En Mouvement / On the Move / In Bewegung
Mobilités des hommes, des objets et des idées pendant le Paléolithique supérieur européen
Mobility of people, objects and ideas during the European Upper Palaeolithic
Mobilität von Menschen, Objekten und Ideen im europäischen Jungpaläolithikum
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Population estimates for the Final Palaeolithic (14,000 to 11,600 years cal. BP) of Europe – challenging evidence and methodological limitations

Estimation du peuplement en Europe pendant le Paléolithique final (14 000 à 11 600 années cal. BP) – des preuves contestables et des limites méthodologiques

Bevölkerungsschätzungen für das Spätpaläolithikum (14.000 bis 11.600 Jahre cal. BP) in Europa – eine herausfordernde Datenlage und methodische Einschränkungen

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Abstract: The impressive corpus of recently published research on the Final Palaeolithic of Europe contrasts with few studies explicitly dealing with the demography of these hunter-gatherer communities. Our paper presents new results on population estimates for the period from 14,000 to 11,600 years cal. BP. The population estimates are obtained by applying the so-called 'Cologne Protocol' to the specifically challenging evidence of Final Palaeolithic human occupation across Europe, which is characterised by – environmental, cultural, and economical – changes and variability. Therefore, the paper explicitly focuses on effects of these factors as well as related methodological constraints.
In doing so, we find strong arguments that our results of around 6,600 people (with minima and maxima of 3,100 to 10,900 people) likely overestimate the actual population size of the Final Palaeolithic. For the current dataset, low temporal resolution of the available data is one of the most critical factors. Additionally, a diachronic comparison of our results with estimates for preceding periods indicates a general population decline after the Late Magdalenian. This finding is fostered by evidence from independent proxies used in regional studies. The present case study demonstrates the importance of approaching prehistoric demography through independent proxies, disentangling causal relations between proxies, and by considering different spatial and temporal scales.

Keywords: Hunter-gatherers, Palaeodemography, Cologne Protocol, Population size and density, Final Palaeolithic, Younger Dryas.

Résumé : Le corpus impressionnant de recherches sur le Paléolithique final en Europe, publié récemment, est en contraste avec le faible nombre d'études qui traitent explicitement de la démographie des communautés de chasseurs-cueilleurs. Dans notre article, on présente des résultats nouveaux au sujet des estimations démographiques concernant la période entre 14 000 et 11 600 années cal. BP. Ces estimations de population sont obtenues en appliquant le « protocole de Cologne » aux preuves existantes, particulièrement

difficiles à interpréter, concernant l'occupation humaine de l'Europe au cours du Paléolithique final. Cette période est caractérisée par la variabilité et le changement dans le domaine environnemental, culturel et économique. Pour cette raison, dans la présente contribution, on met explicitement l'accent sur les effets des dits facteurs et sur les contraintes méthodologiques qui y sont liées.
En se servant de données archéologiques sur la distribution des sites et la mobilité des chasseurs-cueilleurs ainsi que de documents ethnographiques sur la taille de ce type de groupes, le protocole de Cologne nous permet d'évaluer aussi bien la taille des populations locales que la densité démographique paneuropéenne. Soit les sites archéologiques inclus dans la base de données (n = 1 120) sont datés directement, soit ils sont attribués, pour des raisons typologiques, au Paléolithique final. En effet, afin de modéliser des « Core Areas » d'occupation humaine, on applique, à l'intérieur d'une zone globale d'évaluation, le « Total Area of Calculation » (TAC), une approche d'extrapolation géostatistique, fondée sur la densité de sites. Des données régionales sur la mobilité, c'est-à-dire sur le transport de la matière-première lithique, servent à estimer le nombre de groupes habitant potentiellement dans ces Core Areas. Que ce soit à l'échelle régionale ou paneuropéenne, les estimations démographiques fournies par le protocole de Cologne, en tant que tel, peuvent être comparés aux résultats des autres études, obtenus par des approches ou avec des variables différentes.
Pour ce qui est du Paléolithique final, d'après les résultats de la présente étude, on estime le nombre d'individus vivant en Europe en même temps à 6 600 personnes environ (avec des minima et des maxima de 3 100 à 10 900 individus) ; ceci correspond à une densité estimée de 0,25 individus par 100 km^2 (avec des minima et des maxima de 0,12 à 0,42 individus par 100 km^2). Les estimations de densité diffèrent selon les Core Areas, la densité la plus faible s'élevant à 0,83 individus par 100 km^2 – notamment dans les régions actuelles de la Grande-Bretagne, du Benelux, du Danemark, et de la Pologne – et les valeurs maximales à 1,91 individus par 100 km^2, surtout dans le sud-ouest de l'Europe.
La comparaison avec les estimations existantes pour le Magdalénien précédent – basées également sur le protocole de Cologne – fait apparaître que l'augmentation nette et continue, aussi bien de la taille des populations que de la densité démographique, constatée pour l'ensemble des phases du Magdalénien, se termine soudainement au cours du Paléolithique final. En revanche, à l'échelle paneuropéenne, nos estimations indiquent une stabilité, toutefois avec une légère tendance à la baisse, du Magdalénien supérieur au Paléolithique final.
Cependant, nous disposons d'arguments que nos estimations ont tendance à surestimer la densité réelle du peuplement pendant le Paléolithique final. Vraisemblablement, les êtres humains de cet époque étaient confrontés à un déclin de population plus important qu'indiqué par nos données actuelles. Quant au fichier de données actuel, la faible résolution temporelle des données disponibles est particulièrement inquiétante.
Un examen plus approfondi des facteurs potentiels de biais, inclus dans le jeu de données, montre que des changements rapides se sont probablement produits, notamment en ce qui concerne les modes de mobilité humaine ainsi que l'extinction ou le déplacement de groupes régionaux. Par conséquent, dans la présente étude, les Core Areas modélisées couvrent des zones habitées uniquement pendant des phases distinctes du Paléolithique final sans être fréquentées de façon continue. On considère que la prise en compte de tels intervalles, avec une résolution temporelle plus mieux, engendrera des estimations démographiques moins élevées.
Par ailleurs, parmi les caractéristiques de l'ensemble actuel de données, des différences régionales concernant les estimations démographiques sont à noter. Étant donné que, sur le plan méthodologique, dans le cadre du protocole de Cologne, le jeu de données est étroitement lié aux données sur le transport des matières premières, il sera essentiel de mieux comprendre les différences régionales, surtout pour ce qui est de la mobilité et des stratégies d'approvisionnement. Spécialement, en ce qui concerne le Paléolithique final, la clarification du système technico-économique et chronoculturel engendrera des estimations démographiques réduites dans les régions qui génèrent, à l'heure actuelle, les valeurs les plus élevées. Ceci devient également apparent lorsqu'on compare nos résultats avec ceux des études régionales, portant p. e. sur le sud-ouest de la France ou le nord de l'Italie, qui se servent d'indicateurs démographiques indépendants.
Cependant, en raison des densités globalement faibles pendant l'ensemble du Paléolithique supérieur en Europe, la déviation des évaluations futures, améliorées, sera assez limitée. Quant à la période du Dryas récent, la surestimation escomptée du peuplement en Europe pourrait devenir significative. Les recherches futures devraient viser à mieux concevoir le changement diachronique des indicateurs démographiques, ce qui nécessiterait de comparer des variables indépendantes et de comprendre les liens de causalité. Avant tout, l'augmentation de la résolution temporelle des donnés sur le Paléolithique final sera indispensable. Dans le cadre de la recherche d'échelles spatiales et temporelles appropriées, permettant de suivre la dynamique démographique au cours du Paléolithique final et dans d'autres contextes similaires, les estimations paneuropéennes présentées ici servent de base aux études futures.

Mots-clés : Chasseurs-cueilleurs, Paléodémographie, Protocole de Cologne, Taille et densité de la population, Paléolithique final, Dryas récent.

Zusammenfassung: Die beeindruckende Menge der kürzlich veröffentlichten Forschungen zum Spätpaläolithikum Europas steht ungleich wenigen Studien gegenüber, die sich explizit mit der Demographie der Jäger-Sammler-Gemeinschaften dieser Zeit befassen. Die vorliegende Arbeit präsentiert erste Bevölkerungsschätzungen für den Zeitraum von 14.000 bis 11.600 Jahren cal. BP. Die Schätzungen wurden anhand des sogenannten Kölner Protokolls für Europa ermittelt. Die Datenlage zur Besiedlungsgeschichte ist besonders komplex während des Spätpaläolithikums, welches durch ökologische, kulturelle und wirtschaftliche Veränderungen und Variabilität gekennzeichnet ist. Daher konzentriert sich die vorliegende Arbeit explizit auf die Auswirkungen dieser Faktoren sowie auf die damit verbundenen methodischen Einschränkungen.
Die Untersuchung legt nahe, dass die ermittelten Schätzwerte von rund 6.600 Menschen (Minimum 3.100, Maximum 10.900 Menschen) die tatsächliche Bevölkerungsgröße des Spätpaläolithikums vermutlich überschätzen. Für den aktuellen Datensatz ist die geringe zeitliche Auflösung der verfügbaren Daten methodisch ein entscheidender Faktor für diese Überschätzung. Weitere Hinweise finden sich zum einen im diachronen Vergleich der Ergebnisse mit Schätzungen für vorangegangene Perioden, die ebenfalls auf einen Bevölkerungsrückgang nach einem Bevölkerungsmaximum im späten Magdalénien hindeuten. Zum anderen zeigen unabhängige Proxys verschiedener regionaler Studien eine vergleichbare Tendenz. Die vorliegende Arbeit zeigt, wie wichtig es ist, sich der prähistorischen Demographie über verschiedene, unabhängige Proxies zu nähern, kausale Beziehungen zwischen Proxys auseinanderzuhalten und unterschiedliche räumliche und zeitliche Skalen zu berücksichtigen.

Schlüsselwörter: Jäger und Sammler, Paläodemographie, Kölner Protokoll, Populationsgröße und -dichte, Spätpaläolithikum, Jüngere Dryas.

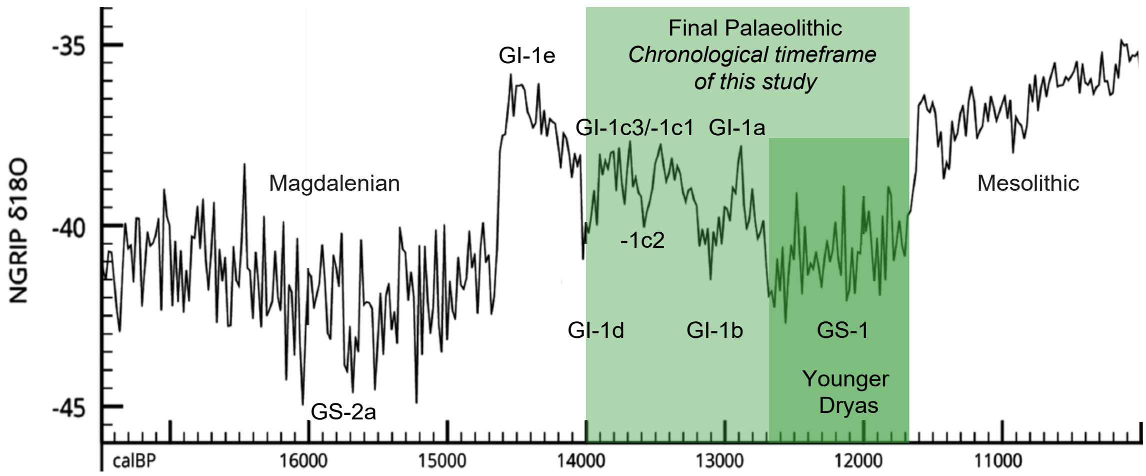

Fig. 1 – Chronological and climatic context of the study (green shading) including the Younger Dryas (dark green shading). GI – Greenland Interstadial; GS – Greenland Stadials (graph modified after: Philippsen et al., 2019).

Fig. 1 *– Cadre chronologique et climatique de l'étude (vert clair). Le Dryas récent est en vert foncé.* GI – Greenland Interstadial; GS – Greenland Stadials *(graphique modifié d'après Philippsen et al., 2019).*

Abb. 1 *– Chronologischer und klimatischer Kontext der Fallstudie (farblich markierter Bereich), einschließlich der Jüngeren Dryas (dunkle Schattierung). GI – Grönland-Interstadial; GS – Grönland-Stadial (Abbildung verändert nach: Philippsen et al., 2019).*

INTRODUCTION

Pan-European studies on demographic developments during the Final Palaeolithic are scarce. This is different for the preceding Magdalenian period, associated with the repopulation of northern central Europe after the Last Glacial Maximum (LGM). Different approaches to trace demographic developments independently predict a considerable increase of the Pan-European population density for the Magdalenian (~19 to 14 ky cal. BP, see fig. 1; Bocquet-Appel et al., 2005; Kretschmer, 2015; Tallavaara et al., 2015; Maier et al., 2016). Mean density estimates are modelled as increasing by a factor of 0.25 (Tallavaara et al., 2015), 2 (Schmidt et al., 2021; after: Kretschmer, 2015; Maier, 2015, 2017; Maier et al., 2016) or even 3 (Bocquet-Appel et al., 2005) between the LGM (here ~20 ky cal. BP) and Late Magdalenian (~14 ky cal. BP). However, even within the Magdalenian, this general trend becomes more variable if either higher temporal resolution is applied (Tallavaara et al., 2015), or smaller spatial scales, including relative proxies on demographic developments, are considered (French and Collins, 2015; Kretschmer, 2015). This methodological problem of scales in demographic research has been subject to debate (Schlummer et al., 2014; Zimmermann et al., 2020; Zimmermann, in press; Schmidt et al., 2021) and shows how decisive this factor is for palaeodemographic research.

While the material culture of the later Magdalenian phases is characterised by a rather homogenous appearance across the subcontinent – concerning technologies, artistic expressions, subsistence and mobility behaviour – clear cultural changes and regional trajectories become apparent during the interchanging warm and cold phases of the Greenland Interstadial (GI) 1e-a and during the cold Greenland Stadial (GS) 1 (fig. 1). The Final Palaeolithic marks the emergence of clear regional technological solutions and styles, as well as distinct settlement patterns and economic adaptations. The apparent variability and regional diversity make it difficult to establish chronocultural sequences, especially at larger spatial scales (Fagnart, 1997; Baales et al., 2002; Baales, 2014; Kegler, 2007; Holzkämper et al., 2013; Sobkowiak-Tabaka and Winkler, 2017; Grimm, 2019; Grimm et al., 2020). This difficulty is also enhanced by political borders, large regions with few directly dated assemblages, and abundant palimpsest assemblages from surface collections and open air sites. The robustness of techno-typological markers, their timing, and even the order of succeeding phases are currently under discussion (Reynolds and Riede, 2019; Sauer and Riede, 2019; contributions in Grimm et al., 2020; as well as contributions this volume). In addition, recent genetic studies suggest a regional population breakdown and an east-to-west repopulation scenario for Europe, roughly covering the period from 14 to 8 ky cal BP, with a likely source area in south-eastern Europe (Fu et al., 2016; Posth et al., 2016; Reich, 2018, fig. 13.5).

The only available Pan-European demographic study for the Final Palaeolithic models an initial decrease and subsequent increase in population density (Tallavaara et al., 2015). Further data from methodologically distinct regional studies are available. For a sub-region of south-western France high resolution proxies such as radiocarbon data and site counts indicate a general decrease (French and Collins, 2015). For northern Italy, the same proxies have been collated, however, synchronous changes in human mobility patterns are discussed as causing changes in proxies of site frequencies and dates, not necessarily demography (Naudinot et al., 2014). Initial results of a study for Denmark and its immediate surrounds, including southern Scandinavia

Site	Country	Number of source-to-site datasets	km² of RM-polygon	Included (0 = no; 1 = yes)	References
Ruien 'Rosalinde'	Belgium	4	7,563	1	Crombe et al., 2014
Eindegoorheide 1	Belgium	2	2,751	1	Verbeek, 1997
Tongeren-Plinius	Belgium	9	2,671	1	Dijkstra et al., 2006
Kopačina Cave	Croatia	4	13,918	0	Vukosavljević et al., 2011
Les Chaloignes	France	2	173	0	Marchand et al., 2011
La Grotte-Abri de Troubat/Moulin	France	2	2,522	1	after: Barbaza, 2011
Port-de-Penne	France	4	1,894	1	Langlais et al., 2014
La Borie del Rey	France	4	1,982	1	Langlais et al., 2014
Mas d'Azil	France	9	40,448	1	Kegler, 2007
L'Abri Rhodes II	France	2	12,789	1	Fat Cheung et al., 2014
Le Grotte Abri de Peyrazet	France	1	1,237	0	Langlais and Laroulandie, 2009
Champ Chalatras	France	2	1,524	1	Pasty et al., 2002
Blot	France	1	475	0	Surmely et al., 2009
Grotte Béraud	France	6	28,674	1	Surmely et al., 2009
Abri des Douattes, Est	France	2	689	1	Affolter, 2015
Abri nord de Bavans	France	2	997	1	Affolter, 2015
Gahlen-Schermbeck	Germany	1	323	0	Richter, 1981
Wesseling-Eichholz	Germany	4	1,100	1	Parow-Souchon and Heinen, 2017
Altenrath-Ziegenberg	Germany	2	5,711	1	Street, 1998
Bad Breisig	Germany	3	8,708	1	Grimm, 2004
Andernach-Martinsberg	Germany	3	10,789	1	Street, 1998
Gönnersdorf	Germany	2	4,960	1	Baales, 2005
Kettig	Germany	4	5,220	1	Baales, 2001
Niederbieber	Germany	5	13,925	1	Gelhausen, 2007; Baales, 2005
Urbar (20)	Germany	3	853	1	Baales et al., 1996
Rüsselsheim 122 (A, B)	Germany	3	5,897	1	Loew, 2006
Bad Buchau-Kappel	Germany	3	3,056	1	Jochim et al., 2015
Sattenbeuren-Kieswerk	Germany	1	876	0	Kind, 1995
Helga-Abri	Germany	5	10,312	1	Hess, 2014
Geldrop 3-4	Netherlands	1	797	0	Deeben, 1999
Heythuysen-De Fransman	Netherlands	4	5,118	1	Stoop, 2014
Horn-Haelen	Netherlands	5	3,910	1	Stoop, 2014
Dzierżysław	Poland	1	1,302	0	Trabska et al., 2008
Tarnowa 1	Poland	1	975	0	Sulgostowska, 2006
Janów 21	Poland	1	976	0	Płaza et al., 2015
Rzuchów 24	Poland	1	963	0	Płaza et al., 2015
Chełmno 4	Poland	2	963	1	Płaza et al., 2015
Cichmiana 2	Poland	3	7,924	1	Płaza et al., 2015
Kraków-Bieżanów	Poland	2	2,129	1	Stefański and Wilczyński, 2012
Całowanie	Poland	1	605	0	Sulgostowska, 2006
Berniollo	Spain	2	587	1	Berganza, 2005
Urratxa III	Spain	2	2,479	1	Berganza, 2005
Forcas I	Spain	2	755	1	Sánchez de la Torre, 2014

Site	Country	Number of source-to-site datasets	km² of RM-polygon	Included (0=no; 1=yes)	References
Grotte du Bichon	Switzerland	2	361	0	Chauvière et al., 2008
Monruz (Neuchâtel)	Switzerland	5	5,025	1	Affolter, 2015
Champréveyres	Switzerland	7	5,025	1	Affolter, 2015
Neumühle, Abri	Switzerland	7	3,110	1	Affolter, 2015
Lengbau-Chlini Ey	Switzerland	15	8,937	1	Affolter, 2015
Abri Wachtfels	Switzerland	15	6,455	1	Affolter, 2015
Birseck-Ermitage	Switzerland	5	2,352	1	Affolter, 2015
Geispel	Switzerland	11	3,351	1	Affolter, 2015
Fürsteiner	Switzerland	7	13,905	1	Affolter, 2015
Wauwil-Sandmatt 25	Switzerland	6	2,814	1	Nielsen, 1999
Gunzwil-Beromünster	Switzerland	5	1,523	1	Affolter, 2015
Grindel I / II / VI	Switzerland	5	2,687	1	Affolter, 2015
Cham-Grindel III	Switzerland	8	5,876	1	Affolter, 2015
Langrüti	Switzerland	12	10,310	1	Affolter, 2015
Altwasser-Höhle 1	Switzerland	5	10,944	1	Affolter, 2015

Table 1 – Assemblages with information on raw material (RM) transport from sources to the site; data are collated from the literature (Schmidt, 2019). For the application of the Cologne Protocol, areal values (km²) of polygons around sources and the site are calculated. Sites outside the defined Total Area of Calculation, with only one source-to-site dataset, or with polygon sizes <500 km² were not included.

***Tableau 1** – Assemblages comportant des informations sur la circulation des matières premières (RM) depuis les gîtes d'approvisionnements jusqu'aux sites ; données collectées d'après la bibliographie (Schmidt, 2019). Pour l'application du protocole de Cologne, la superficie des polygones (km²) autour des sources et des sites sont calculées. Les sites en dehors du* Total Area of Calculation *possédant une seule source d'approvisionnement ou avec des polygones avec des surfaces inférieures à 500 km² n'ont pas été intégrés.*

***Tabelle 1** – Inventare mit Informationen zum Transport des lithischen Rohmaterials (RM) vom Materialaufschluss zur Fundstelle; die Daten wurden aus der Literatur zusammengestellt (Schmidt, 2019). Für das Kölner Protokoll werden Flächenwerte (km²) mithilfe von Polygonen um Aufschlüsse und Fundorte errechnet. Fundstellen außerhalb der TAC, mit nur einer Aufschluss-Fundort-Distanz oder mit einer Polygonfläche <500 km², werden im Folgenden nicht berücksichtigt.*

(Lundström and Riede, 2019; Lundström et al., 2021), indicates a population growth from the Final Palaeolithic to the early Holocene Mesolithic.

This paper attempts to estimate both a Pan-European population density and regional population sizes using the challenging dataset with the described inherent problem of highly variable and diverse cultural developments and chronological and techno-typological classifications. Specific methodological constraints that thus emerged from the data during the application of the Cologne Protocol (Zimmermann et al., 2009; Schmidt et al., 2021) will be detailed in the discussion.

MATERIALS AND METHODS

Data on archaeological site-distribution and raw material acquisition were collated for the period from roughly 14,000 to 11,600 years cal. BP (fig. 1). The period corresponds to the Late Glacial which is refined for northern Europe GI 1 phases c-a – comprising GI 1c3 and GI 1c1, GI 1a (cf. Litt et al., 2001), interrupted by colder events (GI1d, GI 1c2, GI 1b) – and followed by the cold GS 1, also known as the Younger Dryas (YD), dating from 12,700 to 11,600 years cal. BP. The eruption of the Laacher See Volcano around 13,000 years ago affected large areas of northern Europe (Baales et al., 2002; Reinig et al., 2020) and was probably responsible for larger-scale cultural developments at the interface of the two periods (Riede, 2008; see also Weber et al., 2011).

The current database comprises 1,120 sites located across Europe (fig. 2; Schmidt and Zimmermann, 2020), however, an updated version with regionally revised data will be available soon (Schmidt et al. in prep.). The sites are either directly dated or typologically assigned to the Final Palaeolithic. Of these sites, 1,054 are located within the 'Total Area of Calculation' (TAC, see fig. 2), an area defined as potentially inhabitable and excluding under-researched areas and areas of disputed evidence. As such, the TAC covers 2.6 million km² of western and central Europe, including southern England and northern Italy. Glaciated areas are excluded. Other regions, such as southern Italy, the Balkans and north-eastern and eastern Europe were not considered during the final analysis. Accessibility of quantitative and qualitative comparable data on sites and assemblages were found uneven here, making it difficult to integrate the areas. However, chronometrically dated evidence is becoming increasingly available from these regions, providing promising research conditions for the future.

Data on raw material transport were recorded from the literature for 58 assemblages encompassing 240 individual source-to-site distances (table 1; Schmidt, 2019).

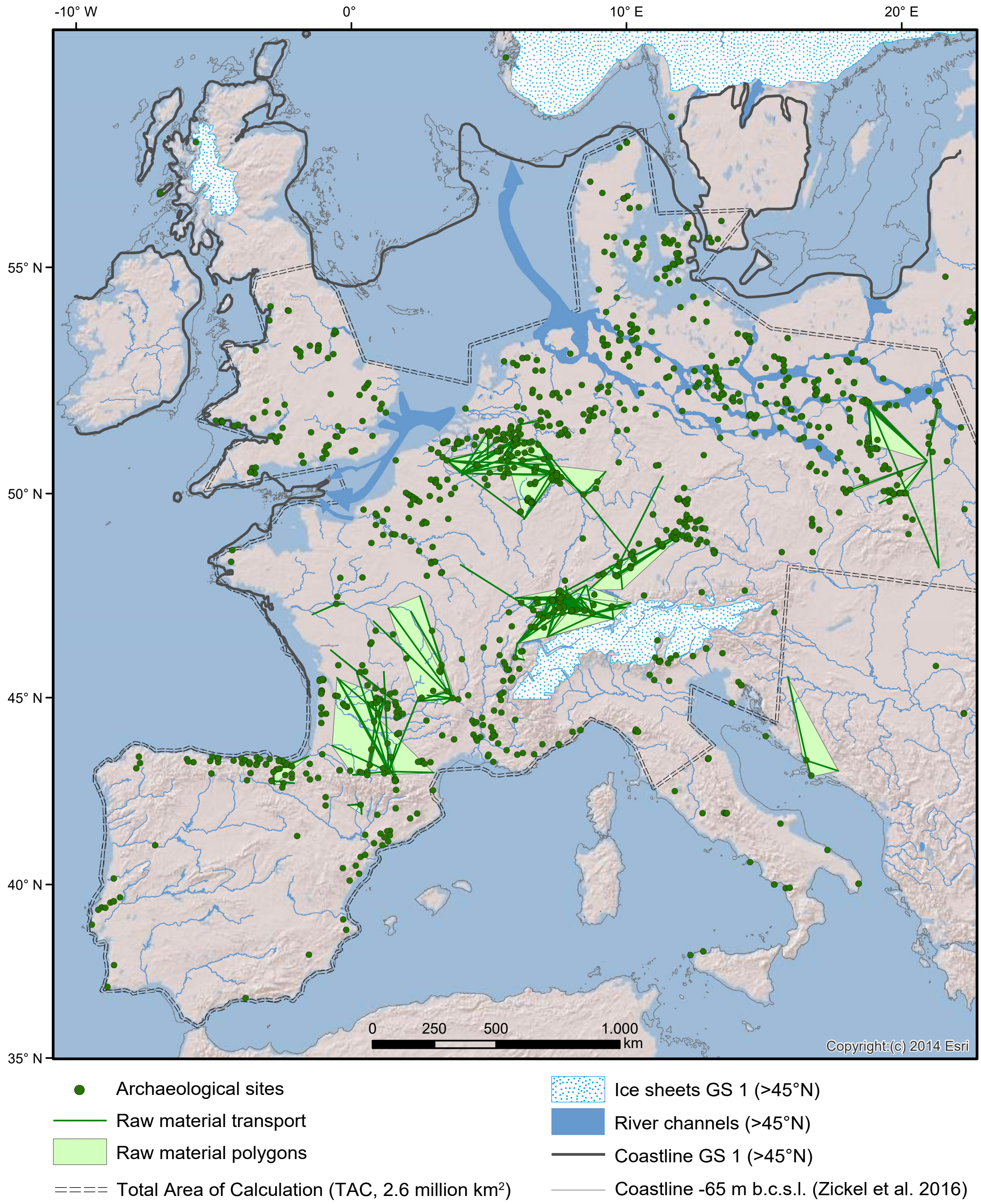

Fig. 2 – Distribution of Final Palaeolithic sites and raw material transport distances (data available online at: Schmidt, 2019; Schmidt and Zimmermann, 2020) considered in this study. Reconstructions of ice sheets, river channels, and coastline (> 45°N) correspond to conditions of Greenland Stadial 1 (GS 1), i.e. Younger Dryas (Grimm, 2019, and references therein).

***Fig. 2** – Distribution des sites du Paléolithique final et distances de la circulation des matières premières (données disponibles en ligne à: Schmidt, 2019 ; Schmidt et Zimmermann, 2020) considérées dans cette étude. La reconstitution des inlandsis, des chenaux et des côtes (supérieurs à 45°N) correspond aux conditions du* Greenland Stadial 1 (GS 1)*, c.-à-d. du Dryas récent (Grimm, 2019 et références y figurant).*

***Abb. 2** – Verteilung der spätpaläolithischen Fundstellen und der Transportdistanzen von lithischem Rohmaterial (Daten sind online verfügbar unter: Schmidt 2019; Schmidt und Zimmermann, 2020), die in dieser Studie verwendet wurden. Die Darstellung der Verläufe von Inlandeisflächen, Flussläufen und Küstenlinien (> 45°N) entsprechen den rekonstruierten Bedingungen während des Grönland-Stadials 1 (GS 1), i.e. der Jüngeren Dryas (Grimm, 2019 und Referenzen dort).*

We exclude raw materials documented by single pieces, and only considered raw materials representing at least 1% of an assemblage. For each site and each assemblage, we then determined the raw material polygon by constructing a convex hull around the site and its raw material sources. Around the archaeological site, an additional buffer of 5 km radius representing a local procurement radius was added. Finally, for the calculation of population densities, we used data from 45 of the raw material polygons, excluding all polygons which only comprised a single source-to-site distance, as well as polygons which were smaller than 500 km², since they turned out to be exceptional outliers among the overall polygon sizes.

To determine the population estimates, we use the Cologne Protocol, developed and applied to Neolithic case studies (Zimmermann et al., 2009; Wendt et al., 2010; Wendt and Zimmermann, 2015) as well as adjusted to hunter-gatherer contexts (Kretschmer, 2015; Schmidt et al., 2021) and applied to a continuous series of Upper Palaeolithic periods, i.e. the Aurignacian (Schmidt and Zimmermann, 2019), Gravettian (Maier and Zimmermann, 2017), the Last Glacial Maximum (Maier et al., 2016), and Magdalenian (Kretschmer, 2015). For an overview on the results of the demographic estimates for the European Upper Palaeolithic, the reader is referred to the paper by Schmidt et al. (2021). This geostatistical upscaling procedure (for details see: ibid.) identifies the radius of the Largest Empty Circle (LEC) which is located between each group of three nearest sites. The LEC radius values serve as a distance measure for site density and are interpolated using ordinary Kriging. By identifying a plateau or peak in the areal increase of the interpolated LEC radius values, we determine areas of similar site density (or smallest LEC-radii, respectively). The delimiting Isoline of this area is termed the Optimally Describing Isoline (ODI). Since the curve of areal increase can show several peaks, we also consider the percentage of sites enclosed by the ODI (see also Broich and Peters, 2020: p. 15-17). Previous research has shown that the ODI should cover at least 70% of sites (Zimmermann et al., 2009). The area enclosed by the ODI is called the Core Area. Core Areas comprise areas where a certain distance between sites is not exceeded, and they are interpreted to describe most likely continuously and intensively occupied areas. In this study we used MapInfo V8.5 to conduct the geostatistical procedure. To allow comparison with previous work, we used the same projection (WGS 84/UTM zone 32N, see Kretschmer, 2015).

To derive absolute numbers of people, we divide the square kilometres of each Core Area by the quartiles (Q1, Q2, Q3) of the raw material polygon areas (see table 2). These polygons are considered indicative of the mobility range of hunter-gatherer groups, thus reflecting a potential area of land-tenure. Their size thus determines the number of groups that lived within a Core Area. Since data on raw material provenience are not available for all regions, we had to extrapolate polygon sizes into adjacent regions (cf. Maier et al., 2016). The results are then multiplied by an average group size, derived from ethno-historic cases selected based on economic considerations (see Kretschmer, 2015). This average size, termed GROUP 2 according to Binford (2001), is considered to represent a hunter-gatherer group size which fuses during the course of a year and accounts in this sample for 43 persons per Group (Schmidt et al., 2021).

The density of persons within the Core Areas is given per 100 km² (table 2). To calculate the subcontinental density, we divide the estimated number of persons by the TAC of 2.6 million km² (fig. 2), consequently resulting in a lower density at this scale.

RESULTS

The Optimally Describing Isoline (ODI) for the site distributions of the Final Palaeolithic (fig. 3) is identified by the geostatistical approach of the Cologne Protocol at the Largest Empty Circle (LEC) radius of 32 km (fig. 4). The Core Areas as enclosed by the ODI sum up to 600,150 km² within the TAC. These Core Areas capture 87% of the sites (915 out of 1,054).

The total population estimate for the Final Palaeolithic comprises 6,600 people, with minima and maxima of 3,100 to 10,900 (table 2). Population density differs between Core Areas, with the lowest density of 0.83 persons per 100 km² being in the northern regions (Great Britain, Benelux, Denmark, Poland) and a highest value in southwestern Europe at 1.91 persons per 100 km². For the TAC, we derive an estimate of just 0.25 persons per 100 km², and minima and maxima of 0.12 to 0.42 persons per 100 km², respectively.

DISCUSSION

The results for the Final Palaeolithic presented in this study can be directly compared to results produced using the same approach for earlier periods at a European scale (fig. 5, diagram; Kretschmer, 2015 and 2019). While Kretschmer noted a clear continuous increase in population size and density throughout the Magdalenian – with maximum estimates for Core Areas of the Late Magdalenian (see fig. 5, map) – our estimates for population size and density at the European scale suggest stability from the Late Magdalenian to Final Palaeolithic, with a slight tendency to decrease (fig. 5, diagram, and table 3). This tendency is not pronounced and remains within the uncertainty range of the estimates. However, we suspect that this stability is spurious and caused by three factors which, if better controlled, would most likely reveal a different result: population size and density are more likely to have declined after the Late Magdalenian. Firstly, as outlined at the beginning, the Final Palaeolithic comprises phases of distinct climatic, environmental and cultural change. Regional population displacement or extinction, changes of mobility and subsistence strategies, have taken place during this period,

Core Areas	Optimal isolines (km²)	Q	Catchment area (Q1,2,3)	n	Number of groups	Number of persons	Pop. density Core Areas (P/100 km²)	Pop. density TAC (2.6 M km², P/100 km²)
	50869	Q1	2671		19.0	810	1.591	
United Kingdom *	50869	Q2	5118		9.9	422	0.830	
	50869	Q3	7563		6.7	286	0.562	
	44530	Q1	2671		16.7	709	1.591	
Denmark *	44530	Q2	5118		8.7	370	0.830	
	44530	Q3	7563	17	5.9	250	0.562	
	154216	Q1	2671		57.7	2454	1.591	
Poland, N-Germany *	154216	Q2	5118		30.1	1281	0.830	
	154216	Q3	7563		20.4	867	0.562	
	133480	Q1	2671		50.0	2124	1.591	
Benelux	133480	Q2	5118		26.1	1108	0.830	
	133480	Q3	7563		17.6	750	0.562	
	38417	Q1	2719		14.1	601	1.563	
S-Germany	38417	Q2	4188		9.2	390	1.015	
	38417	Q3	8317		4.6	196	0.511	
	23381	Q1	2719		8.6	366	1.563	
Swiss	23381	Q2	4188	18	5.6	237	1.015	
	23381	Q3	8317		2.8	119	0.511	
	19082	Q1	2719		7.0	298	1.563	
Italy (North) *	19082	Q2	4188		4.6	194	1.015	
	19082	Q3	8317		2.3	98	0.511	
	93283	Q1	1617		57.7	2452	2.629	
S-France *	93283	Q2	2231		41.8	1777	1.905	
	93283	Q3	10222		9.1	388	0.416	
	27626	Q1	1617		17.1	726	2.629	
N-Spain	27626	Q2	2231		12.4	526	1.905	
	27626	Q3	10222	10	2.7	115	0.416	
	4572	Q1	1617		2.8	120	2.629	
C-Portugal	4572	Q2	2231		2.0	87	1.905	
	4572	Q3	10222		0.4	19	0.416	
	10693	Q1	1617		6.6	281	2.629	
E-Spain *	10693	Q2	2231		4.8	204	1.905	
	10693	Q3	10222		1.0	44	0.416	
		Q1			**257**	**10941**	**1.823**	0.42
Sum Core Area	***600148***	Q2		**45**	**155**	**6596**	**1.099**	0.25
		Q3			**74**	**3132**	**0.522**	0.12

Table 2 – Regional population estimates derived for the Final Palaeolithic. Mean (Q2), maximum (Q1) and minimum (Q3) estimates are provided for each region. The number of available Catchment areas (n) is given for entire areas into which values were transferred (indicated by shading). * = instances where several small Optimally Describing Isolines were summed into larger regions (see fig. 3).

***Tableau 2** – Estimation régionale de la population pour le Paléolithique final. Des estimations moyenne (Q2), maximale (Q1) et minimale (Q3) sont fournies pour chaque région. Le nombre de sources d'approvisionnement (n) est donné pour des zones entières dans lesquelles des valeurs ont été transférées (indiqué en dégradé). * = instances dans lesquelles plusieurs petits* ODI *ont été additionnés en zones plus larges (voir la fig. 3).*

***Tabelle 2** – Regionale Populationsschätzungen für das Spätpaläolithikum. Mittelwert (Q2), maximale (Q1) und minimale (Q3) Schätzwerte sind für jede Region angegeben. Die Anzahl der berücksichtigten Rohmaterialeinzugsgebiete (Catchment areas, n) wird für die gesamte Region angegeben, für welche die Flächenwerte übernommen wurden (durch graue Schattierung angezeigt). * = Fälle, in denen mehrere kleine* ODIs *zu einer Fläche addiert wurden (see fig. 3).*

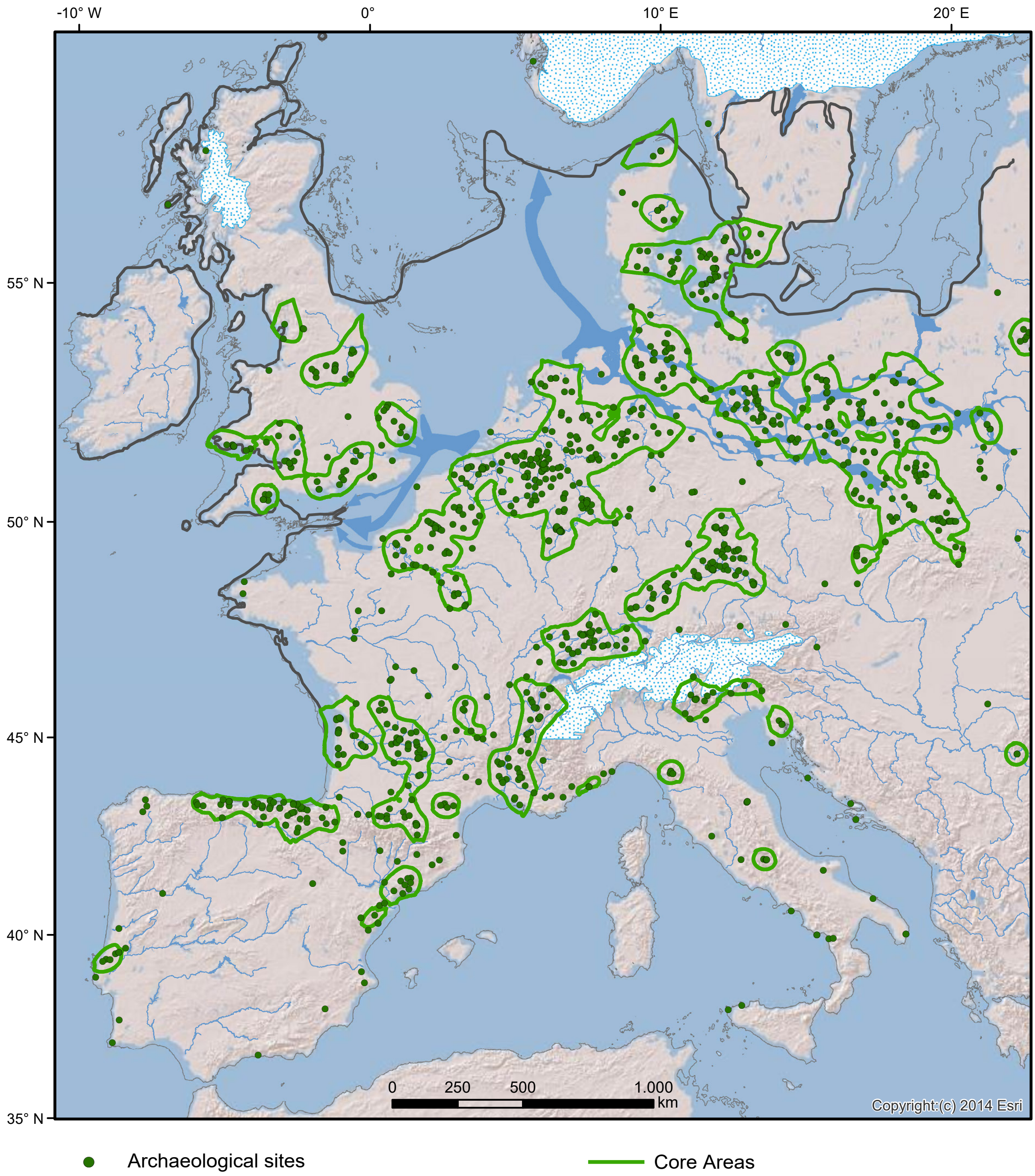

Fig. 3 – Modelled Core Areas for the Final Palaeolithic of western and central Europe. The Optimally Describing Isoline was identified at a 32 km radius of the Largest Empty Circle (fig. 4). For a legend on the map see fig. 2.

***Fig. 3** – Zones centrales modélisées pour le Paléolithique final d'Europe centrale et de l'ouest. La* Optimally Describing Isoline *est localisée dans un rayon de 32 km du* Largest Empty Circle *(fig. 4). Pour une légende de la carte, voir la fig. 2.*

***Abb. 3** – Modellierte Kernregionen für das west- und zentraleuropäische Spätpaläolithikum. Die* Optimally Describing Isoline (ODI) *wurde bei einem Radius von 32 km des* Largest Empty Circle *festgelegt (Abb. 4). Für die Legende der Hintergrundkarte siehe Abb. 2.*

especially in central and northern-central Europe, where the Younger Dryas resulted in clear changes in vegetation and the availability of prey animals (Philippsen et al., 2019). However, given the chronological resolution of the data in the present study, we are currently unable to pinpoint regions in which these diachronic internal changes affected human populations. This is still in the process of evaluation and discussion. A previous application of the Cologne Protocol on demographic developments during the Gravettian demonstrated, that increased temporal resolution allowed to trace regional population breakdowns (Maier and Zimmermann, 2017), which had not been detected by other approaches using lower temporal resolution (Bocquet-Appel et al., 2005).

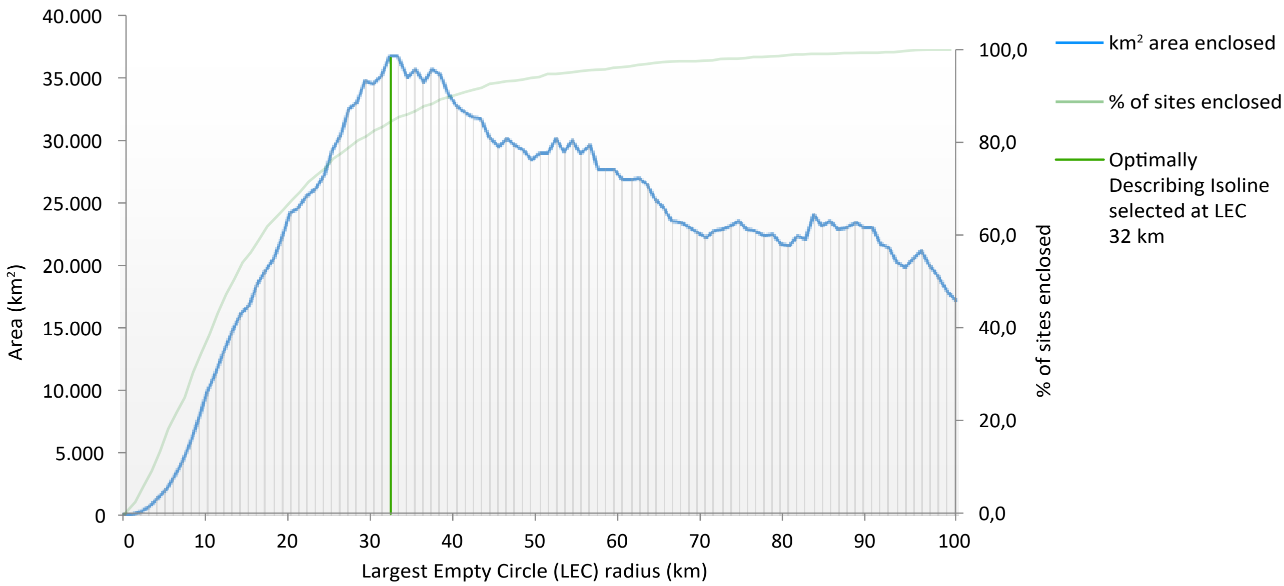

Fig. 4 – Increase of area enclosed by the isolines. The Optimally Describing Isoline is identified at the peak of the areal increase, at a Largest Empty Circle of 32 km. This considers 85% of the sites.

Fig. 4 *– Croissance de la superficie entourée par les contours. La* Optimally Describing Isoline *est localisée au sommet de la croissance de superficie, à un* Largest Empty Circle *de 32 km. 85 % des sites sont pris en compte.*

Abb. 4 *– Flächenzunahme innerhalb der Isolinien. Die* Optimally Describing Isoline *wird anhand des maximalen Flächenzuwachses bei 32 km Radius des* Largest Empty Circle *festgelegt. 85% der Fundstellen liegen innerhalb dieser ODI.*

As such, the modelled Core Areas in this study very likely cover many regions which were not inhabited continuously, but did see occupation only during specific phases of the Final Palaeolithic. A consideration of these gaps at a higher temporal resolution would thus result in a smaller population estimate. Lower temporal resolution in this case results, in turn, in an overestimate of the size of the Core Areas and thus of the population.

The second point relates to the observation that, although mean population density at the Total Area of Calculation (TAC) scale remains fairly stable, mean population density within Core Areas becomes significantly lower for the Final Palaeolithic (table 3). During the calculation procedure of the Cologne Protocol, the density estimate within Core Areas is strongly related to the size of the regionally observed raw-material polygons: large polygons will result in low densities, while small polygons will provide higher densities (see Schmidt et al., 2021: Sup Mat). Thus, differences or changes in the mobility and provisioning strategies of hunter-gatherers are likely responsible for the differences in population density estimates between Core Areas, as well as between periods.

In the present case, i.e. the comparison between Late Magdalenian and Final Palaeolithic, it is noteworthy that overall regional differences in raw-material polygon-size are quite constant across periods: during both periods polygons are highly variable in south-westernmost Europe, but on average the smallest, while in regions further north and east the average raw-material polygon-size is far larger (table 1). For the Final Palaeolithic, Quartiles on the regional raw-material polygon-sizes are provided in table 2 ('Catchment Area'). The observed patterns relate partly to regional characteristics in the distribution of raw material sources, but it should be noted that it is not a continuous pattern throughout the Upper Palaeolithic, and first comparisons indicate that regional mean polygon sizes do vary with time.

So why does the overall population size remain fairly constant, although the mean population density within Core Areas declines dramatically? There are two mechanisms at work. On the one hand, the overall size of the Core Areas during the Final Palaeolithic nearly doubles (table 3). On the other hand, this enormous expansion is counterweighted by the population density values related to this areal increase. The overall Core Area size with high density estimates in south-western Europe actually remains stable, although in some instances, as in Iberia, single Core Areas reduce in size or even disappear. On the northern plains of central Europe, a clear expansion of Core Areas can be noted, as in the modern Benelux region, northern Germany and Poland. These regions are characterised by the lowest densities and contribute less to the overall population size than other areas. Therefore, regional gain or loss of some Core Areas here does not make a difference in terms of absolute population numbers. As a consequence, mean population density estimates can decrease significantly at the scale of Core Areas, while at a Pan-European scale the overall increase of the size of Core Areas and specific patterns of distribution of population density finally determines the effects on absolute numbers. This observation underlines the importance of defining meaningful scales during investigations.

With regard to the areal increase of Core Areas and the distribution of regional population densities, we expect

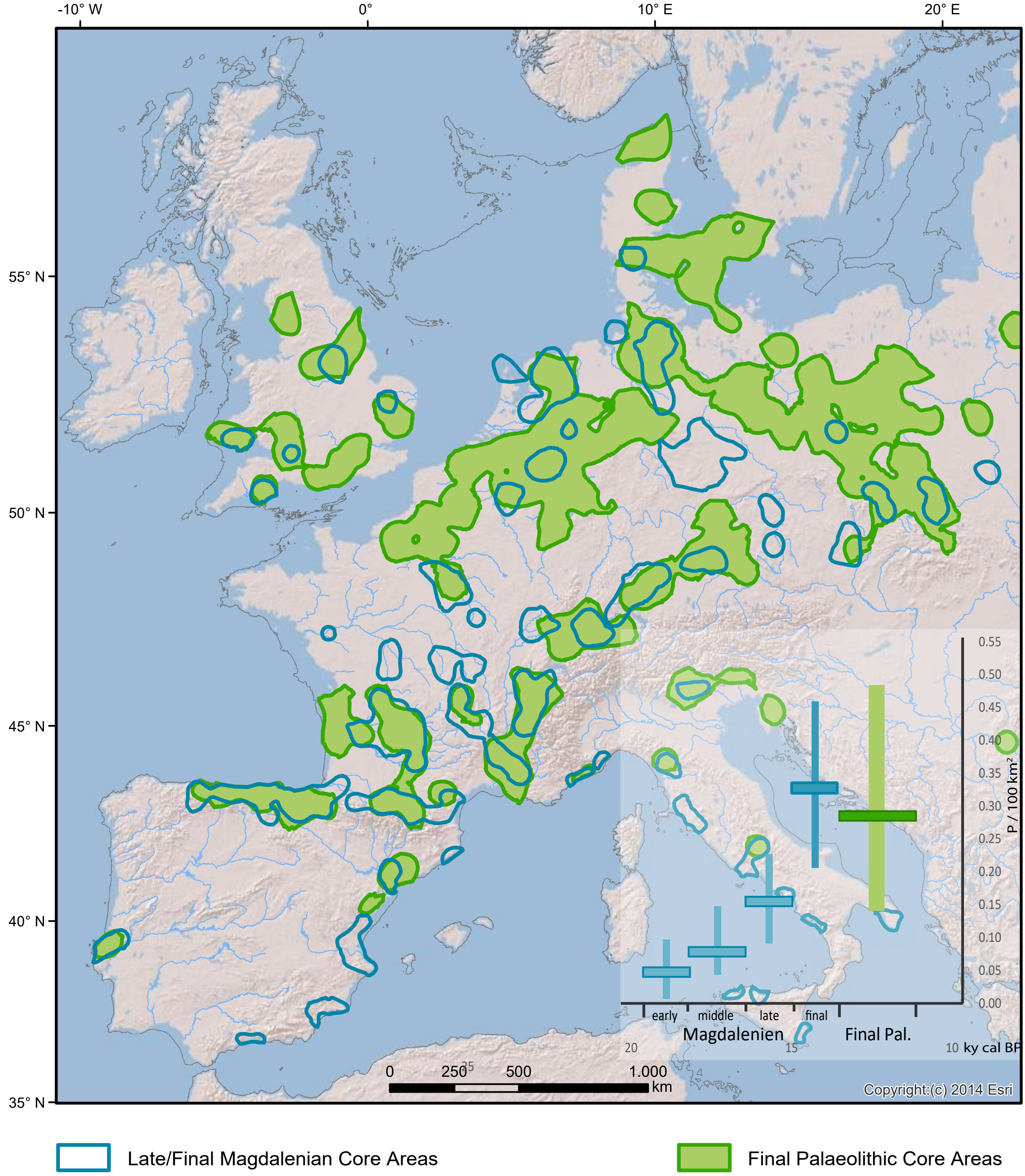

Fig. 5 – Superimposition of modelled Core Areas for the Late Magdalenian (blue lines; after Kretschmer, 2015) and the Final Palaeolithic (green shaded areas, this study). The diagram (bottom right) shows the population density estimates (person per 100 km²) for all phases of the Magdalenian (after Kretschmer, 2015: fig. 13,4–13,6) and this study (green). Horizontal bars represent the median of the estimate, vertical bars the maximum and minimum range (Q1 and Q3).

***Fig. 5** – Superposition des zones centrales modélisées pour le Magdalénien supérieur (lignes bleues ; d'après Kretschmer, 2015) et le Paléolithique final (zones ombrées en vert, cette étude). Le diagramme (en bas à droite) montre les estimations de la densité de population (personne pour 100 km²) pour toutes les phases du Magdalénien (d'après Kretschmer, 2015 : fig. 13,4-13,6) et cette étude (en vert). Les barres horizontales représentent la médiane de l'estimation, les barres verticales la fourchette maximale et minimale (Q1 et Q3).*

***Abb. 5** – Modellierte Kernregionen des Späten Magdaleniens (blaue Linien; nach: Kretschmer, 2015) und des Spätpaläolithiums (grün schattierte Flächen, diese Studie). Das Diagramm (rechts unten) zeigt die Populationsdichteschätzungen (Personen pro 100 km²) für alle Phasen des Magdalenien (nach Kretschmer, 2015: Abb. 13,4–13,6) und dieser Studie (grün). Horizontale Balken repräsentieren den Mittelwert der Schätzung, vertikale Balken das Maximum und Minimum (Q1 und Q3).*

	Core Areas (in TAC, km²)		**Number of persons**	**Pop. density Core Areas (P/100 km²)**	**Pop. density TAC (P/100 km²)**	TAC size
Final Palaeolithic	**600,100** (ODI = 32km)	Max	**10,941**	**1.8**	0.42	**2.6 M km²**
		Mean	**6,596**	**1.1**	0.25	
		Min	**3,132**	**0.5**	0.12	
Late Magdalenian (16.5-14.0 cal. BP)	321,000 (ODI = 27km)	Max	10,200	3.0	0.44	**2.3 M km²**
		Mean	7,300	2.4	0.32	
		Min	4,500	1.5	0.20	

Table 3 – Population estimates for the Final Palaeolithic (this study) and the Late Magdalenian (after Kretschmer, 2015: fig. 13,4–13,6).

Tableau 3 *– Estimation de la population pour le Paléolithique final (cette étude) et le Magdalénien supérieur (d'après Kretschmer, 2015 : fig. 13,4–13,6).*

Tabelle 3 *– Populationsschätzungen für das Spätpaläolithikum (diese Studie) und das Späte Magdalenien (nach Kretschmer, 2015: Abb. 13,4–13,6).*

that clarification of the chronocultural system for the Final Palaeolithic in Iberia, whose various regional complexes may be an artefact of the data (Soto et al., 2015), and new studies on raw-material provisioning will reduce the currently high estimates for this area. Also, improved chronological resolution might reveal temporally constrained, regional occupation hiatuses, as indicated by radiocarbon data (Bicho et al., 2011: fig. 2). These will likely lead to reduced population estimates for the Final Palaeolithic in these areas which currently produce the highest values.

As a final point of this discussion, we consider available predictions from regional studies. As outlined in the introduction, comprehensive regional population histories are still rare for the Final Palaeolithic, although new results from further research are likely to change the picture soon. To demonstrate the benefits of combining regional studies with the scalable results of the Pan-European approach of the Cologne Protocol, we take the well-founded, multiproxi-study of the Vezère region in south-western France as a comparative example (French, 2015; French and Collins, 2015). The study traced several proxies for relative demographic development through time, including the binned and corrected numbers of sites and the summed probability distributions of radiocarbon data. Both proxies show that during the Magdalenian regional population proxies did not follow the same gradual increase as predicted at the continental scale (Kretschmer, 2015 and 2019). If we now turn to the regional Core Areas of south-western France, we see that the independent proxy of areal size of the modelled Core Areas follows the same trend as the summed probability distribution, supporting the irregular regional signal. Differently, for the Final Palaeolithic, the areal size of Core Areas does increase, while both proxies used by Jennifer French (2015) clearly support a demographic decline during the period, returning to such low relative frequencies and numbers as those documented for the Last Glacial Maximum and Early Magdalenian. A possible reason why this trend is not reflected in Core Area size might relate to a different pattern of site-distribution in the present dataset on the Final Palaeolithic, which is characterised by larger distances between sites, i.e. a wider scattering within Core Areas, as compared to the Late Magdalenian. This does hint to different mobility patterns of human groups, as do the above mentioned differences in raw material provisioning distances indicate. This tendency is especially present in the northern areas of the study, and might cause Core Areas in south-western France to become enlarged – even though the relative site counts suggest a regional decrease in site numbers. The role of mobility-patterns for site-distribution and site-frequency seems to play an important factor here, as noted in similar demographic contexts (e.g. Naudinot et al., 2014, Kretschmer et al., 2016). So as stated before, we expect that the high estimates for these regions are overestimations caused by the current approach.

In conclusion, we expect that our data have resulted in an overestimate of the European population during the Final Palaeolithic, and especially for the period of the Younger Dryas. During the latter phase, contractions of Core Areas and populations, migrations, and regional population breakdowns can be expected, as discussed for Iberia and Great Britain and maybe the Benelux region (but see Crombé et al., 2014). The magnitude of these processes is hardly to predict at a continental scale, since regional settlement histories still require further investigation. This holds also true for possible population increases in areas of more suitable preconditions, as people might have encountered in northern-central and -eastern Europe. However, due to the overall low densities during all the Upper Palaeolithic the deviation of future improved estimations will be quite limited. Within the frame to estimate population densities and sizes for the Final Palaeolithic at a continental scale we have identified three main factors that should be methodologically considered when better data are available. Future research should aim to increase the temporal resolution of the Final Palaeolithic data, better control factors of internal diachronic changes in evidence of human presence, and further compare and synthesize results on population dynamics across scales and proxies (see Schmidt et al. in prep.). In the search for adequate scales to trace population dynamics during the Final Palaeolithic and similar settings, the here presented Pan-European estimates serve as a basis for future studies.

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BIBLIOGRAPHICAL REFERENCES

Affolter J. (2015) – Herkunft der Silexrohstoffe, in J. Sedlmeier, *Die letzten Wildbeuter der Eiszeit. Neue Forschungen zum Spätpaläolithikum im Kanton Basel-Landschaft*, Basel, Schwabe Verlag, 300 p.

Baales M. (2001) – From Lithics to Spatial and Social Organization: Interpreting the Lithic Distribution and Raw Material Composition at the Final Palaeolithic Site of Kettig (Central Rhineland, Germany), *Journal of Archaeological Science*, 28, p. 127-141. Available from: doi: 10.1006/jasc.1999.0545, available online at http://www.idealibrary.com.

Baales M. (2005) - *Archäologie des Eiszeitalters - Frühe Menschen an Mittelrhein und Mosel*, Koblenz, Archäologische Denkmalpflege des Landesamtes für Denkmalpflege Rheinland Pfalz (Archäologie an Mittelrhein und Mosel, 16), 173 p.

Baales M. (2014) – Jäger und Sammler am Ende der letzten Kaltzeit in Mitteleuropa. Ein Überblick zum aktuellen Forschungsstand, in LVR-Landesmuseum Bonn (ed.), *Eiszeitjäger. Leben im Paradies?: Europa vor 15 000 Jahren*, Mainz, Nünnerich-Asmus Verlag, p. 44-61.

Baales M., Mewis S. U., Street M. (1996) – Der Federmesser-Fundplatz Urbar bei Koblenz, *Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz*, 43, p. 241-279.

Baales M., Jöris O., Street M., Bittmann F., Weniger B., Wiethold J. (2002) – Impact of the late glacial eruption of the Laacher See volcano, Central Rhineland, Germany, *Quaternary Research*, 58, p. 273-288. Available from: https://doi.org/10.1006/qres.2002.2379.

Barbaza M. (2011) – Environmental changes and cultural dynamics along the northern slope of the Pyrenees during the Younger Dryas, *Quaternary International*, 242, p. 313-327. Available from: doi:10.1016/j.quaint.2011.03.012.

Berganza E. (2005) – El tránsito del tardiglacial al Holoceno en el País Vasco, *Munibe*, 57, 2, p. 249-258.

Bicho N., Haws J., Almeida F. (2011) – Hunter-gatherer adaptations and the Younger Dryas in central and southern Portugal, *Quaternary International*, 242, 2, p. 336-347.

Binford L. R. (2001) – *Constructing Frames of Reference. An Analytical Method for Archaeological Theory Building Using Hunter-Gatherer and Environmental Data Sets*, Berkeley, University of California Press, 583 p.

Bocquet-Appel J.-P., Demars P.-Y., Noiret L., Dobrowsky D. (2005) – Estimates of Upper Palaeolithic meta-population size in Europe from archaeological data, *Journal of Archaeological Science*, 32, p. 1656-68. Available from: https://doi.org/10.1016/j.jas.2005.05.006.avril 2004), Paris, CTHS (Documents préhistoriques, 21), p. 211-225.

Broich M., Peters R. (2020) – Script and example application to model 'Core-Areas' (Optimally Describing Isolines) using R, Online repository (https://github.com/C-C-A-A/CologneProtocol-R).

Chauvière F.-X., Affolter J., Egloff M. (2008) – La grotte du Bichon : un site préhistorique des montagnes neuchâteloises. Hauterive, Office et musée cantonal d'archéologie de Neuchâtel, *Archéologie neuchâteloise*, 42, 164 p.

Crombé P., Sergant J., Verbrugge A., De Graeve A., Cherretté B., Mikkelsen J., Cnudde V., De Kock T., Huismann H. D. J., Van Os B. J. H., Van Strydonck M., Boudin M. (2014) – A sealed flint knapping site from the Younger Dryas in the Scheldt valley (Belgium): Bridging the gap in human occupation at the Pleistocene–Holocene transition in W Europe, *Journal of Archaeological Science*, 50, p. 420-439. Available from: https://doi.org/10.1016/j.jas.2014.07.021.

Deeben J. (1999) – De laatpaleolithische en mesolithische sites bij Geldrop (N. Br.). Deel 5, *Archeologie*, 9, p. 3-35.

Dijkstra P., Bink M., De Bie M., Vynckier G., Van Rechem H., Dyselinck T. (2006) –Laatpaleolithische vindplaatsen op het Plinius-terrein bij Tongeren (prov. Limburg), *Notae Praehistoricae*, 26, p. 109-124.

Fagnart J.-P. (1997) – *La fin de temps glaciaires dans le nord de la France. Approches archéologique et environnementale des occupations humaines du Tardiglaciaire*, Paris, Société préhistorique française (Mémoire, 24), 270 p.

Fat Cheung C., Chevallier A., Bonnet-Jacquement P., Langlais M., Ferrié J.-G., Costamagno S., Kuntz D., Laroulandie V., Mallye J.-B., Valdeyron N., Ballista S. (2014) – Comparaison des séquences aziliennes entre Dordogne et Pyrénées: état des travaux en cours, in M. Langlais, N. Naudinot and M. Peresani (eds.), *Les groupes culturels de la transition Pléistocène-Holocène entre Atlantique et Adriatique*, Actes de la séance de la Société préhistorique française de Bordeaux, 24-25 mai 2012, Paris, Société préhistorique française (Séances de la Société préhistorique française, 3), p. 17-44.

French J. C. (2015) – Demography and the Palaeolithic Archaeological Record, *Journal of Archaeological Method and Theory*, 23, 1, p. 150-99. Available from: http://dx.doi.org/10.1007/s10816-014-9237-4.

French J. C., Collins C. (2015) – Upper Palaeolithic population histories of Southwestern France: a comparison of the demographic signatures of ^{14}C date distributions and archaeological site counts, *Journal of Archaeological Science*, 55, p. 122-34. Available from: http://dx.doi.org/10.1016/j.jas.2015.01.001.

Fu Q., Posth C., Hajdinjak M., Petr M., Mallick S., Fernandes D., Furtwängler A., Haak W., Meyer M., Mittnik A., Nickel B., Peltzer A., Rohland N., Slon V., Talamo S., Lazaridis I., Lipson M., Mathieson I., Schiffels S., Skoglund P., Derevianko A. P., Drozdov N., Slavinsky V., Tsybankov A., Cremonesi R. G., Mallegni F., Gély B., Vacca E., Morales M. R. G., Straus L. G., Neugebauer-Maresch C., Teschler-Nicola M., Constantin S., Moldovan O. T., Benazzi S., Peresani M., Coppola D., Lari M., Ricci S., Ronchitelli A. (2016) – The genetic history of Ice Age Europe, *Nature*, 534, 7606, p. 200-205.

Gelhausen F. (2007) – Verteilungsmuster ausgewählter Fundkonzentrationen des Allerødzeitlichen Fundplatzes Niederbiber, Stadt Neuwied (Rheinland-Pfalz) – Grabungen 1996-1999, *Jahrbuch des Römisch-Germanischen Zentralmuseums*, 54, p. 1-23.

Grimm S. B. (2004) – Ein spätallerødzeitliche Fundplatz bei Bad Breisig, Kreis Ahrweiler, *Berichte zur Archäologie an Mittelrhein und Mosel*, 9, p. 11-32.

Grimm S. B. (2019) – *Resilience and Reorganisation of Social Systems during the Weichselian Lateglacial in North-West Europe. An Evaluation of the Archaeological, Climatic, and Environmental Record*, Mainz, Schnell & Steiner, Monographs of the RGZM, 128, 672 p.

Grimm S. B., Weber M.-J., Mevel L., Sobkoviak-Tabaka I., Eds. (2020) – *From the Atlantic to Beyond the Bug River. Finding and Defining the Federmesser-Gruppen / Azilian*, Proceedings of Session A5b (Commission »The Final Palaeolithic of Northern Eurasia«) of the XVIIth UISPP Congress, Burgos, September 2014. Heidelberg, Propylaeum, 150 p.

Hess T. (2014) – Spätglaziale Steinartefakte aus dem Helga-Abri im Achtal, *Mitteilungen der Gesellschaft für Urgeschichte*, 23, p. 37-56.

Holzkämper J., Maier A., Richter J. (2013) – 'Dark Ages' illuminated – Rietberg and related assemblages possibly reducing the hiatus between the Upper and Late Palaeolithic in Westphalia, *Quartär*, 60, p. 115-136.

Jochim M. A., Kind C.-J., Kleinmann A., Merkt J., Stephan E. (2015) – Eine spätpaläolithische Fundstelle am Ufer des Federsees: Bad Buchau - Kappel, Flurstück Gemeindebeunden, *Fundberichte aus Baden-Württemberg*, 35, p. 37-13.

Kegler J. (2007) – *Das Azilien von Mas d´Azil. Der chronologische und kulturelle Kontext der Rückenspitzengruppen in Südwesteuropa*, PhD-dissertation, Universität zu Köln, 374 p. Available from: http://kups.ub.uni-koeln.de/id/eprint/4231.

Kind C.-J. (1995) – Sattenbeuren - Kieswerk, ein spätpaläolithischer Uferrandlagerplatz am Federsee, *Fundberichte Baden-Württemberg*, 20, 1995, p. 159-194.

Kretschmer I. (2015) – *Demographische Untersuchungen zu Bevölkerungsdichten, Mobilität und Landnutzungsmustern im späten Jungpaläolithikum*, Rhaden, Verlag Marie Leidorf, Kölner Studien zur Prähistorischen Archäologie, 6, 368 p.

Kretschmer I. (2019) – Demographic studies of hunters and gatherers in the European Late Upper Palaeolithic, in B. V. Eriksen, E. Rensik and S. Harris (eds.), *The Final Palaeolithic of Northern Eurasia*, Proceedings of the Amersfoort, Schleswig and Burgos UISPP Commission Meetings (2019), Kiel, Steve-Holger Ludwig, Schriften des Museums für Archäologie Schloss Gottorf – Ergänzungsreihe, 13, p. 231-245.

Kretschmer I., Maier A., Schmidt I. (2016) – Probleme und mögliche Lösungen bei der Schätzung von Bevölkerungsdichten im Paläolithikum, in T. Kerig, K. Nowak and G. Roth (eds.), *Alles was zählt... Festschrift für Andreas Zimmermann,* Bonn, Habelt, p. 47-58.

Langlais M., Laroulandie V. (2009) – Les fouilles de la grotte-abri de Peyrazet (Creysse, Lot): nouvelles données pour le Tardiglaciaire quercinois, *Bulletin de la Société préhistorique française*, 106, 1, p. 150-152.

Langlais M., Detrain L., Ferrié J.-G., Mallye J.-B., Marquebielle B., Rigaud S., Turq A., Bonnet-Jacquement P., Boudadi-Maligne M., Caux S., Fat Cheung C., Naudinot N., Morala A., Valdeyron N., Chauviére F.-X. (2014) – Réévaluation des gisements de La Borie del Rey et de Port-de-Penne : nouvelles perspectives pour la transition Pléistocène-Holocène dans le Sud-Ouest de la France, in M. Langlais, N. Naudinot and M. Peresani (eds.), *Les groupes culturels de la transition Pléistocène-Holocène entre Atlantique et Adriatique*, Actes de la séance de la Société préhistorique française de Bordeaux, 24-25 mai 2012, Paris, Société préhistorique française (Séances de la Société préhistorique française, 3), p. 83-128.

Litt T., Brauer A., Goslar T., Merkt J., Balaga K., Müller H., Ralska-Jasiewiczowa M., Stebich M., Negendank J.F.W. (2001) – Correlation and synchronisation of Late glacial continental sequences in northern central Europe based on annually laminated lacustrine sediments, *Quaternary Science Reviews*, 20, p. 1233-1249. Available from: https://doi.org/10.1016/S0277-3791(00)00149-9.

Loew S. (2006) – *Rüsselsheim 122 und die Federmessergruppen am Unteren Main*, PhD dissertation, Universität zu Köln, 193 p.

Lundström V., Riede F. (2019) – A spatially explicit model of Final Palaeolithic population densities for southern Scandinavia in the period between 14,000 and 12,700 cal BP, *Journal of Archaeological Science: Reports*, 26, p. 1-10. Available from: http://dx.doi.org/10.1016/j.jasrep.2019.101886.

Lundström V., Peters R., Riede F. (2021) – Demographic estimates from the Palaeolithic-Mesolithic boundary in Scandinavia: Comparative benchmarks and novel insights, *Philosophical Transactions of the Royal Society Series B, 376, 20200037.* Available from: http://doi.org/10.1098/rstb.2020.0037.

Maier A. (2015) – *The Central European Magdalenian. Spatial diversity and regional variability*, Dordrecht, Springer, 483 p.

Maier A. (2017) – Population and Settlement Dynamics from the Gravettian to the Magdalenian, *Mitteilungen der Gesellschaft für Urgeschichte*, 26, p. 83-101.

Maier A., Lehmkuhl F., Ludwig P., Melles M., Schmidt I., Shao Y., Zeeden C., Zimmermann A. (2016) – Demographic estimates of hunter–gatherers during the Last Glacial Maximum in Europe against the background of palaeoenvironmental data, *Quaternary International*, 425, p. 49-61. Available from: http://dx.doi.org/10.1016/j.quaint.2016.04.009.

Maier A., Zimmermann A. (2017) – Populations headed south? The Gravettian from a palaeodemographic point of view, *Antiquity*, 91, 357, p. 573-588. Available from: http://dx.doi.org/10.15184/aqy.2017.37.

Marchand G., Naudinot N., Philibert S., Sicard S. (2011) – Hunting for Camps at an Azilian Site in Western, in F. Bon, S. Costamagno and N. Valdeyron (eds.), *Hunting Camps in Prehistory. Current Archaeological Approaches*, Proceedings of the International Symposium, University Toulouse II – Le Mirail, P@lethnology, 3, p. 267-290.

Naudinot N., Tomasso A., Tozzi C., Peresani M. (2014) – Changes in mobility patterns as a factor of ^{14}C date density variation in the Late Epigravettian of Northern Italy and Southeastern France. *Journal of Archaeological Science*, 52, p. 578-590.

Nielsen E. H. (1999) – Wauwil 25-Sandmatt. Eine spätpaläolithische Fundstelle im Wauwilermoos, Luzern, Kantonsarchäologie, *Archäologische Schriften Luzern*, 8, 83 p.

Pasty J.-F., Alix Ph., Ballut C., Griggo C., Murat R. (2002) – Le gisement épipaléolithique à pointes de Malaurie de Champ-Chalatras (Les Martres d’Artière, Puy-de-Dôme), *Paléo*, 14, p. 101-176.

Parow-Suchon H., Heinen, M. (2017) – Rohmaterialökonomie und Mobilität im rheinischen Allerød, *Quartär,* 64, 157-177.

Phillipsen B., Ivanovaite L, Makhotka K., Sauer F., Riede F., Olsen J. (2019) – Eight new late Pleistocene/Early Holocene AMS dates from the southeastern Baltic, *Radiocarbon*, 61, 2, p. 1-13. Available from: https://doi.org/10.1017/RDC.2018.153.

Płaza D. K., Kittel P., Petera-Zganiacz J., Dzieduszynska D. A., Twardy J. (2015) – Late Palaeolithic settlement pattern in palaeogeographical context of the river valleys in the Koło Basin (Central Poland), *Quaternary International*, 370, p. 40-54.

Posth C., Renaud G., Mittnik A., Drucker D. G., Rougier H., Cupillard Ch., Valentin F., Thevenet C., Furtwängler A., Wissing Ch., Francken M., Malina M., Bolus M., Lari M., Gogli E., Capecchi G., Crevecoeur I., Beauval C., Flas D., Germonpré M., Van Der Plicht J., Cottiaux J. R., Gély B., Ronchitelle A., Wehrberger K., Grigorescu D., Svoboda J., Semal P., Caramelli D., Bocherens H., Harvati K., Conard N., Haak W., Powell A., Krause J. (2016) – Pleistocene mitochondrial genomes suggest a single major dispersal of non-Africans and a Late Glacial population turnover in Europe, *Current Biology*, 26, p. 1-7. Available from: https://doi.org/10.1016/j.cub.2016.01.037.

Reich D. (2018) – *Who we are and how we got here. The ancient DNA revolution and the new science of the human past*, Oxford, Oxford University Press, 335 p.

Reinig F., Cherubini P., Engels S., Esper J., Guidobaldi G., Jöris O., Lane C., Nievergelt D., Oppenheimer C., Park C., Pfanz H., Riede F., Schmincke H. U., Street M., Wacker L., Büntgen U. (2020) – Towards a dendrochronologically refined date of the Laacher See eruption around 13,000 years ago, *Quaternary Science Reviews*, 229, p. 106-128. Available from: https://doi.org/10.1016/j.quascirev.2019.106128.

Reynolds N., Riede F. (2019) – House of cards: cultural taxonomy and the study of the European Upper Palaeolithic, *Antiquity*, 93, p. 1350-1358.

Richter J. (1981) – Der spätpaläolithische Fundplatz bei Gahlen, Ldkr. Dinslaken, *Archäologisches Korrespondenzblatt*, 11, p. 181-187.

Riede F. (2008) – The Laacher See-eruption (12,920 BP) and material culture change at the end of the Allerød in Northern Europe, *Journal of Archaeological Science*, 35, 3, p. 591-599. Available from: https://doi.org/10.1016/j.jas.2007.05.007.

Sánchez De La Torre M. (2014) – Detecting human mobility in the Pyrenees through the analysis of chert tools during the Upper Palaeolithic, *Journal of Lithic Studies*, 1, 1, p. 263-279.

Sauer F. (2018) – *Late Palaeolithic Land Use Patterns in Bavaria.* PhD-dissertation, Friedrich-Alexander-Universität Erlangen-Nürnberg, 304 p. Available from: urn:nbn:de:bvb:29-opus4-92875.

Sauer F., Riede F. (2019) – A Critical Reassessment of Cultural Taxonomies in the Central European Late Palaeolithic, *Journal of Archaeological Method and Theory*, 26, p. 155-184.

Schlummer M., Hoffmann Th., Dikau R., Eickmeier M., Fischer P., Gerlach R., Holzkämper J., Kalis A. J., Kretschmer I., Lauer F., Maier A., Meesenburg J., Meuers-Balke J., Münch U., Pätzold St., Steininger F., Stobbe A., Zimmermann A. (2014) – From point to area: Upscaling approaches for Late Quaternary archaeological and environmental data, *Earth-Science Reviews*, 131, p. 22-48.

Schmidt I. (2019) – CRC806-E1 Raw-material-polygons. Database on the Late Palaeolithic of Europe V2019-05-08. CRC806-Database, University of Cologne, DOI: 10.5880/SFB806.48.

Schmidt I., Zimmermann A. (2019) – Population dynamics and socio-spatial organization of the Aurignacian: Scalable quantitative demographic data for western and central Europe, *PLOS ONE*, 14, 2, 1-20 p. Available from: http://dx.doi.org/10.1371/journal.pone.0211562.

Schmidt I., Zimmermann A. (2020) – CRC806-E1 Database on Final Palaeolithic Sites of Europe V2020-08-20. CRC806-Database, University of Cologne. DOI: 10.5880/SFB 806.51.

Schmidt I, Gehlen B., Winkler K., Arrizabalaga A., Arts N., Bicho N., Crombé Ph., Culakova K., Grimm S., Langlais M., Mevel L., Naudinot N., Niekus M., Peresani M., Riede F., Sauer F., Schön W., Sobkowiak-Tabaka I., Vandendriessche H., Weber M., Zander A., Zdeňka N., Zimmermann A., Maier A. (in prep.) – Demographic estimates for hunter-gatherer societies during the Final Palaeolithic in Europe: Mapping and evaluating population dynamics during Greenland Interstadial 1c-a (Alleröd) and Greenland Stadial 1 (Younger Dryas).

Schmidt I., Hilpert J., Kretschmer I., Peters R., Broich M., Schiesberg S., Vogels O., Wendt K. P., Zimmermann A., Maier A. (2021) – Approaching Prehistoric Demography: Proxies, Scales and Scope of the Cologne Protocol in European contexts, *Philosophical Transactions of the Royal Society Series B, 376, 20190714*. Available from: https://doi.org/10.1098/rstb.2019.0714.

Sobkowiak-Tabaka I. (2017) - *Rozwój społeczności Federmesser na Nizinie Środkowoeuropejskiej (The development of the Federmesser culture on the North European Plain)*, Warszawa, Instytut Archeologii i Etnologii Polskiej Akademii Nauk, 400 p.

Sobkowiak-Tabaka I., Winkler K. (2017) – The Ahrensburgian and the Swiderian in the area around the middle Oder River: reflections on similarities and differences, *Quartär*, 64, p. 217-240. Available from: doi: 10.7485/QU64_10.

Soto A., Alday A., Montes L., Utrilla P., Perales U., Domingo R. (2015) – Epipalaeolithic assemblages in the Western Ebro Basin (Spain): The difficult identification of cultural entities, *Quaternary International*, 364, p. 144-152. Available from: https://doi.org/10.1016/j.quaint.2014.05.041.

Stefański D., Wilczyński J. (2012) – Extralocal raw materials in the Swiderian culture: case study of Kraków-Bieżanów sites, *Anthropologie*, 4, p. 427-442.

Stoop D. D. L. (2014) - *Federmesser mobility patterns in the Western Meuse area, Limburg, the Netherlands: the case studies of Horn-Haelen and Heythuysen-de Fransman I*, MA-Thesis, University of Leiden, 145 p.

Street M. (1998) – The archaeology of the Pleistocene-Holocene transition in the Northern Rhineland, Germany, *Quaternary International*, 49/50, p. 45-67.

Sulgostowska Z. (2006) – Final Palaeolithic Societies' Mobility in Poland as Seen from the Distribution of Flints, *Archaeologia Baltica*, 7, p. 36-42.

Surmely P. F., Virmont J., Quinqueton A. (2009) – *Le gisement épipaléolithique ancien de la grotte Béraud à Saint-Privat-d'Allier (Haute-Loire, France)*, hal-00350923.

Tallavaara M., Luoto M., Korhonen N., Järvinen H., Seppä H. (2015) – Human population dynamics in Europe over the Last Glacial Maximum. *Proceedings of the National Academy of Sciences*, 112, 27, p. 8232-7. Available from: http://dx.doi.org/10.1073/pnas.1503784112.

Trabska J., Walanus A., Ciesielczuk J., Samek L., Dutkiewicz E. (2008) – Ferruginous Raw Material Sources for Palaeolithic in Poland (Central Europe) – Provenance Studies: Occurrence, Litostratigraphy and Application, 9th International Conference on NDT of Art, (Jerusalem, Israel, 2008), Jerusalem, p. 1-7. Available from: www.ndt.net/search/docs.php3?MainSource=65.

Verbeek C. (1997) – Epipalaeolithische en Mesolithische sites in het 'Ruilverkavelingsblok Weelde' (prov. Antwerpen), *Notae Praehistoricae*, 17, p. 81-84.

Vukosavljević N., Perhoč Z., Čečuk B., Karavanić I. (2011) – Late Glacial knapped stone industry of Kopačina Cave, *Vjesnik za arheologiju i povijest dalmatinsku (Journal of Dalmatian Archaeology and History)*, 104, p. 7-54.

Weber M.-J., Grimm S. B., Baales M. (2011) – Between warm and cold: Impact of the Younger Dryas on human behavior in Central Europe, *Quaternary International*, 242, 2, p. 277-301. Available from: https://doi.org/10.1016/j.quaint.2010.12.002.

Wendt K. P., Zimmermann A. (2015/2019) – Landschaftsarchäologie IV. Ein Modell zur Rekonstruktion von Landwirtschaftssystemen am Beispiel der Linearbandkeramik und der späten vorindustriellen Neuzeit, *Berichte der Römisch-Germanischen Kommission*, 96, p. 9-218.

Wendt K. P., Hilpert J., Zimmermann A. (2010) – Landschaftsarchäologie III. Untersuchungen zur Bevölkerungsdichte der vorrömischen Eisenzeit, der Merowingerzeit und der späten vorindustriellen Neuzeit an Mittel- und Niederrhein, *Berichte der Römisch-Germanischen Kommission*, 9, p. 221-338.

Winkler K. (2020) – *Ahrensburgien und Swiderien im mittleren Oderraum. Technologische und typologische Untersuchungen an Silexartefakten der Jüngeren Dryaszeit*, Kiel, Wachholtz Verlag, Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein und im Ostseeraum, 11, 496 p.

Zickel M., Becker D., Verheul J., Yener Y., Willmes C. (2016) – Paleocoastlines GIS dataset. CRC806-Database. doi: 10.5880/SFB806.20.

Zimmermann A. (in press) – Population Dynamics and Quality of Life - the perspective of Millennia and Centuries.

Zimmermann A., Hilpert J., Wendt K. P. (2009) – Estimations of population density for selected periods between the Neolithic and AD 1800, *Human Biology*, 81, 2-3, p. 357-380, available from: https://doi.org/10.3378/027.081.0313.

Zimmermann A., Scharl S., Schmidt I. (2020) – Demographic Transitions – Cycles and Mobility in the Neolithic of Western Germany, in T. Lachenal, R. Roure and O. Lemercier (eds.), *Demography and Migration – Population trajectories from the Neolithic to the Iron Age*, Proceedings of the XVIII UISPP World Congress (Paris, 2018), Paris, Archaeopress (Volume 5: Sessions XXXII-2 and XXXIV-8), p. 86-97.

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