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Walking in a winter wonderland? Strategies for Early and Middle Pleistocene survival in mid-latitude Europe

Article

Accepted Version

Hosfield, R. ORCID: https://orcid.org/0000-0001-6357-2805 (2016) Walking in a winter wonderland? Strategies for Early and Middle Pleistocene survival in mid-latitude Europe. Current Anthropology, 57 (5). pp. 653-682. ISSN 0011-3204 doi: https://doi.org/10.1086/688579 Available at https://centaur.reading.ac.uk/43354/

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To link to this article DOI: http://dx.doi.org/10.1086/688579

Publisher: University of Chicago Press

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Site	T_{min} (°C)	T_{max} (°C)	Evidence[1]	Age (MIS)	Source
Happisburgh III (Bed E)	-3 – 0	+16 – 18	Coleoptera	21 or 25	2,10
Pakefield (Bed Cii–Ciii)	-6 – +4	+17 – 23	Coleoptera	17 or 19	2,5
Boxgrove (Unit 4c & Freshwater Silt Bed ≈ Units 4b & 4c)	-4 – +4	+15 – 20	Ostracods (MOTR) & Herpetofauna (MCR)	13	2,7,8
Happisburgh I (Organic Mud)	-11 – -3	+12 – 15	Coleoptera	13/15 or 17	2,5
High Lodge (Bed C1)	-4 – +1	+15 – 16	Coleoptera	13	5
Waverley Wood (Channel 2, Organic Mud)	-	+10 – 15	Coleoptera	13 or 15	5,11
Brooksby (Redland's Brooksby Channel)	-10 – +2	+15 – 16	Coleoptera	13 or 15	5
Barnham (Unit 5c; HoII)	-	+17 – 18	Herpetofauna	11	6
Hoxne (Stratum D[5]; HoIIIa[6])	-10 – +6	+15 – 19	Coleoptera	11	3,4
Bilzingsleben	-0.5 – +3	+20 – 25	Mollusca & ostracods[9]	11	9

Table 1: Winter and summer temperature estimates for Early and Middle Pleistocene north-western and north-central European sites. [1]Sensitivity tests on coleoptera-based MCR procedures suggest that winter temperature estimates are usually too warm (Pettitt and White 2012:35); [2]Ashton and Lewis 2012 (Pakefield listed as -4 – +6°C); [3]Ashton *et al*. 2008a; [4]Coope 1993; [5]Coope 2006; [6]Holman 1998; [7]Holman 1999; [8]Holmes *et al*. 2009; [9]Mania 1995 (the specific source of the palaeo-temperature estimates is not stated, but the fauna includes molluscs and ostracods); [10]Parfitt *et al*. 2010; [11]Shotton *et al*. 1993.

Species	**Home range**[1]	**Density**[1]	**Mobility**[1]	**Site examples**
M. martes	3–82km^2	1/0.8–10km^2	Solitary; not highly territorial; hunting trips upto 28km	Swanscombe (LL)[4]
F. sylvestris	0.6–3.5km^2	1/0.7–10km^2	Sedentary; nomadic	Boxgrove[3] Swanscombe (LG)[4]
C. fiber	500m–5.5km (along river)	1.0–1.8/km^2	Family movements within territory	Boxgrove[3] Bilzingsleben[2] Hoxne (Beds C & E)[5] Swanscombe (LL)[4]
C. lupus	100–10,000km^2 (food-dependent)	1/50–80km^2	Territorial (and correlating with prey migrations)	Bilzsingsleben[2] Swanscombe (LL/LG)[4]

Table 2: Fur-bearing animals, with modern distribution data for comparison, documented on northern European Middle Pleistocene sites. Other documented species include: *V. vulpus; M. putorius; M. erminea; M. lutreola; and L. lutra.* [1]Macdonald and Barrett 1993 (modern European data; it is fully acknowledged that Early and Middle Pleistocene species' ecology would not have been identical to their modern equivalents); [2]Mania and Mania 2005; [3]Parfitt 1999; [4]Schreve 1996; [5]Stuart *et al*. 1993. Site units: Swanscombe (LL): Lower Loam; Swanscombe (LG): Lower Gravels.

Species	Home range[3]	Density[3]	Mobility[3]	Site examples
C. capreolus	$0.05–1km^2$	$15–25/km^2$ Solitary/small groups in closed woodland[7]	Reduced territoriality in winter & congregation (herds up to 30)	Boxgrove[1] Bilzinsleben[4] Hoxne[10] Swanscombe (LL)[8]
D. dama[6]	$0.5–2.5km^2$	$12(?)/km^2$ Small groups (<7/8) in closed/open woodland[12]	Habitat use shifts seasonally (e.g. summer in open habitats & autumn → spring in woodlands[7])	Barnham[5] Bilzingsleben[4] High Lodge?[9] Hoxne[10] Swanscombe (LG)[8]
C. elaphus	$0.5–8km^2$ Smaller upper limits also suggested[2]	$5–45/km^2$ Small groups (1–3) in closed woodland[7]	Summer → winter range migrations up to 6km (e.g. lowland woodlands → open uplands [UK])	Barnham[5] Bilzingsleben[4] Boxgrove[6] High Lodge?[9] Hoxne[10] Schöningen 13-I & 13 II-4[11,12] Swanscombe (LL)[8]

Table 3: Modern home range, density and mobility data for selected ungulate species, documented on Middle Pleistocene sites. [1]Bello, Parfitt, and Stringer 2009; [2]Clutton-Brock, Guinness, and Albon 1982; [3]Macdonald and Barrett 1993 (modern European data; it is fully acknowledged that Early and Middle Pleistocene species' ecology would not have been identical to their modern equivalents); [4]Mania and Mania 2005; [5]Parfitt 1998; [6]Parfitt 1999 (notes that the fallow deer's late rut results in males' poor condition during winter); [7]Putman 1988; [8]Schreve 1996; [9]Stuart 1992; [10]Stuart *et al*. 1993; [11]Thieme 2005; [12]Voormolen 2008. Site units: Swanscombe (LL): Lower Loam; Swanscombe (LG): Lower Gravels.

Species	Home range[2]	Density[2]	Mobility[2]	Site examples
C. fiber	500m–5.5km (along river)	1.0–1.8/km^2	Family movements within territory	Bilzingsleben[3] Boxgrove[5] Hoxne[8] Swanscombe (LL)[6]
S. scrofa	2–20km^2	ND	Sedentary (if stable env.); ♀Small herds; ♂Solitary	Barnham[4] Bilzingsleben[3]
U. arctos	150–4000km^2	1–190/ 10,000km^2	Solitary; Travel 2–3.5km/day; Hibernation (with accumulated fat)[1]	Swanscombe (LL/LG)[6] Barnham[4] Hoxne[8]
D. bicornis	Few ha–75 sq. km	ND	♀+ young; ♂Solitary; Resident & local (if resources sufficient)	Barnham[4] Bilzingsleben[3] Boxgrove[5] Hoxne[8] High Lodge[7] Swanscombe (LG)[6]

Table 4: Fat-bearing and/or residential winter animals, with modern distribution data for comparison, documented on Middle Pleistocene sites. [1]Jochim 1981; [2]Macdonald and Barrett 1993 (modern European data); [3]Mania and Mania 2005; [4]Parfitt 1998; [5]Parfitt 1999; [6]Schreve 1996; [7]Stuart 1992; [8]Stuart *et al*. 1993.

Species	**Butchery evidence**	**Sites**
Bos or Bison sp.	Marrow extraction & cut-marks (filleting?); Filleting; Cut-marks, defleshing and marrow bone breakage; Dismembering, filleting, defleshing & marrow bone breakage	Barnham[4] Boxgrove[5] Happisburgh I[2] Schöningen 13 II-4[7]
C. capreolus	Cut-marks; Defleshing	Boxgrove[3] Happisburgh I[2]
C. elaphus	Skinning, dismemberment, filleting & marrow bone breakage; Marrow bone breakage & cut-marks (seasonality data: late Summer → Spring); Skinning, dismemberment & filleting; Cut-mark	Boxgrove[5] Hoxne[6] Schöningen 13 II-4[7] Westbury[1]
E. ferus	Disarticulation, filleting & marrow bone breakage; Marrow bone breakage & cut-marks; Dismemberment, filleting, boning, defleshing & marrow bone breakage	Boxgrove[5] Hoxne[6] Schöningen 13 II-4[7]
S. hundsheimensis	Disarticulation & filleting; Disarticulation	Boxgrove[5] Happisburgh I[2]
U. deningeri	Skinning	Boxgrove[5]

Table 5: Butchery by species and technique, from selected Lower Palaeolithic sites.

[1]Andrews and Ghaleb 1999; [2]Ashton *et al*. 2008b; [3]Bello, Parfitt, and Stringer 2009; [4]Parfitt 1998; [5]Parfitt and Roberts 1999; [6]Stopp 1993; [7]Voormolen 2008.

Family/Species identified at Hoxne[3]	Modern winter foraging species[1,2]		
	Species	**Habitat**	**Key Nutrients**
Caryophyllaceae	Common chickweed (*Stellaria media*)	Woodland fringe	Vitamins A, D, B complex, C, and Rutin
	Common mouse-ear chickweed (*Cerastium holosteoides*)	Grassland	-
Brassicaceae (previously *Cruciferae*)	Garlic mustard or Jack-by-the-hedge (*Alliaria petiolata*)	Woodland fringe	Vitamins A, C & E
Ericaceae	Cowberry (*Vaccinium vitis-idaea*)	Pine forest	Vitamins A, B & C
Apiaceae (or Umbelliferae)	Wild parsnip (*Pastinaca sativa*)	Grassland	Potassium
T. latifolia	Reed mace/Bulrush (*Typha latifolia*)	Wetland	Protein & carbohydrate
Urticaceae	Stinging nettle (*Urtica dioica*)	Woodland & river valley	Protein and vitamin C

Table 6: Plant families identified at Hoxne, with comparison to modern plant species available to winter foragers. [1]Mabey 2012; [2]Mears and Hillman 2007; [3]Mullenders 1993, table 6.3 & figs. 6.1–6.3.

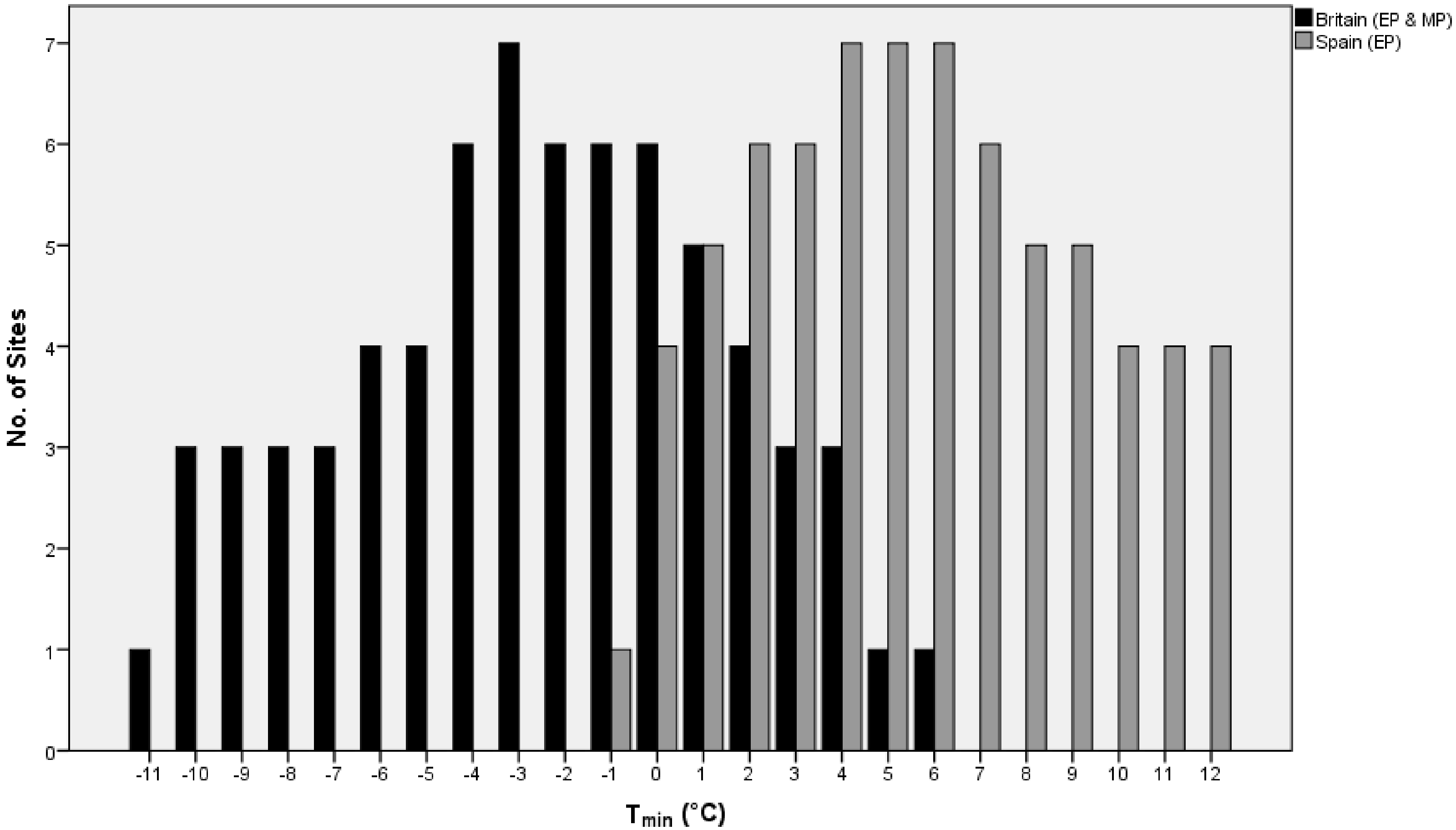

Figure 1: Comparison of winter temperature ranges for Spanish (Early Pleistocene; EP) and British (Early Pleistocene and Middle Pleistocene; EP & MP) sites. Number of sites calculated according to the temperature ranges for each site (e.g. 7 sites have a T_{min} range which spans -3°C). Spanish site data (Almenara-Casablanca 3; Cal Guardiola; Cúllar Baza 1; Barranca León 5; Fuente Nueva 3; Trinchera Dolina (TD6); Trinchera Elefante (TERc)) from Agusti *et al*. (2009); British site data (Boxgrove, Brooksby, Happisburgh I, Happisburgh III, High Lodge, Hoxne, Pakefield) from Ashton *et al*. 2008a; Ashton and Lewis 2012; Coope 1993, 2006; Holman 1998, 1999; Holmes *et al*. 2009; Mania 1995; Parfitt *et al*. 2010.

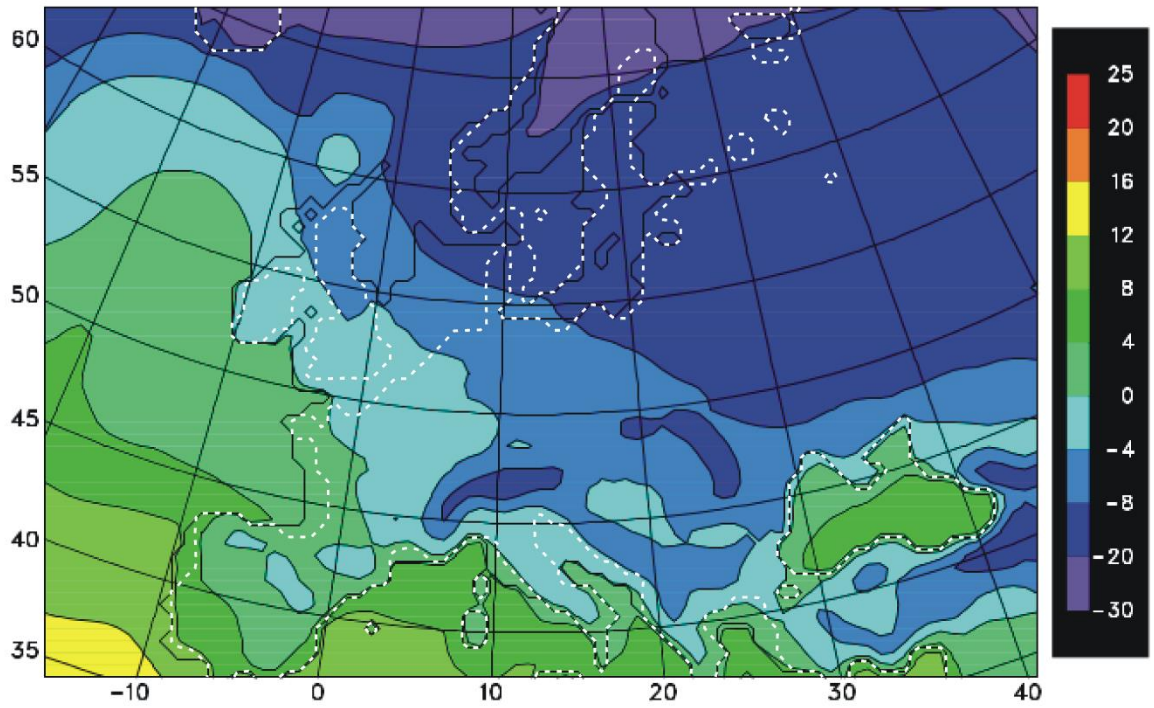

Figure 2: Mean winter air temperature data (°C) from the Stage 3 Project's MIS-3 'warm' simulation (Barron, van Andel, and Pollard 2003, fig. 5.7 [Stage 3 Warm Phase DJF]). Dashed white line: Modern European coastline.

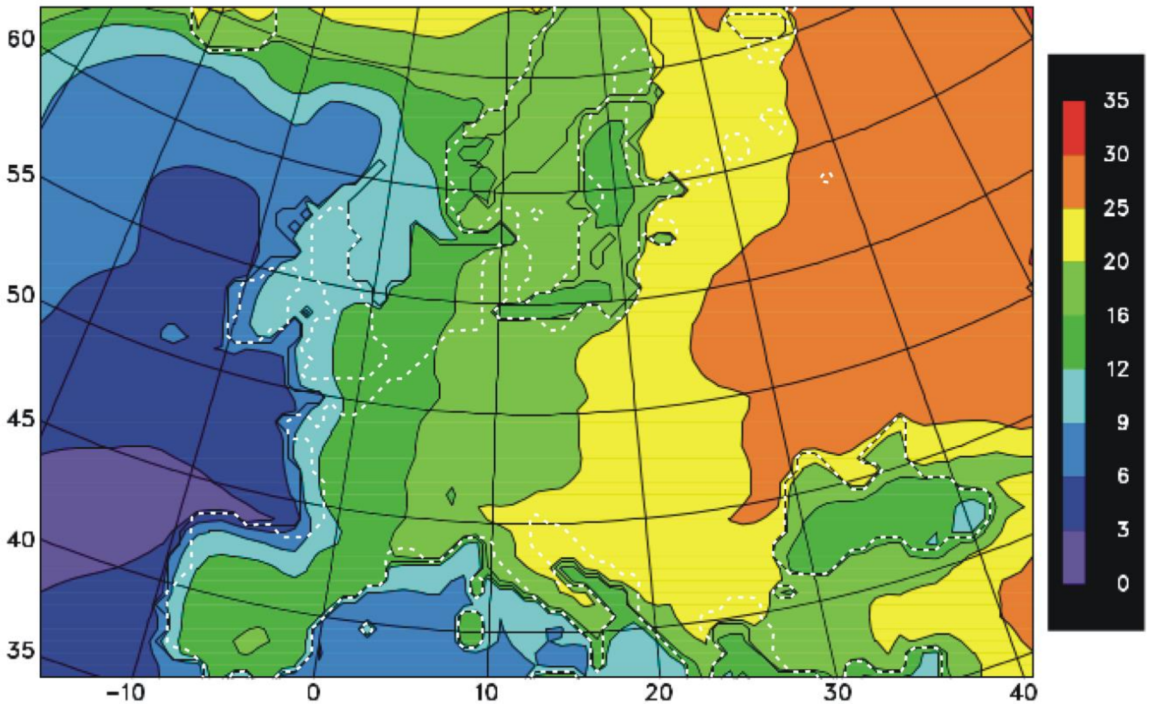

Figure 3: Summer/winter contrasts in mean air temperature data (°C) from the Stage 3 Project's MIS-3 'warm' simulation (Barron, van Andel, and Pollard 2003, appendix 5.1). Dashed white line: Modern European coastline.

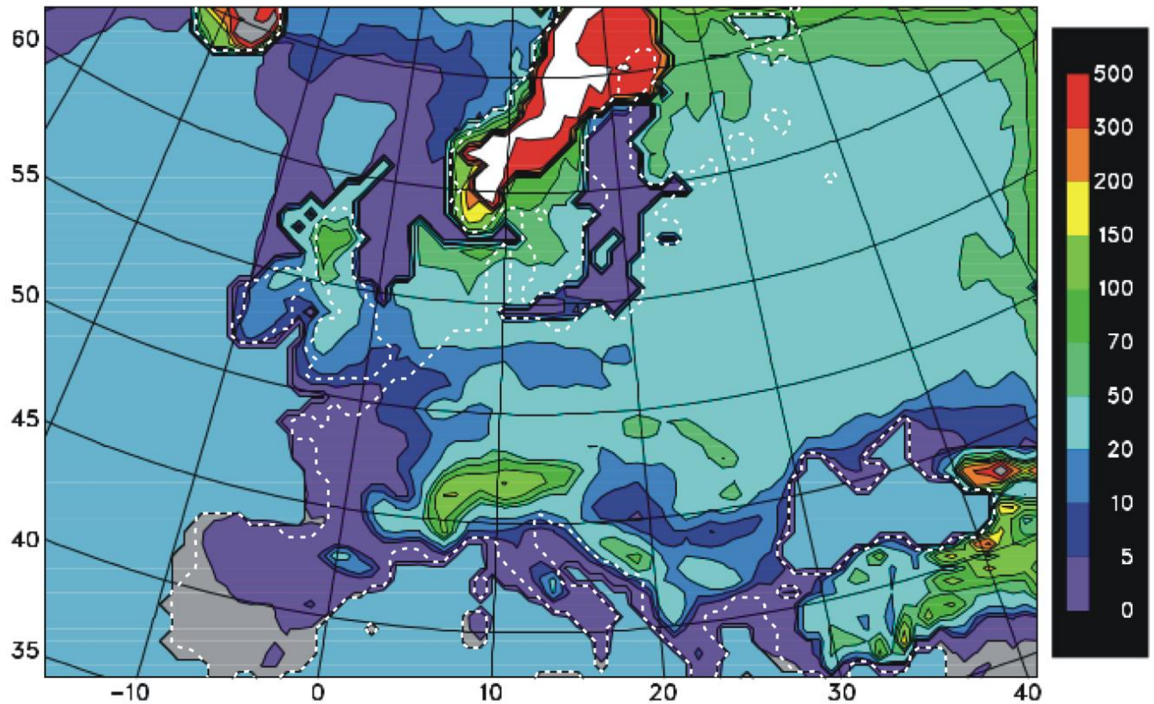

Figure 4: Snow depth (cm) data from the Stage 3 Project's MIS-3 'warm' simulation (Barron, van Andel, and Pollard 2003, fig. 5.9). Dashed white line: Modern European coastline.

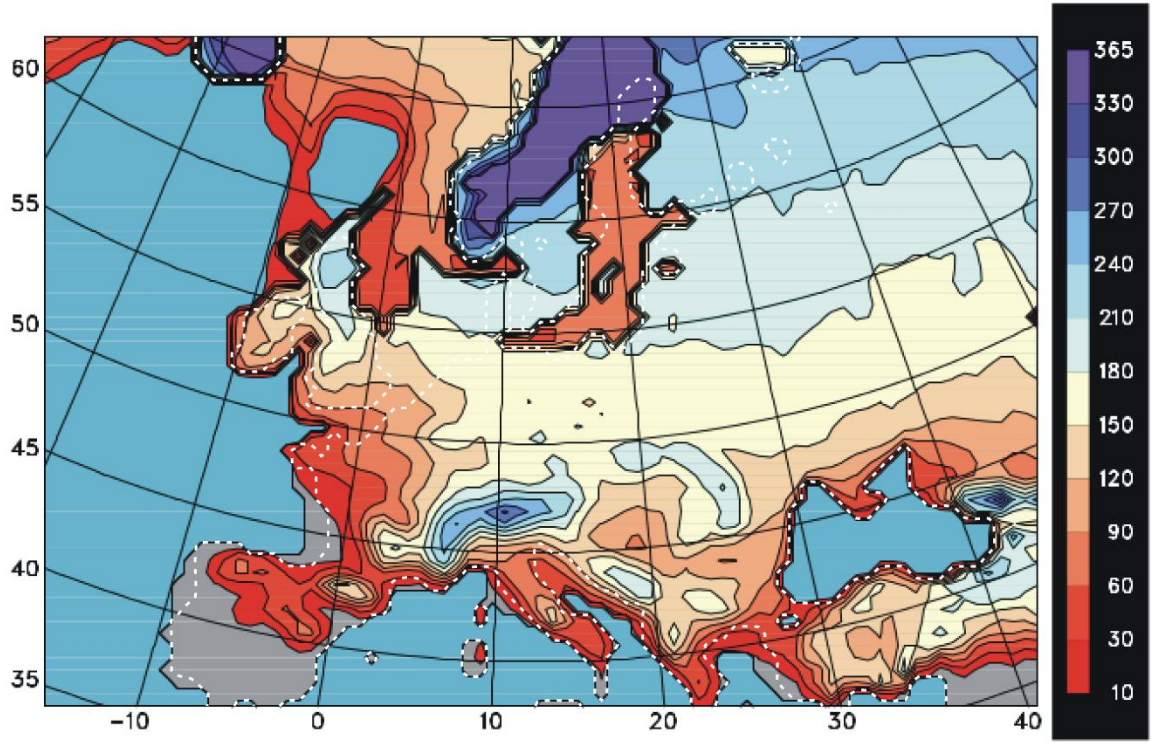

Figure 5: Number of days with snow cover data from the Stage 3 Project's MIS-3 'warm' simulation (Barron, van Andel, and Pollard 2003, fig. 5.9). Dashed white line: Modern European coastline.

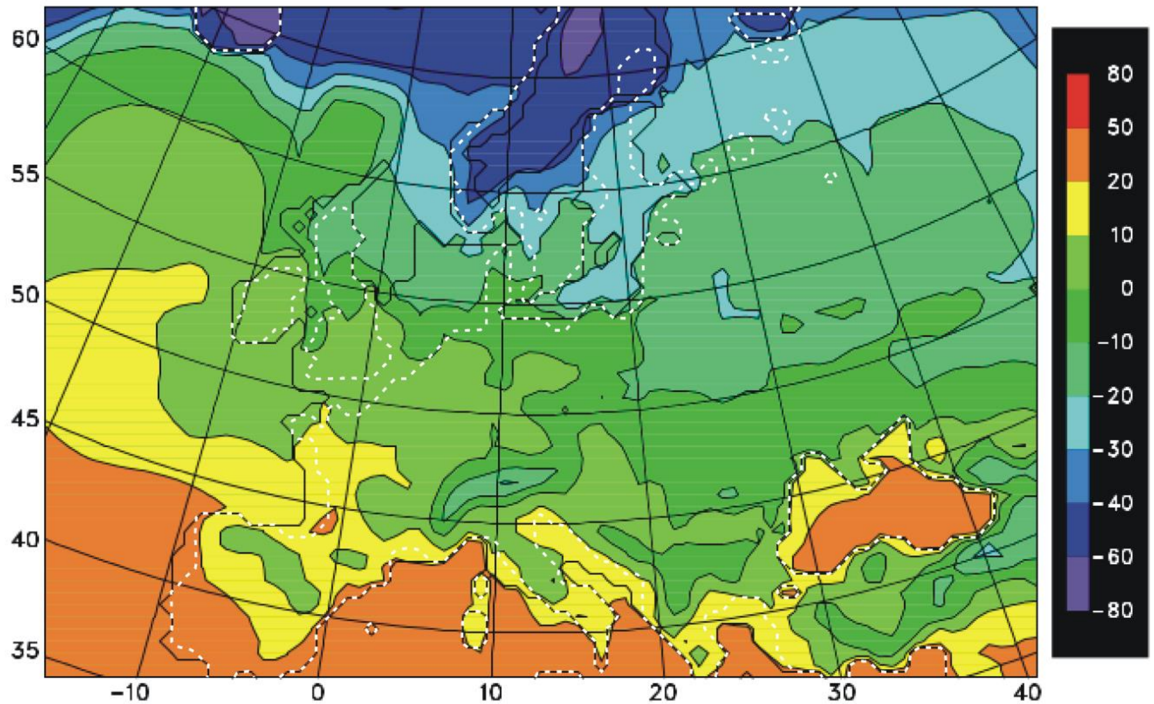

Figure 6: Wind chill (°F) data from the Stage 3 Project's MIS-3 'warm' simulation (Barron, van Andel, and Pollard 2003, appendix 5.1). Dashed white line: Modern European coastline.

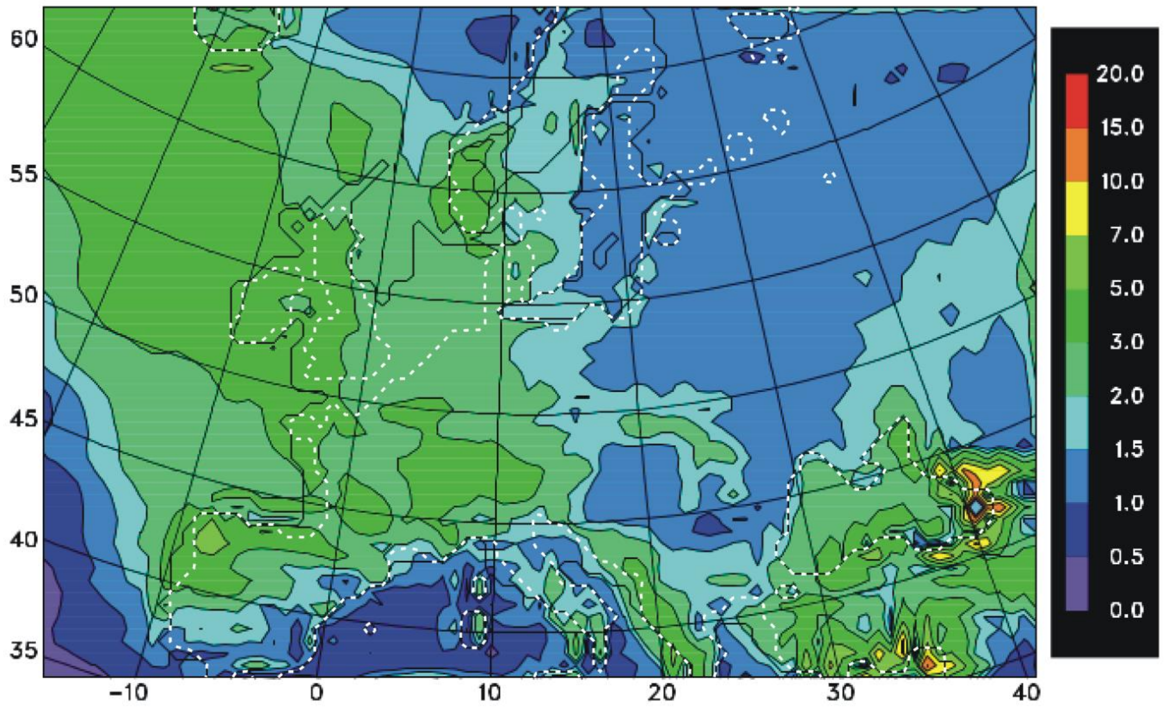

Figure 7: Precipitation (mm/day) data from the Stage 3 Project's MIS-3 'warm' simulation (Barron, van Andel, and Pollard 2003, appendix 5.1). Dashed white line: Modern European coastline.

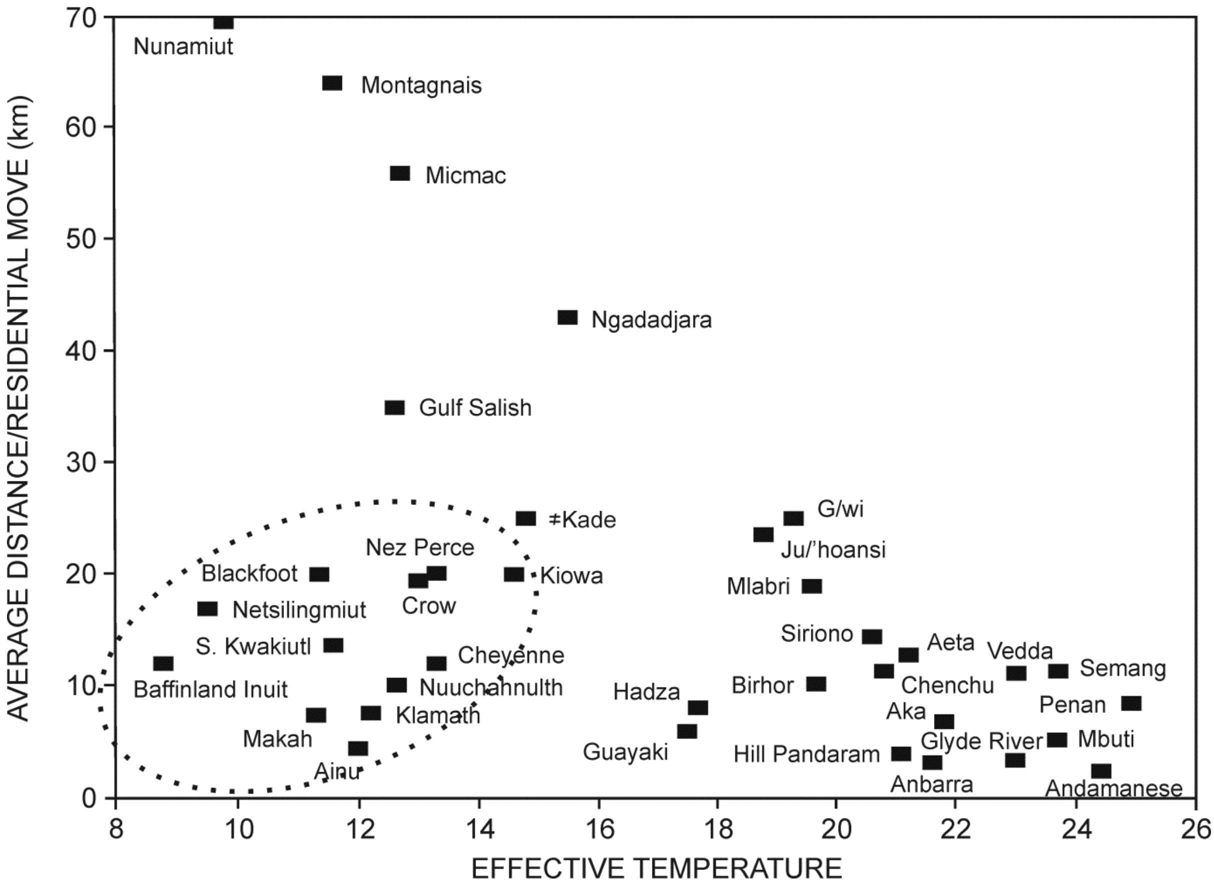

Figure 8: Relationship between effective temperature and average distance/residential move (after Kelly 1995, fig. 4-7). Note the examples (circled) for groups making relatively short mean residential moves in low effective temperature environments (see Kelly 1995:128–130 for details). Effective Temperature (*ET*) is derived from the mean temperatures (°C) of the warmest and coldest months (*W* and *C*; where $ET = \frac{18\,W - 10\,C}{(W - C) + 8}$), and its value varies from 26 (equator) to 8 (poles). High *ET* values are associated with tropical, non-seasonal environments (in terms of temperature, not precipitation) with long growing seasons. Low *ET* values are associated with cold, seasonal environments with short growing seasons (Kelly 1995:66–69).

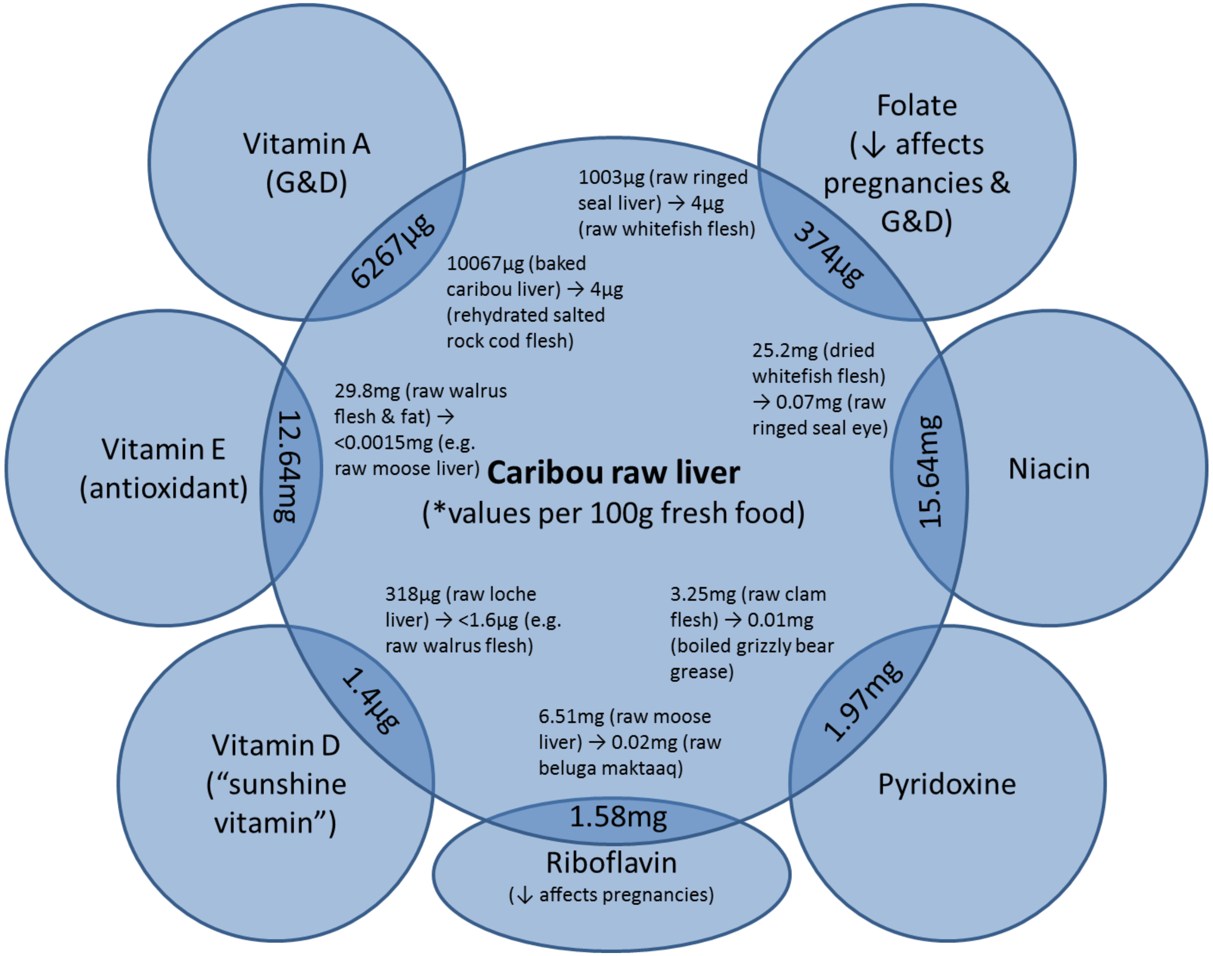

Figure 9: Selected sources of vitamins in Arctic hunter-gatherer diets (data from Hidiroglou *et al*. 2008; Kuhnlein *et al*. 2006). Values per 100g of fresh raw caribou liver (e.g. 1.58mg for Riboflavin) compared against alternative food sources (e.g. raw moose liver [6.51mg] and raw beluga muktuk [0.02mg] for Riboflavin). G&D: growth and development.

Figure 10: A winter residency model.

Supplementary Materials

	H. erectus[1]		*H. sapiens*[2]	
	Kleiber BMR[3]	Elevated BMR[4]	Kleiber BMR[3]	Elevated BMR[4]
Body Mass (kg)	68	68	70	70
Stature (cm)	185	185	177	177
BMR	80.512	92.589	82.282	94.624
Body surface area[5]	1.900	1.900	1.862	1.862
Human Conductance A[6]	5.0	5.0	5.0	5.0
Total Conductance A[7]	9.498	9.498	9.312	9.312
Lower Critical Temperature A (°C)[8]	28.5	27.3	28.2	26.8
Minimum Sustainable Temperature A (°C)[9]	11.6	7.8	10.5	6.5
Human Conductance B[10]	4.750	4.750	4.750	4.750
Total Conductance B[7]	9.023	9.023	8.846	8.846
Lower Critical Temperature B (°C)[8]	28.1	26.7	27.7	26.3
Minimum Sustainable Temperature B (°C)[9]	10.2	6.2	9.1	4.9
Human Conductance C[11]	2.817	2.817	2.817	2.817
Total Conductance C[7]	5.351	5.351	5.246	5.246
Lower Critical Temperature C (°C)[8]	22.0	19.7	21.3	19.0
Minimum Sustainable Temperature C (°C)[9]	-8.1	-14.9	-10.1	-17.1

Table 1: Lower critical and minimum sustainable ambient temperatures for *H. erectus* and *H. sapiens* (after Aiello and Wheeler 2003, tables 9.1–9.3). [1]*H. erectus* data from KNM-WT 15000 (Ruff 1994); [2]*H. sapiens* data from Předmost 3 & 9, Skhul 4 and Grotte des Enfants 4 (Ruff 1994); [3]BMR = 3.4 x mass (kg)$^{0.75}$ (Kleiber 1961); [4]Elevated BMR = BMR raised by 15% to account for climatic and dietary-induced increases (after Aiello and Wheeler 2003:150); [5]Body surface area (m^2) = 0.00718 x mass (kg)$^{0.425}$ x stature (cm)$^{0.725}$; [6]Typical human conductance = 5 W.m^{-2}.°C^{-1}; [7]Total conductance = typical human conductance x surface area (m^2); [8]Critical temperature (°C) = 37°C – (BMR/Total conductance); [9]Minimum sustainable ambient temperature (°C) = 37°C – ((3 x BMR)/Total conductance); [10]Typical human conductance reduced by 5% to account for hominin muscularity (after Aiello and Wheeler 2003:150); [11]Typical human conductance reduced by c. 44% to account for 1 clo of insulation (after Aiello and Wheeler 2003:150). 1 clo is roughly equivalent to the insulation provided by a western business suit.

Palaeoclimate Measure[1]	**MIS 3 ‘warm’ interval**			**Modern data**		
	52°N 0°E	**45°N 0°E**	**50°N 10°E**	**52°N 0°E**	**45°N 0°E**	**50°N 10°E**
Min. monthly lowest-level air temperature (°C)	-4 – 0	0 – +4	-4 – -8	4 – 8	4 – 8	0 – 4
$T_{max} – T_{min}$ (°C)	12 – 16	12 – 16	16 – 20	9 – 12	9 – 12	12 – 16
Diurnal range of lowest level air temperature (°C)	1 – 2	2 – 3	1 – 2	1 – 2	3 – 4	1 – 2
No. of days/year with snow cover	90 – 120	10 – 30	150 – 180	< 10	< 10	30 – 60
Snow depth, actual (cm)	5 – 10	0 – 5	20 – 50	0 – 5	0	0 – 5
Wind chill (°F)	0 – 10	10 – 20	0 – 10	20 – 50	20 – 50	10 – 20
Precipitation (mm/day)	2 – 3	3 – 5	2 – 3	2 – 3	3 – 5	1.5 – 2
Net primary productivity (gC/m2/year)	200 – 300	300 – 400	200 – 300	600 – 700	900 – 1000	600 – 700
Annual growing days above 5°C (°C.day)	750 – 1000	1000 – 1500	1000 – 1500	1500 – 2000	2000 – 3000	1500 – 2000
Annual growing days above 0°C (°C.day)	1500 – 2000	2000 – 3000	2000 – 3000	3000 – 4000	4000 – 5000	3000 – 4000

Table 2: Selected palaeoclimate simulation data for three point-specific locations, for an MIS 3 ‘warm’ interval and the present day. Data from Barron, van Andel, and Pollard (2003). [1]Descriptions of palaeoclimate measures from Barron, van Andel, and Pollard (2003:78).