sediment rather than in a two-dimensional circumstance are more variable, which is important when applying to footprints made in a similar sediment. Research within Chapter 5 of this thesis suggests that aging an individual above ten years from footprints made in clayey silt sediment is complex due to the footprint formation process. Scales (2006) had noted in her research that a person aged

14+ will have adult sized footprints, the current research has demonstrated that aged 10+ needs to be considered adult instead, due to differences in growth among individuals. There can be a large variation in footprints made in clayey silt sediment, which is influenced further by the moisture content, so a precise age such as those provided by Scales must be treated with caution.

Reanalysis of Scales' (2006, 2007a) footprint data (Table 6.31), applying the principle of children aged ten years old and above as having the potential to have adult sized footprints did not change any of Scales findings significantly. Scales identified two adults within her dataset, these individuals were also identified as adults within the current research. Person 6 was identified by Scales (2006, 2007a) as being a child aged between 8½ and nine years old, the current research identifies this individual as aged 10 +/- 1 year, similar to Scales (2006, 2007a) findings. Person 11 also had a similar age estimate, Scales estimated this child to be aged between four and five depending on the sex, the current research identified this child to be aged 5.5 +/- 1.5 years, regardless of sex. Five of the individuals from Scales (2006, 2007a) research were possibly adolescents as she suggested, though they also could have been adult females. Person 3, Person 5, and Person 7 were estimated by Scales to be aged between 13½ to 16 depending on the sex. Reanalysis of the data within this study suggests that although these may have been made by either adults or children, the footprint-tracks made by Person 5 and Person 7 were above 26cm and more likely to be made by adults than children, though they could also have been large children. Person 3 may have been a child aged 10+ or an adult of either sex.

Table 6.32 presents the information gathered within this study in a similar way to Scales summary; this allows the full range of the 17 years of footprint-track research at Goldcliff East to be viewed. Seven of the 21 people identified by Scales (2006, 2007a) provided insufficient footprint-track trail data so were not included within the final analysis of Goldcliff East footprint areas. There were nine footprint-track trails recorded during the current study. Of the 22 footprint-track trails recorded throughout research at Goldcliff East, four (18%) trails were made by children (Figure 6.80), one was possibly younger than four years old, two were aged 5.5 +/- 1.5 years, and one was 6 +/- 1.5 years. Three (14%) further footprint-track trails were identified as 10 +/- 1 years old. The assemblage at Goldcliff East also had a very high proportion of children aged 10+/ adult females, nine (41%) trails fell into this range indicating that pubescent children and/ or adult females were within this area in a relatively high amount. Six (27%) trails were a size that could be either children aged 10+, adult females or adult males, four of these were above 26cm in length so possibly from small adult males, or large females/ children. There were not any footprint-track trails made at Goldcliff East that were made by large adult males, though there were singular footprint-tracks that may have been.



Person	Age category	♂/♀	Age (years)	Height (m)	Height (ft/in)	Wgt(kg)	Foot size (cm)	British Shoe size (Clarks)	Walk speed	No of footprints	Site	Season of activity
Person 1	Sub-adult	♂	10½ -11	1.47	4ft 10	38	22.1	3½	101	16	H	Spring/ summer
		♀	11-12	1.42	4ft 8				107			
Person 2	Sub-adult	♂	12½	1.6	5ft 3	58	24	5½	97	9		Spring/ summer
		♀	14+	1.62	5ft 3½	61			114			
Person 3	Sub-adult	♂	13½ - 14½	1.69	5ft 6½	80	25	7+	93	7		Spring/ summer
		♀	14+	1.67	5ft 5½	85			113			
Person 4	Sub-adult	♂	12½ -13½	1.65	5 ft 5½	65	24.8	7+	103	8		Spring/ summer
		♀	14+			69			124		E	
Person 5	Adult	♂	16+	1.75	5ft 9	72	26.8	9 ♂	92	9		Spring/ summer
		♀	14+	1.72	5 ft 8	76			107			
Person 6	Child	♂	8½	1.34	4ft 5	30	20.9	2		4		Spring/ summer
		♀	9									
Person 7	Adult	♂	14½ +	1.73	5 ft 8	61	26.3	9+ ♂	86	4		Autumn/ winter
		♀	14 +	1.7	5ft 7	65			110			
Person 8	Young child	♂	6	1.16	3 ft 10	28				3		Autumn/ winter
		♀	6½									
Person 9	Child	♂	7½	1.31	4ft 4	33				1		Autumn/ winter
		♀	8									
Person 10	Young child	♂	3	0.98	3ft 2½	20				2		Autumn/ winter
		♀	3-4									
Person 11 = 18	Young child	♂	4	1.03	3ft 5	21	16.1	Child size 10		108±10		Spring/ summer
		♀	5								C	
Person 12	Sub-adult	♂	10½	1.4	4ft 7	19	21.9	3		57±10		Spring/ summer
		♀	11									
Person 13	Sub-adult	♂	10½ -11	1.43	4ft 8	23	*22.4	* 4		2		Spring/ summer
		♀	11-12	1.49	4ft 10½							
Person 14	Young child	♂	6	1.15	3ft 9	20	*18	*Child size 11½		1		Spring/ summer
		♀	6½									
Person 15	Sub-adult	♂	13½	1.65	5ft 5	76	24.8	7+		4	H	
		♀	14+			72						
Person 16	Young child	♂	5	1.08	3ft 6½					2	E /C	
		♀	5½									
Person 17	Young child	♂	9 ½	1.38	4ft 6		21.6	2		3	C	
		♀	10									
Person 19	Young child	♂	4-5	1.1	3ft 7					4		
		♀									C	
Person 20	Adult	♂	14+	1.8	5ft 10			11 ♂		2		
		♀										
Person 21	Adult	♂	14+	?	?					2		
		♀										

Table 6.30 Summary of 21 identifiable human footprint-track trails, including age, height and shoe size, adult (14+), sub-adult (age 11-14), child (age 7-11), young child (age 3-6). Walk speed is steps per minute (Scales 2007a; Table 12.1)

Person	Footprint-track length (cm)	Age	Sex
Person 1	22.1	10+ years/adult female	Either
Person 2	24	10+ years/adult female	Either
Person 3	25	10 + years/adult	Either
Person 4	24.8	10+ years/adult female	Either
Person 5	26.8	10+ years/adult	Most likely adult male though could be robust adult female or child
Person 6	20.9	10 +/- 1 years	Either
Person 7	26.3	10+ years/adult	Most likely adult male though could be robust adult female or child
Person 11	16.1	5.5 +/- 1.5 years	Either
Person 12	21.9	10 +/- 1 years	Either
Person 13	22.4	10+ /adult female	Either
Person 14	18	6 +/- 1.5 years	Either
Person 15	24.8	10+ /adult female	Either
Person 17	21.6	10 +/- 1 years	Either

Table 6.31 Reanalysis of the age and sex of footprint-tracks from Scales (2007a; Table 12.1)

Footprint-track number	**Age range (years)**	**Average Height (cm)**	**Average Height (foot)**	**Footprint-track average length (cm)**	**British shoe size**	**Walk speed (meters per second)**	**Run speed (meters per second)**	**Direction of movement**	**No of footprints in trail**	**Site**	**Seasonality of use**
2015:114 to 2015:115	Adult	172.1	5.6	26	8	1.69	2.2	30° north/ 18° north	2	C/E	Spring/ Summer
2015:116 to 2015:117	10+ / adult female	154.9	5	22	3	0.77	0.93	310° west of north/ 290° west of north	2	C/E	Spring/ Summer
2010:1 to 2010:5	Adult	161.3	5.2	26	8	1.96	1.92	233° west south west	5	M	-
2015:160 and 2015:163	10+/ adult female	164	5.3	24.3	5.5/6	2	2.75	230° south west	2	M	Spring/ Summer
2015:17 to 2015:20	10+/ adult	167.2	5.4	25	6.5	1.66	2.15	60° north east	3	N	Autumn/ Winter
2016:50 to 2016:56	10+/ adult female	161.9	5.3	23.9	5/5.5	1.46	1.89	Between 50° and 70° north east	7	N	Autumn/ Winter
2016:73, 2016:75, 2016:100	10+ / adult female	161.1	5.2	23.2	4.5	1.49	1.9	295° west north west	3	R	Spring/ Summer
2016 108 and 2016:103	5.5 +/- 1.5	108.3	3.5	16.3	Children’s 10	0.92	1.15	64° east	2	S	Spring/ Summer

2017:10 and 2017:11	4 or younger	97.75	3.1	13.8	Children's 5.5	0.42	0.43	308° north west/ 310° north west	2	S	Spring/ Summer

Table 6.32 Summary of the footprint-track trails of Mesolithic humans recorded during 2010-2017. Adults are aged 10+ due to similar sizes in pubescent children and adults

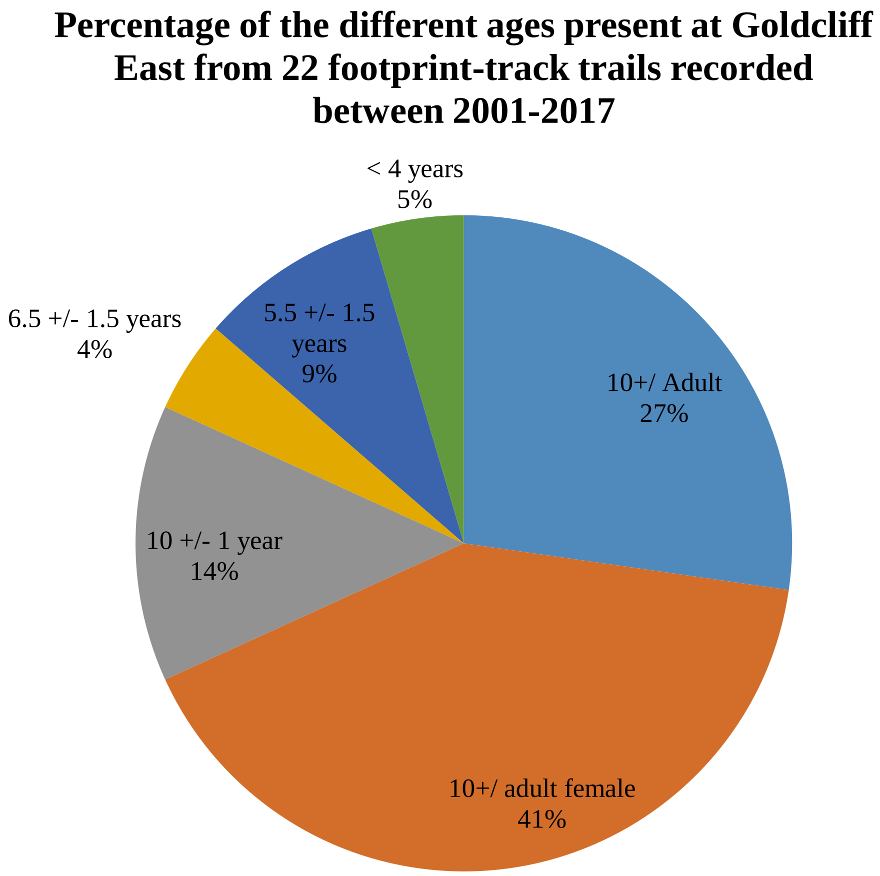


Figure 6.80 Combination of the footprint-tracks trail data from Scales (2006) and the current study, to demonstrate the percentage of children and adults at Goldcliff East

6.11 Discussion

The Mesolithic footprint-tracks from Goldcliff East provide an intriguing insight into the daily lives and activities of this hunter-gatherer population. Often the Mesolithic individuals of Britain are invisible; there are few Mesolithic skeletal remains resulting in there being very little sense of demographic diversity. The population and social demographics that can be established from footprint-tracks are therefore incredibly important. Footprint-tracks provide evidence of an active community, going about their daily lives and engaging in their social relationships.

6.11.1 Height and sex

The footprint-tracks made at Goldcliff East were made by people who ranged in height, from a young juvenile under four years old with an approximate height of 97.5cm (3’2”) to an adult male with an estimated height of 198.5cm (6’6”). The average height of those aged over ten years old was 166.5cm (5’5”). Due to the large overlap between possible male and female footprint sizes (Table 6.3), as well as the issue caused by pubescent children who were still growing, an average height was not determined for males and females. It is evident that there were tall individuals within the population; at least four of the footprint-tracks were likely made by individuals taller than 182cm (5’11”).

6.11.2 The Role of children at Goldcliff East

The two separate studies of the footprint-tracks at Goldcliff East have defined child footprint sizes differently. Within the current research children are considered to be aged ten years old or under, with a footprint length less than 22cm, due to the number of adult females who also made footprints between 22cm and 25cm when walking on clayey silt sediment. 63% of modern females within this study had footprint-tracks an average of between 22cm and 24cm in length, 56% of children aged between ten and 15 years old also fell into these measurements, plus a further 5% of individuals aged ten to 15 years old who made footprints with an average length under 22cm. Scales (2006) defined children as under 14 years of age, with a footprint-track size below 25cm. There is therefore the possibility that some of Scales’ (2006) results identifying sub-adults may have also been made by adult females. 320 possible human footprint-tracks were recorded by Scales (2006), and were thought to have been made by between 18 and 21 individuals. 159 of the 320 footprint-tracks were made in a trail by two individuals, Person 11 and Person 12. Person 11 had an average footprint-track length of 16.1cm and Person 12 had an average footprint-track length of 21.9cm. Of the remaining 161 possible human footprint-tracks, Scales (2006) identified a further 58 as likely to be human, with 6 footprint-tracks less than 22cm, 13 between 22cm and 24.9cm, 22 between 25cm and 29.9cm and 17 over the length of 30cm. Of the total 320 footprint-tracks recorded by Scales (2006), her data suggests that 56% of the footprint-tracks were made by children under 14 years old. It is clear that the footprint-tracks trails made by Person 11 and 12 created a skewed representation towards a high proportion of young children, making up half of Scales entire footprint-track database.

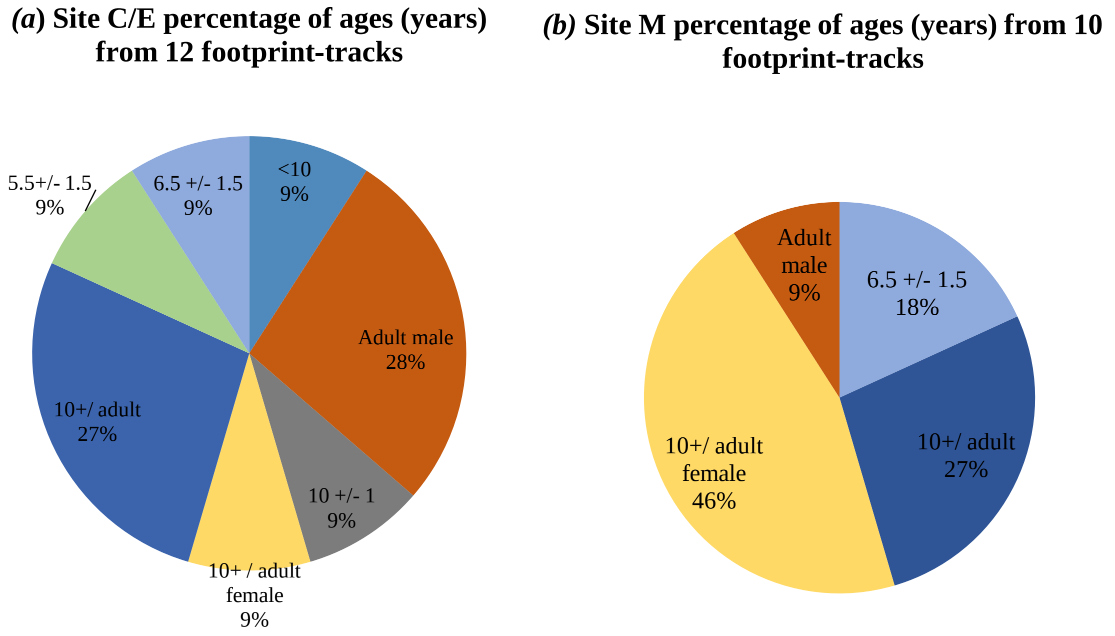
The current research argues that 52% of Scales (2006) footprint-track data has the metric dimensions of children, not 56%. In addition to this, a further 61 possible human footprint-tracks were recorded in the current study, with 30% thought to be children aged under ten years old. Overall, there have been 381 possible human footprint-tracks recorded at Goldcliff East between 2001 and 2017, 183 (48%) of which are similar in length to children, as defined by the author, as the footprint**s** were a length of less than 22cm.

Previous research (Scales 2006; 2007a) has suggested that there were a high percentage of children along the area of Goldcliff East that is now part of the intertidal zone; the current research also suggests this. Smaller footprint-tracks were observed less often in a footprint-track trail during this study, with trails generally made by footprint-tracks 20cm or larger, which may be related to a preservation bias, though this was evidently not the same experience for Scales' (2006) research, as half of her footprint-tracks were made by two trails of footprints made by children (Person 11 and Person 12).

Archaeological reconstructions of hunter-gatherers generally depicts an image of adult males performing activities such as flint knapping and hunting, and women gathering and child rearing. Footprint-tracks can provide evidence of population composition and reveal individuals who are almost completely hidden in the prehistoric archaeological record, the children. Within this record we have actual evidence of different parts of the community engaging in activities.

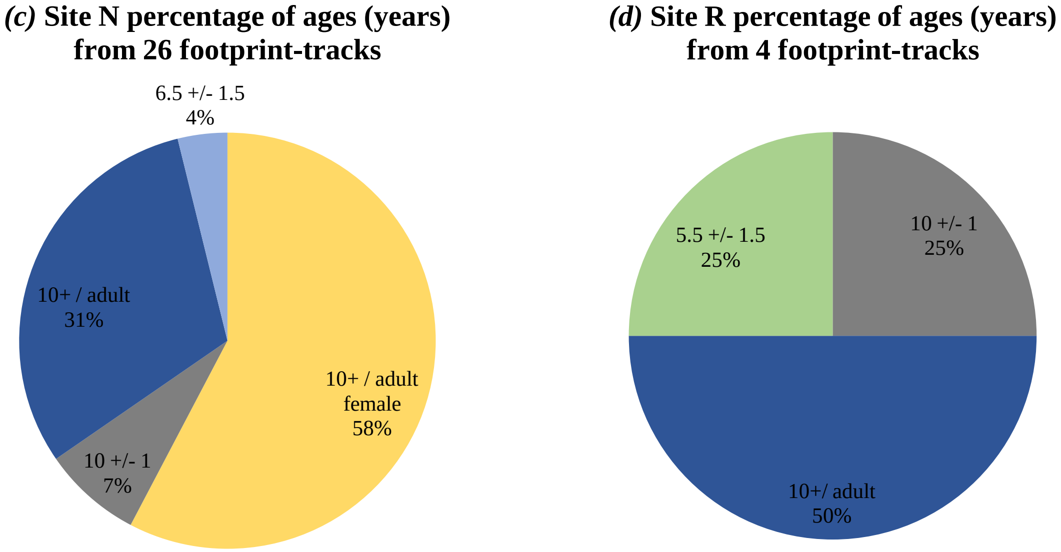
In every footprint area recorded between 2014-2016 at least 20% of the footprints were made by children aged ten years or younger (Figure 6.81). The only exception to this was Site M, where 18% of those recorded belonged to young people. The highest percentage of footprint-tracks with the metric dimensions of children was found in Site S, where 78% of the footprint-tracks were made by individuals aged ten or under.

During the research period 2014-2017 there were no child footprint-track trail**s** discovered which were made of more than three footprints, so a comment cannot be made about their activity (eg. playing or prey stalking), however juvenile footprint-tracks trails recorded by Scales (2006) indicates children were moving in a way that indicated mud larking or play. There can however be an inference made about the individuals at Site N; 69% of footprint-tracks recorded from Site N between 2014-2017 were made by children and adult females. The other 31% may have been made by small adult males, adult females or children aged above ten years old. The footprint-tracks within this area were all orientated on an axis which would take them towards places where wood structures have been found in palaeochannels, these are possibly remains of fish traps (Site T and Site L). This may indicate that these children were not just using the saltmarsh environment to play or learn as indicated by Scales (2006), but were actively participating in fishing activity, which would require them to check the traps at least twice a day at low tide.



(*a*) Site C/E percentage of ages (years) from 12 footprint-tracks

(*b*) Site M percentage of ages (years) from 10 footprint-tracks



(*c*) Site N percentage of ages (years) from 26 footprint-tracks

(*d*) Site R percentage of ages (years) from 4 footprint-tracks

Figure 6.81, (a-e) Pie chart representation of the approximate ages of the people who made the footprint-tracks in the different areas, recorded 2010-2017, (f) the percentage of children and adults from all footprint-tracks recorded 2010-2017

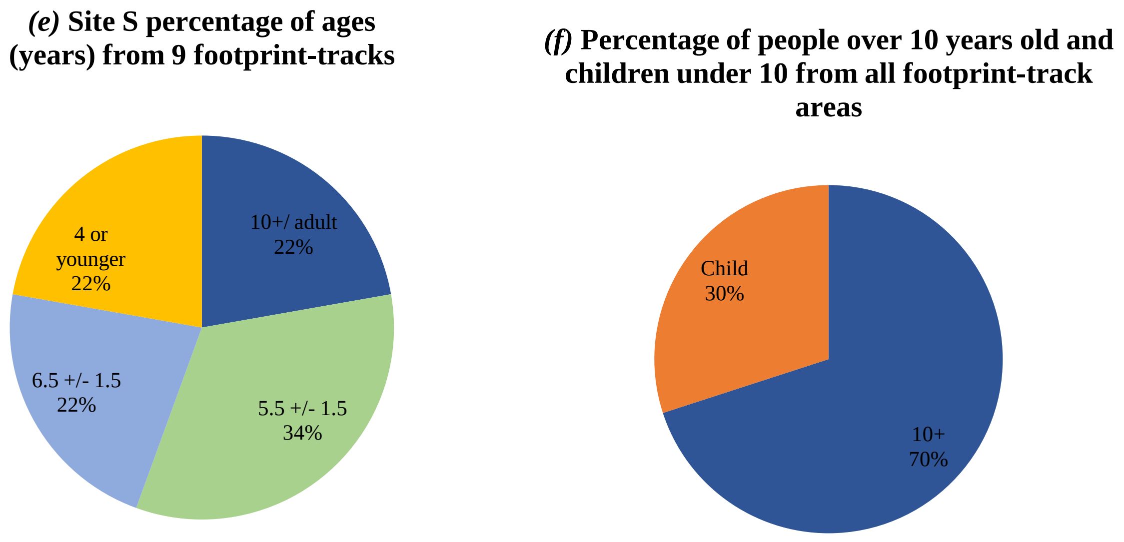


Figure 6.81 continued, (a-e) Pie chart representation of the approximate ages of the people who made the footprint-tracks in the different areas, recorded 2010-2017, (f) the percentage of children and adults from all footprint-tracks recorded 2010-2017

6.11.3 Direction of movement, banding and seasonality

Particle size analysis of the sediments from the footprint areas demonstrated that all footprint sites except Site N were made upon fine-grained sediments (Chapter 8). Although the precise surface of the human footprints could not be identified, avian footprints were often found preserved, rather than overtraces or undertraces, which meant that the actual surface the birds walked upon could be analysed. Avian footprint-track 2016:70, a crane footprint from Site C/E, was made on very fine-grained sediment as opposed to the underlying lamination and suggests a warmer sea-temperature and a gentle wind-wave climate, indicating a summer period when these footprints were made (Allen 2004; Dark and Allen 2005), likely to be when the human footprint-tracks on the same lamination were made.

Particle size analysis from a Site N human footprint (2015:18) indicated a coarser-grained particle size than those from the other footprint-track areas. Although the footprint-tracks from Site N were overtraces/undertraces so the precise surface that the human footprints were made upon could not be established, the footprints of grey heron were also found on these laminations, only 8cm from footprint-track 2015:17, which forms a human footprint-track trail with 2015:18. Particle size from the lamination the heron (2015:16) directly walked upon suggested that the grey heron footprints were also made on coarser grained sediment. This indicates that the avian footprints in this area were created when there was a colder sea temperature and a harsher wind-wave climate, most likely during the autumn and winter months (Allen 2004; Dark and Allen 2005), though as the human footprint-tracks are overtraces/undertraces it cannot be established if these footprint-tracks were also made in the winter period.

There were similarities in the direction of movement from the individuals at both Site C/E and R. There were a high proportion (28%) heading in a north-west direction, however there were also a high proportion heading west (24%), as well as 28% of footprint-tracks where the direction of movement was unclear. The final 20% of footprint-tracks were heading north (8%), north-east (4%), east (4%) and south (4%).

The footprint-tracks made on the lower laminated sites (M, N and S), had an evident direction of movement, with 26% of individuals heading in a north-east direction, and a further 4% of footprint-tracks orientated in an east direction away from Goldcliff Island. 4% of footprint-tracks were orientated south and a further 50% of footprint-tracks heading south-west towards Goldcliff Island, to the same area the east and north-east footprints were heading away from. Only 3% of individuals were directed to the west-north-west, and 7% were heading north-west. Within these areas 6% of the footprint-tracks had an indistinct direction of movement. Within these footprint areas half of the footprint-tracks recorded were heading in a south-west direction, towards Goldcliff Island. Although the actual orientation for each footprint-track recorded between 2010-2014 is unknown, evidence from the tracing indicates that all footprint-tracks were moving in a north-west and south-east direction, at right-angles with a palaeochannel (Figure 6.65; Appendix 3.2).

The direction of movement suggests these individuals were all heading to a specific static area. Areas of activity have been recorded at Goldcliff Island (Bell 2007), and there was a wooden structure (Site T) recorded during this study on the same axis as the footprint-tracks from Site N. A further 26% of footprint-tracks were orientated in a north-east direction, away from Goldcliff Island, likely to be heading out from the areas of activity where they had been based. Sites M, N and S are on different laminations and suggest that these footprint-tracks were lain down on successive laminations over multiple years, with individuals returning to a similar area, year after year.

6.11.4 Speed of movement of adults

Most footprint-tracks from Goldcliff East (2014-2017) were made by people who were moving at a leisurely pace, not indicative of hunting or stalking. Only two of the eight footprint-track trails indicated a person moving at speed, one was from Site C/E, the other was from Site M.

The hunter-gatherer from Site M who made footprints 2015:160 to 2015:163 was moving at the fastest speed, at approximately 10km per hour (6mph), the hallux of footprint 2015:163 was visible in this trail. This speed of travel suggests a steady jogging pace, though there were only three footprint-tracks in this trail so a clear idea of pace of movement is difficult to establish. Another individual was moving at a slightly slower pace and made footprint-track 2015:114 and 2015:115, travelling 8km per hour (5mph). The prominent arches of the footprints indicate that this person was either walking quickly or had modified their running technique due to the soft substrate they were moving upon.

All other footprint-tracks recorded during 2014-2017 suggest individuals who were walking at a slow pace, so were unlikely to have been engaged in a hunting activity as there was no footprint-track evidence to suggest individuals were moving quickly, or any evidence of stalking (Bird and Bliege Bird 2005). The footprint-track trails from Site N suggested all individuals were walking at a relatively normal walking speed, 2015:17, 2015:18 and 2015:20 were averaging 6km per hour (4mph), and 2016:50-56 were slightly slower at 5km per hour (3mph). These individuals were between 161.7cm (5’3”) and 172.1cm (5’7”), and 154.9cm (5’0”) to 167.8cm (5’6”), indicating that neither of the footprint makers would be considered short by today’s standards. It may be that these individuals were walking slowly due to the wet, soft, substrate they had to walk across, or that they were carrying something, which would explain the short stride lengths.

The footprint-track trail in Site R indicates another person who was walking slowly, on this same lamination there was evidence of both a human child and a large ungulate, possibly red deer. The footprint-track trail was made by an adolescent or a full-grown adult of either sex, with a height between 152.0cm (4’11”) and 172.1cm (5’7”), heading north-west 295°. The singular child footprint-track was heading 270° north-west, in a similar direction. The ungulate footprint-tracks were indistinct and may even have been poorly formed or poorly preserved human footprint-tracks, so cannot be utilised for the interpretation of this area, though there was one obvious red deer footprint-track that crossed the human footprint-track trail at 140°. The human footprint-tracks from Site R had evidence of toes, heels and arches indicating that they were walking at an average pace, 7km per hour (4mph) and were not just on the balls of their feet, so this trail is not indicative of animal stalking. The human and deer were travelling in different directions so it is unlikely this deer was being hunted by the human. The presence of a footprint-track made by a child aged 5.5 +/- 1.5 years old may suggest that these individuals had gone to the same place together, heading from the south-east direction, so possibly returning from hunting or gathering by the sea.

6.12 Conclusion

The Mesolithic footprints at Goldcliff East provide archaeologists with an interesting snapshot of the lives of these hunter-gatherers. One of the most important aspects of this site is the prevalence of juveniles. The prehistoric footprint-tracks at Goldcliff East indicate that young children were present in the intertidal zone, as were adolescent children, adult females and to a lesser extent, adult males. Site C/E and M are the only areas where there were footprint-tracks that were clearly male. Though smaller footprint-tracks could also have been made by males, it does indicate that children and adult females were predominant within this site.

The potential fish trap discovered on the same axis as the footprint-tracks from Site N adds a new dimension to this data. Site N was a small area (16m x 6m) that was walked over multiple times, always heading in a similar direction, indicating that these individuals were walking to perform a routine activity at a static place. These individuals were children and possibly adult female, suggesting this was an activity that only certain members of Goldcliff East society were performing.

Chapter 7

Mesolithic avian footprint-tracks on the Severn Estuary

7.1 Introduction

This chapter will present and analyse Mesolithic avian footprint-tracks recorded at Goldcliff East, Severn Estuary. Within the field of archaeology bird footprints are rarely thoroughly analysed or even fully reported. They are often viewed as a curiosity, with hominin footprint-tracks gaining the most interest. This results section will demonstrate that avian footprint-tracks can provide useful information regarding the species present on a site, rather than relying completely on skeletal remains of birds, which are often sparse in wetland areas. Modern wetland avian data will be used as an analogue to facilitate prehistoric species identification. A consideration of nationwide and localised extinction assists in our understanding of whether a species was once native to an area or if it is invasive. This is particularly relevant regarding birds, where slight changes to climate or habitat can greatly affect a species, their migratory behaviours and competitive balance (Ahola *et al*. 2007; Both *et al*. 2010; Robinson *et al*. 2009). A variety of coastal birds depend on unique habitats found in Britain, either as a year-round home, a breeding area, or a stop during migration. The presence of birds can be an environment or habitat indicator. Prehistoric birds would have had specific habitat needs; evidence of their presence may give an indication of the environment and habitat of an area, as well as availability of resources.

There are a number of avian species that may have been exploiting the wetland and mudflats of the Severn Estuary during prehistory, some of which may no-longer migrate to or exploit this area.

7.1.1 The importance of common crane in Wales: prehistory to present

The common crane (*Grus grus*) is a large, long-necked, migratory bird. They require quiet, secluded wetland areas to breed. The common crane no longer flocks to Britain to breed during its migration, this is thought to be due to historic over-hunting, drainage of wetlands and destruction of their habitat. Although it is no-longer considered a breeder in Britain, a small population has been recorded migrating to East Anglia each summer since the 1970’s (Buxton and Durdin 2011).

Cranes are ingrained in our history, with certain British towns, villages and even fields named in reference to this species (Figure 7.1). A survey in 1938 recognised place names around Britain which are associated with cranes. A place named Corndon Hill, which means ‘Hill frequented by Cranes’, in Montgomeryshire was included in the report. Though there has not been any crane skeletal remains found in this area the name suggests that at some point cranes were frequenting this hill, perhaps to gain access to a shallow body of water. Their presence appears to have been used by humans to recognise this hill from the surrounding landscape features (Charles 1938), perhaps suggesting a large number of crane or that they were frequent visitors.

It is thought that the numbers of crane living on the Welsh side of the Severn Estuary dropped dramatically due to Roman overhunting. At the Roman fortress of Caerleon, Newport, which was active from around 75AD for approximately 200 years (Gardner and Guest 2010), bones of common crane were recovered from the bottom of a well. The bones had cut marks suggesting that these birds were being eaten (Hamilton-Dyer 1993). This is the latest archaeological evidence for common crane so far reported in Wales.

During King Henry III’s reign, a Christmas feast list from 1251 indicated that the King was eating a variety of birds, including 115 common cranes. During the Christmas feast of 1387 King Richard II exploited an even greater range of birds, however there were only 12 common cranes included in the feast (Hobusch 1980). There were a supposed 204 common cranes eaten at a feast in 1465 to celebrate George Neville becoming the Archbishop of York (Gurney 1921). By the reign of King Henry VIII (1509-1547) crane were rare throughout Britain (Rackham 1986), with sightings mainly recorded in East Anglia. A statute was introduced by King Henry VIII in 1534, making the removal of crane eggs between the months of March and June illegal, with penalties including a fine of 20 silver pennies for every crane egg taken, and even imprisonment (Gurney 1921). This statute is thought to be the first legislation in Europe to protect the common crane, with a very heavy penalty for those not doing so.

The evidence for common crane in Wales is sparse when compared to England. It is likely that, by the Medieval period, common crane were almost completely extinct in Wales, as there have been no recorded sightings or faunal remains discovered from this period or afterwards. It may be that the Romans were primarily responsible for this extinction due to over-hunting, drainage and land reclamation. It is therefore likely that our understanding has been affected by recorded historic sightings, which only began during the medieval period, with a primarily English focus.

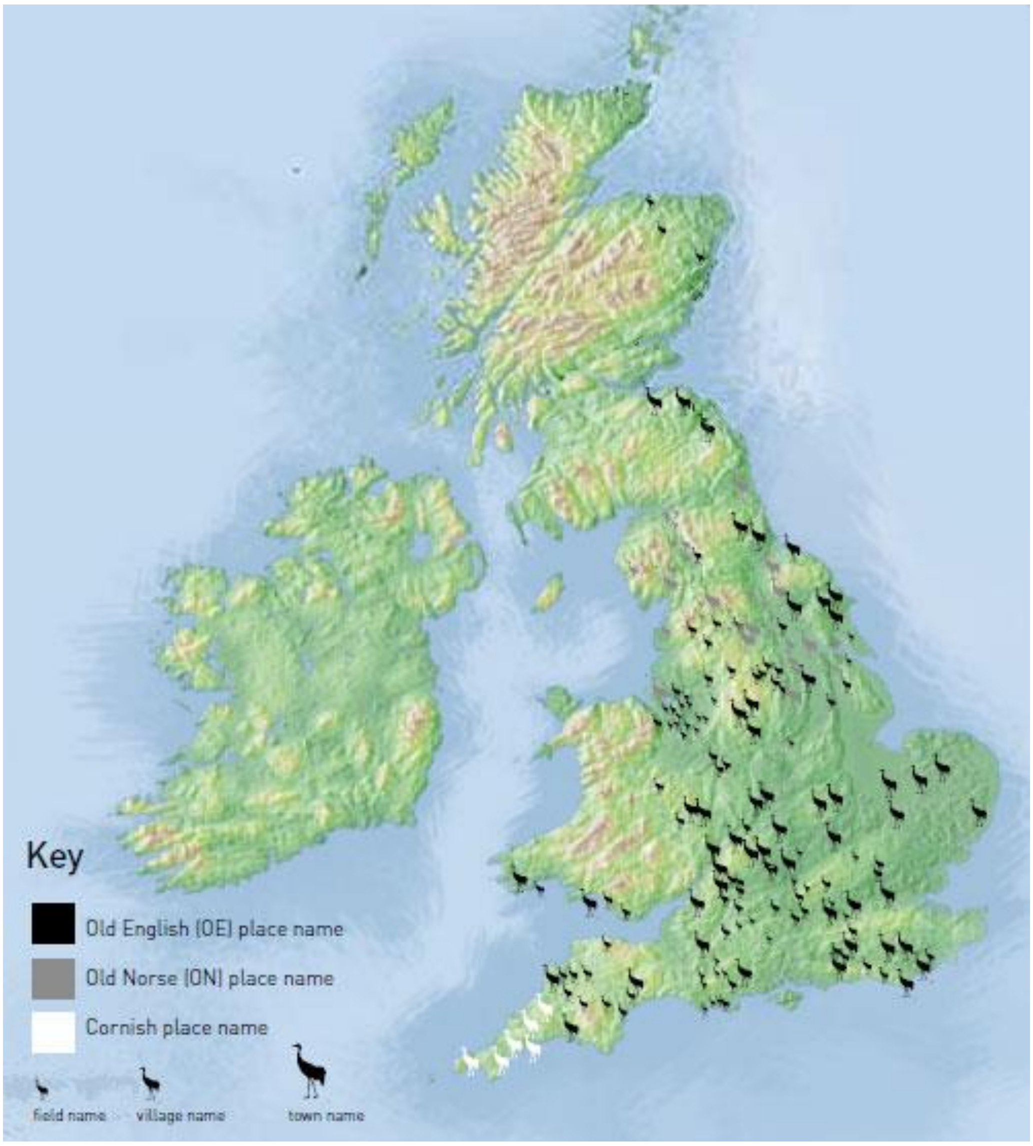


Figure 7.1 Place names in the UK related to common crane (Wildfowl and Wetlands Trust)

7.1.2 An extinct crane species or exploitation of Europe by the Sarus crane?

Across Europe the skeletal remains of a large crane species have been recorded, though finds are still relatively sparse in number. The remains of these large cranes have been found in Late Bronze Age/Early Iron Age deposits on the Isle of Jura in Scotland, from the Ipswichian interglacial in Ilford, Essex (Harrison and Cowles 1977), and at the Iron Age (150 BC-50 AD) dwelling at Glastonbury Lake Village (Andrews 1899; Harrison and Cowles 1977). Further large crane bones were recorded in Pleistocene deposits in France, at the sites of Grotte des Eyzies, Dordogne, at Grotte de la Madelaine, and at Grotte Gourdan. There is also a record of large crane bones at Ehrenstein bei Ulm, Germany which is Neolithic in date (Milne-Edwards 1869; 1875; Soergel 1955).

The large crane species that appears sporadically across Europe is thought to be either an extinct giant crane, which has been named *Grus primigenia*, or the remains of the sarus crane (*Grus antigone*), a species which is currently found in Asia and Australia (Harrison and Cowles 1977; Northcote and Mourer-Chauviré 1985; Lydekker 1891). This large species of crane is important to note when examining prehistoric crane footprint-tracks; due to changing habitats, environments and human behaviour such as hunting, there were multiple avian species living during prehistory that may have been markedly different to their descendants today, or are now extinct. Modern sarus cranes are a non-migratory species that do not share their territory with common crane. Their presence in Britain may suggest a large shift in their behaviour from migratory to non-migratory, that they were once non-migratory residents of Europe, or that their habitat needs were once supported by Europe's environment, and they were possibly outcompeted by common crane. The other explanation is that the remains are in fact from an extinct species, *Grus primigenia*, the behaviours of which we know nothing about.

7.1.3 Evidence of white stork in Britain

White stork (*Ciconia ciconia*) are large, long-legged, wetland breeders. They prefer a slightly warmer climate and are more often seen nesting on the roofs of houses and chimneys in Europe (Cramp & Simmons 1977; Tryjanowski *et al.* 2009) or feeding at the edge of a watering hole in Africa than visiting the damp environment of modern Britain. The habitat and climate of Britain during prehistory may however have fulfilled the needs of this species.

White stork bones have been recorded in two Pleistocene cave deposits, both found at Creswell Crags, Worksop (Jenkinson and Bramwell 1984; Jenkinson 1984). Evidence of white stork during the Holocene has been found at two Bronze Age sites in the form of skeletal evidence, at Jarlshof, Sumburgh, Shetland and at Nornour, Isles of Scilly (Platt 1933, 1956; Turk 1971; 1978). Possible white stork bone evidence was also found at two Iron Age sites, Dragonby, in Linconshire and Harston Mill, in Cambridgeshire (Harman 1996). White stork bones were recorded at Silchester Roman town (Newton 1905; Maltby 1984), and at the Saxon site at Westminster Abbey (West 1994). In Oxford white stork bones have been recorded at the Medieval site of St Ebbes (Wilson *et al*. 1989), there are also written records of white stork breeding in Edinburgh during the fifteenth century (Yalden & Albarella 2009). The archaeological presence of white stork throughout these periods suggests this species was existent in Britain, though it may have been uncommon. This species was recorded mainly in southern and eastern Britain during the Holocene period, perhaps due to their preference for warmer climates, and it may be that the breeding pair in Edinburgh were blown off course of their migratory route.

Common crane and white stork are just two prominent wetland birds; by understanding their presence within archaeology, as well as other species, we may also begin to understand the palaeoecology of Mesolithic coastal sites.

7.2 Method

To understand the prehistoric avian footprint-track evidence it is important to consider the species that were likely to be frequenting the Severn Estuary. Both prehistoric faunal evidence and evidence from contemporary coastal birds was considered (Chapter 2, Table 2.7 and Table 2.8). The ways in which each footprint was recorded, measured and analysed are described fully in Chapter 4.3. The techniques of recording archaeological and contemporary avian footprints was dependant on the recording situation, and included multi-image photogrammetry, standard photography, measuring the lengths and widths of a print, measuring the angle between toe II and toe IV, and looking for the presence of 1st toe, webbing and claw marks.

Each bird species will have adapted specifically to their environment. These bodily adaptations can affect the way in which a bird walks, which can be used as a further identifying factor for a species. The position of the pelvic girdle determines the location of a bird’s legs, this location is due to the specific needs of the species (Baker 2013, p 28). Animals with legs positioned in the centre of the body, such as plovers, will have a stable centre of gravity, creating a footprint from an evenly distributed weight. Birds with their legs positioned towards the back of their torso are more likely to have a heavy tread, especially at the metatarsal pads. The *Anatidae* family (ducks, geese, swans) have legs that are positioned further back on their bodies, resulting in very pronounced metatarsal pad marks in their footprints. This positioning indicates that these birds are capable of swimming or standing on branches (Baker 2013, p 28). Families such as *Charadriidae*, *Haematopodidae* and *Gruidae* (plovers, lapwigs, oystercatcher, common crane), have developed central or slightly forward positioning of the legs, allowing steady footing when walking in their preferred environment and in an upright position, with the ability to hunt and strike their prey.

Birds from the *Anatidae* (ducks, geese and swan), *Ardeidae* (heron, egret, bittern), and *Gruidae* (crane) families were observed to all have specific walking behaviour which makes trails clear to see. *Anatidae* tend to walk in pairs with their feet turned slightly inwards, creating a waddle, and *Gruidae* will often walk in pairs, weaving in and out of each other’s paths. This can cause difficulties in identification when these birds are in the same area over a prolonged period, causing trampling. Small flocking birds such as those from the *Scolopacidae* family (turnstone, dunlin, little stint) will weave in and out of one another whilst feeding, making identifying trails and individuals extremely difficult, though when a single bird has wandered from the group a stride and pace can be established.

The identification of bird feet via the extent of webbing can assist in identifying species (Baker 2013, p 29). The most common webbed foot is known as palmate, this is where the 2nd to 4th toe are connected by webbing; birds such as ducks, geese and gull have this type of webbing. Totipalmate is where all four toes are connected by webbing to enable strong swimming; birds such as pelican have this type of webbing. If a bird has partial webbing near the base of toes 2-4 they are semipalmate, and have adapted this feature to enable both swimming and walking upon soft surfaces; sandpipers and plovers have this webbed feature. The final webbing that can be apparent in footprint data is when a bird is lobate, this is where the foot has lobes of skin; coots have the most prominent lobate webbing.

In Britain, changes to habitats can cause localised extinctions of certain species. The skeletal remains of avians found in archaeological assemblages must also be considered to understand the changes in British bird species over time, these were explored fully in Chapter 2.5.

This study considered the footprint morphology and formation of 21 bird species, with the footprint database developed to assist in the identification of prehistoric footprint-tracks. Out of the 21 species, five were geese, two were swan, two from the heron and egret family, one from the crane family, one corvid, one gull, one oystercatcher, one from the plover family, three from the duck family, and three were small waders. All the geese and swan recorded in this study were resident breeders at the Wildfowl and Wetlands Trust (WWT), Slimbridge, except for some migratory greylag geese that exploit the WWT for its resources yearly. All the small waders, heron, egret, gull, corvid, oystercatcher and plover were wild birds from the intertidal zone of the Severn Estuary. The duck species were primarily recorded at the WWT, though common shelduck footprints were also recorded at Goldcliff East. The Eurasian bittern footprint was recorded by a volunteer at the RSPB Minsmere nature reserve, from a wild bird.

Avian footprint tracking literature (Bang and Dahlstrom 1974; Brown *et al*. 1987) was also referenced to enable a thorough understanding of the footprints of birds not included within this study, as well as the differences within the literature and the experimental database.

The prehistoric bird footprint length, width, toe angles, presence of first toe, webbing or claw marks were compared to the writers' contemporary avian footprint database for identification. This database contains 1558 photographs of 329 modern bird footprints made at Goldcliff East, the Wildfowl and Wetlands Trust (WWT) and the RSPB Minsmere nature reserve, and relates to 21 avian species recorded. The database also contains eight multi-image photogrammetry models of at least eight different species. The footprints made by modern birds at Goldcliff East were made naturally upon estuarine sands and mud. Binoculars and the RSPB field guide were used to directly identify the birds (Hume 2014), the footprints were then recorded The Eurasian bittern footprints recorded at Minsmere had walked upon a sand footprint 'trap', and was then identified by the RSPB.

The footprints recorded at the WWT were recorded from 04.01.2016 to 07.01.2016 and from 11.01.2016 to 14.01.2016. The footprints were made on mud and sand around the reserve, and also in the estuarine clayey silt 'footprint trap'. This 'footprint trap' was a large plastic seed tray measuring 1.5m in length and 60cm in width. Four of these were left for several days in different enclosures, so that the birds became accustomed to them. The trays were placed into the enclosures of bird species which appear in bone assemblages at a variety of prehistoric sites (Table 2.7). 11 of the 21species recorded during this experiment were from the Wildfowl and Wetland Trust, Slimbridge.

It was not practical to dig a pit in the bird enclosures to stop the tray moving which was the method used for the human experiment (Chapter 5.2). Instead wood chips from the enclosures were tightly packed around the tray (Figure 7.2). This caused the least disruption to the birds and meant that they did not need to step over the side of the tray. Estuarine sediment was then added to the 'footprint trap', this sediment was compressed as much as possible using a plastic plastering trowel,and spread evenly. After recording, the sediment was compressed and spread across the tray again to remove traces of previous footprints.

In enclosures where there were multiple bird species it was not always possible to ascertain which species made footprints in the trap. A further method was therefore used to ensure certain species at the WWT were recorded. With the assistance of staff members these species were caught and placed in a cage. The staff members habitually capture the birds and feed the birds treats in these cages so the birds were all calm when caged. The 'footprint trap' was then prepared outside of the cage, and the bird was released, walking over the trap. This provided excellent data, as the gait of the bird could be observed, as well as any medical issues. The European white-fronted goose, for example, was a 14-year-old arthritic female, so may have altered her gait to lessen joint pain.

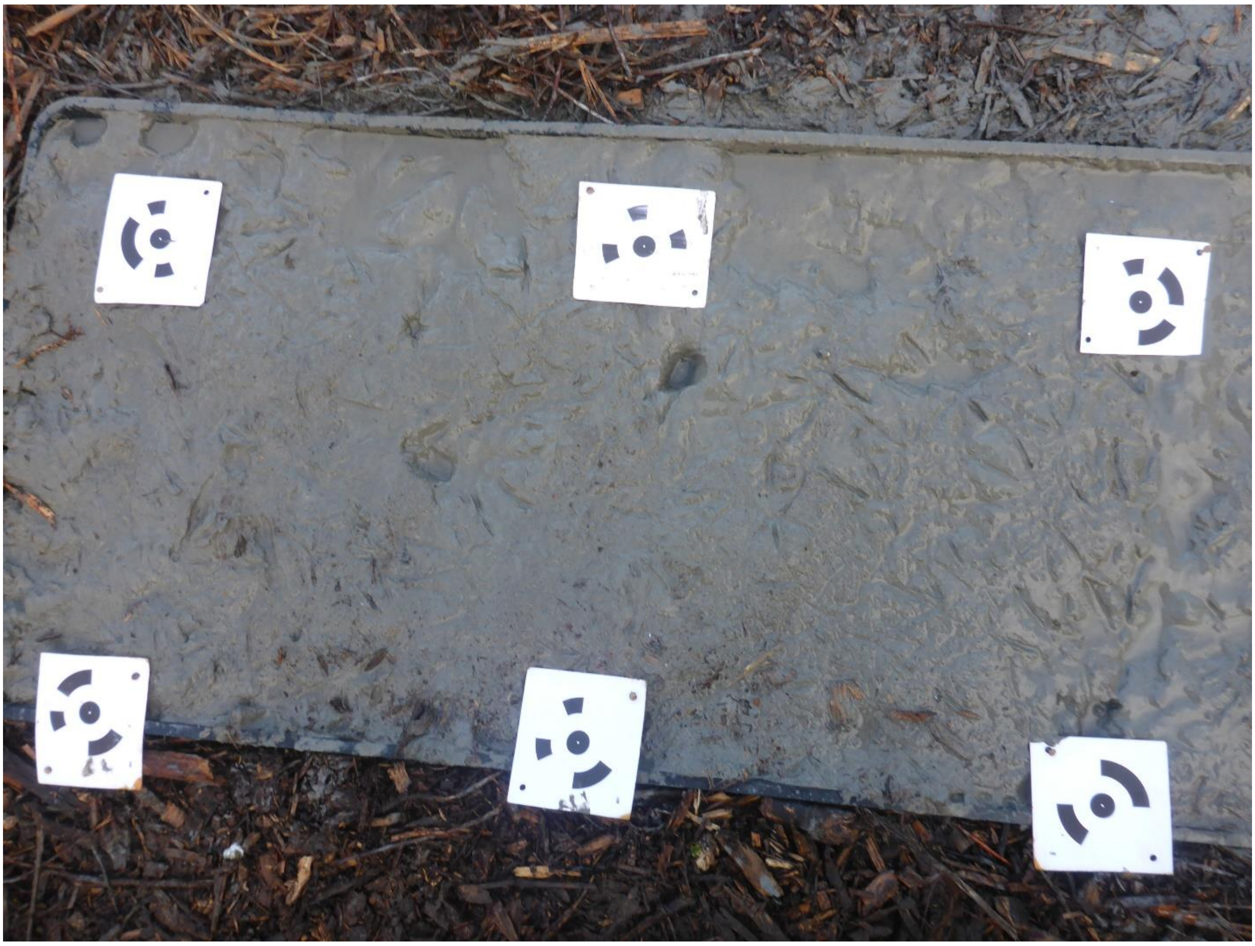


Figure 7.2 Example of the plastic tray 'footprint trap' filled with clayey silt sediment left in enclosures at WWT for bird species to walk upon. The woodchips were pilled around the edges to prevent the birds needing to step into the tray

7.3 Archaeological avian remains within proximity to the Severn Estuary

There are very few sites in Wales where Mesolithic bird bones have been found, with Port Eyon Cave, Gower Peninsula, Wales, by far the richest. The avian remains found there contained a mixture of coastal species that are still found in Wales, some that are rare visitors in these areas, and some that are no longer visitors to Wales. The skeletal remains found at Port Eyon Cave included barnacle goose, turnstone, white-fronted goose and wigeon (Harrison 1987a); these bird species have all been included within the experimental study. Greylag goose remains were recorded at the Neolithic site of Hazelton North, Gloucestershire (Saville 1990). The final two important sites near to the Severn Estuary are the Iron Age sites of Glastonbury Lake Settlement and Meare Lake Settlement (Andrews 1899; Bulleid & Gray 1911-1917; Harrison 1980b). At these sites Eurasian bittern, Dalmatian pelican, brent goose, cory's shearwater, possible extinct European crane, grey heron, mallard, pochard, teal, tufted duck and wigeon have all been recorded (Harrison 1987a). Many of these birds were included in the experiment; however, it was not possible to gather footprint data for several species. Dalmatian pelican, for example, are not a common visitor to the British Isles. Others are migrant seabirds and so are difficult to record as they spend very little time on the land.

There have been very few Mesolithic bird bones recorded at Goldcliff East, perhaps due to poor preservation, so these cannot be relied upon to assist in identification. Within Site A, context 315, there were three small bone fragments; these were not able to be identified (Scales 2007b, p 164, Table 13.2). Two further bones, possibly from mallard duck (*Anas platyrhynchos*) were recorded at Site W.

7.4 Experimental results

The results in Table 7.1 indicate the similarities in the metric dimensions of certain species and the importance of including information on identifiable features, with the presence of first toe and webbing being of most assistance in the identification process. Figure 7.3 demonstrates that species from different families may have similar metric dimensions but may appear morphologically different. The pace and stride of species is also useful in understanding gait, and thus may assist in differentiating two species of a similar size, as gait can help to indicate the leg placement on the body.

A further identifying feature of a species is the angle between the second and fourth toe (Table 7.2). Although toe angle is generally used as an identifying factor, there are a lot of discrepancies within the literature, and within this experiment it was found that the sediment walked upon affected the angle of the toe, one species could produce a large variety of toe angles. For example, in this experiment the toe angle of 26 crane footprints were measured from three adult cranes, the angle was found to range between 100-175°. Footprint tracking literature identifies common crane as a species that has a toe angle that is larger than 120° and can be almost 180° (Table 7.2). If relying solely upon toe angle there would be some crane footprints that would not be classed as this species, it is therefore important to consider all aspects of the foot when identifying species.

Birds from the same family tend to share specific morphology, which can be seen in their footprints. Those from the *Anatidae* family generally have feet almost as wide as they are long, with evidence of webbing and the second and fourth toes curving slightly inwards (Figure 7.4, b-d, h-i). A member of the *Corvidae* family will have a very long but narrow foot (Figure 7.4e), whereas those from the *Gruidae* and *Ardeidae* families will have very large footprints, in both length and width, with toes widely spread (Figure 7.4 a, f, g).

Figures 7.5 and 7.6 show the multi-image photogrammetry models generated from some of the modern bird footprints, three of the models were made from footprints of birds at the WWT Slimbridge, and one model was from a wild grey heron walking across mud at Goldcliff East. These models demonstrate the benefit of recording using photogrammetry. Colour and lighting can cause shadows which prevent footprints being seen in detail, creating a solid colour model means that this area can then be studied without this distraction.

Family	**Species**	**Average length (cm)**	**Average width (cm)**	**1st toe**	**Webbing**	**Average stride length (cm)**	**Average pace length (cm)**	**Sediment**
Anatidae	Barnacle goose (*Branta leucopsis*)	8.4	9	No	Slight	35	19.2	Estuarine silt/clay
	Bewick swan (*Cygnus columbianus bewickii*)	17.5	12	Claw mark only	Yes	-	-	Estuarine silt/clay
	Common shelduck (*Tadorna tadorna*)	6.9	7.7	No	Yes, not on clay prints	25	14.4	Estuarine silt/clay and mud
	European white fronted goose (*Anser albifrons*)	9.8	9	Claw mark only	Slight	33.8	20.2	Estuarine silt/clay
	Greylag goose (*Anser anser*)	10.3	10.9	No	No	44.5	24.4	Mud
	Mute swan (*Cygnus olor*)	16.3	14.9	No	Yes	19.6	12	Mud
	Pink-footed goose (*Anser brachyrhynchus*)	7.7	8	No	No	21.3	13.4	Estuarine silt/clay and mud
	Pintail (*Anas acuta*)	7.2	6.5	Yes	Yes	22.7	12.8	Estuarine silt/clay
	Tundra bean goose (*Anser fabalis*)	10	9.5	Yes	Yes	37	22.5	Estuarine silt/clay
	Wigeon	6.25	5.75	Yes	Slight	21.2	35.6	Estuarine silt/ clay
Ardeidae	Grey heron (*Ardea cinerea*)	8.3	8.3	Yes	Slight	36.2	19.2	Estuarine sand and silt
	Little egret (*Egretta garzetta*)	12.3	8.5	Yes	No	44	23	Estuarine sand
	Eurasian Bittern (*Botaurus stellaris*)	8.1	7.8	No	No	-	-	Sand
Charadriidae	Ringed plover (*Charadrius hiaticula*)	5.75	3.1	No	No	10.5	4.7	Estuarine silt/clay

Corvidae	Carrion crow (*Corvus corone*)	10.2	4.1	Yes	No	-	28	Estuarine mud/ sand
Gruidae	Common crane (*Grus grus*)	12.8	14.5	No	No	80	42.4	Estuarine silt/clay and mud
Haematopodidae	Oystercatcher (*Haematopus ostralegus*)	5.5	5.8	Yes	No	24.1	8.5	Mud
Laridae	Lesser black-backed gull (*Larus fascus*)	6.8	7.4	No	Yes	33	16	Estuarine sand
Scolopacidae	Dunlin (*Calidris alpina*)	2.7	3	No	No	6.9	3.7	Estuarine silt
	Little stint (*Calidris minuta*)	2.6	3.3	Slight	No	14.2	7.4	Estuarine silt/sand
	Turnstone (*Arenaria interpres*)	2.8	3.1	No, except in 3 prints	No	7.4	4.9	Estuarine silt/sand

Table 7.1 Experimental results of a variety of contemporary wetland bird footprints and the features that can be used for identification

Species	**Toe angle between II and IV (Brown *et al.* 1987)**	**Toe angle between II and IV (Bang and Dahlstrom 1974)**	**Toe angle range (II and IV) within current study**	**Number of footprints observed in current study**	**Sediment walked upon**
Barnacle goose (*Branta leucopsis*)	Not specified	Not specified	70 -110°	4	Estuarine clayey silt
Bewick swan (*Cygnus columbianus bewickii*)	Not specified	Not specified	150°	2	Estuarine clayey silt
Common crane (*Grus grus*)	120°	Almost 180°	100 -175°	26	Mud and estuarine clayey silt
Common shelduck (*Tadorna tadorna*)	Not specified	Not specified	70 -120°	54	Mud, estuarine clayey silt and estuarine mud
Carrion crow (*Corvus corone*)	>70°	Not specified	60-80°	2	Estuarine silt
Dunlin (Calidris alpina)	Not specified	Not specified	80-160°	34	Estuarine mud
Eurasian Bittern (*Botaurus stellaris*)	Not specified	Not specified	130°	1	Sand
European white fronted goose (*Anser albifrons*)	Not specified	Not specified	60 - 70°	4	Estuarine clayey silt
Grey heron (*Ardea cinerea*)	Not specified	Almost 180°	140 -180	24	Estuarine mud
Greylag goose (*Anser anser*)	Not specified	Not specified	70-125°	27	Mud
Lesser black-backed gull (*Larus fascus*)	< 90°	Not specified	60-90°	7	Estuarine mud
Little egret (*Egretta garzetta*)	Not specified	Almost 180°	110-125°	3	Estuarine mud
Little stint (*Calidris minuta*)	Not specified	Not specified	80-120°	25	Estuarine mud
Mute swan (*Cygnus olor*)	Not specified	Not specified	110-125°	4	Mud
Oystercatcher (*Haematopus ostralegus*)	>150°	Almost 180°	80-165°	41	Estuarine mud

Pink-footed goose (*Anser brachyrhynchus*)	Not specified	Not specified	65 - 95°	40	Mud and estuarine clayey silt
Pintail (*Anas acuta*)	Not specified	Not specified	80 - 110°	8	Estuarine clayey silt
Ringed plover (*Charadrius hiaticula*)	>120°	Almost 180°	110- 160°	4	Estuarine mud
Tundra bean goose (*Anser fabalis*)	Not specified	Not specified	70 - 90°	3	Estuarine clayey silt
Turnstone (*Arenaria interpres*)	Not specified	Not specified	100-140°	12	Estuarine mud
Wigeon (*Anas penelope*)	Not specified	Not specified	80 -100°	4	Estuarine clayey silt

Table 7.2 Angle between toe II and toe IV of the different species from experimental work compared against footprint-track literature

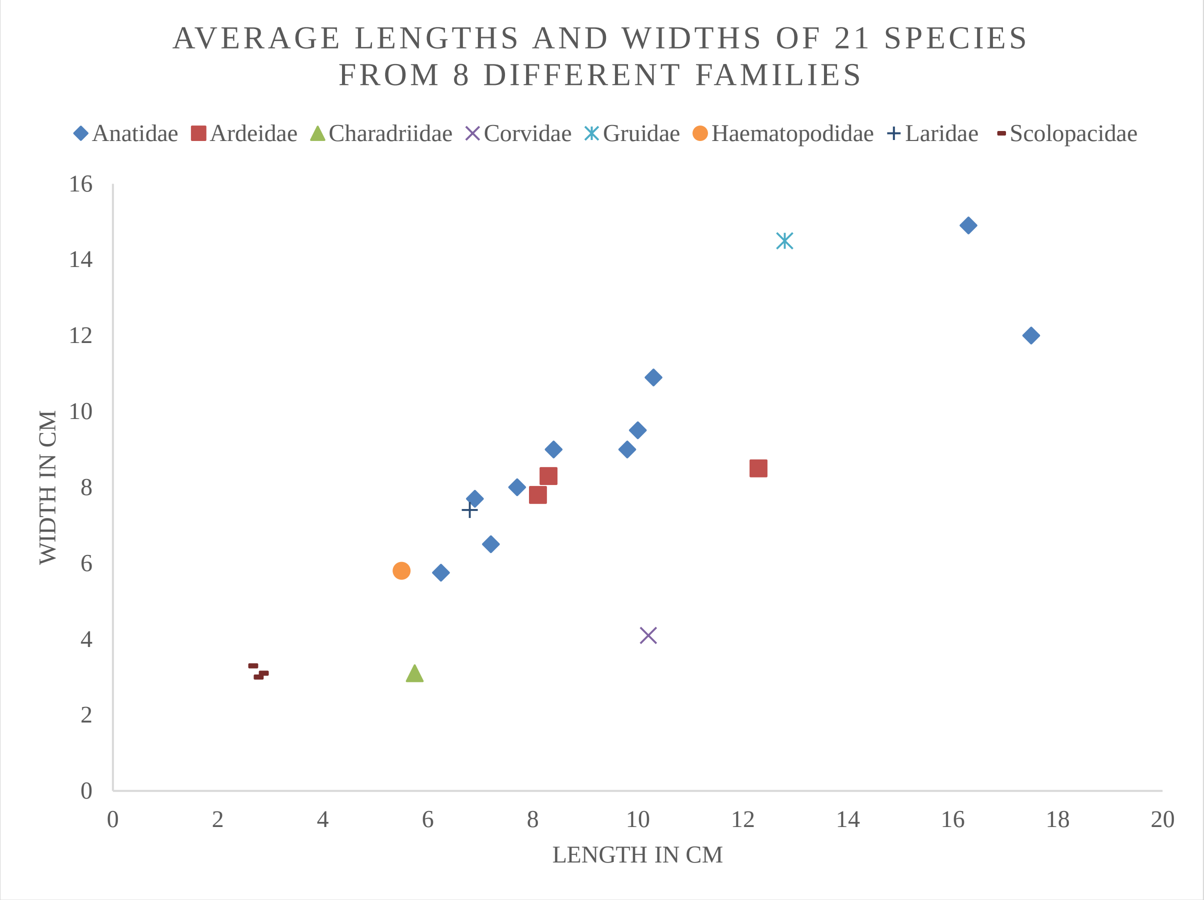


Figure 7.3 Average footprint lengths and widths of the 21 species from 8 different families as seen in Table 7.1

Figure 7.4
a) Grey heron, *b*) Common Shelduck, *c*) Lesser black-backed gull, *d*) Pink-footed goose

Figure 7.4

e) Carrion crow, *f*) Oystercatcher, *g*) Common Crane, *h*) Barnacle goose, *i*) European white-fronted goose, *j*) Tundra bean goose, *k*) Bewick's swan, *l*) Pintail

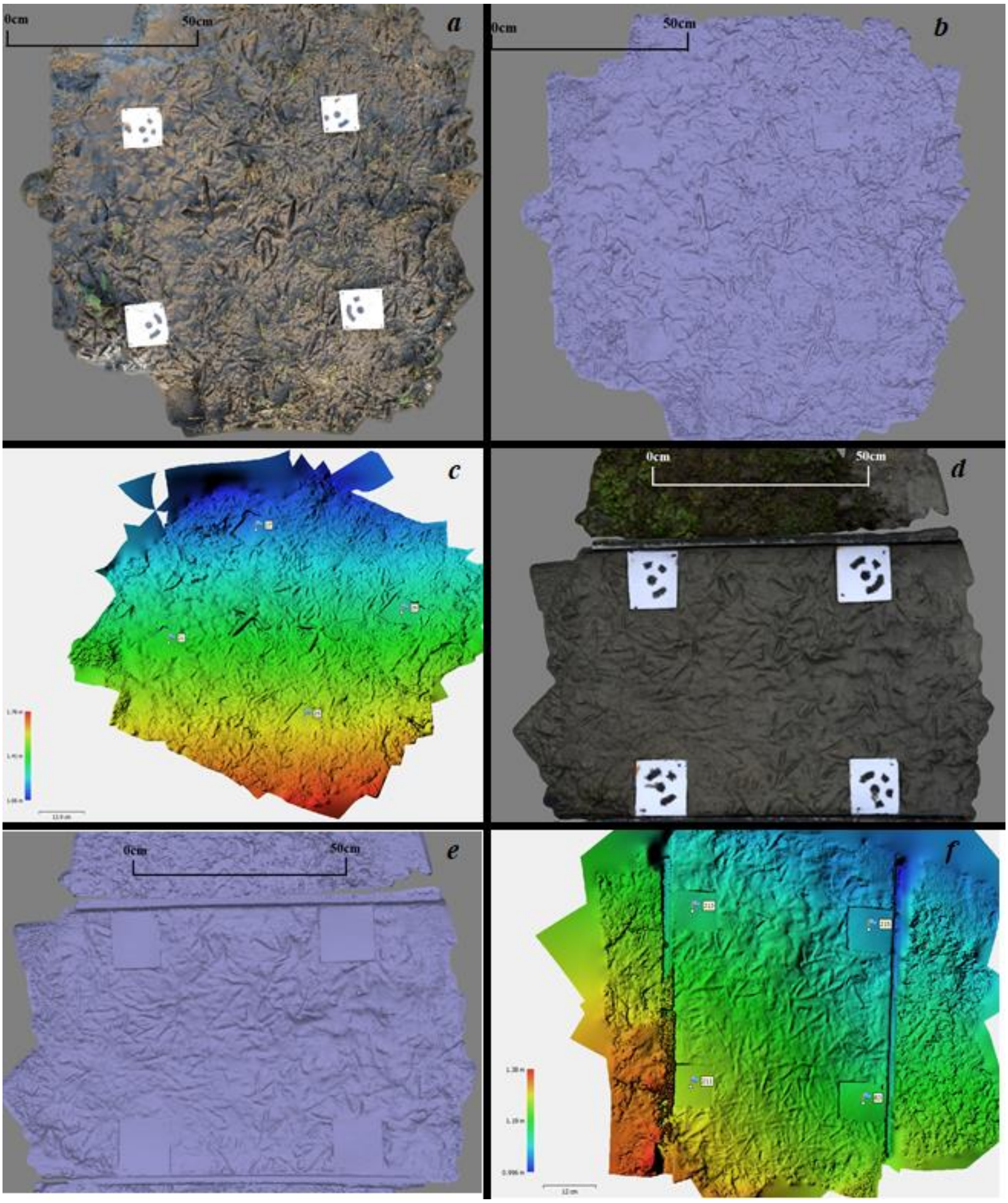


Figure 7.5 Multi-image photogrammetry models generated in Agisoft Photoscan Pro. (a,b,c) Footprints of common crane, as well as multiple unknown duck species, made on mud that pooled on top of grass. (d,e,f) Pink-footed goose footprints made in clayey silt in the 'footprint trap'. a and d are the models, b and e are solid colour models and c and f are digital elevation models. All footprints recorded at WTT Slimbridge

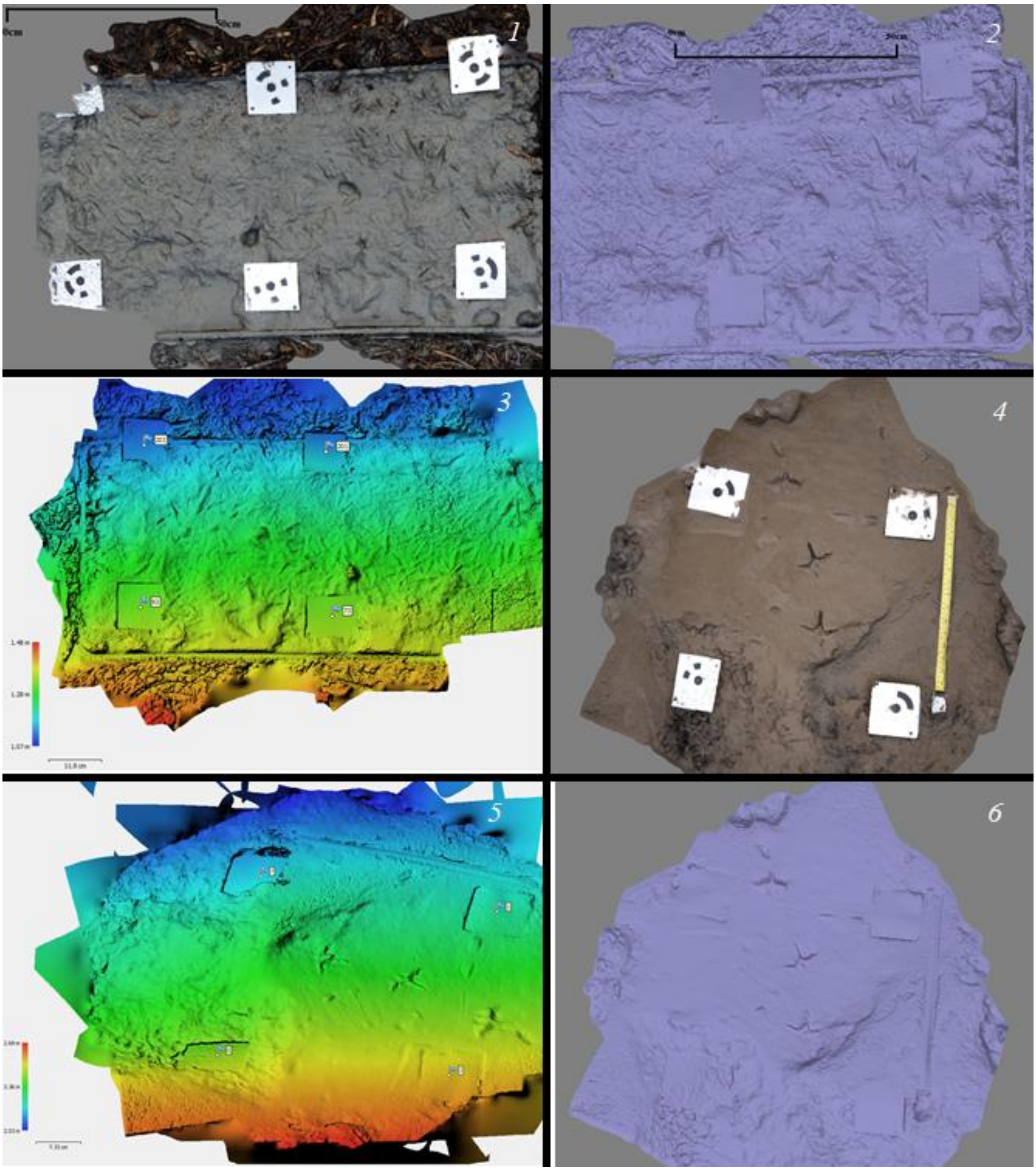


Figure 7.6 Multi-image photogrammetry models generated in Agisoft Photoscan pro. (1,2,3) Footprints of common crane, shelduck and other possible species made in the clayey silt 'footprint trap', recorded at the WWT. (4,5,6) Grey heron footprints made upon sandy mud at Goldcliff East, Severn Estuary. 1 and 4 are the full models, 2 and 6 are the solid colour models and 3 and 5 are the digital elevation models

Experimental work demonstrated that the type of sediment walked upon greatly influences the size and shape of a footprint. Common shelduck were recorded walking on a variety of sediment types; clayey silt sediment taken from the Mesolithic context at Goldcliff East, on mud as they walked across a grassy area, and estuarine sand/silt. The appearance of the footprint was different in each situation, with the extent of webbing, features of the toes and footprint preservation influenced by the sediments (Figure 7.7). Whilst walking on the sandy sediment the webbing of common shelduck footprints were preserved, these footprints had very prominent claw marks. The footprints made by shelduck on mud demonstrated that wet sediment can cause the definition of features to be lost quickly, with little evidence of claws, webbing and even an entire toe appearing indistinct. The footprints made on silty clay in the footprint-trap had the clearest toe definition, again there was very little evidence of webbing or claw marks to assist in identification. Although different features have preserved, these footprints are all comparable to one another; the fourth toe has a greater spread between it and the third toe, as opposed to the second and third toe. The footprint is slightly asymmetrical and in all prints the third toe is the longest. The common shelduck footprints in this experiment had a range of angles, between 70° and 120° which is a fairly large range of angle size. It is by comparing footprint data such as this that an understanding of the features shared by footprints, no matter the sediment, can be applied to the prehistoric data for identification.

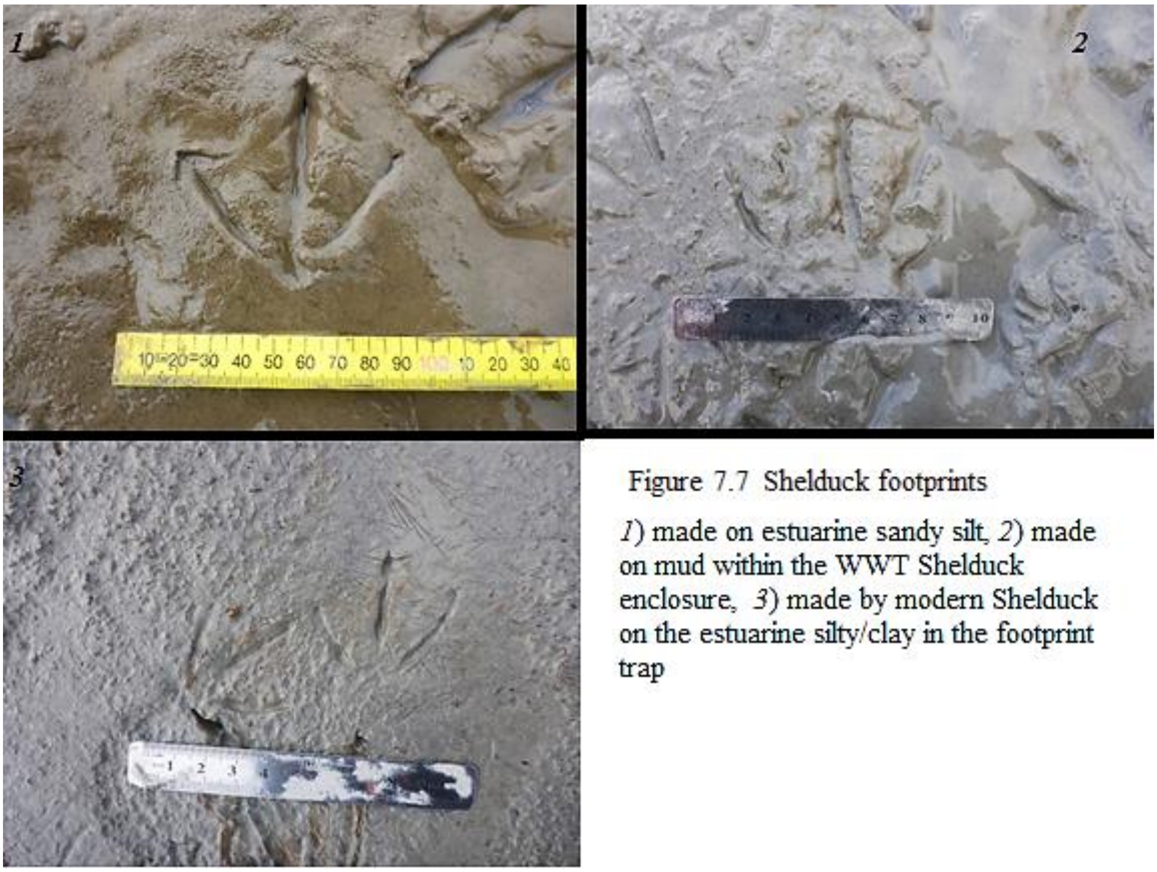


Figure 7.7 Shelduck footprints

1) made on estuarine sandy silt, *2*) made on mud within the WWT Shelduck enclosure, *3*) made by modern Shelduck on the estuarine silty/clay in the footprint trap

7.5 Mesolithic bird footprint-tracks from Goldcliff East

There were 155 avian footprint-tracks recorded at Goldcliff East between 2001-2017. These were all recorded on Mesolithic clayey silt banded laminations from five different areas, Site C, E, M, N and O (Figure 6.2). Site C and E are on a higher lamination shelf than M, N and O and are a little later in date but probably no more than a century or two given the height difference and the fact that the sediments are annually laminated. Scales (2006) recorded a further 116 small bird footprint-tracks from a lamination between Site C and E. These footprints were recorded via tracing but they were not analysed in detail in Scales (2006) work which was focused on human footprint-tracks (Figure 7.8). Tracing can be unreliable as evidence as these are subjective, though there were obviously many small birds in this area. The species cannot be accurately identified, though from the small size and the amount of trampling in a small area it is likely that these were made by a flocking bird such as a small wader, or multiple small wader species.

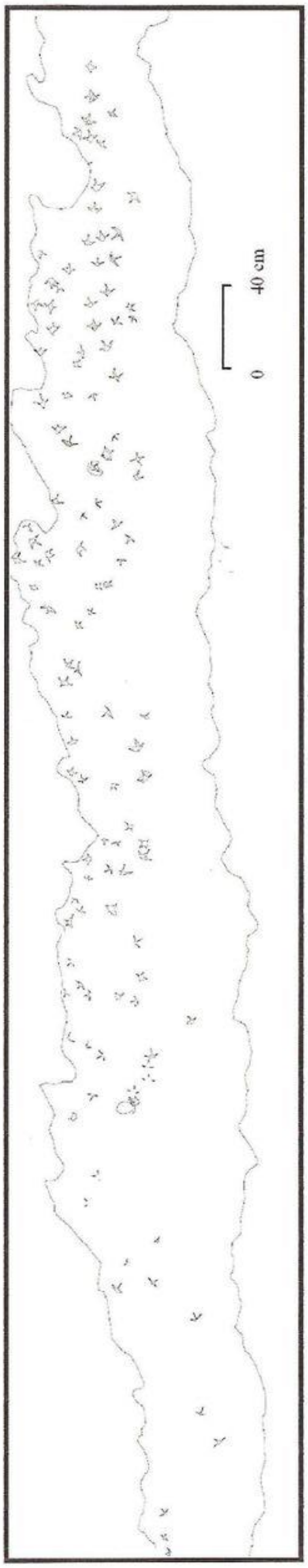


Figure 7.8 Digitisation of small footprints near Site C, Scales (2006)

7.5.1 Site C/E

Although Site C and E were previously investigated by Scales (2006), within this study footprint-tracks were found in areas around both sites rather than directly where finds were previously recorded. It was therefore decided that the best method of recording was to refer to Site C and E regarding Scales (2006) work, and to refer to Site C/E in terms of everything recorded by the writer from 2014-2016, where the site boundaries were less clear. All of the footprint-tracks at Site C/E were recorded on consolidated banded laminations, on laminated cliffs exposed through erosion. The areas exposed on Site C/E during 2014-2017 were generally small patches or strips of the banded sediments below the submarine sand dunes. Further information regarding Site C/E is provided in Chapter 6.5.

The footprint-tracks preserved at Site C/E were the best examples of bird footprint-tracks at the site of Goldcliff East. These footprints were generally much better preserved than the human footprint-tracks during the period of study. Many were footprints as opposed to overtraces or undertraces (Figure 7.9). Of the 99 bird footprint-tracks recorded at Site C/E, 53 were considered to be large as they were 10cm or longer (Table 7.3). Within this area footprint-tracks were found on multiple laminations, indicating an area used yearly by these bird species.

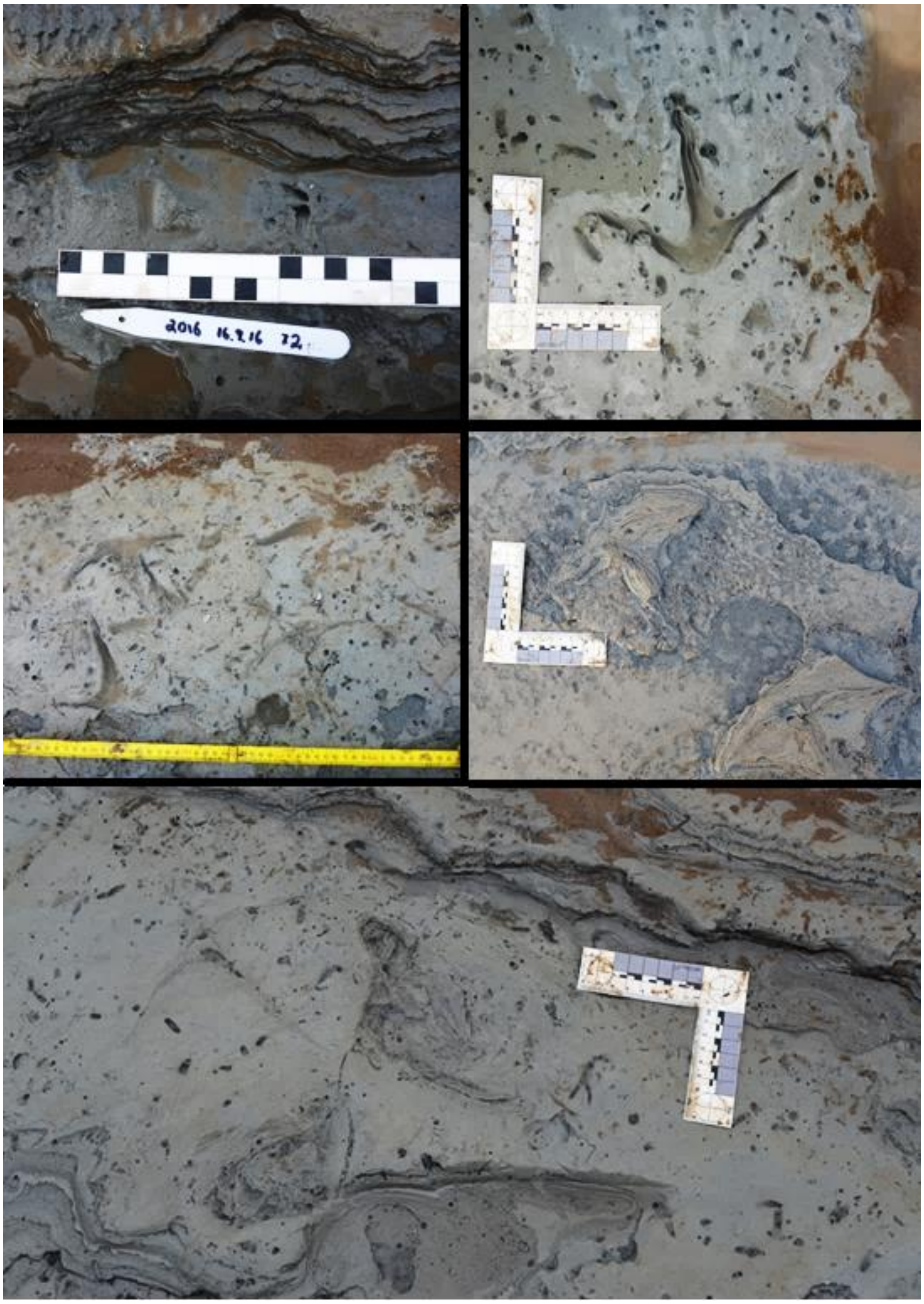


Figure 7.9 Mesolithic avian footprint-tracks from Site C/E, 1) Oystercatcher (2016:72), 2-5) Common Crane [top right] (2015:87), [middle left] (2016:70, multiple crane prints from trampled area), (2015:130, 2015:131), [bottom] (2015:127 human and 2015:127.11 crane). Scale divisions in cm

Footprint-track number	Site	Length (cm)	Width (cm)	1st toe	Webbing	Claw marks	Toe angle between II and IV	Species
2002:1	E	5.5	6	Yes	No	No	150	Grey heron (?)
2002:2	E	5	7	Yes	No	No	190	Grey heron (?)
2002:3	E	4	6	No	No	No	148	Grey heron (?)
2002:4	E	5.5	4	Yes	No	No	138	Grey heron (?)
2002:5	E	6	4	No	No	No	132	Grey heron (?)
2002:6	E	6	7.5	Yes	No	No	148	Grey heron
2002:7	E	5.5	7	Yes	No	No	142	Grey heron (?)
2002:8	E	5.5	10	Yes	No	No	150	Grey heron
2002:9	E	5	5	Yes	No	No	135	Grey heron (?)
2002:10	E	7	6	Yes	No	No	130	Grey heron
2002:11	E	6	6	Yes	No	No	150	Grey heron
2002:12	E	4	5.5	No	No	No	150	Grey heron (?)
2002:13	E	5	7.5	No	No	No	142	Grey heron
2002:14	E	5	7	Yes	No	No	155	Grey heron
2002:15	E	5	7.5	No	No	No	160	Grey heron
2002:16	E	6.5	6.5	Yes	No	No	160	Grey heron
2002:17	E	6	7	Yes	No	No	140	Grey heron
2002:18	E	4	5.5	No	No	No	130	Grey heron (?)

2002:19	E	7	8	Yes	No	No	145	Grey heron
2002:20	E	5.5	5.5	Yes	No	No	160	Grey heron (?)
2002:21	E	6	5	Yes	No	No	120	Grey heron (?)
2003:1	C	11.2	14.8	No	No	No	170	Crane
2003:2	C	5.6	16.3	No	No	No	174	Crane
2003:3	C	5.6	12.7	No	No	No	200	Crane
2003:4	C	12.8	18.7	No	No	No	180	Crane
2003:5	C	11	16.2	No	No	No	168	Crane
2003:6	C	11.1	14.2	No	No	No	168	Crane
2003:7	C	8	11	No	No	No	170	Crane
2003:8	C	8.1	15.4	No	No	No	170	Crane
2003:9	C	9.1	15.2	No	No	No	130	Crane
2003:10	C	10.2	10.4	No	No	No	165	Crane
2003:11	C	9.2	15.3	No	No	No	185	Crane
2003:12	C	11.4	15.4	No	No	No	150	Crane
2003:13	C	9.3	15.1	No	No	No	130	Crane
2003:14	C	10.1	14.2	No	No	No	150	Crane
2003:15	C	10.4	14.1	No	No	No	148	Crane
2003:16	C	9.6	15.7	No	No	No	160	Crane
2003:17	C	13.4	15.6	No	No	No	160	Crane
2003:18	C	13.5	16	No	No	No	160	Crane
2003:19	C	12.4	16	No	No	No	172	Crane
2003:2	C	9.7	15.5	No	No	No	148	Crane
2003:21	C	10.3	15.4	No	No	No	158	Crane
2003:22	C	10.7	14.1	No	No	No	160	Crane
2003:23	C	11.3	16.7	No	No	No	158	Crane
2003:24	C	9	13.4	No	No	No	150	Crane
2003:25	C	10.2	12.5	No	No	No	140	Crane
2003:26	C	9.3	14.2	No	No	No	220	Crane
2003:27	C	10.7	14.9	No	No	No	162	Crane
2003:28	C	10.7	14.9	No	No	No	138	Crane
2012:1012	E	10.9	14.5	No	No	No	160	Crane
2012:1013	E	8.4	14	No	No	No	175	Grey heron
2014:300	C/E	7	5.8	Slight	No	On 1st toe	142	White stork

2014:301	C/E	5.5	5	Slight	No	On 1st toe	150	White stork
2015:55.1	C/E	2.5	2.5	Yes	No	No	110	Small wader (Scolopacidae?)
2015:55.2	C/E	7	7	Yes	Yes	No	140	Grey heron
2015:87.1	C/E	11	16	No	No	No	140	Crane
2015:87.2	C/E	12	17	No	No	No	138	Crane
2015:87.3	C/E	12	13	No	No	No	140	Crane
2015:90	C/E	12	13.6	No	No	No	168	Crane
2015:112	C/E	8.2	8	Yes	No	No	170	Grey heron
2015:113	C/E	8.5	8.5	Yes	Slight	No	170	Grey heron
2015:127.1	C/E	15.2	13.5	Yes	No	No	155	Crane
2015:127.2	C/E	17.5	17	No	No	No	150	Crane
2015:127.3	C/E	22	11	No	No	No	150	Crane
2015:127.4	C/E	20	12	No	No	No	150	Crane
2015:130.1	C/E	14	12.5	No	No	No	160	Crane
2015:130.2	C/E	14.3	19	No	No	No	162	Crane
2015:130.3	C/E	11.7	18	No	No	No	152	Crane
2015:126.1	C/E	6	7.5	No	No	No	125	Oyster-catcher
2015:avian	C/E	6	7.5	Yes	No	No	140	Grey heron
2015:129.1	C/E	9	5.6	No	No	No	130	Oyster-catcher
2015:131	C/E	7.6	6.2	No	No	No	170	Oyster-catcher
2015:132.1	C/E	14.4	12.5	No	No	No	168	Crane
2015:132.2	C/E	14	18.5	No	No	No	155	Crane
2015:132.3	C/E	12	18	No	No	No	140	Crane
2015:132.4	C/E	14	13	No	No	No	150	Crane
2015:148.1	C/E	12	16	No	No	No	175	Crane
2016:70.1	C/E	16.5	15	Slight	No	No	160	Crane
2016:70.2	C/E	15	15.4	Slight	No	No	160	Crane
2016:70.3	C/E	14.2	14.5	Slight	No	No	168	Crane

2016:70.4	C/E	14.4	12	Slight	No	No	170	Crane
2016:70.5	C/E	15.3	15.2	Slight	No	No	160	Crane
2016:70.6	C/E	12.6	15	Slight	No	No	165	Crane
2016:70.7	C/E	16.5	17.5	Slight	No	No	170	Crane
2016:70.8	C/E	16	16.5	Slight	No	No	150	Crane
2016:70.9	C/E	12.5	15.4	Slight	No	No	178	Crane
2016:70.10	C/E	10	15	No	No	No	160	Crane
2016:70.11	C/E	13	14	No	No	No	165	Crane
2016:70.12	C/E	11.8	17.2	Slight	No	No	180	Crane
2016:70.13	C/E	11.6	16	Slight	No	No	160	Crane
2016:70.14	C/E	15.2	14	Slight	No	No	178	Crane
2016:70.15	C/E	12	15	Slight	No	No	167	Crane
2016:70.16	C/E	10	12	Slight	No	No	170	Crane
2016:70.17	C/E	16.2	16	Slight	No	No	168	Crane
2016:70.18	C/E	14	13.5	Slight	No	No	170	Crane
2016:72	C/E	5	6.6	No	No	No	125	Oystercatcher
1	C	7	11.6	No	No	No	Unclear	Crane
2	C	8	11.2	No	No	No	Unclear	Crane
3	C	15.7	14.9	No	No	No	Unclear	Crane

Table 7.3 Metric dimensions from avian footprint-tracks recorded on Site C/E

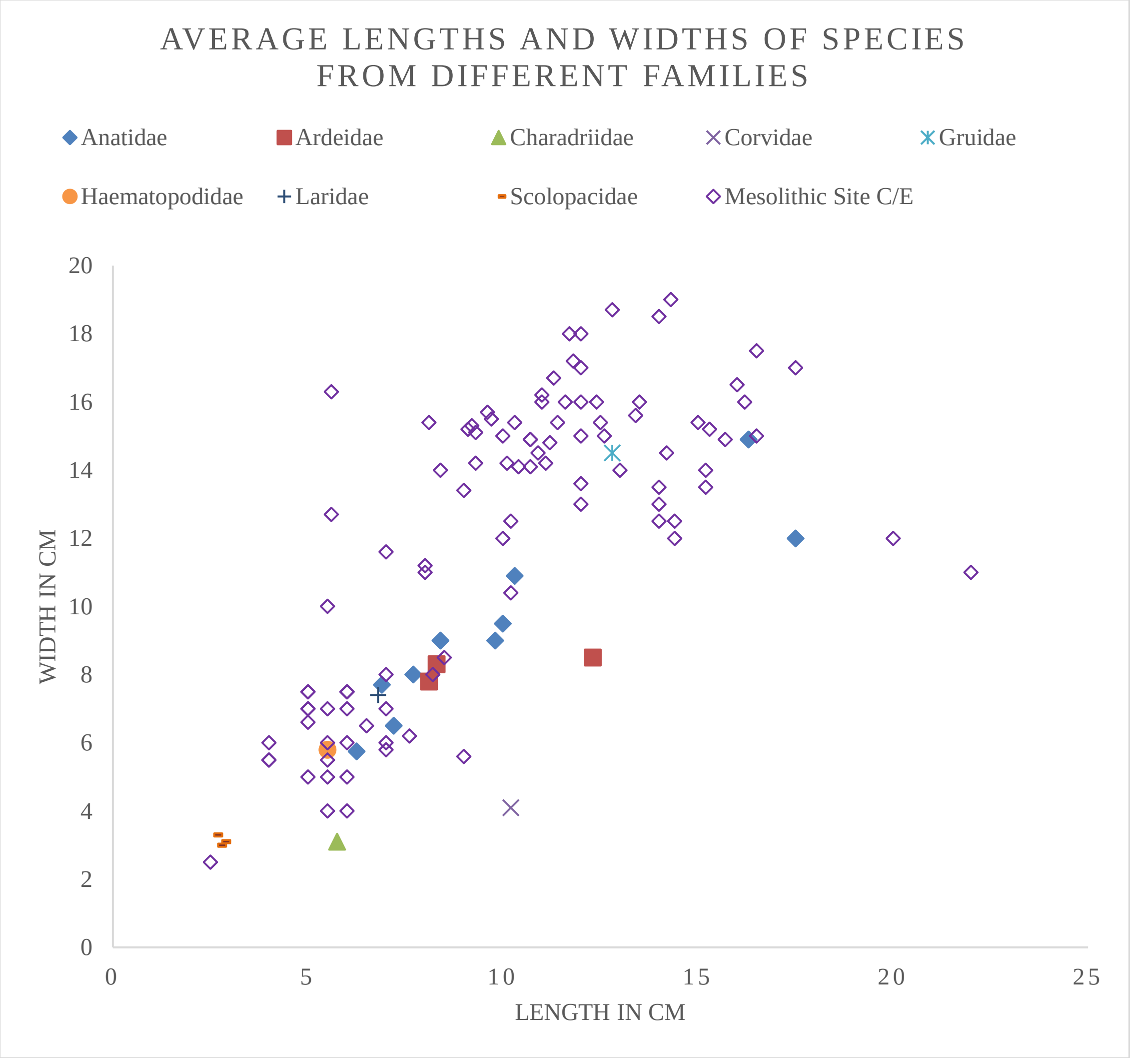


Figure 7.10 Lengths and widths of footprints from 21 species from 8 different families (Table 7.1), plotted against Mesolithic avian footprint-tracks from Site C/E

Of the 99 footprint-tracks recorded at Site C/E, 66 were metrically and morphologically similar to common crane (Figure 7.10), with measurements ranging in length between 5.6cm and 22cm. Two footprint-tracks measuring 5.6cm in length (2003:2 and 2003:3) were missing a large portion of the third toe, the width of these was 12.7cm and 16.3cm. Morphologically these footprint-tracks were all similar, with three large toes, no evidence of webbing, claw marks or any mark made by a 1st toe. The median for the lengths of the possible common crane footprints recorded at Site C/E was 12.5cm, with a mode of 12cm. There were seven footprint-tracks that were over 16cm in length. Previous research involving prehistoric crane footprint-tracks has indicated that Mesolithic crane may have been larger than the common crane of today due to the larger lengths of the footprint-tracks (Scales 2006; Roberts 2014). This research suggests that this is not the case. The footprint-track literature contradicts itself regarding the expected size of a common crane footprint. Certain texts describe the common crane footprint as similar in size and length to a grey heron, approximately 8cm in length, although without a 1st toe (Bang and Dahlstrom 1974). Others noted that the common crane footprint can be up to 16cm in length, 18cm in width and with a 3rd toe that can be as long as 11cm (Brown *et al*. 1987). If we accept Brown *et al.*'s (1987) common crane metric measurements, along with the results of the experimental research, where the average crane footprint-track was 12.8cm in length and 14.5cm in width, it is apparent that the birds found in Site C/E, all sharing the same shape and features (Figure 7.9 2-5), are from the common crane species. Though there were seven footprint-tracks that were morphologically similar to common crane, but longer than 16cm, so these may have been particularly large common crane, or a larger crane species.

Footprint-tracks 2015:87(1-3) were some of the best preserved avian footprint-tracks recorded during the fieldwork period. These were the actual footprint or a very slight undertrace, and had not been infilled with silt. Figure 7.11 shows the quality of the footprints; there appeared to be no evident trail, leading to the conclusion that one or several birds had walked across the lamination multiple times. These footprint-tracks were recorded with multi-image photogrammetry and could then be compared against models made of modern bird footprints for a comparison. Figure 7.12 shows footprint-tracks 2015:87(1-3) compared to footprints made by modern common crane in mud. These footprints are all clearly made by a large bird species that does not leave a 1st toe impression, even when walking in wet mud substrate. Tracings of modern common crane footprints demonstrate the general shape of this species' footprint (Figure 7.13), though the toe spread will be variable depending on sediment. Tracings of Mesolithic avian footprints thought to be crane demonstrate that there are some features that are slightly different (Figure 7.14, Figure 7.15). The width of the toes is narrower in modern crane; this difference may be explained by the way in which the prehistoric footprints were preserved, or the differences in the sediments walked upon.

Figure 7.16 is a footprint made by a modern crane walking upon estuarine sediment within the footprint trap. The toes are less spread than the toes of the same bird walking upon a muddy area (Figure 7.13), this print also has a very pronounced metatarsal pad. Figure 7.17, a Mesolithic crane footprint-track, has a slightly wider toe spread than the modern footprint; this footprint is the only preserved Mesolithic crane print to also exhibit a metatarsal pad indentation. Experimental work found that when walking on softer sediment, common crane will spread their toes wider to enable a safer footing. The footprints shown in Figure 7.13 had a slightly wider toe spread than those seen in Figure 7.16, even though they were made by the same bird. This, along with the evidence of a 1st toe, indicates that the sediment walked upon by the prehistoric crane was either wet or soft.

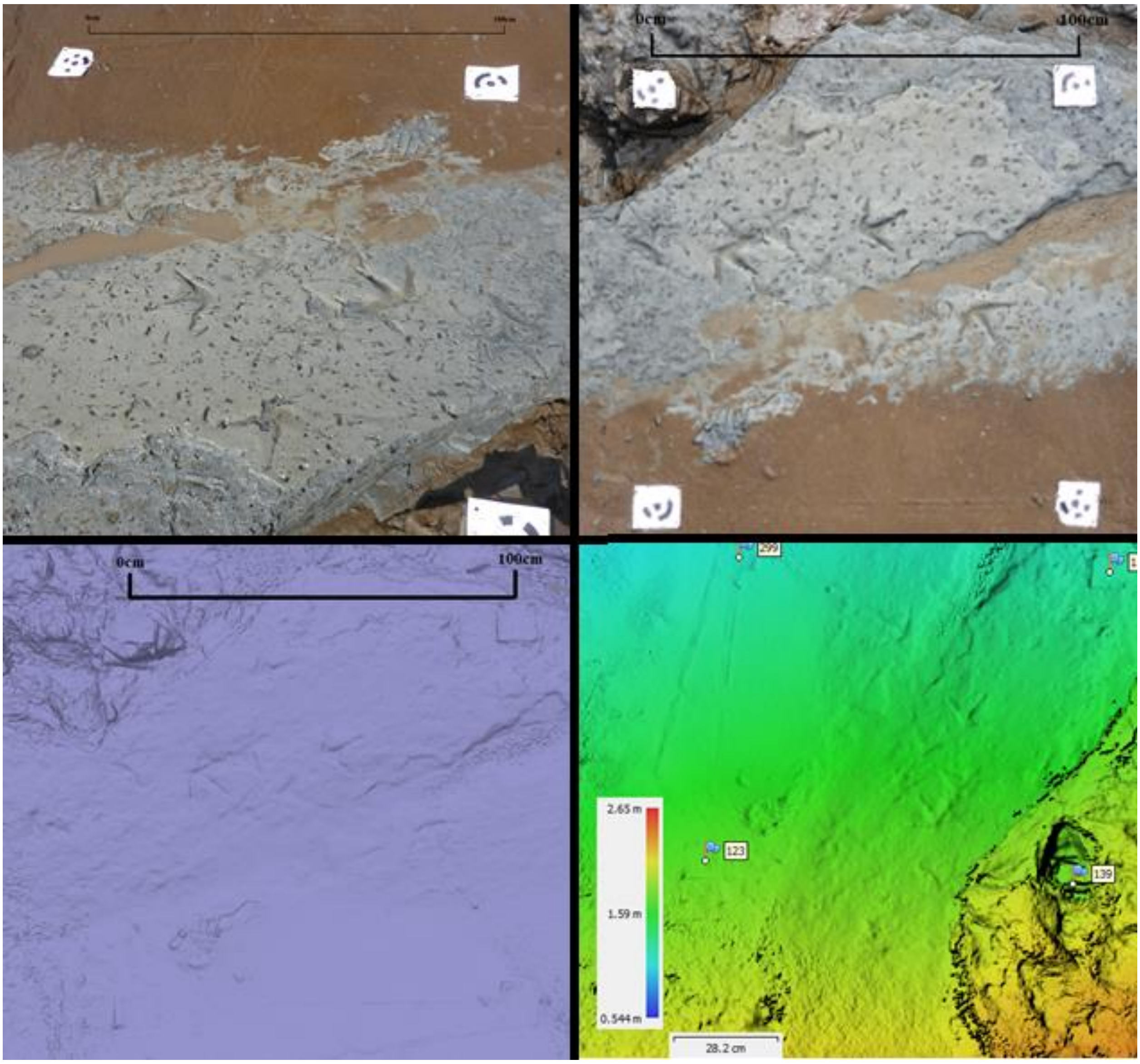


Figure 7.11 Footprint-track area 2015:87. Top (left) standard photograph of footprints, (right) multi-image photogrammetry model of the footprints generated in Agisoft Photoscan Pro. Bottom (left) solid colour of the model, (right) digital elevation model of the model. Note that the DEM does not provide the OD heights for this area.

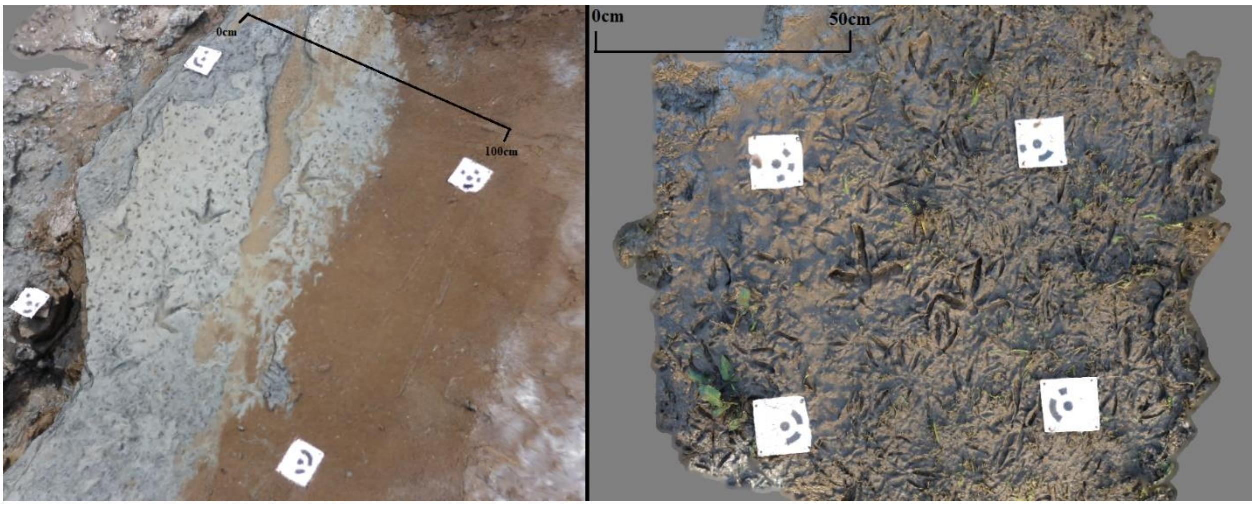


Figure 7.12 (left) Multi-image photogrammetry model of Mesolithic footprint-tracks 2015:87, (right) common crane footprints made by modern birds in mud on top of grass, recorded at WWT

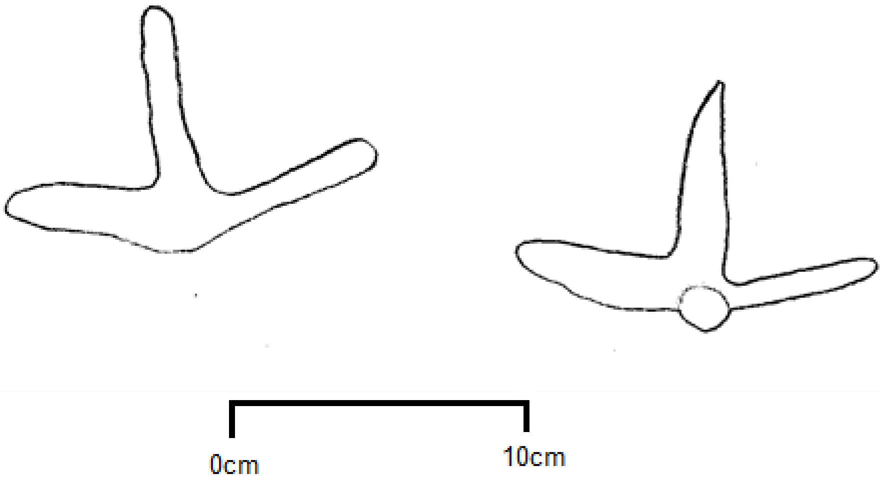


Figure 7.13 Tracing of modern crane footprints, walking in mud. Note the wide toe angle and deep metatarsal pad, as seen in Figure 7.12

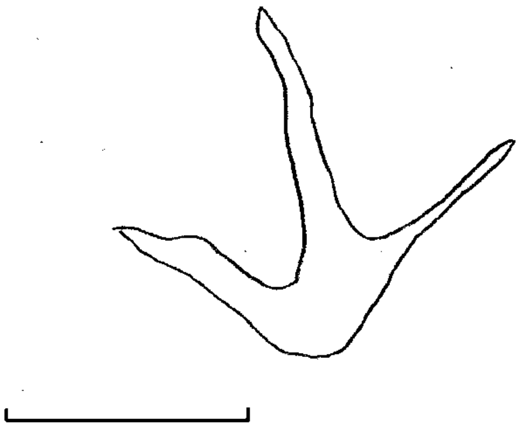


Figure 7.14 Tracing of possible crane footprint-track 2015 87, recorded in Site C/E. Scale bar 8cm

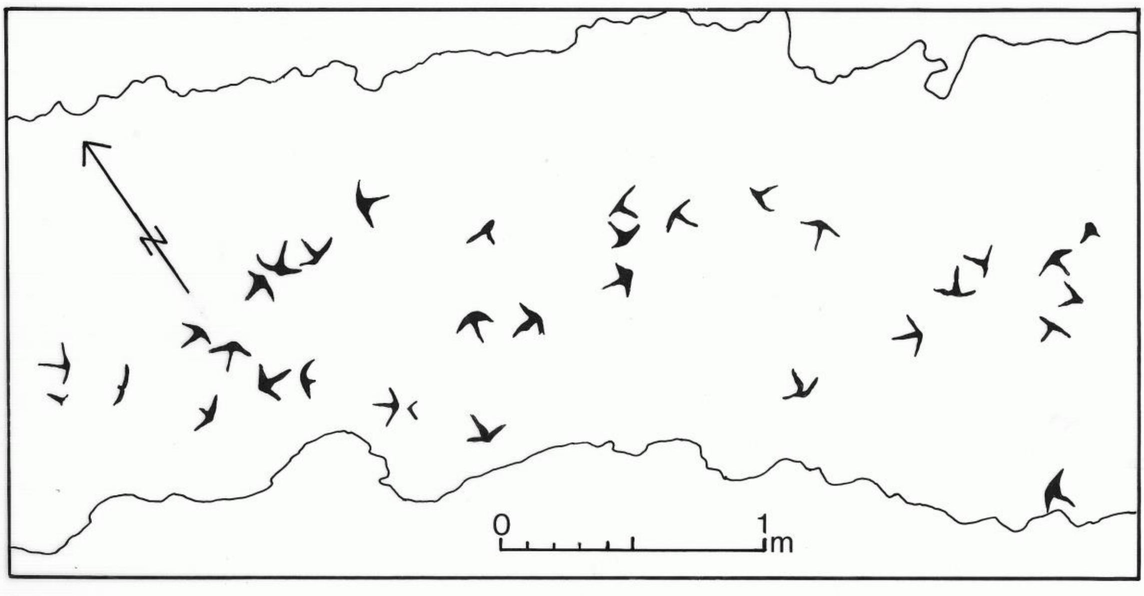


Figure 7.15 Digitalisation of common crane footprints from Site C Scales (2006)

Figure 7.16 (top) Modern crane walking in estuarine clay footprint trap. Note deep metatarsal pad of the top left crane print and the areas trampled by multiple unidentified wetland species. (bottom) the same image as the top, but with the prints digitally traced for visual clarity

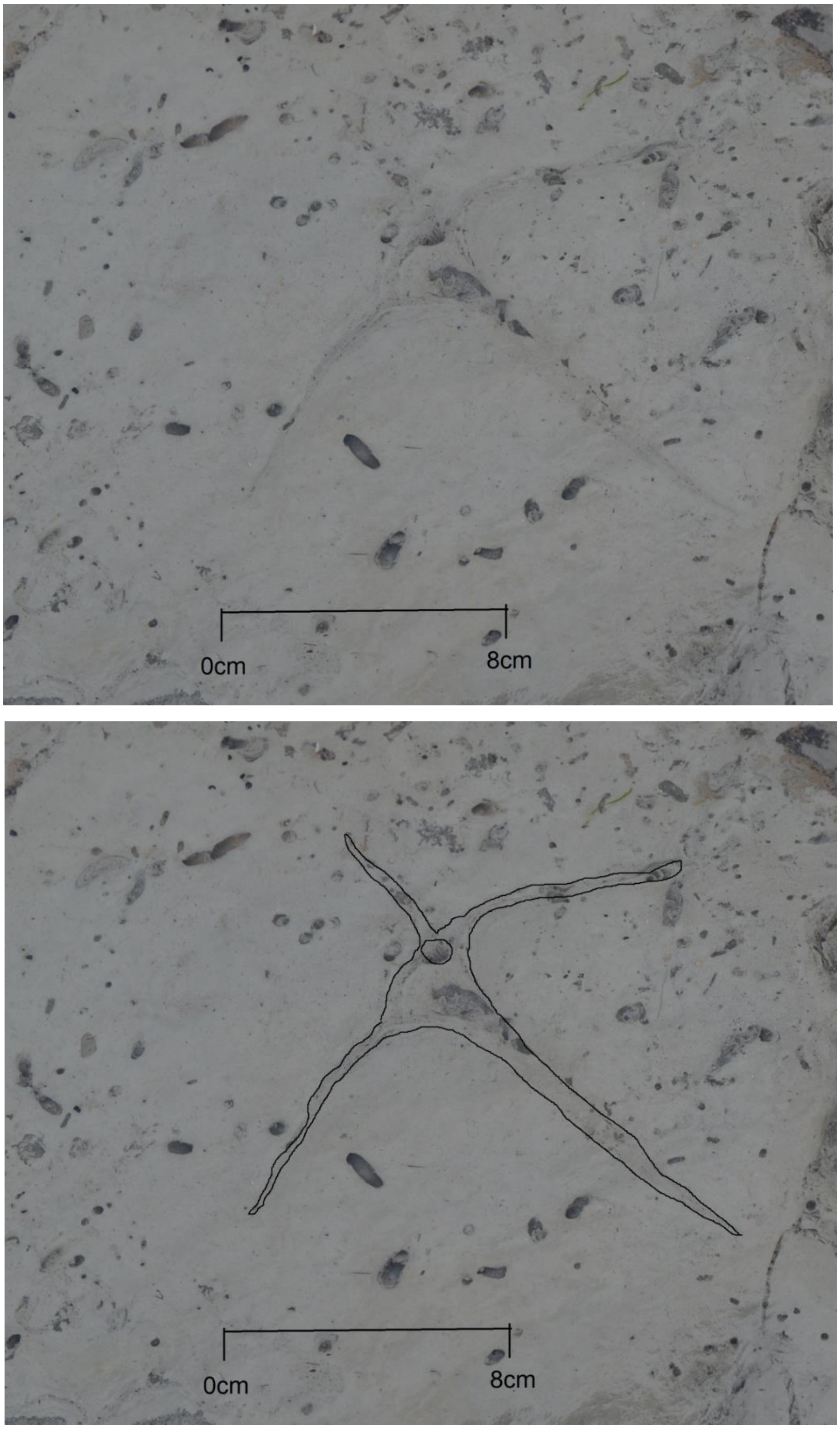


Figure 7.17 (top) Mesolithic crane (2015:127.1) made on a clayey silt banded lamination. Note the small but visible metatarsal pad. (Bottom) outline of footprint 2015:127.1 is traced for clarity

Footprint-tracks 2014:300 and 2014:301 were marked out in the lamination by dark organic matter and had a similar look to a grey heron footprint, though they were smaller and the 1st toe was only evidenced by a distinct claw mark (Figure 7.18). Grey heron will often make a small 1st toe imprint but it is unusual for a small amount of 1st toe to be indicated via a claw mark. These footprints were identified as white stork with the assistance of ornithology expert Damon Bridge from the Royal Society for the Protection of Birds (RSPB). Footprint-track 2014:300 was 7cm long and 5.8cm wide, footprint-track 2014:301 was 5.5cm long and 5cm wide. The literature suggests varied average footprint dimensions for this species; Bang and Dahlstrom (1974) state that a white stork footprint will measure 8cm in length and 6.5cm in width, whereas Brown *et al*. (1987) give a range between 7cm and 14cm in length, and 12cm in width. This discrepancy within the literature makes identification difficult. Figure 7.19 shows the appearance of the footprint-tracks when they have been traced; this is relatively comparative to Figure 7.20, a tracing of a white stork footprint from Brown *et a*l. (1987). The tracings demonstrate the similarities in the toes, especially the 1st toe. The deep central metatarsal pad and asymmetrical 1st toe makes the white stork species a probability for these footprint-tracks. The small size may suggest a juvenile bird, that the sediment was relatively soft when walked upon, or that this footprint-track was an undertrace.

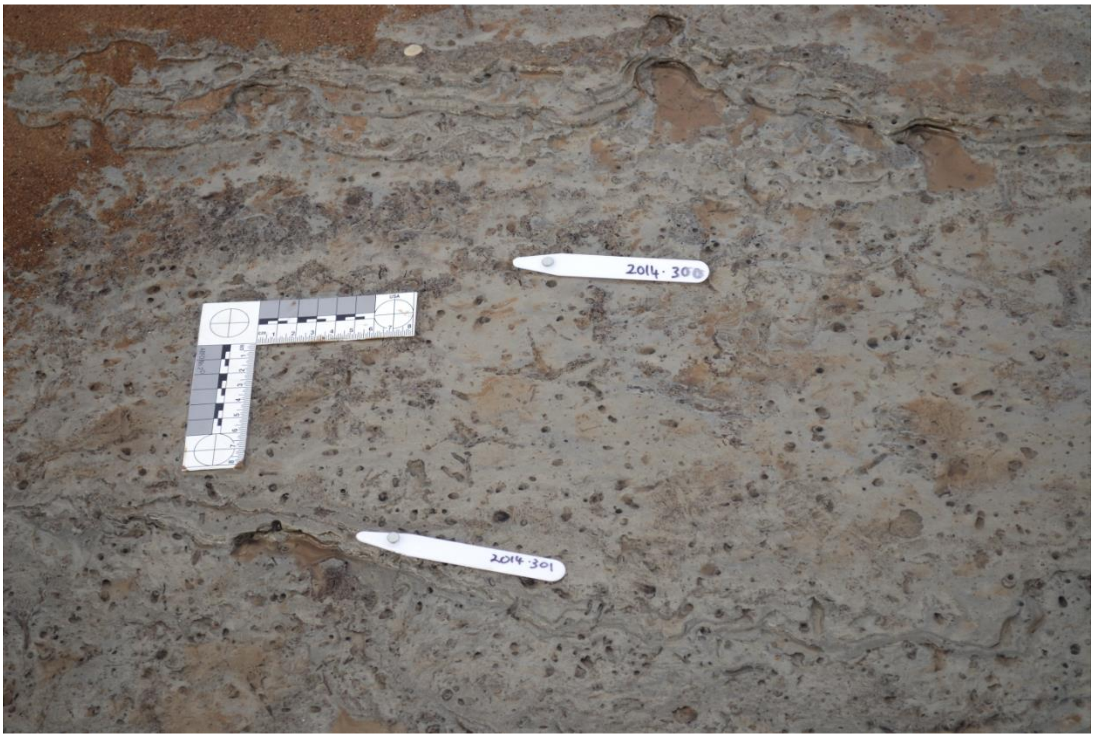


Figure 7.18 Footprint-track 2014:300 and 2014:301. Possible juvenile white stork at Site C/E. Scale in cm divisions

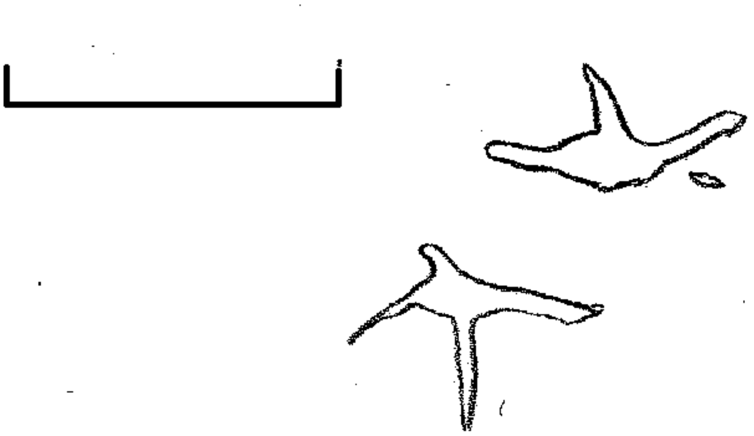


Figure 7.19 Tracing of footprint-track 2014:300 and 2014:301, possible white stork footprints. Scale bar 8cm

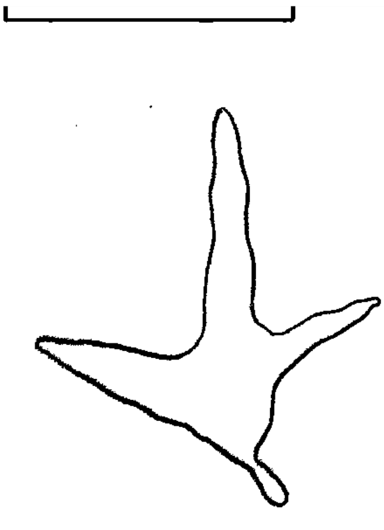


Figure 7.20 Tracing of white stork footprint from Brown et al. Scale 10cm

Four oystercatcher footprint-tracks were identified at Site C/E (Figure 7.21), these were larger than those recorded experimentally (Figure 7.4f). The literature suggests that oystercatcher footprints are approximately 4.5cm in length and 6cm in width (Bang and Dahlstrom 1974; Brown *et al.* 1987). Within the experimental database the average size of an oystercatcher footprint was 5.5cm in length and 5.8cm in width. The Mesolithic oystercatcher footprint-tracks were between 5cm and 9cm in length, and 5.6 and 7.5cm in width. The prehistoric footprints were similar in morphology to those recorded experimentally, however they were up to 3.5cm longer. The difference in sizes may be due to the creation of the footprints in different sediment types. Modern oystercatcher were recorded walking on wet sand, resulting in size and features quickly becoming indistinct. The prehistoric footprint-tracks exhibited well defined toes, indicating a hard or dry sediment was walked upon, preventing the foot fully sinking into the sediment or causing the sediment to fall back into the footprint, which can be seen in the modern oystercatcher footprints (Figure 7.4 f). The size of the prehistoric footprint-tracks may indicate that the oystercatcher species were slightly larger than they are today, or possibly that they were made by full grown males.

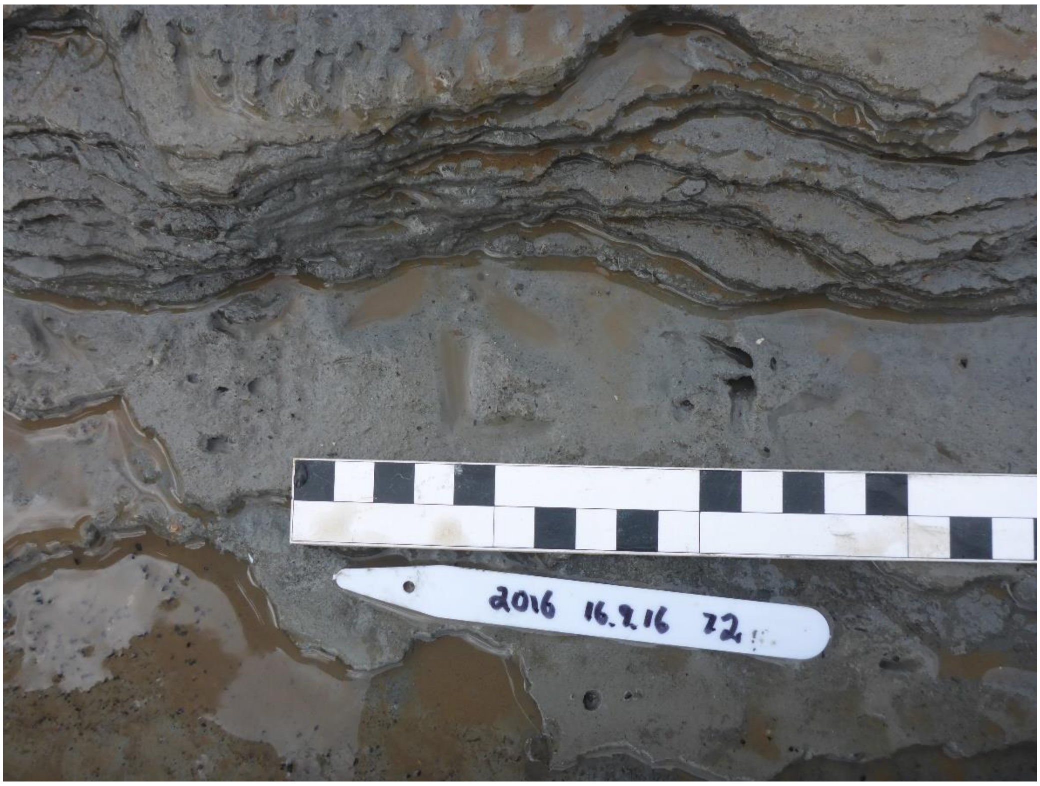


Figure 7.21 Footprint 2016:72, identified as an oystercatcher made at Site C/E

Scales (2006) recorded 21 bird footprint-tracks at Site E during 2002 via tracing, and identified them all as grey heron (Figure 7.22). Although the tracing provides some metric dimensions, they were often smaller than modern heron footprint measurements, though the angle of the toe and morphology are similar to grey heron. Eleven of the footprints were 5cm or less in length or width, which is unlikely to be metric dimensions from an adult grey heron, though the shape and toe angle, as well as association to adult grey heron, may indicate these were the footprints of their fledglings.

Of the 21 footprint-tracks recorded in the tracing by Scales (2006), 10 could be accurately identified as grey heron due to the metric dimensions and morphology, often including a 1st toe (Figure 7.22). The sizes of the remaining 11 footprint-tracks were morphologically similar to grey heron, though they were smaller than adult grey heron; some were as small as 4cm in length and width. Due to the morphology, presence of 1st toe, and the angle between toes II and IV being very similar to grey heron, as well as the adult grey heron in the vicinity, these are likely to have been made by grey heron fledglings.

Four further footprint-tracks were recorded in Site C/E, between 2012-2016, all with an obvious 1st toe but only slight evidence of semilobate webbing and no evidence of claw marks (Figure 7.23 and 7.24). The footprints were asymmetrical and the morphology of the print suggests a large wader: a grey heron, Eurasian bittern, or a white stork. The appearance of a long 1st toe is indicative of the grey heron species, as white stork have a very short and blunt 1st toe and Eurasian bittern have prominent slender toes with lobes on the distal phalange, large claws, and often leave no 1st toe imprint, or only a slight one (Figure 7.25). Due to the obvious 1st toe, the large size and lack of a distal phalange lobe, they were identified as grey heron.

One of the footprint-tracks from Site C/E had the morphology and metric dimensions of a small wader, with evidence of a 1st toe, and a lack of any curve in the toe indicative of webbing. There are a variety of small waders that frequent the coast of Britain which may have also visited this area during the prehistoric period that were not recorded in the experimental study, meaning that a positive identification could not occur, though *Scolopacidae* is most likely. Birds belonging to the *Scolopacidae* family are wetland waders, feeding in flocks around shallow waters and on mudflats, hunting for aquatic prey. The reason that the species or sub-species could not be identified is that they are all fairly similar in size, shape, toe angle, behaviour and habitat. Even using published illustrations in footprint tracking guides and knowledge of the birds' behaviours (Brown *et al*. 1987; Bang and Dahlstrom 1974), there were too many similarities between these footprints for accurate species identification. The only way to rectify this would be to get every small wading species of the British Isles to walk on the silt sediment to highlight any minute variations; even then the species in question may not still be a resident of Britain.

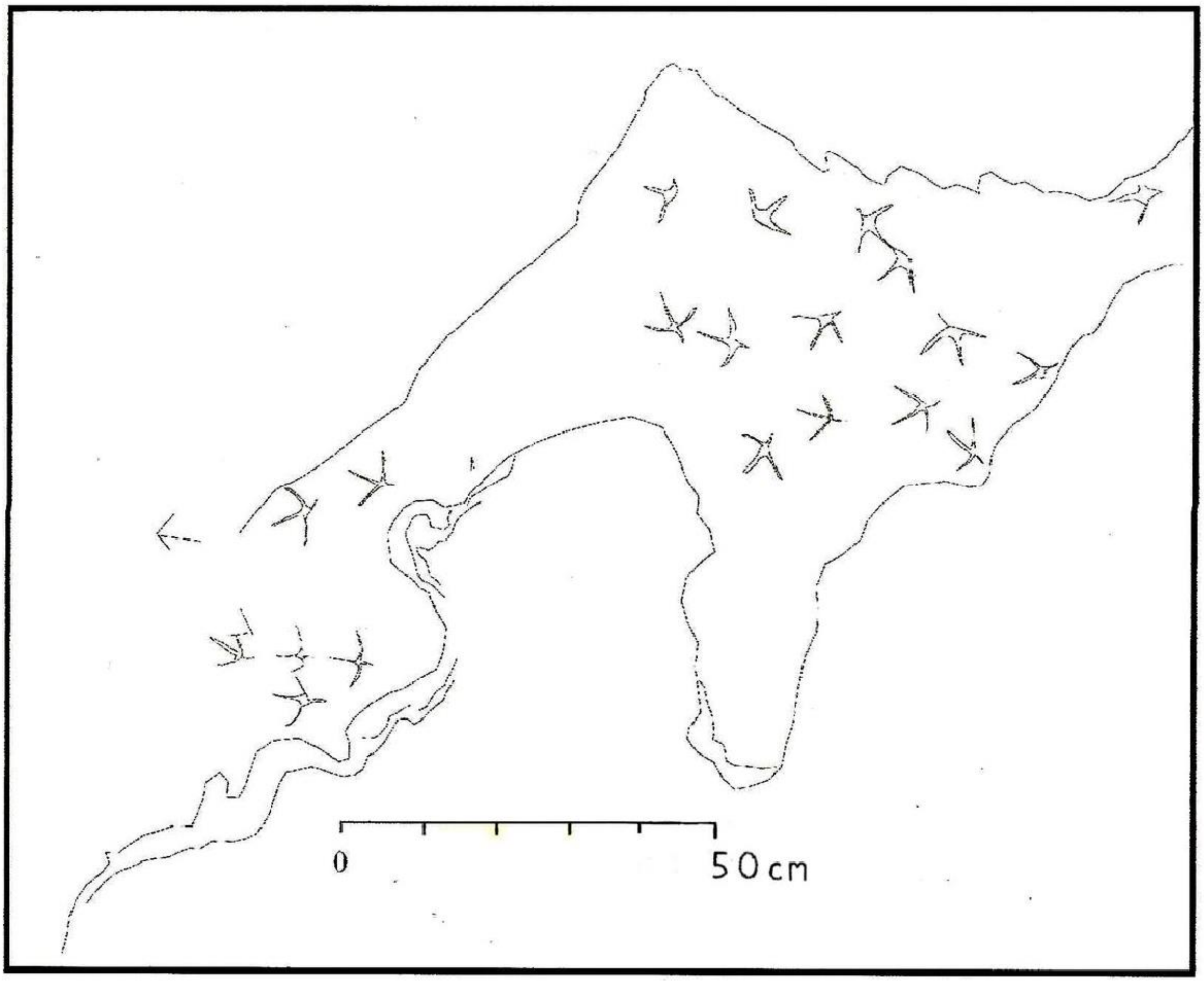


Figure 7.22 Footprints recorded by Scales (2006), possible Grey heron, Site E

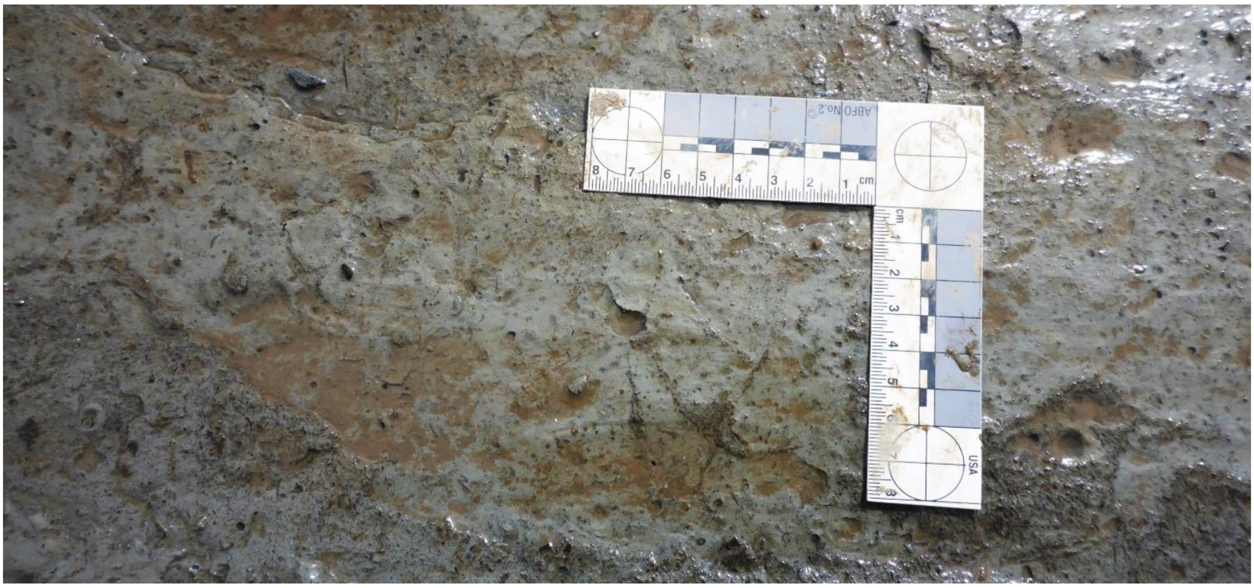


Figure 7.23 Grey heron footprint (2015:55.2) picked out on the lamination by finely divided organic matter

Figure 7.24 Grey heron footprint (2015:55.2) picked out on the lamination by finely divided organic matter and drawn around to highlight its morphology

Figure 7.25 Eurasian bittern footprint made in a sand footprint trap used by the RSPB to record species diversity. Scale bar in inches (photograph courtesy of David Baskett, RSPB Minsmere Nature Reserve volunteer)

The varied large bird footprint-tracks within Site C/E, and lack of small bird species, indicated that small birds either found the habitat at the time unsuitable, or that the smaller birds' weight was unable to leave much of an impression upon the sediment during this time. A firm sediment is also implied through the general lack of first toe in the crane species; in soft sediments common crane will leave a 1st toe impression. It must be also be noted that Scales (2006) did record 116 small bird footprint-tracks at Site C from the same lamination, so it may be that the environment was correct for the preservation of these smaller footprint-tracks at the time.

7.5.2 Site M

Avian footprint-tracks were recorded in Site M during 2015 (Figure 6.2). This area had multiple human footprint-track trails, discussed in Chapter 6.6. The level of preservation in this area was poor; the human footprint-tracks were all overtraces/undertraces rather than the true footprints. Site M covered multiple laminations, between -4m and -4.8m OD, and was exposed at low spring tides. When exposed, linear erosion gullies separating ridges of laminated sediment could be seen, with footprint-tracks preserved on these ridges. The avian footprint-tracks were recorded in the very northern part of Site M, where there was a small area of well-preserved lamination, this area was only 1m^2 and many footprint-tracks were difficult to identify on the laminations, with only four footprint-tracks clear enough to include. This area is usually covered in thick mud and was only exposed for one day of fieldwork, on the 19.05.2015.

The avian footprint-tracks from Site M were generally small (Table 7.4; Figure 7.26, 7.27), with a set of footprint-tracks measuring 2.5cm in length and 2.5cm in width; the 1st toe was visible, and there was no evidence of webbing. This was a probable small wader, possibly from the *Scolopacidae* family. The tracings of 2015:a and 2015:c (Figure 7.28) compared against modern dunlin footprints (Figure 7.29), demonstrate similarities in the lack of any webbing, long 3rd toes and the occasional presence of a slight 1st toe indentation.

Footprint-track 2015:b was morphologically similar to a bird belonging to the heron or egret family. The footprint was as wide as it was long, 7cm, and had a long first toe and evidence of semipalmate webbing between two toes. Experimental work within this study found the average size of a grey heron walking on sandy estuarine sediment to be 8.3cm in length and width, with evidence of a 1st toe and slight webbing at the base of two of the front toes. Bang and Dahlstrom (1974) note that the average grey heron footprint is 7.5cm in length and width, whereas Brown *et al*.(1987) record that the length of a grey heron footprint can range between 13cm and 18cm, with a width of 8cm or 9cm. Within the literature there is a substantial difference between the sizes of the grey heron footprints. Experimental work does indicate that sediment can greatly change the size of a footprint, which may assist in understanding these differences. The grey heron recorded by Brown *et al*. (1987) were recorded in silt, the grey heron recorded in this study were recorded in sandy sediments, and Bang and Dahlstrom (1974) do not state the sediment the footprints were recorded in. A tracing of 2015:b (Figure 7.30) compared to a tracing of a modern heron (Figure 7.31) walking on wet sand demonstrates that although the shape of the print is similar, the toes of the grey heron in wet sand created a fairly wide print. When walking on dry sand, heron created a similar shaped footprint, with toes that were slender in comparison to those made in wet sand. Little egret is also a possible species for this footprint, though there have been no little egret skeletal remains found in the British archaeological record (Yalden & Albarella 2009, pg 90), and there have only been regular sightings of this species in Britain since 1989 (Lock and Cook 1998), suggesting that it is improbable that they were present in Britain during prehistory.

Footprint-track 2015:53.a was made by a web-footed species (Figure 7.27). The dimensions and morphology suggest it comes from either the *Laridae* or the *Anatidae* family, though due to the very small metatarsal pad, a feature not exhibited by either of these species, positive identification was not possible. This footprint-track is currently unidentifiable until the formation of web-footed birds on different sediments has been more thoroughly explored.

The poor preservation of laminations in Site M has resulted in only a small area with evidence of bird activity. Within this small 1m^2 area, there were at least two different species present at a relatively similar time.

Footprint-track number	**Site**	**Length of print (cm)**	**Width of print (cm)**	**1st toe visible**	**Webbing visible**	**Claw marks**	**Toe angle between II and IV**	**Species**
2015:a	M	2.5	2.5	Yes	No	No	110	Small wader (*Scolopacidae*?)
2015:b	M	7	7	Yes	Yes	No	142	Grey heron
2015:c	M	2.5	2.5	Yes	No	No	110	Small wader (*Scolopacidae*?)
2015:53.a	M	5.3	5	No	Yes	No	130	Unidentified

Table 7.4 Metric dimensions of avian footprints recorded on Site M

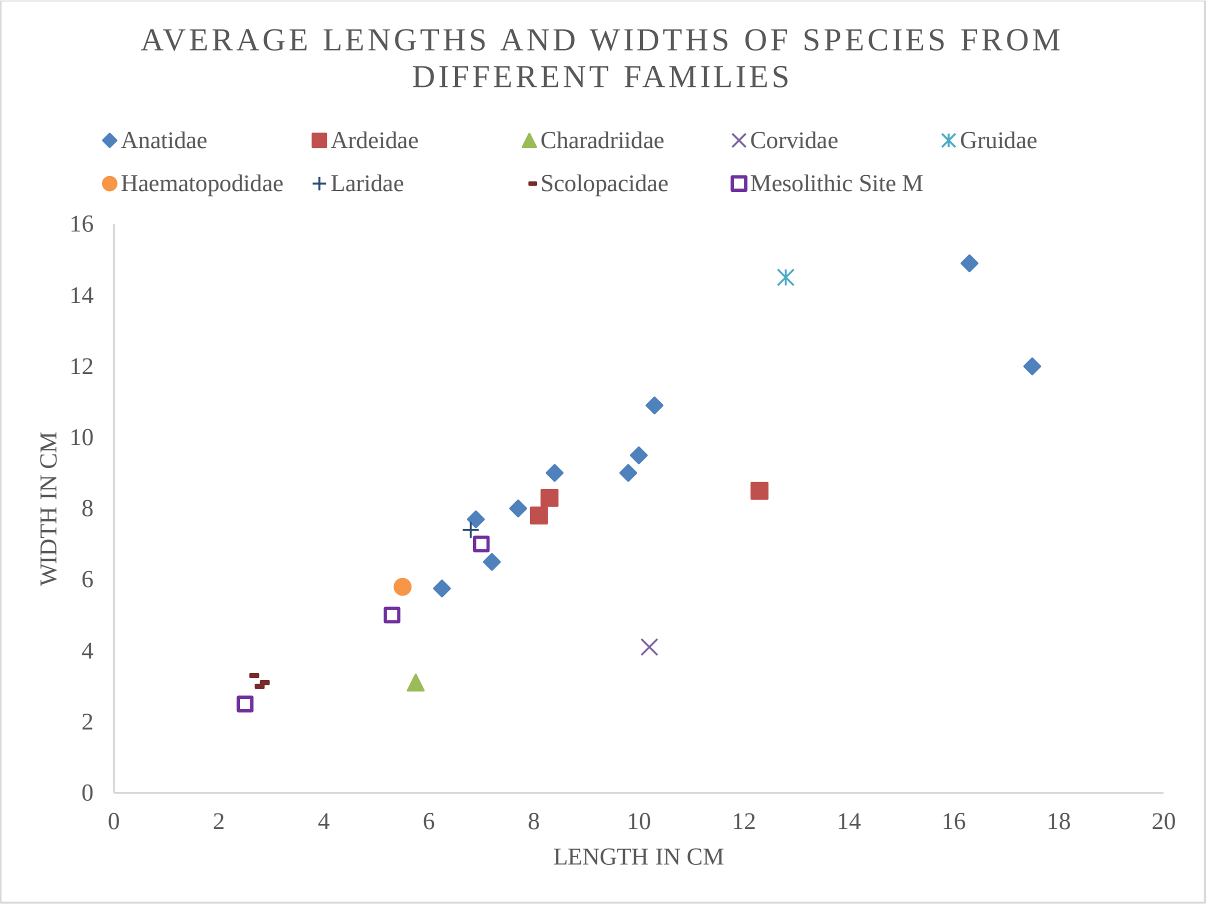


Figure 7.26, Avian footprint-tracks from Site M compared against lengths and widths of 21 species within 8 families recorded from modern birds (Table 7.1)

Figure 7.27 (top left) unidentified webbed species (2015:53.a), (top right) grey heron (2015:b), (bottom) small waders (2015:a and 2015:c)

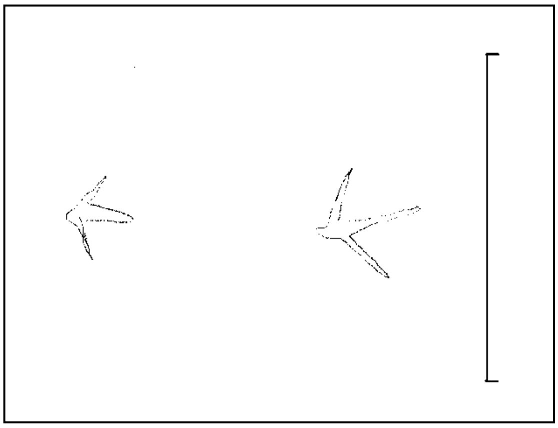


Figure 7.28 Tracings made in Site M, from footprints 2015:a. Scale bar 8cm

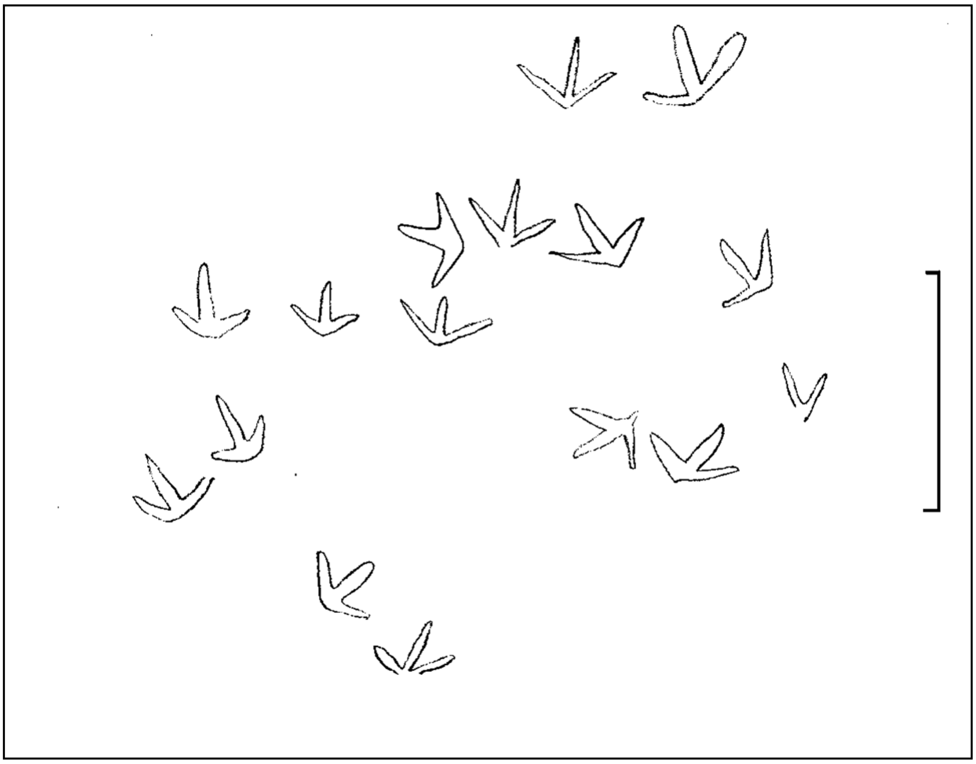


Figure 7.29 Tracings made from modern dunlin footprints. Note the long central toe shared by all prints, this can also be seen in the Mesolithic footprint-tracks and is indicative of small waders. Scale bar 8cm

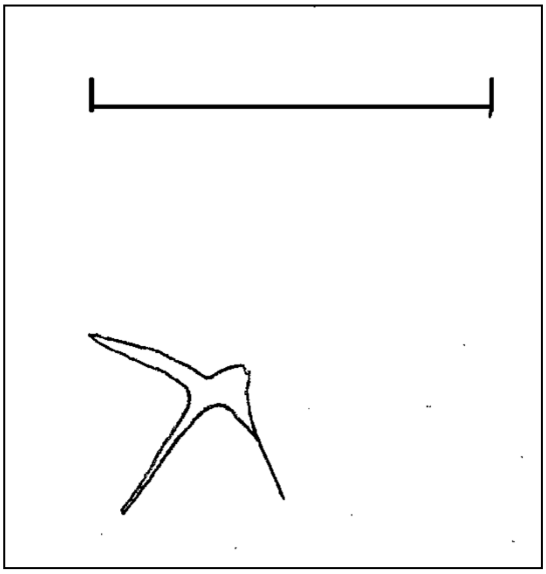


Figure 7.30 Digitalised tracing from footprint-track 2015:b, recorded from photograph at Site M. Scale bar 8cm

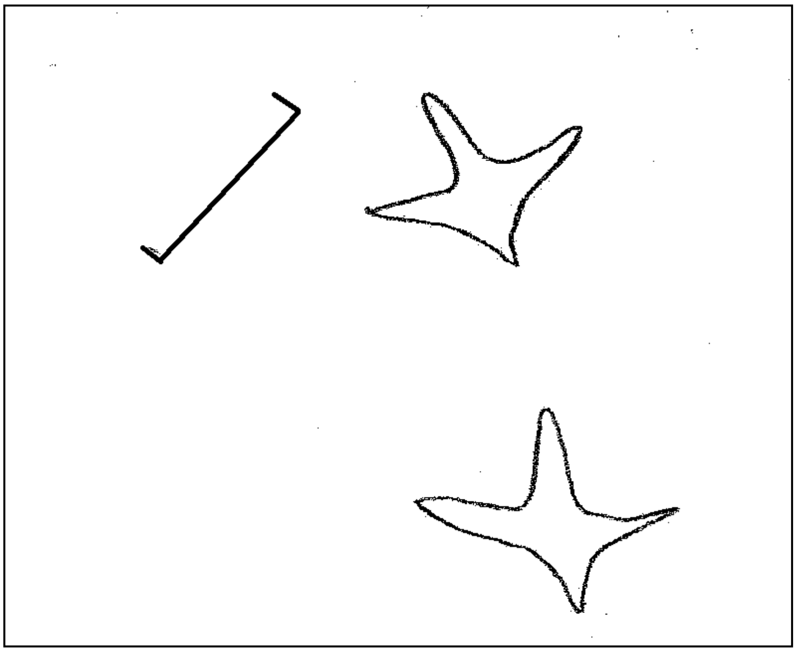


Figure 7.31 Digitalised tracings from modern heron footprints made in thick wet sand. Scale bar 8cm

7.5.3 Site N

Site N was located in laminated sediments between a prominent gravel bar and an area of permanent open water, and is exposed at OD c -5.30m (Figure 6.2). This was the most southern footprint site and was exposed for the least amount of time, when the tide was below 0.6m chart datum at the lowest spring tides. At the edge of the gravel bar laminated sediment was sometimes exposed, though these were poorly preserved due to the constantly shifting gravel bank, resulting in damaged laminations caused by gravel drag. The footprints in this area were primarily poorly preserved human footprint-tracks. The avian footprints recorded in this area were more detailed and well preserved than the human footprint-tracks, though they were not of the same quality as those from Site C/E.

Avian footprint-tracks 2014:302, 2014:303, 2014:304, 2014:305 and 2014:306 were recorded on 23.11.2014, on a small laminated area exposed at Site N. They were on similar laminations to the human footprint-tracks however they were not associated with any and were slightly to the north of the main 16m by 6m footprint area at Site N, near to Site O. This area was less than 50cm^2 and was covered with gravel throughout the rest of the fieldwork period.

Footprint-tracks 2015:16.1, 2015:16.2, and 2015:19 were made on the same laminations. Footprint-track 2015:16.1 and 2015:16.2 created footprint-tracks at the same, or similar times in the same area, and were between 10cm and 30cm away from human footprint-track 2015:17. 2015:19 was made approximately 30cm away from the toes of footprint-track 2015:18, and was slightly more northerly.

Footprint-track 2016:15a was made in an area where multiple human and possible ungulate footprint-tracks were recorded (2016: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,26, 29 and 31), and was less than 30cm directly in front of the toes of human footprint-track 2016:15. Footprint-track 2016:30 was also recorded on this lamination, 5cm away from the toes of human footprint 2016:18.

Site N appears to have been exploited by a variety of bird species (Table 7.5; Figure 7.32). All footprint-tracks were made on the same laminations as human footprint-track trails, and they were generally near to human footprint-tracks, this can be seen in Figure 7.33 where avian footprint-track 2015:16.1 was within 10cm of a human footprint-track (2015:17).

Footprint-track number	Site	Length of print (cm)	Width of print (cm)	1st toe visible	Webbing visible	Claw marks	Toe angle between II and IV	Species
2011:94.1	N	4	5.5	No	No	No	130	Unidentified
2011:94.2	N	6	8	No	No	No	155	Grey heron
2011:94.3	N	5.5	4.5	No	No	No	180	Unidentified
2011:94.4	N	3	3	No	No	No	165	Small wader (Scolopacidae)
2011:94.5	N	3	5	No	No	No	165	Unidentified
2011:94.6	N	5	7	No	No	No	170	Unidentified (possibly oystercatcher)
2014:302	N	8	12.2	No	No	No	130	Grey heron
2014:303	N	12	10.9	Yes, slight	No	No	130	Grey heron
2014:304	N	8.7	10.4	No	No	No	130	Grey heron
2014:305	N	8	11.9	No	No	No	130	Grey heron
2014:306	N	5	12.8	Yes, slight	No	No	130	Grey heron
2015:16.1	N	4	6	Yes	No	No	130	Unidentified (possibly juvenile grey heron)
2015:16.2	N	9	8	Yes	No	No	150	Grey heron
2015:19	N	7	7	Yes	No	No	145	Grey heron
2016:15a	N	8	6.4	Yes	Slight	No	148	Grey heron
2016:30	N	7.8	7.8	Yes	Slight	No	144	Grey heron

Table 7.5 Metric dimensions of avian footprints recorded at Site N

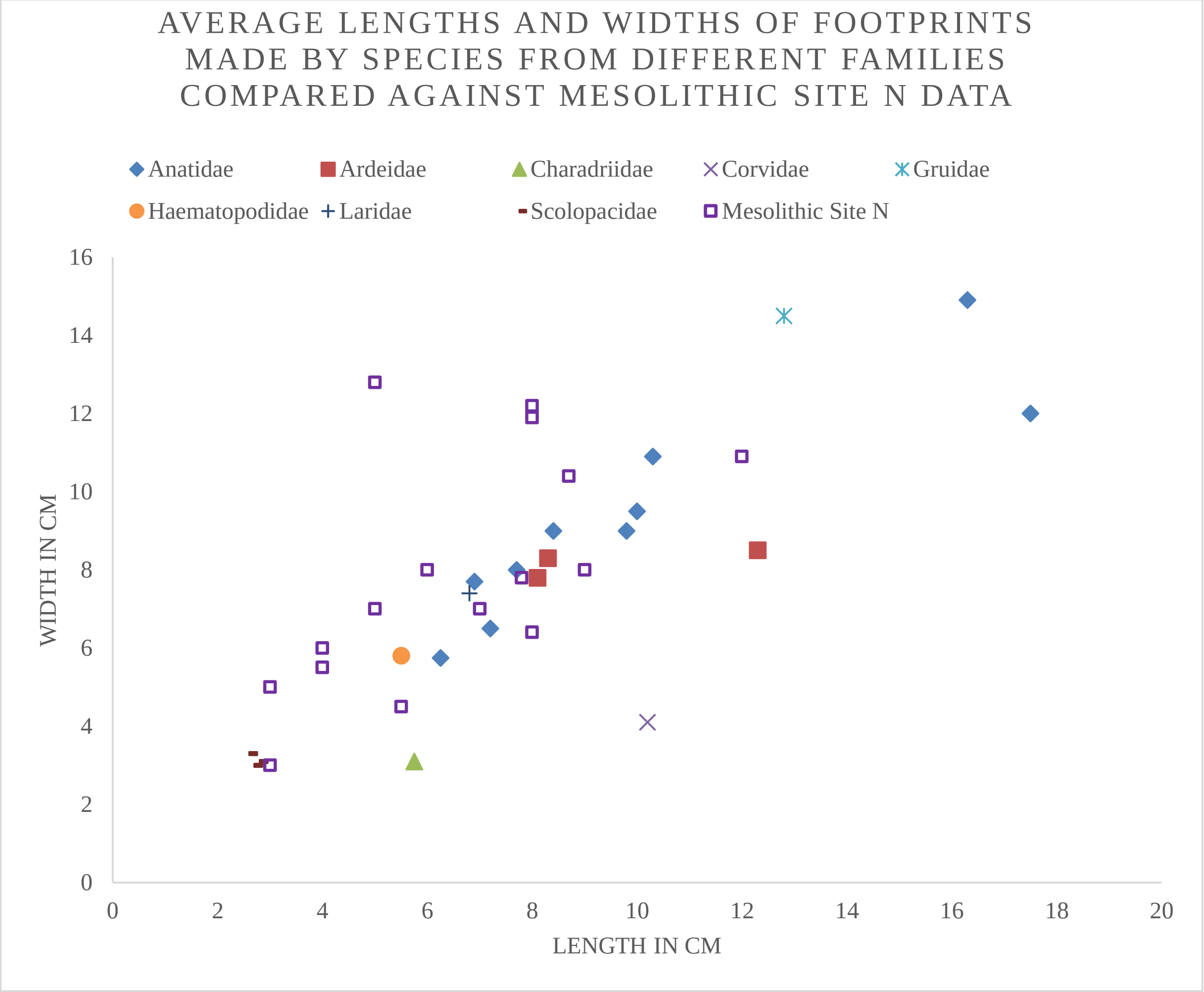


Figure 7.32 Lengths and widths of Site N footprint-tracks compared against modern analogues

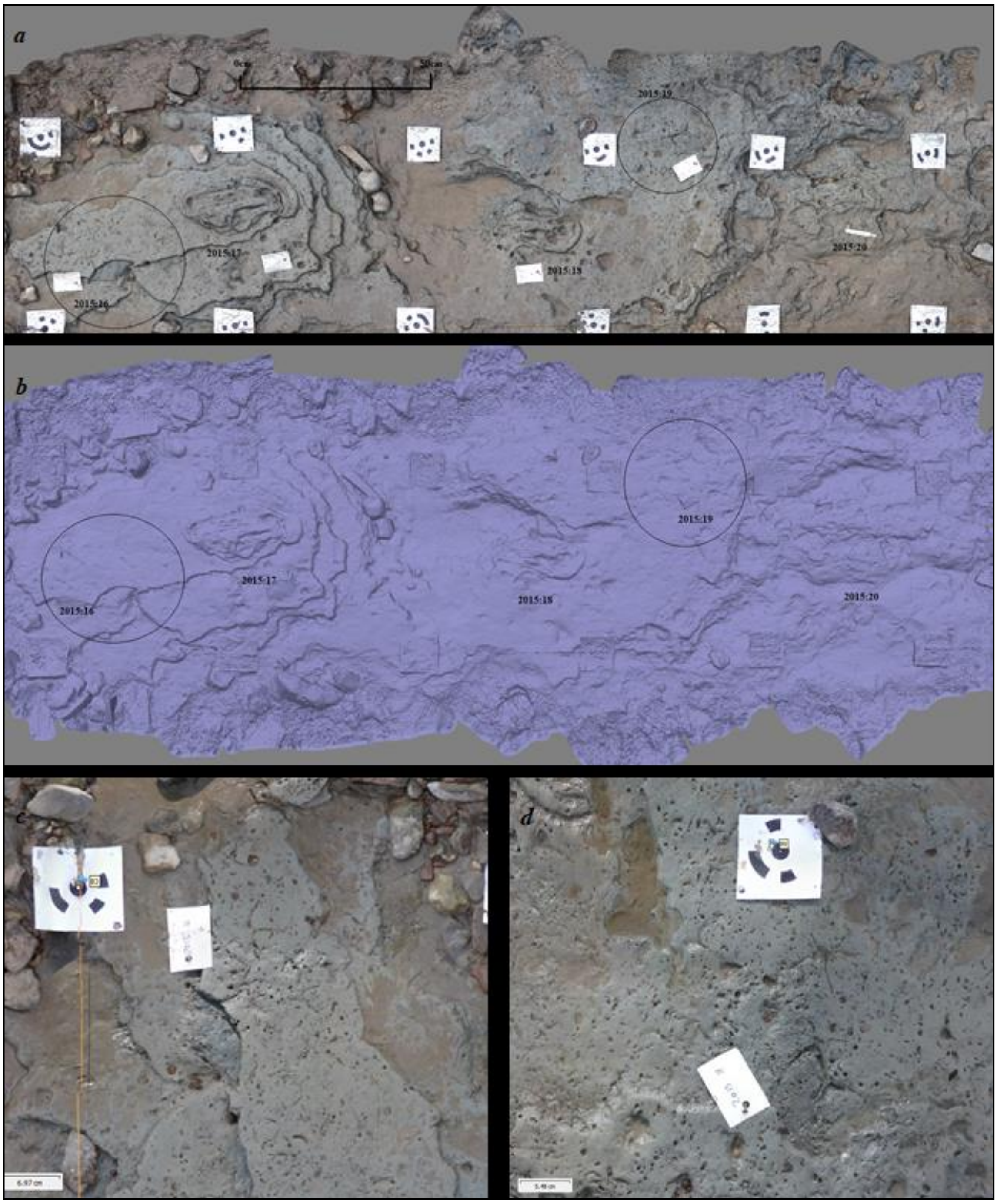


Figure 7.33 (a) Multi-image photogrammetry model generated in Agisoft Photoscan Pro. Note that avian footprints 2015:16.1 and 2015:16.2 are within 10cm of human footprint-track 2015:17. The bird footprint areas are circled for clarity. (b) The same model as (a) but shown in a solid colour. The reduction in shadows and slight differences to the colour of the footprint infill prevents the bird footprints showing up well in this model. (c) Orthomosaic model of footprint-tracks 2015:16.1 and 2015:16.2. (d) Orthomosaic model of 2015:19 footprint trail

Nine of the footprint-tracks at Site N were morphologically similar to grey heron, though not all had an obvious 1st toe. Footprints 2015:19 were all made by the same bird, in a trail (Figure 7.34). Only two footprints that were part of this trail had a 1st toe, though the trail was evidently all the same bird. Experimental work with heron indicated that when a heron walks through a plastic or wet substrate, although the 1st toe leaves an imprint, it quickly becomes indistinct; this would explain the lack of a 1st toe in these prints (Figure 7.4a). Heron behaviour also explains why the footprints did not have a 1st toe. Heron spend a lot of their time wading as they hunt aquatic animals; they will often follow the water line as the tide goes out, exploiting large pools of water as a hunting ground. Grey heron walk into these small pools of water, making very indistinct footprints, then if they tread onto firmer sediment such as silt, the 1st toe will be preserved. Observation of modern grey heron indicated that this creates a footprint trail featuring footprints both with and without a 1st toe (Figure 7.35).

Footprint-track 2015:16.2 (Figure 7.33), exhibited the clear morphology of grey heron footprints, with similar metric dimensions and toe angle. On the same lamination as 2015:16.2 was footprint 2015:16.1. These footprint-tracks were 4cm in length and 6cm in width with evidence of a 1st toe, but no evidence of webbing or claw marks, though they did exhibit a fairly large metatarsal pad. The wide spread of the toes without an inward curve indicated this was not made by a webbed species such as gull or duck. There was evidence of semilobate webbing, indicative of a wader, and a similar footprint appearance to grey heron, though smaller. These were made on the same lamination and were made among the footprint-tracks made by a grey heron (2015:16.2). If grey heron were nesting nearby then there may be young chicks learning to hunt with their parents, however due to the uncertainty these prints are currently considered unidentifiable. Further work with young grey heron and their footprint formation would enable these prints to be identified.

Footprint 2011:94.4 is a definite small wader, sharing similar dimensions, 3cm long and 3cm wide, to the turnstone, dunlin and little stint recorded for this study. The precise species cannot be identified due to the very minimal differences in size and shape, however the family is identifiable as *Scolopacidae*.

Figure 7.34 footprints 2015:19 grey heron trail. Scale 7.5cm

Figure 7.35 Grey heron trail made on sandy estuarine mud and in an area covered by a small amount of water, note the poor preservation in the wetter sediment. Scale 1cm divisions

7.5.4 Site O

During fieldwork in 2011 Site O was discovered. Bird footprint-tracks were found on a small laminated area, slightly north-east of Site N, since then these laminations have been covered up by a gravel bank. At the time of discovery, they were recorded via photography and tracings. There were 36 bird footprint-tracks recorded at Site O. The species of some were identifiable due to their morphology and size (Table 7.6), however nine footprint-tracks were unidentifiable due to a lack of clear photographs or observations of the footprints.

Footprint-tracks 2011:208.1 to 2011:208.4 had the metric dimensions and morphological appearance of common crane (Figure 7.36). The presence of a 1st toe in two of these four footprint-tracks indicated that the sediment was very soft, soft enough to cause the bird to sink down slightly into the sediment, resulting in the preservation of the 1st toe in two of the prints. This is also evident from the greater width of two of the footprints (2011:208.3 and 2011:208.4); in soft or slippery sediment birds will spread their toes to distribute their weight over a larger area to prevent risk of slipping. The widths of these range from 15cm and 15.5cm to 16cm and 17.5cm.

Footprint-track number	Site	Length of print (cm)	Width of print (cm)	1st toe	Webbing	Claw marks	Toe angle between II and IV	Species
2011:95.1	O	2.5	2.1	No	No	No	75	Small wader
2011:95.2	O	1.9	2.3	Yes	No	No	115	Small wader
2011:95.3	O	1.7	1.2	Yes	No	No	80	Small wader
2011:95.4	O	3.4	3.4	Yes	No	No	110	Small wader
2011:96.1	O	2.5	6.8	No	Slight	No	125	Unidentified
2011:96.2	O	4.7	7.2	Slight	No	No	125	Unidentified
2011:96.3	O	4.3	-	No	No	No	n/a	Unidentified
2011:96.4	O	6.6	6.4	Slight	No	No	130	Grey heron
2011;96.5	O	3.7	3.8	No	No	No	125	Small wader
2011:96.6	O	1.8	2.7	No	No	No	95	Small wader
2011:96.7	O	5.6	6.5	No	No	No	125	Oystercatcher
2011:96.8	O	2.2	2.7	No	No	No	105	Small wader
2011:96.9	O	5.7	5.4	No	No	No	180	Oystercatcher
2011:96.10	O	5.5	6.6	No	No	No	180	Oystercatcher
2011:96.11	O	6.2	6.6	No	No	No	135	Oystercatcher
2011:98.1	O	8.1	6.8	Yes	No	No	170	Grey heron
2011:98.2	O	8.7	8.2	Yes	No	No	115	Grey heron
2011:98.3	O	5.6	7.2	Yes	No	No	130	Grey heron
2011:98.4	O	3.7	4.4	No	No	No	135	Small wader
2011:98.5	O	6.8	7.8	Yes	No	No	144	Grey heron
2011:140.1	O	2.1	5	No	No	No	120	Unidentified
2011:140.2	O	4	7	No	No	No	115	Unidentified
2011:140.3	O	2.7	2.8	No	No	No	130	Small wader
2011:140.4	O	5.8	7.5	Yes	No	No	125	Unidentified
2011:140.5	O	3.4	4.4	No	No	No	110	Small wader
2011:140.6	O	5.7	5.5	No	No	No	105	Oystercatcher
2011:140.7	O	1.2	1.3	No	No	No	115	Small wader
2011:140.8	O	1.8	3.4	No	No	No	105	Small wader
2011:141.1	O	5.5	8.1	No	No	No	115	Unidentified
2011:141.2	O	5.9	7	No	No	No	95	Unidentified
2011:141.3	O	7	6.5	Yes	No	No	115	Grey heron (?)
2011:141.4	O	6.5	5.2	Yes	No	No	110	Unidentified
2011:208.1	O	13	15	No	No	No	165	Common crane

2011:208.2	O	14	15.5	No	No	No	165	Common crane
2011:208.3	O	15.5	17.5	Yes	No	No	170	Common crane
2011:208.4	O	14.5	16	Yes	No	No	145	Common crane

Table 7.6 Metric dimensions from avian footprints recorded at Site O

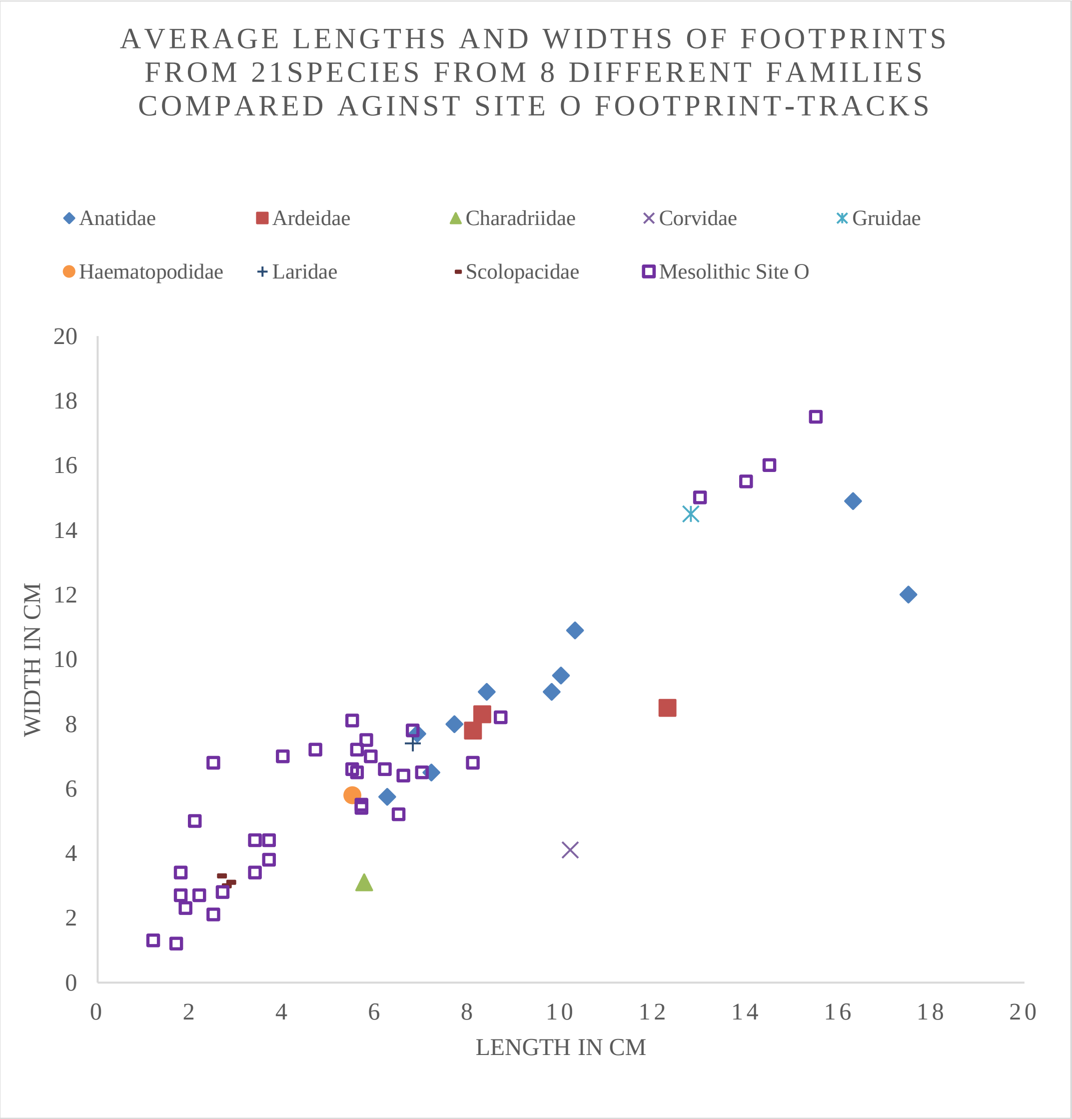


Figure 7.36 Lengths and widths of avian footprint-tracks from Site O, compared against modern avian analogues

Figure 7.37 shows one of the digitised tracings made of avian footprint-tracks at Goldcliff East. These tracings, although simplistic, still captured identifiable features. The digitised tracings indicated that the footprint-tracks had no webbing, and a very wide angle between toes 2 and 4, between 145° and 170°. There was a slight indication of a 1st toe, which is small. The metatarsal pad of these footprints was large, all these features suggest the footprint-tracks were made by a species of crane. Figure 7.38 shows the tracing of footprint-tracks that were likely made by grey heron, these had delicate toes in comparison to Figure 7.37, as well as a smaller metatarsal pad and toe angles ranging between 115° and 170°.

Out of the 36 avian footprint-tracks recorded at Site O, 12 were identified as small waders, likely to belong to the *Scolopacidae* family due to small size, no evidence of webbing and a very slight 1st toe in some footprints. The 2nd and 4th toe of these possible small waders differed in angle size between 75° and 135°. During experimental work dunlin, little stint and turnstone were all found to have toe angles within these parameters (Table 7.2). A further five footprint-tracks were identified as oystercatcher, these prints had very similar metric dimensions and overall appearance to those recorded during experimental work.

There were nine footprints within this area that were unable to be identified as they were indistinct, these were likely to have been made by small waders, due to the lack of webbing evidence. Some of these footprint-tracks had unusual dimensions; footprint-track 2011:96.1 was the most ambiguous, with slight evidence of webbing, no claw marks and a length of 2.5cm and a width of 6.8cm. This print will most likely have been made by a small member of the *Anatidae (*ducks, geese, swan) or *Laridae* (gull) family, however due to the unusual dimensions a species could not be identified using the literature (Brown *et al*. 1987; Bang and Dahlstrom 1974), or the experimental database.

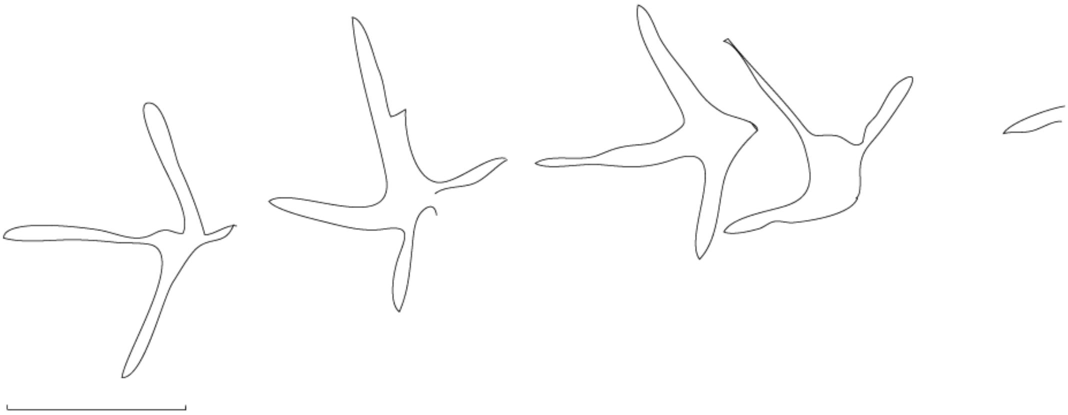


Figure 7.37 Digitised tracing of footprints 2011:208.1 – 208.4, scale bar 10cm

Figure 7.38 Digitised traced footprints 2011:98.1-4, scale bar 10cm

The sites at Goldcliff East provided Mesolithic birds with rich resources and hunting opportunities, as the footprint-track evidence suggests a variety of species were present. Grey heron were found at all the footprint sites discussed, indicating the prevalence of this species, likely year-round. Avian footprint-tracks 5cm or longer were predominantly made by oystercatcher, grey heron and common crane and were the most commonly recorded species at all sites, apart from Site O. This is possibly due to a bias in recovery as the larger birds leave bigger, deeper footprints which are easier to spot in the muddy conditions of the intertidal environment. Site O had a slightly different species composition to the other sites, with 33% of footprint-tracks within this area measuring 3.7cm in length or less, made by small wading birds. The footprint-tracks at Site O were all on the same lamination; the larger avian footprint-tracks were seen first, and then the extent of the smaller bird footprint-tracks was established. This suggests that there are likely far more small bird footprint-tracks on the laminations than those recorded, but they were not necessarily registered in terms of footprint traces.

7.6 Discussion: The effectiveness of experimental work and species interpretation

The utilisation of modern bird footprints and behaviours as a comparison to prehistoric data is an appropriate method for establishing species, however there will be differences seen in the modern bird footprints recorded. Many of the birds used in this experiment were from the WWT, meaning that they were kept in enclosures with their wings clipped. The captive birds suffered from calluses on their feet, generally seen on the central metatarsal pad. These calluses develop on the bird’s feet because they were walking on unnatural surfaces such as concrete, and is due to the birds spending more time being sedentary then they should, as their feeding and breeding needs are met within the enclosures. This sedentary lifestyle can also cause weight gain (M. Roberts, pers comm, 12/01/2014).

Captive birds are not the only creatures to suffer from overeating, wild birds are also affected by human domestication of grass plants and the destruction of food sources such as fish. With fields of crops and grains easily accessible to these animals, species such as geese will often eat far more than they need to when grazing (Coleman & Boag 1987). Other food sources offered to birds, such as feeding ducks bread, provides birds with a continuous source of sustenance which is of low nutritional value and can interrupt the migratory instinct. Birds such as gulls exploit human food waste; white stork are another species that exploit humans, using rubbish dumps to nest in countries such as Spain and Germany, instead of migrating (Flack *et al*. 2016). Due to human activity birds have altered their natural behaviours, enabling them to expend less energy.

Both captive and wild bird footprints may be slightly affected by these changes to their behaviour. Some of the captive birds at the WWT were considered to be overweight or obese (M. Roberts, pers comm, 12/01/2014). This obesity may alter their gait, as there will be excessive weight creating pressure on the pelvic girdle, and may result in shorter strides, with the feet facing inwards at a more prominent angle than those who are a healthy weight. The overweight birds may also create wider footprints due to the extra weight shifting the birds' centre of gravity. The impact of the consumption of nutritionally empty foods on the skeletal and muscular system of birds has not yet been studied fully within ornithology.

7.6.1 The species present within prehistory

At Goldcliff East there is evidence of a variety of bird species exploiting the wetlands (Table 7.7), with the species present indicating a wetland habitat.

Species	**Site C/E**	**Site M**	**Site N**	**Site O**	**Total**	**%**
Common Crane	66	0	0	4	70	**46**
Grey Heron	26	1	10	6	43	**27**
Oystercatcher	4	0	0	5	9	**6**
Small wader	1	2	1	12	16	**10**
White stork	2	0	0	0	2	**1**
Unidentifiable	0	1	5	9	15	**10**
Total	**99**	**4**	**16**	**36**	**155**	**100**

Table 7.7, Mesolithic avian species identification at Goldcliff East, footprint-tracks recorded during Scales (2006) fieldwork, from fieldwork during 2010-2011 and recorded by the author, 2014-2016

7.6.2 Common Crane

The evidence for common crane within both history and prehistory indicates that these birds used to be common breeders in Britain before their localised extinction and recent reintroduction. The footprint-track evidence recorded at Goldcliff East is some of the earliest evidence for common crane in Britain, with only Star Carr and Thatcham containing earlier skeletal evidence (Clark 1954; Harrison 1980b; 1987b; King 1962). The evidence for common crane at Goldcliff East was the first recorded within Holocene Wales. Site C/E exhibited a large amount of common crane footprints, 66 in total, suggesting that this area was walked over on multiple occasions or that there were several individuals present. Of these 66 prints it is possible that seven of them belonged to the larger, extinct European crane species *G.primigenia* or to sarus crane as they were 16cm or longer.

The extent of crane footprints within this relatively small area, spreading across multiple laminations, indicates that common crane were recurrently frequenting this area. Modern common crane return year after year to their breeding site and generally pair for life, their chicks will then also return to a similar area when they too are old enough to breed, and the parents will use the same nest every year if the area is still suitable. In general, these common crane nests will be large mounds of wetland vegetation built in or near fresh water in undisturbed marshland (Figure 7.39; Månsson *et al.* 2013). Common crane are territorial, so although there are a large number of footprint-tracks, it is fairly unlikely that there were a large number of crane within the small area of Goldcliff East. Modern common crane will defend a territory between 2ha and 500ha depending on the resources available, meaning that there may or may not have been other nesting cranes in this area of the estuary, though slight territory overlap is not uncommon (Månsson *et al*.2013). Many of the footprint-tracks exhibited excellent levels of preservation; however, there was not a clear trail to establish the gait of these birds. Within experimental work the common crane pair observed were noted to weave in and out of one another’s paths and due to their large pace and stride this confused the footprint trail; if there was more than one bird present in this area, or if the bird walked over this area several times this may explain the lack of a clear trail (Figure 7.40). There is also the possibility that the lack of a clear crane trail, as well as the chaotic patters of their feet may reflect that these cranes were undertaking the ‘crane dance’ which is believed to be a behaviour they exhibit when increasing their social bonds or to diffuse tension (Russell and McGowan 2002), performed before mating or hunting, among other activities. If the Goldcliff East birds were doing the crane dance, then they may have been dancing on drying mudflats away from wetter areas they would hunt in. When rearing their chicks, modern common crane feed predominately on caterpillars (*Lepidoptera*), beetles (*Diptera*), grasshoppers (*Saltatoria*) and small mammals (Nowald and Fleckstein 2001). They use wetlands to nest, and hunt in wet forests (*Leito et al.*

2005), so the footprints may represent a family dancing and bonding on the drying mudflats, slightly away from the nesting area.

Figure 7.39 Remains of a modern common crane nest (image courtesy of Damon Bridge, RSPB)

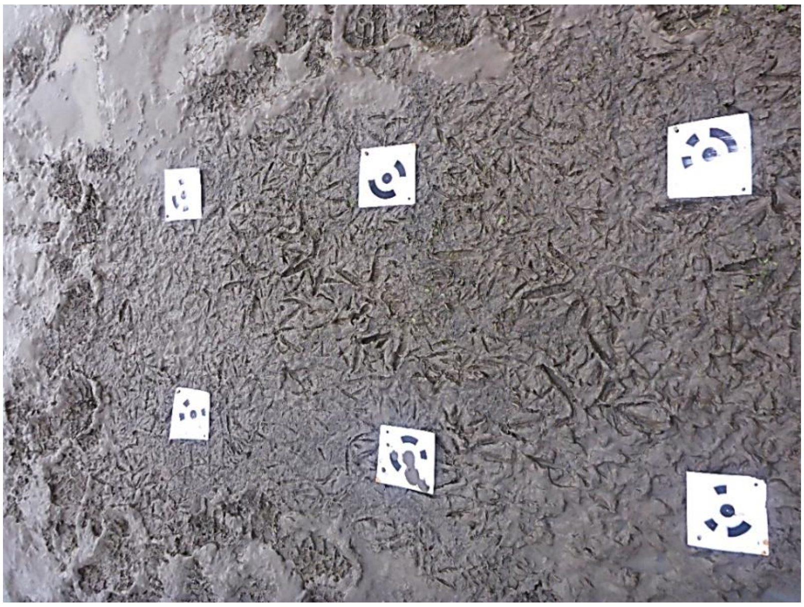


Figure 7.40 An area trampled by modern common crane, common shelduck, mallard and greylag goose at the Wildfowl and Wetlands Trust, Slimbridge

Common crane currently nest during May to July and then rear their young during the warm summer months (Hume 2014), therefore the presence of common crane footprint-tracks over multiple laminations suggests the birds were returning year after year to a favoured nesting site. The common crane at Goldcliff East created footprint-tracks that had a complete length between 8cm and 22cm. This 14cm difference in length may be indicative of two separate crane species. It may also be due to chicks exploring an area with their parents while not fully grown, or it may be due to the substrates walked upon.

There have not been any prehistoric crane skeletal remains recorded in this area, however there have been a limited amount of avian skeletal remains discovered, which may indicate avian remains were not preserved well within this area (Scales 2007b, p 164, Table 13.2). The archaeological assemblage from the Severn Estuary is notably sparse in avian skeletal remains compared to mammals. Although footprint-track evidence indicates that humans were sharing the landscape with crane during the summer months, they may not have been hunting them. Other areas, including Roman Caerleon, Newport (Hamilton-Dyer 1993) and Iron Age Glastonbury Lake Village (Harrison 1987a) do have remains from this species and are relatively near to Goldcliff East, though they are much later in date. This lack of skeletal remains does not indicate a lack of birds within the area; the footprint-tracks indicate an area where wildfowl were clearly present, it is likely that footprints over multiple laminations indicate repeat visits to exploit the nesting environment to breed and raise their young during the summer months (Chapter 8).

7.6.3 White stork

The appearance of possible juvenile white stork footprints at Goldcliff East was evidence of the presence of this species in Britain during the Mesolithic. Possible skeletal evidence for Mesolithic white stork was found at Star Carr, however it was a small fragment and argued to be from common crane instead (Clark 1954; Harrison 1987b). The two footprint-tracks at Goldcliff may be evidence that during the Mesolithic period this species was present in Britain as far north as the Gwent Levels, Wales. Further skeletal evidence has been found of white stork during different periods indicating that on occasion this species was frequenting Great Britain (Chapter 2, Table 2.7).

The white stork footprints were recorded at Site C/E, near to where humans and other birds such as common crane, grey heron and oystercatcher frequented. These laminations were later in date than those from Site N, M and O and may have indicated that they were made when the climate was mildly warmer or the habitat more favourable. Both white stork and common crane require shallow water with access to grassland as their habitats.

The white stork footprints are further archaeological evidence for this species in Britain. The small size of the prints may indicate that like the common crane, this species was utilising the coasts of Britain to hatch and rear chicks. The bird that made the footprint-tracks did not have the large metric dimensions of a full grown white stork. Stork breed in wetland environments, with nesting currently occurring during April to June (Hume 2014), so the presence of a white stork during spring or summer is not unlikely.

7.6.4 Grey heron

When grey heron nest they favour tall trees, 12m or more, ideally alder (*Alnus glutinosa*), oak (*Quercus robur*) and willow (*Salix alba*), and as near to a water source or reed swamp as possible to enable the incubation of eggs whilst being able to easily access fish (Cheshire and Wirral Ornithological Society 2008). They are social nesters, nesting in large heronries, though they will nest in reed beds if this area is more suitable. Grey heron are very early nesters, laying their first eggs as early as January, with all eggs laid and chicks fledged by May (Hume 2014, p 97). They are year-round residents of the Severn Estuary and can usually be seen walking across the intertidal zone, hunting, and waiting for the water to retreat further.

There was one set of unidentifiable footprint-tracks (2015:16.1) from Site N that looked like they were made by grey heron, but were far smaller than the expected dimensions. They measured 4cm long and 6cm wide, whereas adult grey heron footprints from the experiment measured 8.3cm in length and width. The toe angle between the 2nd and 4th toe of footprint-track 2015:16.1 was 130°; grey heron have a toe angle between 140° and 180°, though these angles change depending on the sediment walked upon. The morphology of these small footprint-tracks leads to the conclusion that these may have been made by grey heron chicks, though this cannot currently be proven due to lack of metric and morphological data about grey heron foot growth.

Grey heron are large predatory birds, and are easily seen across a landscape. There was a human footprint-trail as well as a singular human footprint located near the grey heron prints at Site N, on the same laminations. This may indicate that humans were heading to similar areas as the grey heron to fish.

The contrast in bird species, specifically heron and crane, between Site N and Site C/E is rather striking given the contrasting quality of human footprint-tracks between the same areas

(Chapter 6). This may possibly be due to an environmental contrast. Herons tend to stand at the very edge of shallow water as this is their main hunting environment. Common crane use the wetland environment as a safe habitat to nest and raise their young, however when they have chicks they do a lot of foraging in wet wooded areas (*Leito et al. 2005),* so their footprints may be better preserved due to the mud being drier away from the water's edge. A future study of the foraminifera from the Site C/E and Site N footprint-track sediments may assist in determining the environmental reason behind these contrasting site preferences of common crane and grey heron.

7.6.5 Oystercatcher

Oystercatcher are a medium sized wading bird that live year-round in Britain. In the winter months they can be seen on tidal estuaries and rocky shorelines, during the summer months they spend more of their time inland, rearing their young along linear waterways (Simm 2016). They will generally be seen in small groups eating at the water's edge. At Goldcliff East, Site C/E and O exhibited evidence of this species. The oystercatchers' preferred food is cockles and they are excellent at finding this food type. Oystercatchers may have been indicators of cockle beds to Mesolithic hunter-gatherers, though at Goldcliff East there have not been any shell middens recorded from human activity. There is however a distinctive natural cockle horizon which occurs within the Mesolithic sequence, the cockle bed is present within *c.*50m of Site I (Allen and Haslett 2002).

7.6.6 Other Coastal Birds

It is fairly difficult to establish the difference between certain species' footprints; small waders such as dunlin, turnstone and little stint for example are incredibly similar in size and appearance. Geomorphemetrics was initially utilised in an attempt to establish any obvious differences, however the variation in the appearance of features in a single individuals' footprints indicated that this technique would be ineffective in this instance. A larger avian footprint database, with more bird species, and multiple sediment types would provide a dataset that could then be accurately analysed with geomorphmetrics. The current database contains 50 footprints, from three species of small wader, all from the *Scolopacidae* family, this is therefore a relatively small data source.

In situations where there are no clear identifying features present a trail needs to be observed, as species express different walking behaviours. This does not always help in archaeological situations, where finding complete bird trails is unusual; in these instances smaller bird footprints may only be identifiable as small waders instead of the explicit species. This does not devalue these footprints; the presence of small waders indicates the habitat of the area. The *Scolopacidae* family, for instance, indicates the proximity of surface water, which this family require for feeding.

The archaeological avian skeletal record for small waders is relatively sparse. From the Ipswichian period at Bacon Hole and Minchin Hole, Gower, the remains of dunlin, golden plover and turnstone were recorded (Harrison 1987a). Within the Holocene period, remains of golden plover, grey plover and turnstone were recorded at Port Eyon Cave, Gower (Harrison 1987a). Plovers are part of the *Charadriidae* family, with feet about twice as long as those from the *Scolopacidae* family. The presence of turnstone within the Holocene archaeological record and also the metric and morphological similarities between the prehistoric footprints and the experimental data, suggests that turnstones may have made the small wader footprints at Goldcliff. Turnstones are winter migrants, so their appearance would suggest they were in the area between October and March. Though it is possible that other small wader species made some of the footprints.

7.6.7 Unidentifiable

The experimental studies on modern bird footprints were relatively successful in identifying the species of prehistoric birds, however some footprints could not be assigned a species due to their formation, lack of detail when recording, or the variability of footprint preservation. Others are currently unidentifiable as they do not accurately match with both the morphology and metric size of the modern coastal birds used within this study, nor are their features similar to any of those found in the footprint-track literature. Avian footprints have been understudied in both archaeology and ornithology, meaning that there is a small amount of literature on bird footprints available, often with differing identification specifications (Brown *et al*. 1987; Bang and Dahlstrom 1974). When literature is available there is generally no indication of the sediment the footprint was created on or the kind of behaviour (feeding, territorial displays and hunting) which the animal was engaging in when the footprints were recorded, even though these behaviours will affect the gait of the bird.

An extensive study of the appearance and formation of the footprints of birds that frequent Britain would enable more of these unidentified prehistoric footprints to be assigned a species. A rigorous footprint study may also help to identify very small differences in bird species, such as small waders, which would then result in a comprehensive understanding of the environment these prehistoric birds were living in.

7.7 The importance of the archaeological data to species reintroduction

Common crane are an important bird, ingrained in our history, with places named in reference to them. They were also a status symbol for the wealthy, however very few people living in Britain presently have seen a wild crane as they became locally extinct. Due to wetland development the common crane and their habitats have suffered, possibly as early as the Roman period. Archaeological and historical evidence indicates that common crane were locally extinct throughout most of Britain by the Medieval period (Rackham 1986). The archaeological evidence for common crane, such as the footprint-tracks from Goldcliff East and Formby Point, led to a breeding programme at the Wildfowl and Wetlands Trust, Slimbridge (Bridge 2015), to re-introduce common crane to Britain. This resulted in the eventual release of crane on the Somerset levels once they reached adulthood. In August 2016 a pair of crane raised a fully-fledged chick on the Gwent Levels, Wales (Figure 7.41). This is the first common crane to breed in Wales for at least 500 years, though it is very possible that there might not have been a breeding pair in Wales since the Roman period (Harrison 1987a; Racham 1986). This success indicates the need for conservationists to be aware of the value of archaeology, which can lend weight to the argument for the reintroduction of many extinct species to a variety of different habitats.

Prehistoric avian footprint-tracks can be utilised in a similar way to skeletal remains for the argument of reintroduction. Often habitats such as the wetlands, which would have been teeming with wildfowl, have a very limited skeletal record. The footprint-tracks recorded at Goldcliff East indicate that common crane were once a flourishing species in Wales, making their reintroduction in England extremely positive. The Eurasian beaver was reintroduced to Scotland successfully and has now been reintroduced in several places of the UK, including Devon. This reintroduction was a result of the argument that the prehistoric and historic record showed them to be natives (Coles 2006). There have been tentative suggestions that white stork should be reintroduced into Britain as there has been great success in their introduction in Europe (Carter *et al*. 2008). The white stork footprint evidence from the Mesolithic period, as well as the skeletal remains from across Britain from multiple time periods (Chapter 2, Table 2.7), suggest that they may not have been migrating to Britain on mass, but that Britain is a place that some of these birds used to frequent throughout prehistory and history. That being the case there could be a firm argument made for the reintroduction of this species. Not only are we able to use archaeological footprint-tracks to understand the past, but they can become an argument to shape a species’ future.

Figure 7.41 Female crane 'Gibbles', the first common crane to lay eggs in Wales in at least 500 years, image from the Great Crane Project

7.8 Conclusion

Avian footprint-tracks are often under-reported or under-analysed when recorded at archaeological sites, however they can assist in understanding the palaeoenvironment of an area. The footprint-tracks recorded at Goldcliff East demonstrate a variety of species were present, some of which would have been year-round residents, like oystercatcher and grey heron, and others would have been migrants, such as common crane and white stork. The skeletal data at Goldcliff is lacking in avian evidence (Scales 2007b, p 164, Table 13.2), however the footprints indicate that a variety of birds were in this area. The lack of skeletal remains may indicate that they were either not being hunted or that the skeletal remains of the birds were not surviving in this wet environment.

Avian footprints would benefit from further study, both in archaeology and in ornithology, to create a database of different species footprints and any identifying factors. A greater understanding of the differences between species, especially the smaller species, would be beneficial to further archaeological footprint work as well as to conservation research.

Chapter 8

Sediment composition of footprint-track Site C/E, M, N, R and S

8.1 Introduction

The Severn Estuary has a complex tidal regime, which influences estuarine sediment accumulation from autochthonous sources (marsh plants, plant roots, plant litter and debris) and allochthonous sources (rivers, sea bed, cliffs) (Figure 8.1; Dark and Allen 2005). Holocene estuarine sediments are made up of sequences of transgressive silts, predominantly from a salt marsh environment, layered between regressive peats, with sands and gravel (Allen 2001b).

There are three main ways in which particle size analysis is important to this particular body of work. The first is the characterisation of the sediment, to establish an accurate and consistent description of the deposit containing the evidence, as field descriptions are often not precise enough. The second aspect is to establish the environment of deposition, and the third is the seasonality of deposition of particular sedimentary units.

Research by Allen (2004; Allen and Dark 2007), suggests that the textual banding in transgressive silts can provide an insight into the seasonality of sediment deposition. Laminated silt bands at Goldcliff and other sites across the Severn Estuary are made up of bands of coarse-grained sediment, which alternates with a much finer-grained sediment; these can range from submillimetres to millimetres in thickness. Allen and Duffy (1998) studied present day seasonal sediment deposition over a two-year period and found that coarse-grained sandy sediment with a low clay composition was deposited on saltmarsh and mudflats during February and March, whereas during August to late October the sediment deposited was found to be more clayey and less sandy. This sediment deposition was suggested to have been caused by seasonal changes in sea temperature, seasonal changes in pollen types found within the air and held in suspension in water (Figure 8.1), water viscosity and the wind-wave climate of the environment (Allen 2004; Dark and Allen 2005).

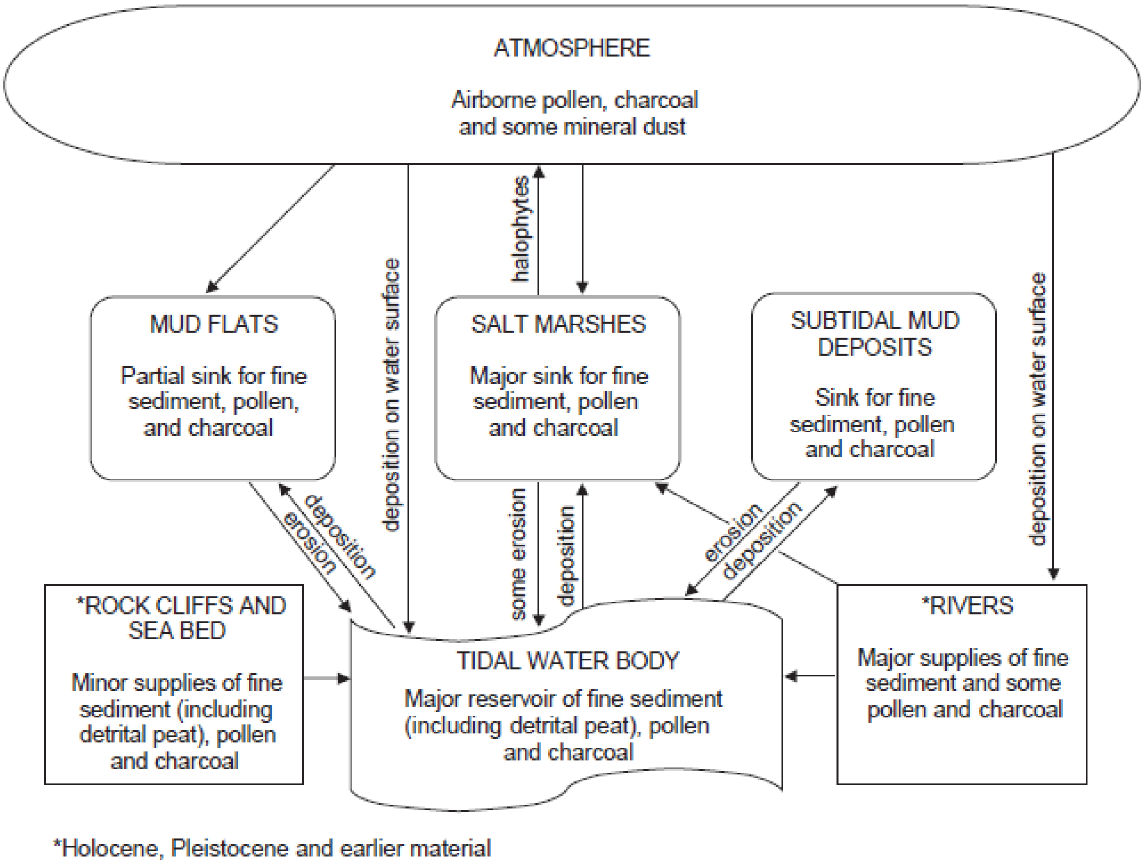


Figure 8.1 The modern Severn Estuary as a system (Dark and Allen 2005, Figure 3)

The banded laminations on the Severn Estuary have preserved the footprint-tracks of humans, birds and mammals. To enable preservation, the footprints would have been covered rapidly by sediment, as there is no evidence of post-formational modification (Allen 2004). The particle size of sediments recorded at Goldcliff East during the fieldwork period of 2014-2017 were investigated; differences in particle size can assist in understanding the season in which the footprints were made by observing textual differences between sediment and underlying and overlying banded laminations (Figure 8.2; Figure 3.6). It should however be emphasised that the seasonality of a footprint can only be determined if the actual footprint surfaces is identifiable, rather than overtraces/undertraces. In the case of this study, the actual footprints of multiple birds were identifiable, however there were not any clear footprints made by humans. The overtraces/undertraces of the human footprints were still recorded to see if there were any general trends in particle sizes at different footprint areas.

Figure 8.2 Example of banded laminations in section, shown in a fallen block of sediment. Scale 1cm divisions

8.2 Samples

A total of 27 sediment samples were collected during 2014-2017. Of these, 15 were from Site C/E, four were from Site M, four from Site N, two were from Site R and two were from Site S (Chapter 6, Figure 6.2). Of the 15 samples collected from Site C/E, ten were recorded from the lamination the footprint-track was found upon, and the other five were taken from the lamination directly under the footprint-track. The samples were taken from both human and avian footprint-tracks. From Site M two samples were recorded from the upper lamination, though these were from overtraces/undertraces, and a further two were recorded from the lamination below, these were from human footprint-tracks. Site N was also investigated; two samples were collected from the footprint-track surface and two from the laminations underneath, one of the footprint-tracks was human, the other was avian. Sediments from one human footprint-track were collected in Site R, from the surface where overtraces were visible, and from the underlying lamination. A sample from Site S was recorded from one footprint-track, the only one in this area where the morphological details of the footprint were clear; this was collected from the footprint-track surface and the underlying lamination.

8.3 Analytical methods

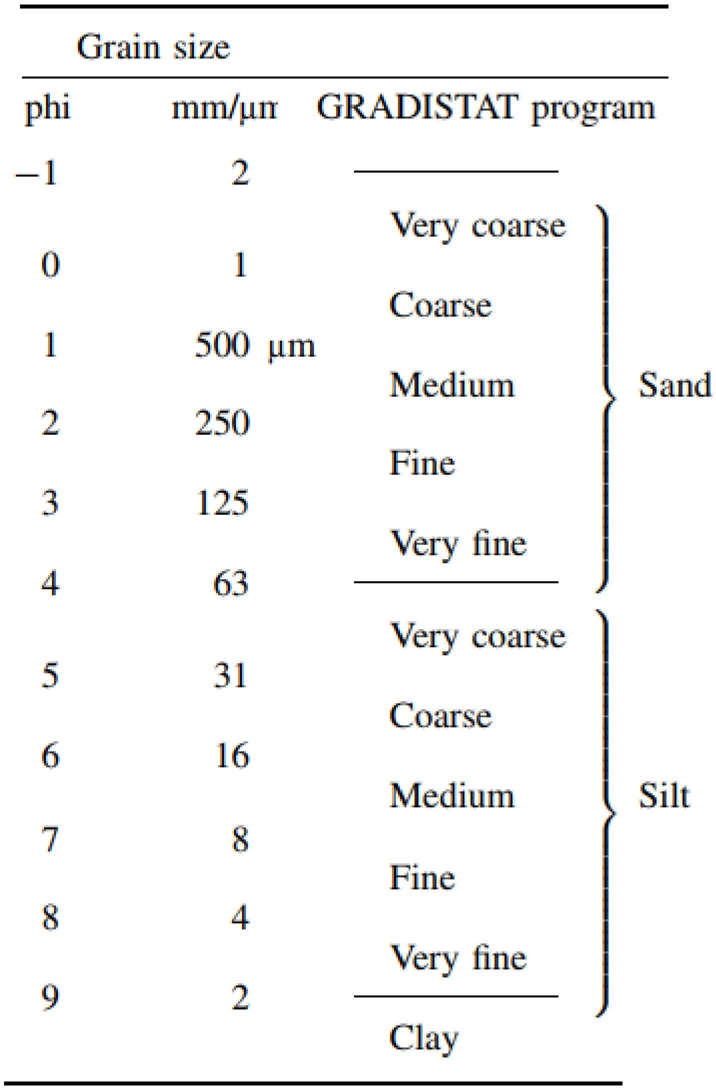
The samples were all analysed using a Malvern Mastersizer 3000 laser granulometry machine. This machine uses laser diffraction to measure particle sizes, ranging between 10nm and 2mm (Malvern 2017). The software used alongside the machine was the Mastersizer 3000 software, a relatively simple piece of software that guides the user step by step through the process of laser granulometry. This software provides instant feedback on the results and allows particle size to be viewed immediately as well as the percentage of sand, silt and clay in the sample.

Each sediment sample was prepared in the same way. 5g of the sample was measured out and rehydrated with filtered water. The sample was spread thinly onto a plastic palette. Using a small metal scoop, a random sample was taken from the sediment, this was approximately less than 1g. This was then placed onto a further plastic palate and mixed with three pipette drops of calgon, a dispersing agent, which was used to separate the sediment by mixing with a small plastic plunger. The sample was then added to the laser granulometry machine when prompted by the software. This technique was repeated five times to allow for an average from the sample to be achieved. The software ran each of the five samples five times, with a further sixth result as the calculation of the averages. This allowed for 25 results, plus five averages, from one sediment sample.

Once the samples had been run, an average for all the 25 results from one sample was calculated and a report was generated providing the percentages of sediment that were clay, silt and sand. This was then plotted onto Blott and Pye’s (2012) particle size distribution software to create a sand, silt and clay trigon diagram for comparison of the sediments.

8.3.1 Particle size range

This study used the GRADISTAT statistics package to analyse the data (Blott and Pye 2001). Figure 8.3 shows the size of the particles and their classification within this program, this classification is the same as that given by Friedman and Sanders (1978), but is different to the earlier work by Udden (1914) and Wentworth (1922) where part of the clay classification falls in the same size range as fine silt in Friedman and Sanders (1978) classification. The GRADISTAT statistic package was used to create trigons to accurately represent the data from the collected samples.



Grain size			
phi	mm/µm	GRADISTAT program	
−1	2		
		Very coarse	Sand
0	1		
		Coarse	
1	500 µm		
		Medium	
2	250		
		Fine	
3	125		
		Very fine	
4	63		
		Very coarse	Silt
5	31		
		Coarse	
6	16		
		Medium	
7	8		
		Fine	
8	4		
		Very fine	
9	2		
		Clay	

Figure 8.3 Particle size range utilised by the GRADISTAT Grain size statistics programme (Blott and Pye 2001)

8.4 Results

The results for sediment composition are presented within the different sites in which they were found, with percentages of clay, silt and sand all included. This information is also conveyed on sand, silt and clay trigons to understand the sediment texture and composition of each sample.

8.4.1 Site C/E

The bird footprint-tracks recorded at Site C/E were predominantly footprints rather than overtraces/undertraces. This made obtaining particle sizes for this area most accurate as sediments could be taken from the very lamination the footprints were made upon, as well as in some cases the underlying sediments to compare the textural banding (Table 8.1). The human footprint-tracks were less well preserved and were likely overtraces/undertraces, though one footprint-track (2015:116; Figure 6.11) had the appearance of a true footprint, or was an undertrace that was possibly a few millimetres lower than the actual footprint given its detailed morphology. The sediment collected from the human footprint-tracks are plotted on one sand, silt and clay trigon and the avian footprint sediment are plotted on the other. Figure 8.4 shows the sediment composition of the laminations walked upon by humans. The composition of clay within the sediments ranged from 2.29% to 24.02%, silt composition ranged from 60.98% to 80.96%, and sand composition ranged from 15% to 33.02%, indicating predominantly silt sediments. Footprint 2016:116 comprised of the only sediment to be classified as slightly sandy clayey silt. Two of the footprint-tracks recorded from the lamination surface upon which the footprint was made, 2015:89 and 2015:106, were slightly sandy slightly clayey silt. The sediment from the surface of footprint 2015:129 was a very slightly clayey slightly sandy silt, whilst the underlying lamination for this print was composed of very slightly clayey sandy silt. Although there is not a huge difference in sediment composition, it is evident that all the samples recorded from the laminations where the footprint-tracks were visible were made of a very fine sediment, with a higher silt and clay composition than the lamination under the footprint-tracks, which was a slightly clayey sandy silt. This difference is small but may indicate the footprints were being made during a time when the sediment being walked on had a smaller particle size.

Sample number	**Clay %**	**Silt %**	**Very fine sand %**	**Fine sand %**	**Medium sand %**	**Coarse sand %**	**Very coarse sand %**	**Total sand %**
2015:87 avian footprint surface	3.79	80.13	7.83	6.88	1.37	0	0	16.08
2015:87 lamination under avian footprint	20.2	75.77	2.73	1.22	0	0.07	0.02	4.04
2015:89 avian footprint surface	7.03	75.74	9.72	6.3	1.19	0.02	0	17.23
2015:106 human footprint-track surface	8.38	75.72	8.63	5.7	1.15	0.42	0	15.9
2015:113 avian footprint surface	2.89	53.18	19.21	15.88	7.62	1.22	0	43.93
2015:113 lamination under avian footprint	3.93	62.16	19.84	10.69	2.66	0.69	0.02	33.91
2015:116 human footprint surface	24.02	60.98	8.27	5.36	1.33	0.05	0	15
2015:129 human footprint-track surface	2.66	80.96	12.66	2.15	0.01	0.69	0.72	16.23

2015:129 lamination under human footprint-track	2.29	64.69	22.28	10.43	0.31	0	0	33.02
2015:129 heron footprint surface	22.38	51.87	10.44	7.92	1.92	3.42	1.64	25.35
2015:129 lamination under heron footprint	11.17	62.57	14.69	10.88	0.68	0	0	26.26
2015:130 lamination under footprint surface	2.97	49.56	23.13	21.27	2.98	0.1	0	47.47
2015:130 avian footprint surface	26.05	54.3	10.7	7.69	1.13	0.13	0	19.65
2016:70 avian footprint surface	40.03	54.35	2.19	2.5	0.52	0.3	0.09	5.59
2016:70 lamination under avian footprint surface	16.6	53.88	10.3	17.71	1.51	0	0	29.52

Table 8.1 Percentage of clay, silt and sand from the sediment samples from Site C/E

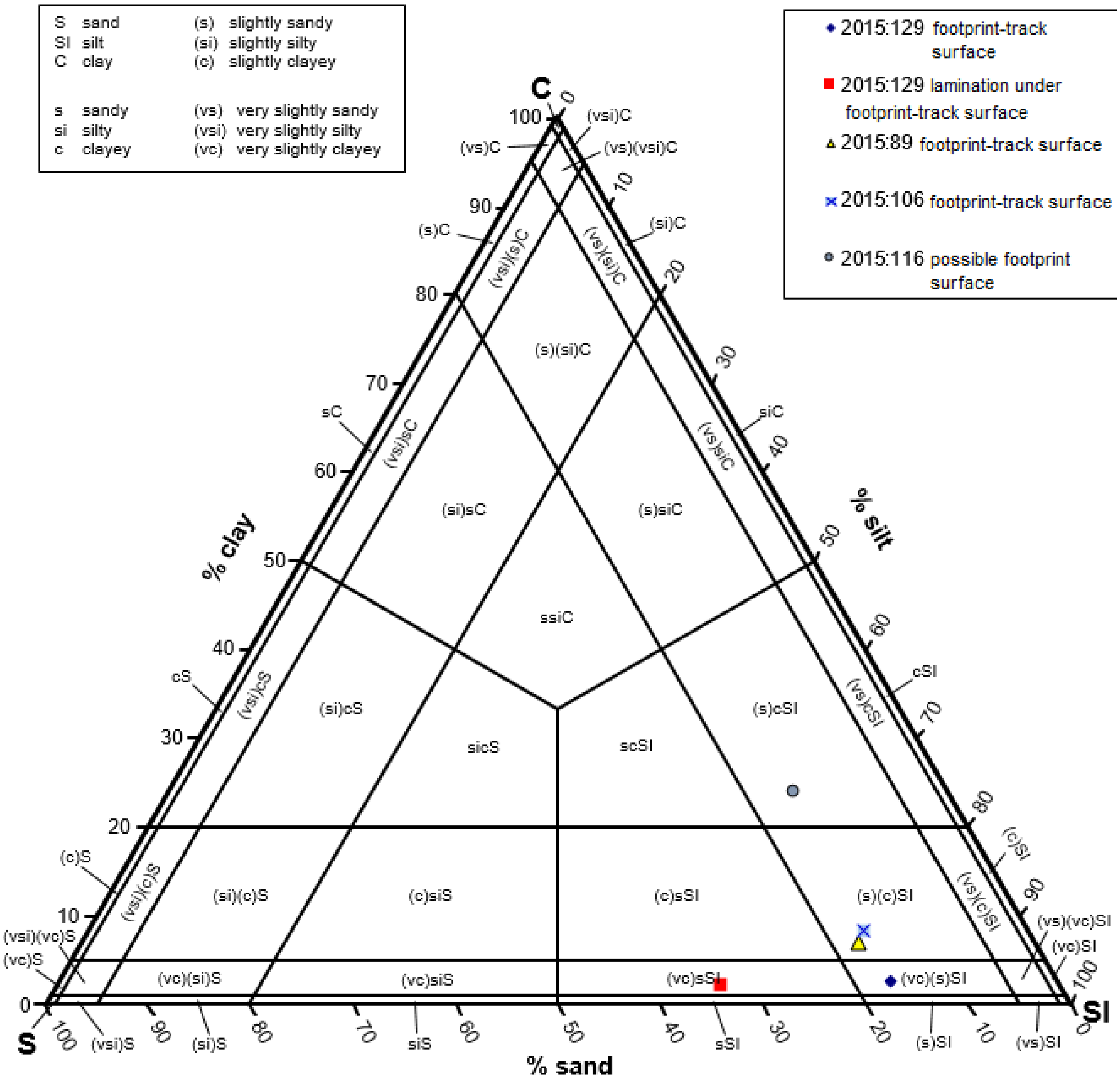


Figure 8.4 SCC Trigon of sediment particle size from the human footprint-tracks from Site C/E. All human footprint-tracks within this area were overtraces/undertraces with the exception of 2015:116 which may have been the footprint

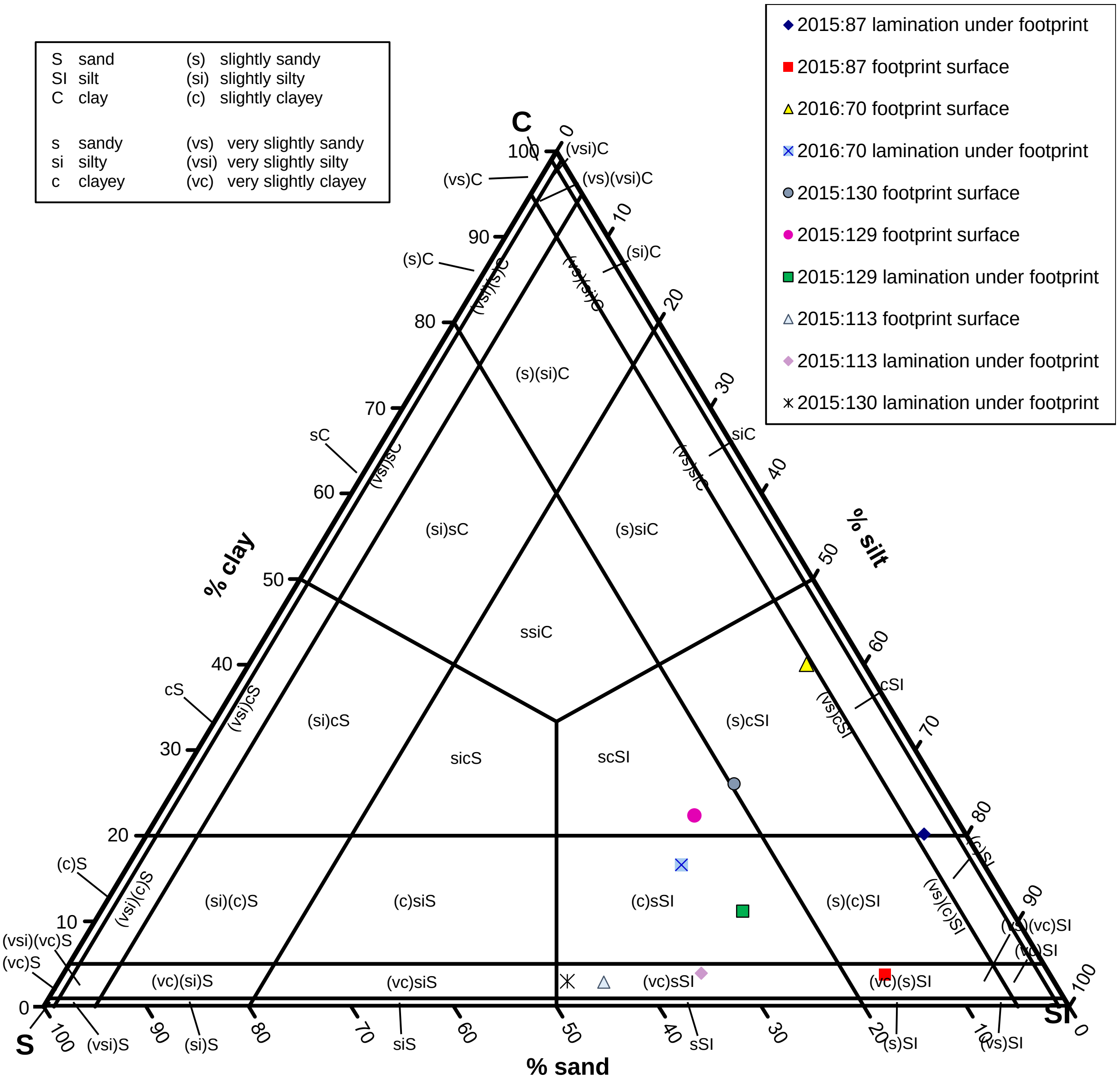


Figure 8.5 SCC Trigon of sediment particle size from avian footprints from Site C/E. 2015:87, 2016:70 and 2015:130 were common crane, 2015:129 was an oystercatcher and 2015:113 was a small wader

The avian footprint-tracks displayed in the SCC trigon in Figure 8.5 demonstrate more clearly than Figure 8.4 the difference in sediment composition between the laminations where the footprints were made, and the laminations below. This is due to the preservation of the actual footprints of the birds, as opposed to the undertraces/overtraces of human footprint-tracks. The clay composition of the laminations ranged from 2.89% to 40.03%, the silt composition ranged from 49.56% to 80.13%, and sand composition ranged from 4.4% to 47.47%. Two of the samples recorded from the surface of footprint 2016:70 and 2015:130 were made on slightly sandy clayey silt, though the surface of 2016:70 is on the border between a very slightly sandy and slightly sandy particle size. Sediment collected from the footprint surface of 2015:129 was made of sandy clayey silt, and sediments from under footprint 2015:129 and 2016:70 were made of a slightly clayey sandy silt. Sediment collected from under footprint 2015:130 had a much sandier composition than all other samples, being composed of very slightly clay sandy silt, this sample consisted of 47.47% sand sized particles. There were a further two samples that fell in the very slightly clayey sandy silt composition, from the surface of and below footprint 2015:113. Sediment from the surface of 2015:87 had a very slightly clayey slightly sandy composition, whilst the lamination under this footprint had a slightly clayey silt composition.

The difference between the sediment composition of the footprint lamination and underlying lamination of 2016:70 is most evident, with sand making up a far larger percentage in the underlying lamination (29.52%) as opposed to the footprint surface only containing 5.59% (Figure 8.6). The sediment recorded from 2015:130 also has some differences between the sediment from the footprint-track surface and that underlying it. The sediment compositions of 2015:113 were very similar for the footprint surface and underlying lamination, both were made on a very slightly clayey lamination, though unlike the other samples the footprint was made on a sandier sediment than the underlying layer. 2015:87 was the only sample where the underlying lamination contained a smaller particle size, only 4.04% of the sample was composed of sand. The sample from the actual footprint still had a relatively silty composition, with 16.08% sand sized particles. This was far siltier than all others, 80.13% of the sample was composed of silt sized particles.

The sediment samples from Site C/E demonstrate the sediments were all silty, but the amount of clay or sand in the composition varied. In general, those taken from the surface of the footprints had a smaller particle size, of the nine samples collected from the footprint surface there was only one, 2015:113, that fell within the very slightly clayey sandy sediment, all other sediments recorded from the footprint surface had smaller particle sizes. This trend was not seen in the sediment excavated from under the lamination, three of the six samples from under the footprints were comprised of very slightly clay sandy sediment, with a further two comprised of slightly clay sandy sediment, indicating that the laminations under the footprints generally have a larger particle size. The lamination under footprint 2015:87 had a smaller particle size than the footprint surface, indicating this footprint was likely made in different circumstances to the others.

Figure 8.6 Common crane footprints (2016:70) from Site C/E made on a (very slightly) clayey silt lamination. Scale in mm

8.4.2 Site M

The samples collected from Site M were more problematic than Site C/E due to the differences in footprint preservation. The footprint-tracks recorded on Site M were all poorly preserved undertraces/overtraces which meant that the footprint itself was not evident, and the exact lamination that was walked upon could not be identified with confidence. Samples were collected in the same way as Site C/E, from the laminated surface where the footprint-tracks could be observed, and from the underlying lamination, this provides an idea as to the types of sediment that footprints remain preserved in, even if the exact lamination layer cannot be established.

Although the sampling and interpretation of Site M is problematic, the sediment composition results are not too different from Site C/E, where the footprint surface was composed of smaller particle sizes than the underlying layer (Table 8.2). The footprint overtraces/undertraces where sediment was removed, 2014:308 and 2014:310, were only composed of 7.4% and 10.32% of sand, whereas the underlying laminations had a slightly larger sand percentage of 18.81% and 20.92% (Figure 8.7). The compositions of these were similar to those recorded at Site C/E. Very coarse sand particles were not largely represented within the sample, the composition was mainly fine sand.

Sample number	**Clay %**	**Silt %**	**Very fine sand %**	**Fine sand %**	**Medium sand %**	**Coarse sand %**	**Very coarse sand %**	**Total sand %**
2014:308 footprint-track surface	19.74	72.86	4.65	1.41	0.45	0.78	0.11	7.4
2014:308 lamination under footprint-track	14.33	66.86	13.88	4.76	0.16	0.1	0	18.81
2014:310 footprint-track surface	24.24	65.44	8.19	2.08	0.4	0.01	0	10.32
2014:310 lamination under footprint-track	17.22	61.86	15.89	4.98	0.05	0	0	20.92

Table 8.2 Percentages of clay, silt and sand from sediments recorded from human footprint-tracks at Site M

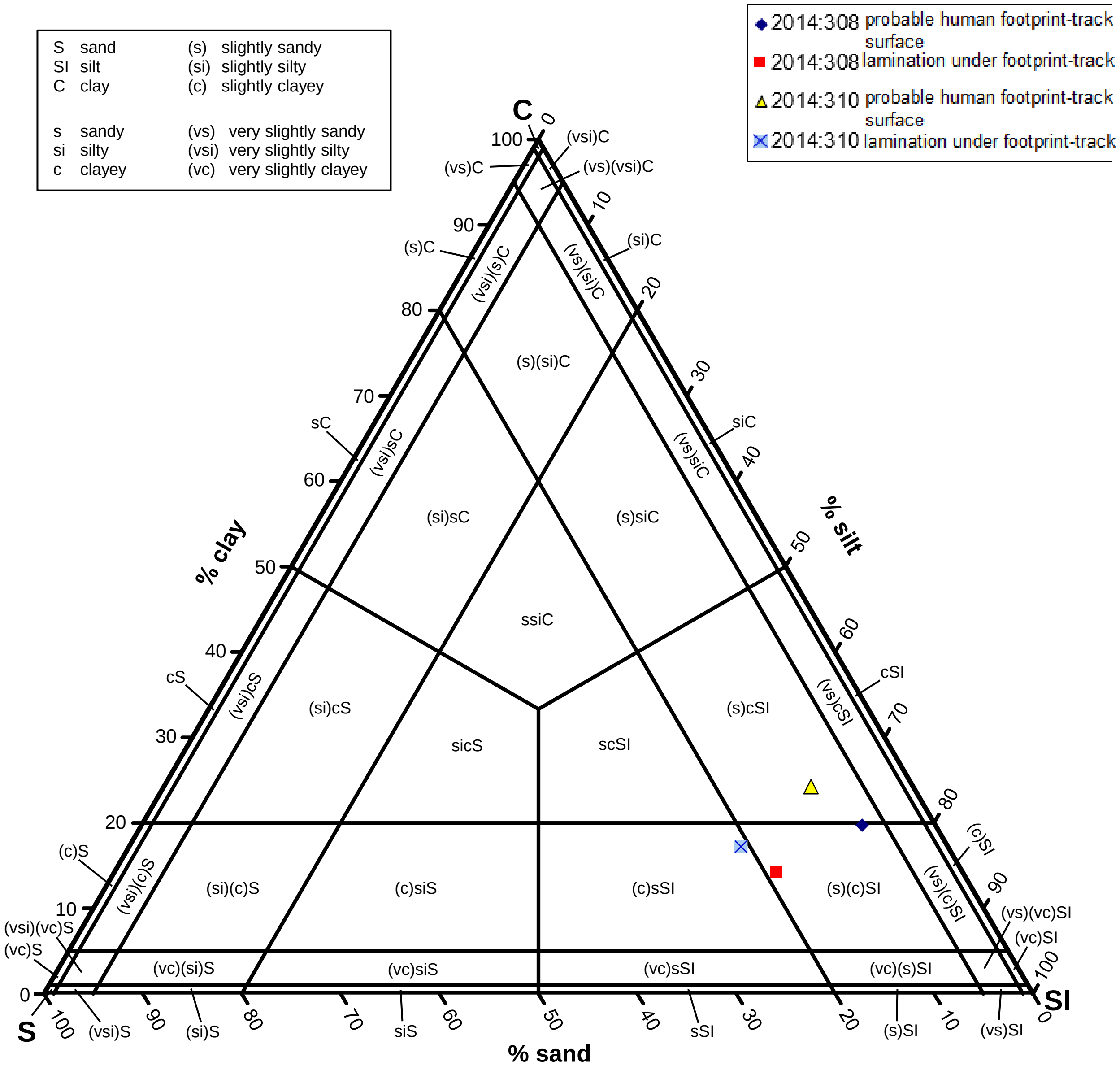


Figure 8.7 SCC trigon showing sediment from probable human footprint-tracks at Site M

8.4.3 Site N

The samples from Site N were collected from the same laminations; a human footprint-track trail containing footprints 2015:17, 2015:18 and 2015:20, and multiple bird footprints (2015:16 and 2015:19). The human footprint-tracks were overtraces/undertraces, whereas avian footprint 2015:16 was possibly an actual footprint. Samples were gathered from the top laminated surface where the footprint-tracks were exposed, as well as the lamination underneath it.

Unlike Site C/E and Site M, the sediment from Site N indicated a larger particle size within the walked-upon lamination, whereas the underlying laminatin had a smaller particle size (Table 8.3). The particle sizes of the underlying footprint-track laminations at Site N ranged from slightly sandy clay silt to slightly sandy slightly clayey silt (Figure 8.8). The slightly clayey sandy silt composition of the footprint surface at Site N was not a sediment composition seen in any of the other footprint sites, indicating these prints were made at a different time, during different conditions, perhaps from a different facet of the foreshore environment or at a time of the year of higher energy conditions.

Sample number	**Clay %**	**Silt %**	**Very fine sand %**	**Fine sand %**	**Medium sand %**	**Coarse sand %**	**Very coarse sand %**	**Total sand %**
2015:16 footprint surface	6.73	62.67	19.85	8.98	1.68	0,9	0	30.6
2015:16 lamination under footprint	14.9	70.84	7.94	4.28	1.26	0.38	0.27	14.13
2015:18 footprint-track surface	12.25	65.28	13.53	7.12	0.67	0.5	0.48	22.3
2015:18 lamination under footprint-track	21.98	66.66	6.61	3.92	0.42	0.32	0.09	11.35

Table 8.3 Percentages of clay, silt and sand from sediments recorded from Site N

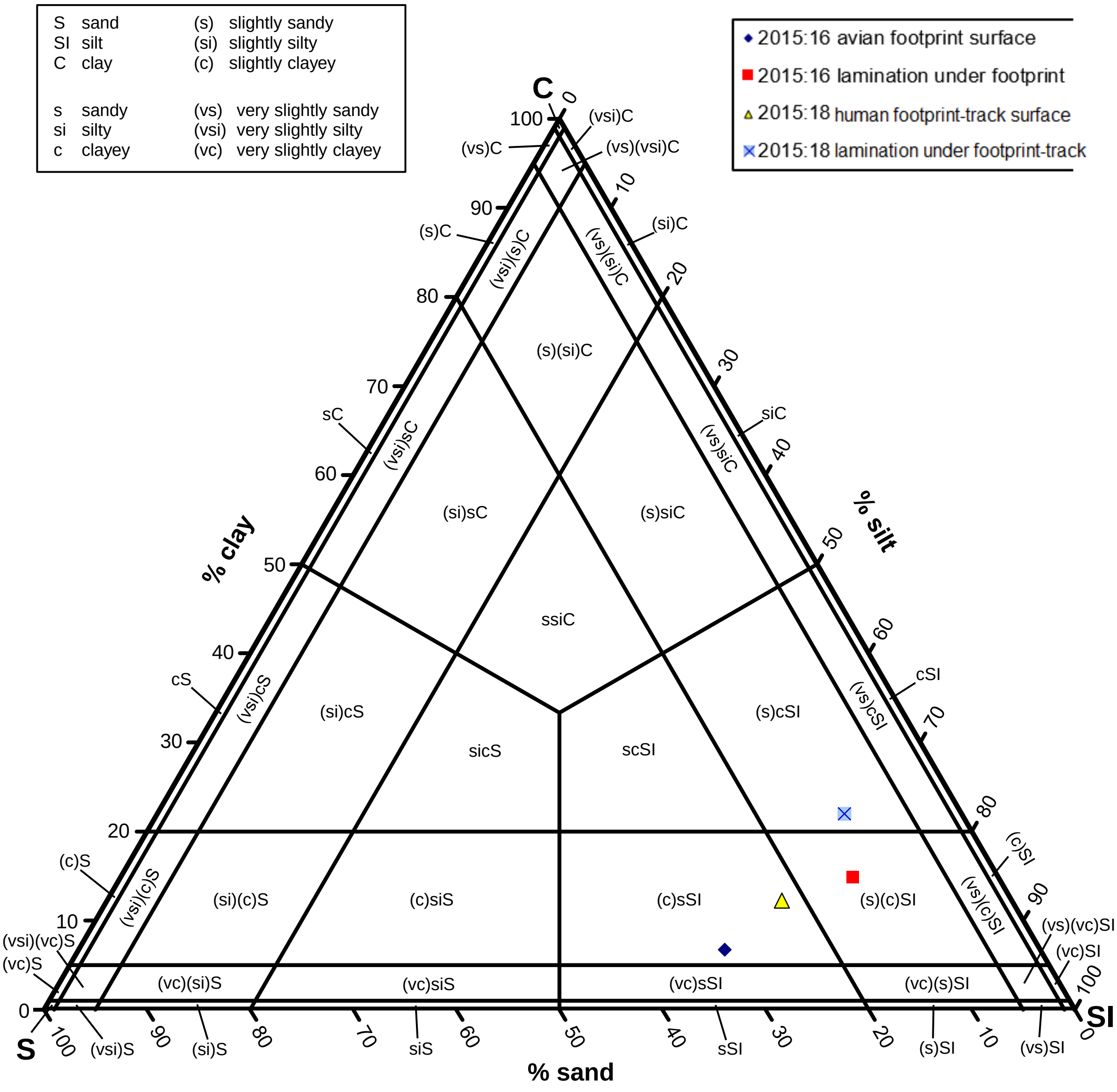


Figure 8.8 SCC trigon showing the results of sediment composition from laminations walked on by grey heron s (2015:16) and a human footprint-track (2015:18) at Site N

8.4.4 Site R

Site R was close to the edge of the Mesolithic palaeochannel, 9.5m from the edge of the lower peat shelf which the palaeochannel cut into. The consolidated laminations in Site R were the most straightforward to observe (Figure 8.9), though the footprints themselves are overtraces/undertraces. Site R was similar in sediment composition to Site C/E and Site M, where the sediment collected from the footprint-track laminated surface had a more clayey composition than the underlying sediment. Table 8.4 shows the percentages of the different sized particles each sample contained. Figure 8.10 demonstrates the difference in composition between the two samples, with very little sand and a high percentage of clay sized particles in the sample recorded from the footprint-track surface. The finer particle size of this sample could relate to the fact that it was close to the edge of the palaeochannel which was up to 2.5m deep, so it was away from the higher energy parts of the channel further to the east.

The sediment from the footprint surface indicates that the surface where the footprint-track could be seen had a higher percentage of clay than the underlying sediment, though the percentage of sand sediment was not much smaller than the percentage of the underlying lamination.

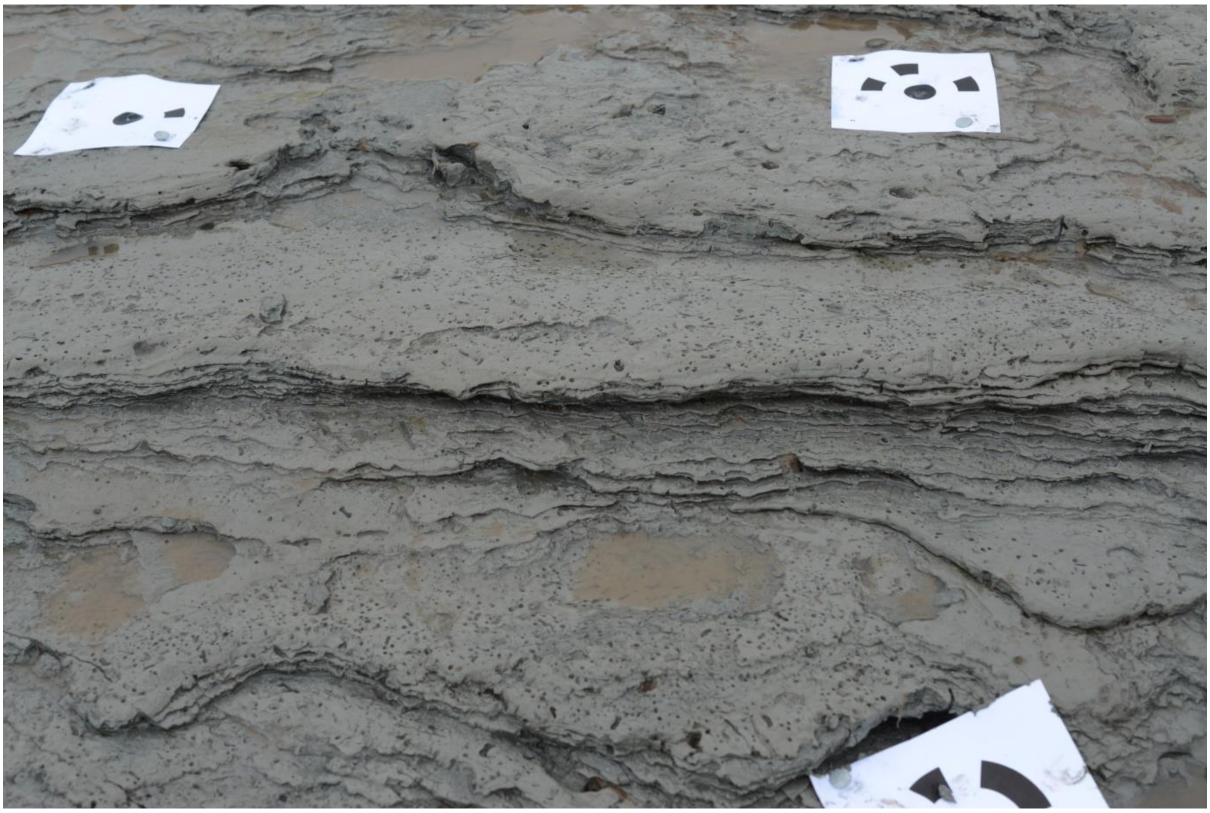


Figure 8.9 Consolidated laminations at Site R

Sample number	Clay %	Silt %	Very fine sand %	Fine sand %	Medium sand %	Coarse sand %	Very coarse sand %	Total sand %
2016:73 footprint-track surface	22.58	67.85	5.82	3.53	0.2	0.02	0	9.57
2016:73 lamination under footprint-track	8.54	79.79	7.74	3.69	0.1	0.02	0.08	11.63

Table 8.4 Percentages of clay, silt and sand from sediment recorded in Site R

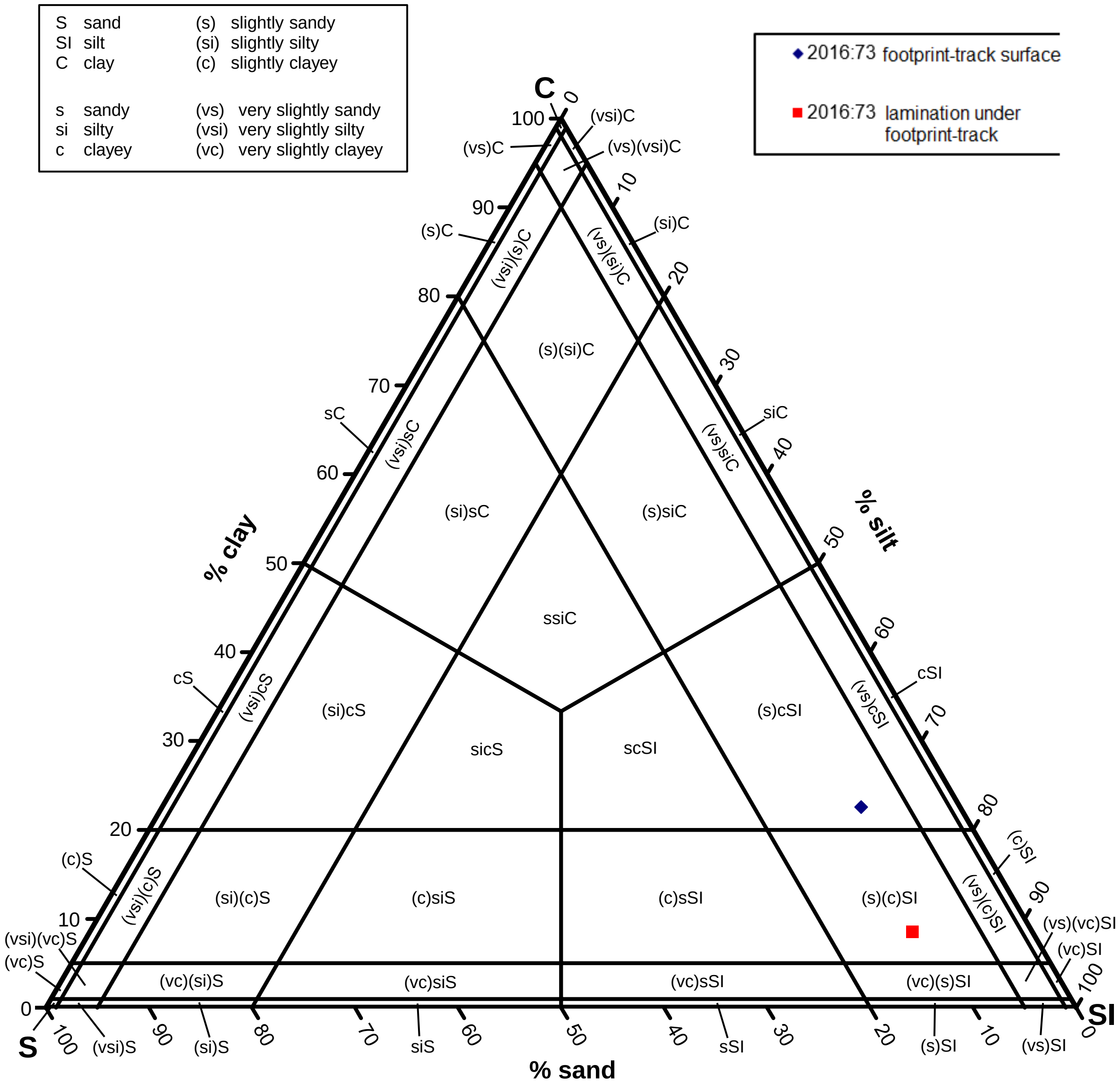


Figure 8.10 SCC trigon demonstrating sediment types from Site R human footprint-tracks

8.4.5 Site S

The sediment samples collected from Site S were gathered to allow the data for this area to be fully analysed, though the site was problematic due to the collapsed laminations and its position in a gully where water was flowing almost constantly, resulting in sloped laminations which were not clearly consolidated. Two samples were taken at this site, one from the surface of footprint-track 2016:103 and one from the underlying lamination. This footprint-track was the most convincing one in the area, with a clear hallux mark, arch of foot and heel, the others in this area were less obviously human. Table 8.5 shows the small differences between the overall sediment composition, with Figure 8.11 providing a visual representation of this data, with both samples composing of slightly sandy clayey silt.

Sample number	**Clay %**	**Silt %**	**Very fine sand %**	**Fine sand %**	**Medium sand %**	**Coarse sand %**	**Very coarse sand %**	**Total sand %**
2016:103 footprint-track surface	22.41	59.81	11.32	6	0.46	0	0	17.78
2016:103 lamination under footprint-track	29.48	57.68	6.93	4.98	0.55	0.36	0.02	12.84

Table 8.5 Percentages of clay, silt and sand from Site S samples

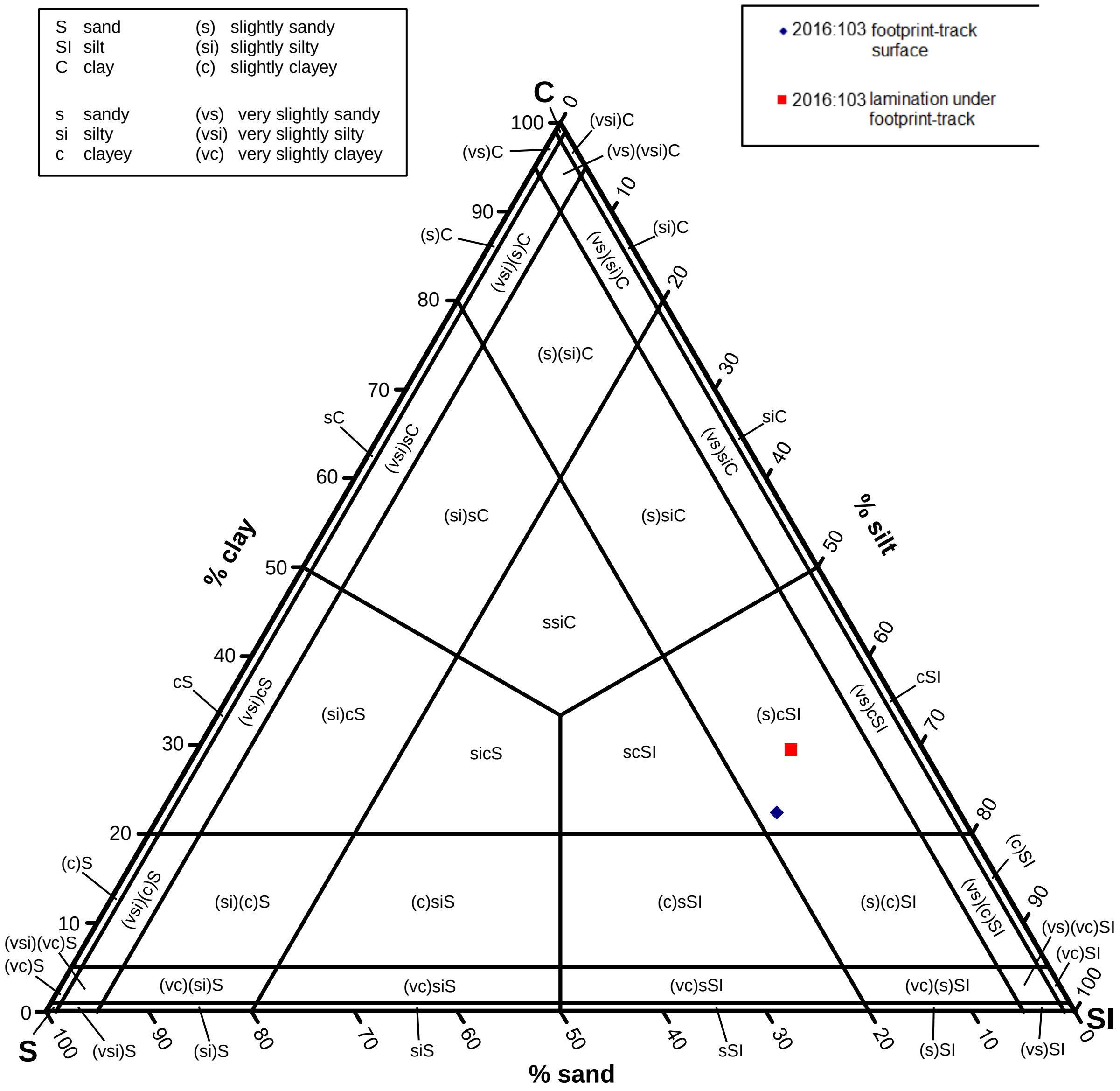


Figure 8.11 SCC trigon showing sediment size of samples from Site S human footprint-track 2016:103

8.5 Discussion

Within all the sediment sampled, silt was the main component, with only one sample, 2015:130, which was collected from under the footprint surface, falling below 50% silt composition. This high silt percentage is to be expected, previous work by Allen (2004) described the sediments as sandy-clayey silts and this is generally seen in areas such as the Severn Estuary, where there has been a transgressive marine environment (Figure 8.12). Allen (2004) sampled four complete lamination bands at Goldcliff (G2-G5) as well as most of a fifth band (G1) and part of a sixth

(G6). The bands had alternating groups between recessive (coarse-grained) and protrusive (fine-grained) laminae. The bands were found to be vertically asymmetrical, G1-G3 especially, with coarse-fine transition occurring sharply, and with the transition from fine-coarse more gradual (Figure 8.13). Although the compositions of the silts were similar, the trigons demonstrate that this site exhibited differences in sediment size which seems to have been dependent on which footprint area it was made in. This is also seen in Allen's (2004) research, where there was a noticeable difference between the particle size and the band the sediment came from.

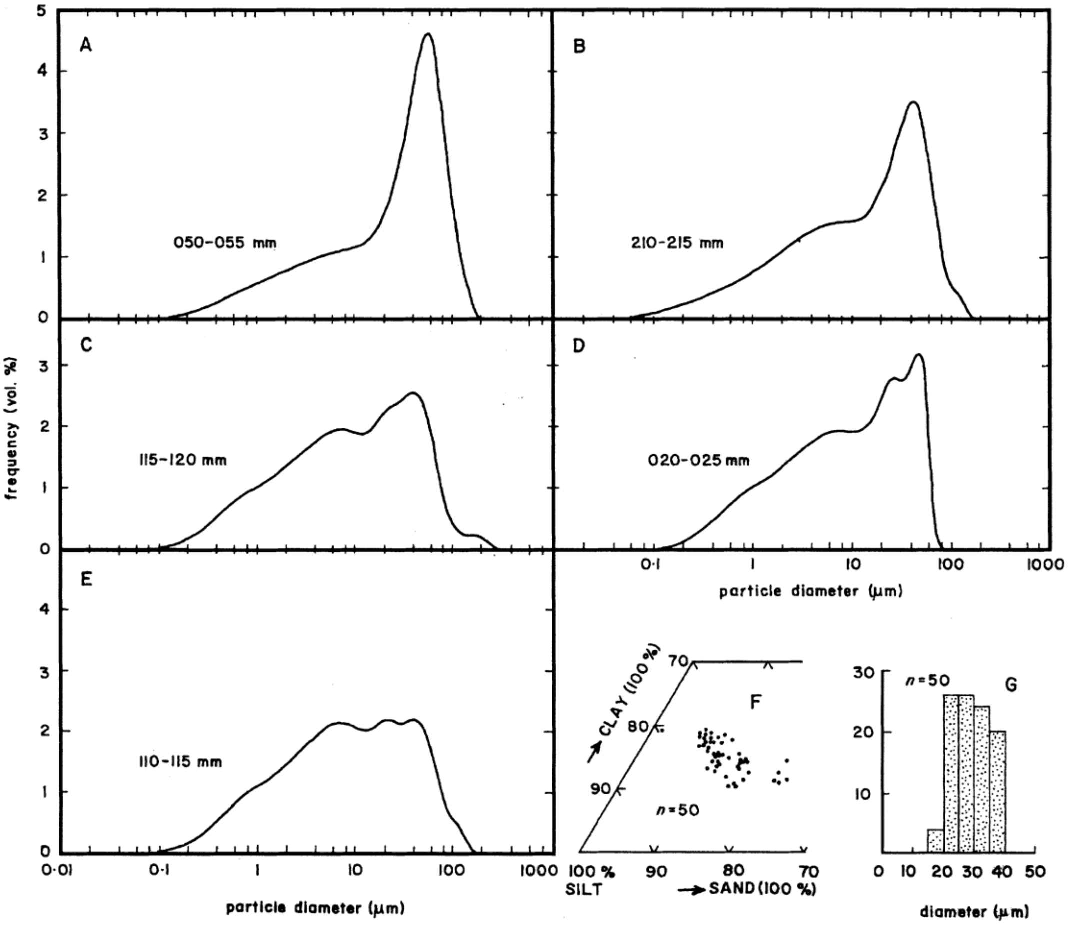


Figure 8.12 Grain size characteristics from Goldcliff monolith, (A-E) representative grain-size distribution, (F) Clay-silt-sand ratios, (G) Frequency distribution of values for mean diameter (Allen 2004)

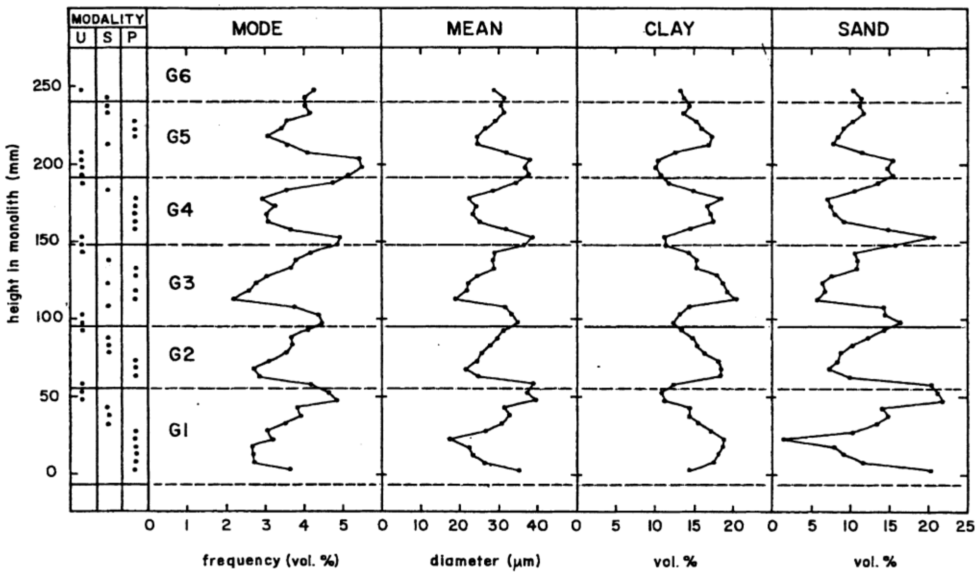


Figure 8.13 Patterns of asymmetry between recessive and protrusive laminae (Allen 2004)

8.6 Banded laminations and seasonality of the footprint sites

There were five main footprint sites investigated during this study period. These sites were all preserved within 150m by 100m of one another, however footprint preservation varied according to site. The footprint-tracks from Site C/E were on exposed erosion cliffs through laminated sediments (Figure 8.14), Site R footprint-tracks were on consolidated banded laminations exposed in plan (Figure 6.69), Site M footprint-tracks were on laminated sediments with recent erosion gullies cutting across them (Figure 8.15), Site S footprint-tracks were found within one of the gullies on a small, sloped, laminated area (Figure 6.76). Site N footprint-tracks were exposed on laminated sediments which were covered and uncovered periodically by a gravel bar which must be gradually abrading them to some extent (Figure 8.16).

Performing particle size analysis upon the sediment from the footprint-track surface and the underlying lamination band allowed a comparison of composition to be observed. All but five of the samples collected from the surface demonstrated a sediment composition that contained smaller particles than the underlying layer. The majority of the samples showed a difference in particle size between the footprint-track lamination and the underlying lamination, demonstrating that these bands were deposited during times of different sea temperatures and wind-wave climates (Allen 2004), meaning that they may provide useful data where there are footprints preserved. Six of the eleven footprint-tracks that were made on the surface had less than half of the sand content of the underlying laminations. Two of the eleven footprint-tracks exhibited similar sediment composition between the surface they were made on and the underlying layer, and three of the footprint-tracks had double the amount of sand compared to the underlying lamination.

The footprint-tracks from Site N were made upon sandier sediment, rather than this being the composition of the underlying lamination. Footprint-track 2015:16 was a probable footprint, as opposed to an overtrace/undertrace, which meant that the sediment collected from this lamination was the surface that the birds directly walked upon. The footprint-tracks from Site N were made on a slightly clayey sandy silt, avian footprint 2015:16 was made on a sediment comprised of over 30% sand, this is noticeably different to the underlying lamination comprised of 14.3% sand. It is likely that the footprints made in the sandier deposit were made during the winter months due to the evidence of a coarser particle size. The footprint-tracks found at Site N are from the most southern footprint area so far recorded at Goldcliff East. It is likely that during the spring tides this area would have been well exposed and walked on during the winter months as the bird footprint-tracks are detailed and indicate that they were formed on plastic sediments, completely out of the water. There is not any blurring of footprint detail, the details are all sharp indicating a sediment that was not in water (Chapter 7). The sediments may have been rather wet when the humans walked on them, as the footprint-tracks were lacking in detail which may be an indication of sinking and the shaft wall collapsing slightly upon itself as the foot was removed from the sediment. As they were overtraces/undertraces it is also possible that they were made at a different time to the bird footprint-tracks which may be the cause for the different levels of preservation. Site N contained multiple human footprint-tracks and two clear trails, covering an area 16m by 6m. The former edge of Goldcliff Island, marked by the Ipswichian raised beach, is c.160m west of Site N. People were walking over Site N, heading towards and away from Goldcliff Island. The implication of this repeated visit to the specific area is discussed further in Chapter 9.

Footprint-track 2015:87 and 2015:113 from Site C/E were recorded in an area where footprint-tracks were made predominantly in slightly sandy clayey silt. The avian footprints 2015:87 were made by the common crane species, whilst 2015:113 was made by a small wader. The sediments collected from 2015:87 were from a common crane trail containing three footprint-tracks, these were overtraces. The underlying sediment from this footprint was of a very slightly sandy slightly clayey silt composition, whereas the overlaying layer was of a very slightly clayey slightly sandy silt composition, neither of which had large sized particles in the sediment to suggest deposition during the winter months. The sediment from 2015:113, however, was very sandy for a sediment sample from this area. Both of the samples taken from the underlying and overlying laminations were very slightly clayey sandy silt sediments, 43.93% of the sample taken from the footprint surface was composed of sand sized particles. It is likely that this bird made the footprints in a time where the sea-temperature was lower or the wind-wave climate was different. A large summer storm may have caused coarser sediment to be lain down where this bird walked. All other footprint-tracks in this area were likely made during the summer months, and during a time of warm sea temperature and a calmer wave-wind climate.

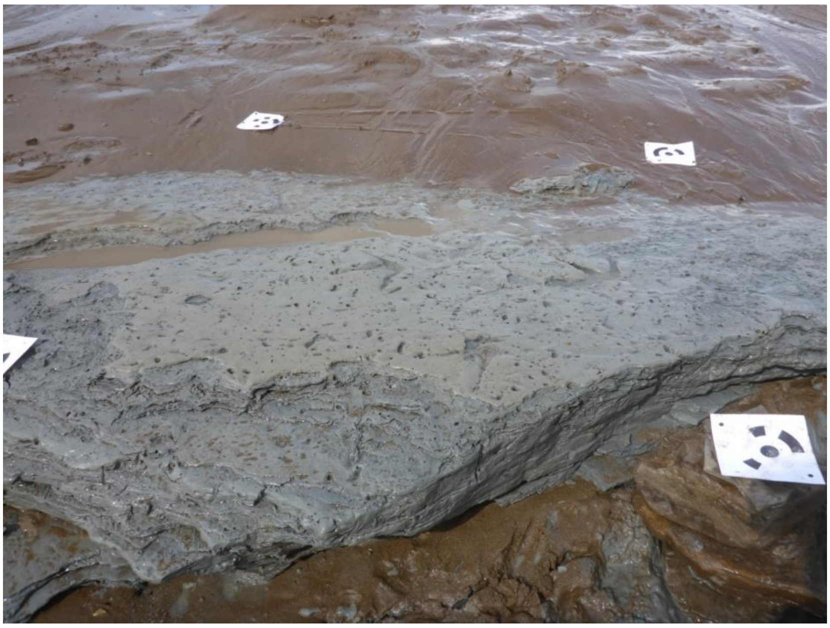


Figure 8.14 Exposed erosion cliffs of laminated sediments at Site C/E where common crane footprints (2015:70) were recorded

Figure 8.15 Laminated sediments cut by erosion gullies at Site M

Figure 8.16 Laminated sediments and the covering gravel at Site N

8.7 Summary

The use of particle size analysis and the visual representation of the data in SSC trigons suggests that this technique can be successfully utilised to characterise the types of sediments that prehistoric footprint-tracks were being preserved in on the Severn Estuary, possible environmental conditions and the season in which footprints were being made.

The evidence suggests that all of the footprint sites except Site N, and avian footprint 2015:113 from Site C/E, were made upon fine-grained sediments, likely during periods of warm sea temperatures and a gentle wind-wave climate. The inference of this data when combined with the archaeological dataset from Goldcliff East is that people were present on the site more often during the warmer months. Avian footprint-tracks were found in both coarse-grained and fine-grained sediments; there were both migratory and resident birds of Britain on these laminations, with summer migrants such as common crane only on the fine-grained laminations. The implications of seasonality from avian footprint-tracks is discussed in Chapter 9.

The footprint-tracks at Site N were made upon laminations with a coarser-grained particle size, which was likely deposited during the colder winter months. Knowledge of the particle size of the laminations walked upon, as well as of the species that formed the footprints, assists in our interpretation of a site, such as in ascertaining the season in which certain activities were occurring and site usage of the area.

Chapter 9

The paleoecology of Mesolithic Goldcliff East: footprint-tracks and other archaeological data

9.1 Introduction

The extensive prehistoric human exploitation of saltmarsh wetland at Goldcliff East spans throughout the Mesolithic, to the Iron Age and beyond. The saltmarsh environment provided a habitat rich in nutrients, which would appeal to grazing animals, and was utilised during the Bronze Age for sheep and cattle dairy husbandry (Barr and Bell 2016). During the Mesolithic, hunter-gatherers were exploiting the area for resources, with data indicating seasonal activities. By examining the environmental, skeletal and artefact data from previous research at Goldcliff, alongside the footprint-track data, a more detailed understanding of the people who were in the area and the activities they were undertaking can be gained.

9.2 Vegetation succession at Goldcliff East

Goldcliff was a rich environment; the ecology was heavily influenced by the sea, with sea level fluctuations influencing the vegetation (Dark 2007, p 185). Pollen evidence at Goldcliff indicates a dynamic wetland edge environment. The Mesolithic settlements were on the edge of the former island and rose up the island edge with rising sea level and associated sedimentation. The footprints correspond with successive settlements on the island and were made during transgressive phases when saltmarsh sediments were accumulating. The vegetation succession at Goldcliff is complex, and is dealt with thoroughly by Caseldine (2000), Timpany (2007), and Dark (2007), however a very brief summary of the relevant succession is given below to highlight the environmental changes at Goldcliff during the Mesolithic. Some of the resources that may have been available and activities being undertaken by the footprint-track makers are also discussed.

High representation of goosefoot pollen in the basal zone at Site W, as well as high levels of wild grass pollen, indicate that both saltmarsh and reed swamp were developing in the wetland environment and at the edge of the island. Radiocarbon dates from the site vary from 6760 ±80 BP (OxA-6683) to 6420 ±60 BP (SWAN-28; Caseldine 2000, p 214). At the edge of the island there was a woodland of oak (*Quercus*), elm (*Ulmus*), lime (*Tilia*) and hazel (*Corylus*). Between *c*.6400-5900 radiocarbon years BP marine inundation occurred (Caseldine 2000). Pollen values were low and suggest a wild salt marsh and coastal grass habitat (Dickson 1988). It is during this phase that the footprint-tracks from the Lower Wentlooge Formation were found on the banded laminations made by individuals walking in the saltmarsh environment. At Uskmouth the pollen and foraminifera from the fill of one of the Mesolithic footprint-tracks were analysed (Caseldine 1992; Culver and Lundquist 1992), this footprint was made in clayey silt that predates 6250±80 BP (OxA-2627) and results indicate that the environment was mudflats and saltmarsh (Aldhouse-Green *et al*. 1992).

Following rapid sea level rise from the early Holocene, which facilitated saltmarsh development and palaeochannel incision, sea level rise slowed by c.6000 radiocarbon years BP. This phase of reduced marine influence resulted in an expansion of sedge and reed (Caseldine 2000, p 216). It is still likely that there would have been some saltmarsh, however there would have been a large area of reed swamp, sedge, and carr-woodland on the fringe between the saltmarsh and dry land.

During the period of 5650-4900 radiocarbon years BP there was a rise in birch fen woodland (Caseldine 2000). The carr-woodland that fringed the island began to decline, with alder declining steadily. This carr-woodland decline is thought to have been brought on by a brief marine phase before 5530±90 BP (CAR-657; Caseldine 2000; Smith and Morgan 1989). The dry land island environment remained relatively unchanged, oak was still a dominant species, however there began to be a decline in elm. By 4900±60 BP (CAR-1500; Caseldine 2000, p 218), after around 1000 years of carr-woodland, raised bog began to grow and replace the birch fen woodland. The raised bog would have affected people’s ability to hunt, and animals’ ability to graze, and there is very limited evidence of human activity in the wetland environment with no human, bird or animal footprint-tracks recorded at this site during this time.

During the Mesolithic the woodland and saltmarshes would have provided a variety of resources to both humans and animals such as roots, tubers, nuts, berries, bark, and reeds. Submerged forests were found at Goldcliff East and other surrounding intertidal sites such as Redwick and Magor (Timpany 2002, 2007). At Redwick there were as many as 100 trunks and tree stumps from oak, believed to represent a dense oak woodland (Timpany 2005). Some of the Holocene estuarine peats contained charcoal horizons indicating multiple episodes of vegetation burning (Bell 2001). At Site W a charcoal spread was found in association with multiple artefacts, dated to *c*. 6420±80 BP (GU-2759; Bell *et al*. 2000). A comparison of the pollen and charcoal data from Goldcliff East Sites B and D, as well as the charcoal spread at Site W, indicated that the burning of reed swamp and hazel woodland was occurring on the fringes of Goldcliff Island, as well as possible burning in hearth and activity areas (Dark 2007, p 183). If the people of Goldcliff were deliberately burning reedbeds before or during the flowering season then this burning would have likely been occurring in summer/early autumn.

Possible deliberate burning of reedbeds has been reported at Star Carr (Mellars and Dark 1998), where it is thought this was done to prevent plants from flowering and promote new reed growth which would attract animals, such as red deer, to graze (Mellars 1976). At the site of Neumark-Nord 2, Germany, there was possible evidence of strategic vegetation burning by Neanderthals (Pop and Bakels 2015). It is debated whether the primary goal of this technique was long term or short term (Bliege-Bird *et al*. 2008, 2013; Holdaway *et al*. 2013; Mooney *et al*. 2011; Morton *et al.* 2011), however the new vegetation did create a mosaic of old and new plant life which would appeal to game and other animals. It is difficult to distinguish if Mesolithic burning episodes were deliberate or if they were natural occurrences such as wild fires (Brown 1997), however burning at coastal sites is probably more likely to be deliberate, as the area would have been very wet (Rackam 1986).

In an ethnographic study by Scherjon *et al*. (2015), it was found that the deliberate burning of vegetation was a seasonal activity, to take advantage of the dry plants. It was often done by women to flush prey out towards the male hunters, or to trap them in a certain area. Among the hunter-gatherer Tiwi camp, Australia, grass burning is implemented to hunt kangaroos and to encourage new vegetation growth to attract game, indicating that this tribe hunt with fire for an immediate gain, the kangaroo meat, as well as the future gain of the new game and foraging opportunities that will occur in this area. Although the burning at Goldcliff may have been an accident, such as a hearth fire getting out of control, it may also have been a woodland clearing strategy (Gale 2007, p 186).

Hazelnuts were heavily exploited during the Mesolithic period. Oak and hazel trees were both growing at Goldcliff, so both types of nuts would have been available, however no evidence of acorns was found, perhaps for preservation reasons. Hazelnuts can be eaten cooked or raw and store well; acorns however require processing to remove the tannis so would be a complicated food source (Driver 1953). In Britain sites such as Staffin Bay, Isle of Skye, contained evidence of hazelnut exploitation, with charred hazelnut fragments radiocarbon dated to 6800-6600 cal BC (Page 2016). At a further Mesolithic site, Broom Hill, Hampshire, there were hundreds of thousands of charred hazelnuts which had been deposited in a large, circular depression (Mithen 1999). Hazelnuts also appear in multiple Mesolithic sites across Europe, as well as other sites from prehistory, indicating that this was a popular, and common, food choice (Jessen 1924, Regnell *et al*. 1995; Robinson & Harild 2002). Regnell (2012), studied the Mesolithic site Tagerup, Scania, Sweden, as well as other sites along the West Coast Line Railway track project, where it was found that hazelnut shells made up 81% of the plant remains from this site, in comparison to the Neolithic site containing 21%, and the Bronze Age just 8%. Zvelebil (1994) defines the Mesolithic hunter-gatherers' exploitation of hazelnuts as 'systematic and intensive'.

At the site of Goldcliff East the evidence for hazelnut can be found at several of the Mesolithic areas. At Site J there were 2794 hazelnut fragments recorded, and at Site A charred hazelnut shells have been found (Dark 2007, p 181). Many of the hazelnuts from Site J were not charred, but had been buried, presumably by squirrels, which gives another insight into the ecology of the area. Hazelnuts have a high plant protein content, as well as dietary fibre, fat, essential vitamins and amino-acids, so they would have been an appealing food source (Amaral *et al*. 2006). They would have been targeted by humans and mammals; deer and pig are very fond of ripe hazelnuts, so many hazel trees may have attracted game to the area.

The charred remains of hazelnuts at Site A, B and J are possibly from food that was being collected during the autumn months, however they do store well so any hazelnuts found on site may have been from the year before (Dark 2007, p 183). Further seasonal and environmental evidence is found in the charred and uncharred remains of soft fruit. Unlike hazelnuts, fruit need to be consumed relatively quickly before they start to rot, and so are a seasonal indicator. Several hundred uncharred seeds came from elder (*Sambucus nigra*), these trees have ripened fruits during August and September. There was also evidence of sloe (*Prunus spinosa*) and two possible dog wood stones from Site A, again these would have been available during late August and September (Dark 2007, p 183). Site W also contained evidence of plant remains, including charred seeds such as the seed of greater plantin (*Plantago major*), a fragment of hazelnut and rush and grass species (Bell 2007, Table 18.3). The plant species burned in these areas suggests a predominance of summer and autumn activity at Goldcliff, however evidence throughout the sites from a variety of sources indicates activity at other times of the year (Bell *et al*. 2007). These other seasonal indicators will be discussed throughout the rest of this chapter which focuses on the Mesolithic footprint-tracks and what this information can tell us about the palaeoecology of Goldcliff.

9.3 Footprint-track assemblage at Goldcliff East

The footprint assemblage at Goldcliff East is extremely rich, with 856 Late Mesolithic human, birds and mammal footprint-tracks recorded over the past 16 years (Table 9.1). Over this period recording techniques have developed, with the tracing of footprints being replaced with utilising multi-image photogrammetry (Chapter 4). Multi-image photogrammetry allows for quick and accurate recording. The advantage of this technique over tracing is that all details of the footprint-track get recorded. This contrasts with tracing, where interpretation is fairly subjective.

Recording the footprint-tracks using standard photography, planning, metric measurements, direction of orientation and in certain situations casting, also compliment multi-image photogrammetry and are all techniques that should still be utilised when recording footprint-tracks in intertidal zones.

Type	**Scales 2001-4**	**2005-9**	**2010-2014**	**Barr 2014-2017**	**Total**
Human	233	0	47	62	342
Possibly human/ ungulate	87	2	68	20	177
Ungulate / Deer	62	0	1	0	63
Aurochs	1	0	1	0	2
Dog/wolf	2	0	0	0	2
Bird	165	0	44	61	270
Total	550	2	161	143	856

Table 9.1 Number of footprint-tracks from different species recorded at Goldcliff East by Scales during 2001-2004, during sporadic fieldwork undertaken by Professor Martin Bell in 2005-2009 and 2010-2014, and footprint-tracks recorded by the writer during the fieldwork period 2014-2017

9.4 Wildfowl

The wetland and estuarine conditions created by the Severn river provide a desirable habitat for a range of avian species which exploit the area for its resources. Avian footprint-tracks recorded on the silt laminations suggest that a variety of species were present in the area (Table 9.2). Bird bones are relatively lacking in the skeletal assemblage at Goldcliff, with only two bones of an identifiable species recorded at Site W (Coard 2000). These were determined to be mallard duck (*Anas platyrhychos*). No footprint evidence for Mallard has yet been found. Bird bones from unidentified species have also been found at Site W and Site A (Coard 2000; Scales 2006).

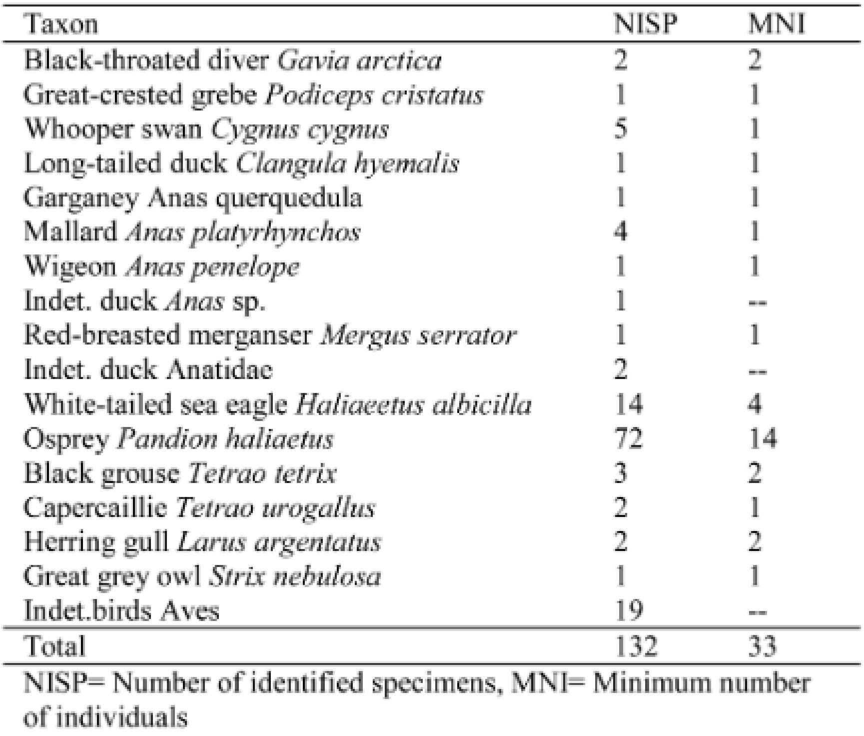
Although the avian bone assemblage at Goldcliff is poor, evidence for coastal birds has been found at other Mesolithic sites. At Star Carr remains were small and fragmentary with each species only represented by one or two elements. Star Carr had an assemblage with evidence of at least seven species, these were all species that are still found in Britain today. Two were summer migrants, the red throated diver (*Gavia stellate)* and common crane *(Grus grus).* Two were year-round residents, the great crested grebe (*Podiceps cristatus)* and little grebe *(Tachybaptus ruficollis*). There were also three species who were winter residents, the brent goose *(Branta bernicla),* red-breasted merganser *(Mergus serrator)* and common scoter *(Melanitta nigra)* (Clark 1954; Harrison 1987b). Most of the bird bones at Star Carr are from waterfowl that nest on wetland areas, and were perhaps shot within the wetland environment or at the water's edge by hunters using small bows (Taylor *et al.* 2018).

At the Late Mesolithic burial site at Yuzhniy Oleniy Ostrov, Lake Onega, Western Russia, bird bones were found in some of the human burials, with an osprey tibiotarus radiocarbon dated to 7570 ± 60 BP (Hela-1374; Mannermaa *et al*. 2008). There were 22 human graves at this site that included bird remains, and 14 identifiable species (Table 9.3), it is thought that the species may have had a significant meaning in relation to each burial (Mannermaa *et al*. 2008). All of the species from this Russian site, excluding the great grey owl (*Strix nebulosa*), are either residents or migrants of Britain today (Hume 2002), and were possibly in Britain during the Mesolithic.

The Goldcliff East avian assemblage is similar to Star Carr in that all the identified avian evidence is from species that are still found living on, or migrating to, the Severn Estuary. The only exception is white stork which is no-longer a migratory visitor to Britain, instead it can be found migrating to other European countries to spend the summer breeding season before returning to Africa to winter (Johst *et al.* 2001). The same is true of the common crane, although their recent reintroduction into England has resulted in this species returning to the Severn Estuary. 21% of bird footprint-tracks were not identifiable in this study. The identification of these footprint-tracks was complicated, due to the lack of detail in some. The toe angle, morphology, and footprint dimensions did not mirror species that are currently found on the estuary and so were not part of the experimental data results assemblage. More experimental work may allow these unidentified species to be ascertained. Although footprint-tracking field books can be useful (Bang and Dahlstrom 1974; Brown *et al*. 1987), experimental work indicates that when the footprints were made in clayey silt they were often very different in appearance and size to those found in footprint tracking literature.

Species present in environs of Goldcliff Island	**Goldcliff East bone assemblage**	**Goldcliff West bone assemblage (SiteW)**	**Goldcliff East footprint-track assemblage**
Common Crane (*Grus grus*)	Absent	Absent	Site C, E & O
Grey Heron (*Ardea cinerea*)	Absent	Absent	Site C, E, M, N & O
Oystercatcher (*Haematopus ostralegus*)	Absent	Absent	Site C & E
Mallard (*Anas platyrhynchos*)	Absent	Present (1202)	Absent
Tern (*Sterna* sp.)	Absent	Absent	Site C & E
Common Gull (*Laurus canus*)	Absent	Absent	Site C & E
Black-headed Gull (*Laurus redibundus*)	Absent	Absent	Site C & E
White Stork (*Ciconia ciconia*)	Absent	Absent	Site C/E
Waders (*Scolopacidae* sp.)	Absent	Absent	Site C, E, M, N & O
Bird, unidentified	Site A	Present (1202)	Site E, M, N & O

Table 9.2. Avian species present in environs of Goldcliff Island, evidenced by skeletal remains and footprint-tracks (Scales 2007, Table 13.2), additions by author



Taxon	NISP	MNI
Black-throated diver *Gavia arctica*	2	2
Great-crested grebe *Podiceps cristatus*	1	1
Whooper swan *Cygnus cygnus*	5	1
Long-tailed duck *Clangula hyemalis*	1	1
Garganey Anas querquedula	1	1
Mallard *Anas platyrhynchos*	4	1
Wigeon *Anas penelope*	1	1
Indet. duck *Anas* sp.	1	--
Red-breasted merganser *Mergus serrator*	1	1
Indet. duck Anatidae	2	--
White-tailed sea eagle *Haliaeetus albicilla*	14	4
Osprey *Pandion haliaetus*	72	14
Black grouse *Tetrao tetrix*	3	2
Capercaillie *Tetrao urogallus*	2	1
Herring gull *Larus argentatus*	2	2
Great grey owl *Strix nebulosa*	1	1
Indet.birds Aves	19	--
Total	132	33

NISP= Number of identified specimens, MNI= Minimum number of individuals

Table 9.3 Bird taxa from the graves at Yuzhniy Oleniy Ostrov, Lake Onega, Western Russia (Mannermaa et al. 2008)

The majority of footprint-tracks made by birds were made by a crane species (46%). This avian species was originally deemed to be larger than the common crane found in Britain today due to the footprint size (Scales 2006, p 159), and was thought to possibly be from *Grus primigenia.* Experimental research (Chapter 7) involving common crane walking on silt sediments suggests that although the avian footprints were large, they were likely made by common crane. The larger footprint-track size is caused by the way a footprint forms on silt sediment as opposed to firmer sediment (Chapter 4), rather than the foot itself being larger. There were, however, seven extremely large footprint-tracks that may have been made by a larger crane species, such as *Grus primigenia* or sarus crane, though they could also have been from large male common crane.

The common crane footprint-tracks from Site C/E at Goldcliff East indicated that the birds were present during the breeding season, during the summer months. This was shown in the fine-grained particle size of the clayey silt laminations being walked upon (Chapter 8), and indicated that the common crane may have been breeding and raising their chicks near this area. Modern common crane currently nest between May and June (Hume 2014), with chicks tending to be fully fledged by August or September. There are not any crane chick footprints, which may suggest that the adults were exploiting the wetland resources, but they had nested elsewhere. They will also avoid allowing their chicks to graze in areas where there is livestock, as these large animals disturb the invertebrates that crane prey upon (Buxton and Durdin 2011, p 92), so the presence of crane footprint-tracks in areas where ungulate footprint-tracks are lacking may suggest that ungulates were not often exploiting these areas.

The Mesolithic crane footprint-tracks recorded at Goldcliff East are in an area that would have suited their habitat needs for breeding, as well as where there was a reduced risk of predators. In Site C (Scales 2006), the footprint-tracks of Person 11 and Person 12 were recorded on the same lamination as common crane footprint-tracks (Figure 9.1). These footprint-tracks were generally small, with reanalysis within this study of the original data suggesting Person 11 was aged 5.5 +/- 1.5 years, and Person 12 aged 10 +/- 1 years old. It was suggested by Scales (2006) that the presence of human footprints on the same lamination as crane may indicate the activity of wildfowling; eggs from common crane and meat of the young birds is reported to be the best to eat, as adult meat is tough (Albarella 1997). During the egg incubation period common crane are extremely territorial and will perform extensive distraction behaviour which can involve physical attack, including bill-stabbing, kicking, and wing-beating (Moll 1963; Cramp and Simmons 1980). Common crane can be up to 130cm tall, which would have been taller than Person 11 who was approximately 107.5cm (3’6”) tall and around the same height as Person 12, 132.3cm (4’4”) tall. The birds would have fought viciously to protect their nest so are unlikely to have run or flown away when chased. The child would have had to face a large opponent, as well as injury, to get at most two eggs. It is therefore unlikely that these footprint-tracks represent humans attempting to steal eggs from adult crane.

It is a possibility that the children may have been chasing young chicks once they had hatched but before they were fully fledged, though the majority of the laminations with crane footprint-tracks did not form a clear trail, and suggested time was spent in the area, rather than moving anywhere at a run. There was also a lack of any juvenile common crane footprint-tracks, all were large and adult in size. It was noted by Månsson *et al*. (2013) that common crane are most active on wetlands and marshlands at around dusk, just before they roost. The human footprint-tracks on the same lamination as the crane may be an indication that humans had been in the same area during the day, perhaps exploiting similar resources that drew the crane to the area, but were not hunting them. This may also provide an explanation as to why there were no crane bones found at any of the Mesolithic sites, though it was noted that the other faunal remains found at Goldcliff East were very fragmented, possibly due to ungulate trampling (Scales 2007b, p 163), which may have contributed to the lack of avian bones, as they are lightweight and porous.

At Goldcliff there is a lack of distinct crane trails and they appear to make rather chaotic patterns, which may indicate that these cranes were engaging in dance behaviour. Common cranes perform this 'dance' by stiff-legged marching, pirouetting, bowing, beating their wings, running and leaping; they generally perform this display in an almost circular formation and can even be encouraged to dance if humans begin the display (Russell and McGowan 2003; Snow *et al*. 1998). This dancing behaviour is not well-understood but thought to be a form of social display, pair bonding and an attempt to ward off aggression (Russell and McGowan 2003). Although we cannot know if the Goldcliff cranes were dancing with certainty because the areas of footprint exposure are small, it is worth considering. Dancing behaviour of these cranes is further indicated by how well formed the footprints were, which suggests that they were made in drying mud instead of in shallow water.

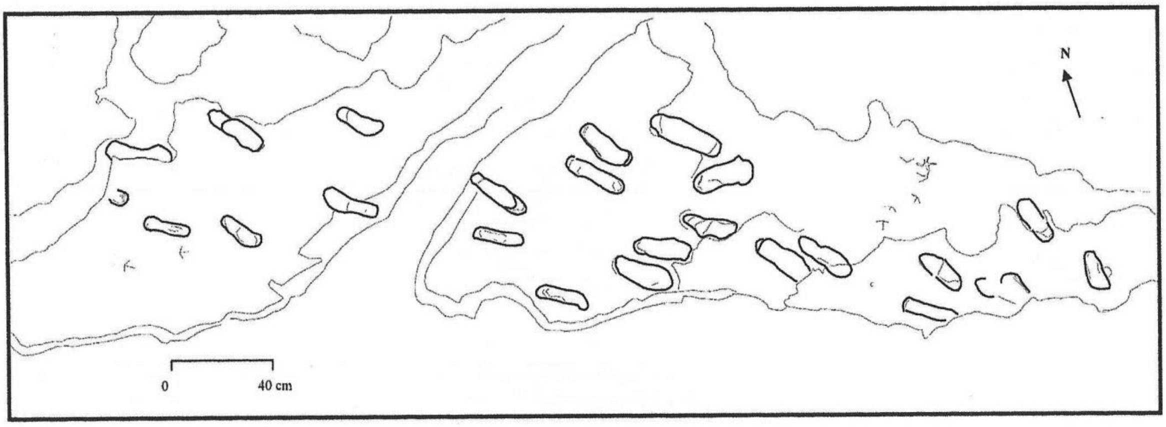


Figure 9.1 Goldcliff East, Site C. Plan of the trails of Person 11 and Person 12 and the avian footprints (Scales 2006)

Throughout differing time periods across the world there has been indication that crane species were important, considered sacred, or the killing of the bird was taboo. Celtic mythology, for example, considers eating crane flesh to be bad luck due to the reputation that they unman warriors, stealing their will to fight (Ettlinger 1943). Other areas of the world deem the crane species to be symbols of longevity, fertility and good fortune (Armstrong 1943; Balzer 1996; Johnsgard 1983).

At the Neolithic site of Çatalhöyük, Turkey, the bones of crane only made up 2% of the identified bird bones, indicating that these animals were not being extensively hunted (Russell and McGowan 2005). A crane wing, complete from distal humerus to tip (Figure 9.2), was found within a deposit also containing other 'special' items such as cattle horn core, wild goat horn core and a dog head (Russell and McGowan 2003). This crane wing had marks on the bone that did not indicate standard butchery, and is argued to have been part of a costume used to perform the crane dance (Russell 2011). Humans from prehistory and ethnographic contexts across the world have been found to replicate the crane dance (Figure 9.3), possibly to strengthen relationships or to re-enact the origins of important stories (Garfinkel 2003; Russell and McGowan 2003). Russell and McGowan (2003; Armstrong 1943) suggest that, although evidence of cranes and the crane dance appear in different contexts across the globe, it is likely that the mimicking of the crane dance and fascination with cranes arose independently within the different societies.

Crane also appear in prehistoric artwork, the wall painting from Çatalhöyük being an example of this (Figure 9.4), depicting two probable crane facing each other with their heads raised (Mellart 1966). Other wall paintings at Çatalhöyük depict pairs of animals facing each other, such as the onagers directly below the crane, and are thought to be symbolic paintings linked to twins or mating pairs (Russell and McGowan 2003). Pillars with reliefs of animals, including crane, were recorded at the Neolithic site of Göbekli Tepe, Turkey (Figure 9.5). These birds have the appearance of crane in many ways, though the legs are bent, giving a human appearance to the bird; possibly these carvings are a representation of masked humans partaking in the crane dance (Schmidt 2012). Although the crane have legs that are human in appearance, the feet are clearly that of a crane, with three toes evident. Schmidt (2012) suggests that this image may not be representative of humans simply dressing as crane, but rather it captures the humans physically transforming into the bird during the dance.

The importance of crane in some societies may provide a further explanation for the lack of skeletal remains in Mesolithic sites, which may indicate that common crane were not being hunted at Goldcliff East, possibly due to the birds themselves being viewed as important rather than just dangerous and territorial.

Figure 9.2 Çatalhöyük crane wing (after Russel and McGowan 2003)

Figure 9.3 An imagined crane dance at Çatalhöyük, image by J.Swogger (Russell and McGowan 2003, Figure 9.4)

Figure 9.4 Çatalhöyük wall paining of two crane stood below a fragmentary boar and above a pair of onagers (picture courtesy of Picture of Records, Inc.: Çatalhöyük by James Mellart)

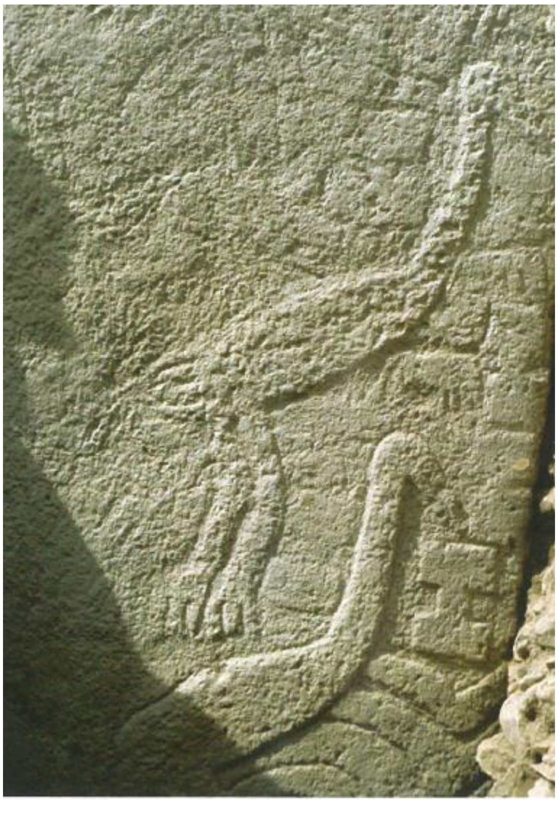


Figure 9.5 Göbekli Tepe pillar 33, with engravings of crane. Identified through the long necks, legs and tail feathers though the legs are bent, and more human in appearance than crane (Schmidt 2012)

Further avian footprint-tracks at Goldcliff East, often on the same lamination as humans, were made by grey heron (*Ardea cinerea*). Again, there is no clear evidence of a footprint-track trail, rather many footprints in a small area heading in multiple directions which suggests these birds were spending time at a specific place, possibly standing at the water's edge in a similar way that the current grey heron residents at Goldcliff East can be observed hunting, rather than walking about the site. Grey heron are a year-round resident in Britain at present and the same was likely during the Mesolithic, with footprint-tracks made on areas recorded containing fine-grained summer sediments (Site C/E), as well as coarser winter sediments (Site N).

Evidence of prehistoric grey heron is relatively scarce in south west Britain, they are found at the Iron Age settlement, Meare Lake, Somerset (Harrison 1987a), and in Hampshire in south east Britain, from the Iron Age phase at Winnal Down (Jay and Richards 2007). Complications also arise in heron being mistaken for common crane (Wood 2010). In terms of footprint-tracks, these bird species are different in appearance, with common crane being much larger than grey heron, which assists in identification and the conclusion that grey heron were present year-round at Goldcliff East.

The variety of avian species present in the area when conditions were favourable for the preservation of footprint-track evidence indicates that this site was likely exploited for resources. There were two footprint-tracks found at Site C/E that were possibly made by an avian species that is no-longer a common migrant to Britain, white stork (*Ciconia ciconia*). The presence of white stork at Site C/E suggests that during the Mesolithic period this species was a seasonal migratory bird. Like common crane, this large bird was probably using this area to raise chicks, modern white stork currently nests during April to June (Hume 2014), so may have been at Goldcliff East during late spring to mid-summer to allow the chicks to hatch and fledge. White stork will avoid tall trees and shrubland areas, preferring marshland, swamps and riverbeds to hunt. Modern white stork show no fear of humans, so it may be that this species lived in this area, even when humans were active. There is evidence of white stork present in Europe during the Mesolithic, with ulna, radius and carpometacarpus of the right wing of a stork from Erfttal, Germany, as some of the earliest postglacial evidence of white stork in Europe (Street and Peters 1991). The Mesolithic site of Star Carr also had possible skeletal remains of white stork, though there was only one bone from this species and it has been argued that it is actually common crane (Harrison 1987b: Milner 1999), which would make the Goldcliff East footprint-tracks some of the earliest evidence of white stork in Holocene Britain.

The avian footprint-tracks recorded provide evidence of species diversity which is not seen within the skeletal record. Footprint-track evidence indicates that species which exploit the estuary today are relatively similar to those of prehistory, taking advantage of the unique ecosystem that the Severn Estuary provides (Figure 9.6). This variety of species may have provided sustenance to the hunter-gatherers in the forms of eggs, feathers, and meat. They may have also provided an indication of good hunting or fishing grounds. Where there was an abundance of birds it may have been an indication to the Mesolithic individuals that resources were rich with a certain food. Within the modern indigenous Hazda society people have learned to use a species of bird, the Greater Honeyguide bird (*Indicator indicator*) to locate bee hives and access honey (Wood *et al.* 2014). This is a unique example of hunter-gatherers exploiting the abilities of an avian species to gain the benefits themselves, but it also indicates that humans may use birds to find food.

Figure 9.6 Dunlin, Grey Plover and Common Shelduck feeding on the mudflats at Goldcliff East during the winter (image courtesy of M. Cath, Royal Society for the Protection of Birds)

9.4.1 Seasonality of avian footprint-track evidence

Avian footprint-tracks assist in our understanding of the species present on a site; the species indicates the likely habitat and the season in which the bird was physically present and may be a signal of certain resources (e.g. large amounts of oystercatcher may indicate cockle beds). When an avian footprint is on the same lamination as a human this also indicates when those humans were present within the area (Table 9.4). Figure 9.7 demonstrates that 40% of the footprints recorded at Goldcliff were made by year-round residents of the Severn Estuary. A further 20% of the species present on site were unidentifiable and therefore could not have their seasonality established.

10% of the unidentified bird footprint-tracks were made by small waders. The difficulty that arises with the identification of small waders is that presently in the British Isles alone there are 25 species of waders, many of which are similar in size and share habitats and behaviours. There is also the possibility that the wader species present during prehistory are no longer in Britain. Of the 25 wader species currently found in Britain, 52% are migratory, coming to the Severn Estuary during the winter months (Figure 9.8). Although the winter period is when around half the wader species are found, they are also found during the other seasons, including 12% of the species being year-round residents. The small wader species footprint-tracks can therefore not be utilised to determine the season as there is too much variation, though they all indicate that the area was a coastal wetland environment.

Of the four species who were not year-round residents, the footprint-tracks enabled seasonal identification. Common crane, for instance, are a late spring to late summer passage migrant to the British Isles, nesting between May and June (Hume 2014), with chicks becoming fully fledged by August/September; the footprint-tracks from the Mesolithic laminations indicate the crane were present during warmer periods as the particle sizes were fine-grained (Figure 9.9; Chapter 8) which suggests that these birds may have come to Britain to nest.

Tern are a species that use the Severn Estuary as a passage to get to the end of their migratory route, they do not stay for a long length of time. They are visitors that can be seen mainly during autumn along the coastline (Hulme 2002). Arctic tern (*Sterna paradisaea*), for instance, are not generally present within footprint databases as they are passage migrants that are often not kept in British breeding programmes, so their footprint morphology could not be compared to the prehistoric database making the species of tern identification problematic.

Species present in environs of Goldcliff Island	**Season**
Common Crane (*Grus grus*)	Spring/summer
Grey Heron (*Ardea cinerea*)	Resident
Oystercatcher (*Haematopus ostralegus*)	Resident
Mallard (*Anas platyrhynchos*)	Resident
Tern (*Sterna* sp.)	Summer/autumn
Common Gull (*Laurus canus*)	Winter
Black-headed Gull (*Laurus redibundus*)	Resident
White Stork (*Ciconia ciconia*)	Spring/summer
Waders (*Scolopacidae* sp.)	Unknown
Bird, unidentified	Unknown

Table 9.4 The species present in environs of Goldcliff Island and the season the species were likely in the area

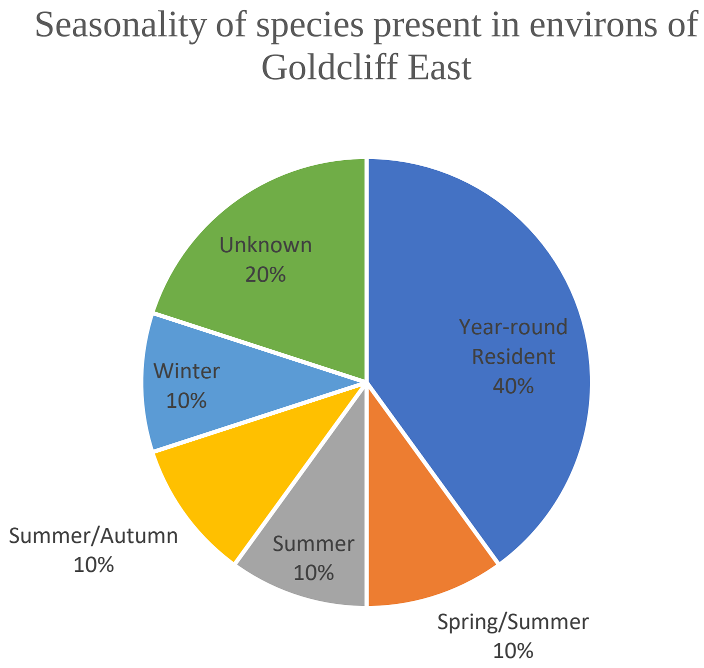


Figure 9.7 Pie chart demonstrating the differences in seasonality of the Goldcliff Island avian species

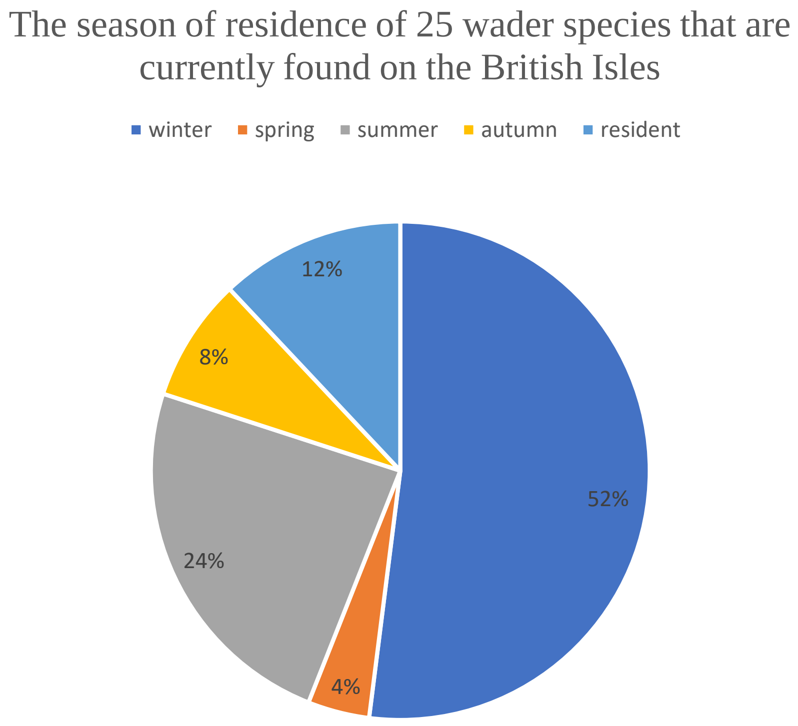


Figure 9.8 Pie chart showing the percentages of the seasonality of 25 small wader species currently found in the British Isles (Hume 2014)

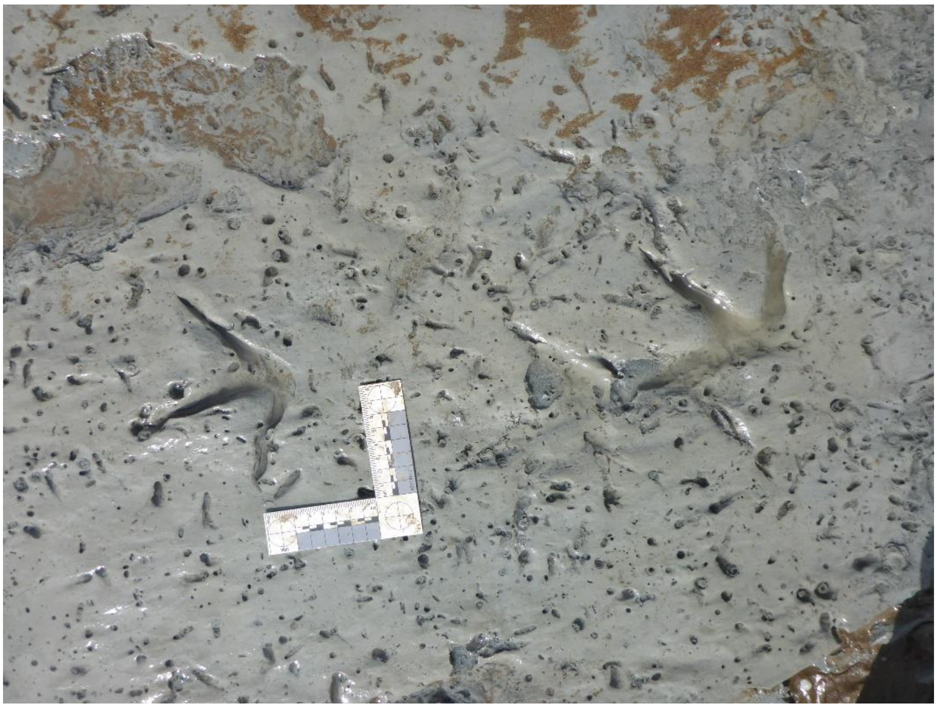


Figure 9.9 Common crane footprint area 2015:87 at Site C/E, made on fine-grained sediment. Scale 1cm divisions

9.5 The faunal record inferred from mammal bones and footprint-tracks

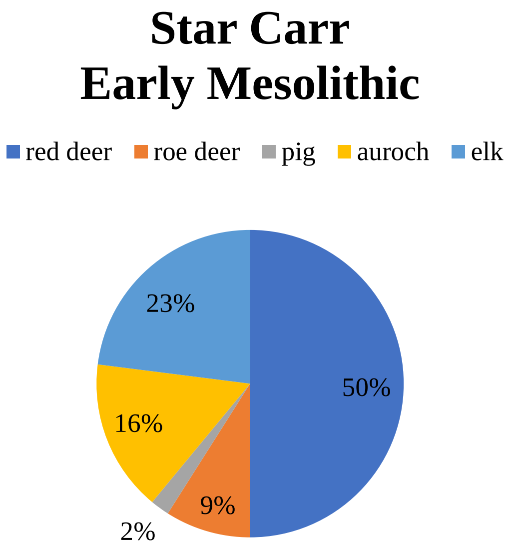
The Early Mesolithic large game of Britain included aurochs (*Bos primigenius*), elk (*Alces alces*), red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*), though by the Late Mesolithic elk already seemed to have become locally extinct, possibly due to habitat changes (Grigson 1981). Large fauna are thought to have had a profound effect on the habitats in Britain, with their trampling and grazing likely to have affected woodland regeneration and altered the woodland species diversity (Maroo and Yalden 2000).

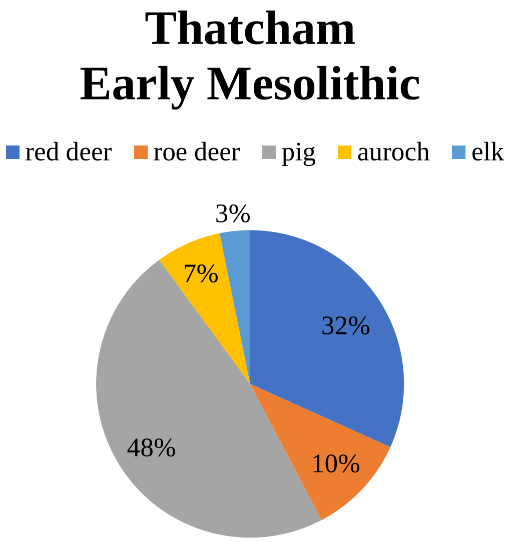
Previous research at Goldcliff Island indicates the faunal record included red and roe deer, aurochs, wild boar (*Sus scrofa*) and wolf (*Canis lupus lupus*) at Goldcliff East, as well as evidence of these species with the exception of aurochs and addition of otter (*Lutra lutra*) at Site W, Goldcliff West (Table 9.5; Scales 2007b, p 162).

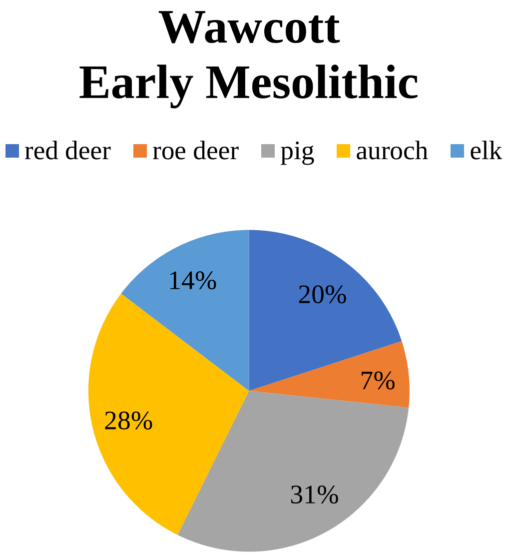
Species present in environs of Goldcliff Island	Goldcliff East bone assemblage	Goldcliff West bone assemblage (SiteW)	Goldcliff East footprint-track assemblage
Red deer (*Cervus elaphus)*	Sites A, B, & J	Present (1202)	Sites A, B, C, E, F, G & J
Roe deer (*Capreolus capreolus*)	Sites A, B, & J	Present (1202)	Possible presence at Sites C & J
Aurochs (*Bos primigenius*)	Sites A, B, & J	Absent	Sites B, E & N
Wild boar (*Sus scrofa*)	Sites A, B, & J	Present (1202)	Absent
Otter (*Lutra lutra*)	Absent	Present (1202)	Absent?
Wolf (*Canis lupus*)	Absent	Present (1202)	Near Site C?

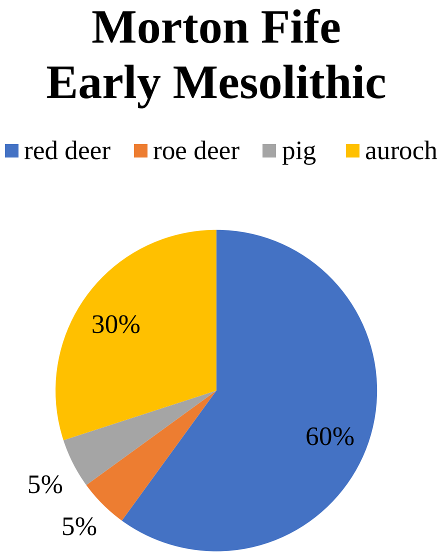
Table 9.5. Species within the environs of Goldcliff Island (Coard 2000; Scales 2007b), additions by author

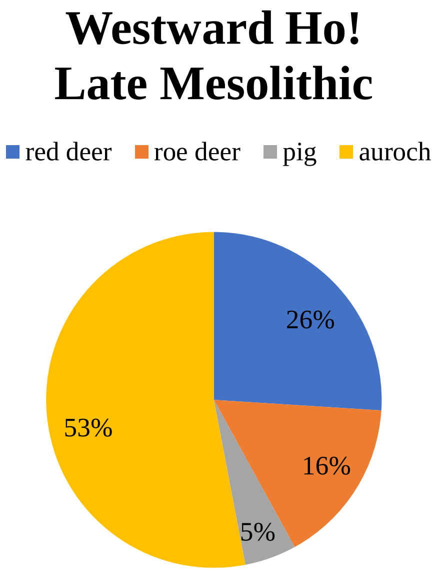
There are multiple sites in Britain that can assist in our understanding of the meat sources being exploited by hunter-gatherers during the Mesolithic. Figure 9.10 is a pie chart representation of the most common meat sources being consumed among Mesolithic people from differing geographical locations across the British Isles. Red deer and pig remains are found at all nine of the sites represented, however the overall species compositions are variable and demonstrate that there was not a specific meat source that was exploited during the Mesolithic.

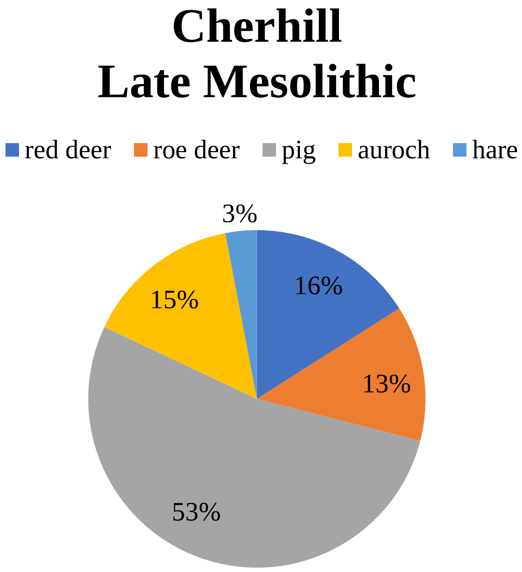

Star Carr
Early Mesolithic


Thatcham
Early Mesolithic


Wawcott
Early Mesolithic


Morton Fife
Early Mesolithic


Westward Ho!
Late Mesolithic


Cherhill
Late Mesolithic

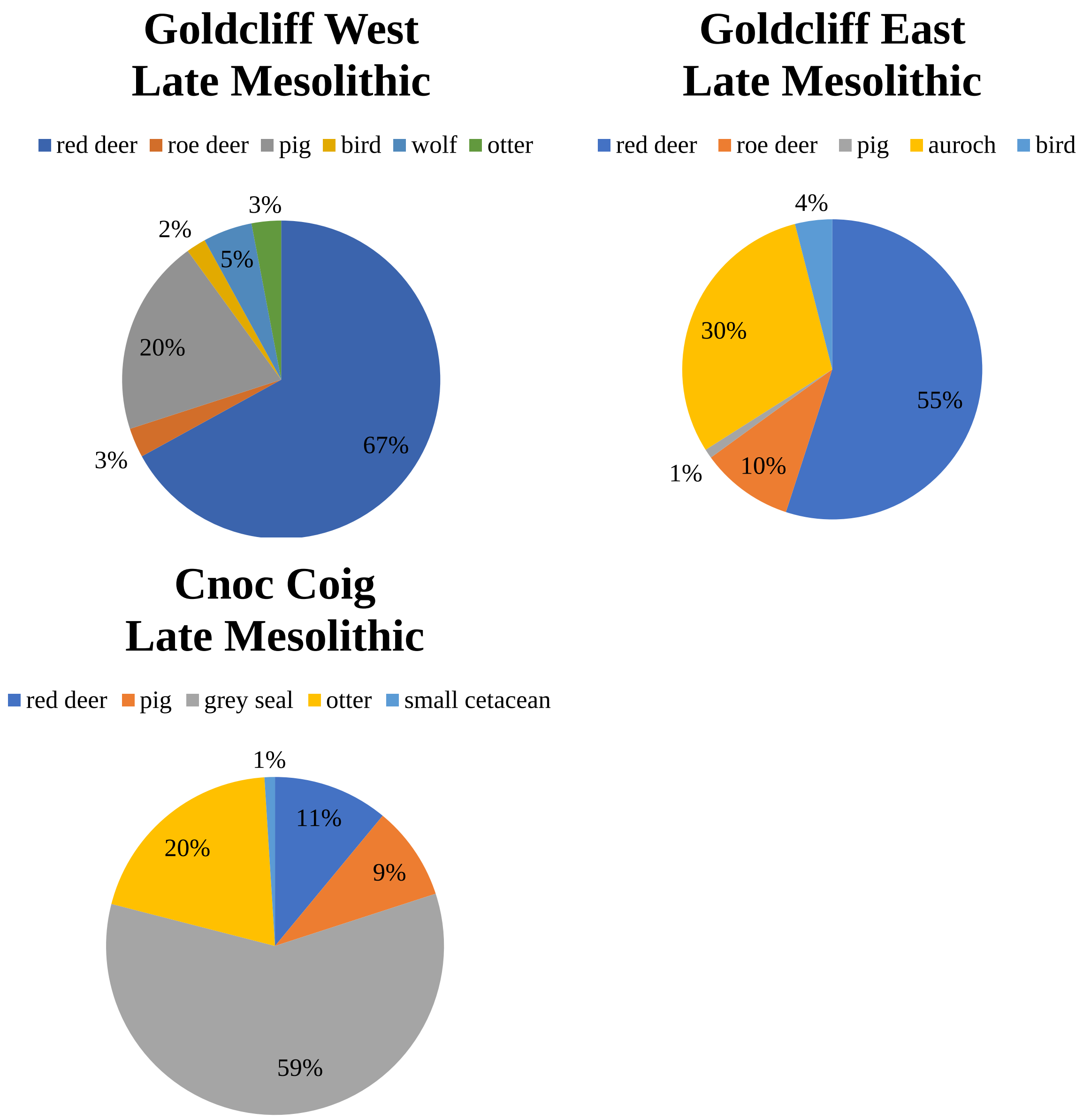


Figure 9.10, percentages of species from number of bones identifiable to species recorded at different Mesolithic sites. ***A****) Star Carr assemblage based on 1087 bones (Legge and Rowley-Conwy 1988), radiocarbon dated 9670 ±100BP (OxA-4577; 9300-8700 cal BC) to 9060 ±220BP (OxA-4450; 8800-7500 cal BC; Dark et al. 2006).* ***B****) Thatcham assemblage based on 189 bones (Wymer 1962), dated 9200±90 BP (OxA-2848; 8636-8261 cal BC; Hedges et al. 1994).* ***C****) Wawcott Sites XV, XXX based on 75 bones (Carter 1975).* ***D****) Morton Fife based on 12 bones, dated c.8050 BP (Coles 1971).* ***E****)Westward Ho! assemblage based on 19 bones, dated c.6585 BP (Grigson 1978).* ***F****) Cherhill based on 122 bones, 5280 BC (Evans et al. 1983; Grigson 1978).* ***G****) Goldcliff West assemblage based on 139 bones, 5820±50 BP (GrN-24143; 4790-4540 cal BC; Bell et al. 2000; Coard 2000)* ***H****) Goldcliff East assemblage based on 108 identifiable bones, 7002±35 BP (OxA-13927; 5985-5784 cal BC) to 4978±27 BP (OxA-14023;*

*3910-3660 cal BC) (Bell 2007). **I**) Cnoc Coig based on assemblage of 761 bones, radiocarbon dated c. 6000-5400 BP (Grigson 1978).*

9.5.1 Red deer and roe deer

During the research period of 2014-2017 there were not any footprint-tracks found that were convincingly made by mammals at Goldcliff East, though one footprint-track at Site R may have been from red deer. The footprint areas recorded in this study were more eroded than those studied by Scales (2006), and it may be that mammal footprint-tracks may have been mistaken for heavily eroded or incomplete human footprint-tracks. Scales (2006) recorded 83 red deer footprints and five roe deer during her research, although three of the roe deer may have been red deer juveniles. There was also ungulate evidence recorded at Uskmouth by the writer (Figure 9.11), a site approximately 4km west of Goldcliff East. Uskmouth was only visited on one low tide, with ungulate footprint-tracks discovered on trampled clayey silt laminations below a peat shelf, resulting in a number of unclear footprint-tracks. The most extensive laminations were 5m in length and 2m in width, with a further trampled lamination approximately 10cm under the top laminations, and again approximately 5m in length and approximately 1m in width. From these two large trampled laminations, 11 footprint-tracks were well-preserved enabling dimensions to be obtained (Figure 9.12 and 9.13).

Of the 11 recognisable ungulate footprint-tracks recorded from Uskmouth, all were made by a deer species. Four of the footprint-tracks were between 5.5cm and 6cm in width and 6cm and 6.5cm in length, likely adult females. One footprint-track was similar in length to a full grown red deer, likely a male, and five of the footprint-tracks were much larger than modern red deer (9cm), ranging from 10cm and 12cm indicating full-grown stags. The final footprint-track was either a roe deer or a juvenile red deer. The footprint-tracks that could be identified all had closed toes, suggesting the animals were not moving quickly and likely grazing. The red deer footprint-tracks made on the laminated sediments were often larger than those from footprint-track field guides (Figure 9.14; Lawrence and Brown 1967; Bullion 2014; Baker 2013), which may be due to larger red deer than today or the footprint formation process. Formation is affected by the plasticity of the sediment, gait and speed of movement, and the way the foot has come into contact with the sediment, which can result in a range of footprint sizes from just one individual. Appearance of the footprint is therefore significant, with each footprint considered independently of the other data.

The herd composition suggested by this evidence indicates that this herd had a dominant male who would have been there to breed. The rut currently occurs in September/November and then the stag will generally stay with the females until June/July when the oestrous period is over

(Figure 9.15). Calves are mainly born in May/June, so the appearance of very small deer footprint-tracks among large stag and hind indicates that this is likely a red deer neonate born before the male had left the herd. If rutting, oestrous, and birthing patterns of red deer are similar today as those in prehistoric Britain (Ahlen 1965; Darling 1937), then these footprint-tracks were likely to have been made between May and July.

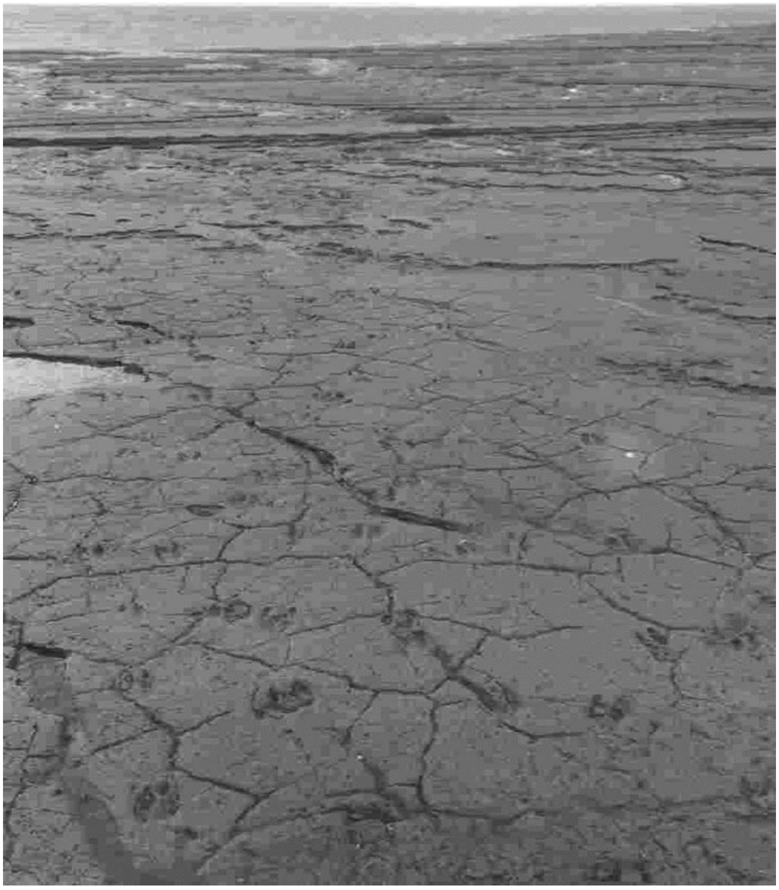


Figure 9.11 Laminations trampled by ungulates at Uskmouth, photographed by M. Bell in 1994

Figure 9.12. Adult red deer footprint-track, and probable juvenile footprint-track from Uskmouth. Scale in cm

Figure 9.13. Large red stag footprint-track recorded at Uskmouth. Scale in cm

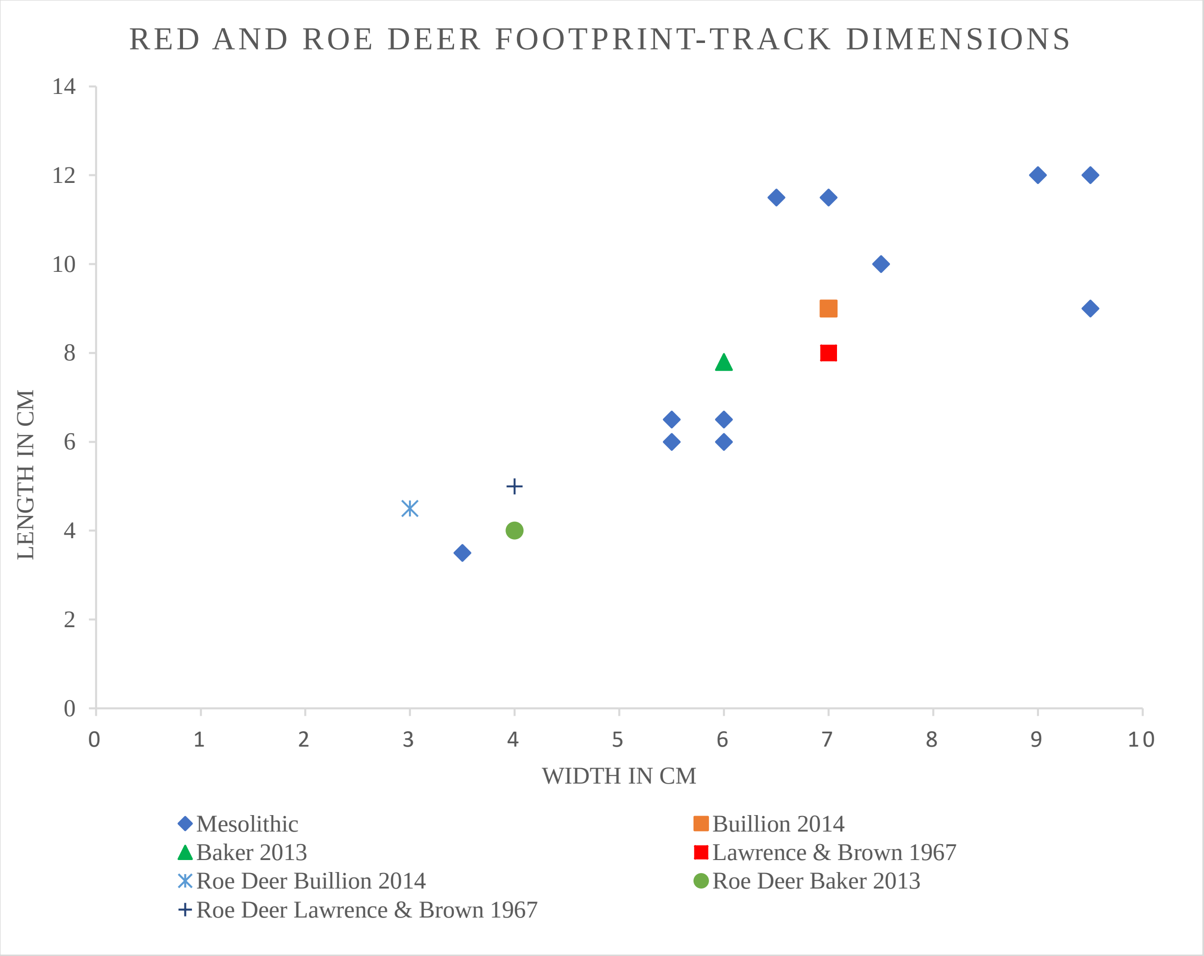


Figure 9.14. Uskmouth deer footprint-tracks plotted against measurements for red deer and roe deer found in footprint tracking literature

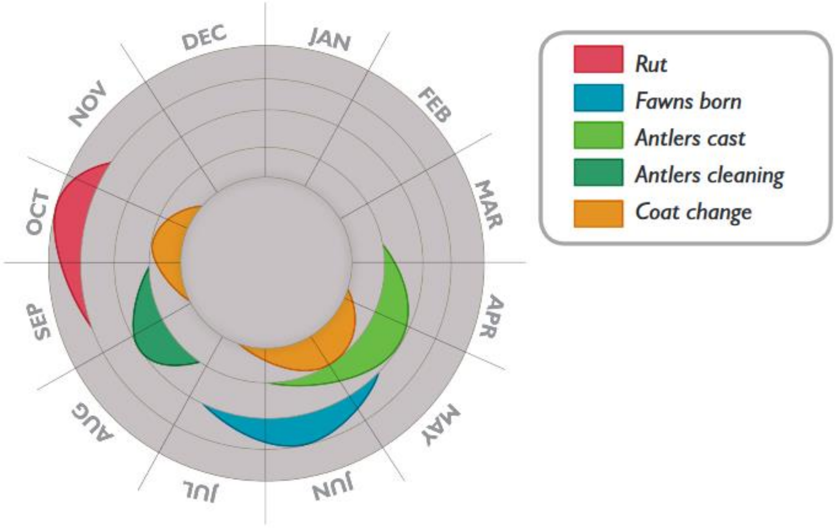


Figure 9.15. Yearly cycle of modern red deer behaviour (The Deer Initiative 2008a)

Exploitation of fauna at Goldcliff and the surrounding sites indicates that red deer may have made up a large proportion of the hunter-gatherers' diet, with half the faunal remains recorded at Goldcliff East, and two-thirds of the Site W assemblage at Goldcliff West made up of red deer remains (Scales 2006). Antler tools were also found, with an unstratified antler mattock-hammer discovered near Site C, a split antler from Site B, and bone scrapers probably used for processing and scraping red deer skins which were found in Site J (Bell 2007). These artefacts could have been bought in from elsewhere, and so are not necessarily an indication of seasonality (Fraser and King 1954b, p 93), however red deer footprint-tracks recorded at Goldcliff East (Scales 2006), and trampling recorded at Uskmouth indicate that deer were physically in the area.

Goldcliff and Uskmouth provided an environment that was favourable to red deer due to the mineral rich marshes, and at Goldcliff there was woodland habitat at the edge of the island. Red deer today will still exploit salt marshes for rich grazing, such as the Teifi marshes, Pembrokshire (Wildlife Trust of South and West Wales n/d). Red deer have been documented at a variety of Mesolithic and Neolithic sites across Britain, with red deer footprint-tracks found at Druridge Bay and Low Hauxley in Northumberland, Formby Point, Merseyside and Lyndstep II, Pembrokeshire, along with skeletal remains, among others (Cowell *et al*. 1993; Eadie & Waddington 2013; Huddart *et al* 1999b; Jones 2010; Tooley 1970). A further example comes from the submerged Mesolithic landscape at Seaton Carew, Durham. This site had a trampled land surface underneath peat with evidence of red deer footprint-tracks (Figure 9.16), these footprints were splayed and indicate that the animal may have been running. Skeletal remains of red deer and auroch were found in a similar area to the red deer footprints which may indicate that these deer were being hunted (Rowe 2015). Ungulate footprints such as these are often mentioned briefly in site reports, meaning that there may be more footprint-track sites that are relatively unknown due to the little importance given to mammal and avian footprints.

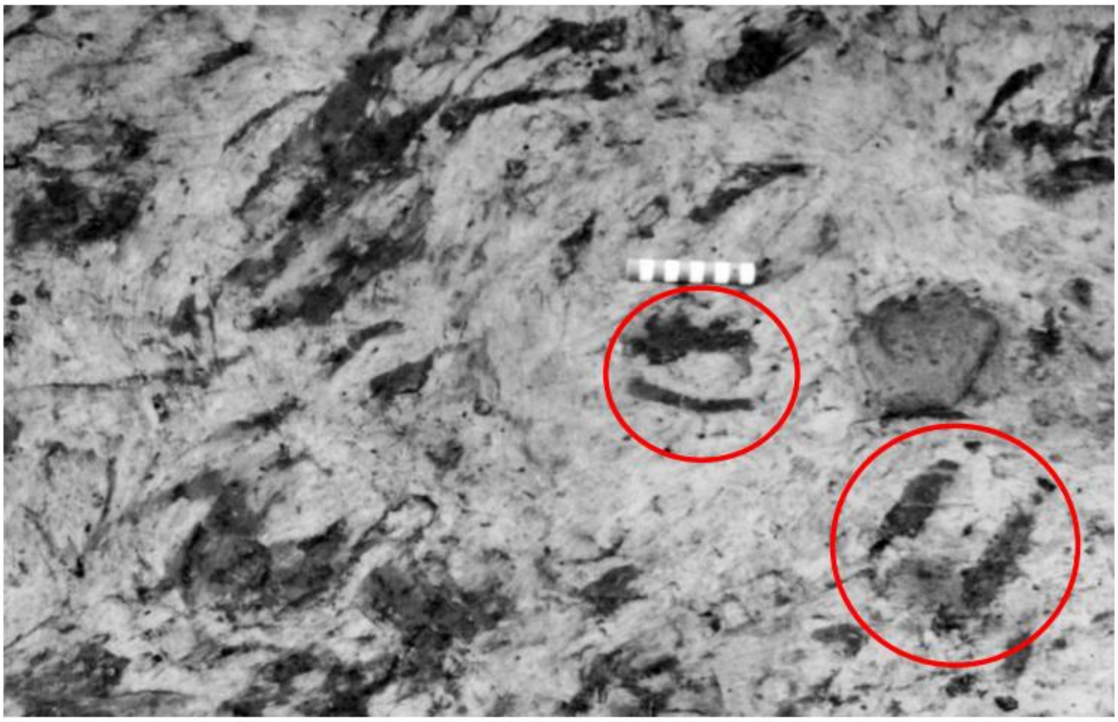


Figure 9.16 Evidence of a trampled Mesolithic old land surface at Seaton Carew, Durham, where ungulates, likely red deer, had been running (Rowe 2015)

The dominance of red deer at Mesolithic sites suggests that this species was a staple food source for Mesolithic hunter-gatherers, even in coastal sites. Jarman (1972) analysed 165 European Mesolithic assemblages and summarised that these were dominated by the remains of red deer and pig, with the mean number of red deer almost double that of pig. This predator-prey relationship may have improved the health of the deer herd and their overall survival. The two trampled laminations discovered at Uskmouth indicated that deer were continuously using this area for many years, or were returning yearly to this area as a safe place to birth their calves. The evidence of juvenile red deer footprint-tracks at both Uskmouth and Goldcliff, as well as evidence of large stag and hind present within the herd supports this theory. As Mesolithic humans favoured red deer as a protein source they may have treated these herds with care to ensure their own survival, creating a stable ecological relationship which would last over a long period (Jarman 1972). Of the red deer assemblage at Star Carr, Jarman (1972) noted that 70% of the animals that had been killed were male; however re-examination of the remains, excluding the antlers, suggested that the male to female ratio was fairly equal with no predominance to culling males (Legge and Rowley-Conwy 1988, p 58). Legge and Rowley-Conwy (1988) found that of the 541 red deer remains, approximately 60% were from individuals aged between 3-5 years old and had been culled during a late stage of dental maturity. Red deer aged 3-4 years old are at an age when they leave their mothers, with the males leaving earlier than the females. At this age red deer are more vulnerable and so would be easier to kill, it is therefore thought that red deer bones which were around this age would be more likely to be male (Legge and Rowley-Conwy 1988, p 44). The age range of 6-9 years old was also prominent, at this age the remains were more likely female as a greater number reach this age (Lowe 1969). There were also the remains of at least five juveniles/neonates in the Star Carr assemblage (Legge and Rowley-Conwy 1988, p 44). This assemblage indicates that this site was likely occupied during the spring/summer months when deer have their young, with juvenile roe deer remains also indicating a spring/summer focus.

The culling of young males allows the dominant red deer stags to be more successful during rutting season and thus ensure that the majority of females in a herd are impregnated, allowing the herd to become more successful as a result (Deer Initiative 2008a,b). There is very little skeletal evidence that has survived at Goldcliff East that may enable the age of the animals to be determined; the land surfaces were trampled which caused fragmentation to many of the bones (Scales 2007b, p 160). From the red deer fragments observed it was evident that epiphyseal fusion had occurred in all of the bones, and enamel wear on the four complete teeth indicated limited dental wear which led to the tentative conclusion that the animals within this area ranged in age from juvenile to young adults when they died. Scales (2007a) identified 11 red deer footprint-tracks at Site J; seven were adult female, three were large male, and one was small and likely a juvenile red deer calf, or possibly roe deer. The footprint evidence is similar to Uskmouth and again indicates they were probably made between May/July. The skeletal and footprint-track record at Goldcliff East indicates that these deer were probably in the area during the spring and summer months when the tidal range is reduced and saltmarsh vegetation is lush, and were being hunted by humans during this time.

Roe deer are also found within Mesolithic assemblages, though they were far less prolific than red deer (Figure 9.10). Roe deer are smaller than red deer and spend most of their lives in small family groups, or solitary, though in winter slightly larger groups may form (The Deer Initiative 2008b). Their preferred habitat is open mixed coniferous or completely deciduous woodland, and they will often spend spring and summer in open grassland areas with nearby woodland for safety. They are most active at dawn and dusk and will eat the buds, leaves and bark of deciduous trees, shrubs, ferns, herbs, conifers, heather and grasses. If predators become problematic roe deer will become nocturnal until the threat to the family group is over (The Deer Initiative 2008b).

At Goldcliff East 10% of the recorded skeletal remains were from roe deer, these skeletal remains lack the bones of the head or feet which may indicate that this species was hunted inland and their remains were bought to Goldcliff Island (Scales 2007b, p 162). Although there were possible roe deer footprints recorded by Scales (2006) from Sites C and J, these may have been made by juvenile red deer. Within the current study there was not any evidence of roe deer recorded at Goldlcliff East. On the trampled surface at Uskmouth there was one footprint-track with dimensions similar to modern roe deer (Figure 9.12), however it is more likely that this was the footprint of a juvenile red deer due to its association to other red deer footprint-tracks.

The preference for red over roe deer within Mesolithic assemblages may be due to the difference in the size of the animals, as red deer would provide more protein and resources. Red deer also travel in larger herds so may have been easier to locate and track compared to roe deer. The difficulty finding a solitary roe deer and effectively hunting it in woodland may provide an explanation for the preference for red deer at coastal and marginal environments; roe deer were more likely to have been successfully hunted inland in open grassy areas (Barja and Rosellini 2008). The other possibility is that during the Mesolithic period, red deer were more numerous than roe.

9.5.2 Auroch

Within the Mesolithic period auroch are often seen in bone assemblages (Figure 9.10), with the site of Westward Ho! dominated by auroch remains. During the fieldwork period of 2014-2017 there were not any likely aurochs footprint-tracks recorded at Goldcliff East. Previous research at Goldcliff East recorded a possible auroch footprint-track at Site B, this was noted during block-lifting and micro-excavation (Scales 2007a, p 154). The ungulate footprint-track had two large, cleaved toes and measured 11.8cm in length and 11cm in width. Figure 9.17 demonstrates the metric dimensions of this possible footprint plotted against a probable auroch footprint-track found poorly preserved in Site N during 2010 fieldwork, as well as against Neolithic/Bronze Age auroch footprint-tracks from Peterstone (Barr and Bell 2016). Both footprint-tracks from Goldcliff East are small compared to the Peterstone auroch, though the shape of the cleaves and the large width of the prints indicate they are more likely auroch than red deer.

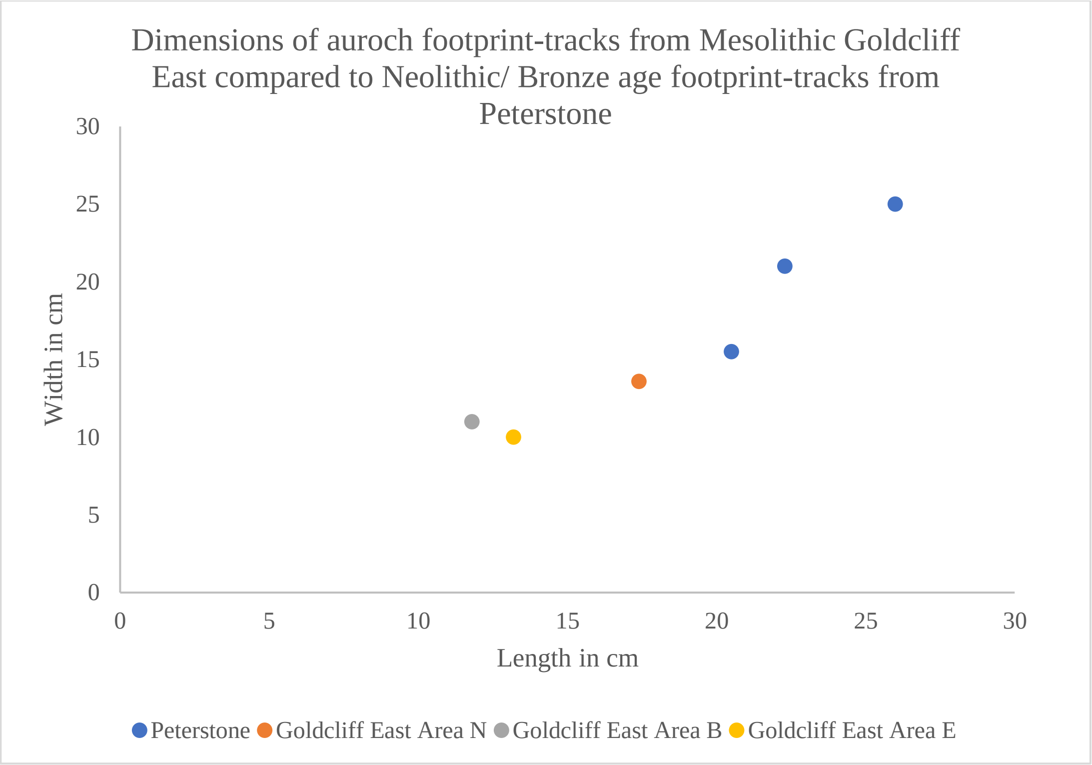


Figure 9.17 Dimensions of auroch footprint-tracks from Neolithic/Bronze Age site of Peterstone compared against those from Goldcliff East to demonstrate range of size

The skeletal remains of auroch were also found at Goldcliff East, though these may have been brought to the site from a different area. In Site J an auroch bone awl was recorded (Bell 2007, p 134), as were some bone and tooth fragments, and two long bones with evidence of butchery (Scales 2007b, p 163). The skeletal data in this area indicates that epiphyseal fusion had occurred in all bones. Of the two teeth where dental wear could be observed one was unworn and likely from a juvenile, the other worn and was from an animal that had reached dental maturity (Scales 2007b, p 162). There was also a bone from a distal end of an auroch radius that may have been utilised as a tool. Of the skeletal remains from Goldcliff East, 30% were auroch (Figure 9.10), however the footprint-track data for this species is rather lacking. What is also interesting is Site W's lack of auroch skeletal remains (Coard 2000, p 49). The footprint-tracks identified as auroch at Goldcliff East were all far smaller than the Neolithic/Bronze Age auroch footprints from Peterstone (Figure 9.17), which may indicate that young aurochs were exploiting the marginal saltmarshes of Goldcliff East, possibly for safety away from predators (Barr and Bell 2016). The saltmarsh environment may have been hazardous for adult auroch, Neolithic palaeochannels at Uskmouth and Rumney contain skeletal remains of auroch (Whittle and Green 1988; Green 1989), which may indicate that venturing out into the wetlands put these large animals at risk of becoming stuck (Bell 2007, p 236). The bone assemblage suggests that the people of Goldcliff East were processing the remains of auroch, as most body parts were represented at Goldcliff East (Scales 2007b). Auroch may have been hunted away from the wetlands and then the remains processed at Goldcliff East, which would explain the absence of auroch bones at Site W and lack of footprint-track data. There may also have been a seasonal aspect to the site occupation or usage.

9.5.3 Wild boar

Wild boar bone evidence from Goldcliff, represented by the head and feet of the animal and an absence of meat-bearing parts, suggests the pigs were being butchered on site but most of the carcass was being cooked and consumed elsewhere (Coard 2000; Scales 2007b). Juvenile and neonates were among the pig remains at Goldcliff, evidenced by dental wear, it is therefore suggested that the hunting of these animals occurred in late autumn/early winter (Coard 2000, p 52). There are not any boar footprint-tracks at Goldcliff which indicates that they were probably hunted in the woodland, as pig do not favour the saltmarsh environment (Spitz and Janeau 1995).

Wild boar bones are often found in high numbers at Mesolithic sites (Figure 9.10), the Early Mesolithic sites of Thatcham and Wawcott have relatively small bone assemblages but pig make up a large proportion of these. At Thatcham 48% of the 181 bones were from pig (Wymer 1962), and 31% of the 75 bones from Wawcott were also this species (Carter 1975). The Late Mesolithic site Cherhill also has a large percentage of pig bones, 53% of the 122 bones from this site were pig and demonstrate that this was a popular species to eat throughout the Mesolithic period (Evans *et al*. 1983; Grigson 1978).

9.5.4 Otter, wolf or domesticated dog

Site W has skeletal remains of otter (*Lutra lutra*), although this evidence is lacking from Goldcliff East (Coard 2000). Modern otters still live within this area (Figure 9.18), demonstrating the habitat is favourable to this species. There was also the possibility that the two wolf footprint-tracks, found on Site C (Scales 2006), may have been made by otter. Otter forefoot prints can look canine when made in certain sediments, they are also similar in size and shape to the prehistoric footprint-tracks, which were 5.9cm long and 6.4cm wide. The prehistoric footprint-tracks were also noted as having an absence of a central pad impression which lead Scales (2007a, p 155) to infer that this may have been a wolf which was running.

Modern otter forefeet tend to measure 6.5cm long and 6cm wide (Bang and Dahlstrom 1974). Although footprint impressions often capture evidence of webbing and the large sole pad of the foot, this is not always the case. Figure 9.19 is a photograph of a plaster of Paris forefoot footprint cast from an otter currently residing on the banks of the river Usk cast by a Natural Resource Wales volunteer. The cast was taken from an otter print found in the river sediment as the tide receded and is compared against the photograph of the Site C footprint-track. When comparing Figure 9.20, the modern otter footprint outline, against the possible wolf print from Site C, they are clearly similar. The otter footprint had no evidence of webbing, which is used as a main identifying feature in footprint tracking field guides (Bang and Dahlstrom 1974; Baker 2013). The toes were also larger than the field guides suggest, likely due to the formation of the footprint in wet river sediment; there was only a slight impression from the central pad. The Site C footprint-track did not create an impression of a central pad and all the toes were without webbing which lead to the identification by Scales (2006) as wolf or a large domesticated dog. Unfortunately, only one of the footprint-tracks was photographed due to the tide encroaching, and the quality of the photograph is poor so an accurate identification between otter and canine cannot be made. Both wolf and otter remains were recorded at Goldcliff West, there was also evidence of carnivore gnawing on some of the bones, though only eight out of the 1000 bones recorded at Site W had evidence of carnivore gnawing (Coard 2000, p 49).

Figure 9.18. Otter feeding at the RSPB Newport Wetlands site (image by David Brooks), which is an area of the Gwent Levels protected by Natural Resource Wales. Goldcliff is also part of this protected area.

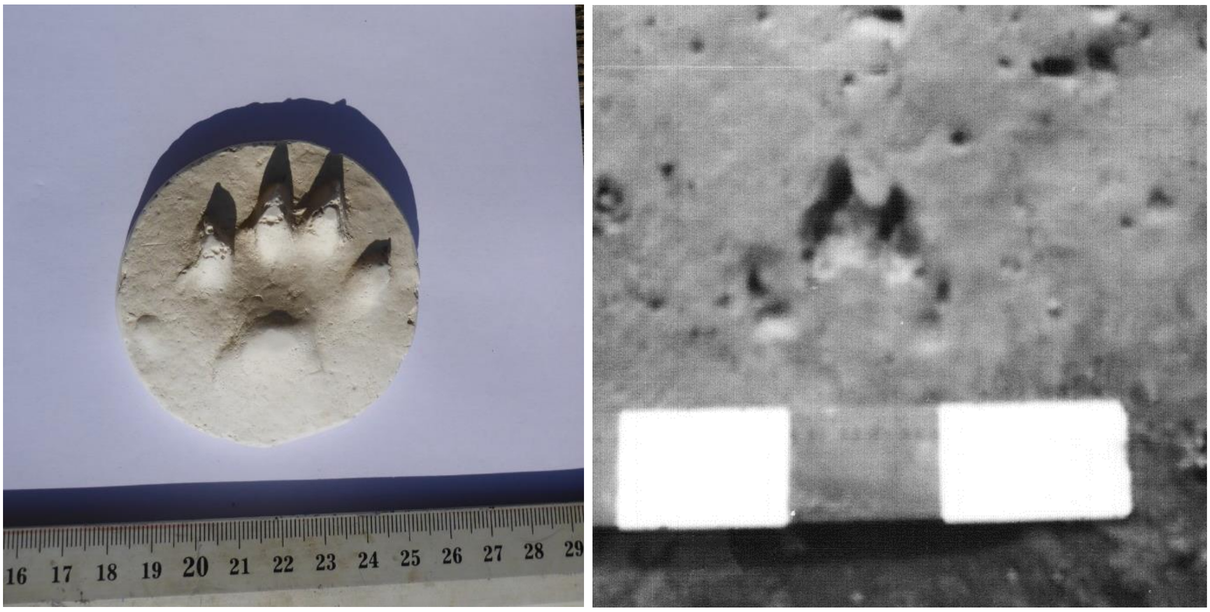


Figure 9.19. (left) Plaster of Paris cast of modern otter footprint (photographed by author). Scale in cm. (right) photograph of mammal footprint from Site C (photographed by Eddie Sacre). Scale 5cm divisions

Figure 9.20. (left) modern otter footprint morphology (by author) compared against (right) footprint morphology of Site C Mesolithic mammal footprint-track (Scales 2006). Not to scale

Within Mesolithic archaeology, otter remains have been found across Europe, though otter bone assemblages are small, with some of the earliest evidence of otter in Lundby, Svaerborg and Holmegard dated to *c*. 9500 cal BP (Winge 1919, 1924; Aaris-Sorensen 1976; Rosenlund 1980). The Early Mesolithic Former Sanderson Site on the River Colne had a faunal assemblage of 1072 bone fragments, 30.22% of these fragments were identifiable, with otter making up only 0.09%, in comparison the red deer faunal remains at this site which made up 15.86% of the assemblage (Overton 2014).

Otters at Goldcliff may have been a nuisance to the Mesolithic fisherman. In modern Amazon riverine communities, the fishermen are in direct competition with giant otters for the fish, with otters having been noted to not only eat the fish and chase them away, but also cause deliberate damage to the fishing gillets (Rosas-Riberio *et al*. 2011). This issue between fisherman and otters is documented in a variety of otter species (Gómez & Jorgenson 1999, Roopsind 2002, Carrera 2003, Gómez 2004, Recharte *et al.* 2008, Akpona *et al.* 2015), including in the Czech Republic with Eurasian otters (*Lutra lutra*) which would have been present during Mesolithic Britain (Václaviková *et al*. 2010). Eel are amongst otters’ favourite food source, which is also the marine food most exploited by the hunter-gatherers of Goldcliff (Ingrem 2000, 2007).

A further possibility is that the footprint-track was made by neither otter nor wolf, but by domesticated dog (*Canis familiaris*). It is not implausible for domesticated dogs to be at Goldcliff, as the earliest evidence of domesticated dog in Britain comes from the Early Mesolithic site of Star Carr, where there is a significant amount of carnivore gnawing on bones which were made by domesticated dogs (Clark 1954). Although the presence of domesticated dog at Goldcliff is possible, there has not been skeletal evidence of dog remains in this area and the proportion of gnawed bones is very low, only eight bones at Goldcliff exhibit gnawing. We therefore cannot know if these footprint-tracks were made by otter, wolf, or a domesticated dog as all are possibilities.

9.5.5 Summary of mammals

The footprint-tracks of mammals at Goldcliff East indicate a site full of activity, though the number of mammal footprints is lower than that represented by humans or birds. The majority of the mammalian footprint-tracks were made by red deer, the skeletal assemblage was also dominated by red deer remains (Scales 2006). The possible presence of juveniles as well as stags allows for the tentative conclusion that these animals were present during the period of May to July and were being hunted, butchered and consumed. There was limited footprint-track evidence for other species, though roe deer and auroch were also in the area, but did not venture too far into the wetlands.

9.6 Fish and marine resources

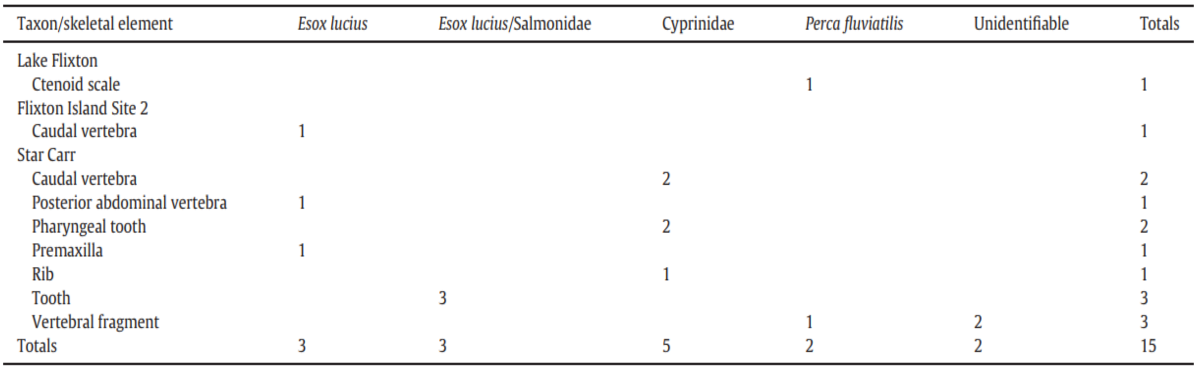
The variety of fish and marine resources may have been one of the appeals of this area to Mesolithic hunter-gatherer-fishers. Fish bones were recovered from the site of Goldcliff East by the utilisation of wet-sieving, with Site A providing the most abundant fish remains (Ingrem 2007, Table 13.3). There were 513 fragments from 6 taxa: salmon, eel, bass, bib, mullet and flatfish as well as nine fragments from possible shellfish (Table 9.6). 404 of the bones were burnt, indicating that these were likely to have been the remains of human food. At Site W, a further 812 identified fish bones were recorded (Ingrem 2000, p 53). The species recorded within the fish bone assemblage are all still found in the Severn Estuary, which provides a unique ecosystem containing approximately 110 fish species. Salmon, eels and sea trout all use the Severn Estuary as a migratory route from rivers to the sea for spawning, with the estuary having the largest eel run in Great Britain today (Severn Estuary Partnership 2016). Eel dominate the fish skeletal assemblage at Goldcliff East (83% from Site A), indicating that this species was being targeted. The majority (60%) of eel bones from Goldcliff were small (150-300mm), almost a quarter of the fish were medium sized (300-600mm) and the rest were very small, under 150mm (Ingrem 2007). Eel migrate from freshwater sources to spawn in the sea, and are generally adults of about 410mm in length when they make this journey (Wheeler 1969). As a result of this migratory spawning behaviour, eel will be numerous in estuaries and the mouths of rivers during September/October where they can be easily trapped. Almost a quarter of eel from Goldcliff would have been of migratory size, and so it can be suggested that these fish were caught in the autumn (Ingrem 2007, p 168). Modern fishing techniques capture eels with traps, nets, lines and spears, it is reasonable to think that this may have been the case in prehistory.

At Site J at Goldcliff East there was evidence of molluscs, one cockle, (*Cerastoderma edule*), one whelk (*Buccinum undatum*), and tiny periwinkles (*Littorina obtusata*, *Littorina* ‘saxatalis type’ and *Littorina littoralis)*. Mesolithic shell middens are often considered to be a defining characteristic of the Mesolithic, so the lack of heavy shellfish exploitation of this site may indicate shellfish were only eaten to supplement the diet. That said, the estuary is a very muddy environment so edible shellfish, whilst present, are not particularly abundant as they do not flourish in mud (Bell 2007, p168).

Species	**Site A**	**Site J**	**Unknown Site**	**Total number**	**Total %**
Salmon (Salmonidae)	2	-	-	2	<1
Cyprinid (cf. Cyprinidae)	1	-	-	1	<1
Eel (*Anguilla anguilla*)	415	2	8	425	83
cf. *Anguilla Anguilla*	6	-	-	6	1
Gadidae	10	-	-	10	2
Bib (*Trisopterus luscus*)	1	-	-	1	<1
Bass (*Dicentrarchus labrax*)	44	-	-	44	9
cf. *Dicentrarchus labrax*	6	-	-	6	1
Sand eel (cf. Ammodytidae)	1	-	-	1	<1
Mullet (Muglidae)	3	-	-	3	1
Flatfish	4	-	1	5	1
Shellfish (?crab)	9	-	-	9	2
Total %	502	2	9	513	100

Table 9.6. Evidence of fish remains at Goldcliff East (Ingrem 2007, Table 13.3)

There is limited evidence of extensive fish exploitation from the Mesolithic in the British Isles, although Oronsay in Scotland (Mellars and Wilkinson 1980; Mellars 1987) and Ferriter's Cove in Ireland (Woodman *et al*. 1999) are important assemblages. The Early Mesolithic site of Star Carr was considered to have no evidence of fish remains (Wheeler 1978), which was surprising due to its proximity to Lake Flixton. Further investigation of the site of Star Carr utilising excavation, sediment coring, flotation and microwear analysis indicated that a small amount of fish remains were present (Figure 9.21; Robson *et al*. 2016), though in a far smaller amount to that of Goldcliff. It is thought that the previous absence of fish remains at Star Carr was due to lack of sieving, the acidity of the sediment and the bones being unburnt when deposited on dry land which would limit the likelihood of preservation (Robson *et al*. 2016). In contrast, the fish bones from Goldcliff were mostly burnt, preserving the assemblage (Ingrem 2000, 2007).



Taxon/skeletal element	*Esox lucius*	*Esox lucius*/Salmonidae	Cyprinidae	*Perca fluviatilis*	Unidentifiable	Totals
Lake Flixton						
Ctenoid scale				1		1
Flixton Island Site 2						
Caudal vertebra	1					1
Star Carr						
Caudal vertebra			2			2
Posterior abdominal vertebra	1					1
Pharyngeal tooth			2			2
Premaxilla	1					1
Rib			1			1
Tooth		3				3
Vertebral fragment				1	2	3
Totals	3	3	5	2	2	15

Figure 9.21 Results of excavation and post-excavation analysis of Lake Flixton and Star Carr (Robson et al. 2016, Table 1).

Although some Mesolithic sites lack evidence for a reliance on shellfish, there are other sites in the British Isles which exhibit evidence for more thorough shellfish exploitation. Prestatyn in North Wales has evidence of six shellfish middens; the four that were found on the wetland edge were mainly mussels, and the two within peat were mainly cockles (Armour-Chelu *et al*. 2007). Other midden evidence in southern Britain includes Westward Ho! in North Devon (dated 6000-4800 cal BC; Balaam *et al* 1987) and Portland (dated 6460-5300 cal BC; Palmer 1999), which provide evidence of larger assemblages. Scottish middens are more extensive than those found in England or Wales, with Oronsay (Mellars 1987), Morton (Coles 1971,1983), Risga (Pollard *et al*. 1996), the Forth Valley (Sloan 1984; 1989), and the Oban area (Lacaille 1954) rich in midden preservation. The Oronsay middens included grey seal (*Halichoerus grypus*), otter (*Lutra lutra*), common seal (*Phoca vitulina*) and a small amount of cetacean bones (Grigson and Mellars 1987). There were also red deer and wild boar in this assemblage, though these were not thought to be living on the island, which was likely too small for such large grazing mammals to live. This supposed difference in subsistence behaviour between Scotland and the rest of the British Isles may be as simple as preservation, as the Scottish middens were on raised later Mesolithic shorelines (Armour-Chelu *et al*. 2007). It may also represent a fundamental difference in subsistence strategies, indicating the hunter-gatherers of Scotland exploited the marine sources rather than focusing of terrestrial food resources which may have been more difficult to obtain. The people of Oronsay for example, would have had to travel over water to get large terrestrial game.

Other Scottish middens are smaller than that of Oronsay, and are perhaps more representative of the hunter-gatherer-fishers of Mesolithic Britain and their dietary preferences. Loch a Sguirr, Skye, contains a small rock shelter with the remains of a midden inside (Hardy and Wickham-Jones 2009), whilst the midden at Sand, Applecross, was built up over one or two extensive episodes, with a focus on shellfish exploitation (Hardy and Wickham-Jones 2009; Milner 2009a). Middens can provide an insight into the dietary preferences of prehistoric people, with puffin remains prevalent at the midden in An Corran, as well as salmon/trout, gadids, roe deer and red deer, again indicating that a mix of marine, avian and terrestrial animals were consumed (Bartosiewicz 2012).

Mesolithic fishing sites in Europe are extensive; Denmark in particular is abundant in Mesolithic fish assemblages and indicates that the exploitation of one fish species above others was not uncommon (Aaris-Sorensen 1980; Enghoff 1986; Noe-Nygaard 1983b). The people of the Ertebølle culture did a lot of fishing, with their middens containing large accumulations of fish bones and oyster shells from at least 41 species (Enghoff 1995, p 67). Their skeletons have an oxygen isotopic composition which suggests marine resources played a key part in the diet (Tauber 1993). Evidence of Mesolithic fish traps are also found in Denmark and compliment the fish bone assemblage to indicate that fishing was an important subsistence practice (Pedersen 1995; Pedersen 1997, p 140), with lime-based nets, fish hooks and harpoons being common finds from Mesolithic settlements (Andersen 1995). At the centre of an ancient lake at the site of Zamostje 2, Moscow, Russia, 300 wooden artefacts including fish traps, weirs, paddles and fish screens were recorded and dated between Late Mesolithic and Early Neolithic. One of the fish traps was C14 dated to 6550 ±40 BP (Beta-283033; 5560-5470 cal BC), an Early Neolithic date (Lozovskaya and Lozovski 2016). At the bottom of a prehistoric reservoir, lying close to three Early Neolithic fish traps, a fishing screen dating to the Late Mesolithic was recorded, indicating that this site was exploited for fishing over hundreds of years (Lozovski *et al*. 2013).

Enghoff (1995) has classified approximately 100,000 fish bones from Mesolithic coastal sites in Denmark and has found that the fish being caught in the area were caught in stationary fish traps and were fish species present near the coastline during the summer months, though eel seem to be a target. Eel are a food source that is high in fat, protein and vitamins (Suhr 1972, p 493), and are simple to preserve by smoking so did not need to be consumed immediately (Pedersen 1997, p 141). Complete and fragmentary eel baskets have been discovered throughout Denmark, with one example from a refuse layer in Villingbaek, N.E. Zealand dated to 7280-7040 BP (Kapel 1969).

In Denmark, archaeologists working on the Fehmarn Belt Tunnel Scheme discovered at least two prehistoric human footprint-track trails along the edge of a post-and-wattle fish trap (Museum Lolland-Falster 2014). This site is unique; not only does it contain a prehistoric fish trap, but proof of the people who were using these for fishing, with evidence that they had repeatedly repaired and moved part of the catch system to enable it to remain functioning.

In Britain, there are few examples of Mesolithic fish traps, there has so far only been two found in Ireland. The main example was found in Dublin Docks, Ireland and dated to the Late Mesolithic (McQuade and Gowen 2007). There have been Neolithic fish traps found, with a fish trap from Seaton Carew, Durham (Figure 9.22), radiocarbon dated to the Neolithic period (3950-3650 BC). This fish trap was woven mainly out of hazel and is thought to have acted as a funnel to encourage the fish to swim into some sort of basket (Rowe 2015).

Stationary fish traps are a considerable investment, they take skill and time to make and there needs to be a large quantity of building material in the area to make them and maintain them. Individuals also need to have an understanding of their environment so that they can be in the right place at the right time for important migratory events, such as salmon and eel. Once they have been built however, they need minimal effort to operate and can provide a large protein source (Pedersen 1995, p 85).

Figure 9.22. Neolithic fish trap at Seaton Carew, Durham (Rowe 2015)

Possible fragments of a wooden fish trap at Goldcliff East were recorded in Site L, found in 2002 between Site H and the lower submerged forest (Site I). Site L was a marked channel feature, where three small pointed stakes were recorded in the laminated silts. There were four pieces of wood, as well as seeds and two hazelnut fragments found in this area, with a further 14 small pieces of wood found in a similar area when the channel was observed a year later (Bell 2007, p 50). A recent find on the Severn Estuary provides much more convincing evidence for a Mesolithic fish trap. On the final visit to Goldcliff East for this research in 2017, a wooden structure was revealed, less than 30m west of Site N, and was named Site T. The wooden structure lay along the edge of a palaeochannel and is made of roundwood posts at intervals of c 1m with wattlework woven round to create a fence, one is in the form of a v-shape fence structure which would presumably have led fish into basket traps. It is not clear if the 18m length is one trap or shorter lengths of smaller traps on a similar alignment. The alignment is well preserved in places, eroded away or below water in others. This structure was ^{14}C radiocarbon dated to 6107 ± 45 BP (UBA-35012; 5210-4912 cal BC). The human footprint-tracks from Site N are all on a similar axis to this fish trap, heading south-west towards Site T, and north-east away from the fish trap, almost at right angles to the palaeochannel. Site N is east of Site T and given the dip of the laminated sediments is likely to be later in date and related to another fish trap at a time when the channel had migrated further to the east, possibly to Site L. The bones of fish, predominately eel (Ingrem 2007), and the fish trap and footprint-track evidence indicate that the people of Goldcliff were fishing in this area.

9.7 Human footprint-tracks

Almost all human footprint-tracks from Prehistoric Europe are unshod. A possible exception to this is the Neolithic site of Yenikapı, Istanbul, Turkey, where 390 footprints have been recorded, many of which are clearly shod (Figure 9.23; Polat 2013). The earliest evidence of shoes from Eurasia comes from Areni-1 cave, Vayots province, Armenia (Figure 9.24). This shoe was made of leather and dated to 3627–3377 Cal BC, from the Chalcolithic period (Pinhasi *et al*. 2010). The shoe is 24.5cm in length, between 7.6cm and 10cm in width and was worn on the right foot of an individual. A single piece of leather was used to make this shoe, which would have wrapped around the foot and includes a section of upper leather which covers the front and middle of the foot (known as the vamp). The heel and hallux caused the most wear, this occurs when a person has a normal gait as the heel and hallux are the two parts of the foot where most pressure is asserted (Pinhasi *et al*. 2010). Further European evidence of shoes comes from Ötzi the iceman, dated to 3365–3118 Cal BC (Kutschera 2000). Only parts of Ötzi’s footwear remained preserved, with deer and bear leather creating a sole and an upper part of the shoe (Goedecker-Ciolek 1993). Ötzi's footwear is atypical to other evidence of shoes in prehistoric Europe, as shoes are generally made with one piece of leather and include a vamp (Pinhasi *et al*. 2010). Examples of shoes can also be found preserved on prehistoric bog bodies, including the Bronze Age site at Ronbjerg Mose, Denmark, where one-piece cow hide shoes have been recorded (Hald 1972).

All Mesolithic human footprint-tracks recorded at Goldcliff East were made by people who appear to be unshod, with the single exception of an individual recorded by Scales (2006) who was thought to be wearing a kind of footwear, similar to moccasins. The wetland environment would have been unstable underfoot so the removal of footwear may have been considered necessary to prevent damage to the footwear and to enable a firm grip on the sediments.

The footprint-track evidence from Goldcliff East can be utilised to make inferences about the people who were present on the estuary, their statures, age and their activities.

Figure 9.23 Footprints recorded at Yenikapı, 88 of the best footprints were casts and several were made by feet that were shod (Today Zaman 02.04.2012)

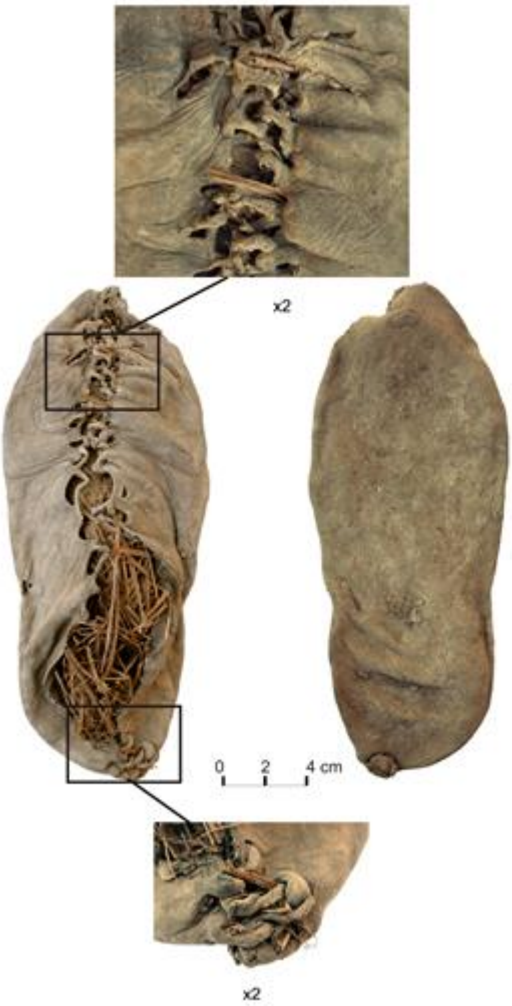


Figure 9.24 A leather shoe discovered at Areni-1 cave, Vayots province, Armenia (Pinhasi et al. 2010)

9.7.1 The people of Goldcliff and other prehistoric hunter-gatherers

An understanding of the Mesolithic hunter-gatherer demographic is complicated by the lack of human skeletal remains at Goldcliff East. The largest collection of Mesolithic human remains in the British Isles is from Aveline's Hole, Mendip Hills, Somerset, this is within the Severn Estuary region and as such is relatable to the Goldcliff East data (Figure 9.25). Aveline's Hole is far earlier in date than Goldcliff, dated between 9115±110 BP (BM-471) and 8740±100 BP (OxA-1070; Shulting and Wysocki 2002). Preservation of organic material at Goldcliff has meant that dating opportunities are excellent, and indicate that the site was visited by humans over hundreds of years, though this was likely to be sporadic visits. Optically stimulated luminescence (OSL) dating at Goldcliff East from the banded lamination containing footprint-track 2014:310 which indicated a date of 8890±790 years before 2017 (GL16185), and the lamination from Site R had an OSL date of 6620±610 years before 2017 (GL16184) (Appendix 1.2). Footprint-tracks from laminations at Site E were dated via the organic material within the banded laminations, dated to 7300±65 BP (OxA-14037; 6340-6030 cal BC; Bell 2007, p 223). The earliest horizon with artefacts at Site B was dated via the remains of a charred hazelnut to 7002±35 BP (OxA-13927; 5985-5784 cal BC; Bell 2007, p 45) and Site A was also dated from a charred hazelnut, dated to 6629±38 BP (OxA-13928; 5622-5482 cal BC; Bell 2007, p 58).

At Aveline's Hole there were originally estimated to be between 50 and 100 individuals recorded within this 'cemetery' (Anon 1805, cited by Jacobi 1987). Most of the skeletal remains from Aveline's Hole was lost during bombings on Bristol in the Second World War, and all remaining information is rather fragmentary. Ages were determined via dental wear analysis, with the conclusion that it was rare for an individual to reach the age of 50 (Schulting and Wysocki 2002). Within this sample there were five juveniles recorded, one was neonatal or perinatal, one was a baby aged between 6-18 months, one aged 2.5-4.5 years, one aged 3.5-6.5 years, and one aged 5-7 years. The children had been included within the assemblage, rather than buried separately from the adults. Schulting and Wysocki (2002) analysed the surviving data, and determined that there were 15 or 16 adult individuals present. The sexing of these individuals was problematic; it had previously been suggested that they were predominately female (Fawcett 1922; Tratman 1922). Work by Schulting and Wysocki (2002) suggests that this conclusion may be due to the small statue of the individuals. Most bones which would enable stature estimations were missing; a distal humerus was estimated to be from an adult female who was between 143cm-159cm (4'8" to 5'2"), this would be considered very short by today's standards and even short by prehistoric standards (Table 9.7).

The adults at Goldcliff East were estimated to have a stature of 166.5cm (5'5"), this was the average height for all adult individuals, as sex was difficult to establish from the footprint-tracks due to the variations in footprint formation on estuarine sediment. The smallest probable adult female in the dataset had an estimated stature of 154.9cm (5'0"); the tallest adult male had a stature of 198.5cm (6'6"). The assemblage at Goldcliff East suggests adults of both sexes were present, as were children, with a large range in stature. The results from Scales' (2006) study of footprint-tracks at Goldcliff East found the average stature of the individuals who made the footprints to be 178.7cm (5'10"). This is a 12cm height difference from the findings in the current study, and is relatively tall even by today's standards. Reanalysis of Scales (2006) data (Table 9.8), utilising the stature equations within Chapter 5, suggests that the individuals recorded may have a differing average height to that which Scales (2006) suggested, with adults averaging 169.1cm (5'6"). This is an average stature that is 9.6cm shorter than Scales (2006) original estimate, however the adjusted stature estimates in the current study are also similar to the stature estimates from other prehistoric sites (Jakes *et al.* 1997; Hedges 1984; Schulting *et* *al.* 2010). One of the explanations for this possible difference in stature estimates comes from Scales' (2006) recording technique. Scales (2006) established statures by utilising the theory that a footprint is 15% of an individual's stature (Giles and Vallandigham 1991) and estimated ages using Clark's (1990) shoe survey of age and foot size, as well as primary school children aged between 4-11 years old, who drew around their feet to provide foot size dimensions. Although this technique may work well in certain situations, specifically forensic work (Robbins 1986), the experimental work in this study indicated that footprints made upon clayey silt are more variable. The formation of a footprint on specific sediment influences the overall size, they do not always conform to the generalisation that a foot length is 15% of a person's overall stature. Bennett and Morse (2014) found that empirical data from two-dimensional footprints (such as those drawn around or ink-printed) were between 1cm and 2cm smaller than the actual foot. Three-dimensional footprints were found to be 7% longer and up to 12% wider when compared to the foot tracings. Within the current study it was found that footprints made upon clayey silt sediment could range between 2cm shorter than the actual foot, up to 2cm longer. When comparing the three-dimensional footprints to the two-dimensional, it was found that they could be up to 9.5% longer than foot tracings. We must therefore treat footprints with caution when calculating stature directly from the size, as they may be an underestimate or an overestimate of actual foot length, in these situations stature regression equations may provide more accurate results.

Scales' (2006) data from footprint-track trails has been reanalysed using the three-dimensional data and added to the results of the current study (Table 9.9). The Uskmouth and Magor Pill footprint-track data recorded by Aldhouse-Green *et al.* (1992) has also been reanalysed utilising the techniques from Chapter 5 (Table 9.10). The adults from Uskmouth and Magor Pill were tall, ranging from 172.1cm (5'7") to 188.7cm (6'2"), there were also two children.

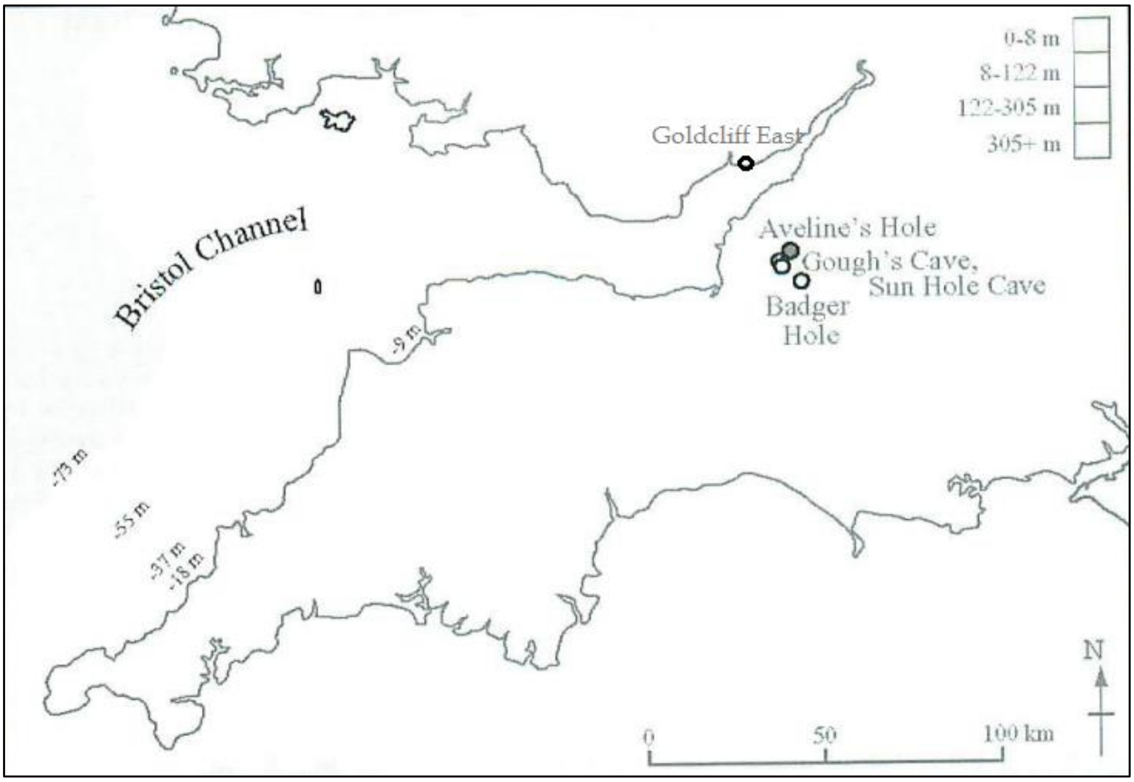


Figure 9.25. Map of Southwest Britain, showing the location of the Mendip sites, specifically Aveline's Hole. The location of Goldcliff East was added by the author to demonstrate the distance between sites (Schulting and Wysocki 2002, drawn by L. Mulqueeny).

Location	**Form of evidence**	**Period**	**Average Adult stature (cm)**	**Average female stature (cm)**	**Average Male stature (cm)**	**Reference**
Aveline's Hole, Somerset	Bones	Early Mesolithic	143 – 159	151	-	Schulting and Wysocki (2002)
Uskmouth, Wales	Footprints	Late Mesolithic	176.5	-	-	Aldhouse-green *et al* 1992
Goldcliff East, Wales	Footprints	Late Mesolithic	178.7	-	-	Scales 2006
Goldcliff East, Wales	Footprints	Late Mesolithic	166.5	-	-	Current research
Magor Pill, Wales	Footprints	Late Mesolithic	-	-	200	Aldhouse-green *et al* 1992
Totty Pot, Somerset	Bones	Late Mesolithic	170	-	-	Schulting *et al*. 2010
Sweden	Bones	Mesolithic	157.9	156.1	159.7	Ahlström 2003
Portugal	Bones	Mesolithic	-	-	160	Jakes *et al.* 1997
Formby Point, England	Footprints	Mesolithic/ Neolithic	152.5	145	160	Roberts 1995
Orkney, Scotland	Bones	Neolithic	166	162	170	Hedges 1984
Denmark	Bones	Neolithic	159	152	166	Waldron 1989
Fussell's Lodge	Bones	Neolithic	-	-	170	Brothwell and Blake 1966

Table 9.7. Stature estimates of prehistoric humans from sites in Britain and Europe

Footprint-tracks and skeletal remains from across Europe can give a further insight into the relationship between hunter-gatherers and their stature (Table 9.7). Footprint-tracks recorded at Formby Point were estimated to indicate an average male height of 166cm (5’5”) and female height of 145cm (4’9”) (Roberts 1995), this is a similar stature to the estimates made from the skeletal remains data at Aveline’s Hole. Neolithic remains recorded from Denmark also show a similar average stature estimate, with males 166cm tall (5’5”) and females 153cm (5’0”) (Waldron 1989). The average British woman is now 161.6cm (5’3”) tall, and average British men are 175.3cm (5’9”) (Office for National Statistics 2011), this is slightly taller than the average statures of individuals seen within prehistory, however there were still prehistoric individuals who were taller than today’s averages. Reanalysis of Scales’ (2006) data indicates that Person 4 was estimated to be 191.8cm (6’3”). This demonstrates the variability of heights within a small population, and that although possibly shorter than today’s average height, the people of Goldcliff East were not markedly short of stature.

Schulting and Richards (2000) performed stable carbon and isotope analysis on three humeri bones from Aveline’s Hole. Interestingly, these results indicated a primarily terrestrial diet, with very little consumption of marine foods, this lack of marine consumption could be due to their geographical location, as the site would have been approximately 100km from the sea (Figure 9.25). Although the lack of marine foods can be explained by distance to the resources, other water resources, such as river salmon, were not being consumed even though multiple water sources would have been in the surrounding landscape (Schulting and Wysocki 2002). Within the Aveline’s Hole skeletal assemblage, two of the individuals exhibited criba orbitlia, which is associated with iron deficiency; this may have been caused by an inadequate diet, or from an infestation of intestinal parasites (Stuart-Macadam 1992). There was evidence of human parasites at Goldcliff Site B and D, these are thought to be whipworm (*T. trichiura*) (Dark 2007, p 170), possibly similar to the parasites that were perhaps infesting individuals at Aveline’s Hole. Seafood is one of the most iron rich protein sources so the lack of marine foods in the diet of the people in the Aveline’s Hole assemblage may indicate the cause of their deficiencies.

Most of the Mesolithic burials from further west in the Bristol channel do show heavy reliance on marine resources but there are a few which do not (Schulting and Richards 2000, 2002a,b). This variation in terrestrial and marine diet is seen throughout the Mesolithic sites across Britain and Ireland (Figure 9.26), and indicates that there was no standard behaviour when it came to diet. The archaeological evidence from Goldcliff indicates a society that were exploiting both terrestrial and marine resources, with fishing, hunting and processing carcasses all occurring in vicinity to Goldcliff Island (Coard 2000; Ingrem 2000; 2007; Scales 2007b).

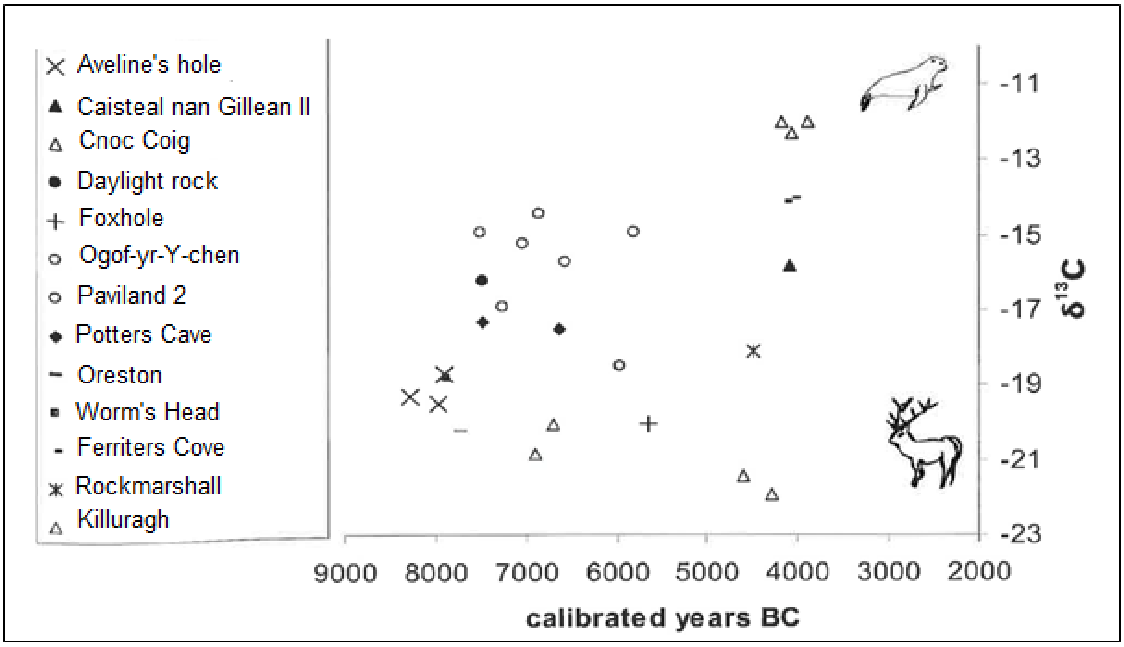


Figure 9.26 Summary graph of published carbon isotope values from British and Irish Mesolithic sites before 4000BC (Milner 2009b, Figure 1).

The assemblage at Goldcliff represents both males and females of a variety of ages. Interestingly, there were only two footprint-track trails at Goldcliff East (Person 5 and Person 6) which could be identified as adult males. From the experimental work involving contemporary footprints only one adult female and two adolescent children (one male, one female) had an average footprint length of over 27cm. Only males had an average footprint length over 28cm, and only 32% of males within the experiment had footprints smaller than 27cm. We can therefore identify Person 5 and Person 6 as adult males who were present at Site E. The presence of these tall males indicates a possible change in site usage over time. Site M, Site N and Site S are earlier sites than Site E, and they have a different direction of movement, north east to south west, as opposed to Site E which has a north-west focus. This change in direction may indicate that males were on site for a specific activity, which the area may have not been used for before that time. Person 4 from Magor Pill was also likely to be an adult male.

The sites of Goldcliff, Uskmouth and Magor Pill are relatively small, however they all contain evidence of young children, indicating that juveniles were allowed out onto the wetlands. The footprint-tracks made by children at Goldcliff were between 100-400m away from dry land, whilst the people at Uskmouth were 3.4km from Goldcliff Island and 6km away from the nearest dry land to the north. The footprint-tracks at Magor Pill were *c*. 3km from the nearest dry land in the north. This demonstrates that children were not just allowed to enter the wetland environment, but could be kilometres away from dry land.

Track-maker	Footprint length	Scales (2006) female height estimates (cm)	Scales (2006) male height estimate (cm)	New stature estimates utilising footprint equation (cm)	Height (foot and inches)	Standard error
Person 1	22.1	148	141	155.3	5’1”	7.3
Person 2	28.2	162	165	181.5	5’11”	7.3
Person 3	29.3	167	169	186.2	6’1”	7.3
Person 4	31	165	168	191.8	6’3”	8.4
Person 5	30.2	172	175	189.2	6’2”	8.4
Person 6	27	134	134	176.4	5’9”	7.3
Person 7	27.8	170	173	179.8	5’10”	7.3
Person 8	23.8	116	116	162.6	5’4”	7.3
Person 9	24.9	131	131	167.3	5’5”	7.3
Person 10	18.6	98	98	118.2	3.8”	8.59
Person 11	16.1	108	110	107.5	3’6”	8.59
Person 12	21.9	149	142	132.3	4’4”	8.59
Person 13	22.3	149	143	156.1	5’1”	7.3
Person 14	18	123	120	115.6	3’9”	8.59
Person 15	24.8	165	165	166.9	5’5”	7.3
Person 16	16.9	108	108	110.9	3’7”	8.59
Person 17	21.6	138	138	153.1	5’0”	7.3
Person 18	16.6	103	103	109.7	3’5”	8.59

Table 9.8. Reanalysis of estimated stature of individuals at Goldcliff East, originally recorded by Scales (2006). Standard error relates to new stature estimates in cm

Footprint-track number	**Foot size average (cm)**	**Age (years)**	**Sex**	**Height (cm)**	**Walking speed (kph)**	**Running Speed (kph)**	**No. of footprint in trail**	**Site**	**Seasonality of use**
2010:1-5	26	Adult	Either	161.3	7.05	6.91	5	M	-
2015:114 to 2015:115	26	Adult	Either	172.1	6.08	7.92	2	C/ E	Spring/ Summer
2015:116 to 2015:117	22	10+	Pubescent child/ Female if adult	154.9	2.77	3.34	2	C/ E	Spring/ Summer
2015:160 and 2015:163	24.3	10+	Pubescent child/ Female if adult	164	7.2	9.9	2	M	Spring/ Summer
2015:17 to 2015:20	25	10+	Either	167.2	5.97	7.74	3	N	Autumn/ winter
2016:50 to 2016:56	23.9	10+	Pubescent child/ Female if adult	161.9	5.25	6.8	7	N	Autumn/ winter
2016:73, 2016:75, 2016:100	23.2	8 to adult	Pubescent child/ Female if adult	161.1	5.36	6.84	3	R	Spring/ Summer
2016 108 and 2016:103	16.3	4 to 7 (4 to 5 probable)	Either	108.3	3.3	4.14	2	S	Spring/ Summer
2017:10 and 2017:11	13.8	4 or younger	Either	97.75	1.51	1.54	2	S	Spring/ Summer
Person 1	22.1	10+	Pubescent child/ female if adult	155.3	4.42	5.4	16	H	Spring/ Summer
Person 2	28.2	Adult	Either	181.5	3.13	4.28	9	E	Spring/ Summer

Person 3	29.3	Adult	Either	186.2	4.32	3.7	7	E	Spring/ Summer
Person 4	31	Adult	Male	191.8	2.98	3.7	8	E	Spring/ Summer
Person 5	30.2	Adult	Male	189.2	2.88		9	E	Spring/ Summer
Person 6	27	Adult	Either	176.4	-	-	4	E	Spring/ Summer
Person 7	27.8	Adult	Either	179.8	3.34	4.17	4	E	Autumn/ winter
Person 8	23.8	Adult	Pubescent child/ female if adult	162.64	-	-	3	E	Autumn/ winter
Person 10	18.6	5 to 8	Either	118.2	-	-	2	E	Autumn/ winter
Person 11	16.1	4 to 7	Either	107.5	-	-	108±10	C	Spring/ Summer
Person 12	21.9	11 or younger	Either	132.3	-	-	57±10	C	Spring/ Summer
Person 13	22.3	10+	Pubescent child/ female if adult	156.1	-	-	2	C	Spring/ Summer

Table 9.9. Age, sex, and stature estimates of individuals who made footprint-track trails at Goldcliff East. The footprint-track size, number of footprints in the trail and likely seasonality are also included. Persons 1-13 are from Scales' (2006 and 2007a) data and reanalysed using age, sex and stature estimates from the current study. The other footprint-tracks are all from within this study. Persons 14-18 are omitted from this reanalysis due to lack of data regarding full trails

Person and site Location	**Footprint-track Length (cm)**	**Age (years)**	**Sex**	**Height (cm)**	**Standard error**	**Height (foot and inches)**
Person 1 (Uskmouth)	27	Adult	Either	176.4	7.3	5’9”
Person 2 (Uskmouth)	26	Adult	Either	172.1	7.3	5’7”
Person 3 (Uskmouth)	21	10 or 11	Either	150.6	7.3	4’11”
Person 4 (Magor Pill)	30.1	Adult	Male	188.7	8.3	6’2”
Person 5 (Magor Pill)	16	4 to 7	Either	107.1	8.59	3’6”

Table 9.10. Reanalysis of the footprint-track data from Uskmouth and Magor Pill (Aldhouse-Green et al. 1992). Standard error relates to height in cm

9.7.2 Hunter-gatherer activities

A unique aspect of intertidal sites is that erosion and changes to sediment deposition result in the constant exposure of important archaeology with very little excavation work required. Fish bone evidence from Site A suggested that at Goldcliff marine resources were being exploited with a focus on eel fishing (Ingrem 2007, p 167), this area was dated through a charred hazelnut to 6629±38 BP (OxA-13928; 5630-5480 cal BC; Bell 2007, p 58). The newly discovered wooden structure at Site T, west of Site N, thought to be a possible fish trap, was radiocarbon dated to 6107±45 BP (UBA-35012; 5210-4912 cal BC), indicating that for at least 500 years this area was used for fishing. The fish bone assemblage from Goldcliff was from species that could be found close to the shore in shallow water (Ingrem 2000, 2007). The presence of the possible stationary fish trap indicates that fish traps and nets were likely being utilised so that people could walk out to their traps at low tide, possibly for basket fishing (Andersen 1995). Although we have evidence of fish bones from Site A, there have not been any fish bones recovered directly from Site T, and so we cannot say with certainty the species that was being trapped with this structure, or the season in which fishing was performed.

Site N footprint-track trails had an obvious axis of movement, moving in two directions in a belt between 50°-103° north east and 240°-250° south west. This axis leads towards and away from Goldcliff Island. The individuals who were walking away from Goldcliff Island were heading in a direction that would take them towards Magor Pill, another area where human footprints have been recorded (Aldhouse-Green *et al*. 1992). They would have been walking across laminated sediments laid down in a palaeochannel, the laminated sediments dip to the east showing that through time the course of the palaeochannel was migrating from west to east (Bell 2007, p 49). At the time of the Site N footprints, the course of the channel would have been somewhere between a few tens of meters and 150m to the east. Possible fragments of a fish trap were found in that direction in the channel during 2004 fieldwork, at Site L (Bell 2007, Figure 4.2), however they were very fragmentary so the purpose of this structure could not be identified with certainty. There is evidence of Mesolithic wooden structures that have been associated with fishing at a variety of sites in Denmark (Pedersen 1995), from the site of Zamostje 2, Moscow Russia (Lozovskaya and Lozovski 2016; Lozovski *et al*. 2013) and from a channel adjacent to the Hoge Vart site, in the Netherlands (Hogestijn and Peeters 2001). This evidence of wooden fishing structures in Europe, as well as that found at Site T, suggests that it is possible that Site L was the remains of an eroded fishing structure still within the palaeochannel, and that the people at Site N were likely exploiting this area for a specific fishing task.

It may be that people who made the footprints on Site N were not based at Goldcliff Island, but as they were using fixed fish-traps they would have had to remain relatively near the area to check their catch. Providing that they are kept moist, eel can survive a long time in a fish trap (Fischer 2007), however as otter and a variety of coastal birds were in the area it is likely that they would have checked their catch with each low tide to prevent it being stolen, up to twice a day. Stationary fishing structures would have needed to be checked for damage after each catch so that any repairs could be carried out (Fischer 2007).

The human footprint-tracks from Site N were made by individuals who ranged in approximate age from 6.5 +/-1.5 years to adult (Chapter 6; Table 6.16). 16 of the footprint-tracks were small and likely made by individuals over ten years old, who may have been of either sex, or they may have been adult females. Eight were over 24cm in length so could have been made by adult males, females, or pubescent children, and nine footprint-tracks were incomplete. The high number of footprint-tracks under 24cm and the recurrent patterns of movement along this routeway (footpath) which we can logically suppose was associated with the use of fish traps in the channel indicates that at Goldcliff it was children, adolescents and possibly adult females who were mainly involved in fishing.

Burials from the Late Mesolithic/ Early Neolithic cemeteries in Dnieper Rapids region of Ukraine suggest that children were buried in the same way as adults and were therefore fully integrated within society and playing an active role in their community from an early age. Evidence such as *Cyprinidae* teeth found within the burials suggests that fishing may have been a subsistence activity that involved children (Lillie 1997, p 222).

Ethnographic hunter-gatherer subsistence strategies can vary depending on specific groups. Roscoe (2006) found that the hunter-gatherers of New Guinea who rely on fish as their main protein source have a higher population density than those relying on terrestrial resources. Bahinemo hunters consumed minimal amounts of marine foods and had a population of 0.2 people/km^{2,} as opposed to the Waropean tribe who mainly exploited saltwater and fresh water foods, and had a population density of 25.8 people/km^2. Although this theory cannot be applied to Goldcliff East as the area was lacking in skeletal remains, Aveline's Hole is the richest Mesolithic site in Britain for skeletal remains and is part of the landscape surrounding the Severn river. The human skeletal remains date between 9115BP and 8740 BP, meaning that this area may have been used by multiple generations (Schulting and Wysocki 2002). The size of this Mesolithic hunter-gatherer population is unknown, however anthropological research finds that mobile hunter-gatherers with a population between 25-35 people who move camp several times a year are most successful, especially when relying on terrestrial food sources (Lee and Daly 1999). The Hazda people, for example, live in camps of approximately 29 (Blurton-Jones *et al*. 1992). Given the reliance on terrestrial protein sources by the hunter-gatherers at Aveline's Hole, as well as a relatively limited amount of skeletal remains across a large time periods, it may suggest that the people of Aveline's Hole had a small population to enable successful terrestrial hunting. The same is possible of the people of Goldcliff, as there is limited evidence for extensive processing and resource exploitation, which would have suggested that a large group was in the area. At Goldcliff the activity areas are small and the quantities of artefacts and bones are not extensive, there is also no evidence of middening of material which might be associated with large numbers of people or extended stays (Bell *et al*. 2000; Bell 2007), such as the extensive kitchen middens seen at Ertebølle, Denmark (Andersen 2000). The quantities of material culture are in the order of what might be expected from visits of a few days to a few weeks rather than months or sedentary occupation (Bell 2007, p 235). Multiple discrete clusters suggestive of fairly short-term occupations and high mobility by fairly small groups are an emerging characteristic of the Mesolithic which is seen at Star Carr (Conneller *et al.* 2012), at Bexhill on Sea in Sussex (Champness and Hughes 2013) and at North Park Farm, Bletchingley, Surrey (Jones 2013), among others.

9.7.3 Children and their behaviours

The presence of children is often hidden within prehistoric archaeology; footprint-tracks provide perhaps our most tangible evidence of these individuals going about their lives. This provides an entirely different perspective from the skeletal remains of children, who we know must have suffered from illness, disease, or encountered an incident which ended their lives during childhood. Oddly, within modern anthropological work, children are often omitted from research, leading Hirschfeld (2002) to explore why children are ignored. It is interesting that modern hunter-gatherer children are mainly absent from studies when the activities of prehistoric hunter-gatherer children are often also missing from the archaeological record and may indicate that as anthropologists and archaeologists we are biased towards assuming adult, generally male, activity. We know that children and adult females were present in the past, however they are often represented as just ‘there’ rather than playing an active role in society (Moore 1997, p 254), with the women’s roles confined to childcare and staying in the settlement (Derevenski 1997). It has even been suggested that within archaeology dogs are more studied than children (Moore 1997, p 255). Chamberlain (1997, p 249) argues that most prehistoric populations had a high mortality rate, and so to keep a stable or slowly growing population at least 50% of individuals would need to be under the age of 18 years old. Both children and women are being ignored in archaeology, possibly due to academic male hegemony (Moore 1997, p 252); if we are ignoring children we are ultimately ignoring half the prehistoric population.

Of the 21 footprint-track trails containing at least two footprints that have been recorded at Goldcliff East between 2001-2017, six were made by children aged less than 11 years old. The percentage of children (29%), may seem unusually high, however this is also reflected in modern hunter-gatherer societies. In Australia a study was undertaken by The Australian Bureau of Statistics (2012) to estimate the population of Aboriginal Australians with comparison to non-indigenous peoples. This study recorded that 36% of Aboriginal people were aged under 15-years-old, whereas only 18% of non-indigenous people fell into this same age bracket, indicating indigenous people had almost double the number of children as non-indigenous. Although Australian aborigines had a higher percentage of juveniles within their community, they also have a higher rate of infant mortality, with 6.2 infant deaths per 1000 births as opposed to non-aboriginal infant death rates of 3.7 per 1000 births. It is thought that the higher percentage of juveniles within the Aborigine population is due to their lifestyle and increased fertility, however their children are also more likely to die when young (The Australian Bureau of Statistics 2014).

A similarly high percentage is seen in Canadian Inuits, where again the indigenous population had a higher percentage of children than those of non-indigenous people (Statistics Canada 2011a). In 2006 the median age of an Inuit individual was just 22 years old, with 12% of the Inuit population aged under four-years-old, and a further 11% aged between four and nine-years-old, indicating 23% of the population were under ten years of age. The study also noted that 56% of the population were aged 24 or younger. In non-indigenous populations in Canada, 11% of the population were aged under ten. Again, there is an evident difference between indigenous and non-indigenous populations, suggesting that native populations have a higher number of children born to their group in comparison to non-native. Increased fertility rates are the explanation given for the larger percentage of young people within Canadian Inuit populations; it is also suggested that the lower life expectancy of indigenous people may be cause for this larger proportion of young children within society (Statistics Canada 2011b).

Figure 9.27 demonstrates the percentages of the population demographics of Goldcliff East hunter-gatherers, compared to modern Australian Aborigines and Canadian Inuits. Goldcliff East footprint-tracks represent a population demographic similar to modern hunter-gatherers, where there is a large proportion of young children. The young population seen in the Goldcliff footprint-track record may indicate a similar trend in reproduction and life expectancy as those seen in today’s indigenous populations, and may suggest that prehistoric children were engaged in intertidal activities in a similar proportion to the proportion of the overall population, behaving in similar ways to older members of the community.

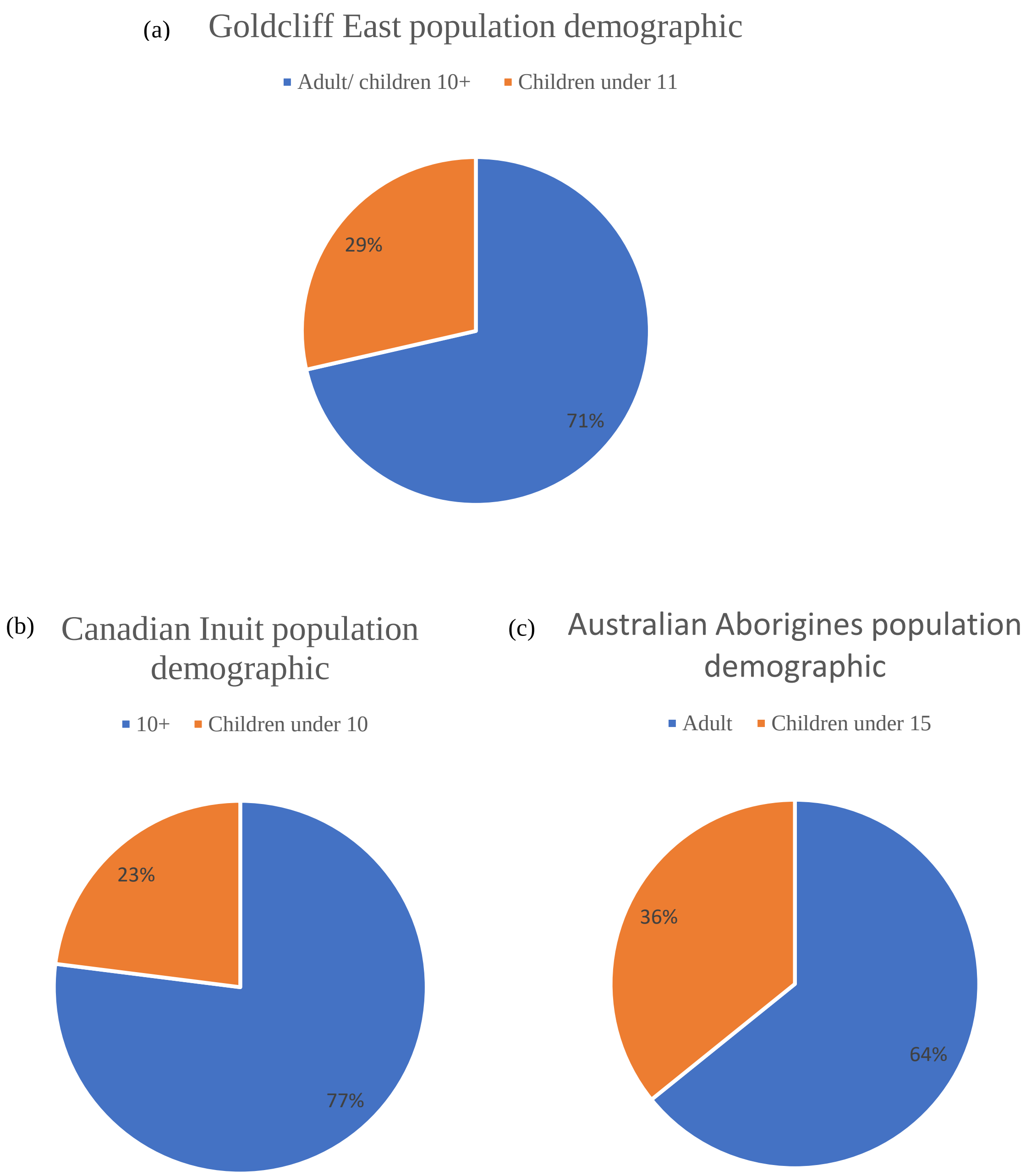


Figure 9.27 Percentages of population demographic of adults compared to children (a) Mesolithic Goldcliff East (b) modern Canadian Inuit population (Statistics Canada 2011a) (c) modern Australian aborigines' population (The *Australian Bureau of Statistics 2012)*

It may seem strange or even dangerous to allow young children into an area such as the intertidal zone where there was the danger of mud, palaeochannels and drowning, however we know through footprint-track evidence that young children were in this area. It is worth consulting ethnographic studies to understand what hunter-gatherer juveniles of a similar age in contemporary hunter-gatherer societies are doing, and what the role is that they play within their community. Though it must be stressed that there is no way of knowing with absolute certainty what the activities of these children were, contemporary hunter-gatherer societies can help us to understand what is expected of children.

Within the Efe tribe, a society of hunter-gatherer pygmies who live in the rainforest in the Democratic Republic of the Congo, the roles for the specific sexes were noted as being unimportant in terms of childcare (Ivey-Henry *et al.* 2005; Tronick *et al.* 1992). In this tribe male and female children were equally involved with the care of the one-year old infants, it was not seen as a role that females participated in any more than the males. A further example is found within Hazda society, where the fathers provide a substantial amount of care for infants and juveniles (Marlowe 2005). Although mothers and grandmothers provide post-weaning children with high-calorie foods and the males are big game hunters, the males also take older juveniles with them to hunt, travelling up to 10-15km away from the camp (Hawkes *et al.* 1995).

The roles and behaviours of hunter-gatherer children observed in ethnographical studies have been found to vary in different hunter-gatherer populations. In the Baka pygmy tribe, individuals who dwell in the Congo, juveniles were observed to rarely engage in any forms of physical activity that would be interpreted as playing whilst mimicking adult activity. Rather, children were playing to learn appropriate social interactions in a similar way as juveniles behave in non-indigenous populations, rather than just being taught survival skills (Kamei 2005). A further study observed that the children of the Nyaka, a Madagascan tribe, engaged in intense foraging, they did not do this because it was a requirement, but because it was interesting and fun and there was very little else to do (Tucker and Young 2005). In this situation, these young people were learning important skills through play, but it was not expected of them. Australian Aboriginal Mardu children aged five years old were just as efficient at hunting lizards as adolescents aged 14 years. The Mardu children were also found to be most productive at hunting when taller, success is not significantly relatable to age (Bird and Bliege-Bird 2005). Most footprint-tracks from Goldcliff East, adults and children, were made by individuals who were moving at a relatively leisurely pace, not indicative of hunting.

Hunter-gatherer children develop important skills by teaching themselves, not by being taught by adults. In the Aka tribe, children as young as six months old are given sticks or stone implements such as spears and encouraged to start moving their arms appropriately (Hewlett and Lamb 2005), and often encouraged to take an early interest in subsistence strategies (Figure 9.28). Studies indicate that hunter-gatherer children are fairly self-reliant and will gather/catch/kill/cook their own foods without a problem from a young age, in some circumstances as young as four or five years old (Figure 9.29; Bird and Bliege-Bird 2005; Tucker and Young 2005).

In ethnographic studies it has been noted that infants and young children are almost continually held or carried by older juveniles, parents, or other adults. Hunter-gatherers among the !Kung of the Kalahari desert tribe carry babies in pouches on their backs when they are under two years of age, and on their shoulders between the ages of two and four. They may be aged seven or eight before they are walking consistently alone (Lee 1972). Children of the !Kung tribe are generally not weaned from milk until four years old, and if the child’s mother is not pregnant they may carry on breast feeding until aged five (Konner 1977). The carrying of young children would enable individuals to go about their activities whilst providing comfort, food and safety for the child.

Of the footprint-tracks recorded at Goldcliff East during the 2014-2017 research period, only 3% were made by juveniles aged under four years old. This small percentage of very young people may indicate these individuals engaged in a similar practice, where the young children were held constantly by individuals within the hunter-gatherer group until they were large enough to be at less of a risk to predators or possible dangers. The footprint-tracks made by young children were generally deep but very slender. This may be an indication of juveniles being put down on the floor, either briefly to reposition the child or so that they could do some walking themselves. Continuous carrying may also explain some of the very wide footprint-tracks created by smaller footed individuals, the extra weight may cause foot spreading to occur. In previous footprint-track research it has been suggested that small but wide footed individuals were pregnant females (Roberts and Worsley 2008), however all ethnographic data indicates an almost constant carrying of small children, this extra weight may also have this effect on the foot.

There was one footprint-track trail at Goldcliff East, on Site S, made by a child aged four or younger (2017:10, 2017:11), this was on the same lamination as footprint-tracks made by a child aged four or five (2016:108, 2016:103), and within 30cm of an adult footprint (2017:12). Given the carrying behaviours of contemporary hunter-gatherer people it is plausible that this child was being carried, possibly on the shoulders. The adult may have put the child down briefly before carrying on, this may be an explanation for the lack of any further footprint-tracks on this lamination made by a very young child. They may have been in this area for a specific subsistence purpose, although the adult may have accompanied the two young children out of camp so that they could explore. Both children were walking at a slow speed, which could again indicate that they were exploring rather than undertaking subsistence strategies (Bird and Bliege-Bird 2005). Children aged under five years old in contemporary hunter-gatherer societies are often left at camp as they do not walk fast enough to engage in hunting, where they are left with adults and younger children so that they can play and explore (Konner 2005).

A further example of an individual who may have been carrying a child is seen in Site C/E. The individual who made footprint-tracks 2015:116 and 2015:117 had a stature between 150.6cm and 159.2cm (4’11” and 5’2”), indicating either a small full-grown female, or a pubescent child of either sex, travelling 3km per hour (2mph). The formation of these footprints preserved an indentation of the hallux as well as all other toes, heel, arch and ball of the foot, indicating a stable substrate was walked upon, the hallux was curled slightly into the sediment. On this same lamination, less than 20cm from 2015:117 there was footprint-track 2015:118. This footprint-track was much deeper and lacked the clear human features such as the toes that were seen in 2015:116 and 2015:117. The slow speed of movement of the individual who made footprints 2015:116 and 2015:117 and the proximity of the single footprint 2015:118 may suggest that the child who made 2015:118 was being carried by the maker of 2015:116 and 117. This hunter-gatherer may have briefly put the child down rather heavily, which would explain the deep formation of this singular footprint, before picking them up again and slowly walking off. The child who made footprint 2015:118 is estimated to be around five years old, so would have been small and light enough to carry on the shoulders when needed. It would be worthwhile to perform more experimental work (Chapter 5) to investigate the effect on an adults’ footprint-track formation when they are pregnant in comparison to carrying children of different ages.

A study by Konner (2005), on children over four years old suggested that childhood was relatively carefree, with no expectation to provide food or care for siblings. Bird and Bliege-Bird (2005; Tucker and Young 2005) conversely, suggested that there were activities and responsibilities expected of children, depending on the social-ecological conditions. They might forage close to camp, in areas where there were not predators or other immediate dangers. Their research suggested that children provided 50% of the calories that they were consuming, indicating that unlike Konners (2005) findings, the hunter-gatherer juveniles may not have been working specifically for the collective group, but they were engaging in activities that taught them important life skills and rewarded them with the ability to supply their own food.

By drawing upon the studies by Bird and Bliege-Bird (2005) and Tucker and Young (2005), it could be suggested that there may be a high concentration of children footprints at Goldcliff East because the socio-ecological conditions allowed for it. Goldcliff is an area where resources would have been rich, not only from wooded areas and the vast resources in the sea, but also the possibility of wild fowl and wetland birds and their eggs. Chapter 7 demonstrated that within the human footprint-track areas, avian footprints were abundant. This was also an area where there would likely be very limited risk from predators. Brown bear (*Ursus arctos*), wolf, wild cat (*Felis silvestris silvestris*) and lynx (*Lynx lynx*) were native predators of Britain during the Mesolithic (Maroo and Yalden 2000), however these animals were unlikely to have strayed a long way out into the wetland due to their preference for rocky outcrops, thickets and dense forests. Goldcliff Island was about 6km from dry land out across saltmarsh. The only possible evidence of a large predator within this area was recorded west of Site C, the evidence being two potential wolf footprint-tracks (Scales 2007a, p 155), though as discussed, it may have been made by an otter or a domesticated dog. If they were made by wolves, these wolves would have been a threat to children if they chose to attack, though Mech (1990) established that wolves are generally hesitant to approach humans as their upright posture is different from their other prey, which makes attack unlikely except in times of starvation. Due to the likely lack of predators within the area, juveniles were probably given more freedom to move about and engage in necessary subsistence strategies such as fishing, activity that is suggested from the footprint-tracks in Site N, and indicates that children were actively contributing to their society.

Contemporary hunter-gatherer societies are a useful source when attempting to understand the lives of prehistoric people, however it is essential to remember that although they may assist in our understanding of hunter-gathering behaviours to some level they are not likely to be representative of exact behaviours of Mesolithic people. These people will have developed and changed with their landscapes and with new situations, such as the interaction with farmers and habitat change. Surviving hunter-gather groups mostly live in very marginal environments, and so may behave very differently or for differing reasons to prehistoric hunter-gatherers. There is also variation among different hunter-gather groups regarding skills and behaviours, so it is also important to remember that these differences were likely to have been present within prehistory. A Mesolithic population is not going to be the same, Scotland and Wales for example will be differing in landscape and resources. These slightly different populations will exhibit variation in their diets and behaviours.

Figure 9.28. Efe children playing whilst learning about subsistence strategy (Image by P.I. Henry, after Jones 2005)

Figure 9.29. Hazda children cooking their meal, they hunt and gather approximately half the calories that they consume (Ember 2014)

9.8 Seasonality of the evidence

There are many sources of evidence for the seasonality of activity at Goldcliff, however the identification of a specific season is challenging and we must rely on modern analogues regarding bird, fish and mammal migratory and breeding behaviours when considering the data. Evidence of a particular resource from one time of year does not mean that the site was unoccupied on other occasions (Bell 2007, p 243). Site W provides evidence of an autumn/winter activity area, this was inferred through the presence of pig bones, eel bones and smelt at particular growth stages. Of the identifiable fish bones at Site W, 56% were from eel and 8% were smelt. The size range of the eel and smelt bones suggested that adult eel and smelt over a year old were being caught seasonally, as they often congregate in estuaries and river mouths during winter months to spawn (Ingrem 2000, p 54). The pig bones from Site W indicated that juveniles and adults were being hunted. The dental eruption stage of three mandibles indicated that the piglets were older than seven months but under a year when killed. If the piglets were born during early spring then this would suggest a winter/spring occupation (Coard 2000, p 52). Although the faunal assemblage suggests an autumn/winter occupation, the plant assemblage from burnt seeds of greater plantain, rushes, and sea club rush indicates that burning occurred during July/October (Bell 2007, Table 18.3). This evidence therefore indicates that Site W was occupied during summer/autumn, though activity also extended into the winter or the site was returned to during the winter months (Bell *et al*.2000; Bell 2007).

The sites at Goldcliff East have similar evidence for seasonality as Site W (Bell 2007, Figure 18.4). Again, pig bones provide seasonal evidence, with neonates bones from Site A and J, suggestive of activity during March/April, and the bones of neonatal roe deer suggesting activity in about May (Scales 2007b, p 162). Scales (2007a) identified 11 red deer footprint-tracks at Site J, the presence of both stag and neonate in this assemblage suggests that these deer were present May/July, however they were not made upon a surface with human footprint-tracks so we cannot say with certainty if they were being hunted at Goldcliff during these months. The same is true regarding roe deer, there is not enough evidence to determine if the animals were on the wetlands at the same time as humans.

At Site A 83% of bones from identified fish species came from eel, and about 25% of those were a size that suggests that they were caught during their autumn migration (Ingrem 2007, p 167). The remaining eel were a smaller size and would have been available in the estuary year-round, though Ingrem (2007) states that it is unlikely that they were caught in winter.

Plant based evidence from Goldcliff East is again similar to Site W, with charred seeds at Site B, A and D representing 10 species, which indicates burning between June to October (Dark 2007, p 183). Charred hazelnuts from Site A, B and possibly J are evidence of possible autumn/winter activity as they are best collected in September/October, however they store well and can be eaten months later (Dark 2007).

The avian and human footprint-track data provides evidence of seasonality, though there has not been a case where bird and human footprints have been recorded on the exact same lamination, the human footprint-tracks were overtraces/undertraces and so were not an absolute indication of the lamination walked upon. All the avian footprint-track laminations sampled in Chapter 8, except those from Site N, and also footprint 2015:113 from Site C/E, were made upon fine-grained sediment, these laminations were likely lain down in the calm summer months. There were two species of bird from Site C/E that are suggestive of summer migrants, white stork and common crane. These are both migratory birds that spend the summer breeding in northern Europe before returning to winter in warmer climates. Neither of these species are currently considered to be an established migrant of Britain, although a small population of crane has been introduced in Norfolk and recently in Somerset (Buxton and Durdin 2011; Bridge 2015). Historic evidence of the crane migrating and breeding in Britain is rich, with many of our villages named after this species (Charles 1938), there is less reference to white stork however there is still evidence of this bird migrating to Britain throughout history (Harman 1996; Platt 1933, 1956; Turk 1971; 1978).

There were two further avian species identified, the common gull and the tern, that are migrants to Britain. There are several tern species that currently use the Severn Estuary as a passage to their migration routes and can be present at any point between March and October (Hume 2002), so the appearance of tern footprints may indicate any time between Spring and Autumn. Common gull currently winter on the Severn Estuary, but they can be seen across Britain year-round so they do not provide any evidence of seasonality. The other four identified bird species are all current residents of the Severn Estuary (Hume 2002), and so we cannot infer anything about season from these footprint-tracks.

Scales (2006; 2007a) calculated that ten of the 14 footprint-track trails recorded were all made upon fine-grained sediment, walked upon during the summer months. Within this current study there were not any human footprints recorded where the exact lamination could be established, due to being undertraces/overtraces, however there is new footprint-track evidence of possible winter visits to the area, evidenced by Site N. Particle size analysis from grey heron footprints made in the same area as human footprint-tracks suggests that the Site N avian footprints were made on a sediment with a coarser particle size compared to the other footprint areas, with research by Allen (2004; Dark and Allen 2005) suggesting that coarse-grained banded silts are likely deposited during the winter months. The human footprint-tracks at Site N were overtraces, however they may have been on the same lamination as the grey heron footprints.

Persons 7, 8 and 10, recorded by Scales (2006) were also on laminations with a coarser particle size; these were later in date than Site N, higher up on the laminations.

The autumn exploitation of eel may be the reason that humans were present in Site N. These people were walking in the direction of the palaeochannel where there is fish trap evidence at Site T and possibly Site L. It is likely that the ‘pathway’ seen at Site N represents these individuals walking the area over multiple occasions to check on their catch. The hunter-gatherer footprints at Goldcliff East relate to activities in the saltmarsh and mudflats and it is possible that these were concentrated in some seasons relating to salmon and eel runs, whereas other hunting and plant activities may have been associated with visits at other times of year. It is important to not class Goldcliff East as a late summer/autumn camp, as evidence indicates that the site was not disused during the winter period (Bell 2007, Table 18.4). The main visits were likely in late summer/autumn but brief stays were made at other times of year including winter, spring and high summer.

9.9 Conclusion of the palaeoecology at Goldcliff East

A site such as Goldcliff East provides an excellent insight into the palaeoecology of Mesolithic hunter-gatherers, due to the range of archaeological evidence. Bone assemblages are relatively few, and are essentially portable artefacts. The faunal evidence suggests that there was a focus on red deer hunting, though pig and auroch were also at some sites. Uskmouth provided heavily trampled deer footprint-track areas, the presence of stag, juvenile and hind in the assemblage suggests that red deer may have been specifically grazing on the wetlands during the late spring and early summer periods.

Fish were an important resource to the Mesolithic people of Goldcliff, there were 4432 fish bones from Site A and 1516 from Site W, many of the fish bones were calcined and it is likely that uncalcined bones have not survived so well (Ingrem 2000; 2007). Around a quarter of eel bones from Site A were large, and would have been from migrating eel (Ingrem 2007, p 167). Two wooden structures, one from Site L (Bell 2007, Figure 4.2) and the other from Site T, suggest fishing with stationary wooden fish traps was occurring, possibly with a focus on migrating eel during the autumn months. Grey heron footprint-track**s** from Site N, near Site T, were made during the autumn/winter season, evidenced by the coarse-grain particles that formed the lamination. Although the people of Goldcliff occupied a coastal island edge location, the hunter-gatherer-fishers exploited a mixture of terrestrial animals and plant resources, in addition to fishing.

Other evidence from the archaeological, skeletal and footprint-track assemblages indicate activity in this area occurred throughout the year for different tasks. Site W contained artefacts indicating a summer/autumn occupation, with winter visits. This is indicated by juvenile pig remains, the size of eel and smelt bones and the burnt seeds from plants that flower July/October (Bell 2007, Table 18.4). Similar seasonal evidence is seen at Goldcliff East. The bones of neonate pig from Site A and J indicate the animal died in March/April, and neonatal roe deer bones suggest the animal died in May (Scales 2007b). Large eel migrate during September/October; over one quarter of eel remains from Site A were this size, though the other 75% were a small size and would be available year round (Ingrem 2007). Charred seeds from Site A, B and J are from plants that currently flower June/October (Dark 2007).

Fine-grained laminations would have been lain down during a period of warmer sea temperature which would affect water viscosity. There would also have been a calm wind-wave climate and seasonal changes in pollen (Allen and Dark 2007). The appearance of common crane footprint-tracks on these fine-grained laminations indicates that birds were in the area during the late spring/late summer months, probably to breed. Their presence indicates that the wetland environment would have been rich in food resources, as there was space for this territorial bird species to feed or breed. There was not any evidence for the hunting of these birds which may indicate that food was plentiful, humans had a dietary preference for red deer and fish over wildfowl, that they specifically did not hunt these species, or that humans and these bird species were not present at the same time. The seasonal evidence from the footprint-tracks and other archaeology indicates that Goldcliff was visited most during the summer/autumn, however shorter trips during the winter and spring were also occurring.

The population demographic at Goldcliff East indicates people who ranged in age from under four years old to adult, and were a mix of both sexes. The adults of this area had an average stature of 166.5cm which is similar to other estimates of statures of prehistoric people in Britain and Europe (Table 9.7). Although the footprint-track dataset from Goldcliff is not large, the stature estimates add to the relatively limited record of Mesolithic people from Europe. There were several males who were tall, even by modern standards, and were over 182cm (5’11”), this indicates a variation of height even between individuals of the same population. The footprint-track trails that could be identified as male were only seen in Site E and the individuals in this area, as well as Site C/E and Site R, were generally orientated north-west. This is a different direction to the areas where male footprint-track trails could not be confidently identified (Site M, N and S), and who were heading in a south-west, north-east direction. The presence of male footprint-tracks, as well as a differing direction of movement may suggest a change in site usage over time or contrasting patterns of activity between adult males (hunting) and females and children (monitoring fish traps).

The children of Goldcliff East make up a large percentage of the population demographic, with a similarly high percentage to contemporary indigenous populations. The footprint-track evidence from Site N and at Goldcliff overall suggests that children were actively participating in subsistence activities, rather than just using the area to play. The involvement of children in subsistence activities is also attested by much of the ethnographic data. The evidence of children within the footprint-track assemblage is particularly important as it enables archaeologists to observe their daily activities, rather than remains of dead children, who would only have been in the skeletal record if they had been unwell or had an accident, preventing them from becoming adults.

Footprint-tracks can indicate the season in which a footprint was made, the species, age and sex of an animal, and the sort of habitat and diet that these animals would have required to live. This information is relevant not only to understanding hunter-gather activities but also those involving domestic animals in later periods (Barr and Bell 2016).

Chapter 10

Public Engagement and Impact on the Gwent Levels, Wales

10.1 Introduction

The intertidal environments and coastal wetlands discussed in this thesis are increasingly recognised to be of great importance as sources of archaeological and palaeoenvironmental evidence, but there are many stakeholders in these landscapes and many factors which impact on their future management. There is increasing recognition that progress requires dialogue with the multiple stakeholders and communication with the wider public so that they are aware of the scientific importance of the coastal zone. The public's awareness of the scientific value of coastal zones is becoming increasingly important to ensure that our coasts and our wetlands remain places of conservation. The preservation of the important heritage and nature in and around the Severn Estuary is at threat from humans. This chapter will address some of the challenges that are facing the Severn Estuary, and what archaeologists can do to help preserve these special areas.

There is currently a proposal to build a relief road for the M4 around Newport, which would go through a substantial area of the Gwent Levels. The Gwent Wildlife Trust survey has suggested that the risk of pollution entering waterways and poisoning fish is likely, which would have a knock-on effect for the rest of the unique wildlife in the area (Gwent Wildlife Trust, n/d). This relief road would be 14 miles long and cut through the heart of the Gwent Levels (Figure 10.1), destroying resources and wildlife, not to mention the damage to the archaeological landscape.

There is a large amount of opposition to the proposed route for the M4, with 22 possible alternatives. The Future Generations Commissioner has voiced concerns about the "dangerous precedent" this relief road would set if allowed to destroy valuable parts of the wetlands (Future Generations Commissioner for Wales 2017). These alternatives are currently under review by the government and a decision was due to be reached by the end of 2017, however this has been delayed and their decision will not be announced until the end of summer 2018 at earliest.

The threats to the Gwent Levels do not just come from the land, but also by sea, with the proposal of tidal lagoons. The main proposed lagoon is in Swansea. There are also proposals to build other lagoons if the Swansea lagoon is successful, with one of the proposed sites being Cardiff, which would cover a large proportion of the Gwent levels (Figure 10.2; Tidal lagoon power, n/d). A further lagoon east of the river Usk at Newport is also being considered, this lagoon would cover Goldcliff as well as other areas of the Gwent Levels. The UK government has expressed an aspiration to become world leaders in tidal lagoon power plants. If the lagoons are built they would provide clean energy due to the huge tidal range on the Severn Estuary.

Although there is the potential to generate clean energy, the Severn Estuary is a site of Special Scientific Interest, a Special Area of Conservation, and a RAMSAR site as it is home to a range of rare birds, mammals, fish and plants. In the past decade the RAMSAR convention has changed slightly to include cultural heritage as well as wildlife. There is concern about the effects of the tidal lagoons not just on the fauna but also on the archaeology, with the effects on Goldcliff East and other Severn Estuary sites being of concern. The Severn Estuary risks changes in sediment deposition and changes in water levels if the lagoon is built in Cardiff, this could have an impact on the archaeology, possibly covering areas constantly in water or in meters of sediment which would prevent any future recording, or of greatest concern cause abrupt erosion to the sites.

The Cardiff and Newport Lagoon have not yet had approval and there are still many groups lobbying against them being built. This is where public archaeology becomes incredibly important as, if we can raise issues such as the threats to the archaeology, the public may protest against certain proposals and insure the survival of our heritage for future generations. Archaeology is after all essentially a democratic subject, where the past is investigated by means of material culture, instead of written records made by the elite. Due to its democratic capability, archaeology has certain responsibilities to engage with the public. The human aspect of archaeology, footprints for example, grab the attention of the public and this interest may assist in the preservation of this unique landscape.

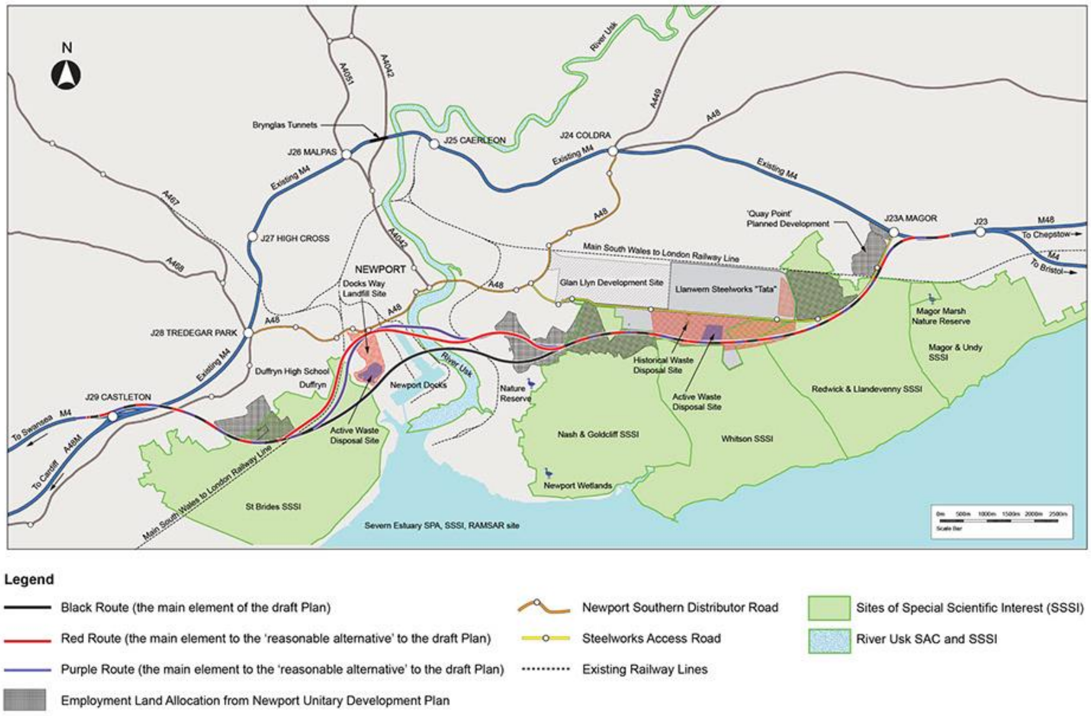


Figure 10.1 Proposed route of M4 relief road (The Welsh Government 2014)

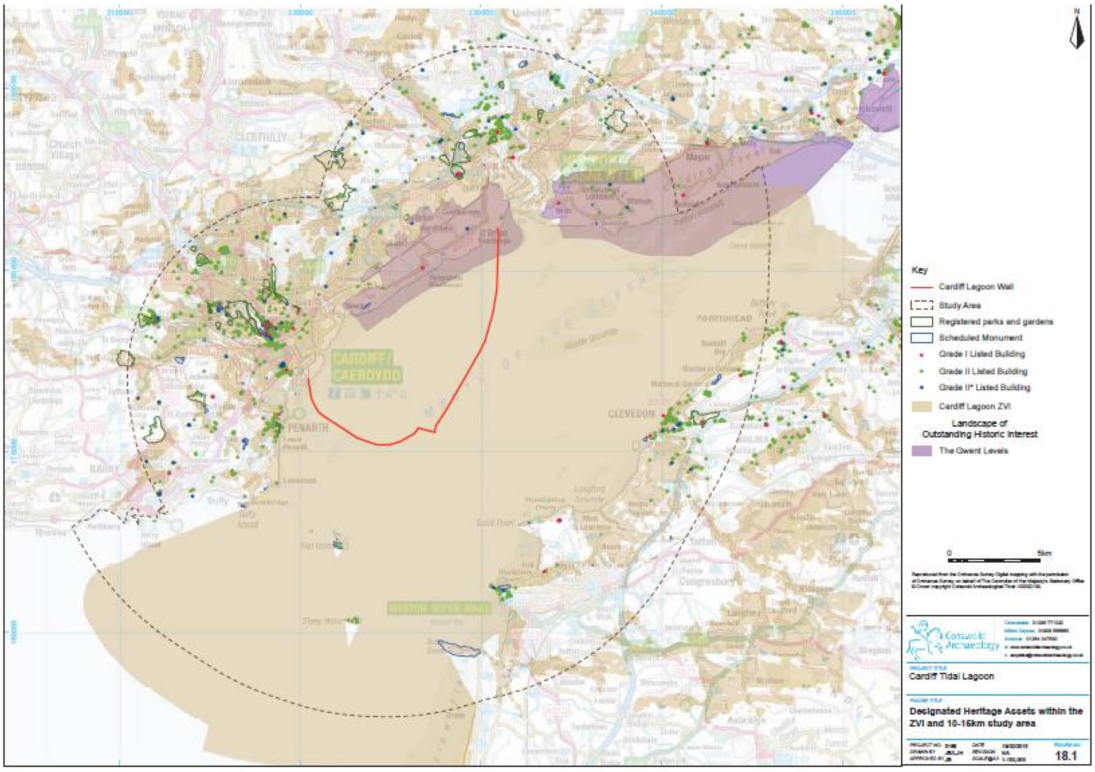


Figure 10.2 Proposed site of the Cardiff Tidal lagoon. The Gwent levels is represented by the purple denomination on the map. A large proportion of this (approximately one third) will fall in the Cardiff lagoon flood area (Cotswolds archaeology 2015)

10.2 Public Archaeology

One of the many challenges in working within the heritage sector is appealing to a variety of individuals and interests. Public archaeology was conceived to encourage financial interests and political support from the public for archaeological sites (McGimsey 1972). A key question of concern to members of the public regarding archaeology is 'who pays and who benefits?' (Klamer 2014). When the public are involved in the financial funding of projects archaeologists must be able to demonstrate how the money is being spent and the way in which it engages all members of the local community.

It is easy to assume that 'archaeology is a public activity' (Schadla-Hall 1999), the reality of the situation is that archaeology has often excluded the general public. Archaeologists see themselves as specialists, and so archaeological knowledge can stay within the discipline, published in journals, within the past these have often been without open access, and with public engagement treated with lower priority than other tasks (Rocks-Macqueen 2012). As of the late 1990's there has been recognition within the field that a diverse range of approaches are needed to fully contribute to archaeological interpretation, these need to be both scientific and social (Hodder 1999). Hodder (1999) introduced two concepts, multivocality and self-reflexivity, these challenge the self-importance of the 'expert view'. The former concept values a diversity of approaches and the latter an understanding of the effects that scientific and archaeological assumptions can cause, and the effects on the public (Bell 2015)

This study will be drawing upon the 'multiple perspective model', which recognises differences in perspectives and the need to tailor information to the audience (Figure 10.3; Grima 2016). This model, like the two concepts introduced by Hodder (1999), disregards other techniques that use simplified language to refer to archaeology, assuming that the public has a 'deficit' of archaeological knowledge, simplifying the research for accessibility but losing meaning (Merriman 2004). The 'multiple perspective model' attempts to foster public engagement with archaeologists operating from the perspective of members of the wider community (Grima 2016).

Organisations in England, such as the Coastal and Intertidal Zone Archaeological Network (CITiZAN), are monitoring the coastlines of England, and are embracing public archaeology by utilising members of the public as volunteers and training them in the processes of archaeological recording. This provides resources to members of the public to enable direct involvement in their coastal heritage (CITiZAN n/d), which will foster awareness of coastal archaeology and a desire to preserve the local heritage. Although CITiZAN is a positive step towards engaging the public with archaeology, there are still issues regarding the presentation of the artifacts and the lack of availability of local archaeology to the general public. Many people may be interested in their own heritage but do not have the time to record sites or become involved in archaeological projects. CITiZAN is a step in the right direction but does not fully embrace the ‘multiple perspectives model’, as the public would still need to have specific knowledge to access and understand their own coastal heritage.

The writers’ discussions with local people and visitors to the area suggest that the prehistoric archaeology on the Gwent Levels, Wales is subject to very little public engagement, and so there is a lack of awareness of the prehistory of this site amongst the public. Although there have been many attempts to engage with the public, such as conferences, lectures and the archaeology featuring within television programmes and radio broadcasting, these types of activities will generally appeal to members of the public who already have an interest or awareness, rather than from people who are unlikely to have any kind of knowledge, and so does not embrace the ‘multiple perspectives model’. The challenge of public archaeology is increased when studying intertidal archaeology, as regular site tours cannot be arranged and artefacts found are often small, occasionally organic and are not generally of a quality where they are displayed in museums. It is also difficult to display the information when there is little to see from the sea wall that overlooks the prehistoric intertidal sites, these are all challenges archaeologists have had to deal with whilst trying to engage the public.

Prehistoric footprint-tracks preserved in the intertidal zone of the Severn Estuary are evocative but ephemeral and often in difficult to access, dangerous areas, meaning it is impractical to undertake tours such as those at Formby Point (National Trust, n/d). The areas along the Severn Estuary are protected Sites of Special Scientific Interest, and there are concerns about disturbances to birds during periods of breeding or very cold/stormy weather when bird populations may be under stress. The strong tides and dangerous muddy terrain make it an unsafe, impractical archaeological site to open up for public tours.

Within this study the public archaeology and engagement techniques utilised on the Gwent Levels were assessed. Natural Resources Wales protects the areas of intertidal zone between Uskmouth and Magor Pill, which are of interest due to preservation of prehistoric material. Part of the wetlands have been turned into a Royal Society for the Protection of Birds (RSPB) Nature Reserve, ‘Newport Wetlands’, where there is information about the surrounding area and its important ecology at the interpretation centre and display boards, but there is no information about the archaeology and heritage of this stretch of intertidal zone. It is essential to understand the demographic of the Newport Wetlands visitors, why they are visiting and what they are interested in before attempting to address the issue of public archaeology and what can be done to engage the public on the Gwent Levels.

Figure 10.3 Multiple perspective model (Grima 2016)

10.3 Professional placement for archaeological public outreach

The information that will be presented within the remainder of this chapter was obtained by the writer during a professional placement with the Heritage Lottery funded project, Living Levels Landscape Partnership in Newport, Gwent, attended August 2016 – October 2016, and funded by the South West and Wales Doctoral Training Partnership. This project worked with a variety of organisations, such as the Royal Society for the Protection of Birds, the Gwent Wildlife Trust, Buglife and Gwent archives. The placement allowed the writer, as an archaeologist who focused on the prehistory of the intertidal zone of the Severn Estuary, to work alongside the partnership organisations, to bring more public awareness of the importance of the rich heritage on the Gwent Levels, specifically the prehistory (Appendix 4.1).

10.4 Method

A survey was carried out in 2015 by Natural Resource Wales, which was adapted by RSPB Newport Wetlands Visitor Centre to understand the demographics of visitors to the Gwent Levels and reasons for attendance, the survey did not provide details on the number of people who were questioned. Members of the public were asked to supply their gender, age, social class, working status and information on limiting illnesses, as well as if they have children, their ethnicity and ability to speak Welsh. The information was added to by the RSPB Newport Wetlands Reserve, who lease their land from Natural Resource Wales. They recorded visitor numbers, the length of visit, previous visits, travel time and activities undertaken.

Further information was obtained by The Living Levels Landscape Partnership, during 2016, asking community groups, schools, workshops, and pop-up events questions to ascertain the degree of their knowledge about their local landscape. Twenty groups were involved in this study, who lived or worked on the Gwent Levels, including children who were pond-dipping at the Newport Wetlands, families attending days out at cinemas and at the Women’s Institute. Groups ranged in size between two to twenty people. They were encouraged to take part in a simple flip-board activity called Good Levels/Bad Levels, in which they were free to write any thoughts they had about the Gwent Levels. This activity was thought up by Gavin Jones, the community engagement officer for the Living Levels Landscape Partnership project.

The final information gathered was during an RSPB committee event, in which the author displayed prehistoric faunal remains and casts of preserved footprint-tracks, allowing the twenty RSPB Cymru committee members to handle the archaeology and ask questions, engaging in a dialogue about their knowledge of the area.

10.5 Results

Of those surveyed by the RSPB (Table 10.1), only 7% went to the Newport Wetlands Nature Reserve to explore the nature/natural history whilst out walking (Figure 10.4). The survey did not ask if people were specifically interested in the archaeology of the area however in this survey archaeology was included within nature/natural history and so the percentage interested in the archaeology of the area would be 7% or less.

The main visiting demographic were employed adults who worked full time (Table 10.2), 97% of those visiting were White British, 3% were White Other and there were no visitors who took part in this survey who were of any other ethnicity. Males were slightly more likely to visit the reserve than females, and of those, over the age of 55, non-manual workers were most likely to visit (Figure 10.5). 98% of people visiting the RSPB Newport Wetlands were there as part of a day trip and 88% of people travelled less than 3 hours to visit the site, suggesting that a fairly large proportion of the visitors were from the local or surrounding areas (Table 10.2).

The results suggest the visiting demographic is not diverse, and that the sites are primarily visited for people to go on walks or use the other facilities, rather than due to an interest in the wildlife or the prehistoric landscape. This is an issue that needs to be addressed as the public are not engaging with the natural landscape.

RSPB VISITOR SURVEY	
VISITOR NUMBERS:	
	Reserve before visitor centre (2008) = 18,000 approx visitors
	Year 1 2008-2009 = 39,255 visitors
	Year 8 2015-2016 = 102,210 visitors
VISIT LENGTH:	
	1-2 hours = 57%
	3-6 hours = 22%
OTHER VISIT INFO:	
	Repeat visits = 70%
	Travelling time to site <3hrs = 88%
	Day trip visits = 98%
	Activities undertaken =
	Walking = 96% (this then includes additional activities undertaken or reason for visit such as 39% bird watching, 23% play area, 40% cafe, 35% shop, 8% photography, 7% nature /natural history)
AGE GROUPS:	
	16 – 34 years = 20%
	35 – 54 years = 36%
	55+ years = 44%
SITE RATINGS:	
	Excellent = 75%
	Very Good = 23%
	Good = 2%
	Likelihood of recommending site as place to visit = 92%

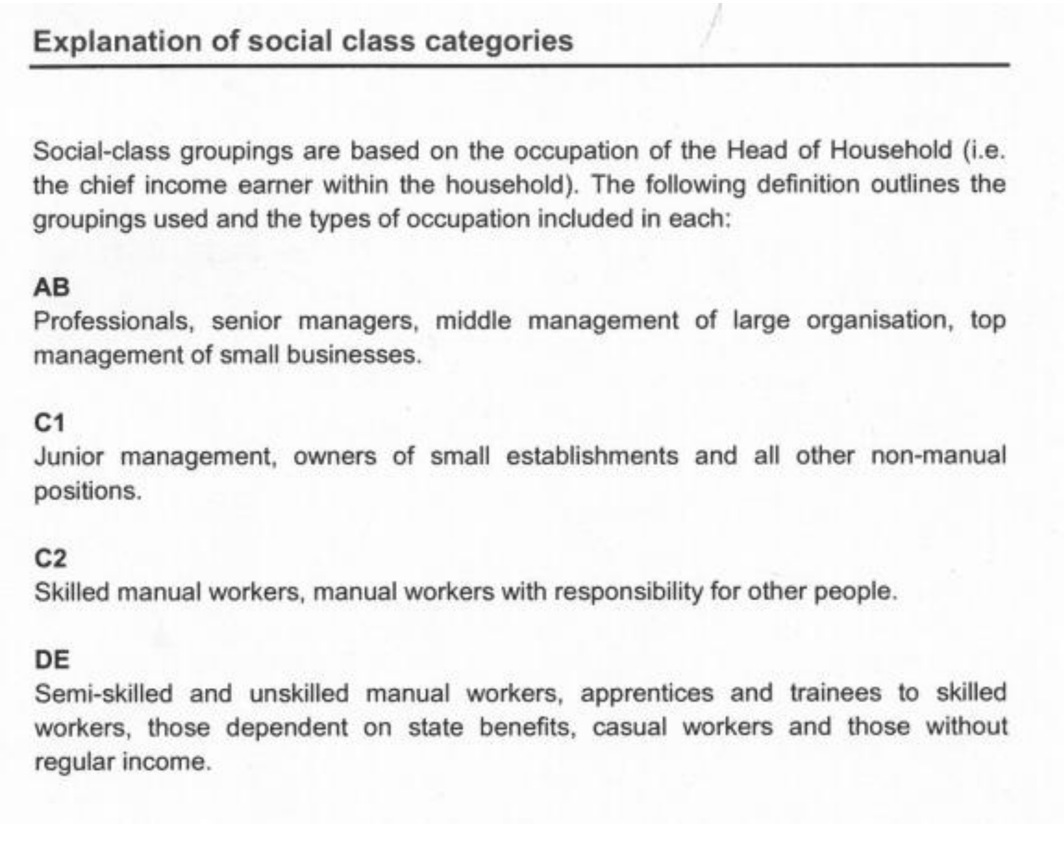
Table 10.1 RSPB Newport Wetlands Visitor Survey 2008-2016

Figure 10.4 Approximate area that incorporates the RSPB Newport wetlands nature reserve (map by Natural Resource Wales). The 'you are here' symbol marks the Newport Wetland visitor centre. Location of Goldcliff East and Goldcliff West added by writer.

Demographic Groups		**Newport Wetlands visitors 2015 %**	**All visitors to Wales reserves %**
Gender	Male	55	58
	Female	45	42
Age	16-24	3	6
	25-34	17	16
	35-44	22	21
	45-54	14	22
	55-64	25	19
	65+	19	15
	Refused	<1	1
Social class	AB	25	32
	C1	49	43
	C2	14	16
	DE	11	9
	Refused	0	1
Working status	Full-time employee (30+ hours per week)	53	59
	Part-time employee (<30 hours per week)	11	9
	Self-employed	3	6
	Government supported training	1	<1
	Full-time education	<1	3
	Unemployed	<1	1
	Permanently sick/ disabled	3	1
	Retired	26	18
	Looking after the home	2	2
	Other	<1	<1
	Refused	0	1
Limiting illness	Yes – limited a lot/ a little	11	6
	No	88	92
	Refused	2	2
Children in household	Yes	32	29
	No	68	70
	Refused	<1	1

Ethnicity	White – British/Welsh/Irish	97	91
	White - other	3	7
	Black/ Asian/ Mixed	0	2
Welsh speaker	Yes	10	13
	No	90	87

Table 10.2 Natural Resource Wales Visitor Survey 2015, the survey demonstrates the percentages from visitors at the Newport wetlands compared to the percentages of the visitor demographic of the rest of welsh reserves



Explanation of social class categories

Social-class groupings are based on the occupation of the Head of Household (i.e. the chief income earner within the household). The following definition outlines the groupings used and the types of occupation included in each:

AB
Professionals, senior managers, middle management of large organisation, top management of small businesses.

C1
Junior management, owners of small establishments and all other non-manual positions.

C2
Skilled manual workers, manual workers with responsibility for other people.

DE
Semi-skilled and unskilled manual workers, apprentices and trainees to skilled workers, those dependent on state benefits, casual workers and those without regular income.

Figure 10.5 Explanation of social class categories listed in Table 10.2, as provided by Natural Resource Wales

10.5.1 Good Levels/Bad Levels

The results obtained from the Good Levels/Bad Levels activity were varied; often features disliked by one individual were considered a good feature by another person. Very few people who took part in Good Levels/Bad Levels were aware of the historical and archaeological importance of the area, though a large majority did know that Newport was important to the Romans because of the site of Caerleon, and were aware of the Newport Medieval Ship. Both of these are present in the minds of the locals living on the Gwent Levels, as Caerleon is a local tourist destination and many people were involved in the demonstrations to save the Newport Medieval Ship.

Only one of the twenty groups questioned highlighted the significance of the wetlands in terms of its important archaeology. This group was made up of individuals who worked for the Newport Museum, and had worked with some of the Gwent Levels archaeology.

Eight groups commented on the history of the area, and groups containing children discussed the Romans and the Celts as they had studied this at school. Children were not aware that the Gwent Levels contained prehistoric sites or that there were artefacts available for public viewing.

Very few people were aware that they were living on the Gwent Levels, with four groups thinking that the Gwent Levels were somewhere on the Somerset Levels. Over a quarter of the groups had heard of the prehistoric footprints found on the Gwent Levels. Many had watched a television programme in which they were featured, though they were not aware that these footprints were located on the Gwent Levels.

Once made aware of the prehistoric footprints and other finds, members of the public expressed a need for information boards along the coastal paths near areas of prehistoric significance. People also wanted to see reconstruction drawings of the sites as they struggled to imagine the landscape without the prominence of the Severn Estuary. Over a quarter of those spoken to wanted more information about the area in general, linking the archaeology, history, natural history and conservation together to create a clearer picture of the importance of the Gwent Levels.

Another of the main concerns raised was the lack of public knowledge of where to view the artefacts found on the Gwent Levels. Twenty members of the public who were at the RSPB Newport Wetlands Centre were asked if they knew about their local museums, two of the twenty were aware of the National Museum of Wales, Cardiff, but none knew about the Newport Museum. When these twenty people were told that most of the Gwent Levels finds were held at the National Museum of Wales, eighteen of the twenty people expressed their disappointment at this as they were unwilling to travel to this museum, and felt that some of the artefacts should be available to view at the RSPB Newport Wetlands Centre so that they could see the artefacts and then look out onto the prehistoric landscape.

This lack of archaeological knowledge of the area was not only demonstrated within members of the general public living on or near the Gwent Levels, but also by the RSPB Cymru committee. Individuals attending the RSPB committee event were asked about what they knew about the significant archaeological sites along the Gwent Levels, specifically the site at Uskmouth within the RSPB reserve, or the site of Goldcliff within the Natural Resources Wales reserve, and not one of the people spoken to was aware that the area was significant for anything other than wildlife and history.

10.6 Where to go from here

The results of the NRW and RSPB visitor surveys indicate a clear visitor demographic for the wetlands. There is a lack of archaeological knowledge of the area among members of the public and those working near the prehistoric sites.

The two visitor surveys identify a large gap in the visitor demographic, with young people aged 16-24 having little interest in visiting the area. This study has determined that the Gwent Levels have a high educational value that can be utilised to improve the public’s understanding of their own heritage. Information boards and small artefacts at the RSPB Newport Wetlands may encourage local Key Stage 3 and A-Level students to visit, specifically those studying history or archaeology. Archaeology and heritage can be utilised as a tool to attract visitors belonging to the younger demographic.

During this project a variety of outreach materials were created aimed at school children (Figure 10.6), to assist in the teaching of the archaeology of the Gwent Levels. Key Stage 2 children were the target audience, with the hope that their interest may encourage the guardians of these children to visit nearby archaeological sites. A Prehistoric Heritage Trail booklet was also created (Appendix 4.2), which will be accessible to all members of the public via the Living Levels Landscape Partnership. The booklet is a guided walk along the prehistoric coast, from the RSPB Newport Wetlands visitor centre to Magor Pill. The booklet contains information about the prehistoric sites and pictures of a selection of artefacts for those who are unable to attend the museums. The need to put information boards along the coastal path near the prehistoric sites was also seen as an incredibly important part of public engagement and the ‘multiple perspectives model’, this information board should incorporate the archaeology of the area with local heritage, ecology and geological information, to engage a broader range of the public.

Figure 10.6 Public engagement activity involving the prehistoric 'Bone Booth' run by the writer, which was hosted at the RSPB Newport Wetlands reserve as an activity for a Girl Guides Jamboree involving over 800 children in 2016 (photograph courtesy of Gavin Jones)

A main concern about heritage projects is 'who pays and who benefits?' (Klamer 2014), an area such as the Gwent Levels that is completely lacking in public engagement material would potentially see a large benefit from extra resources being added to the area, such as those being provided by the Heritage Lottery Fund. This benefit would be for the locals, public archaeology would benefit locals in terms of increased awareness of local heritage, and a potential increase in local business due to tourism. A public archaeology project run in Crete suggests that when locals become involved in the project the focus shifted from primarily archaeology based to one that incorporates all the village heritage (Kyriakidis and Anagnostopolos 2015). This hands-on style of public archaeology would be entirely beneficial to the Gwent Levels, encouraging local investment and positive influence on the project. There has also been discussion between the writer and the Gwent Wildlife Trust about the possibility of creating a permanent reconstruction archaeology area.

The successful integration between scientists and members of the public has been achieved on the English side of the Severn Estuary, in Somerset. On the Somerset levels the Sweet Track was discovered in 1970, John Coles who led archaeological work in Somerset during the 1960's before the Sweet Track was found became so interested in the find that he subsequently ran the Somerset Levels project from 1973-1989 (Brunning 2000). This project was dedicated to the recording of wetland archaeology, and was primarily funded by English Heritage. The success of the Somerset Levels project resulted in further projects being established, such as a small museum being set up, and archaeologists and nature conservationists have worked in collaboration at places such as the Avalon Marshes Centre where they have reconstructed a Roman villa and a Saxon hall in a similar area to where they would have been built in the past (Avalon Marshes Centre, n/d). The successful collaboration between Natural England, the South West Heritage Trust and nature conservation groups such as the RSPB and the Somerset Wildlife Trust indicates that archaeologists may need to look beyond their own discipline when dealing with the public, as work in Somerset has proven that nature conservation and archaeology can be presented together very successfully.

The Somerset Levels project was so successful it has become a project to aspire to. Their success indicates that although areas are currently lacking in public interest, projects can rectify this. People of the Gwent Levels have become disassociated from the archaeology and the landscape in general with very little easily accessible information about their heritage. If the archaeology of the landscape can be metaphorically brought to life, it will seem tangible and almost touchable, which would encourage the local people to learn more about their area. It is through public archaeology and engagement that we can protect the importance of this heritage.

10.7 Conclusions

Public archaeology could benefit from the 'multiple perspective model' in places such as the Gwent Levels to captivate individuals who might usually be uninterested in or unaware of archaeology. Archaeologists should be considering the benefits of merging their specialised knowledge with the ecological and conservation sector, as there are many situations in which awareness of the area's specific archaeology may assist in building a stronger picture of the landscape, fauna and flora that they are fighting to preserve. The examples of NRW and RSPB demonstrate that archaeology is often not considered in their procedures and policies; the inclusion of archaeological information may attract individuals with interests outside of conservation. Funding provided by organisations such as the Heritage Lottery Fund provides areas with the opportunity to develop projects, hopefully this will soon start to include the merging of disciplines to create a far stronger form of public engagement and archaeology.

Chapter 11

Conclusions and recommendations for future work

11.1 Conclusions

This research set out to investigate prehistoric bird, human and mammal footprint-tracks from intertidal sediments as evidence of human palaeoecology, the key aims and questions asked in Chapter 1 are answered within this conclusion along with recommendations for future work.

11.1.1 Experimental work with human footprints

The experimental analysis of modern footprints made on clayey silt by 177 males and females aged between 3 and 71 years enabled the relationship between the length and width of the footprint and the age, sex, height and weight of an individual to be explored. The experiment included 89 adults aged above 16 years old, 30 males and 59 females. There were 88 children aged under 16 years involved in the experiment, 46 females and 42 males. The difference between ethnicities was not studied, though the majority of individuals were White European (94%). Those who identified as British Indian (3%), Black British (2%), Filipino (0.5%) and Filipino American (0.5%) also took part within the study.

Footprints made in clayey silt sediment were found to be larger than the actual parameters of the foot, up to 9.5% longer than tracings made around the foot, and could be 2cm shorter or 2cm longer than the foot itself. We must therefore be careful with data that has assumed that two-dimensional foot tracings or ink-prints provide the same evidence as three-dimensional footprints, as footprints are not the exact size of the foot. The weight of an individual was not found to be a significant variable regarding the footprint length and width when footprints are made in clayey silt. The heaviest individual in the experiment, volunteer 131, a 50-year-old male who was 126kg, had a foot width of 11.8cm. The average footprint width of a male in this experiment was 11.3cm, meaning that although this individual was 16kg heavier than anyone else, his footprints were only 0.5cm wider than the average male and slimmer than multiple male and female footprints.

The height of a person and the length of a footprint has a positive relationship. A stature equation was created for the estimation of height for adult males, adult females and children of both sexes. The stature equation for a footprint that could be an adult of either sex is $Y=60.3+4.3x$ with a standard error of 7.3. The stature equation for children aged under 10 years old of either sex is $Y= 38.82+4.27x$ with a standard error of 8.59. Both equations can be applied to either the left or right foot and give a height estimate in centimetres. Interestingly the adult male regression equations for the left ($y=82.48+3.53x$) and right ($y=89.24+3.31x$) foot were most similar to the work of Fawzy and Kamal (2010) and Uhrova *et al*. (2014). Fawzy and Kamal (2010) created stature equations for the left foot and right foot ($88.34+3.25 \times T1L\ (\text{left});\ 91.88+3.1 \times T_1R\ (\text{right})$), from 50 Egyptian males aged 18-25 who made two-dimensional ink footprints. Research by Uhrova *et al.* (2014) of 120 Slovakian males aged 18-24 also resulted in equations for the left and right foot ($86.32+3.55\ (\text{left});\ 84.09+3.64\ (\text{right})$), these again were from two-dimensional footprints. Female stature regression equations were found to be different from other female studies, though it should be noted that there are far fewer studies regarding the relationship between female footprints, and most studies that we have are from Asian populations (Chapter 2, Table 2.2). At the time of writing the author is unaware of any stature equations which deal with the relationship between the height of a child and footprint length, other than the one created within this study.

It was not possible to identify the sex of children between 3-10 years old from their footprints. It was also not possible to differentiate adult female footprints from those of children aged 10+, though it was found that 71% of adult females aged over 16 years old had footprints between 23cm and 25cm in length, as opposed to 56% of children aged between 10 and 15 years old. Large adult males can be identified from their footprints, with footprints over 30cm in length being male. There were not any adult females or children aged between 10 and 15 years old in the experimental work who had an average footprint length of over 27cm. Only 32% of adult males had footprints with an average length under 27cm. One adult female, volunteer 130, made a singular footprint from her footprint-trail that was over 30cm (<1% of footprint assemblage), however this footprint had obvious toe drag, and overall the average size of her footprints was 26.7cm. If a footprint-track trail is made up of multiple footprints over 30cm we can therefore say it is an adult male, though caution should be applied to single footprint-tracks.

Speed of movement was established from the footprint data using Dingwall *et al's* (2013) equation, though this deals with a specific hunter-gatherer group and was a small sample of just 38 adults, with no children included.

The estimates and findings from the modern footprint data made upon clayey silt can be applied to prehistoric individuals. This comparison should be made cautiously. Sex cannot be identified with certainty, though large adult males are identifiable. The approximate age, height and speed of movement can be calculated. It is important to emphasise that these results are applicable to footprints made on clayey silt sediment and may not produce accurate results when compared to footprints made on other sediments.

11.1.2 Limitations of previous work and necessary improvements

The relationship between a footprint size and age, sex, stature, weight and even ethnicity has been thoroughly studied in forensic science and anthropology. Although this important relationship is being studied worldwide the data underpinning the research is rarely freely available. Bennett and Morse (2014) identify the lack of open data access as an issue for advancement of footprint analysis. If all footprint researchers made their data freely accessible then a larger study on the relationship between a footprint and a person could be established. Findings could then advance rapidly as broader research questions could be explored if we had access to a far larger dataset, as at the present time sample sizes are often small and contain only a certain group of people (e.g. many studies only use university students who are generally under the age of 30). Although the footprint data from this study is not currently available for open access on a specific website, the data underpinning the results is all available in this thesis.

11.1.3 Footprint formation and recording of footprint-tracks in the intertidal zone

Ichnological research has established that the type of sediment and its moisture content greatly influences footprint formation, which in turn affects the size and shape of footprints. Research as part of this study demonstrates the importance of a comparison with contemporary footprint data made on similar substrates to archaeological data. A single individual can make footprints of a variety of sizes when walking on different sediments, it is therefore important to establish the type of sediment walked upon in prehistory before attempting experimental work, for example there will be a marked difference in the size and shape of a footprint made in wet clay compared to one made in dry sand.

Every footprint is different and each recording situation in the intertidal zone varies, so recording methods must be flexible and adaptable. Standard photography and metric measurements are an important method to utilise in the field, as although they may not be the most accurate they provide a record of the size and morphology of the footprint, in case other methods fail or situations only allow for extremely fast recording, such as the encroaching tide. Footprint-track tracings and conventional plan drawings are an established method of recording the Goldcliff East footprints and are helpful in terms of understanding the location of each footprint in regard to others in the same area, as well as the axis of movement. Footprint-tracks are complex and therefore should be treated as three-dimensional features, rather than two-dimensional, as in plans or tracings. The latter do not include sufficient detail of the footprint itself or the way it may have been affected by the formation processes. Experience in this research has shown that tracings are too subjective and provide a two-dimensional record of a three-dimensional object, so measurements of footprints should not be taken directly from them. A further established method of footprint recording is casting. Casting footprints in dental alginate enables a permanent plaster of Paris cast of the footprint to be made. This is beneficial when a particularly good footprint is found. Casting is destructive but in areas where erosion and destruction can happen in a short time it is still a preferable technique. It also provides material for future museum displays.

Digital recording methods for recording ephemeral footprints were experimented with. The Faro Handheld laser scanner was found to not be an appropriate machine to use in the intertidal zone, due to variable weather conditions, the need to re-calibrate between uses which used up time, and the expense of hiring a machine. Technological advancements may enable laser scanners to be used in the intertidal zone in the future perhaps in less challenging contexts (i.e. less muddy and less wet contexts) with a longer tidal window.

In the intertidal zone recording using multi-image photogrammetry was found to be most effective. This technique was relatively fast, could be used in bad weather, equipment was portable, it was accurate, it was not destructive and a model of the footprint-track area could then be reproduced and analysed off site.

Although geometric morphometrics would work well in sites where the features of a footprint are clear (Bennet and Morse 2014), in situations such as Goldcliff where all but a few footprint-tracks are poorly preserved and generally overtraces/undertraces, geometric morphometrics are not appropriate and should not be used, as landmarks of the foot are often indistinct and the parameters of an overtrace/undertrace may be much larger than a normal footprint.

11.1.4 Mammals and birds

Avian footprint literature identifies species depending on certain features, such as total length of footprint, number of toes, and angle of toe. The literature often shows large differences in size, does not state the sediment walked upon, or how many birds were included in the research to establish the average size. The writers experimental research demonstrates that size and toe angle can vary in a singular bird’s footprint trail, and so relying solely on size or toe angle can be misleading. Morphology must always be considered first. Many modern birds are obese, especially ducks and geese (M. Roberts, pers comms, 12/01/2014), and so their gait may have altered to accommodate their change in body size. These differences need to be considered when comparing modern to prehistoric birds as diet, habitat and behaviours may be very different.

329 footprints from 21 modern avian species were analysed in this study. These species were chosen as there is bone evidence for these in prehistoric Britain. Many of these species are still native to Britain or visiting migrants, as well as birds that are common in the Severn Estuary today.

270 Late Mesolithic avian footprint-tracks were recorded at Goldcliff East during Scales' (2006) research, the current research, and sporadic site visits between 2005-2014. These footprint-tracks compliment bone assemblages, and provide data where bone assemblages are missing. The avian bone record at Goldcliff is sparse, with only mallard bones recorded at Site W, as well as unidentified bird bones from Site W and Site A (Coard 2000; Scales 2007b). The footprint-track assemblage therefore provides much stronger evidence for birds from the area and can be utilised similarly at other sites where there are avian footprints preserved even when bone assemblages are lacking. Nine avian species were identified at Goldcliff from the bone and footprint-track record. Of these, four are currently resident birds of the Severn Estuary, one species migrates to Britain for the spring/summer and one species migrates during the autumn/winter. The footprint-tracks made by waders may have been made by a variety of species, likely of the *Scolopacidae* family, which includes turnstone, dunlin and sandpiper.

The earliest evidence of common crane (*Grus grus*) and possible white stork (*Ciconia ciconia*) from Holocene Wales is found at Goldcliff in the footprint-track assemblage. White stork no-longer visit Britain as part of their migration route, but they used to migrate to certain southern areas during the spring/summer months and footprint-track evidence suggests the same may have been true during the Mesolithic period. Common crane also stopped migrating to Britain, or suffered localised extinction, though recent reintroduction programmes within the last decade in Somerset and Norfolk have resulted in a small residential breeding population.

Footprint-tracks of migratory birds can be used as a seasonal indicator for when certain laminations were lain down. Particle size analysis of banded laminations where footprint-tracks were formed has made it possible to identify the season that humans and birds were active (Dark and Allen 2005; Scales 2007a, Table 12.1). In the 2014-2017 research period there were not any clear human footprints recorded, only footprint-tracks that were primarily overtraces/undertraces, so the exact lamination band is not always clear. There were however multiple avian footprints, these were primarily made on a fine-grained sediment (Site C/E), suggesting the birds made the footprints during the summer months. The birds that made the footprints in Site C/E were primarily common crane, a summer migrant. Grey heron footprints from Site N were made on coarser-grained laminations and indicate that these were made in autumn/winter, grey heron are currently year-round residents of the Severn Estuary.

The main evidence for terrestrial animal exploitation at Goldcliff is from red deer, though it should be noted that bones were generally heavily trampled and small and porous bones may not have survived. 86 mammal footprint-tracks have been identified in the Goldcliff East footprint assemblage (Scales 2006). 95% of these footprint-tracks belong to deer; 20% of the deer footprint-tracks were small and may have been roe deer, however the morphology is more suggestive of juvenile red deer. The Goldcliff bone and footprint-track assemblages complement each other and indicate that they were not a single sex herd, but rather a combination of stag, hind and juvenile. This evidence is seen at Site J, below the upper peat and lower foreshore and at Site G (Scales 2007, p 155). The presence of a red deer herd containing stags, hinds and juveniles suggests the deer were physically in the area and probably being hunted there during late spring/early summer when they had just started to birth their young. Red deer footprint-tracks at Uskmouth were also made by a combination of stag, hind and juvenile. The Uskmouth laminations had deer trampling on successive laminations suggesting the area was being used year after year by red deer, possibly as a safe environment to raise their young. The red deer at Uskmouth were also likely in the area in late spring/early summer.

There were also auroch (2%), wolf/otter/domesticated dog (2%) and indistinct (1%) mammal footprint-tracks at Goldcliff East. The small number of auroch and roe deer footprints, and the complete absence of wild boar footprints suggest that the wetland area was not a favourable environment for these ungulate species; these were animals more likely to prefer the wooded island habitat. It is also thought that the saltmarsh environment may have been dangerous to large mammals, as auroch bones have been found stuck in Neolithic palaeochannels at Uskmouth and Rumney (Whittle and Green 1988; Green 1989).

11.1.5 Goldcliff East Palaeoecology

The human footprint-tracks from Goldcliff East are generally poorly preserved overtraces/undertraces, although a few exceptionally well-preserved footprints are present (Figure 6.3). Even poorly preserved examples can be identified as human due to their long and slender shape, and specific features such as evidence of hallux, arch of foot, ball of foot or a heel. The most convincing human footprint-tracks are those that form a left-right-left footprint-track trail. Footprint-tracks are relevant in establishing an understanding of hunter-gather activities and their interactions with each other, their environment and other animals. This interaction can also be seen in footprint-track evidence from other time periods. For example, by the Bronze Age the saltmarshes of Goldcliff and Redwick were being exploited for the seasonal grazing of domestic livestock with a focus on dairy production, evidenced from footprint-track data (Barr and Bell 2016). Footprint-tracks are therefore an important part of reconstructing a rich and varied picture of the palaeoecology of this landscape.

There have so far been 342 human footprint-tracks recorded at Goldcliff East. During the research period of 2014-2017, there were 61 possible human footprint-tracks subjected to detailed recording. These footprint-tracks ranged in size from 13cm to 30cm in length. Scales (2006) recorded 233 human footprint-tracks, and during 2005-2014 there were 47 human footprint-tracks recorded. A further 177 possible human footprint-tracks have been recorded from 2001-2017, however these are poorly preserved and may include some ungulates and some other types of sediment disturbance. There have been 21 human footprint-track trails recorded at Goldcliff East between 2001-2017, with 12 obvious footprint-track trails recorded by Scales (2006) and nine trails recorded between 2010-2017. These trails were found at Site H, Site C/E, Site M, Site N, Site R and Site S.

The adults of Goldcliff East had an average stature of 166.5cm (5’5”). This is shorter than the adult stature from Mesolithic skeletons at Totty Pots, Somerset, which have an average stature of 170cm (5’6”) (Schulting *et al*. 2010), and is most similar to the average stature estimates from Neolithic skeletal remains in Orkney, where there was an average height of 166cm (5’5”) (Hedges 1984). Today an average British adult female has a stature of 161.6cm (5’3”), and males 175.3cm (5’9”) (Office for National Statistics 2011). The average stature of British adults is 168.5cm (5’6”), which is only 2cm taller than the average of Mesolithic humans at Goldcliff East.

Only two of the nine footprint-track trails recorded during 2014-2017 were made by people moving quickly. Footprint-tracks from a hunter-gatherer at Site M (2015:160 and 2015:163) suggest that this person was possibly moving at 10km (6 miles) per hour, a steady jogging speed. From Site C/E an individual (2015:114, 2015:115) was moving at a possible 8km (5 miles) per hour, a relatively slow jogging speed. All other footprint-tracks were made by individuals who were walking. There was no indication of prey stalking.

Scales’ (2006) data was reanalysed and the results added to the data of the current study, with 21 human footprint-track trails all considered. Of the identifiable human footprint-tracks at Goldcliff East, one was made by a child under 4 years old, two were made by children aged 5.5 +/- 1.5 years, one by a child aged 6 +/- 1.5 years and one aged 10 +/- 1 year. There were seven footprint-tracks that may have been made by children aged 10+ or adult females, though three of these were under 23cm so more likely to be made by children as only 13% of adult females made footprints smaller than 23cm in the experimental data. There were five footprint-track trails that may have been made by children aged over 10 years old, adult females or adult males. Two footprint-track trails were made by adult males, identifiable as they were over 30cm, there were a further two probable adult males, who made footprint-track trails with footprints over 27cm in length, though these could also have been large adult females or adolescent males. The adult male and probable adult males all came from Site E.

Footprint-tracks can be utilised to understand a prehistoric individual's direction of movement, even if the actual size of the footprint is unclear. This direction of movement may be an indication as to the location of specific resources or activity areas. The footprint-tracks from Site C/E and Site R were mainly orientated in a west/north-west direction, footprint-tracks from Site M, Site N and Site S were orientated in a south-west and north-east direction. The footprint-tracks that were made in a north-east and south-west direction were heading towards and away from the Goldcliff Island projection, towards a palaeochannel, this orientation would take them towards the probable fish trap at Site T and the possible fish trap at Site L, indicating these people were possibly fishing. The Site C/E and Site R footprint-tracks were mainly orientated west/north-west, this direction would take these individuals towards Site A, Site J, and Site W. The Site C/E and Site R footprint-tracks are on higher laminations than the other sites, and are later in date. The direction of movement in the comparative areas suggests that activities at the site changed over time. The only footprint-track trails that were positively identified as male in origin all came from Site E. In this site they are moving in a different direction to those on the lower laminations which may indicate that these males had a different purpose to the females and children, who made footprint-track trails with a predominant east to west direction, which connects to monitoring the fish traps.

The evidence of a probable fish trap in a paleochannel at Site T, along with 513 identifiable fish bones recorded at Goldcliff from Site A, J and an unknown area, suggest that fish were being exploited by the hunter-gatherer-fishers. Eel made up 83% of the fish bone assemblage. Around 25% of eel were of a size that suggested that they were caught during their migration to spawn, which currently occurs in September/October (Ingrem 2007, p 167). Though the other 75% of eel were smaller and would have been in river mouths from March to November, we can therefore see targeted fishing of eel during their migration in September/October, but also evidence that fishing was occurring early spring until late autumn (Bell 2007, Table 18.4). The fish trap evidence, the eel remains, and the footprint-tracks from Site N, which were heading in the same direction as the location of a palaeochannel, indicate that these people had an understanding of migration times. They were probably in the area to fish for large eel, whilst also still fishing the area at other times of year.

The footprint-track data and other archaeology from Goldcliff suggest that the environs were being exploited throughout the year, though not extensively. It was not on a permanent or sedentary basis, rather at various times through the year different activities were undertaken, with the predominance of activity in the late summer/autumn and with spring and winter activity at some sites (Bell 2007, Table 18.4).

Footprint-tracks can provide evidence of paleosociety. Of the 21 footprint-track trails recorded during 2001-2017 (Table 9.9), 29% of this assemblage was made by children. Site N was dominated by small footprint-tracks, from children (11%) and adolescents/adult females (58%). A further 31% of footprint-tracks from Site N may have been made by adult females, small adult males or children aged over 10 years old. There has so far been no clear evidence of large adult males at Site N. Site N is made up of a ‘pathway’ 16m by 6m, and indicates that people were walking south-west towards Goldcliff Island, and north-east away from it. This pathway is on the same axis as Site T, a probable fish trap, located between Site N and Goldcliff Island. Site N is east of Site T and given the dip of the laminated sediments it is likely to be later in date and relate to another fish trap at a time when the channel had migrated further to the east, possibly related to the wooden structure at Site L. Footprint-track evidence, especially from Site N, suggests that children and adult females were involved in fishing and other subsistence activities but the possibility that small adult males were also involved cannot be excluded. The population composition evidence from Goldcliff East can be cautiously compared to ethnographic data. In hunter-gatherer-fisher communities children often take an active role, learning to hunt at a young age so that they could start to provide some of their own food. In indigenous populations, children under 10 make up at least 23% of the population (Statistics Canada 2011a), with children under 15 years old making up as much as 36% of the population (Australian Bureau of Statistics 2012). The footprint-track data from Goldcliff East suggests that children under 10 years old made up at least 29% of the footprint-track trails, and suggests a high percentage of hunter-gatherer children similar to modern indigenous population demographics. Children were not just on the wetlands to play, they were contributing to activities of daily life.

11.2 Further work and recommendations

Mesolithic Goldcliff has been studied for over 26 years, however as the wooden structure at Site T found in the final fieldwork of the present project in 2017 proves, there is still a possibly of new sites and finds. Due to erosion and shifting sediments, finding a Palaeolithic site in this area is probable, with an unstratified unifacial leaf point from the early Upper Palaeolithic already found between Sites A and B (Barton 2007, p 113), as well as three other more recent finds of the same date. Mesolithic footprint-track sites are also still being found in new areas, indicating that there is scope for more research, especially as technology advances and sites are exposed further by erosion. The benefits of long term monitoring are evident from both Scales’

(2006) dataset and that presented within this further research; new archaeology is constantly being exposed. A comparison of these two bodies of work also indicates the advances in recording techniques which have been made over this timescale. Structure from motion utilising multi-image photogrammetry has been an effective recording technique for footprint-tracks and it would be beneficial to integrate all data from the Goldcliff footprint areas, including differential GPS, EDM survey, air photography and unmanned aerial vehicle data (drones) into one large survey. An integrated survey of the Goldcliff data will allow for the extent of the Mesolithic site to be fully appreciated.

There is a need for further study of mammal and avian footprints, especially in understanding the formation processes in different sediments and the foot features that survive on these sediments. An increase in the avian footprint database would be beneficial for ornithologists and archaeologists alike, as the database is small and generally restricted to tracking guides. This study found that differentiating between similar avian species can be problematic, and this often results in an inability to accurately identify the bird that made the footprint, so a comment on the birds’ migration or residential status could not always be made. There are 122 species of bird that have been seen on the Severn Estuary since 1952, some are extremely rare but some are not. Only 21 species were included in this study; these were from avian species that frequent Britain, specifically the Severn Estuary, and are represented by archaeological bone evidence or are currently found there. It is likely that many species of birds that were in prehistoric Britain have not been preserved in the archaeological bone record but may appear in the footprint-track record.

Further exploration of the formation of mammalian footprints upon different sediments, made by differently aged animals of both sexes would be beneficial. This data would be relevant for footprints made during prehistory to present and would be a valuable resource. The value of this work is presented by Barr and Bell (2016), however a much larger database with more species would be appropriate.

There is still scope for future research regarding the relationship between a human footprint and a person’s height, weight, age, sex and speed of movement. A focus on pubescent children would be beneficial to establish if there are any ways that adult females and adolescent footprints differentiate from one another. Further work with children and the way they walk would also be useful as footprints made by children are vastly understudied and there is very little data available, especially regarding the relationship between stature and foot length, and speed of movement. Further ethnographic data collection involving hunter-gatherer-fisher children would be highly beneficial, as hunter-gatherer children are rarely included in anthropological footprint-track research. It would be of interest to establish if in a larger dataset the differences between an adolescent and an adult female footprint can be identified. A study of pregnant women and women carrying heavy objects/young children would also make an interesting comparison to see if this is identifiable in a footprint made on clayey silt. A worldwide database of this sort of information would be beneficial to forensic scientists, anthropologists and archaeologists alike and would greatly enhance and progress the study of ichnology and forensic podiatry.

Footprint-tracks from intertidal sites provide us with important information about the people of the past who formed them; however these sites are at risk for a variety of reasons. Planned tidal energy lagoons and coastal defence upgrading are current threats to the intertidal zone of the Severn Estuary. Multiple sites are currently being considered for the location of the lagoon, including at Cardiff and east of the Usk river at Newport, these would both effect the intertidal sites of the Gwent Levels. The building of a lagoon east of Newport would permanently submerge lower footprint-track areas such as Site N at Goldcliff East. Site T, which is currently of significant archaeological interest due to possible evidence of a Late Mesolithic fish trap, would also be at high risk of being submerged. Lagoon construction and discharge would lead to extensive erosion of many parts of the intertidal zone, affecting not just Mesolithic sites but the entire area. It is essential that archaeologists work alongside other sectors, such as nature conservationists, to investigate and protect these unique sites. This study, through a placement with the RSPB and Gwent Levels Wildlife Trust as part of the Living Levels Landscape project, has contributed to the establishment of links between archaeology and nature conservation. The writer hopes that this relationship will assist in the protection of the intertidal zone, so that the footprints made by Mesolithic hunter-gatherer-fishers will remain and continue to capture the imagination of the general public and archaeologists alike for generations to come.

Appendix 1

1.1 *CITiZAN Guide: How to Record Prehistoric Footprints. Written by the author*

Increasingly, evidence of ancient footprints is being found in stratified coastal sediments, especially at low tide, exposed by erosion. The CITiZAN project provides the opportunity to involve more people in the search for this fascinating source of archaeological evidence. It can tell us that people or animals were present at a particular time and period, and about the age structure of human populations in an area and past patterns of animal husbandry. To get the most from this evidence the footprints need to be well recorded.

Prehistoric footprints can be found in a variety of situations, however, in the UK the most common find will be from intertidal sediments. Footprints may be of people, wild and domestic animals and birds. The key question is: are the footprints in consolidated sediments which were distorted when they were made but are now consolidated and firm? Or are the footprints in unconsolidated mud and likely to be of very recent origin? Some of the best footprints are found in laminated sediments where there are bands of silty clay separated by thin bands. Human footprints made in this type of environment may be found with an obvious toe, ball of foot and heel indentation. They can also be rather indistinct, only recognisable as footprints because you can see a clear left-right-left-right trail. In any case the process of recording is the same.

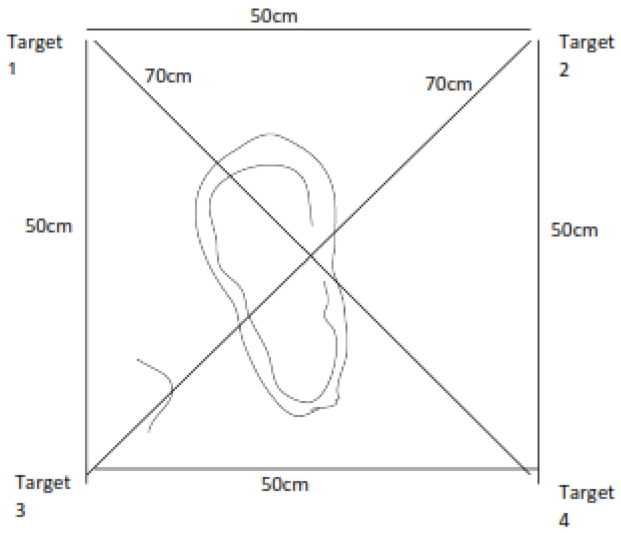
The first stage of footprint recording involves general recording:

1. Give the footprint a find number
2. Photograph with a scale bar
3. Determine the orientation of the footprint using a compass
4. Photograph with a north arrow
5. Take GPS co-ordinates using a handheld GPS, your phone, or if you are lucky enough to have access to one, a differential GPS.
6. If you do not have equipment with GPS but you do have a compass then taking the angle between magnetic north and several fixed points which will be on the map is a useful way of establishing location.

(Any archaeological features near the footprints, such as a submerged forest or palaeochannels, should also be noted on a sketch diagram with measured or paced distances where possible).

Once general recording has occurred, the footprint should then be recorded so that it can processed in photogrammetry software, this involves taking multiple pictures from a variety of angles. Specific targets are required to give the best results possible for this technique; these targets can be found in the attached file, which can be printed out and kept with the rest of your archaeology kit, and used if footprints are discovered.

7. Lay the targets out in a square around the footprints. A drawing square can be used to assist in this (50cm^2 are most effective). If you do not have a drawing square then a measuring tape and base line can be used; again creating a 50cm^2 is best for recording a small area. If the footprints cover a large area this can be increased to 1m^2 if needed.
8. Secure each target with a nail and note down each target's number and its location in reference to the footprint. Make a drawing for easy reference (see below).
9. Measure the exact distance between the white dots in the centre of the targets as this information is sometimes needed when GPS data is insufficient or unavailable.
10. Once you have taken the measurements, if you have a differential GPS with you then you should take the location of each target, by placing the GPS on the white circle in the centre of the targets.



You are now ready to photograph the footprints. The aim is to take as many photographs as possible from a variety of angles.

- Do not use the zoom or flash functions.
- Shoot in RAW if your camera is able, if not use jpeg format.
- A digital SLR camera with a full frame and a fixed angle lens is preferred, but most phones or compact digital cameras today will work fine.
- Each photograph should overlap the last photo's frame by at least a third.
- If you are using a compact digital camera each photograph needs to overlap the last photograph's frame by at least a quarter.
- If at all possible use a tripod; however, in intertidal zones the use of a tripod is often impractical so if a tripod proves difficult to manage then freehand is satisfactory.

11. You should now take as many photographs as possible, from multiple angles, ensuring photograph overlap. The photographs should be not just from the side but also from multiple angles above.

You should back up the photographs as soon as possible.

I am a postgraduate research student working on prehistoric footprints in the Department of Archaeology, University of Reading, Whiteknights, PO Box 227 Reading, RG6 6AB.
You can contact me at k.barr@pgr.reading.ac.uk to discuss your footprint finds, I can also create the 3D models.

1.2 *OSL Report*

University of Gloucestershire
Luminescence dating laboratory

Optical dating of sediments:
Goldcliff East and East Dean Woods excavations, UK

to

Prof. M.G. Bell
University of Reading

Prepared by Dr P.S. Toms, 16 November 2017

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Scope of Report
This is a standard report of the Luminescence dating laboratory, University of Gloucestershire. In large part, the document summarises the processes, diagnostics and data drawn upon to deliver Table 1. A conclusion on the analytical validity of each sample's optical age estimate is expressed in Table 2; where there are caveats, the reader is directed to the relevant section of the report that explains the issue further in general terms.

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Field Code	Lab Code	Overburden (m)	Grain size (µm)	Moisture content (%)	Ge γ-spectrometry (*ex situ*)			α D_r (Gy.ka^{-1})	β D_r (Gy.ka^{-1})	β D_r (Gy.ka^{-1})	Cosmic D_r (Gy.ka^{-1})	Preheat (°C for 10s)	Low Dose Repeat Ratio	Interpolated:Applied Low Regenerative-dose D_e	High Dose Repeat Ratio	Interpolated:Applied High Regenerative-dose D_e	Post-IR OSL Ratio
					K (%)	Th (ppm)	U (ppm)										
OSL Sample III Site R	GL16184	6.0	5-15	26 ± 7	1.62 ± 0.10	7.75 ± 0.51	1.65 ± 0.14	0.26 ± 0.04	1.16 ± 0.15	0.66 ± 0.06	0.06 ± 0.01	220	0.96 ± 0.10	0.97 ± 0.06	1.06 ± 0.10	1.07 ± 0.10	1.00 ± 0.10
Goldcliff East 2016:68	GL16185	6.0	5-15	27 ± 7	1.07 ± 0.06	5.69 ± 0.44	1.73 ± 0.14	0.23 ± 0.03	0.85 ± 0.11	0.51 ± 0.06	0.06 ± 0.01	220	0.96 ± 0.06	0.97 ± 0.06	1.02 ± 0.07	1.04 ± 0.07	0.96 ± 0.07
EDW 16 Trench 5m 0.52-0.58m OSL	GL16186	0.6	5-15	16 ± 4	1.00 ± 0.06	6.92 ± 0.57	2.59 ± 0.16	0.43 ± 0.04	1.14 ± 0.10	0.79 ± 0.06	0.20 ± 0.02	220	1.02 ± 0.03	1.01 ± 0.03	1.00 ± 0.02	1.00 ± 0.02	1.01 ± 0.03

Field Code	Lab Code	Total D_r (Gy.ka^{-1})	D_e (Gy)	Age (ka)
OSL Sample III Site R	GL16184	2.15 ± 0.17	14.2 ± 0.6	6.62 ± 0.61 (0.54)
Goldcliff East 2016:68	GL16185	1.67 ± 0.13	14.8 ± 0.6	8.89 ± 0.79 (0.70)
EDW 16 Trench 5m 0.52-0.58m OSL	GL16186	2.56 ± 0.13	4.1 ± 0.1	1.59 ± 0.10 (0.07)

Table 1 D_r, D_e and Age data of submitted samples located at c. 52°N, 3°W, 4m (GL16184 & GL16185) and c. 51°N, 1°W, 190m (GL16186). Age estimates expressed relative to year of sampling. Uncertainties in age are quoted at 1σ confidence, are based on analytical errors and reflect combined systematic and experimental variability and (in parenthesis) experimental variability alone (see 6.0). Blue indicates samples with accepted age estimates, red, age estimates with caveats (if any, see Table 2).

Generic considerations	Field Code	Lab Code	Sample specific considerations
Absence of *in situ* γ spectrometry data (see section 4.0)	OSL Sample III Site R	GL16184	None
	Goldcliff East 2016:68	GL16185	None
	EDW 16 Trench 5m 0.52-0.58m OSL	GL16186	None

Table 2 Analytical validity of sample suite age estimates and caveats for consideration

Mechanisms and principles

Upon exposure to ionising radiation, electrons within the crystal lattice of insulating minerals are displaced from their atomic orbits. Whilst this dislocation is momentary for most electrons, a portion of charge is redistributed to meta-stable sites (traps) within the crystal lattice. In the absence of significant optical and thermal stimuli, this charge can be stored for extensive periods. The quantity of charge relocation and storage relates to the magnitude and period of irradiation. When the lattice is optically or thermally stimulated, charge is evicted from traps and may return to a vacant orbit position (hole). Upon recombination with a hole, an electron's energy can be dissipated in the form of light generating crystal luminescence providing a measure of dose absorption.

Herein, quartz is segregated for dating. The utility of this minerogenic dosimeter lies in the stability of its datable signal over the mid to late Quaternary period, predicted through isothermal decay studies (e.g. Smith *et al*., 1990; retention lifetime 630 Ma at 20°C) and evidenced by optical age estimates concordant with independent chronological controls (e.g. Murray and Olley, 2002). This stability is in contrast to the anomalous fading of comparable signals commonly observed for other ubiquitous sedimentary minerals such as feldspar and zircon (Wintle, 1973; Templer, 1985; Spooner,1993). Optical age estimates of sedimentation (Huntley *et al*., 1985) are premised upon reduction of the minerogenic time dependent signal (Optically Stimulated Luminescence, OSL) to zero through exposure to sunlight and, once buried, signal reformulation by absorption of litho- and cosmogenic radiation. The signal accumulated post burial acts as a dosimeter recording total dose absorption, converting to a chronometer by estimating the rate of dose absorption quantified through the assay of radioactivity in the surrounding lithology and streaming from the cosmos.

Age = Mean Equivalent Dose (D_e, Gy)
Mean Dose Rate (D)

Aitken (1998) and Bøtter-Jensen *et al*. (2003) offer a detailed review of optical dating.

Sample Preparation

Three sediment samples were collected within opaque tubing and submitted for Optical dating. To preclude optical erosion of the datable signal prior to measurement, all samples were opened and prepared under controlled laboratory illumination provided by Encapsulite RB-10 (red) filters. To isolate that material potentially exposed to daylight during sampling, sediment located within 20 mm of each tube-end was removed.

The remaining sample was dried and then sieved. The fine silt fraction was segregated and subjected to acid and alkaline digestion (10% HCl, 15% H_2O) to attain removal of carbonate and organic components respectively. Fine silt sized quartz, along with other mineral grains of varying density and size, was extracted by sample sedimentation in acetone (<15 μm in 2 min 20 s, >5 μm in 21 mins at 20ºC). Feldspars and amorphous silica were then removed from this fraction through acid digestion (35% H_2SiF_6 for 2 weeks, Jackson *et al*., 1976; Berger *et al*., 1980). Following addition of 10% HCl to remove acid soluble fluorides, grains degraded to <5 μm as a result of acid treatment were removed by acetone sedimentation. Twelve multi-grain aliquots (ca. 1.5 mg) were then mounted on aluminium discs for D_e evaluation.

All drying was conducted at 40°C to prevent thermal erosion of the signal. All acids and alkalis were Analar grade. All dilutions (removing toxic-corrosive and non-minerogenic luminescence-bearing substances) were conducted with distilled water to prevent signal contamination by extraneous particles.

Acquisition and accuracy of D_e value

All minerals naturally exhibit marked inter-sample variability in luminescence per unit dose (sensitivity). Therefore, the estimation of D_e acquired since burial requires calibration of the natural signal using known amounts of laboratory dose. D_e values were quantified using a single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle 2000; 2003) facilitated by a Risø TL-DA-15 irradiation-stimulation-detection system (Markey *et al*., 1997; Bøtter-Jensen *et al*., 1999).

Within this apparatus, optical signal stimulation is provided by an assembly of blue diodes (5 packs of 6 Nichia NSPB500S), filtered to 470±80 nm conveying 15 mW.cm $^{-2}$ using a 3 mm Schott GG420 positioned in front of each diode pack. Infrared (IR) stimulation, provided by 6 IR diodes (Telefunken TSHA 6203) stimulating at 875±80nm delivering ~5 mW.cm^{-2}, was used to indicate the presence of contaminant feldspars (Hütt *et al*., 1988). Stimulated photon emissions from quartz aliquots are in the ultraviolet (UV) range and were filtered from stimulating photons by 7.5 mm HOYA U-340 glass and detected by an EMI 9235QA photomultiplier fitted with a blue-green sensitive bialkali photocathode. Aliquot irradiation was conducted using a 1.48 GBq $^{90}Sr/^{90}Y$ β source calibrated for multi-grain aliquots of 5-15 μm quartz against the 'Hotspot 800' ^{60}Co γ source located at the National Physical Laboratory (NPL), UK.

SAR by definition evaluates D_e through measuring the natural signal (Fig. 1) of a single aliquot and then regenerating that aliquot's signal by using known laboratory doses to enable calibration. For each aliquot, five different regenerative doses were administered so as to image dose response. D_e values for each aliquot were then interpolated, and associated counting and fitting errors calculated, by way of exponential plus linear regression (Fig. 1). Weighted (geometric) mean D_e values were calculated, given sufficient mass, from 12 aliquots using the central age model outlined by Galbraith *et al*. (1999) and are quoted at 1□ confidence (Table 1). The accuracy with which D_e equates to total absorbed dose and that dose absorbed since burial was assessed. The former can be considered a function of laboratory factors, the latter, one of environmental issues. Diagnostics were deployed to estimate the influence of these factors and criteria instituted to optimise the accuracy of D_e values.

Laboratory Factors

Feldspar contamination

The propensity of feldspar signals to fade and underestimate age, coupled with their higher sensitivity relative to quartz makes it imperative to quantify feldspar contamination. At room temperature, feldspars generate a signal (IRSL; Fig. 1) upon exposure to IR whereas quartz does not. The signal from feldspars contributing to OSL can be depleted by prior exposure to IR. For all aliquots the contribution of any remaining feldspars was estimated from the OSL IR depletion ratio (Duller, 2003). The influence of IR depletion on the OSL signal can be illustrated by comparing the regenerated post-IR OSL D_e with the applied regenerative-dose. If the addition to OSL by feldspars is insignificant, then the repeat dose ratio of OSL to post-IR OSL should be statistically consistent with unity (Table 1). If any aliquots do not fulfil this criterion, then the sample age estimate should be accepted tentatively. The source of feldspar contamination is rarely rooted in sample preparation; it predominantly results from the occurrence of feldspars as inclusions within quartz.

Preheating

Preheating aliquots between irradiation and optical stimulation is necessary to ensure comparability between natural and laboratory-induced signals. However, the multiple irradiation and preheating steps that are required to define singlealiquot regenerative-dose response leads to signal sensitisation, rendering calibration of the natural Signal inaccurate.

The SAR protocol (Murray and Wintle,2000;2003) enables this sensitisation to be monitored and corrected Using a test dose, here set at 5 Gy preheated to 220□C for 10s, to track signal sensitivity between irradiation-preheat steps. However, the accuracy of sensitisation correction for both natural and laboratory signals can be preheat dependent.

The Dose Recovery test was used to assess the optimal preheat temperature for accurate correction and calibration of the time dependent signal. Dose Recovery (Fig. 2) attempts to quantify the combined effects of thermal transfer and sensitisation on the natural signal, using a precise lab dose to simulate natural dose. The ratio between the applied dose and recovered D_e value should be statistically concordant with unity. For this diagnostic, 6 aliquots were each assigned a 10 s preheat between 180□C and 280□C.

That preheat treatment fulfilling the criterion of accuracy within the Dose Recovery test was selected to generate the final D_e value from a further 12 aliquots. Further thermal treatments, prescribed by Murray and Wintle (2000; 2003), were applied to optimise accuracy and precision. Optical stimulation occurred at 125ºC in order to minimise effects associated with photo-transferred thermoluminescence and maximise signal to noise ratios. Inter-cycle optical stimulation was conducted at 280ºC to minimise recuperation.

Irradiation

For all samples having D_e values in excess of 100 Gy, matters of signal saturation and laboratory irradiation effects are of concern. With regards the former, the rate of signal accumulation generally adheres to a saturating exponential form and it is this that limits the precision and accuracy of D_e values for samples having absorbed large doses. For such samples, the functional range of D_e interpolation by SAR has been verified up to 600 Gy by Pawley *et al*. (2010). Age estimates based on D_e values exceeding this value should be accepted tentatively.

Internal consistency

Abanico plots (Dietze *et al*., 2016) are used to illustrate inter-aliquot D_e variability (Fig. 3). D_e values are standardised relative to the central D_e value for natural signals and are described as overdispersed when >5% lie beyond □ 2□ of the standardising value; resulting from a heterogeneous absorption of burial dose and/or response to the SAR protocol. For multi-grain aliquots, overdispersion of natural signals does not necessarily imply inaccuracy. However where overdispersion is observed for regenerated signals, the efficacy of sensitivity correction may be problematic. Murray and Wintle (2000; 2003) suggest repeat dose ratios (Table 1) offer a measure of SAR protocol success, whereby ratios ranging across 0.9-1.1 are acceptable. However, this variation of repeat dose ratios in the high-dose region can have a significant impact on D_e interpolation. The influence of this effect can be outlined by quantifying the ratio of interpolated to applied regenerative-dose ratio (Table 1). In this study, where both the repeat dose ratios and interpolated to applied regenerative-dose ratios range across 0.9-1.1, sensitivity-correction is considered effective.

Environmental factors

Incomplete zeroing

Post-burial OSL signals residual of pre-burial dose absorption can result where pre-burial sunlight exposure is limited in spectrum, intensity and/or period, leading to age overestimation. This effect is particularly acute for material eroded and redeposited sub-aqueously (Olley *et al*., 1998, 1999; Wallinga, 2002) and exposed to a burial dose of <20 Gy (e.g. Olley *et al*., 2004), has some influence in sub-aerial contexts but is rarely of consequence where aerial transport has occurred. Within single-aliquot regenerative-dose optical dating there are two diagnostics of partial resetting (or bleaching); signal analysis (Agersnap-Larsen *et al*., 2000; Bailey *et al*., 2003) and inter-aliquot D_e distribution studies (Murray *et al*., 1995). Within this study, signal analysis was used to quantify the change in D_e value with respect to optical stimulation time for multi-grain aliquots. This exploits the existence of traps within minerogenic dosimeters that bleach with different efficiency for a given wavelength of light to verify partial bleaching. D_e(t) plots (Fig. 4; Bailey *et al*., 2003) are constructed from separate integrals of signal decay as laboratory optical stimulation progresses. A statistically significant increase in natural D_e (t) is indicative of partial bleaching assuming three conditions are fulfilled. Firstly, that a statistically significant increase in D_e (t) is observed when partial bleaching is simulated within the laboratory. Secondly, that there is no significant rise in D_e (t) when full bleaching is simulated. Finally, there should be no significant augmentation in D_e (t) when zero dose is simulated. Where partial bleaching is detected, the age derived from the sample should be considered a maximum estimate only. However, the utility of signal analysis is strongly dependent upon a samples pre-burial experience of sunlight's spectrum and its residual to post-burial signal ratio. Given in the majority of cases, the spectral exposure history of a deposit is uncertain, the absence of an increase in natural D_e (t) does not necessarily testify to the absence of partial bleaching.

Where requested and feasible, the insensitivities of multi-grain single-aliquot signal analysis may be circumvented by inter-aliquot D_e distribution studies. This analysis uses aliquots of single sand grains to quantify inter-grain D distribution. At present, it is contended that asymmetric inter-grain D_e distributions are symptomatic of partial bleaching and/or pedoturbation (Murray *et al*., 1995; Olley *et al*., 1999; Olley *et al*., 2004; Bateman *et al*., 2003). For partial bleaching at least, it is further contended that the D_e acquired during burial is located in the minimum region of such ranges. The mean and breadth of this minimum region is the subject of current debate, as it is additionally influenced by heterogeneity in microdosimetry, variable inter-grain response to SAR and residual to post-burial signal ratios.

Turbation

As noted in section 3.1.1, the accuracy of sedimentation ages can further be controlled by post-burial trans-strata grain movements forced by pedo- or cryoturbation. Berger (2003) contends pedogenesis prompts a reduction in the apparent sedimentation age of parent material through bioturbation and illuviation of younger material from above and/or by biological recycling and resetting of the datable signal of surface material. Berger (2003) proposes that the chronological products of this remobilisation are A-horizon age estimates reflecting the cessation of pedogenic activity, Bc/C-horizon ages delimiting the maximum age for the initiation of pedogenesis with estimates obtained from Bt-horizons providing an intermediate age 'close to the age of cessation of soil development'. Singhvi et al. (2001), in contrast, suggest that B and C-horizons closely approximate the age of the parent material, the A-horizon, that of the 'soil forming episode'. Recent analyses of inter-aliquot D_e distributions have reinforced this complexity of interpreting burial age from pedoturbated deposits (Lombard *et al*., 2011; Gliganic *et al*., 2015; Jacobs *et al*., 2008; Bateman *et al*., 2007; Gliganic *et al*., 2016). At present there is no definitive post-sampling mechanism for the direct detection of and correction for post-burial sediment remobilisation. However, intervals of palaeosol evolution can be delimited by a maximum age derived from parent material and a minimum age obtained from a unit overlying the palaeosol. Inaccuracy forced by cryoturbation may be bidirectional, heaving older material upwards or drawing younger material downwards into the level to be dated. Cryogenic deformation of matrix-supported material is, typically, visible; sampling of such cryogenically-disturbed sediments can be avoided.

Acquisition and accuracy of D_r value

Lithogenic D_r values were defined through measurement of U, Th and K radionuclide concentration and conversion of these quantities into, and D_r values (Table 1). and □contributions were estimated from sub-samples by laboratory-based □ spectrometry using an Ortec GEM-S high purity Ge coaxial detector system, calibrated using certified reference materials supplied by CANMET. dose rates can be estimated from *in situ* NaI gamma spectrometry or, where direct measurements are unavailable as in the present case, from laboratory-based Ge □ spectrometry. *In situ* measurements reduce uncertainty relating to potential heterogeneity in the dose field surrounding each sample. The level of U disequilibrium was estimated by laboratory-based Ge spectrometry. Estimates of radionuclide concentration were converted into D_r values (Adamiec and Aitken, 1998), accounting for D_e modulation forced by grain size (Mejdahl,1979), present moisture content (Zimmerman, 1971) and, where D_r values were generated from 5-15m quartz, reduced signal sensitivity to radiation (a-value 0.050 □ 0.002). Cosmogenic D_r sample depth, geographical position and matrix density (Prescott and Hutton, 1994).

The spatiotemporal validity of D_r values were calculated on the basis of values can be considered a function of five variables. Firstly, age estimates devoid of *in situ* □ spectrometry data should be accepted tentatively if the sampled unit is heterogeneous in texture or if the sample is located within 300 mm of strata consisting of differing texture and/or mineralogy. However, where samples are obtained throughout a vertical profile, consistent values of □ D_r based solely on laboratory measurements may evidence the homogeneity of the □ field and hence accuracy of □ D_r values. Secondly, disequilibrium can force temporal instability in U and Th emissions. The impact of this infrequent phenomenon (Olley *et al*., 1996) upon age estimates is usually insignificant given their associated margins of error. However, for samples where this effect is pronounced (>50% disequilibrium between ^{238}U and ^{226}Ra; Fig. 5), the resulting age estimates should be accepted tentatively. Thirdly, pedogenically-induced variations in matrix composition of B and C-horizons, such as radionuclide and/or mineral remobilisation, may alter the rate of energy emission and/or absorption. If D_r is invariant through a dated profile and samples encompass primary parent material, then element mobility is likely limited in effect. Fourthly, spatiotemporal detractions from present moisture content are difficult to assess directly, requiring knowledge of the magnitude and timing of differing contents. However, the maximum influence of moisture content variations can be delimited by recalculating D_r for minimum (zero) and maximum (saturation) content. Finally, temporal alteration in the thickness of overburden alters cosmic D_r values. Cosmic D_r often forms a negligible portion of total D_r. It is possible to quantify the maximum influence of overburden flux by recalculating D_r for minimum (zero) and maximum (surface sample) cosmic D_r.

Estimation of Age

Ages reported in Table 1 provide an estimate of sediment burial period based on mean D_e and D_r values and their associated analytical uncertainties. Uncertainty in age estimates is reported as a product of systematic and experimental errors, with the magnitude of experimental errors alone shown in parenthesis (Table 1). Cumulative frequency plots indicate the inter-aliquot variability in age (Fig. 6). The maximum influence of temporal variations in D_r forced by minima-maxima in moisture content and overburden thickness is also illustrated in Fig.6. Where uncertainty in these parameters exists this age range may prove instructive, however the combined extremes represented should not be construed as preferred age estimates. The analytical validity of each sample is presented in Table 2.

Analytical uncertainty

All errors are based upon analytical uncertainty and quoted at 1□ confidence. Error calculations account for the propagation of systematic and/or experimental (random) errors associated with D_e and D_r values.

For D_e values, systematic errors are confined to laboratory □ source calibration. Uncertainty in this respect is that combined from the delivery of the calibrating dose (1.2%; NPL, pers. comm.), the conversion of this dose for SiO_2 using the respective mass energy-absorption coefficient (2%; Hubbell, 1982) and experimental error, totalling 3.5%. Mass attenuation and bremsstrahlung losses during dose delivery are considered negligible. Experimental errors relate to D_e interpolation using sensitisation corrected dose responses. Natural and regenerated sensitisation corrected dose points(S) were quantified by,

$$S_i = (D_i - x.L_i) / (d_i - x.L) \qquad \textbf{Eq.1}$$

where D_i = Natural or regenerated OSL, initial 0.2 s

L_i = Background natural or regenerated OSL, final 5 s

D_i= Test dose OSL, initial 0.2 s

x = Scaling factor, 0.08

The error on each signal parameter is based on counting statistics, reflected by the square-root of measured values. The propagation of these errors within Eq. 1 generating S_i follows the general formula given in Eq. 2. S were then used to define fitting and interpolation errors within exponential plus linear regressions.

For D_r values, systematic errors accommodate uncertainty in radionuclide conversion factors (5%), attenuation coefficients (5%), a-value (4%; derived from a systematic source uncertainty of 3.5% and experimental error), matrix density (0.20 $g.cm^{-3}$), vertical thickness of sampled section (specific to sample collection device), saturation moisture content (3%), moisture content attenuation (2%), burial moisture content (25% relative, unless direct evidence exists of the magnitude and period of differing content) and NaI gamma spectrometer calibration (3%). Experimental errors are associated with radionuclide quantification for each sample by NaI and Ge gamma spectrometry.

The propagation of these errors through to age calculation was quantified using the expression,

$$\square y\ (\square y/\square x) = (\square\ ((\square y/\square x_n).\square x_n)^2)^{1/2} \quad \textbf{Eq. 2}$$

where y is a value equivalent to that function comprising terms x_n and where $\square y$ and $\square x_n$ are associated uncertainties.

Errors on age estimates are presented as combined systematic and experimental errors and experimental errors alone. The former (combined) error should be considered when comparing luminescence ages herein with independent chronometric controls. The latter assumes systematic errors are common to luminescence age estimates generated by means identical to those detailed herein and enable direct comparison with those estimates.

Fig. 1 Signal Calibration

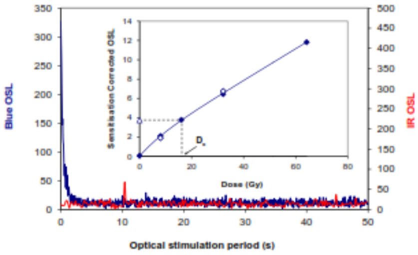


Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Abanico plot of inter-aliquot statistical concordance in D_e values derived from natural irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflect heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching followed by insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

Fig. 5 U Activity Statistical concordance (equilibrium) in the activities of the daughter radioisotope ^{226}Ra with its parent ^{238}U may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium; >50%) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates. A 20% disequilibrium marker is also shown.

Fig. 6 Age Range The Cumulative frequency plot indicates the inter-aliquot variability in age. It also shows the mean age range; an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness is outlined and may prove instructive where there is uncertainty in these parameters. However the combined extremes represented should not be construed as preferred age estimates.

Fig. 2 Dose Recovery

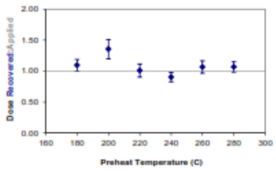
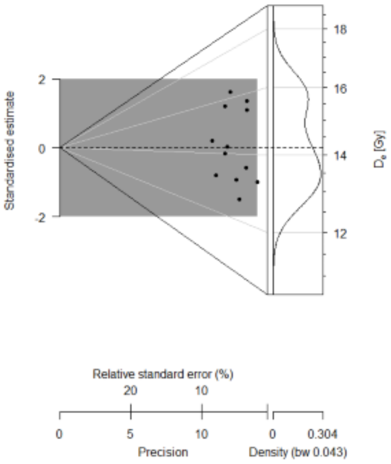


Fig. 3 Inter-aliquot D_e distribution



Sample: GL16184

Fig. 4 Signal Analysis

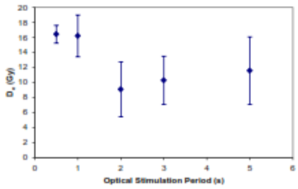


Fig. 5 U Decay Activity

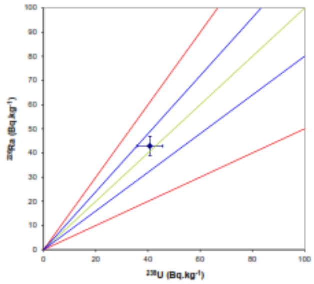


Fig. 6 Age Range

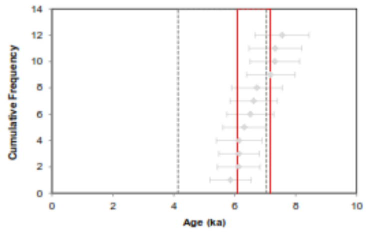


Fig. 1 Signal Calibration

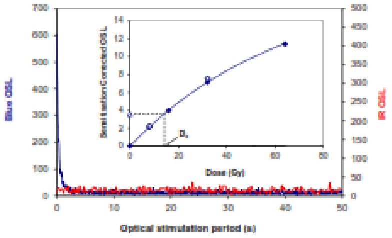


Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

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Fig. 3 Inter-aliquot D_e distribution Abanico plot of inter-aliquot statistical concordance in D_e values derived from natural irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflect heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching followed by insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

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Fig. 6 Age Range The Cumulative frequency plot indicates the inter-aliquot variability in age. It also shows the mean age range; an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness is outlined and may prove instructive where there is uncertainty in these parameters. However the combined extremes represented should not be construed as preferred age estimates.

Fig. 2 Dose Recovery

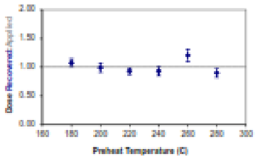
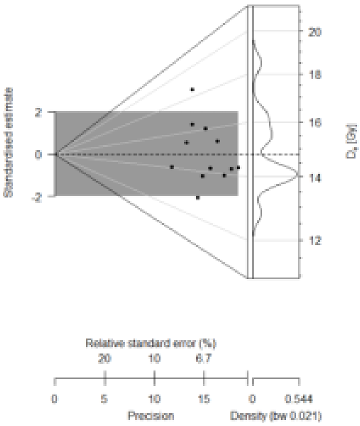


Fig. 3 Inter-aliquot D_e distribution



Sample: GL16185

Fig. 4 Signal Analysis

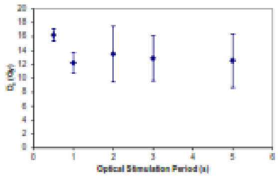


Fig. 5 U Decay Activity

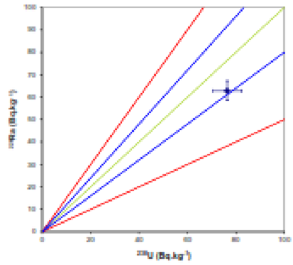


Fig. 6 Age Range

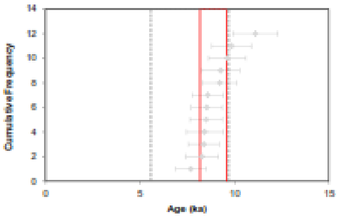


Fig. 1 Signal Calibration

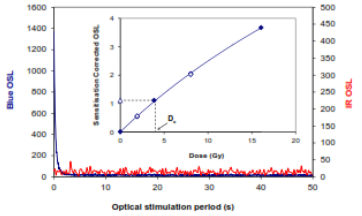


Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Abanico plot of inter-aliquot statistical concordance in D_e values derived from natural irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflect heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching followed by insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

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Fig. 2 Dose Recovery

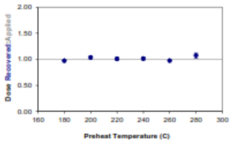
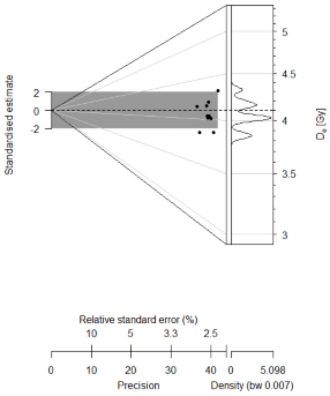


Fig. 3 Inter-aliquot D_e distribution



Sample: GL16186

Fig. 4 Signal Analysis

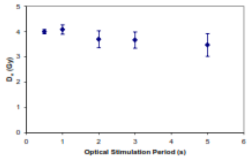


Fig. 5 U Decay Activity

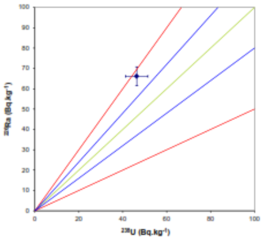
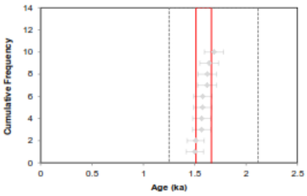


Fig. 6 Age Range



Appendix 1.3 *Footprint recording form*

Site:	**Date:**	**Track No:**

Sketch and observations:

Coordinates:	**Area:**	**Plan No:**	**Level:**
Species:	**Age:**	**Gait:**	**Part of trail?**

Photography:
Standard digital photograph taken: Photo No:
Photogrammetry performed: Photo No:
Photogrammetry model created? Model name:

Laser Scanning Performed? Model name:

Tracings: Small Large Digitised?	**Cast taken?**	**Orientation**	**Block-lifted?**

Micro-CT scanning performed? Info:

Features: Are any of them recognisable?

Drag marks:		**Skim marks:**		**Skid marks:**		**Overtraces:**	
Footprint:		**Marginal ridge:**		**Interdigital ridge:**		**Undertraces**	

Track dimensions in cm:

Further comments: Anything else of particular interest? Was the material the track found in tested for the type of particle size? Any presence of organic material? Was Forum sampled?

Appendix 2.1 *Letter from the University of Reading Ethics Committee regarding their favourable opinion of the footprint experiment involving humans*

UREC 15/38: Understanding the relationship between a child's age and their footprint size. *Favourable opinion*

Thank you for the response (email dated 22 September 2015 from Kirsten Barr, including attachments, refers) addressing the issues raised by the UREC Sub-committee at its September 2015 meeting. On the basis of these responses and the revised documentation, I can confirm that the Chair is pleased to confirm a favourable ethical opinion.

Please note that the Committee will monitor the progress of projects to which it has given favourable ethical opinion approximately one year after such agreement, and then on a regular basis until its completion.

Please also find attached Safety Note 59: Incident Reporting in Human Interventional Studies at the University of Reading, to be followed should there be an incident arising from the conduct of this research.

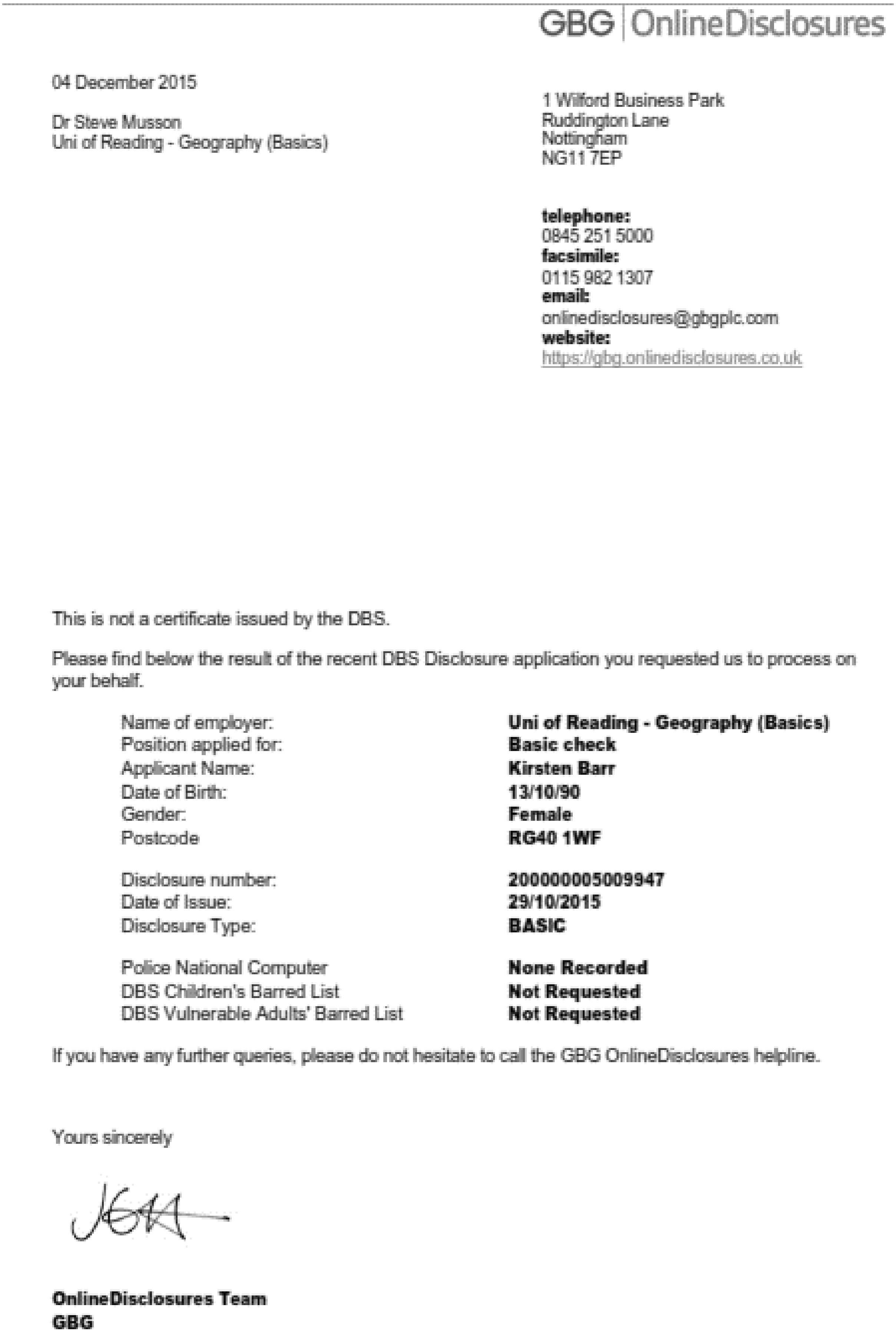
The University Board for Research and Innovation has also asked that recipients of favourable ethical opinions from UREC be reminded of the provisions of the University Code of Good Practice in Research. A copy is attached and further information may be obtained here:

http://www.reading.ac.uk/internal/res/QualityAssuranceInResearch/reas-RSqar.aspx

Yours sincerely

Dr M J Proven
Coordinator for Quality Assurance in Research (UREC Secretary)
cc: Dr John Wright (Chair); Dr Nick Branch (Head of School); Ms Kirsten Barr (PhD student)

Appendix 2.2 *DBS check for Kirsten Barr*



GBG | OnlineDisclosures

04 December 2015

Dr Steve Musson
Uni of Reading - Geography (Basics)

1 Wilford Business Park
Ruddington Lane
Nottingham
NG11 7EP

telephone:
0845 251 5000
facsimile:
0115 982 1307
email:
onlinedisclosures@gbgplc.com
website:
https://gbg.onlinedisclosures.co.uk

This is not a certificate issued by the DBS.

Please find below the result of the recent DBS Disclosure application you requested us to process on your behalf.

Name of employer:	**Uni of Reading - Geography (Basics)**
Position applied for:	**Basic check**
Applicant Name:	**Kirsten Barr**
Date of Birth:	**13/10/90**
Gender:	**Female**
Postcode	**RG40 1WF**
Disclosure number:	**200000005009947**
Date of Issue:	**29/10/2015**
Disclosure Type:	**BASIC**
Police National Computer	**None Recorded**
DBS Children's Barred List	**Not Requested**
DBS Vulnerable Adults' Barred List	**Not Requested**

If you have any further queries, please do not hesitate to call the GBG OnlineDisclosures helpline.

Yours sincerely

OnlineDisclosures Team
GBG

Appendix 2.3 Consent forms for footprint experiment

2.3.1 *Consent form for adults and children over 16 consenting for themselves to take part in the footprint experiment*

Consent Form

Please initial the boxes to indicate your confirmation and consent of each statement:

I confirm that I have read the accompanying Information Sheet relating to the project ☐

I confirm that I have had explained to me the purpose of the project and what will be required of me, and all my questions have been answered to my satisfaction. I agree to the arrangements described in the Information Sheet in so far as they relate to my participation. ☐

I confirm my willingness to partake in this experiment. ☐

I understand that participation is entirely voluntary and that I have the right to withdraw from the project any time, and that this will be without detriment. ☐

This application has been reviewed by the University of Reading Research Ethics Committee and has been given a favourable ethical opinion for conduct.

I have received a copy of this Consent Form and of the accompanying Information Sheet.

Name: ………………………………………………………………………………

Date of birth: ……………………………………………………………………

Signed: ………………………………………...………………………………

Date: …………………………………………………...………………………

2.3.2 *Consent form for adults consenting for their children for the footprint experiment*

Consent Form

Please initial the boxes to indicate your confirmation and consent of each statement:

I confirm that I have read the accompanying Information Sheet ☐

I confirm that I have had explained to me the purpose of the project and what will be required of my child. Any questions that I have about the project have been answered to my satisfaction. I agree to the arrangements described in the Information Sheet in so far as they relate to my child's participation. ☐

I give consent for my child to partake in this experiment. ☐

I understand that participation is entirely voluntary and that my child may withdraw from the project any time, and that this will be without detriment. ☐

This application has been reviewed by the University of Reading Research Ethics Committee and has been given a favourable ethical opinion for conduct.

I have received a copy of this Consent Form and of the accompanying Information Sheet.

Name: ………………………………………………………………………………

Date of birth: ……………………………………………………………………

Signed: ……………………………………………...………………………………

Date: ………………………………………………………...………………………

Appendix 2.4 Information sheets for footprint experiment

2.4.1 *Information sheet for children under 7 years old*

University of Reading

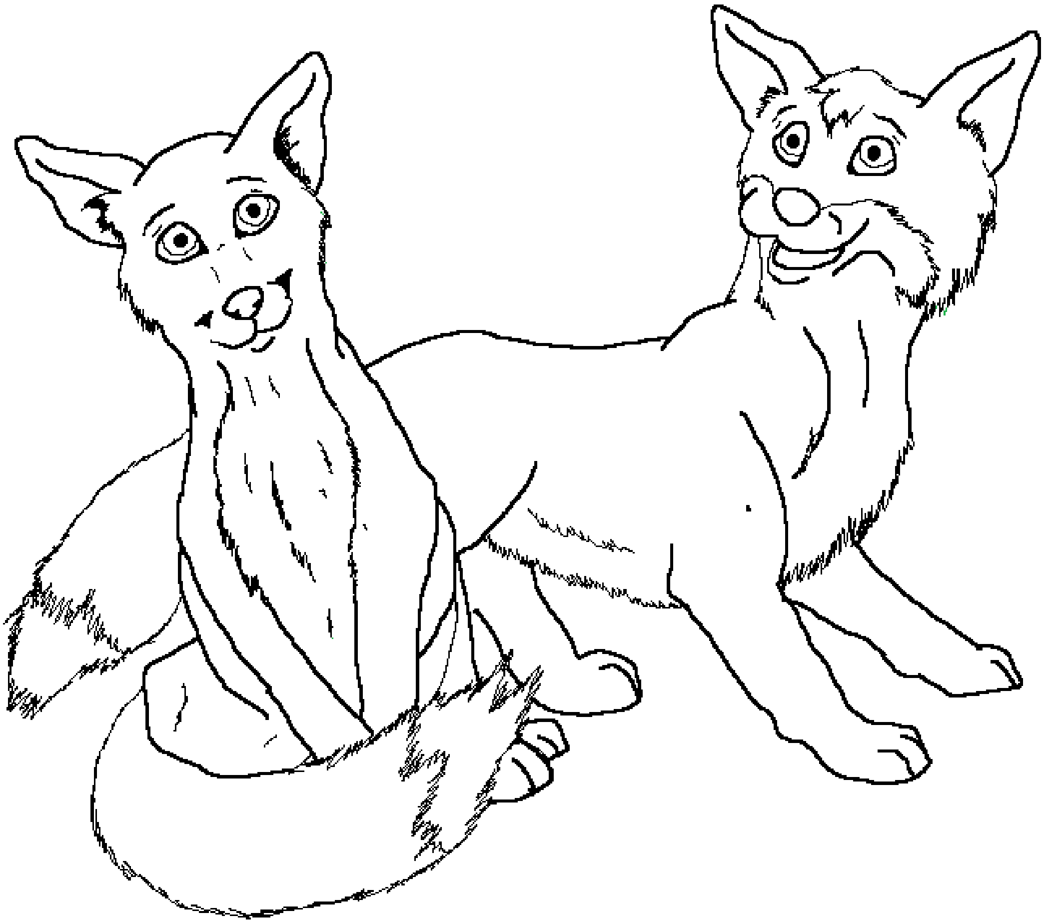
Kirsten Barr MSc
Doctoral Research Student
07875381244
k.barr@pgr.reading.ac.uk

Allen Lab 1.11,
Department of Archaeology,
School of Archaeology, Geography and Environmental Science
University of Reading
Reading RG6 6AH
Phone +44 (0) 118 378 8132
Email archaeology@reading.ac.uk
Web www.reading.ac.uk/archaeology

Information sheet for minors (<7 years old)

Making Footprints

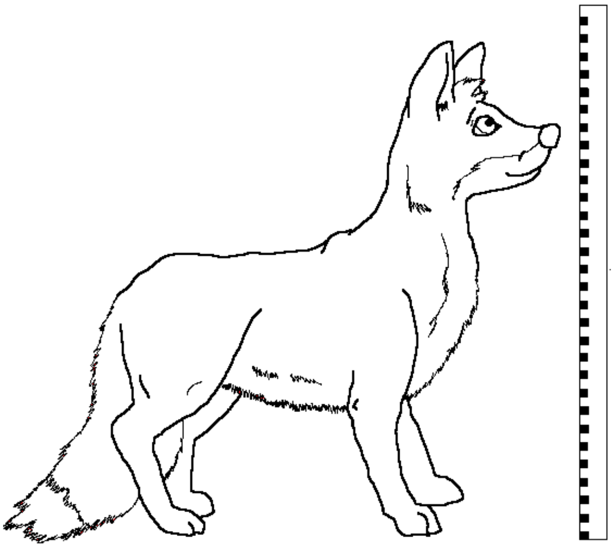
Hi, my name is Charlotte and this is my brother George



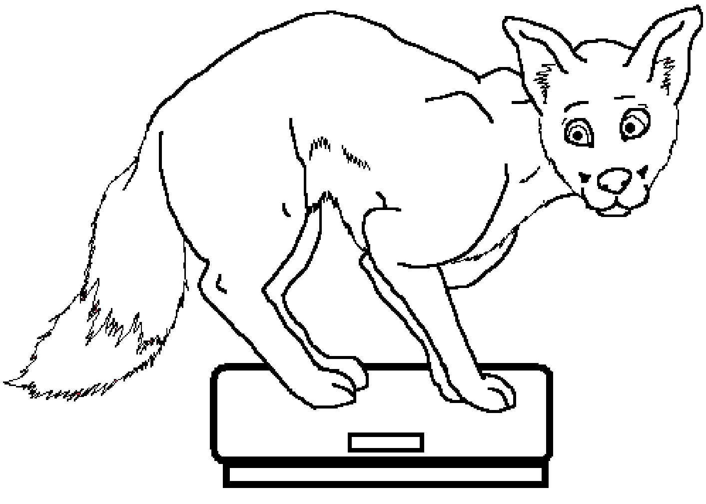
Today we are going to make footprints in some mud to see what they look like.

Would you like to do it too?

First we are going to see how big we are, standing up straight to be measured.

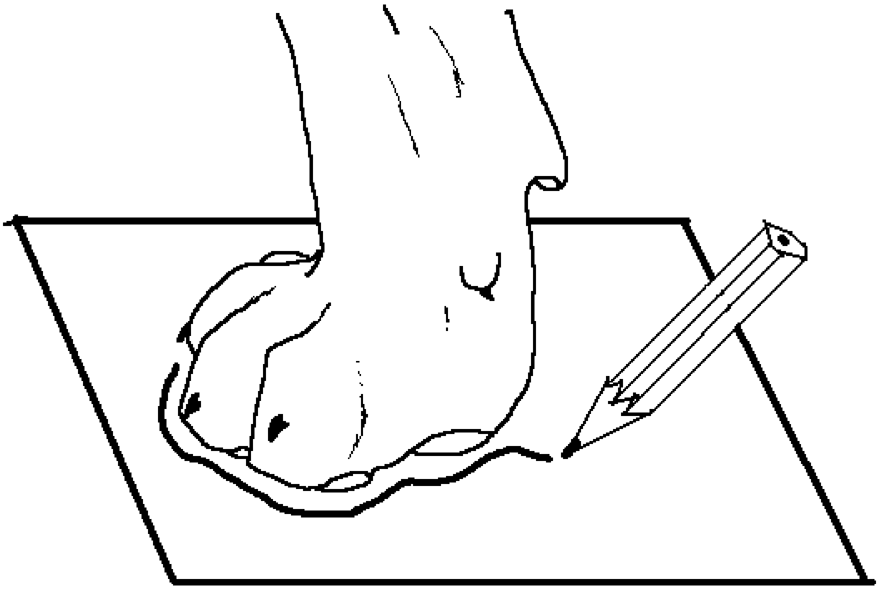


And standing still on the scales.

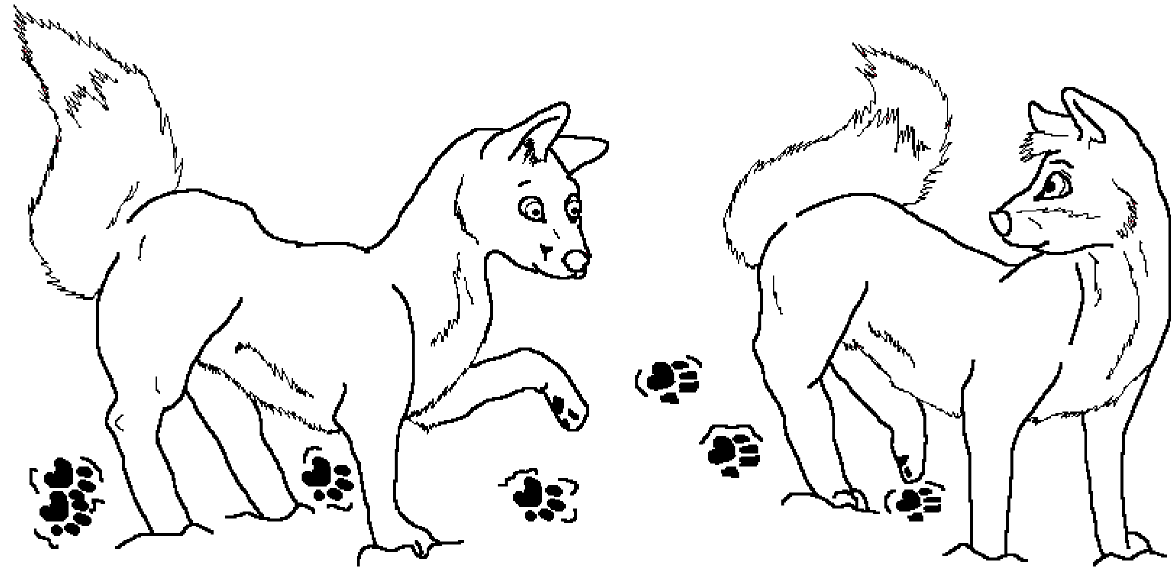


Then we are going to take our shoes and socks off.

Next we will stand on a piece of paper and somebody will draw around our feet.

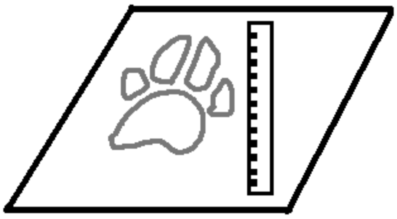


Now it's time to walk barefoot in the mud!



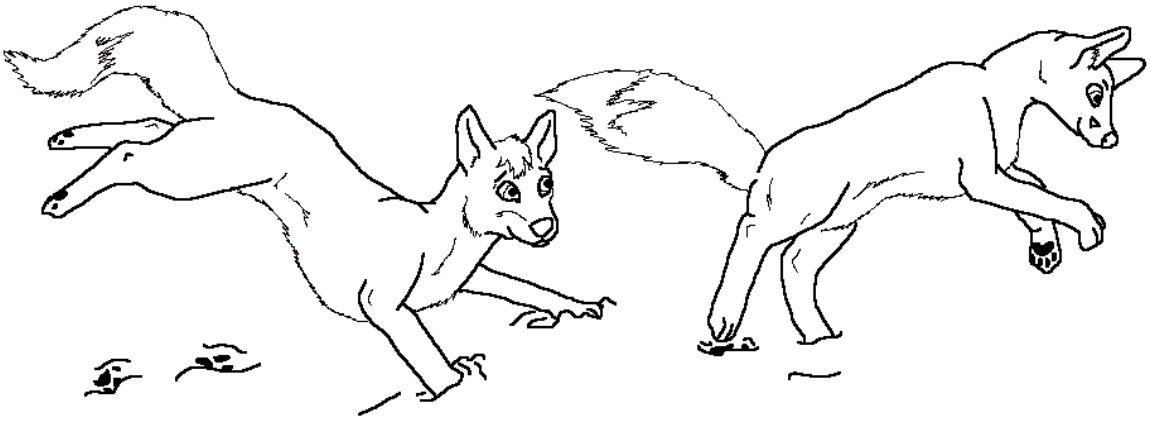
After we have walked, we will run in the mud!

A lady will then take photos and measurements from our footprints.



We will then walk on softer mud, and our footprints might look different in the soft mud.

We will then walk on very soft mud, then we will run on it too!



We are finished now so we will clean our feet off and put our shoes and socks back on.

2.4.2 *Information sheet for children aged between 7 and 11 years old*

University of Reading

Kirsten Barr MSc
Doctoral Research Student
07875381244
k.barr@pgr.reading.ac.uk

Allen Lab 1.11,
Department of Archaeology,
School of Archaeology, Geography and Environmental Science
University of Reading
Reading RG6 6AH
Phone +44 (0) 118 378 8132
Email archaeology@reading.ac.uk
Web www.reading.ac.uk/archaeology

Information sheet for minors (Age 7-11)

Making Footprints

Would you would like to take part in a research project?

Please read this information pack carefully with your parents so that everybody understands why this study is being done and what it is we would like you to do.

If something doesn't make sense, you can get your parents to contact me and we can discuss it.

Thank you for taking the time to read this.

This research is being done to understand if the size of a person's footprints can tell us about their age and height.

Information Sheet

Footprints from prehistoric people have been found in Wales and we are trying to find out if we can look at the footprints of people today to help us understand how old and how big prehistoric people were.

Children of the same age can be a lot of different heights and weights but we are trying to find out if children of a similar age and height have similarly sized feet.

Why have I been asked to take part?

You have been asked to take part in this study as you are aged between 3 and 18 years, and we are interested in footprints made by children.

Did anyone else check that this study is OK to do?

Before any research is allowed to go ahead a group of experts will discuss whether the research is safe and fair.

Do I have to take part?

You don't have to take part and can decide at any point throughout the study that you no longer would like to be involved.

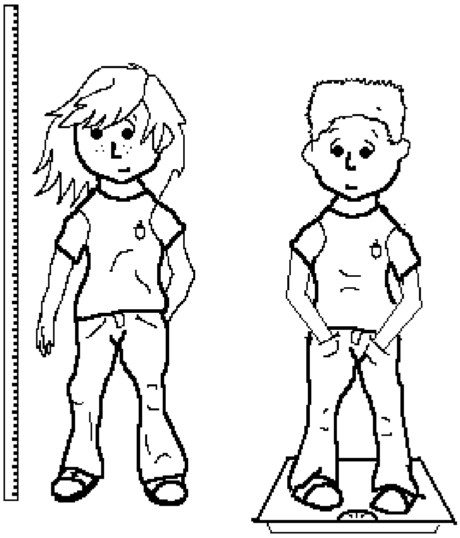
What will happen to me if I take part?

Once we have checked that you and your parents are happy with the project then we are ready to start.

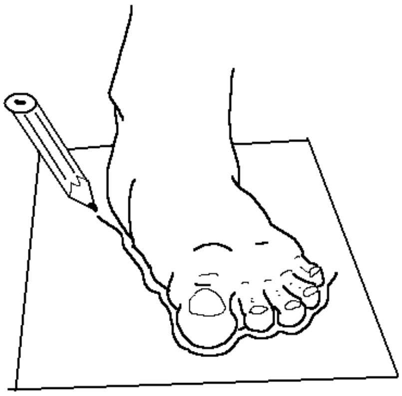
The research will take place at your school/ childminding group/ after school club.

Everyone will be given a number instead of using their name.

We will measure your height and weight and ask you what shoe size you wear.

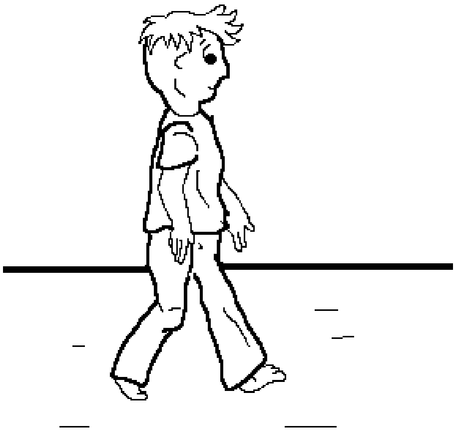


Then we will get you to remove your shoes and socks and stand up straight on a piece of paper, we will draw around both your feet with a pencil, this will show us how big your feet are and the shape of your feet.

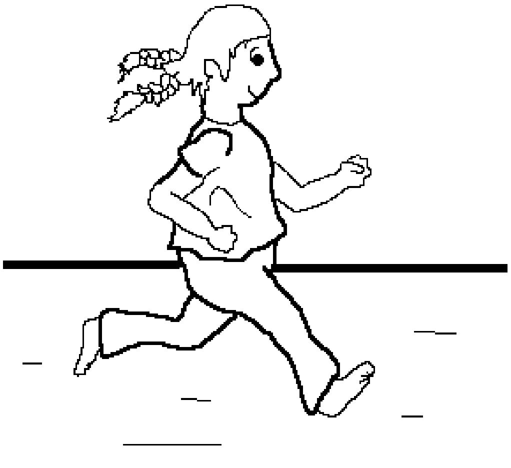


There will be an area that we will get you to walk bare footed over, before you do this we will have checked for anything sharp that could hurt your feet and removed it.

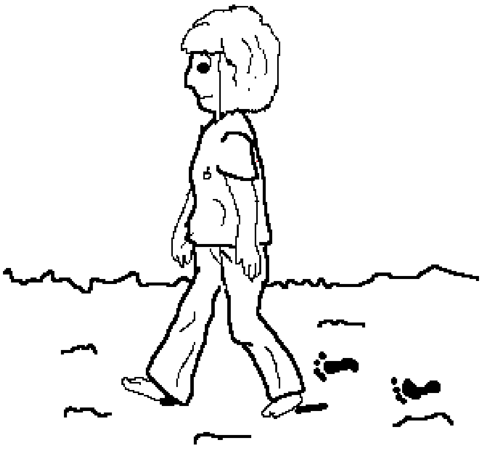
We will ask you to walk bare footed across a hard surface, if you make any footprints we will photograph and measure them.



We will then ask you to run across the same surface to see if running changes the size and shape of your footprints. Make sure you are careful when you run so that you don’t slip up.



Next we will get you to walk over a softer, slightly muddy surface, we will record your footprints. It is possible that you will create more footprints on this surface.

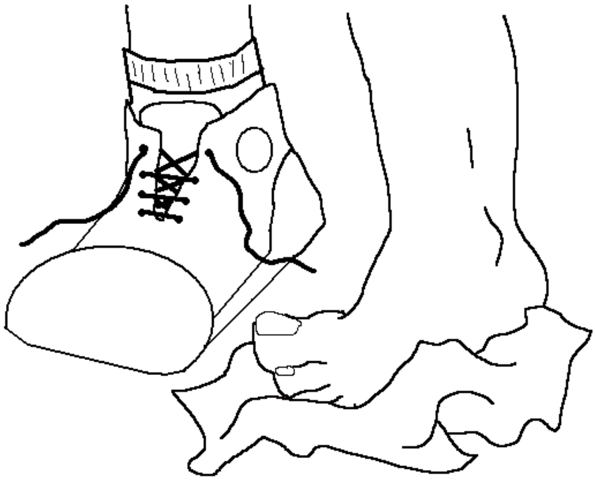


We will then ask you to run across this area.

We will then ask you to walk across a muddy surface, it is possible that your footprints will again be a different size.

Finally we will ask you to run over the muddy surface and record any footprints you make.

The experiment will then be over so you can clean off your feet and put your shoes and socks back on.



Are there any risks?

All surfaces that you will be walking and running over will have been carefully checked for anything that can hurt your feet, and you should walk and run on the mud carefully so you don't slip up.

What happens to the research?

The research will be written and talked about, you won't be talked about directly, only by the number you were given.

Will my information be kept private?

Yes all information will be private, you are given a number when you join the study for your privacy.

What do I do if I don't want to take part in the research?

At any time throughout the study you can decide that you no longer want to take part. You can get your parents to phone or email the researcher or on the day of the experiment you can tell the researcher you no longer want to take part.

2.4.3 *Information sheet for children aged 12-15 years old*

University of Reading

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Making Footprints

I would like to ask whether you would be willing to take part in a research project.

Please read this information pack carefully with your parents so that everybody understands why this study is being done and what it is we would like you to do.

If something doesn't make sense, you can get your parents to contact me and we can discuss it.

Thank you for taking the time to read this.

This research is aiming to understand if the size of a person's footprints can indicate the age and height of the person who made them.

Information Sheet

Footprints from prehistoric people have been found in Wales and we are trying to find out if we can look at the footprints of people today to help us understand the age and height of prehistoric people. Children of the same age can be a lot of different heights and weights, but we are trying to find out if children of a similar age and height have similarly sized feet.

Why have I been asked to take part?

You have been asked to take part in this study as you are aged between 3 and 18 years, and we are interested in the footprints made by young people.

Did anyone else check that this study is OK to do?

Before any research is allowed to go ahead a committee of experts will discuss whether the research is safe and fair.

Do I have to take part?

You don't have to take part and can decide at any point throughout the study that you no longer would like to be involved.

What will happen to me if I take part?

Once we have checked that you and your parents are happy with the project then we are ready to start.

The research will take place at your school/ childminding group/ after school club.

Each person will be given a number instead of their name being used.

We will measure your height and weight and ask you what shoe size you wear.

Then we will get you to remove your shoes and socks and stand up straight on a piece of paper, we will draw around both your feet with a pencil, this will show us the size of your feet and the shape of your feet.

There will be an area that we will get you to walk bare footed over, before you do this we will have checked for anything sharp that could hurt your feet and removed it.

We will ask you to walk bare footed across a hard surface, if you make any footprints we will photograph and measure them. We will then ask you to run across the same surface to see if running changes the size and shape of your footprints. Make sure you are careful when you run so that you don't slip up.

Next we will get you to walk over a softer, slightly muddy surface, we will record your footprints. It is possible that you will create more footprints on this surface. We will then ask you to run across this area.

We will ask you to walk across a muddy surface, it is possible that your footprints will again be a different size. Finally we will ask you to run over the muddy surface and record any footprints you make.

The experiment is now over so you can clean off your feet with the wet wipes, paper towels and clean water, and then you can put your shoes and socks back on.

Are there any risks?

All surfaces that you will be walking and running over will have been carefully checked for anything that can hurt your feet, you should walk and run on the mud carefully so you don't slip up.

What happens to the research?

Though the research will be written and talked about, you won't be talked about directly, only by the number that you were given.

Will my information be kept private?

Yes all information will be private, you are assigned a number when you join the study for your privacy.

What do I do if I don't want to take part in the research?

At any time during the study you can decide that you no longer want to take part. You can get your parents to ring the researcher, or on the day of the experiment you can tell the researcher you don't want to take part anymore.

2.4.4 *Information sheet for those over 16 years old consenting for themselves*

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Information Sheet

I would like to ask whether you would be willing to take part in a research project.

This project aims to understand the relationship between someone's age and height and their footprint size. The purpose of this research is to better understand prehistoric footprints that have been found throughout the UK. Of the footprints recorded, between 70% and 80% are fairly small, likely to have been created by children or young adults, so we are trying to establish the age and size of the people from prehistory. Young people of the same age can be a lot of different heights and weights but we are trying to find out if people of a similar age and height have similarly sized feet.

Thank you for taking the time to read this.

Why have I been asked to take part?

You have been asked to take part in this study as you are aged between 3 and 18 years, and we are interested in the footprints made by children and young adults.

Did anyone else check that this study is OK to do?

Before any research is allowed to go ahead the research will gain ethical approval from the *University Of Reading Ethics Research Committee* who will decide that the research is safe.

Do I have to take part?

You don't have to take part and can decide at any point throughout the study that you no longer would like to be involved.

What will happen to me if I take part?

Once we have determined that you are happy with the project then we are ready to start the footprint experiment. The research will take place at your school/ after school club. You will remain anonymous throughout the whole project as you will be assigned a number.

We will ask you to remove your shoes and socks so that we can measure your height in centimetres and your weight in kilograms, again this will all be anonymous. We will also ask you what shoe sizes you wear.

After we have recorded your weight and height measurements you will be asked to stand up straight on a piece of paper, we will then draw around both your feet with a pencil. This will show us the size of your feet and the shape of your feet, and can be used as a comparison against the footprints that you create.

The experimental area involves a surface approximately two and a half meters in length, filled with sediment. We will ask you to walk barefoot over this area, before you do this we will have checked for anything sharp that could hurt your feet and if anything is found we will remove it.

We will ask you to walk bare footed across the experimental hard surface, try to walk normally and not alter the way that you usually walk. If you make any footprints we will photograph and measure them. We will then ask you to run across the same surface to see if running changes the size and shape of your footprints. Make sure you are careful when you run so that you don't slip up, again try to not alter the way in which you run.

Next we will ask you to walk over a softer, slightly muddy surface, we will record your footprints. It is likely that your footprints will be different from the prints created previously. We will then ask you to run across this area.

We will then ask you to walk across a muddy surface, it is possible that your footprints will again be a different size. Finally we will ask you to run over the muddy surface and record any footprints you make.

The repetitions of the experiment will now be complete so please clean your feet off using the wet wipes, clean water and paper towels provided, then put your shoes and socks back on.

Are there any risks?

All surfaces that you will be walking and running over will have been carefully checked for anything that can hurt your feet, and you should walk and run on the mud carefully so you don't slip up. Due to the potentially slippery surface there is a small risk of falling. We will have a first aid kit on hand in case you do hurt your feet on something and we will be aware of the location of the nearest hospital in the unlikely event of a severe accident.

In regards to your personal safety, all individuals involved with this project will have undergone a full Disclosure and Barring Service check before they are permitted to become involved.

What happens to the research?

The research will be written about and presentations and talks may be given using this information. You won't be talked about directly, only by the number that you were assigned.

Will my information be kept private?

Yes all information will be private, you are assigned a number when you join the study for your privacy.

What do I do if I don't want to take part in the research?

At any time throughout the study you can decide that you no longer want to take part. You can phone or email the researcher, or on the day of the experiment you can tell the researcher you don't want to take part anymore. At any moment throughout the experiment if you decide that you do not want to be involved then tell the researcher, this is absolutely fine for you to do.

2.4.5 *Information sheet for adults consenting for their children*

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Information Sheet

I would like to ask whether you would allow your child to take part in a PhD research project.

This project aims to understand the relationship between a person’s age and height and their footprint size. The purpose of this research is to better understand prehistoric footprints that have been found throughout the UK. We are trying to establish the age and size of the people from prehistory; of the prehistoric footprints recorded, between 70% and 80% are fairly small, likely to have been created by children or young adults. Children of the same age can be a lot of different heights and weights but we are trying to find out if children of a similar age and height have similarly sized feet. We will use the data gathered in this research to create a stature equation that is directly relevant to footprints.

Thank you for taking the time to read this.

Why has my child been asked to take part?

Your child has been asked to take part in this study as they are aged between 3 and 16 years, and we are interested in the footprints made by children and young adults. We are also interested in footprints made by adults.

Did anyone else check that this study is appropriate?

Before we have undertaken any research we submitted the research to the *University Of Reading Ethics Research Committee* and gained full approval.

Does my child have to take part?

Your child does not have to take part and you or your child can decide at any point throughout the study that they no longer would like to be involved.

What will happen to my child if they take part?

Once we have determined that you are happy with the project then we are ready to start the footprint experiment. The research will take place at your child’s school/childminders/ after school club. Your child will remain anonymous throughout the whole project as they will be assigned a number instead of any names or descriptions being used.

We will ask your child to remove their shoes and socks so that we can measure their height in centimetres and their weight in kilograms, again this will all be anonymous. We will also ask your child what shoe size they wear, or if they are very young we will ask you what size they wear.

After we have taken the weight and height measurements your child will be asked to stand up straight on a piece of paper, we will then draw around both their feet with a pencil. This will show us the shape and size of their feet and can be used as a comparison against the footprints that they create.

The experimental area involves a surface approximately two and a half meters in length, filled with sediment. We will ask your child to walk bare footed over this area, before they do this we will have checked for anything sharp that could hurt their feet and if anything is found we will remove it immediately.

We will ask your child to walk bare footed across the experimental hard surface. While doing so we will ask them questions as they walk to distract them from thinking about walking, this will ensure that they walk normally and do not alter the way that they usually walk. If they make any footprints we will photograph and measure them. We will then ask them to run across the same surface to see if running changes the size and shape of the footprints. We will remind your child to be careful when they are running so that they don't slip up, again we will talk to them to take their mind off running to try to prevent them from altering the way in which they run.

Next we will ask your child to walk over a softer, slightly muddy surface, and record any footprints created. It is likely that these footprints will be different from the prints created previously. We will then ask your child to run across this area.

Finally we will ask your child to walk across a muddy surface, it is possible that the footprints will again be a different size and shape. We will ask your child to run over the muddy surface and record any further footprints made.

The experiment will now be complete so your child can then clean their feet off using the wet wipes, clean water and paper towels provided, then they can put their shoes and socks back on.

Are there any risks?

All surfaces that your child will be walking and running over will have been carefully checked for anything that can hurt their feet. Your child should walk and run on the mud carefully so that they don't slip up and hurt themselves. Due to the potentially slippery surface there is a small risk of slipping and falling. We will have a first aid kit on hand in case they do hurt their feet on something and we will be aware of the location of the nearest hospital in the unlikely event of a severe accident.

In regards to your child's personal safety, all individuals involved with this project will have undergone a full Disclosure and Barring Service check before they are permitted to become involved.

What happens to the research?

The research will be written about and presentations and talks may be given using this information. Your child won't be talked about directly, only by the number they were given.

Will the information be kept private?

Yes all information will be private, your child will be assigned a number when they join the study for their privacy.

What do I do if I don’t want my child to take part in the research?

At any time throughout the study you can decide that you no longer want your child to take part. You can phone or email the researcher or on the day of the experiment you can tell the researcher you don’t want your child to take part any longer. At any moment throughout the experiment if your child decides that they do not want to be involved then they can tell the researcher, this is absolutely fine for them to do.

Appendix 3

3.1 *Footprint catalogue of all footprints recorded at Goldcliff East between 2007-2017. These findings lead directly on from the Bell (2007) monograph. The work of this thesis has focused on footprint-tracks found from 2014-2017, although those found during 2010 and 2011 are briefly mentioned.*

Footprint number	Date a	Date b	Area	GPS Hand E/N	GPS (Dif)	OD Ht	Degrees	Plan	Tracing	photo	model	Cast	notebook ref A	Notebook ref B	ident	Recorder
2007	28.10.07									yes				15p49	bird	
2008	19.4.08													15p52-55	bird	
2008.1				37800 81872												
2008.2				37848 81878											crane	
2008.3				37851 81877											crane	
2010:a	15.5.10			37778 81854					yes	yes				42p32	human	
2010:b	15.5.10			37737 81857					yes						bird	
2010:c	27.7.10		1	37813 81881	handheld			1	?					42,p43	human (3)	
2010:1	26.7.10	25-30.7.10	3	37774 81848		-4.2		3+15	yes	yes	no	no	44 pg4-5		human	
2010:2	26.7.10	25-30.7.10	3	37774 81848		-4.18		3+15	yes	yes	no	yes	mb 2010,44, pg6-7		human	
2010:3	26.7.10	25-30.7.10	3	37774 81848		-4.19		3+15	yes	yes	no	no	mb 2010,44 pg8-9		human	
2010:4	26.7.10	25-30.7.10	3	37774 81848		-4.25		3+15	yes	yes	no	no	mb 2010,44 pg10-11		human	
2010:5	26.7.10	25-30.7.10	3	37774 81848		-4.24		3+15	yes	yes	no	no	mb 2010,44 pg12-13		human	

2010:6	26.7.10	25-30.7.10								yes	no	no				
2010:11	26.7.10	25-30.7.10	1					1	yes	yes	no	no	mb 2010,44 pg24-25		human	
2010:12	26.7.10	25-30.7.10	1					1	yes	yes	no	no	mb 2010,44 pg26-27		human	
2010:13	26.7.10	25-30.7.10	1					1	yes	yes	no	yes	mb 2010,44 pg28-29	42,p43	human	
2010:21	0.7.2010	25-30.7.10	2	37774 81867	handheld	-3.94	210	5+15	yes	yes	no	no	mb 2010,44 pg 44-45		human	
2010:22	0.7.2010	25-30.7.10	2	37773 81867	handheld	-3.93	210	5+15	yes	yes	no	yes	mb 2010,44, pg46-47		human	
2010:23		25-30.7.10	2	37773 81867	handheld	-3.95	210	5+15	yes	yes	no	no	mb 2010,44 pg48-49		human	
2010:24		25-30.7.10	2	37773 81867	handheld	-3.95	210	5+15	yes	yes	no	no	mb 2010,44 pg50-51		human	
2010:25		25-30.7.10	2	37770 81865	handheld	-3.99	210	5+15	yes	yes	no	no	mb 2010,44 pg52-53		human	
2010:26		25-30.7.10	2	37771 81865	handheld	-4	210	15		yes	no	no	mb 2010,44 pg54-55		human	
2010:27		25-30.7.10	2	37770 81865	handheld	-3.96		15			no	no	mb 2010,44 pg56-57		human	
2010:28		25-30.7.10	2	37771 81863	handheld	-3.97		15			no	no	mb 2010,44 pg58-59		ungulate	
2010:29		25-30.7.10	2	37769 81865	handheld	-3.97		15		yes	no	no	mb 2010,44 pg60-61		human?	
2010:30		25-30.7.10	2	37768 81863	handheld	-3.99		15		yes	no	no	mb 2010,44 pg 62-63		human?	
2010:31 a	29.7.10		2					Area 2 15							?	
2010:31 .1-5	27.7.10		4	37787 81880	handheld			2+4		yes	no	yes, 31.1	mb 2010 pg64-65+152	42, p43	bird (17)	Long

2010:32.1-9	27.7.10		1	37820 81879	handheld			4	yes		no	no	mb 2010,44 pg66-67		bird (9)	Long
2010:33.1-2	25-30.7.10		1			-3.42		2	yes		no	no	mb 2010,44pg68-69	44, p65	bird (2)	
2010:34	xx.7.10	25-30.7.10		37803 81841	handheld					yes	no	yes	mb 2010,44pg70		bird	
2010:43	xx.7.10	25-30.7.10		37769 81862	handheld	-4					no	no	mb 2010,44 pg88-89		human	
2010:44	xx.7.10	25-30.7.10	2	37769 81863	handheld	-4.01		15			no	no	mb 2010,44 pg90	42p55	birds	
2010:45	xx.7.10	25-30.7.10		37764 81861	handheld						no	no	mb 2010,44 pg92-93		human	
2010:46	xx.7.10	25-30.7.10	M5	37767 81855	handheld	-4.11				yes	no	no	mb 2010,44 pg94-95		human	
2010:47	xx.7.10	25-30.7.10	M5	37768 81851	handheld	-4.22				yes	no	no	mb 2010,44 pg96		human?	
2010:48	xx.7.10	25-30.7.10	M5	37768 81849	handheld	-4.24	197				no	no	mb 2010,44 pg98-99	42p112	human	
2010:49	xx.7.10	25-30.7.10	M5	37769 81855	handheld	-4.19	197				no	no	mb 2010,44 pg 100	42p112	?	
2010:50	xx.7.10	25-30.7.10	M5	37769 81855	handheld	-4.18	197				no	no	mb 2010,44 pg102-103	42p112	human	
2010:51	xx.7.10	25-30.7.10	M5	37770 81857	handheld	-4.15	197				no	no	mb 2010,44 pg104-105	42p112	human	
2010:52	xx.7.10	25-30.7.10	M5	37781 81859	handheld	-4.15	197				no	no	mb 2010,44 pg106-107	42p112	human	
2011:48		20.4.11	M5					15 + 28	yes (52)	yes	no			42p73, 95	human	
2011:49		20.4.11	M5					15 + 28	yes (52)	yes	no			42p73, 95	human	
2011:49b		20.4.11	M5					15 + 28	yes (52)	yes	no			42p73, 95	human	

2011:50		20.4.11	M5		Dif 355-8	-4.63		15 + 28	yes (52)	yes	no			42p73, 95	human	
2011:51		20.4.11	M5		Dif 347-50	-4.6		15 + 28	yes (52)	yes	no			42p73, 95	human	
2011:52		20.4.11	M5		Dif 339-42	-4.59		15 + 28	yes (52)	yes	no			42p73, 95	human	
2011:53										yes	no				human	
2011:54	31.8.11		P		Dif ?54					yes	no			43, p7	human	
2011:55	31.8.11		P		Dif ?55					yes	no			43, p7	human	
2011.56	31.8.11		P		Dif?56									43, p7		
2011.57	31.8.11		P		Dif ?57									43, p7		
2011:60	31.8.11		N	37845 81817	Dif 187-90			18	yes	yes	no		43.8-9; mb2010,44p 108-109	43, p8-9	human	
2011:61	31.8.11		N	37845 81817	Dif 191-2			18	yes	yes	no		m.b.8-9; mb2010, 44p109	43, p8-9	human	
2011:62	31.8.11		N	37846 81817	Dif 193-6			18	yes	yes	no		m.b.8-9; mb 2010,44 pg110	43, p8-9	human	
2011:63	31.8.11		N	37845 81818	Dif 197-201			18	yes	yes	no		m.b.8-9; mb 2010,44 p111	43, p8-9	human	
2011:64	31.8.11		N	37845 81817	Dif 202-5			18	yes	yes	no		m.b.8-9; mb 2010,44 p112	43, p8-9	human	
2011:65	31.8.11		N	37845 81817	Dif 206-9			18	yes	yes	no		m.b.8-9; mb 2010,44 p113	43, p8-9	human	
2011:66	31.8.11		N	37846 81817	Dif 210-13			18	yes	yes	no		m.b.8-9; mb 2010,44 p114	43, p8-9	human	
2011:67	31.8.11		N	37846 81817	Dif 214-17			18	yes	yes	no		m.b.8-9; mb 2010,44 p114	43, p8-9	human	
2011:68	31.8.11		N	37846 81813	Dif218-21			18	yes	yes	no		m.b.8-9; mb 2010,44 p115	43, p8-9	human	
2011:69	31.8.11		N	37847 81816	Dif161-4			18	yes	yes	no		m.b.8-9; mb 2010,44 p116	43, p8-9	human	
2011:70	31.8.11		N	37846 81817	Dif159-60			18	yes	yes	no		m.b.8-9; mb 2010,44 p117	43, p8-9	human	
2011:71	31.8.11		N	37846 81817	Dif155-8			18	yes	yes	no		m.b.8-9; mb 2010,44 p118	43, p8-9	human	

2011:72	31.8.11		N	37846 81817	Dif151-4			18	yes	yes	no		m.b.8-9; mb 2010,44 p119	43, p8-9	human	
2011:73	31.8.11		N	37845 81819	Dif147-50			18	yes	yes	no		m.b.8-9; mb 2010,44 p120	43, p8-9	human	
2011:74	31.8.11		N	37848 31817	Dif143-6			18	yes	yes	no		m.b.8-9; mb 2010,44 p123	43, p8-9	human	
2011:75	31.8.11		N	37848 31817	Dif139-42			18	yes	yes	no		m.b.8-9; mb 2010,44 p123	43, p8-9	human	
2011:76	31.8.11		N	37846 81819	Dif135-8			18	yes	yes	no		m.b.8-9; mb 2010,44 p124	43, p8-9	human	
2011:77	31.8.11		N	37845 81818	Dif131-4			18	yes	yes	no		m.b.8-9; mb 2010,44 p125	43, p8-9	human	
2011:78	31.8.11		N	37847 81821	Dif129-30			18	yes	yes	no		m.b.8-9; mb 2010,44 p126	43, p8-9	human	
2011:79	31.8.11		N	37846 81820	Dif126-8			18	yes	yes	no		m.b.8-9; mb 2010,44 p127	43, p8-9	ungulate?	
2011:80	31.8.11		N	37847 81819	Dif122-5			18	yes	yes	no		m.b.8-9; mb 2010,44 p128	43, p8-9	human	
2011:81	31.8.11		N	37846 81818	Dif112-15			23	yes	yes	no		m.b.8-9; mb 2010,44 p129	43, p8-9	human	
2011:82	31.8.11		N	37846 81818	Dif101-111			23	yes	yes	no		m.b.8-9; mb 2010,44 p 130	43, p8-9	ungulate	
2011:83	31.8.11		N	37848 81818	Dif107-109			23	yes	yes	no		m.b.8-9; mb 2010,44 p 131	43, p8-9	human?	
2011:84	31.8.11		N	37845 81818	Dif103-106			23	yes	yes	no		m.b.8-9; mb 2010,44 p132	43, p8-9	human	
2011:85	31.8.11		N	37846 81818	Dif99-102			23	yes	yes	no		m.b.8-9; mb 2010,44 p123	43, p8-9	human	
2011:86	31.8.11		N	37846 81820	Dif95-98					yes	no		m.b.8-9; mb 2010,44 p134	43, p8-9	human	
2011:87	31.8.11		N	37850 81822	Dif91-94					yes	no		m.b.8-9; mb 2010,44 p135	43, p8-9	human	
2011:88	31.8.11		N	37848 81820	Dif87-90					yes	no		m.b.8-9; mb 2010,44 p136	43, p8-9	human	
2011:89	31.8.11		N	37849 81820	Dif83-6	-5.21				yes	no		m.b.8-9; mb 2010,44 p137	43, p8-9	human	
2011.91	31.8.11			37768 82082		Upper Peat				yes				42p93	cow + sheep	KB
2011.93	31.8.11		N	37848 81813	Dif 116-7					yes			m.b.8-9; mb 2010,44 p141	43p8-9	ungulate	

2011:94	31.8.11		N	37849 81819	Dif 120-1			23	yes	yes	no		m.b.8-9; mb 2010,44 pg142		bird	
2011:95	31.8.11		O	37824 81830	handheld			19	yes		no		mb 2010,44 pg143	42	bird	
2011:96				37824 81841	Dif297						no		mb 2010,44 p144	43, p18-19	bird	
2011.97	31.8.11					Upper Peat				yes				42p93	sheep	KB
2011:98	30.8.11	2.9.11	O	37825 81840				20	yes				mb 2011,45 p2		bird	
2011:99	31.8.11		N		Dif222-5				yes (51)	yes			mb 2011,43 pg14-15		human?	
2011:100	31.8.11		N		Dif226-9			23	yes	yes			mb 2011,43 pg14-15		human?	
2011:101	31.8.11		N		Dif230-3			23	yes	yes			mb 2011,43 pg14-15		human?	
2011:102	31.8.11		N		Dif234-7			23	yes	yes			mb 2011,43 pg14-15		human?	
2011:103	31.8.11		N		Dif238-9, ?241			23	yes	yes			mb 2011,43 pg14-15		human?	
2011:104	31.8.11		N		Dif242-5			23	yes	yes			mb 2011,43 pg14-15		human?	
2011:105	31.8.11		N		Dif414-17			23	yes	yes			mb 2011,43 pg14-15		human?	
2011:106	31.8.11		N					23	yes	yes			mb 2011,43 pg14-15		human?	
2011:107	31.8.11		N					23	yes	yes			mb 2011,43 pg14-15		human?	
2011:108	31.8.11		N					30	yes	yes			mb 2011,43 pg14-15		human?	
2011:109	31.8.11		N					30	yes	yes			mb 2011,43 pg14-15		human?	
2011:110	31.8.11		N					30	yes	yes			mb 2011,43 pg14-15		human?	
2011:111	31.8.11		N					30	yes	yes			mb 2011,43 pg14-15		human?	
2011:112	31.8.11		N					30	yes	yes			mb 2011,43 pg14-15		human?	
2011:113	31.8.11		N					30	yes (51)	yes			mb 2011,43 pg14-15		human?	
2011:114	31.8.11		N		Dif246-9			30	yes (51)				mb 2011,43 pg14-15		human?	

2011:115	31.8.11		N		Dif250-1			30	yes (51)				mb 2011,43 pg14-15		human?	
2011:116	31.8.11		N		Dif252-5			23	yes (51)				mb 2011,43 pg14-15		human?	
2011:117	31.8.11		N		Dif418-21			23	yes (51)				mb 2011,43 pg14-15		human?	
2011:118	31.8.11		N						yes (51)				mb 2011,43 pg22			
2011:119	31.8.11		N					30	yes (51)				mb 2011,43 pg22		human?	
2011:120	31.8.11		N					30	yes				mb 2011,43 pg22		human?	
2011:121	31.8.11		N					30	yes				mb 2011,43 pg22		human?	
2011:122	31.8.11		N					30	yes				mb 2011,43 pg22		human?	
2011:123	31.8.11		N					30	yes				mb 2011,43 pg22		human?	
2011:124	31.8.11		N					30	yes				mb 2011,43 pg22		human?	
2011:125	31.8.11		N					30	yes				mb 2011,43 pg22		human?	
2011:126	31.8.11		N		Dif 390-3			30	yes				mb 2011,43 pg22		human	
2011:127	31.8.11		N		Dif385-8			30	yes				mb 2011,43 pg22		ungulate	
2011:128	31.8.11		N		Dif381-4			30	yes				mb 2011,43 pg22		ungulate	
2011:129	31.8.11		N		Dif377-80			30	yes				mb 2011,43 pg22		human	
2011:130	31.8.11		Oi6		Dif282/408-9	-5.21							mb 2011,43pg19		bird	
2011:131	31.8.11		Oi7	3782881839	Dif290-3	-5.25		21	yes				mb 2011,43 pg16-17		human	
2011:132	31.8.11		Oi7	3782881839	Dif294-7	-5.27		21	yes				mb 2011,43 pg16-17		human	
2011:133	31.8.11		Oi7	3782881839	Dif298-9	-5.21		21	yes				mb 2011,43 pg16-17		human	L. Snape

2011:134	31.8.11		Oi7	3782881839	Dif300-3	-5.18		21	yes				mb 2011 ,43pg16-17	42p94	human	L. Snape
2011:135	31.8.11		Oi7	3782881839	Dif304-7	-5.2		21	yes				mb 2011,43pg16-17	42p94	human	
2011:136	31.8.11		Oi7	3782881839	Dif308-11	-5.19		21	yes				mb 2011,43 pg16-17	42p94	human	
2011:137	31.8.11		Oi7	3782881839	Dif312-15	-5.17							mb 2011,43 pg16-17	42p94	bird	
2011.137a	31.8.11		Oi7		Dif406	-5.36								43p16-17	bird	
2011.137b	31.8.11		Oi7		Dif407	-5.33								43p16-17	bird	
2011:138	31.8.11		M6	3778181848	Dif363-5	-4.76							mb 2011,43pg24-25	42p95/45p11	human	
2011:139	31.8.11		M6	3777181842	Dif366-9	-4.89							mb 2011,43 pg24-25	42p95/45p11	human	
2011:140.1-8	31.8.11		Oi5b	3781581860				25	yes					42p94	bird	
2011:142	31.8.11		Oi2		Dif398-401	-5.29		29	yes				mb 2011,43 pg19		bird	L.Snape
2011:143	31.8.11		Oi2		Dif402-5/410-13	-5.28		29	yes				mb 2011,43 pg19		bird	L.Snape
2011.143A	19.4.11		Oi4		Dif271	-5.34									bird	
2011.144C	19.4.11		Oi1		Dif262	-5.004		4.4	yes						human	
2011.145D	19.4.11		Oi1		cDif263	-4.963		4.4	yes						human	

2011.146E	19.4.11		Oi1		cDif264	-4.944		4.4	yes						human	L.Snape
2011.147F	19.4.11		Oi1		cDif262	-5.004		4.5	yes						human	
2011:150	31.8.11		M		Dif335-8	-4.59		15 + 28	yes				mb 2011,43 pg24-25	43, p19	human	L.Snape 2011 Fig 4.5
2011:151	31.8.11		M		Dif331-4	-4.57		15 +28	yes				mb 2011,43 pg24-25		human	L.Snape 2011 Fig 4.5
2011:152	31.8.11		M		Dif351-4	-5.34		15 + 27	yes			yes	mb 2011,43 pg24-25	42p95	human (Lola)	L.Snape 2011 Fig 4.5
2011:153	31.8.11 + 17.8.12		M5		Dif327-30			15 + 28	yes	yes			mb 2011,43 pg24-25	42p95	human	
2011:154	31.8.11 + 17.8.12		M5		Dif323-6			28	yes	yes			mb 2011,43 pg24-25	42p95	human	
2011:155	31.8.11 + 17.8.12				Dif343-6			28	yes				mb 2011,43 pg24-25		human	
2011:156	31.8.11 + 17.8.12		M5a		Dif359-60			28	yes				mb 2011,43 pg24-25		ungulate	
2011:157	31.8.11 + 17.8.12		M9	37781 81848	Dif371-4/?370-3		15	yes (48)					mb 2011,43 pg98	42p98	human	
2011:158	31.8.11		M9/3	3778 81850					yes (49)				mb 2011,43 pg24-25		human	
2011:159	31.8.11		M8		Dif422-5				yes (50)	no				43p26	human	
2011:160a	31.8.11		M8		Dif426-9				yeas (50)	no				43p26	human	
2011?:160b	2011 + 31.8.12		M5		Dif 101-3			15					KB 31.8.12		human	
2011:161a	18.4.12		7		?Dif160-5			15							?	
2011?:161	2011 + 31.8.12		M5		Dif 104-6								KB 31.8.12		human	
2011:162a	18.4.12		?M7	37791 81842	Dif101-116				yes (46)	yes				42p62-3	human	
2011?:162	2011 + 31.8.12		M5	37792 81838	Dif 107-8				yes (52)	no			KB 31.8.12		human	

2011:163a	18.4.12		M7	37791 81843	?Dif101-116				yes (46)	yes				42 p62	human	
2011?:163	2011 + 31.8.12		M5		?Dif109-12				yes (52)	no			KB 31.8.12	42p62-4	human	
2011.163C	18.4.2011			37828 81855				sketch	yes (47)					42 p63	human	
2011.163D	18.4.2011			37828 81855										42 p 63	human	
2011.163E	18.4.2011														human	
2011.163F	18.4.2011			37794 81843				sketch						42 p 62	bird	
2011:164	2.9.11 +31.8.12		F/5		Dif13-14			15		yes ?	yes	yes	mb 2011,42 pg98-99	42p98-9	human	
2011.164a			F													
2011:165	2.9.11		F		Dif115-16					yes ?	yes	yes	mb 2011,42 pg98-99	42p98-9	human	
2011.165a			F										MB 31.8.12, KB 31.8.12			
2011.166-178	2.9.11		N							yes ?				42p100/45p35	?human	
2011.179	31.8.12			none	no					yes ?			42 p 99		human	
2011:200					Dif430-5				yes							
2011:201					Dif430-5				yes							
2011:202					Dif430-5				yes				42,p100		?human	
2011:203	12-13.9.11				Dif464				yes	yes	no		mb 2011,43 pg28-29		bird	
2011:204	12-13.9.11				Dif464				yes	yes	no		mb 2011,43 pg28-29		bird	
2011:205	12-13.9.11				Dif467				yes	yes	no		mb 2011,43 pg28-29		human	
2011:206	12-13.9.11								yes	yes	no					
2011:207	12-13.9.11								yes	yes	no					
2011:208	12-13.9.11								yes	yes	no				bird	

2011:209					Dif476-7					yes	no		mb 2011,43 pg28-29		human	
2011:210					Dif478-9					yes	no		mb 2011,43 pg28-29		human	
2011:211					Dif470-81?					yes	no		mb 2011,43 pg28-29		human	
2011:212					Dif482-3					yes	no		mb 2011,43 pg28-29		human	
2011:213					Dif484-5					yes	no		mb 2011,43 pg28-29		human	
2011:214	12-13.9.11				Dif486-7					yes	no		mb 2011,43 pg28-29		human	
2011:215	12-13.9.11									yes	no		mb 2011,43 pg30-31		bird	
2011:216													mb 2011,43 pg30-31		human	
2011:217													mb 2011,43 pg30-31		human	
2011:218													mb 2011,43 pg30-31		bird	
2011:219				37864 81999	handheld					yes	no	yes	mb 2011,43 pg30-31		human & bird	
2011:A:220				37791 81843	handheld				yes				mb 2011 pg24-25		human	
2011:B 221				37791 81842	handheld				yes				mb 2011 pg24-25		human	
2011:C:222				37791 81842	handheld				yes				mb 2011 pg24-25		human	
2011:D:223				37791 81842	handheld				yes				mb 2011 pg24-25		human	
2011:E:224				37791 81842	handheld				yes				mb 2011 pg24-25		human	
2011:F:225				37791 81842	handheld				yes				mb 2011 pg24-25		huamn	
2011:226	31.8.11		S		Dif375-6									43p21-2	birds	
2012.1				37868 81892					yes	yes				43,p41	deer	
2012.2				37868 81892					yes	yes				43p41	deer	
2012.3				37869 81897					yes	yes		yes		43p41	birds	

2012.4				37881 81902						yes				43p41	birds	
2012:35										yes	no				human	
2013:29a			S	37810 81836						yes	no			43p44	human	
2013:30a			S	37809 81837						yes	no			43p44	human	
2014:2										yes	no				human	
2014:6											no				bird	
2014:7										yes	no				human	
2014:9										yes	no				human	
2014:22										yes	no				human	
2014:24										yes	no				human	
2014:60a	1.2.14			37790 81873	handheld	210 °							mb 2011 pg128	42p128	human	
2014:71	17.7.14		S	37800 81840					yes	yes				48p142	human	
2014:72	17.7.14		S	37800 81840					yes	yes				48p142	human	
2014:73	17.7.14		O	37823 81846											bird	
2014:74	17.7.14		N	37851 81814					yes	yes					human	
2014:300			E	37905 81921	handheld				yes	yes	no	no	kb.1 pg1-2	43p62	bird	
2014:301	22.11.14		E	37905 81922	handheld				yes	yes	no	no	kb.1 pg1-2	43p62	bird	
2014:302					differential GPS			no	yes	yes	no	no	kb.1 pg1-2		bird	
2014:303					differential GPS			no	yes	yes	no	no	kb.1 pg1-2		bird	

2014:304					differential GPS			no	yes	yes	no	no	kb.1 pg1-2		bird	
2014:305					differential GPS			no	yes	yes	no	no	kb.1 pg1-2		bird	
2014:306					differential GPS			no	yes	yes	no	no	kb.1 pg2-3		bird	
2014:307			E	37904 81919	handheld			no	yes	yes	yes	yes	kb.1 pg3-4	43p62	bird	
2014:308	23.11.14		M5a	37772 81858	handheld			36 +15	no	yes	yes	yes	kb.1 pg5-6, 10-11	43p58/86	human	
2014:309	23.11.14		M5a	37772 81858	handheld			36 +15	no	yes	yes	yes	kb.1 pg5-6, 10-11	43p58/86	human	
2014:310	23.11.14		M5a	37771 81858	handheld			36 +15	no	yes	yes	yes	kb.1 pg5-6, 10-11	43p58/86	human	
2014:311				37906 81918	handheld			no	no	yes	no	no	kb.1 pg15		bird	
2014:312				37906 81918	handheld			no	no	yes	no	no	kb.1 pg15		bird	
2014:313				37906 81918	handheld			no	no	yes	no	no	kb.1 pg15		bird	
2015:6	?/02/2015		N	37849 81810	handheld			no	no	yes	yes	yes	kb.1 pg17-18		human	
2015:7	?/02/2015		N	37851 81810	handheld			no	no	yes	yes	yes	kb.1 pg17-18		human	
2015:8	?/02/2015		N	37850 81810	handheld			no	no	yes	yes	yes	kb.1 pg19		human	
2015:9				37850 81810	handheld			no	no	yes	yes	no	kb.1 pg20		ungulate?	
2015:10			Parton	41583 83257	handheld		76°	no	?	yes	yes	no	?	43, p72, 77	human	
2015:11			Parton	41583 83257	handheld		76°	no	?	yes	yes	no	?	43, p72, 77	human	
2015:12	22.4.15		M5a	37773 81857	handheld			12+15	no	yes	yes	no	kb.1 pg55	43p86	human	
2015:13	22.4.15		M5a	37773 81857	handheld			12+15	no	yes	no	no	kb. 1 pg.66	43p86	human	
2015:14	22.4.15		M5a	37773 81857	handheld			12+15	no	yes	no	no	kb.1 pg 66	43p86	human	

2015:15	22.4.15		M5 a	37773 81857	handheld			12+15	no	yes	no	no	kb.1 pg66	43p86	human	
2015:16				37852 81810	handheld			no	no	yes	yes	no	kb.1 pg56-63		bird	
2015:17	19-21.4.15		N	37852 81810	handheld			yes	no	yes	yes	no	kb.1 pg56-63	43p81-2	human	
2015:18	19-21.4.15		N	37853 81809	handheld			yes	no	yes	yes	no	kb.1 pg56-63	43p81-2	human	
2015:19	19-21.4.15		N	37853 81809	handheld			yes	no	yes	yes	yes	kb.1 pg56-63	43p81-2	bird	
2015:20	19-21.4.15		N	37855 81810	handheld			yes	no	yes	yes	no	kb.1 pg56-63	43p81-2	human	
2015:27				37852 81810	handheld			no	no	yes	no	no	kb. 1 pg64		human	
2015:28				37852 81810	handheld			no	no	yes	no	no	kb. 1 pg64		human	
2015 deer				37852 81812	handheld			no	no	yes	no	no	kb. 1 pg64		ungulate	
2015.40 a	18.5.15		M3 a					36								
2015:42	22.4.15		N	37852 81812	handheld			no	no	yes	no	no	kb. 1 pg69		human	
2015:43	22.4.15		N	37852 81812	handheld			no	no	yes	no	no	kb.1 pg69		ungulate	
2015:44	22.4.15		N	37852 81812	handheld			no	no	yes	no	no	kb.1 pg69		ungulate	
2015:45	22.4.15		N	37852 81812	handheld			no	no	yes	no	no	kb.1 pg69-70		ungulate	
2015:46				37770 81858	handheld			no	no	yes	no	no	kb.1 pg62-63		large and small bird	
2015:53	18.5.15		M5 a		differential GPS			36.15	no	yes	no	no	kb.1 pg84-85	43 p87	human and bird	
2015:54	18.5.15		M5 a		differential GPS			no	no	yes	no	no	kb.1 pg84-85	43 p87	human	
2015:87	13.9.15		?E	37864 81894	handheld			no	no	yes	yes	yes	kb.1 pg96, 146-147	43p88,	bird	
2015:88	13.9.15			37872 81894	handheld			no	no	yes	no	no	kb.1 pg97	43p89	human	
2015:89	13.9.15			37873 81894	handheld			no	no	yes	no	no	kb.1 pg97	43p89	human	
2015:90 a	13.9.15		C/E	37850 81883	handheld			no	no	yes	no	no	kb.1 pg99	41, p 1	bird	

2015:106	14.9.15		C/E					no	no	yes	no	no	kb.1 pg102-103	43p93-4,	human	
2015:107	14.9.15		C/E					no	no	yes	no	no	kb.1 pg102-103	43p93-4,	human	
2015:112	28.9.15			37376 81904	handheld			no	no	yes	no	no	kb.1 pg108-109	43, p 95	bird	
2015:113	28.9.15			37916 81920	handheld			no	no	yes	no	no	kb.1 pg108-109	43p95	bird	
2015:114	28.9.15			37881 81904	handheld			no	no	yes	no	no	kb.1 pg110-112	43p95	human	
2015:115	28.9.15			37883 81903	handheld			no	no	yes	no	no	kb.1 pg110-112	43, p 95	human	
2015:115a	28.9.15		C/E							yes					human	
2015:116	30.9.15		C	37853 81899	handheld			no	no	yes	yes	yes	kb.1 pg 126-130	43p98	human	
2015:117	30.9.15		C	37853 81899	handheld			no	no	yes	yes	yes	kb.1 pg126-130	43p98	human	
2015:118	30.9.15		C	37853 81899	handheld			no	no	yes	yes	no	kb.1 pg126-130	43p98	human	
2015:119	30.9.15		C	37849 81897	handheld			no	no	yes	yes	no	kb.1 pg126-130	43p98	human?	
2015:120	30.9.15		C	37849 81897	handheld			no	no	yes	yes	no	kb.1 pg126-130	43p98	human?	
2015:121	30.9.15		C	37849 81897	handheld			no	no	yes	yes	no	kb.1 pg138-139	43p98	human	
2015:122	30.9.15		C	37849 81897	handheld			no	no	yes	yes	yes	kb.1 pg138-139	43p98	human	
2015:123	30.9.15		C	37849 81897	handheld			no	no	yes	yes	yes	kb.1 pg138-139	43p98	human	
2015:127	27.10.15			37852 81900	handheld			no	no	yes	yes	no	kb.1 pg140-142	43p99	human and bird	
2015:human and bird				37883 81905	handheld			no	no	yes	yes	no	kb.1 pg150-151		human and bird	
2015:130				37849 81885	handheld			no	no	yes	yes	no	kb.1 pg152-153		bird	
2015:131a	27.11.15			37889 81916	handheld			no	no	yes	no	no	kb.2 pg3	43p103	oystercatcher	
2015:131				37867 81891	handheld			no	no	yes	yes	yes	kb.2 pg4		human	
2015:132	27.11.15		E	c37870 81892	handheld					yes	yes			43p101-2	human	

2015:133-9	27.11.15		E	c3787081892	handheld					yes	yes			43p101-2	bird	
2015:144-6	27.11.15		E							yes	yes			43p101-2	bird	
2015:147	27.11.15			3791281921						yes				43p103	human	
2015:148				3787881901	Dif									43p104	bird	
2015:160	28.11.15			3788981904	handheld			no	no	yes	yes	no	kb.2 pg5, 9	43p107	human	
2015:161	28.11.15			3788981904	handheld			no	no	yes	no	no	kb.2 pg7-8		bird	
2015:162	28.11.15			3788981904	handheld			no	no	yes	no	no	kb.2 pg5-8		bird	
2015:163	28.11.15							no	no	yes	no	no	kb.2 pg10	43p107	human	
2016:15	5-6.6.16		N		differential GPS			no	no	yes	yes	no	kb.2 pg98,106	43p110	human	
2016:16	5-6.6.16		N		differential GPS			no	no	yes	yes	no	kb.2 pg99,106	43p110	human	
2016:17	5-6.6.16		N		differential GPS			no	no	yes	yes	no	kb.2 pg99,106	43p110	human	
2016:18	5-6.6.16		N		differential GPS			no	no	yes	yes	no	kb.2 pg101,106	43p110	human?	
2016:19	5-6.6.16		N		differential GPS			no	no	yes	yes	no	kb.2 pg100,106	43p110	human?	
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2016:26	5-6.6.16		N	3784781811	differential GPS			no	no	yes	yes	no	kb.2 pg102,106	43p110	human	
2016:27	5-6.6.16		N		differential GPS			no	no	yes	yes	no	kb.2 pg97,106	43p110	human	

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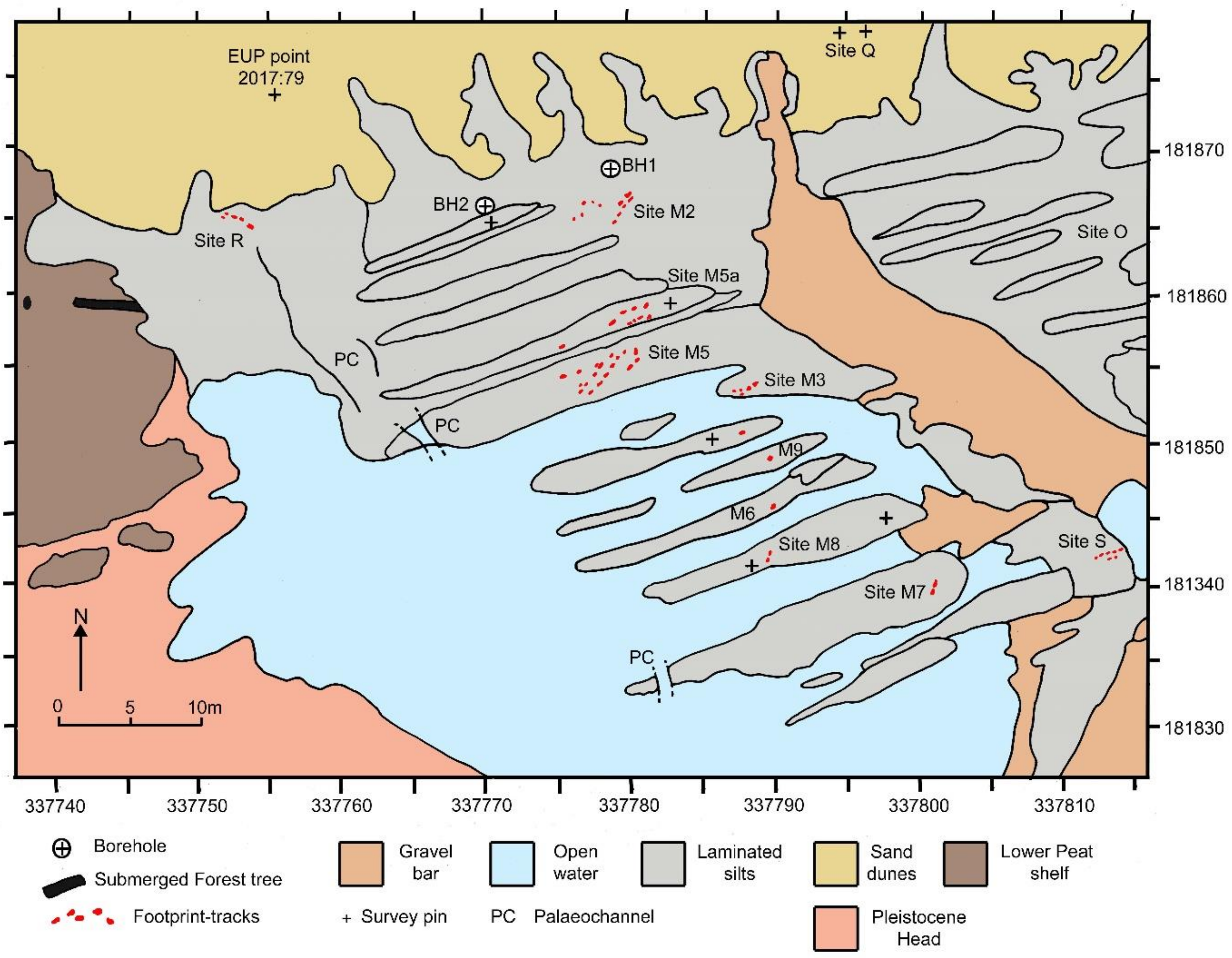
2016:31	5-6.6.16	2.9.16	N		differential GPS			no	no	yes	yes	no	kb.2 pg102,106	43p112	human	
2016:50	5-6.6.16	2.9.16	N	37847 81825	Dif76-7	-5.31		no	no	yes	yes	no	mb ; kb.3 pg6-7	43p117-18	human	
2016:51	5-6.6.16	2.9.16	N	37845 81825	Dif74-5	-5.33		no	no	yes	yes	no	mb ; kb.3 pg6-7	43p117-18	human	
2016:52	5-6.6.16	2.9.16	N	37847 81825	Dif72-3	-5.38		no	no	yes	yes	no	mb ; kb.3 pg6-7	43p117-18	human	
2016:53	5-6.6.16	2.9.16	N	37847 81825	Dif70-1	-5.43		no	no	yes	yes	no	mb ; kb.3 pg6-7	43p117-18	human	
2016:54	5-6.6.16	2.9.16	N	37849 81826	Dif68-9	-5.44		no	no	yes	yes	no	mb ; kb.3 pg6-7	43p117-18	human	
2016:55	5-6.6.16	2.9.16	N	37849 81827	Dif66-7	-5.45		no	no	yes	yes	no	mb ; kb.3 pg6-7	43p117-18	human	
2016:56	5-6.6.16	2.9.16	N	37849 81826	Dif64-5	-5.48		no	no	yes	yes	no	mb ; kb.3 pg6-7	43p117-18	human	
2016:57	5-6.6.16	2.9.16	N	37848 81826	handheld			no	no	yes	yes	no	mb ; kb.3 pg6-7	43p117-18	human	
2016:58:00	5-6.6.16		N											43p114	human	
2016:59:00	5-6.6.16		N											43p114	human	
2016:60	5-6.6.16		N											43p114	human	
2016:61	5-6.6.16		N											43p114	human	
2016:67	2.9.16		M	37771 81864	handheld			no	no	yes	no	no	kb.2 pg113	43p116	human	
2016:70a	16.9.16		E	37872 81898	handheld			no	no	yes	no	no	kb.2 pg115-116	43p122	bird	

2016:71	16.9.16		E	37872 81893	handheld			no	no	yes	no	no	kb.2 pg117-118	43p122	human	
2016:72	16.9.16		E	37872 81893	handheld			no	no	yes	no	no	kb.2 pg117-118	43p122-3	bird	
2016:73	16.9.16		R	37746 81866	Dif targets+15-16			no	no	yes	yes	no	kb.2 pg119-125	43p124-5	human	
2016:74	16.9.16		R	37746 81865	Dif targets			no	no	yes	yes	no	kb.2 pg119-125	43p124-5	ungulate	
2016:75	16.9.16		R	37746 81866	Dif targets+13-14			no	no	yes	yes	no	kb.2 pg119-125	43p124-5	human	
2016:76	16.9.16		R	37745 81867	Dif targets			no	no	yes	yes	no	kb.2 pg119-125	43p124-5	human	
2016:77	16.9.16		R	37746 81866	Dif targets			no	no	yes	yes	no	kb.2 pg119-125	43p124-5	ungulate	
2016:82	16.9.16		R	37746 81866	Dif targets+11-12			no	no	yes	yes	no	kb.2 pg 136-138	43p124-5, 128	ungulate?	
2016:83	16.9.16		R	37746 81866	Dif targets+8			no	no	yes	yes	no	kb.2 pg136-138	43p124-5, 128	human	
2016:99	16.9.16		R	37746 81867	Dif targets+9-10			no	no	yes	yes	no	kb.2 pg 136-138	43p124-5	ungulate?	
2016:100	16.9.16		R	37746 81866	Dif targets+17-18			no	no	yes	yes	no	kb.2 pg136-138		human	
2016:101	16.9.16		R	37746 81866	Dif targets+19-20			no	no	yes	yes	no	kb.2 pg136-138		human?	
2016:102	13.11.16		S	37804 81841	Dif 100?83-4			no	no	yes	no	no	kb.2 pg132-135	43p132	human	
2016:103	13.11.16		S	37804 81841	Dif 101 ?85-6			no	no	yes	no	no	kb.2 pg132-135	43p132	human	
2016:104	13.11.16		S	37804 81841	Dif102 ?87-8			no	no	yes	no	no	kb.2 pg132-135	43p132	human	
2016:105	13.11.16		S	37804 81841	Dif103, ?89-90			no	no	yes	no	no	kb.2 pg132-135	43p132	indistinct	
2016:106	13.11.16		S	37804 81841	Dif104, ?92-93			no	no	yes	no	no	kb.2 pg132-135	43p132	bird	
2016:107	13.11.16		S	37804 81841	Dif105 ?94-95			no	no	yes	no	no	kb.2 pg132-135	43p132	human	
2016:108	13.11.16		S	37804 81841	Dif106,96-7			no	no	yes	no	no	kb.2 pg132-135	43p132	human	
2016:109	13.11.16		S		Dif107									43p132	?	
2017: 1				37803 81842	handheld			no	no	yes	no	no	kb.3 pg11		human	

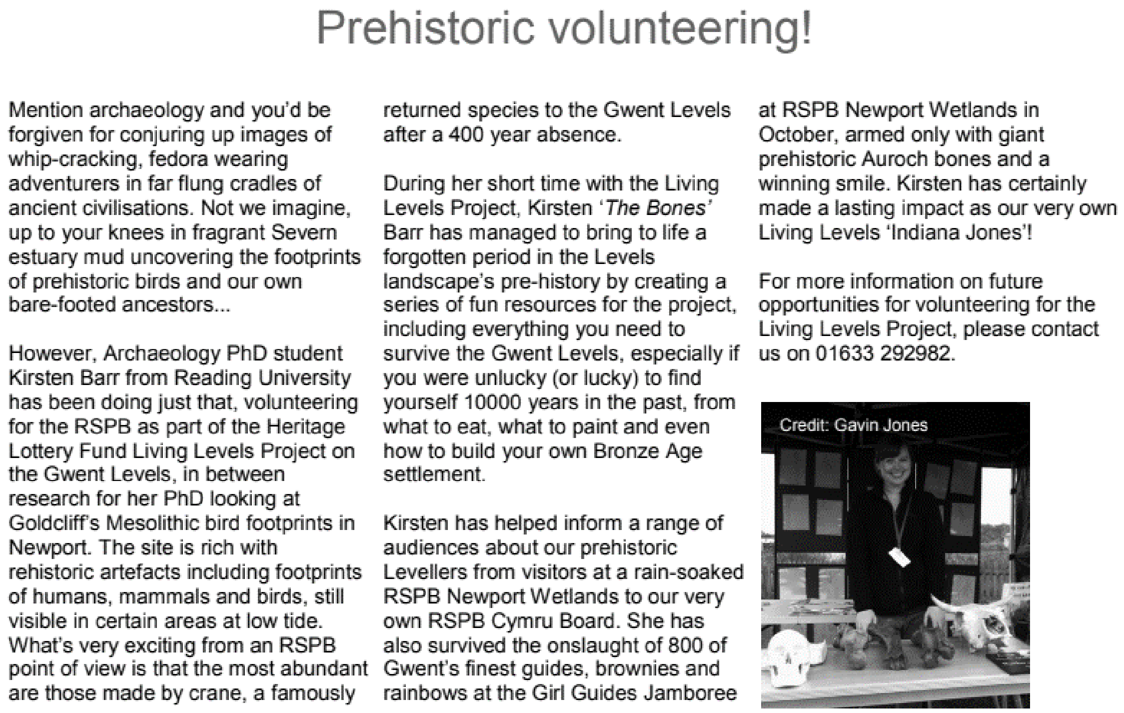
2017: 2				37803 81842	handheld			no	no	yes	no	no	kb.3 pg11		human	
2017:3				37802 81842	handheld			no	no	yes	no	no	kb.3 pg11		human	

Appendix 3.2 *Plan of footprint Sites R, M, S and O and their relationship to each other and the topography. Plan by M.Bell and J.Foster*



Appendix 4

4.1 *Extract from 'Involve RSPB volunteering newsletter, issue 07 Winter 2016'*



Prehistoric volunteering!

Mention archaeology and you'd be forgiven for conjuring up images of whip-cracking, fedora wearing adventurers in far flung cradles of ancient civilisations. Not we imagine, up to your knees in fragrant Severn estuary mud uncovering the footprints of prehistoric birds and our own bare-footed ancestors...

However, Archaeology PhD student Kirsten Barr from Reading University has been doing just that, volunteering for the RSPB as part of the Heritage Lottery Fund Living Levels Project on the Gwent Levels, in between research for her PhD looking at Goldcliff's Mesolithic bird footprints in Newport. The site is rich with rehistoric artefacts including footprints of humans, mammals and birds, still visible in certain areas at low tide. What's very exciting from an RSPB point of view is that the most abundant are those made by crane, a famously returned species to the Gwent Levels after a 400 year absence.

During her short time with the Living Levels Project, Kirsten '*The Bones*' Barr has managed to bring to life a forgotten period in the Levels landscape's pre-history by creating a series of fun resources for the project, including everything you need to survive the Gwent Levels, especially if you were unlucky (or lucky) to find yourself 10000 years in the past, from what to eat, what to paint and even how to build your own Bronze Age settlement.

Kirsten has helped inform a range of audiences about our prehistoric Levellers from visitors at a rain-soaked RSPB Newport Wetlands to our very own RSPB Cymru Board. She has also survived the onslaught of 800 of Gwent's finest guides, brownies and rainbows at the Girl Guides Jamboree at RSPB Newport Wetlands in October, armed only with giant prehistoric Auroch bones and a winning smile. Kirsten has certainly made a lasting impact as our very own Living Levels 'Indiana Jones'!

For more information on future opportunities for volunteering for the Living Levels Project, please contact us on 01633 292982.

Credit: Gavin Jones

Appendix 4.2 *Prehistoric Heritage Trail by the author for the Living Levels Landscape Partnership*

Prehistoric Heritage Trail

By Kirsten Barr

Newport Wetlands, Newport, Wales. Aerial view, August 2007

Credit Line: David Wootton (rspb-images.com)

Introduction

The Gwent Levels are an extensive low lying area rich in sites of archaeology and history. The area is easily reached, with central Newport less than 6 miles from the RSPB Wetlands reserve, and the M4 (junction 25) a mere 9.5 miles away. The countryside in this area is beautiful, once you leave central Newport you will be surrounded by wildlife, cows and sheep.

If using public transport there are excellent rail links to Newport train station, there is also a bus service from Newport Central Bus Station (63) directly to the RSPB wetlands reserve, this is a demand responsive bus so does need to be booked http://www.newportbus.co.uk .

The heritage trail begins at the RSPB Newport Wetlands centre and then carries on along the coastal path; evidence of the prehistory of the area has survived on the tidal mud flats of the Severn Estuary and its surroundings. This walk is suitable for people of all ages, providing they have a good level of fitness and mobility. The walk is fairly flat but the ground is uneven and there are steps onto some of the coastal paths, so it is not suitable for wheelchairs or those who struggle with uneven ground.

The full coastal route from the RSPB Wetlands reserve to Redwick covers approximately 14.5 km, walking there and back takes about 5 hours at a fairly brisk pace and covers almost 30km. There are some pubs and a seawall tearoom near the route, as well as a café at the wetlands visitor centre.

If you have the time you could extend your walk a few kilometres further, viewing the prehistoric areas of Coldharbour Pill and Magor Pill.

The coastal path does go further than the suggested Prehistorical Heritage Trail, you can find information about this here http://www.newport.gov.uk/documents/Leisure-and-Tourism/Coastal-Path-Booklet.pdf. In some parts the pavements are narrow and pedestrians should take care.

The trail describes much of the prehistoric landscape. The best time to walk the coastal path is low tide, where the mudflats are often exposed allowing you to see certain archaeological features. That said, high tide can be beautiful, with plenty of coastal birds to see.

THE WALK

On this coastal walk you will see a small part of the Gwent Levels, an area steeped in archaeology and history, as well as rich in interesting and often endangered flora and fauna. The landscape that you see before you has been completely shaped by humans. Since Roman times much of the land that you can see has been reclaimed from the sea, which is why it has such a flat appearance.

Environmental evidence suggests that relative sea-levels have risen since the last glaciation, though they do so in a fluctuating manner. The coast of the Gwent Levels often significantly retreated because of erosion, slight changes caused the coast line to then advance again with saltmarshes growing rapidly.

The trail mainly involves walking along a coastal path which runs adjacent to the Severn Estuary, much of it is on the seawall, built for a defence against the sea and providing a phenomenal view.

The prehistory of this area is rich, with humans having lived in the area for possibly over 40,000 years. When you look out into the Severn Estuary you need to remember that water levels have changed a lot during this time, the extreme tides can reach 14.8m, however during prehistory that wasn't the case, and in many periods the tide would be under 1m. Sea-level rise, especially over the last 8,000 years, resulted in wetlands forming at close to sea level, creating the vast Severn Estuary Levels (c.840km^2).

These wetlands were exploited by prehistoric humans in many ways, including providing saltmarsh grazing for livestock, safe places for their animals to birth their young, rich fishing, forests to hunt in and as a source of seafood.

1. **Start at the RSPB Newport Wetlands Centre**

RSPB Newport Wetlands Centre, West Nash Road, Newport, Wales. NP18 2BZ

The RSPB Wetlands centre was built in 2008, it has a shop, a café, toilet facilities, an education room and a conference room. The visitor centre is open every day (except Christmas) from 9am until 5pm.Entrance is free though donations are very much appreciated.

Parking is free, the carpark opens at 8.30am and closes at 5.30pm so if you are parking here be sure to make it back by 5.30.

2. East Usk Lighthouse/ Uskmouth

The East Usk Lighthouse is still functioning; it is one of two lighthouses situated upon the mouth of the River Usk. It has its own unique history which you can read about at the lighthouse itself.

In terms of the Prehistoric Heritage Trail this area is very important. The Gwent Levels have a variety of buried prehistoric and Roman landscapes. Preserved due to the excellent waterlogged conditions, the area contains features and artefacts from multiple time periods. The sediment (a mix of silt, clay, sand and gravel) that covers many sites can make it difficult to identify important areas, but has provided an environment where preservation of organic material is excellent.

Stand by the lighthouse and look out onto the mud flats. About 600 meters from the seawall out onto the estuary there have been a variety of prehistoric finds recorded. The finds range in date from the Mesolithic (Middle Stone Age) c.10,000-5,500 years ago, when humans were still hunter-gatherers, to Iron Age finds, c. 750 BC-43AD, the period just before the Romans and the start of recorded history. The site of Uskmouth covers about 1.6km of the walk along the sea wall.

Saltmarsh at Uskmouth. The Prehistoric landscape is completely covered by the sea at this point
Image by Kirsten Barr

The first prehistoric footprints discovered on the Gwent Levels were found in 1986 by a local, Derek Upton, who worked as a warden at the Magor Marsh Wetland Reserve. It was through his diligent exploration that archaeologists became involved in the area and the importance of the Gwent Levels, and the rare form of evidence provided by the footprints, was truly appreciated.

Mesolithic footprints from human, auroch (extinct wild cattle) and red deer have been recorded at Uskmouth (Aldhouse-Green *et al*. 1993). There is evidence of areas being trampled by red deer over multiple years, indicating that these animals were returning to this area yearly, perhaps to safely raise their young.

A variety of skeletal remains have also been found in this area in a palaeochannel (ancient river channel), where the remains of auroch, pig and juvenile horse have been discovered. Of the auroch bones that have been found (ribs, tibia, femur, vertebrae), none exhibit any kind of butchery evidence, making it probable that the animals did not die due to hunting, but for some other reason. It is possible that they got stuck and drowned in the river as they were large and heavy animals.

Red deer Mesolithic footprint made at Uskmouth
Image by Kirsten Barr

3. Wetlands nature reserve

The wetlands nature reserve may look like a beautiful natural area that has always been here, however that is not the case. This area between Goldcliff and Uskmouth (about 4km by 1km) used to be covered in ash due to the coal-fired Usk power station. The land was given to the Countryside Council of Wales as compensation for loss of wildlife habitat at Cardiff. Since 2000 this area has been completely re-landscaped and now includes salt marsh, reed beds and saline lagoons, a perfect habitat for a variety of birds.

Large fungi providing food to a variety of animals
Image by Kirsten Barr

You should follow the signs for the NRW coastal paths for this part of the walk, heading towards Redwick.

The view across the wetlands includes a large amount of foreshore, this area is not open to visitors due to breeding bird populations but can be viewed from the seawall at Goldcliff and Uskmouth.

The next point of the Prehistoric Heritage Trail can be observed at the saline lagoons. When the lagoons were made an underlying buried landscape of Romano-British drainage ditches were found by Glamorgan-Gwent Archaeological Trust. The lagoons were designed so that they did not damage this underlying archaeological landscape, which is evidence of the Romans actively altering the Gwent Levels.

It is hard to imagine that without human interference the wetlands that surround the Severn Estuary would exist in the way they do today, instead they would be vast areas of mudflats and lush salt marshes that were flooded regularly by the tide.

A family of Mute swans using the wetlands as a safe place to raise their cygnets
Image by Kirsten Barr

Once the Romans came to the Gwent Levels they embarked on the construction of earthen embankments, this was to prevent the tide encroaching on certain areas, a technique we still utilise with the use of the stone sea wall. Once they had begun to prevent the tide flooding the area the Romans then dug ditches to drain the land, enabling land reclamation and the creation of a landscape that would be similar to the one we see today.

The saline lagoons that you can see from the hides were drainage ditches that would have been essential in preventing flooding of this landscape. Once the Roman Empire fell and the Romans abandoned Wales there was nobody to continue the upkeep of these ditches, meaning that through a combination of sea level rise and lack of drainage, this area was flooded once again, with a thick layer of alluvium covering the Roman landscape and preserving it. A lesson that we can learn from the Romans is that it is essential to keep drainage ditches maintained, otherwise the sea will very quickly flood an area.

View of the three saline lagoons from the viewing hide
Image by Kirsten Barr

The saline lagoons are now home to a variety of breeding birds, with even common crane (*Grus grus*) spotted in this area. It is thought that it may have been the Romans who extensively hunted common crane.These crane were possibly hunted by the Romans to extinction on the Gwent Levels, as the Roman period was the last time crane skeletal remains were discovered on the Gwent Levels, or indeed in Wales (Hamilton-Dyer 1993). There is something poetic about these birds returning to their natural habitat thousands of years after their localised extinction and taking up residence on top of a roman feature, the very people who once hunted them to extinction.

4. Goldcliff East

Goldcliff East is one of the best areas along the Gwent Levels in which to experience the full 40,000 years of human activity. Once you have passed the saline lagoons you will be in Goldcliff and should head towards the sea wall, which is signposted. There is also the opportunity to pop into the Seawall Tearooms or The Farmers Arms pub, as they are one of the only places on the Prehistoric Heritage Trail where you can stop for refreshments. Bear in mind that the Farmers Arms pub does not tend to open for lunch during normal weekdays.

Head onto the sea wall and look out onto the estuary, it is best to view this area at low tide, but if the tide is not out you can still see a variety of coastal birds.

Standing on the sea wall, facing the estuary, there is a land projection on your right where there is a house. This is Goldcliff Island, this land surface used to project out further than it does now and was its own small island until the sea wall was built, and erosion has destroyed the majority of it.

Scraper with invasive retouch on the ventral surface Perhaps made on a leaf piece Early Upper Palaeolithic, c.40,000 years, found at Goldcliff East November 2015 Image courtesy of Martin Bell

Early evidence for human activity at Goldcliff East is assumed from the recent finds of four Early Upper Palaeolithic flints, dated to c.40,000 years. These flints would not have come from Wales, as Welsh flint on the Gwent Levels is very poor quality. Instead, these flints would have been brought over from the English side of the estuary. Again, it is important to remember that sea levels were much lower at this time, the Early Upper Palaeolithic was before the main glacial period, with a large amount of the Earth's water being tied up in ice.

The oncoming glaciations also meant that Wales would become uninhabitable for approximately 10,000 years due to the severity of the ice age.

Example of the laminated sediments where Mesolithic footprints are discovered. Notice the fine bands and the darker, coarser sandy bands. The coarser sandy bands represent winter periods, the lighter the summer, so they can assist in establishing seasonality of a site (Dark & Allen 2005).
Image by Kirsten Barr

The Severn Estuary is hugely significant regarding Mesolithic archaeology, as it is incredibly rich in Mesolithic evidence. The Mesolithic, or Middle Stone Age, period was approximately 10,000-5,500 years ago. With a large amount of the Earth's water still held in ice, areas of land were inhabited which are now completely under water. The unique tides of the Severn Estuary, however, mean that at certain times throughout the year water levels are low enough to access this submerged landscape, walking where our ancestors walked. Due to the fantastic preservation of organic material thanks to the waterlogged environment, these sites contain information about our coast dwelling ancestors.

Of all the sites on the Severn Estuary, Goldcliff East is one of the richest in terms of Mesolithic finds and is the most thoroughly studied site of the Gwent Levels.

Spring tides are the best time to few the Prehistoric landscape at Goldcliff East. Looking out onto the foreshore you may be able to see tree trunks or stumps. These are from a Mesolithic oak forest that once covered the area upon which you are now stood. This submerged forest is one of many found across the coastal regions of Britain and is a reminder that the water levels are naturally and continuously changing.

On the very lowest of tides (>2m), areas of Mesolithic activity and footprint sites are uncovered.

Mesolithic deer bone, found at Goldcliff East. Due to the anaerobic waterlogged conditions it is not uncommon to find organic material such as bones preserved in the Severn Estuary
Image by Martin Bell

View of the Mesolithic landscape at low tide (0.3m) at Goldcliff East.
Image by Kirsten Barr

Charred hazelnut shell from Goldcliff East, dated to the Mesolithic period. There have been hazelnuts found at multiple Mesolithic sites across Goldcliff East, indicating people were probably cooking them before eating. Charred hazelnuts preserve well in the waterlogged environment of the estuary and indicated to us that as well as an oak forest, hazel trees would have been growing nearby.
Image by Martin Bell

Mesolithic Footprints

The Mesolithic footprints at Goldcliff East are perhaps the most famous prehistoric archaeology on the Gwent Levels. Featuring in a variety of television programmes and media coverage including ‘Time Team’, ‘BBC Horizon: First Britons’, ‘National Geographic’, and ‘Coast’ to name a few, they have captivated the British public.

Prehistoric footprints are ephemeral in nature, meaning that archaeologists are at the mercy of the tide and shifting sediments. It is not unknown for an area to be exposed one day and be covered by two meters of sand the next. It is because of this that recording must be done quickly and efficiently, as there is often only 1.5 hours of exposure.

The tide is both friend and foe of the intertidal archaeologist; erosion uncovers Mesolithic footprint areas that were once covered with overlying sediment, meaning that archaeologists have to do very little destructive excavation here. The problem is that the erosion that uncovered these prints also will erode the footprint, destroying it completely, so it is essential to constantly monitor the area.

Laminated silty clay shelfs where a variety of Mesolithic human footprints have been recorded. Image by Kirsten Barr

Mesolithic footprints have been observed at Goldcliff East for almost 20 years, and so far over 200 human footprints, 50 crane prints, a variety of other bird species including oystercatcher, heron, white stork, small waders, and red deer have been found (Scales 2007).

The common crane footprints all come from laminations made of fine sediments, indicating the prints were made during the summer months (Dark & Allen 2005). The human and other bird prints are made on both the summer and coarse winter laminations.

Mesolithic human child footprint, c.5,500 BP. Image by K.Barr

Common Crane Mesolithic footprints recorded on laminations made on summer sediments. Image by K.Barr

The common crane footprints are the earliest evidence we have of crane living on the Gwent Levels, and some of the earliest evidence of crane from the entirety of Holocene Britain. These crane prints were made around 5,600 BC during the summer months, so were likely made by birds using the area as a safe breeding ground and place for their chicks to fledge.

Some of the human footprints at Goldcliff East have a similar direction of movement, heading directly towards, or away from, Goldcliff Island. There was a site of occupation on Goldcliff Island and it would seem that these individuals were walking there. They range from children to adults.

The later Mesolithic footprints, c.5,600 BC, exhibit slightly less definite behaviour patterns, with individuals heading in a variety of directions. Although both children and adults are present, children dominate this assemblage.

Bronze Age ungulate footprints recorded at Goldcliff East (photograph by K. Barr).

The Bronze Age at Goldcliff East

If you look out into the estuary you may be able to see the large wooden weirs of the fish traps, fairly near the wall. These are built into the Bronze Age reed peat land surface at Goldcliff East. To the left of these traps animal footprints have been discovered, including a few from red deer, cattle and sheep. There is a palaeochannel on this peat, and it is around this area that most trampling occurs, perhaps caused by animals drinking at the water's edge. Interestingly, there are a large amount of juvenile sheep and cattle prints, indicating this area was being used as healthy salt marsh grazing for nursing animals. Due to the herd type, with a large amount of juveniles, it is likely that one of the primary functions of these herds and flocks was milk production. These footprints provide some of the first evidence of dairy farming on the Gwent Levels (Barr & Bell 2016).

Follow the coast path on, heading towards Redwick. Once you get past the small land projection, meaning that you can no longer see the coastal path at Goldcliff, you will have entered the part of the coastal path in Porton.

5. Porton

In terms of the Prehistoric Coastal Trail, Porton is far sparser compared to the magnitude of evidence we have from Goldcliff East and Redwick. Porton can be viewed from the seawall but there is very little to see and it is a difficult area to access as the intertidal zone is covered in very deep, dangerous mud. If you are able to stand on the seawall near to Porton House and look out onto the estuary you will be looking at the area of Porton. Finds at Porton have included a Mesolithic tranchet axe, reed matting, a Bronze Age palstave and a Bronze Age spearhead, as well as a few potential deer and cattle hoof prints (Bell *et al.* 2000).

There is not much to see at Porton but it is important to remember the importance of the evidence which might still be there under the deep mud.

Once you have seen Porton, carry along the coastal path and head to Redwick.

6. Redwick

At Redwick there is a final opportunity for a refreshment stop, at the Rose Inn. This pub is a slight diversion from the coastal path and has parking. The pub is open daily and serves a variety of foods.

Whilst in the village of Redwick bear in mind that the English name, Redwick, means ‘settlement where reeds grow’, indicating the strong relationship between the village and the wetlands.

On the sea wall, Redwick is not much to look at and is a very small, less than a kilometre in length. In a similar way to Goldcliff East, Redwick is hugely rich in prehistoric archaeology and is a key site in understanding the prehistoric humans’ relationship to the area.

Bronze Age in date, 1691–1401 cal BC, the peat shelves at Redwick have preserved a variety of data, including rectangular Bronze Age buildings, a thumbnail scraper, a human cranium, burnt bone, charcoal, heat fractured stone, reeds and woodchips, as well as footprints from a variety of animals, including humans, cattle, sheep/goat and pig. The humble selection of artefacts in this occupation area suggests that these buildings were not a long-term campsite. Many of the finds such as the heat fractured stone, are related to cooking, suggesting cooking in the area (Bell 2013). The buildings were surrounded by a large amount of trampling, mainly by cattle, but also sheep/goat. These animals were likely from a dairy herd, as many of the footprints were made by young animals (Barr & Bell 2016). This evidence, as well as the limited amount of artefacts, suggest that the site of Redwick was being used during the spring/summer as a safe place for the livestock to raise their young on the nutrient rich salt-grass.

The peat is occasionally washed clean by a good tide, the remains of the buildings’ location can just about be seen on these occasions, though erosion is wiping out this evidence.

7. Coldharbour Pill/Magor

Further along from Redwick there are two other important sites from the Prehistoric trail that you may wish to view if you have time, and are also viewable from the coastal path, these are Coldharbour Pill and Magor Pill. Footprints are some of the most important finds in these areas, as well as Iron Age pottery, post stakes and flints.

Where to visit next?

To see the actual prehistoric artefacts from the area don’t forget to pay Newport Museum a visit, here you can see the remains of an auroch found in a palaeochannel (ancient river), as well as flints, and casts of Mesolithic footprints, all found on the Severn Estuary.

If you have the time, take a trip into Cardiff and visit the National Museum of Wales at St. Fagans, this is where most of the estuarine finds from the Gwent Levels end up, as well as all the other interesting finds from across Wales.

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