Journal of Archaeological Science: Reports 42 (2022) 103375

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

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

Neolithic occupations (c. 5200-3400 cal BC) at Isolino Virginia (Lake Varese, Italy) and the onset of the pile-dwelling phenomenon around the Alps

F. Antolín [a,b,*], H. Martínez-Grau [a], B.L. Steiner [a], F. Follmann [b], R. Soteras [b], S. Häberle [a], G. Prats [c], M. Schäfer [a], M. Mainberger [d], I. Hajdas [e], D.G. Banchieri [f]

[a] IPNA/IPAS, Department of Environmental Sciences, University of Basel, Switzerland
[b] Department of Natural Sciences, German Archaeological Institute, Germany
[c] GIP, Departament d'Història, Universitat de Lleida, Spain
[d] UwArc, Staufen i. Br, Germany
[e] Laboratory of Ion Beam Physics, ETH Zürich, Switzerland
[f] AgriChange Project, Switzerland

ARTICLE INFO

Keywords:
Radiocarbon dating
Bayesian modelling
Western Europe
Early farmers
Pile-dwelling site

ABSTRACT

Neolithic pile dwelling sites are known particularly well North of the Alps, with a boom starting from *ca.* 4300 cal BC. These sites are famous for the excellent preservation conditions of organic material (wooden tools, textiles, fruit remains and foodstuffs have been preserved in many of them), but their origin is still unclear. In Europe, only three reliably-dated settlements of this type are documented in the Early Neolithic: La Marmotta *ca.* 5700–5300 cal BC (Lake Bracciano, Italy), Dispilio *ca.* 5400–3500 cal BC (Lake Orestias, Greece) and La Draga *ca.* 5300–4900 cal BC (Lake Banyoles, Spain). New interventions within the framework of the AgriChange project have made it possible to expand and improve the knowledge on the dynamics of occupation at Isolino Virginia *ca.* 5200–3400 cal BC (Lake Varese, Italy), the earliest known pile-dwelling site around the Alps. Our results suggest that this site could have been the spark of the pile-dwelling phenomenon in the area.

1. Introduction

Due to their excellent conditions of conservation of organic materials, lakeshore settlements represent a crucial source of information for the reconstruction of social and economic practices of prehistoric communities (i.e. Hafner, 2012, Jacomet, 2013). Lakeshore settlements are known since the Upper Paleolithic (i.e. Ohalo II, in Israel Kislev and Simchoni 2002), and wetlands have been crucial for the development of the first farming societies in Southwestern Asia (i.e. Tell Aswad, in Syria (Stordeur et al., 2010), or Çatalhöyük, in Turkey (Wolfhagen, et al., 2020)) and Southeastern Europe (Naumov, 2018).

The first pile-dwelling sites in the Mediterranean area are dated to *ca.* 5600-5000 cal BC. Only three are known to date: La Marmotta (*ca.* 5700-5300 cal BC, Lake Bracciano, Italy) (Fugazzola and Tinazzi, 2010, Salavert, et al., 2020), Dispilio (*ca.* 5400-3500, Lake Orestias, Greece) (Facorellis, et al., 2014) and La Draga (*ca.* 5300-4900 cal BC, Lake Banyoles, Spain) (Andreaki, et al., 2020). Their scarcity may be due to changes in the landscape and the anthropogenic impact on wetlands, lack of research tradition and climate change. Pile-dwellings have a much longer research tradition and are much more abundant and better known in the Circumalpine Area, being labelled under the UNESCO World Heritage since 2011. The earliest known pile-dwelling sites north of the Alps are Kleiner Hafner (Lake Zurich, Switzerland) *ca.* 4200-3800 cal BC (Hafner and Suter, 2003) and Egolzwil 3 (Wauwilermoos, Switzerland) *ca.* 4280-4250 cal BC (Seifert, et al., 2013). They are grouped into the so-called Egolzwil Culture, which has been repeatedly connected, based on several indicators such as pottery typology (non-decorated bowls) and crops (dominance of naked wheat and opium poppy) to the Western Mediterranean area (i.e. Gibaja, et al., 2017, Jacomet, et al., 1989), but the lack of contemporary pile-dwelling sites in that area made further parallels very difficult to establish.

In Northern Italy there are around 120 of this kind of prehistoric settlements documented both on lake shores and in river-channel depressions (Martinelli, 2019). Isolino Virginia (Lake Varese) is the earliest well-preserved pile-dwelling known in the region, with its oldest dates around 5200 BCE (Banchieri 2017). The Neolithic in northern Italy (*ca.*

* Corresponding author.

https://doi.org/10.1016/j.jasrep.2022.103375
Received 24 June 2021; Received in revised form 1 February 2022; Accepted 6 February 2022
Available online 21 February 2022

5900-3400 cal BC) is particularly well dated until 4400 BCE, while the number of reliable dates after this period dramatically drops, as observed by other authors (Skeates 2013) (Fig. 1; see ESM 2 for a broader chronometric discussion). This, once more, made it difficult to establish direct comparisons North and South of the Alps for the period when the first pile dwellings are documented in the Swiss Plateaux. Nevertheless, there is good evidence that during the second half of the 5th millennium and 4th millennium BC, pile-dwelling sites in northern Italy extended beyond the Varesian zone and were mainly concentrated on the central and eastern southern alpine areas in places like the Lake Fimon, the Revine lakes or the Friuli wetlands (Martinelli, 2007).

The arrival of the first farming groups to northern Italy is characterised by multiple dynamics (Biagi, et al., 2020) and must be explained as at least two processes of human spread (from the Adriatic and from the Ligurian side), none of which -according to the most recent evaluations of available radiocarbon dates and bioarchaeological assemblages studied to date- seem to involve long-lasting contacts with the previous Mesolithic populations (Martínez-Grau et al., 2020; Martínez-Grau and Antolín, 2021; Starnini et al., 2018; Perrin and Manen, 2021). Dramatic geomorphological changes in areas such as the Po floodplain may blur the picture of this decisive historical moment (Berger, 2021) and new research could shed some light on this complex process. While the first Neolithic sites on the Ligurian shores date to *ca.* 5800 cal BC (Binder, et al., 2018), in the Po valley and Alpine regions the first Neolithic evidences started *ca.* 5400 and *ca.* 5000 cal BC, respectively (Martínez-Grau et al., 2020; Martínez-Grau and Antolín, 2021; Pearce, 2013; Starnini et al., 2018). The first farming evidences in Po valley suggest a more direct relationship with communities from the northern Adriatic shores and the North-western Balkans (Tozzi, et al., 2003, Rottoli, 2014, Vander Linden and Silva, 2021). Isolino Virginia has always been defined within a particular pottery style (Isolino Group), differentiated from the Vho Group. This style is also detected in the Ticino area and even in the Valais region (Borrello, 2011, Müller, 1995) so this paper also aims to investigate in which ways Isolino could have acted as connection point between eastern and western cultures.

2. The site: Isolino Virginia

Isolino Virginia is a small island (*ca.* 250 m long, *ca.* 100 m of maximum width, and *ca.* 15000 m^2 of surface) located on Lake Varese (Lombardy, Italy) (Fig. 2). Previous archaeological, stratigraphic and geological studies confirmed that human occupations started on natural deposits of limnic origin and generated the current artificial island, resulting from multiple occupations during prehistory. New occupations compressed older deposits, thus submerging them under the water table and allowing waterlogged preservation conditions (Banchieri, et al., 2015a, Bini and Zuccoli Bini, 2016, Bini, et al., 2016).

With more than four meters of stratigraphy, Isolino Virgina records human occupations from *ca.* 6th to 3rd millennia cal BC, covering from the Early Neolithic to the Bronze Age. Some phases were documented in surface excavations (particularly the Early and Late Neolithic) and others only from scattered finds of ceramic, cores and trial trenches, but also dendrodating of wooden piles found at the borders of the island (Banchieri et al., 2009), under the current water table (Banchieri, 2016). As a result, three phases were identified: Gruppo Isolino (*ca.* 5500-4500 BCE), VBQ with Chassey elements (*ca.* 4500-3900 BCE) and Lagozza di Besnate e Isolino (*ca.* 3900-3400 BCE) (Pedrotti et al., 2022; Banchieri and Baglioni, 2012; Banchieri 2017) (Fig. 3). The earliest occupations (Gruppo Isolino) are relatively well known, with wooden platforms and wooden posts defining house areas. No additional structures (i.e. hearths, pits) were documented to date. The later Neolithic occupations (Lagozza) were systematically investigated over a relatively small surface excavation, which allowed to document several post holes, ceramic and lithic tools (Banchieri and Baglioni, 2012, Banchieri, 2017).

A total number of 25 radiocarbon dates had already been done at the site. Except one sample which was a hazel nutshell fragment and a second sample using poppy seeds (Salavert et al. 2020), the rest of the dates were performed on charcoal/wood/aggregated charred materials. These dates indicated human activity at the site between 5300 and 4550 and from 4700 to 4000 cal BC (Banchieri, 2009, Baioni, et al., 2005, Bini, et al., 2016). The youngest phases were not as intensively sampled, with 6 dates. Three of these 6 dates had standard deviations beyond 100, which gives a very low precision (for what is needed in this chronological period) after calibration.

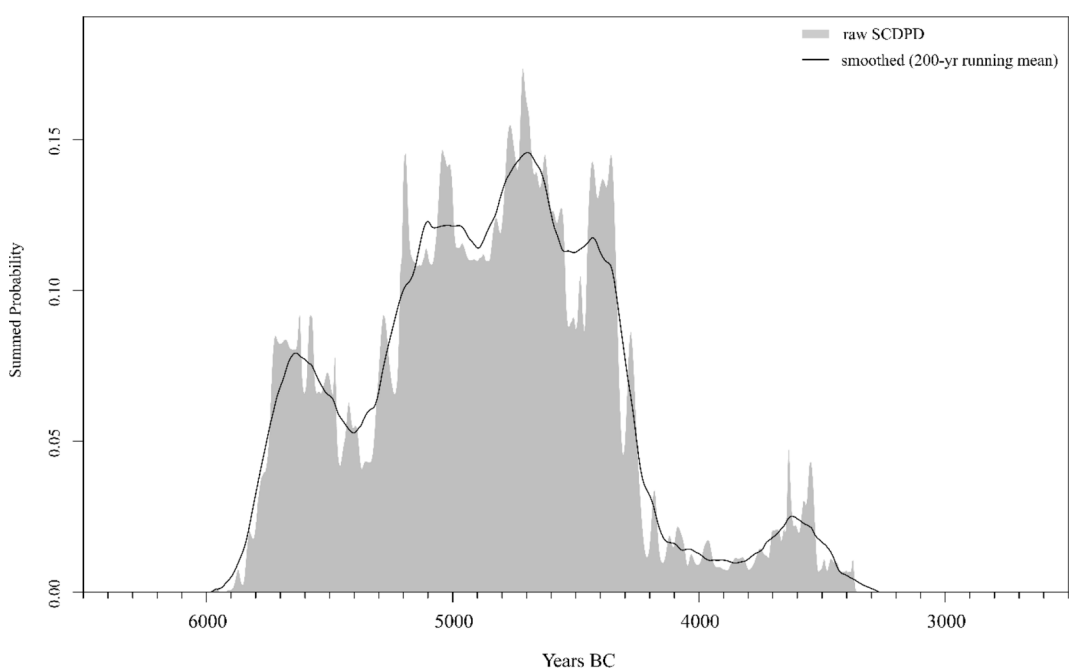

Fig. 1. Summed Calibrated Dates Probability Distribution (SCDPD) of the reliable radiocarbon dates (n = 168) for the Neolithic sites (n = 32) in northern Italy with a 200-years running mean. Data based on Martínez-Grau, et al. (2021) and available in ESM 1; and methodology based on Crema and Bevan (2021). Graph by HMG.

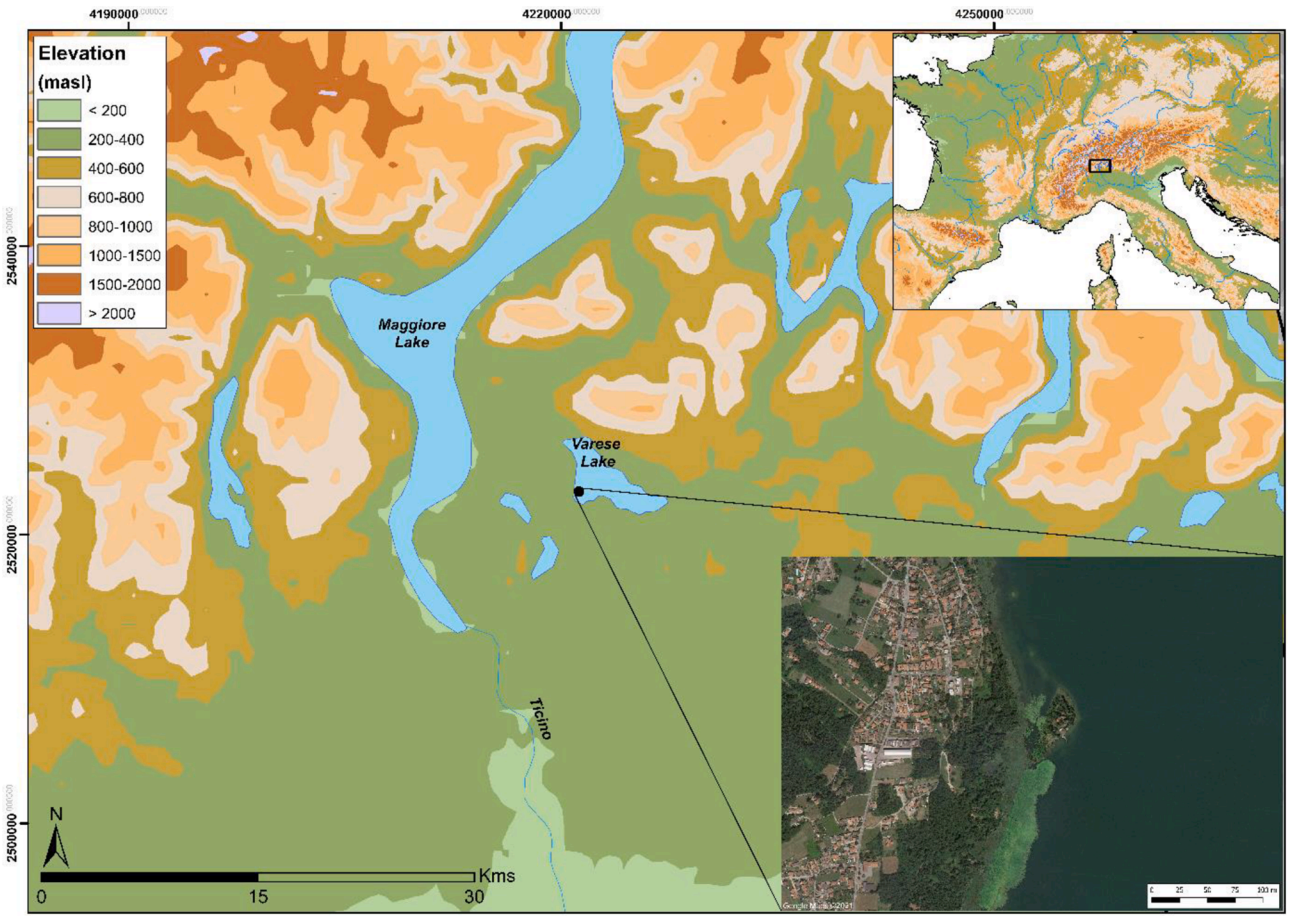

Fig. 2. Location of Isolino Virginia. Graph by HMG.

Given the fact that it is a potentially strategic site to understand the onset of the pile-dwelling phenomenon and that no representative archaeobotanical analyses had been undertaken to date (Banchieri et al., 2015b), it was decided to include it within the scope of the AgriChange Project (Antolín, et al., 2018). This paper puts together all new radiocarbon dates generated within the project as well as published dates in order to reconstruct the dynamics of the site, provide a synthetic view of its temporal evolution during the Neolithic and compare it to its broader context of the early history of pile-dwellings in the western Mediterranean and the Swiss Plateaux to understand its relevance. Because of the focus of the project on archaeobotany and the lack of surface excavations, these broader comparisons will be based on archaeobotanical data, which may help to define territories of exchange networks, as observed in other regions (Antolín, et al., 2015).

3. Methods

The fieldwork undertaken in June 2018 focused on two different actions: one, taking samples from the northern profile of the area excavated by M. Bertolone in the 1950s to better understand the stratigraphy and to obtain enough archaeobotanical remains of the corresponding phases. Additionally, eight coring spots were chosen in order to identify Neolithic deposits along the island (Fig. 4). This was done following three transects from the central open trench: one to the Northeast (1270 and 1269), one to the West (1274, 1273), one to the South (1277 and 1276) and one in the open trench (1262). A final core (1268) was taken to the east of the island, near the current shore, because it was required by the Soprintendenza of the Lombardy. A manual borer of *ca.* 3 cm of width and one meter of length was used to test the adequacy of the spot for sampling and to make a description of the stratigraphy in each meter. A rough description was performed (with a main and a secondary sedimentary component: e.g. sand with organic material; silt; etc.) using a scale reference (ESM 3). This core was sampled on-site following this description for a preliminary evaluation and the identification of the most interesting samples. A maximum of three consecutive metres were sampled, normally reaching natural lake deposits (lake marl or lake silt) at that point.

Charred crop remains were prioritized for dating but uncharred remains were used if nothing else was available. All of the ^{14}C measurements have been done using AMS technique at the ETH Laboratory of Ion Beam Physics in Zurich. The chemical process was based on the ABA (acid-base-acid) 60° (Hajdas, 2008: 12).

A complete table with all radiocarbon dates from the site, the nature of the samples dated, as well as an indication on whether they were used for chronological modelling can be found in ESM 4. The reliability of the samples was determined according to a set of criteria adopted from available literature, which consider the evaluation of the type of context sampled (to exclude unclear contexts or contexts with potential taphonomic biases, especially if the site archaeologists also consider them unreliable), type of sample (prioritizing short-lived samples) and standard deviation (prioritizing dates with smaller standard deviation) (Martínez-Grau, et al., 2021 and references therein). Thus, the Neolithic occupations of Isolino Virginia yielded 42 reliable radiocarbon dates, out of a total of 51. From previous work, there are 17 reliable radiocarbon dates (out of a total of 25) from short-lived charcoal samples belonging to wooden posts and floors that inform us about different construction activities. Additionally, there are 25 new reliable Neolithic radiocarbon dates (from a total of 26, since one date from the uppermost levels turned out to be from the Bronze Age) from crop and wild fruit remains dated as part of the AgriChange project. The calibration of the

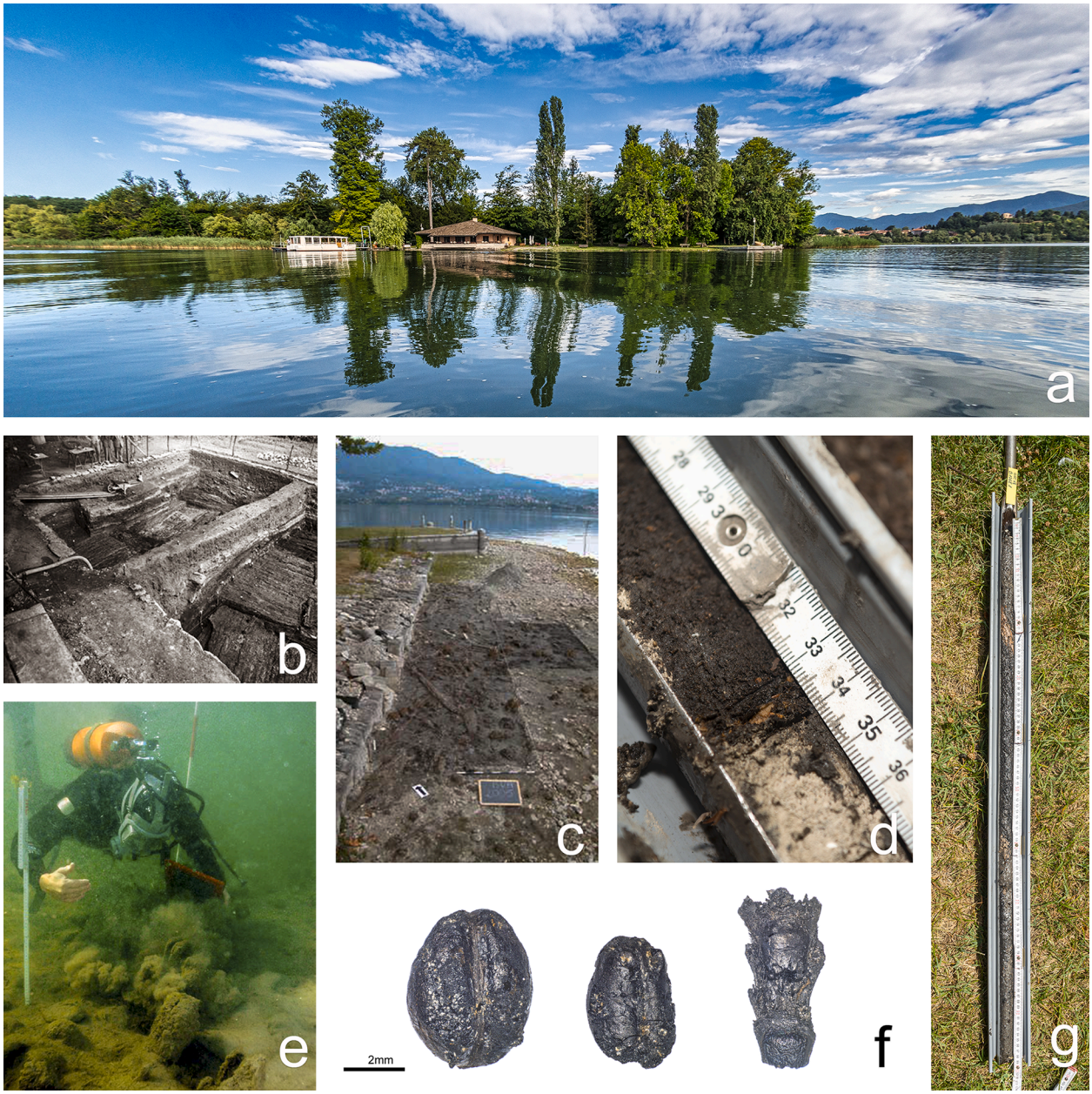

Fig. 3. Archaeological research at Isolino Virginia. a) View of the island from the east (Photo: R. Soteras), b) superimposed wooden floors in the centre of the island uncovered in the 1950s by M. Bertolone (Photo: M. Bertolone); c) wood remains in the north-eastern lake shores during the excavations of Dr. D. Banchieri in 2005–6 (Photo: D.G. Banchieri); d) detail of the transition between lake marl deposits and the first archaeological layer (Photo: R. Soteras); e) wooden piles under water observed during prospections by M. Mainberger in the years 2012–3 and 2015 (Photo: P. Alemani); f) From left to right: *Hordeum vulgare* var. *nudum* grain (ISVA18_US304), *Triticum aestivum/durum/turgidum* grain (ISVA18_US310), *Hordeum vulgare* var. *nudum* rachis dated within this project (ISVA18_C1276_1_3) (Photos: R. Soteras); g) core 1268.1 with different organic layers obtained during fieldwork within the AgriChange Project in 2018 (Photo: R. Soteras).

dates and the different models were performed using the atmospheric curve IntCal20 (Reimer, et al., 2020) and *rcarbon: Calibration and Analysis of Radiocarbon Dates* (Crema and Bevan, 2021) package in RStudio v4.0.5 (RStudio Team, 2021), with the exception of the Bayesian model, which was performed by OxCal v4.4.2 (Bronk Ramsey, 2017).

In order to define the chronological span of the Neolithic occupations in Isolino Virginia, we used the Kernel Density Estimation (KDE) of the radiocarbon dates since with this method it is possible to summarize the distribution of the events in a way that the signal is retained, the noise of the SCDPD is supressed and the changing frequencies are better visualised (Crema and Bevan, 2021, Brown, 2017).

In order to better understand the temporality of the occupations of the site, and given the type of sampling performed and the coarse understanding of the stratigraphy of the site, we developed a Bayesian model of three overlapping phases (Bronk Ramsey, 2009). These phases were called 1 (being the earliest), 2 and 3 (the youngest). We have to assume that the different phases are completely independent and we simply try to estimate their beginning and end. The division between the phases has a spatial and stratigraphic basis and was tested on a chronometric basis.

4. Results

The CKDE model (Fig. 5) results (*Amodel* = 98, *Aoverall* = 97,9) provide a beginning date with an increase in the summed probability *ca.*

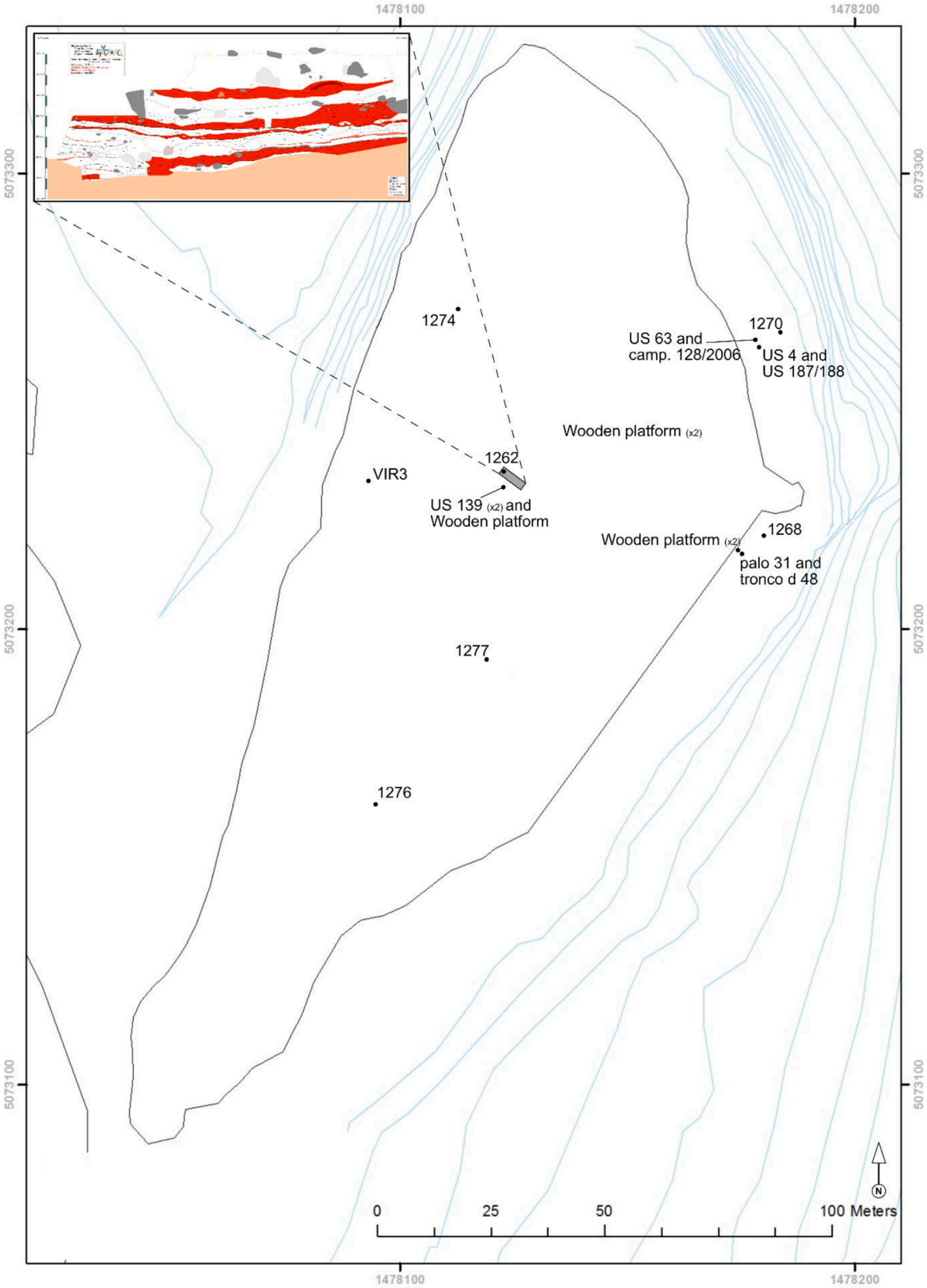

Fig. 4. Isolino Virginia: topographic map indicating the points at which radiocarbon dates were obtained. Graph by HMG.

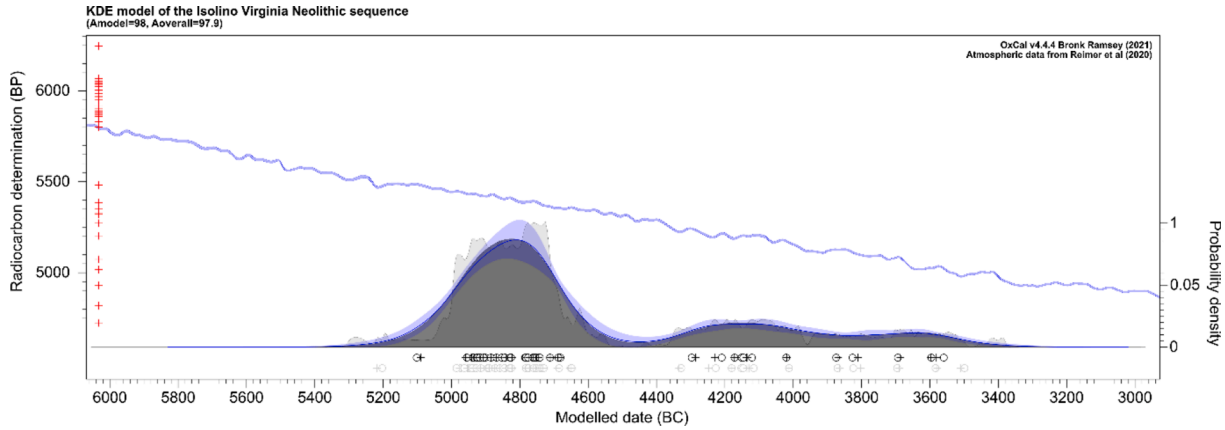

Fig. 5. KDE model of the reliable Neolithic dates of Isolino Virginia (see ESM 4). Graph by HMG.

4900 cal BC and an ending date *ca.* 3700 cal BC for the Neolithic occupations. A remarkable aspect is how this model shows three grouped peaks which support a 3-phased division of the settlement history. The first *ca.* 400 years of island occupation (Phase 1) are by far those with higher probability density (they belong to the best-documented and probably most-extensively-preserved phase and the most intensively dated one). There are 30 reliable dates for Phase 1, 6 for Phase 2 and 3 for Phase 3 (ESM 4). While the transition between Phases 2 and 3 does not seem to show a significant hiatus, it does between Phases 1 and 2, where the summed probability drops significantly *ca.* 4600-4400 cal BC. Finally, it is worth also highlighting how the KDE model does not consider the distribution tails observed with the raw SCDPD. Regarding the tail at the youngest part of the distribution, it is probably an effect of the calibration curve, but at the oldest part it is due to a date (LTL-4122A: 6247BP ± 45), which is understood as noise and the model considers it an outlier. This date refers to a constructive event (wooden post), but it could be affected by the so-called old wood effect.

The Bayesian results (Fig. 6) based on a three-phase model (*Amodel* = 93.9, *Aoverall* = 87.9) frame Phase 1 *ca.* 4950-4700 cal BC (95.4%), Phase 2 *ca.* 4250-4000 cal BC (95.4%) and Phase 3 *ca.* 4000-3550 cal BC (95.4%). The Bayesian results suggest a hiatus period between the end of Phase 1 and the start of Phase 2. The probability distribution for the difference between them has been calculated, providing a result of 436 ± 88 years of interval (Fig. 6).

Phase 1 dates were recorded in the open trench at the centre of the island, both in samples from the profile and in core 1262. In this central area, there may be more than 2 m of deposits dated to this phase (*ca.* 4950-4700 cal BC). Additionally, it is also documented in cores 1268, 1270 and 1274. The results of cores 1268 and 1270 concur with nearby dated wooden posts from the 2006 intervention (ESM 4). Core 1274

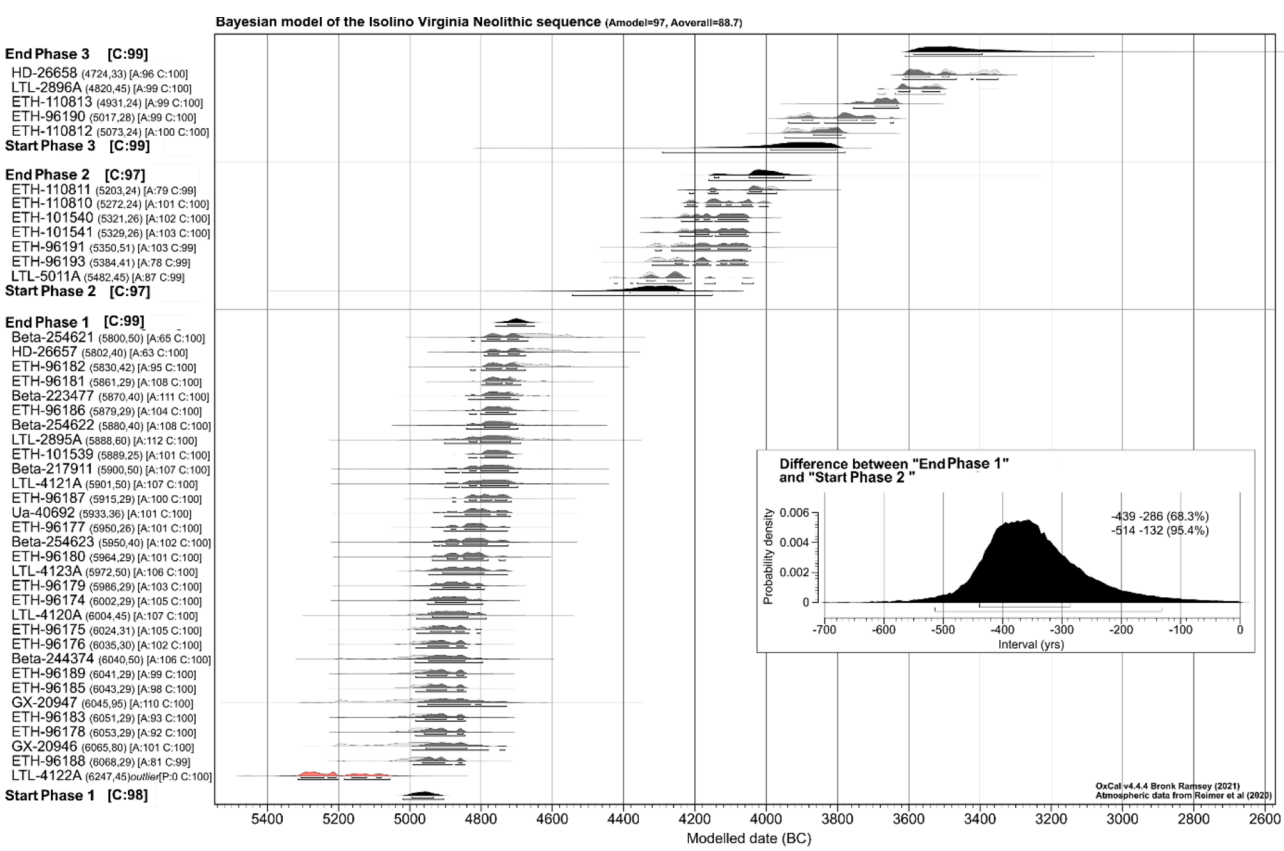

Fig. 6. Three overlapping Bayesian model built with reliable Neolithic dates from Isolino Virginia (see ESM 2). Graph by HMG.

indicates the presence of at least 30 cm of well-preserved waterlogged deposits dating to *ca.* 4900-4700 cal BC at the basis of the core. Cores 1268 and 1270 seemed to have a single organic layer of a maximum depth of 30 cm. This phase was also detected in the core VIR3 (Fig. 4).

Phase 2 occupations were detected in inland cores, north (1274) and south (1277, 1276) of the island. In core 1274 a second deposit above Phase 1 was dated to *ca.* 4250-4050 cal BC. This phase was also detected in VIR3 and cores 1277 and 1276. In the southernmost core 1276, the dates at the bottom layers belonged to Phase 2 but subsequent deposits expanded into Phase 3 without clear stratigraphic hiatuses (i.e. lake marl deposits), actually with a certain continuity (4350-3950 and 4000-3550 cal BC respectively). These superimposed organic layers added up to *ca.* 1 m of thickness. Additional Phase 3 dates were obtained during previous work at the centre of the island and both dates were obtained on charcoal remains (*ca.* 3700-3300 cal BC) (Banchieri and Baglioni, 2012).

5. Discussion

5.1. Neolithic occupations at Isolino Virginia

The available radiocarbon dates from Isolino Virginia allow an approximation to occupation dynamics (their span in time and spread in space) during the Neolithic period (Fig. 7). During Phase 1, *ca.* 4950-4700 cal BC, the occupations were focused in the northern part of the island. Both dated evidence for agricultural and constructive activities confirm this phase of occupation. Dated plant macroremains indicate the cultivation of naked barley (*Hordeum vulgare* var. *nudum*) and naked wheat (*Triticum aestivum/durum/turgidum*), as well as the gathering of fruits such as hazelnuts (*Corylus avellana*) and acorns (*Quercus* sp.) (ESM 4).

After this first occupation, there could have been a long hiatus of at least 350 years (Fig. 6), although there may be deposits dating to this phase that remained undetected by our sampling strategy or the site could have been relocated elsewhere along the shores of lake Varese such as Pizzo di Bodio, a nearby site with an Early Neolithic phase (second half of the 6th millennium cal BC), but also with occupations *ca.* 4750-4350 cal BC (Banchieri, 2009), thus possibly implying a partial or total migration of population.

For Phase 2, *ca.* 4250-4000 cal BC, no constructive evidence has been found or dated, but well-preserved organic deposits have been identified at the central part of the island. Dated crop remains indicate the continuation of cultivation of naked barley and naked wheat (ESM 4).

Phase 3, *ca.* 4000-3550 cal BC has been better documented at the central trench of the island, indicating the potential presence of dwellings and domestic activities at the site. Dates on charred remains of posts suggest the presence of constructions. Additionally, waterlogged deposits in core 1276 at the southernmost part of the site indicate agricultural activities at the settlement involving naked barley and emmer (*Triticum* cf. *dicoccum*). It seems that if there were any occupations during Phases 2 or 3 on the shore of the island they must have been completely eroded. Otherwise, it could be that the occupation was less intensive than in Phase 1, yielding less datable evidence and more spatially scattered.

5.2. Isolino Virginia in the context of early farming communities in the western Alps

We compared the reliable Neolithic dates for northern Italy (presented in Fig. 1) with the new ones from Isolino Virginia (Fig. 8). This makes it clear that the latter complement the information available so far, especially for the end of the 4th millennium and the first half of the 3rd millennium cal BC, since these periods are not particularly well dated for the region.

This data suggests the beginning of farming activities in Lake Varese

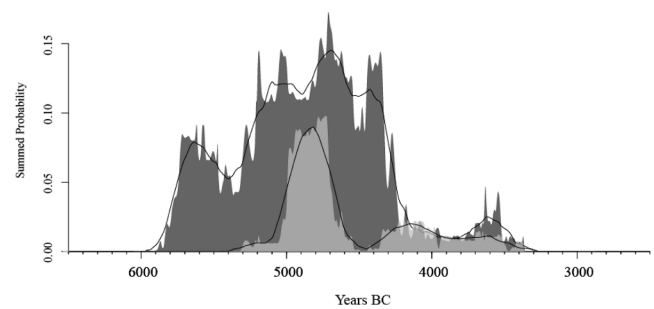

Fig. 8. In dark grey, the raw SCDPDs of Neolithic dates from northern Italy (data in ESM2) with a smoothed function of a running mean of 200 years, and, in light grey, the SCDPDs of all reliable dates from Isolino Virginia. Graph by HMG.

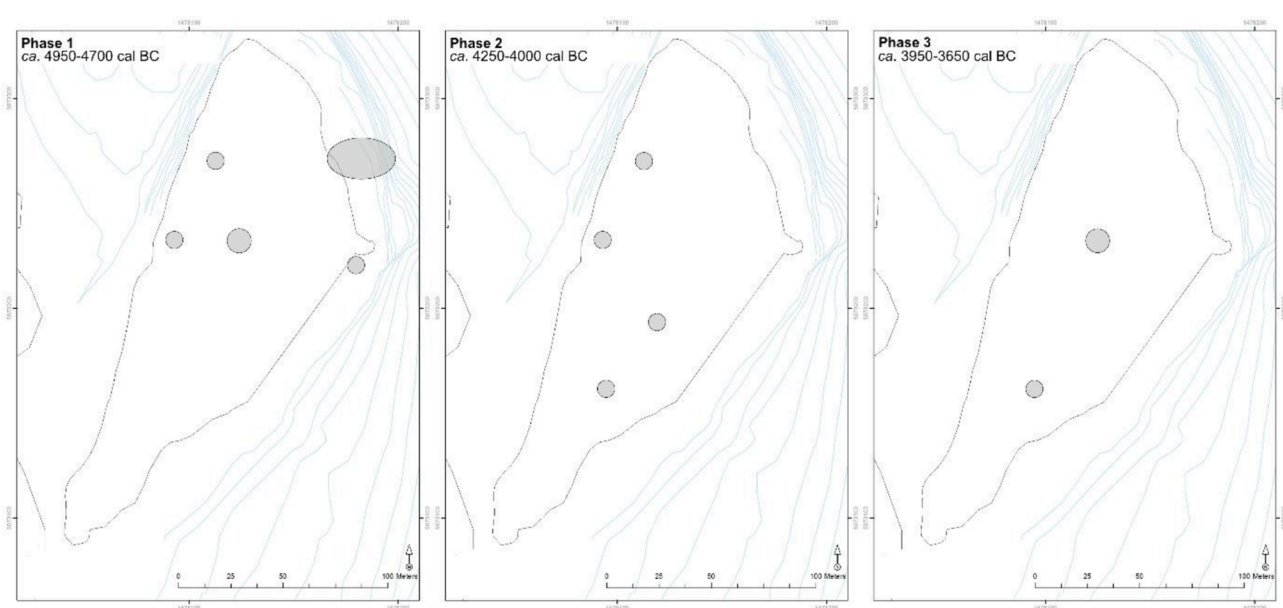

Fig. 7. Distribution of radiocarbon dates within the site divided by occupation phases. Graph by HMG.

area around *ca.* 5000-4850 cal BC, which fits well with the state of the art for the western Lombardy area (i.e. Banchieri et al., 2015b; Biagi, et al., 2020), where these first activities are documented *ca.* 5200-5000 cal BC at sites such as Isorella (Starnini, et al., 2018) or Vhò – Campo Ceresole (Biagi, et al., 2020). Actually, the dates would apparently fit well with the arrival of the Neolithic populations from the east but the crop spectrum found at Isolino (without traces of glume wheats) does not fit with agricultural practices in the Friuli area or the Balkans (Rottoli and Castgilioni, 2009, Antolín, et al., 2021, Antolín, et al., 2020, de Vareilles et al., 2020, Kreuz and Marinova, 2017). Consequently, other or additional areas of influence should be searched for. Southern France shows some diversity in crops being grown in the Early Neolithic, but from 5000 cal BC onwards, naked wheat and naked barley dominate the assemblages (Bouby, et al., 2020), similarly to the first farming sites in the Valais region (Martin, 2015). This would link farming practices at Isolino mostly with western communities and not so much with the east.

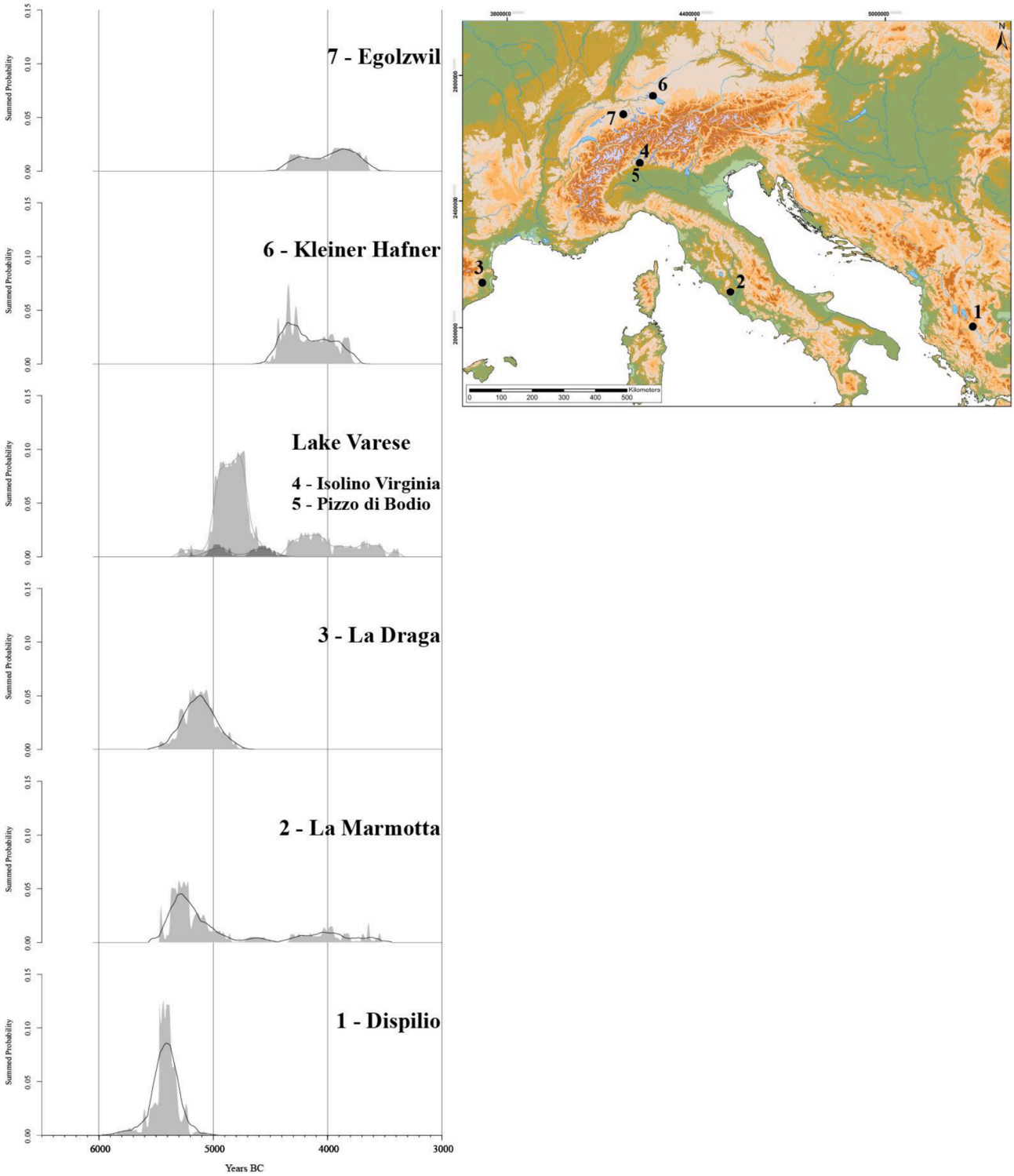

Fig. 9. SCDPD of the radiocarbon dates available for the earliest pile-dwelling sites in western Europe (data extracted from Martínez-Grau, et al., 2021; Fugazzola & Tinazzi, 2010; Facorellis et al. 2014 and presented in ESM 5).

During Phase 2, after a possible abandonment of the island, the pottery remains of the site suggest influences of the Chassey Culture (particularly from southern France) (Borrello and van Willigen, 2012; Guerreschi, 1990), but also from the Balkans, with the presence of *pintaderas* (stamp seals) (Banchieri, 2017). The dated archaeobotanical record, with presence of naked wheat and naked barley, confirms the similarities with the data available from southern France (Jesus, et al., 2021). The record in Northern Italy is scarce, but it seems to be generally dominated by glume wheats (Rottoli and Regola, 2014).

A change is detected around 4000 cal BC, by the onset of Phase 3 of Isolino Virginia, when Lagozza-"Complesso Besnate"-type elements become more frequent (Banchieri and Baglioni, 2012; Borrello and van Willigen, 2012; Guerreschi, 1990). We observe a continuation of the occupation of the central area of the island and a possible emphasis on other crops, such as emmer. A change towards more glume wheats is observed in other sites of Southern France at this time (Jesus, et al., 2021), which could be a sign of wider networks reaching further east, where glume wheats had been important crops since the Early Neolithic (Rottoli and Castgilioni, 2009).

5.3. Isolino Virginia in the context of the earliest pile-dwellings in Europe

Isolino Virginia fills up an important gap in the presence of pile-dwelling sites in the western Mediterranean area (Fig. 9). La Marmotta was abandoned *ca.* 5300 cal BC, while La Draga was occupied from 5300 to 4900 BCE. Both sites are at a considerable distance from each other, but several similarities in the crop and wild plant assemblages have already been highlighted: among others, the presence of tetraploid naked wheat and opium poppy (Antolín, et al., 2015, Antolín, 2016), but there are also differences: glume wheats seem to be quantitatively important at La Marmotta (Rottoli, 1993). Isolino has similarities with the crop assemblage of La Draga, both based on naked wheat and naked barley, as well as opium poppy (Banchieri and Rottoli, 2009). This may suggest that the site originated at least in its majority from populations coming from the West, since their economic practices do not resemble those typical of the Po region. The same crops seem to be the best represented ones in the earliest pile dwellings north of the Alps: Kleiner Hafner (layer 5) and Egolzwil (Jacomet, et al., 1989, Bollinger, 1992). Nevertheless, between the abandonment of Isolino and these occupations in the Swiss Plateau there is a gap of 100–200 years during which no pile-dwelling sites are known in the area (although see the Middle Neolithic phase of Pizzo di Bodio in Fig. 9). It is our hypothesis that part of the community settling in Isolino could have migrated to the north of the Alps, possibly first across the Valais region. The connections between Egolzwil III and La Draga have also been proposed based on a very particular type of sickle with oblique insertion of the flint piece into a wooden haft with an appendix (Gibaja, et al., 2017). This paper would for the first time establish Isolino as a potential driving force for the later development of pile-dwelling sites around the Alps, connecting them to the Western Mediterranean agricultural context, confirming previous impressions based on the appearance of Mediterranean crops and wild plants in the Swiss pile-dwelling sites (Jacomet, 1988; Jacomet et al., 1989).

6. Conclusion

A new set of 25 radiocarbon dates has been obtained for the site of Isolino Virginia. The modelling of these dates has allowed three discrete phases of occupation to be dated: a first occupation period in 4950-4700 cal BC, a second phase between 4250 and 4000 cal BC and a third phase between 4000 and 3550 cal BC. The only clear hiatus is found between the first and the second occupation. The observation of the preliminary results of the archaeobotanical analyses at the site and the results of the dated crop remains indicate an economy based in naked wheat and naked barley during the 5th millennium cal BC. This crop assemblage is typical of the Western Mediterranean areas and this fact, along with the meagre available evidence of early pile dwelling settlements, has been used to postulate the origin of the population founding the site in this area. After the first occupation, it is speculated that the hiatus detected at the site may reflect that at least part of the inhabitants of the site must have migrated and possibly participated in the spread of pile-dwellings north of the Alps. This is supported by the crops grown at the first pile dwelling sites in the Swiss Plateau, namely naked wheat, naked barley, and opium poppy, and the dates associated to these first occupations (*ca.* 4300 cal BC) but also by the characteristic pottery of the Egolzwil culture, which seems to have western connections. More research is needed in south-western Switzerland and the Rhone valley to uncover other possible pile-dwelling sites that could be dated to the period between 4700 and 4300 cal BC. Further investigations of connections between Isolino and other pile-dwelling sites (i.e. sickle types, ceramic, aDNA, etc.) may help to confirm, nuance or disprove our interpretations of the archaeobotanical and radiocarbon data presented in this paper.

Acknowledgements

We would like to express our gratitude to S. Jacomet, S. van Willigen, M. Borrello and M. Rottoli for their help and advice, and G. Serafini for the topographic work, and the Archaeological and Civic Museum – Villa Mirabello. Thanks also to the Soprintendenza of Lombardia. We also want to acknowledge the careful feedback of two anonymous reviewers, which helped to make a significant improvement of the original manuscript. This research took place under the project funded by the Swiss National Science Foundation entitled "Small seeds for large purposes: an integrated approach to agricultural change and climate during the Neolithic in Western Europe" (AgriChange Project, SNSF Professorship grant number: PP00P1_170515, PI: F. Antolín).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2022.103375.

References

Andreaki, V., Barceló, J.A., Antolín, F., Bogdánovic, I., Gassmann, P., López-Bultó, O., Morera, N., Palomo, A., Piqué, R., Revelles, J., Terradas, X., 2020. Un modelo bayesiano para la cronología del yacimiento neolítico de La Draga (Banyoles, Girona). Un caso de estudio con ChronoModel 2.0. In: Barceló, J.A., Morell, B. (Eds.), Métodos cronométricos en arqueología, historia y paleontología. Dextra Editorial, Madrid, pp. 399–414.

Antolín, F., 2016. Local, intensive and diverse? Early Farmers and plant economy in the North-East of the Iberian Peninsula (5500–2300 cal BC). Barkhuis, Groningen.

Antolín, F., Bouby, L., Martin, L., Rottoli, M., Jesus, A., 2021. Archaeobotanical evidence of plant food consumption among early farmers (5700–4500 BC) in the Western Mediterranean region. Food & 19 (1-2), 235–253.

Antolín, F., Häberle, S., Sousa Jesus, A.C., Martinez-Grau, H., Prats, G., Schäfer, M., Steiner, B., 2018. The AgriChange project: an integrated on-site approach to agricultural and land-use change during the Neolithic in Western Europe. PAGES News – Past Global Changes Magazine 26, 26–27.

Antolín, F., Jacomet, S., Buxó, R., 2015. The hard knock life. Archaeobotanical data on farming practices during the Neolithic (5400–2300 cal BC) in the NE of the Iberian Peninsula. Journal of Archaeological Science 61, 90–104.

Antolín, F., Sabanov, A., Naumov, G., Soteras, R., 2020. Crop choice, gathered plants and household activities at the beginnings of farming in the Pelagonia Valley of North Macedonia. Antiquity 94 (376). https://doi.org/10.15184/aqy.2020.119.

Baioni, M., Binaghi Leva, M.A., Borello, M.A., 2005. In: WES'04, pp. 209–214.

Banchieri, D.G., 2016. Nuovi dati dendrocronologici e dendrotipologici dalla riva di Sud-Est dell'Isolino Virginia. Sibrium XXX 135–153.

Banchieri, D.G., 2017. Il Neolitico nel territorio di Varese. In: Harari, M. (Ed.), Il territorio di Varese in età preistorica e protostorica. Nomos Edizioni, Varese, pp. 87–120.

Banchieri, D.G., Baglioni, L., 2012. Il Neolitico Finale della struttura US 417 all'Isolino Virginia: note preliminari. Sibrium XXVI 112–167.

Banchieri, D.G., Bini, A., Mainberger, M., 2015a. Isolino Virginia, a waterlogged Tell in a south pre-alpine Lake: Preservation and Erosion Problems, in: Brem, H., Ramseyer, D., Roulière-Lambert, M.J., Schifferdecker, F., Schlichtherle, H. (Eds.), Monitoring et mesures de protection pour la sauvegarde des palafittes préhistoriques autour des Alpes. Actes de la troisième Rencontre Internationale Arenenberg et Hemmenhofen, mêta jura, Lons-le-Saunier, pp. 181-188.

Banchieri, D.G., Bini, A., Rottoli, M., Mainberger, M., 2015b. Le Prealpi varesine e l'alimentazione durante la Preistoria, in: Istituto Italiano di Preisotria e Protostoria (Ed.), Preistoria del cibo. In: L'alimentazione nella preistoria e nella protostoria. 50ma Riunione Scientifica, Istituto Italiano di Preisotria e Protostoria, pp. 1–7.
Banchieri, D.G., Martinelli, N., Pignatelli, O., 2009. Nuove indagini sui resti lignei dell'Isolino Virginia. Sibrium XXV 179–184.
Banchieri, D.G., 2009. I Laghi prealpini della Lombardia Nord Occidentale (Italia Settentrionale): dati riguardanti aspetti della frequentazione umana durante il Neolitico. Sibrium XXV 9–29.
Banchieri, G.D., Rottoli, M., 2009. Isolino Virginia: una nuova data per la storia del papavero da oppio (*Papaver somniferum* subsp. *somniferum*), Sibrium XXV, 31-49.
Berger, J.-F., 2021. Geoarchaeological and Paleo-Hydrological Overview of the Central-Western Mediterranean Early Neolithic Human-Environment Interactions. Open Archaeology 7 (1), 1371–1397.
Biagi, P., Starnini, E., Borić, D., Mazzucco, N., 2020. Early Neolithic settlement of the Po Plain (northern Italy): Vhò and related sites. Documenta Praehistorica XLVII 47, 192–221.
Binder, D., Lanos, P., Angeli, L., Gomart, L., Guilaine, J., Manen, C., Maggi, R., Muntoni, I.M., Panelli, C., Radi, G., Tozzi, C., Arobba, D., Battentier, J., Brandaglia, M., Bouby, L., Briois, F., Carré, A., Delhon, C., Gourichon, L., Marinval, P., Nisbet, R., Rossi, S., Rowley-Conwy, P., Thiébault, S., 2018. Modelling the earliest north-western dispersal of Mediterranean Impressed Wares: new dates and Bayesian chronological model. Documenta praehistorica. 44, 54–77.
Bini, A., Turri, S., Zuccoli Bini, L., 2016. Geologia del Lago di Varese tra il Pleistocene superiore e l'Olocene. Sibrium XXX 55–95.
Bini, A., Zuccoli Bini, L., 2016. Isolino Virginia: dati stratigrafici, datazioni ^{14}C e sezioni geologiche. Sibrium XXX 97–134.
Bollinger, T., 1992. Wirtschaft und Umwelt des jungsteinzeitlichen Wohnplatzes Egolzwil 3. Universität Basel, Katon Luzern (Schweiz), Philosophisch-Naturwissenschaftlichen Fakultät, p. 159.
Borrello, M.A., 2011. Matières premières, biens de prestige et céramiques: marqueurs de contacts néolithiques dans les Alpes occidentales. Notizie Archeologiche Bergomensi 19, 23–34.
Borrello, M.A., van Willigen, S., 2012. Lagozza e Chassey – Inquadramento cronologico e culturale delle ceramiche della Lombardia occidentale e del Sud – Est della Francia. Sibrium XXVI, 90–111.
Bouby, L., Marinval, P., Durand, F., Figueiral, I., Briois, F., Martzluff, M., Perrin, T., Valdeyron, N., Vaquer, J., Guilaine, J., Manen, C., 2020. Early Neolithic (ca. 5850–4500 cal BC) agricultural diffusion in the Western Mediterranean: An update of archaeobotanical data in SW France. PLOS ONE 15, e0230731.
Bronk Ramsey, C., 2009. Bayesian Analysis of Radiocarbon Dates. Radiocarbon 51 (1), 337–360.
Pedrotti, A., Poggiani Keller, R., Banchieri, D.G., Longhi, C., 2022. Il Neolitico in Lombardia. In: Preistoria e Protostoria della Lombardia. Rivista de Scienze Preistoriche LXXII,, 52.
Bronk Ramsey, C., 2017. Methods for Summarizing Radiocarbon Datasets. Radiocarbon 59 (6), 1809–1833.
Brown, W.A., 2017. The past and future of growth rate estimation in demographic temporal frequency analysis: Biodemographic interpretability and the ascendance of dynamic growth models. Journal of Archaeological Science 80, 96–108. https://doi.org/10.1016/j.jas.2017.02.003.
Crema, E.R., Bevan, A., 2021. Inference from large sets of radiocarbon dates: software and methods. Radiocarbon 63 (1), 23–39. https://doi.org/10.1017/RDC.2020.95.
Facorellis, Y., Sofronidou, M., Hourmouziadis, G., 2014. Radiocarbon dating of the Neolithic lakeside settlement of Dispilio. Kastoria, northern Greece, Radiocarbon 56 (2), 511–528.
Fugazzola, M.A., Tinazzi, O., 2010. Dati di cronologia da un villaggio del Neolitico Antico. Le indagini dendrocronologiche condotte sui legni de La Marmotta (lago di Bracciano-Roma), Miscellanea in ricordo di Francesco Nicosia, Studia Erudita, Studia Erudita, Fabrizio Serra Editore, Pisa, Roma, pp. 1-10.
Gibaja, J.F., Ibáñez, J.J., Nielsen, E., Kienholz, A., van Willigen, S., Linton, J., 2017. The Neolithic reaping knives from Egolzwil 3: A Mediterranean technical tradition in the late 5th millennium Swiss Neolithic. Quaternary International 427, 211–224.
Guerreschi, G., 1990. Nuovi dati sulla stratigrafia dell'Isolino di Varese, The Neolithisation of the Alpine Region. Monografie di Natura Bresciana 13, 197–205.
Hafner, A., 2012. Das UNESO Welterbe "Prähistoriche Pfahlbauten um die Alpen" im Kanton Bern. Frühe Forschungen, aktuelle Situation und Chancen für die Zukunft, Jahrbuch des Archäologischen Dienstes des Kantons Bern.
Hafner, A., Suter, P.J., 2003. Das Neolithikum in der Schweiz, Journal of Neolithic. Archaeology 5, 1–75.
Hajdas, I., 2008. Radiocarbon dating and its implications in Quaternary studies. Quaternary Science Journal 57, 2–24.
Jacomet, S., 1988. Pflanzen mediterraner Herjkunft in neolithischen Seeufersiedlungen der Schweiz. In: Der prähistorische Mensch und seine Umwelt. Festschrift Körber-Grohne. Forschungen und Berichte zur Vor-, 31. und Frühgeschichte in Baden-Württemberg, pp. 205–212.
Jacomet, S., 2013. Archaeobotany: Analyses of Plant Remains from Waterlogged Archaeological Sites. In: Menotti, F., O'Sullivan, A. (Eds.), The Oxford Handbook of Wetland Archaeology. Oxford University Press, Oxford, pp. 497–514.
Jacomet, S., Brombacher, C., Dick, M., 1989. Archäobotanik am Zürichsee. Ackerbau, Sammelwirtschaft und Umwelt von neolithischen und bronzezeitlichen Seeufersiedlungen im Raum Zürich. Orell Füssli Verlag, Zürich.
Jesus, A., Prats, G., Follmann, F., Jacomet, S., Antolín, F., 2021. Middle Neolithic farming of open-air sites in SE France: new insights from archaeobotanical investigations of three wells found at Les Bagnoles (L'Isle-sur-la-Sorgue, Dépt. Vaucluse, France). Vegetation History and Archaeobotany 30 (4), 445–461.
Kislev, M.E., Simchoni, O., 2002. Reconstructing the palaeoecology of Ohalo II, an Early Epipalaeolithic site in Israel. In: Mason, S.L.R., Hather, J.G. (Eds.), Hunter-gatherer archaeobotany. Institute of Archaeology University College London, London, Perspectives from the northern temperate zone, pp. 174–189.
Kreuz, A., Marinova, E., 2017. Archaeobotanical evidence of crop growing and diet within the areas of the Karanovo and the Linear Pottery Cultures: a quantitative and qualitative approach. Vegetation History and Archaeobotany 26, 639–657.
Martin, L., 2015. Plant economy and territory exploitation in the Alps during the Neolithic (5000–4200 cal bc): first results of archaeobotanical studies in the Valais (Switzerland). Vegetation History and Archaeobotany 24, 63–73.
Martinelli, N., 2007. Gli insediamenti palafitticoli dell'antica età del Bronzo nell'area benacense: studio stratigrafico e strutturale su scala cronologica ad alta precisione. Università degli Studi di Padova, unpublished, Dipartamento di Archeologia, p. 174.
Martinelli, N., 2019. Prehistoric pile-dwellings in northern Italy: an archaeological and dendrochronological overview, ARCADE. Archéologie, Dendrochronologie et Environnement, Approche diachronique et Regards croisés, pp. 69–78.
Martínez-Grau, H., Antolín, F., 2021. A Bayesian Chronomodel for an Economic approach to the Onset of Farming in Northwestern Mediterranean and the Western Alpine Forelans. In: Pardo Gordó, S., Bergin, S.M. (Eds.), Simulating Transitions to Agriculture Prehistory. Springer International Publishing, Cham, pp. 47–82.
Martínez-Grau, H., Jagher, R., Oms, F.X., Barceló, J.A., Pardo-Gordó, S., Antolín, F., 2020. Global processes, regional dynamics? Radiocarbon data as a proxy for social dynamics at the end of Mesolithic and during the Early Neolithic in the NW of Mediterranean and Switzerland (ca. 6200–4600 cal BC). Documenta Praehistorica XLVII, 170–191.
Martínez-Grau, H., Morell-Rovira, B., Antolín, F., 2021. Radiocarbon Dates Associated to Neolithic Contexts (Ca. 5900–2000 Cal BC) from the Northwestern Mediterranean Arch to the High Rhine Area. Journal of Open Archaeology Data 9, 1–10.
Müller, K., 1995. Le site de Sion-Tourbillon (VS): nouvelles données sur le Néolithique ancien valaisan. Archäologie der Schweiz 18, 102–108.
Naumov, G., 2018. The formation of wetland identities in the Neolithic Balkans. Vita Antiqua 10, 48–60.
Pearce, M.J., 2013. Rethinking the north Italian Early Neolithic. University of London, London, Accordia Research Institute.
Perrin T., Manen, C., 2021. Potential interactions between Mesolithic hunter-gatherers and Neolithic farmers in the Western Mediterranean: The geochronological data revisited. PLOS ONE 16(3): e0246964.Reimer, P.J., Austin, W.E.N., Bard, E., Bayliss, A., Blackwell, P.G., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kromer, B., Manning, S.W., Muscheler, R., Palmer, J.G., Pearson, C., van der Plicht, J., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Turney, C.S.M., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S.M., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., Talamo, S., 2020. The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 cal kBP), Radiocarbon 62, 725-757.
Rottoli, M., 1993. La Marmotta, Anguillara Sabazia (RM). Scavi 1989. analisi paletnobotaniche: prime risultanze. Bullettino di Paletnologia Italiana 84, 305–315.
Rottoli, M., 2014. Crop diversity between central Europe and the Mediterranean: aspects of Northern Italian agriculture. In: Chevalier, A., Marinova, E., Peña-Chocarro, L. (Eds.), Plants and People. Oxbow books, Oxford, Choices and Diversity through time, pp. 76–81.
Rottoli, M., Castgilioni, E., 2009. Prehistory of plant growing and collecting in northern Italy, based on seed remains from the Early Neolithic to the Chalcolithic (c. 5600–2100 cal B.C.). Vegetation History and Archaeoabotany 18, 91–103.
Rottoli, M., Regola, E., 2014. L'agricoltura in Italia settentrionale nel V millennia a. C.: nuovi dati dal sito di via Guidorossi a Parma. In: Bernabò Brea, M., Maggi, R., Manfredini, A. (Eds.), Il pieno sviluppo del neolitico in Italia: atti del convegno: Museo Archeologico del Finale – Finale Ligure Borgo, 8–10 giugno 2009, Istituto internazionale di studi Liguri. Bordighera, Museo Bicknell, pp. 55–61.
RStudio Team, 2021. RStudio: Integrated Development Environment for R. In: Team, R. (Ed.), RStudio Team, RStudio Inc, Boston. MA URL, Boston.
Salavert, A., Zazzo, A., Martin, L., Antolín, F., Gauthier, C., Thil, F., Tombret, O., Bouby, L., Manen, C., Mineo, M., Mueller-Bieniek, A., Piqué, R., Rottoli, M., Rovira, N., Toulemonde, F., Vostrovská, I., 2020. Direct dating reveals the early history of opium poppy in western Europe. Scientific Reports 10, 20263.
Seifert, M., Somaz, T., Stöckli, W.E., 2013. Die absolute Datierung von Egolzwil 3. In: de Capitani, A. (Ed.), Egolzwil 3. Die Keramik der neolithischen Seeufersiedlung, Denkmalpflege und Archäologie, Luzern, pp. 127–144.
Skeates, R., 2013. Neolithic Italy at 4004 BC: people and places. Working Paper. Durham Research Online (DRO), Durham. http://dro.dur.ac.uk/11425.
Starnini, E., Biagi, P., Mazzucco, N., 2018. The beginning of the Neolithic in the Po Plain (northern Italy): Problems and perspectives. Quaternary International 470, 301–317.
Stordeur D., Helmer D., Jammous B., Khawam R., Molist M., Willcox G., Dentzer J.-M., F., B., 2010. Le PPNB de Syrie du sud à travers les découvertes récentes à Tell Aswad, in: al-Maqdissi, M. (Ed.), Hauran V. La Syrie du sud du Néolithique à l'Antiquité tardive. Recherches récentes. Actes du colloque de Damas 2007, Institut français du Proche-Orient/IFPO, Damas, pp. 41–67.
Tozzi, C., Zamagni, B., Bagnone, D., 2003. Gli scavi nel villagio neolitico di Catignano (1971–1980). Istituto italiano di preistoria e protostoria, Firenze.

Vander Linden, M., Silva, F., 2021. Dispersals as demographic processes: testing and describing the spread of the Neolithic in the Balkans. Philosophical Transactions of the Royal Society B 376, 20200231.
de Vareilles, A., Bouby, L., Jesus, A., Martin, L., Rottoli, M., Vander Linden, M., Antolín, F., 2020. One sea but many routes to sail. The early maritime dispersal of Neolithic crops from the Aegean to the western Mediterranean. Journal of Archaeological Science: Reports 29, 102140.
Wolfhagen, J., Veropoulidou, R., Ayala, G., Filipović, D., Kabukcu, C., Lancelotti, C., Madella, M., Pawłowska, K., Santiago-Marrero, C.G., Wainwright, J., 2020. The Seasonality of Wetland and Riparian Taskscapes at Çatalhöyük. Near Eastern Archaeology 83, 98–109.