





# Beyond the Sum: A Poisson Approach to Radiocarbon Analysis

**Jonathan Hanna**  based on peer reviews by **Thomas Huet**  and 1 anonymous reviewer

Miguel de Navascués, Concetta Burgarella, Mattias Jakobsson (2025) Analysis of the Abundance of Radiocarbon Samples as Count Data. Zenodo, ver. 3, peer-reviewed and recommended by Peer Community in Archaeology.

<https://doi.org/10.5281/zenodo.13381596>

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Archaeological data is inherently uncertain, which is probably why Bayesian approaches have become increasingly valued within the discipline. For radiocarbon analysis, instead of pinpointing one “true” date, Bayesian methods embrace probability, telling us how likely a sample falls within different date ranges based on what we already know (the prior) and what our data tells us (the posterior).

In this new paper, Miguel de Navascués and colleagues offer a method for treating radiocarbon dates as count data (generated through a Poisson process), rather than viewing them as draws from a probability distribution. This shift allows them to model the expected number of samples per year and incorporate uncertainty in both the timing and total number of samples. The result is a more natural representation of how radiocarbon samples accumulate in the archaeological record over time. (They then demonstrate the method using data from Britain and Ireland, revealing patterns that both confirm and refine our understanding of population changes during key transitions, including a possibly earlier start to the Neolithic demographic expansion.)

Overall, the paper represents a valuable contribution to quantitative archaeology that complements, rather than replaces, existing approaches like Sum Probability Distributions (SPDs) and end-to-end Bayesian methods (e.g., see Crema 2022 and Price et al. 2021).

While mathematically heavy, the paper is accompanied by well-annotated R scripts that I encourage readers to experiment with. For researchers working with radiocarbon data, particularly those investigating demographic change or cultural transmission, the methods presented here offer important new analytical possibilities for understanding past human dynamics. Sometimes, to move forward, we just need to count differently.

## References:

Crema, E. R. (2022), Statistical Inference of Prehistoric Demography from Frequency Distributions of Radiocarbon Dates: A Review and a Guide for the Perplexed. *Journal of Archaeological Method and Theory* 29(4):1387–1418. <https://doi.org/10.1007/s10816-022-09559-5>

de Navascués, M., Burgarella, C. & Jakobsson, M. (2025) Analysis of the Abundance of Radiocarbon Samples as Count Data. Zenodo, ver.3 peer-reviewed and recommended by PCI Archaeology <https://doi.org/10.5281/zenodo.13381596>

Price, M. H., Capriles, J. M., Hoggarth, J. A., Bocinsky, R. K., Ebert, C. E. & Jones, J. H. (2021) End-to-End Bayesian Analysis for Summarizing Sets of Radiocarbon Dates. *Journal of Archaeological Science* 135:105473. <https://doi.org/10.1016/j.jas.2021.105473>

## Reviews

### Evaluation round #1

DOI or URL of the preprint: <https://doi.org/10.5281/zenodo.13381596>

Version of the preprint: 2

### Authors' reply, 27 January 2025

Dear Dr. Hanna,

Thank you for managing our submission to PCI Archaeology and for your positive view regarding our work. We have now worked on a new version of the manuscript that addresses the points raised by the reviewers.

#### **Decision by Jonathan Hanna**

[...]

**First, I should note that while we reached out to four reviewers, only two have responded. [...] Should we receive any additional reviews, we'll forward them for your consideration, though we likely won't require additional revisions based on them.**

We have made modifications based on the two reviews that we have received. In addition, we have made some modifications based on feedback that we received on our public preprint independent of the PCI Archaeology process. The comment we received make us realise that some clarifications were needed in the introduction regarding the difference between the SPD and more recent model-based statistical approaches. In some regards these modifications also address the request for clarifications by reviewer 1 (see below). This revision has lead to changes in the text, including the title, abstract, introduction and discussion to better frame our work respect to the state of the art of the field. The analysis, results and conclusion are the same as presented in the previous version of the manuscript.

[...]

#### **Review by Thomas Huet**

[...]

**Currently, archaeologists are accustomed to reading and writing SPDs. To challenge these practices—a goal of this paper—requires a clear, reproducible demonstration. An R package or a set of well-documented functions would certainly facilitate this. However, the lack of documentation for the R project and the absence of an .Rproj file hinder the reproducibility of the statistics.**

[...]

We have revised the documentation included in the R project to improve the usability. We have transformed the example script that was included in the previous version to a vignette to make it accessible to a wider

range of users. All the functions in file DARthABC.R have been documented. The new documented version is available in GitHub and Zenodo.

#### Review by anonymous reviewer 1

[...]

#### Minor comments follow:

**1. A further sentence or two would provide clarity on how “radiocarbon data, [...] is essentially count data” (page 2, lines 33–34), and the subsequent sentences around how the number of radiocarbon date samples in a sum probability distribution model is not a fixed parameter determined by the researcher.**

This part of the introduction has been rewritten, including an expanded explanation of the nature of the data generating process and the fact that the total number of samples is not set by the researcher.

**2. A brief definition and interpretative value of “radiocarbon data abundance” (page 2, line 39) would be helpful in the introduction.**

This paragraph of the introduction has been rewritten, we hope that the new version is more clear regarding the models and their interpretative value.

**3. The difference between potential number of dates and the potential number of items in any given year could be clarified (Lines 52–64).**

We have changed “potential number of items” for “potential number of samples” to improve clarity.

**4. Line 274: replace “build” with “built”.**

Done

**5. The five periods stated on lines 349–350 and indicated by an asterisk in Figure 6b are where positive change in  $\lambda$  is considered significant (i.e., where credibility intervals exclude zero). The positioning of the asterisk in Figure 6b was confusing. Instead these a light grey bar (or equivalent) could represent these significant changes in  $\lambda$ .**

Done

**Also consider removing “the” before “zero” on lines 350–351.**

Done

**6. Line 406: replace comma before “however” with semi-colon.**

Done.

[Download tracked changes file](#)

### Decision by Jonathan Hanna , posted 24 November 2024, validated 27 November 2024

Dear Dr. Navascués,

I hope this email finds you well. I am writing regarding your submission “Analysis of the Abundance of Radiocarbon Samples without the Sum of Probability Distributions” to PCI Archaeology.

First, I should note that while we reached out to four reviewers, only two have responded. Given the quality of these reviews and the time elapsed, we feel comfortable proceeding with a decision based on these two thoughtful assessments. Should we receive any additional reviews, we'll forward them for your consideration, though we likely won't require additional revisions based on them.

I am pleased to inform you that your paper has been **accepted pending minor revisions**. Both reviewers were positive about your novel approach but raised some important points to address (see the full reviews in the PCI dashboard):

- Reviewer 1 suggests more explicitly acknowledging the sophisticated modeling already present in radiocarbon calibration and SPDs, while better clarifying how your method adds to (rather than replaces) existing frameworks.

- Reviewer 2 requests more detailed discussion of the method's practical implementation, particularly regarding parameter selection and model validation protocols.

Related to the last point, we ask that you improve the documentation and usability of your R code.

Please submit your revised manuscript within 45 days (or let me know if you need more time). We look forward to publishing your contribution!

Best regards,

Jonathan A. Hanna, PhD., RPA  
PCI Archaeology

Reviewed by **Thomas Huet** , 03 November 2024

#### **Title and abstract**

- Does the title clearly reflect the content of the article?  Yes,  No (please explain),  I don't know
- Does the abstract present the main findings of the study?  Yes,  No (please explain),  I don't know

#### **Introduction**

- Are the research questions/hypotheses/predictions clearly presented?  Yes,  No (please explain),  I don't know
- Does the introduction build on relevant research in the field?  Yes,  No (please explain),  I don't know

#### **Materials and methods**

- Are the methods and analyses sufficiently detailed to allow replication by other researchers?  Yes,  No (please explain),  I don't know
- Are the methods and statistical analyses appropriate and well described?  Yes,  No (please explain),  I don't know

#### **Results**

- In the case of negative results, is there a statistical power analysis (or an adequate Bayesian analysis or equivalence testing)?  Yes,  No (please explain),  I don't know
- Are the results described and interpreted correctly?  Yes,  No (please explain),  I don't know

#### **Discussion**

- Have the authors appropriately emphasized the strengths and limitations of their study/theory/methods/argument?  Yes,  No (please explain),  I don't know
- Are the conclusions adequately supported by the results (without overstating the implications of the findings)?  Yes,  No (please explain),  I don't know

—

This well-written and structured paper demonstrates, through robust statistical analysis, that treating radiocarbon data as count data captures the chronological information often only represented as Summed Probability Densities (SPD) by archaeologists. SPDs are frequently used as proxies to assess the demography of past societies. According to the authors, counting radiocarbon dates leads to model-based approaches that allow for cross-checking between proposed models (verifiability), whereas SPDs are often used without formal mathematical interpretation (model-free approach). The paper includes a set of R functions and data available on both Zenodo and GitHub, enhancing the authors' demonstration.

As an archaeologist familiar with radiocarbon management, SPD, and distribution laws, I must admit that a significant part of the "Materials and Methods" section is beyond my expertise, requiring extensive knowledge in statistics (including Random Forest and Bayesian modeling). Consequently, I am not able to thoroughly review this part of the submitted paper. My focus will instead be on how the model proposed by the authors might be received by the archaeological community.

Much like the persistence of the QWERTY keyboard over more logically organized alternatives (e.g., alphabetical), established practices are often difficult to change. Currently, archaeologists are accustomed to reading and writing SPDs. To challenge these practices—a goal of this paper—requires a clear, reproducible demonstration. An R package or a set of well-documented functions would certainly facilitate this. However, the lack of documentation for the R project and the absence of an .Rproj file hinder the reproducibility of the statistics.

In my opinion, this ambitious paper needs polishing, starting with improving the usability of the R code to ensure it can significantly impact radiocarbon practices in archaeology.

### **Reviewed by anonymous reviewer 1, 18 November 2024**

This paper presents an important methodological innovation in the analysis of radiocarbon data for archaeological demographic studies. The authors propose abandoning the traditional Sum of Probability Distributions (SPD) approach, "because it lacks a precise definition of its underlying meaning" (p. 2), and instead favour treating radiocarbon data as count data, characterised as the expected number of samples per year. The developed approach is the paper's key contribution and is supported by an explanation of its fundamental components and a case study using radiocarbon date data from Ireland and Britain, notably finding an earlier start to the Neolithic demographic expansion than identified previously. The date count approach is theoretically supported, computationally less intensive and enables more transparent descriptions of significant change in radiocarbon sample abundance (i.e., exclusion of zero in  $\lambda$  confidence intervals) backing of the date count approach, it is also computationally less intensive, which may improve its accessibility and general methodological efficiency. This review offers no major critique.

The paper is clearly structured and has been edited to a high standard. The statistical validity of the new approach is outside of the reviewer's experience and is not included in this review.

Minor comments follow:

1. A further sentence or two would provide clarity on how "radiocarbon data, [...] is essentially count data" (page 2, lines 33–34), and the subsequent sentences around how the number of radiocarbon date samples in a sum probability distribution model is not a fixed parameter determined by the researcher.
2. A brief definition and interpretative value of "radiocarbon data abundance" (page 2, line 39) would be helpful in the introduction.
3. The difference between potential number of dates and the potential number of items in any given year could be clarified (Lines 52–64).
4. Line 274: replace "build" with "built".
5. The five periods stated on lines 349–350 and indicated by an asterisk in Figure 6b are where positive change in  $\lambda$  is considered significant (i.e., where credibility intervals exclude zero). The positioning of the asterisk in Figure 6b was confusing. Instead these a light grey bar (or equivalent) could represent these significant changes in  $\lambda$  Also consider removing "the" before "zero" on lines 350–351.
6. Line 406: replace comma before "however" with semi-colon.

Answers to the PCI reviewer questions follow:

**Title and abstract**

- Does the title clearly reflect the content of the article? [] Yes, [] No (please explain), [] I don't know
- Does the abstract present the main findings of the study? [] Yes, [] No (please explain), [] I don't know

**Introduction**

- Are the research questions/hypotheses/predictions clearly presented? [] Yes, [] No (please explain), [] I don't know
- Does the introduction build on relevant research in the field? [] Yes, [] No (please explain), [] I don't know

**Materials and methods**

- Are the methods and analyses sufficiently detailed to allow replication by other researchers? [] Yes, [] No (please explain), [] I don't know
- Are the methods and statistical analyses appropriate and well described? [] Yes, [] No (please explain), [] I don't know

**Results**

- In the case of negative results, is there a statistical power analysis (or an adequate Bayesian analysis or equivalence testing)? [] Yes, [] No (please explain), [] I don't know
- Are the results described and interpreted correctly? [] Yes, [] No (please explain), [] I don't know

**Discussion**

- Have the authors appropriately emphasized the strengths and limitations of their study/theory/methods/argument? [] Yes, [] No (please explain), [] I don't know
- Are the conclusions adequately supported by the results (without overstating the implications of the findings)? [] Yes, [] No (please explain), [] I don't know