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DIGITAL AND STATISTICAL
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ESTIMATING AND MAPPING ROMAN AMPHITHEATER SEATING CAPACITY

Abstract: While much depends on the definition of the term and the extent to which that accommodates variability, the number of currently known Roman amphitheaters can be put between 260 and 280. By both rough calculation assuming a typical capacity of 11,000 and by taking account of prior scholarship, when possible, to use individual capacities for each structure, the total estimated seating capacity of all Roman amphitheaters is approximately three million. That is a large number in the context of an ancient state such as the Roman Empire. For amphitheaters for which no estimate of capacity is available, this article uses Nearest Neighbors estimation to estimate a capacity on the basis of known dimensions. Doing so accommodates the observation that the seating capacity of any amphitheater was not zero so that a number must be calculated. All the data by which these calculations are made - along with the Python code - are available for download and adaptation so that the process used here is reproducible. With an estimated total having been calculated, the distribution of this capacity is explored as grouped by modern countries as well as by ancient regions. The distribution is also mapped. These visualizations highlight Italy, and particularly Campania, as the area of greatest concentration of amphitheater seating. The central part of Africa Proconsularis, roughly modern Tunisia, is also an area of relatively high concentration. The main goal of this article is to report the approximately three million total estimated seating capacity and to visualize and map its spatial distribution. The article does also suggest that while amphitheaters can be considered important symbols of Roman culture, the unequal distribution of seating implies unequal access to the experience of watching violent entertainments in these buildings. By offering a relatively straightforward approach to calculating total seating capacity, it also intends to be an easy point of reference for scholars integrating amphitheaters into historical narratives that take account of the inherent uncertainty that comes with the study of these large structures.

Keywords: *Roman Empire, Roman amphitheaters, Digital mapping, Digital history, Reproducible research.*

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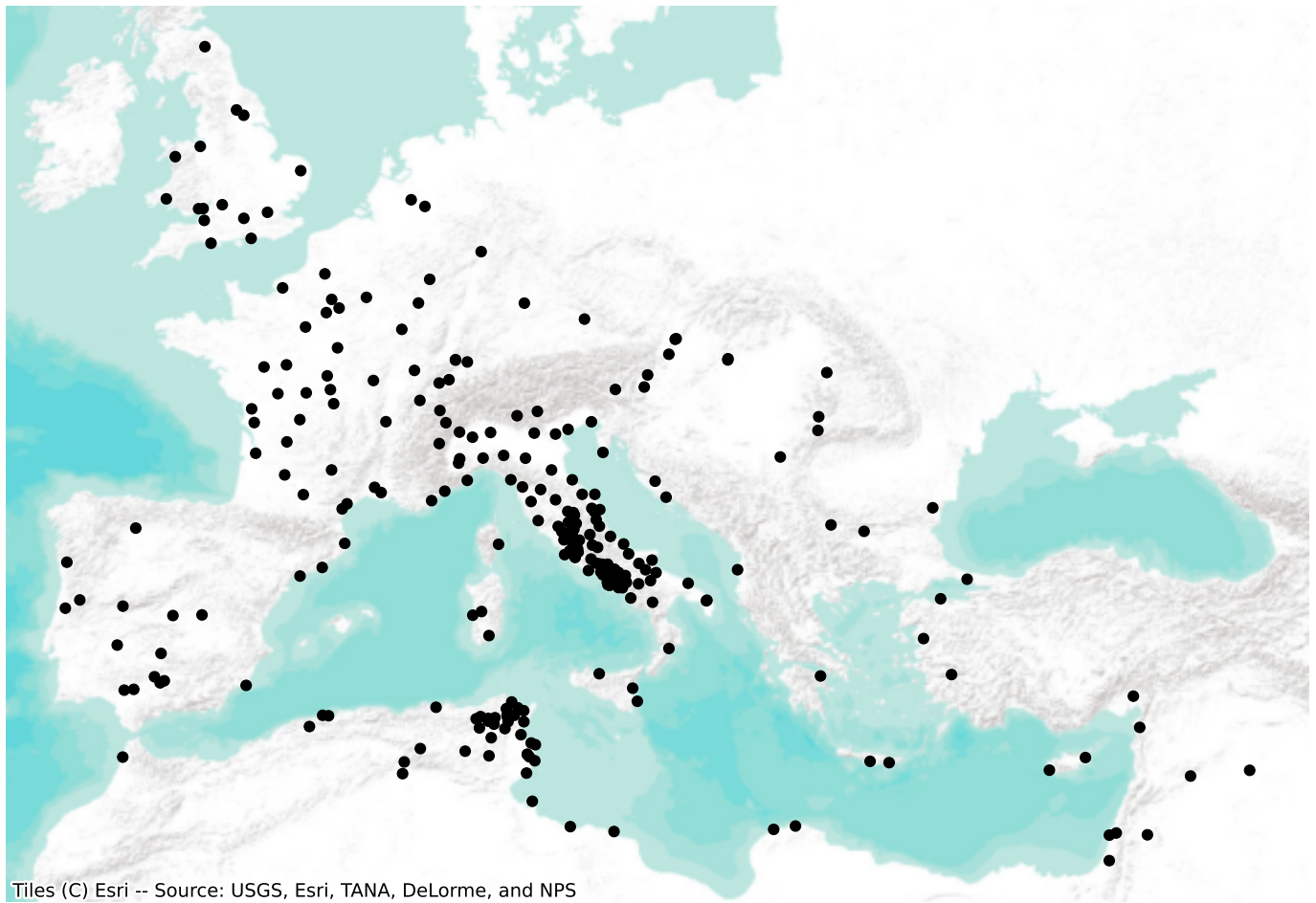
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INTRODUCTION

While much depends on the definition of the term and the extent to which that accommodates variability, the number of currently known Roman amphitheaters can be put between 260 and 280. In the discussion that follows, “amphitheater” is used somewhat narrowly to refer to permanent, purpose-built oval structures having a central arena that is surrounded by essentially complete circuits of seating that rise outward



Tiles (C) Esri -- Source: USGS, Esri, TANA, DeLorme, and NPS

Fig. 1. Map of Roman Amphitheaters built between early first century BCE and fourth century CE.

in concentric bands to an outer wall or bounding natural feature.¹ In general, these structures were built for the display of violent entertainments that included gladiatorial combat, combat involving animals, and execution of condemned persons. From a modern perspective, the archetypal example is the Flavian Amphitheater - or Colosseum - in Rome, which was in operation by 80 CE.² This structure was, however, very much the largest amphitheater, with maximum exterior dimensions of 189 x 156 m and an estimated seating capacity of at least 50,000.³ It is an outlier and most amphitheaters are, as will be discussed below, much smaller.

As a matter of chronology, the permanent and at least partially stone amphitheater had become a recognizable architectural form by the early to mid first century BCE, at which time the greatest number was to be found in southern Italy, especially Campania.⁴ The amphitheater at Pompeii is often taken to be the first such essentially all stone structure and to have established the overall pattern for those that followed.⁵

¹ As a matter of writing style, I will not qualify every statement and so emphasize now that there are no simple givens when it comes to characterizing the phenomenon of Roman amphitheaters within the empire as a whole. One goal of this paper is to acknowledge the inherent imprecision of the exercise it undertakes while still moving ahead in a way that is transparent and seems reasonable.

² HOPKINS/BEARD 2005.

³ ELKINS 2019, 3.

⁴ WELCH 2009.

⁵ DODGE 2014.

Moving ahead, the second century CE saw the greatest number of amphitheaters in use at one time, approximately 250.⁶ The construction of new examples came largely to an end by the early fourth century CE after having diminished substantially over the course of the third. This basic outline of amphitheater chronology is well known, as is the uneven distribution of these buildings within the territory of the Roman Empire.⁷ There are few in the eastern Mediterranean, many in Italy and central Africa *Pronconsularis*, a large number in Gaul, and relatively fewer in Hispania and Britain. Terms such as “many” and “fewer” are inherently qualitative so that a map (Fig. 1) provides a preliminary basis for their use.

The maps and charts in this article explore these distributions and provide quantitative support for these looser terms. (As an aside, it is interesting, though beyond the scope of the discussion here to try to explain, that no amphitheaters are known from Roman Egypt.) An additional theme of this discussion is how to read the maps and charts it presents.⁸ One observation is important in that regard: A map of Roman amphitheaters is not a map of the only places that gladiatorial combats, animal fights, executions were staged. All of these activities took place in other venues throughout the Roman world.⁹ Instead, a map of amphitheaters is a map

⁶ HEATH 2023.

⁷ BOMGARDNER 2000, 198; DODGE 2009.

⁸ WHITE 2010.

⁹ MANN 2009; ROBERT 1940.



Fig. 2. Trier Amphitheater. The arena is 71 x 41 m. The exterior dimensions are 100 x 79 m. The tourists in and near the arena add useful scale. https://commons.wikimedia.org/wiki/File:20180815_Amphitheatre_Trier_03.jpg.

of one particular form of infrastructure that may well have encouraged a particularly intense experience as the circuit of seats provided excellent views of the violence and, when full, will have intensified the sound of the crowd as they faced each other across the central arena.¹⁰

ESTIMATING TOTAL AMPHITHEATER SEATING CAPACITY

The core methodology used in this article is the estimation of total amphitheater seating capacity on the basis of existing published estimates for individual examples. Looking ahead, this approach suggests that approximately three million seats were built between the early first century BCE and the mid-fourth century CE. Even a very rough calculation shows that this is a plausible number. As noted, the Flavian Amphitheater in Rome, with approximately 50,000 seats, was an outlier. As will be discussed, approximately 11,000 seats is a better roughly estimated representative capacity for amphitheaters as a whole. By very rough math, the calculation $11,000 \times 260$ gives a total of 2,860,000 seats; using 280 gives a total of 3,080,000. Rounding these numbers to 3,000,000 is convenient given that the immediate goal is only to reach an estimate. These two numbers also suggest that despite any details of one's preferred method of estimation - and there

are many options - the number of amphitheater seats was large within the context of an ancient state such as Rome.¹¹ Any time a discrete phenomenon can be described using millions that is potentially noteworthy.

Although the above simple calculation communicates much of the intended contribution of this article, there are reasons to move beyond it. Most fundamentally, using 11,000 or any similar value as a representative estimate conceals the great diversity of amphitheater sizes and capacities. The smallest can be as little as 1000 seats, itself too round a number. Towards the other end, at least 35 amphitheaters plausibly had seats for 20,000 or more spectators. Within this set of large amphitheaters are occasional giant examples. The Flavian Amphitheater is again the outstanding instance. Other large examples are those at Bordeaux, Capua, Pula, and Verona. More normal is the amphitheater at Trier (fig. 2) with an estimated seating capacity of approximately 9000 and exterior dimensions of 100 x 79 m.¹²

An emphasis on the variability of amphitheater size is important when addressing the second goal of this note: a preliminary mapping of where the millions of amphitheater seats were located. Assuming a single average capacity would evenly distribute seats among the set so that mapping seating distribution would just map the distribution of structures

¹⁰ COLEMAN 1990; FAGAN 2011; GALINDO/GIRÓN/CEBRIÁN 2020.

¹¹ BOMGARDNER 1993, 386; GOLVIN 1988, 100; HANSON/ORTMAN 2020, 425; WELCH 2009, 53.

¹² KUHNEN 2009.

(fig. 1). As will be seen, the effect of mapping seats is limited from the perspective of divergence from the number of amphitheaters in any one region. For example, 40% of amphitheaters constructed are found within the modern borders of Italy, in comparison to 42% of estimated seating capacity in that same area (Table 1 below). Nonetheless, those numbers are of note. Approximately 40% of both structures and seats is a considerable concentration. Mapping seats therefore contributes to characterizing the concentration of amphitheaters, and the experiences they enabled, within the central Mediterranean.¹³ While it is mainly the intent of this note to report, some interpretation of this observation will come throughout the text, along with more context in the concluding paragraph.

It is important to acknowledge that this study does not start from scratch when collecting data on the seating capacities of individual amphitheaters. Instead, it relies on previous scholarship and makes use of numbers found in earlier publications. In particular, the encyclopedic work of J.-C. Golvin (1988) has been extensively consulted. The capacities given by Bomgardner (2000) are often used in the calculations that follow, particularly for North African buildings. The data has been collected into a single file that is available on the site GitHub and I have also shared the Python code that implements the calculations.¹⁴ The file on GitHub has additional information, including citations to secondary literature, especially when those offered substantially new information on dimensions or seating capacity. The availability of the original data and code will allow future researchers to reproduce or even adapt the quantifications used here.¹⁵

Using prior scholarship has allowed the collection of seating capacity estimates for 152 of the 266 amphitheaters that will contribute to the total capacity. Choosing how to estimate the capacities of the other buildings is essentially the same problem as choosing how to calculate the total number as this single number is just the sum of the individual estimates. In moving towards the estimation of seating capacities that don't rely directly on prior scholarship, one observation is fundamental: The seating capacity of these amphitheaters was not zero. It follows then that a map hoping to explore the distribution of seats must assign a non-zero number to each structure.

In quantitative studies, one generic term for filling in empty data is "imputation".¹⁶ There are many approaches to this problem. It is often considered acceptable simply to take the average of known quantities and fill those in for unknown quantities. In the context of Roman amphitheaters, that would almost certainly be wrong in part because outliers such as the Flavian Amphitheater would affect the number. Because one goal of this note is to generate confidence in readers that the numbers used are plausible, the specific approach adopted here is relatively

easy to explain. Nearest Neighbors estimation consists of considering what information is known for amphitheaters for which no capacity is given and comparing that set of observations to amphitheaters for which an estimation has been provided. Accordingly, "Nearness" in this context refers to similarity of measurements, not spatial proximity. If all that is known is the maximum exterior length of an amphitheater, then capacity will be derived from the amphitheaters with the most similar exterior lengths for which an estimated capacity is available. If exterior length and arena length are known, then both those measurements will be used to establish which known estimated capacities to use in turn when generating the new number. For this article, the open-source Python programming language module SciLearn provides the implementation of Nearest Neighbors estimation. Readers who are comfortable doing so can look at the implementation there in more detail.¹⁷ My intent, however, is that even readers who don't take that step will understand the general approach by which the estimated capacities were generated for the 114 amphitheaters with no estimate recorded in the dataset. Including rounded figures for all amphitheaters in the sum of estimated capacities results in a total of 3,041,400. Again, that is only an estimate, but I do not think that any other reasonable approach will deviate from this dramatically.

A few examples will make the process more clear. Only the exterior dimensions of the amphitheater at Asculum in Italy are known. Its maximum length is 148 meters, and the shorter length of its oval form is 125 m. Those are quite large numbers. The Nearest Neighbors estimation (NN) assigned a seating capacity of 25,700 to the structure when rounded to the nearest hundred. That is a plausible number given that Golvin estimates the amphitheater at Aquileia, which has an exterior dimension 142 x 118 m, to have been approximately 26,100. It is important to stress that the 25,700 is not being used in isolation. It is contributing to a total number of millions of seats and then to visualizing and mapping those distributions at large scale. Accordingly, a thousand more or a thousand less for this one structure will not change the overall picture. At Puppit in North Africa, only the arena dimensions are known (45 x 36 m). NN gives 7000. That again is reasonable given that the amphitheater at Seressi, also in Proconsularis and with arena dimensions of 52 x 41 m, has an estimate of 7,200. The match is again not perfect, and it is not the goal to be. With those arena dimensions, Puppit is likely not a 20,000 seat amphitheater nor a 5,000 seat one. Accordingly, well under 10,000 seats works well. One last example can also build familiarity with the approach. The large imperial amphitheater at Capua was built very close to an earlier republican structure that it replaced.¹⁸ The later building is one of the relatively rare massive examples at 165 x 135 meters exterior dimensions and an estimated seating capacity of 37,000. The republican structure lay just a few meters to the south and excavation has allowed exterior

¹³ BENEFIEL 2016, 446.

¹⁴ <https://github.com/roman-amphitheaters/roman-amphitheaters>.

The archive that accompanies this article includes the data file *roman-amphitheaters.csv*, on which the quantifications discussed here are based.

¹⁵ MARWICK 2017; MARWICK *et al.* 2017; HEATH 2021; 2022.

¹⁶ <https://stats.oecd.org/glossary/detail.asp?ID=3406>.

¹⁷ <https://scikit-learn.org/stable/modules/generated/sklearn.impute.KNNImputer.html> and <https://scikit-learn.org/stable/modules/impute.html#knnimpute>.

¹⁸ TUCK 2007.

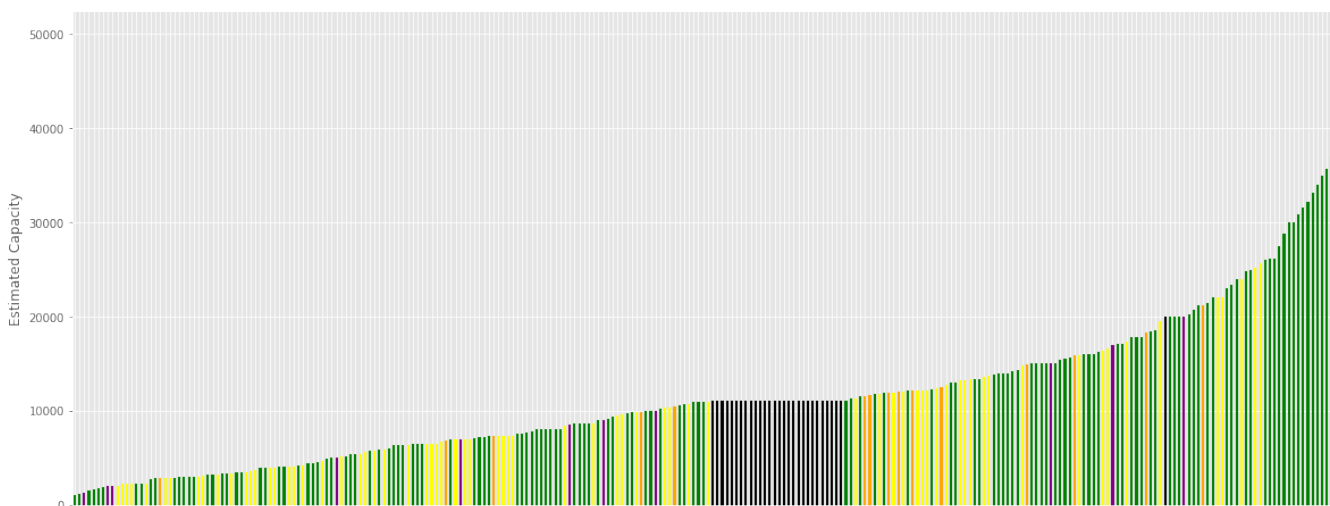


Fig. 3. Index plot of estimated seating capacities

dimensions of 112 x 81 meters to be restored.¹⁹ Using these numbers NN derives a capacity of 12,400. This is more than the recorded 11,900 estimated capacity of the amphitheater at Imola in Italy, which has exterior dimensions of 108 x 81 m, and less than the estimated 13,400 capacity of near Salona in Croatia, which has exterior dimensions of 125 x 101 m. Within the context of two similarly and better preserved structures and by comparison to its massive replacement, an estimated capacity of 12,400 for the Republican amphitheater at Capua is reasonable, especially when it is used within the context of all other estimations.

It is also important, to acknowledge, and even to stress, that this is a fundamentally circular exercise. Ancient textual evidence provides only a loose guide that is usually not accepted at face value. The collapse of a wooden amphitheater at Fidenae is reported to have caused either 20,000 or 50,000 casualties (Suet. *Tiber.* 40; Tac. *Ann.* IV. 63).²⁰ The *Chronicle of 354* in its description of Regio III of the city of Rome states simply that the capacity of the Flavian Amphitheater was 87,000. All these numbers, particularly the last, have been deemed high.²¹ As noted, 50,000 is the conventional estimate of capacity in the Flavian Amphitheater.²² Nonetheless, this evidence does allow for the order of magnitude for the number of spectators that amphitheaters, either temporary or permanent, could hold to be in the tens of thousands. Within this general framework of seating capacities ranging from 1,000 to 50,000, prior scholarship provides many estimates. Again, these broadly plausible numbers can be the basis of deriving likewise plausible numbers for structures for which seating capacities are not recorded in the dataset. In the calculations for this article, I have excluded known capacities greater than 30,000 as they would skew the imputed towards the high end of plausible estimates. The combined numbers - both those recorded in the dataset and those calculated by Nearest Neighbors estimation - can then contribute to calculating an estimated total and then

to mapping the distribution. As emphasized, there is no escaping the circularity of the process, but this is often the nature of ancient quantitatively informed investigations.²³

VISUALIZING AMPHITHEATER ESTIMATED SEATING CAPACITY

Figure 3 is a visualization of all amphitheaters estimated seating capacities, both those based on prior scholarship and those calculated for this study using Nearest Neighbors estimation. The height of each bar indicates the capacity, and the bars are arranged in ascending order from left to right. Beyond showing the range of values (from 1000 to 50000 including the single egregious bar at the right for the Flavian Amphitheater in Rome), it colors each bar to indicate how the information was derived. Green means that a plausible source for the capacity was found and that the following four dimensions of the structure are known: the length of the major axis of the exterior oval, the minor axis of the same, the length of the arena major axis, and the arena minor axis. Yellow means that at least one of these dimensions is known so that the number is a derived value. Purple indicates that I have accepted an estimation of seating capacity even though not all four dimensions are known. Orange means that the four dimensions are known but no estimated capacity is recorded so that the number is a derived value. With one exception, black means that only the location is recorded for a structure. This is the case, for example, at Thuburbo Mais (modern Tebourba in Tunisia) where the amphitheater was entirely destroyed in the late seventeenth century CE.²⁴ The exception is the amphitheater at Nazili in Turkey, recently re-investigated and which is the black bar at 20,000. The other black bars indicate an estimated capacity of 10,900, which is the median of the capacities that can be imputed using at least one dimension

¹⁹ SAMPAOLO 2010, 79.

²⁰ NAPOLITANO/MONCE 2018.

²¹ PLATNER/ASHBY 1929, 6–11.

²² ELKINS 2019, 51.

²³ BOWMAN/WILSON 2009, 14.

²⁴ GOLVIN 1988, no. 69; GREENHALGH 2015 offers details on the destruction of amphitheaters in France, though it is the case that recent work is recovering dimensions for almost completely removed structures; see BERTHELOT *et al.* 2018 for Reims.

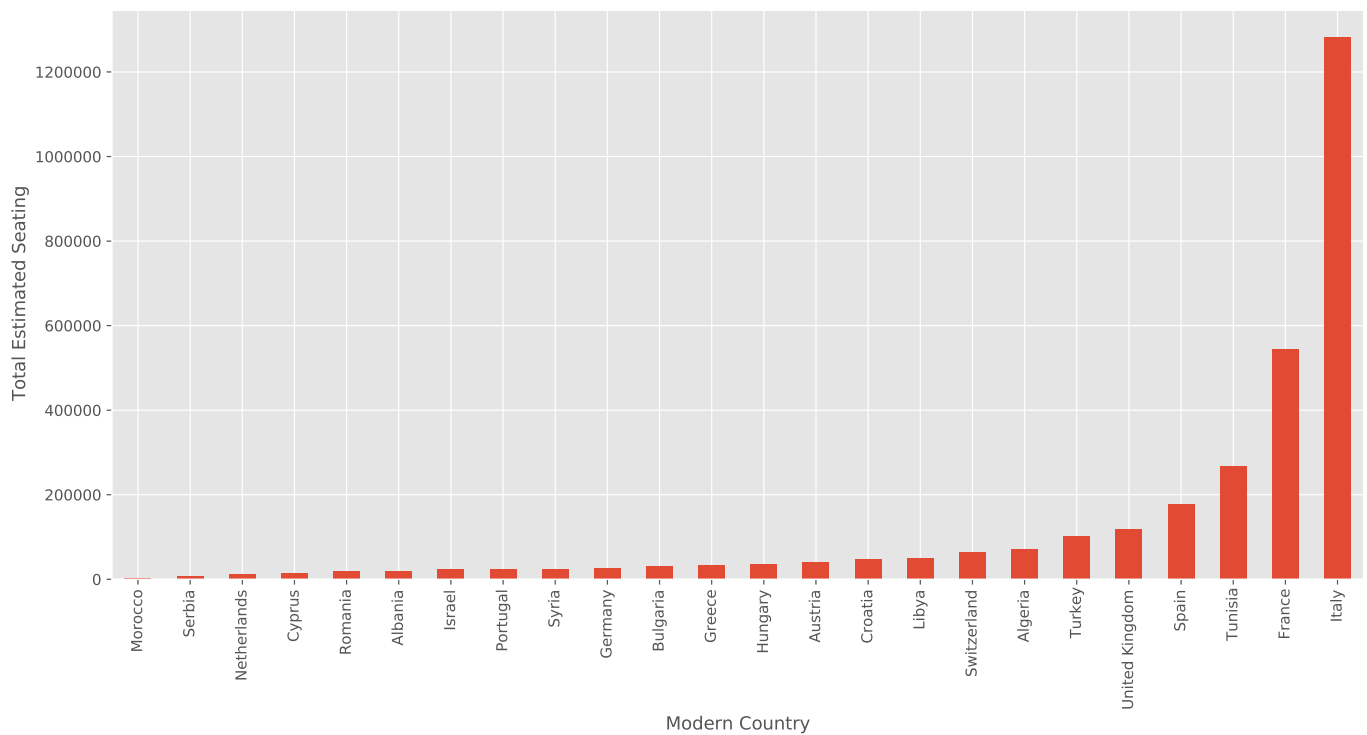


Fig. 4. Distribution of amphitheater seating by modern country

and also the basis for rounding to 11,000 in the initial rough calculation above. The color, the identical value, and that value being the mean does create a very visible distortion in the middle of the chart. I do not mean to hide that. Readers can take that block of values as a reminder that all these numbers are only estimates.

Another clear artifact of the data collection is the bump near 20,000 towards the right. That exact round number has been used in the chart for three amphitheatres for which all four dimensions are known and for one amphitheater - the recently investigated example at Nazilli in Turkey noted above - for which there are not yet precise measurements, but which is clearly a fairly large provincial venue²⁵ Given these artifacts of how the data was collected and processed, this chart is meant to be understood as an overview. It should be read for the forest and not for the trees. And one aspect of seeing these numbers as a group is the observation that the middle range - so excluding the top and lower quartiles - falls between 6000 and 14000 when rounded to the thousands. That is a large range so can

hardly be called a “standard size” but in combination with a median size of 10,900 it does help to characterize what can be considered a typical and unremarkable structure in the Roman world.

As suggested, this variability in capacities makes the question of where these seats are located an adjacent avenue of exploration. Figure 4 and Table 1 start that process. Figure 4 visualizes the distribution of seats within the Roman empire as grouped by their presence within the territory of a modern country. It is an aspect of long term history in the Mediterranean basin that these boundaries have some correlation with the major geographic divisions of Roman territory during the imperial period so that this grouping is offered as a convenience for readers. This observation is especially the case for Italy, France, Spain, and the United Kingdom, which largely overlap with ancient Italy, Gaul, Hispania, and Britannia. For its part, Tunisia is a good proxy for the central region of Africa Proconsularis. Table 1 lists estimated numbers of seats and percentage of the total for those countries with more than 2 percent of that total. It

Tab. 1. Seating capacity and amphitheater counts in the five modern countries with the greatest number of seats.

Country	Total Estimated Capacity	Count of Amphitheatres	Capacity Percent in Country	Count Percent in Country
Italy	1,282,000	107	42	40
France	545,200	35	18	13
Tunisia	266,900	29	9	11
Spain	178,400	15	6	6
United Kingdom	117,600	15	4	6

²⁵ AYDIN İL KÜLTÜR VE TURİZM MÜDÜRLÜĞÜ.

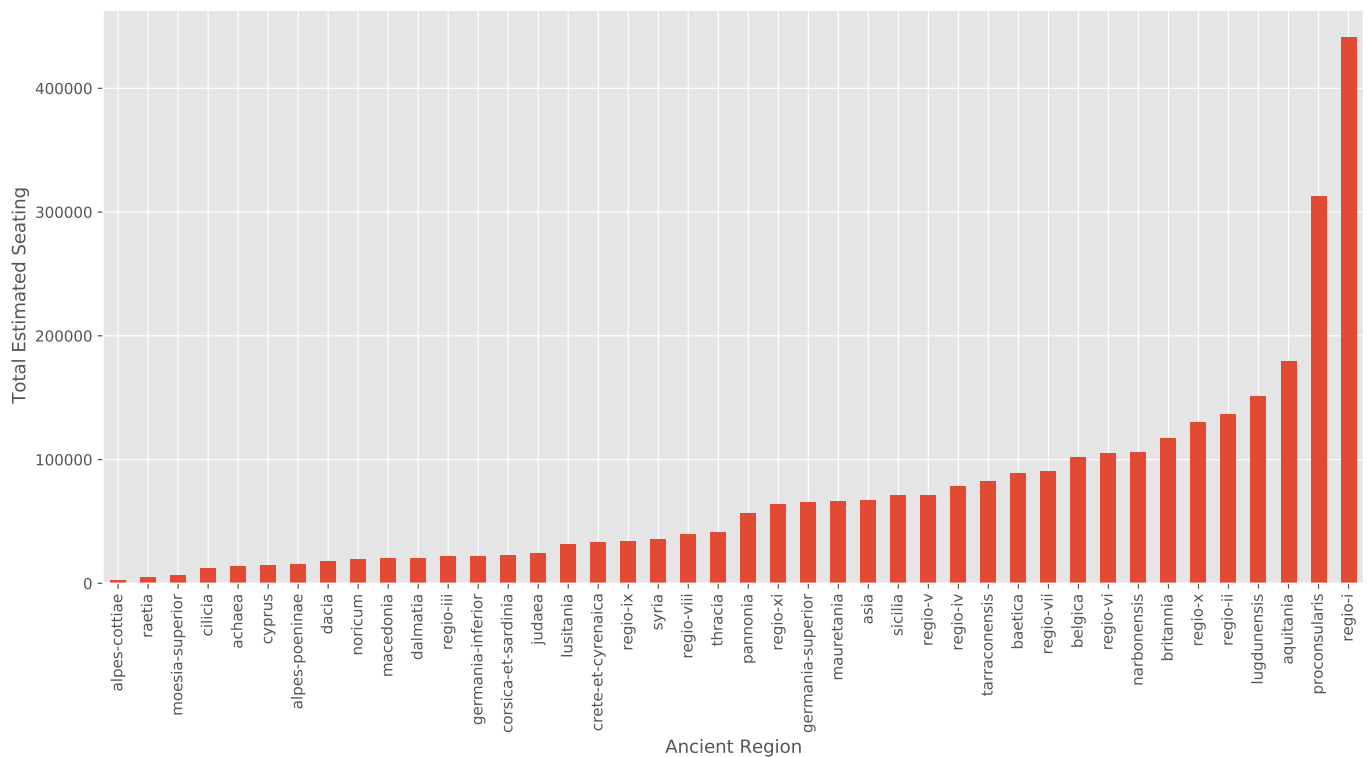


Fig. 5. Estimated amphitheater seating by Roman provinces and Augustan regions of Italy.

Tab. 2. Roman Provinces and Regions of Italy with four percent or more of amphitheater seating capacity.

Province or Augustan Region of Italy	Total Estimated Capacity (rounded to 100s)	Count of Amphitheaters	Capacity Percent in Province or Region	Count Percent in Province or Region
Regio I	441,000	33	14	12
Proconsularis	313,000	32	10	12
Aquitania	179,400	12	6	5
Lugdunensis	151,600	9	5	3
Regio II	136,400	12	4	5
Regio X	130,000	7	4	3

also shows the simple count of amphitheaters by country and the percentage of known amphitheaters in that country. Italy stands out by having over 1.2 million seats, which is 42 percent. It also has 40 percent of known structures. By any reckoning, that is a large share.

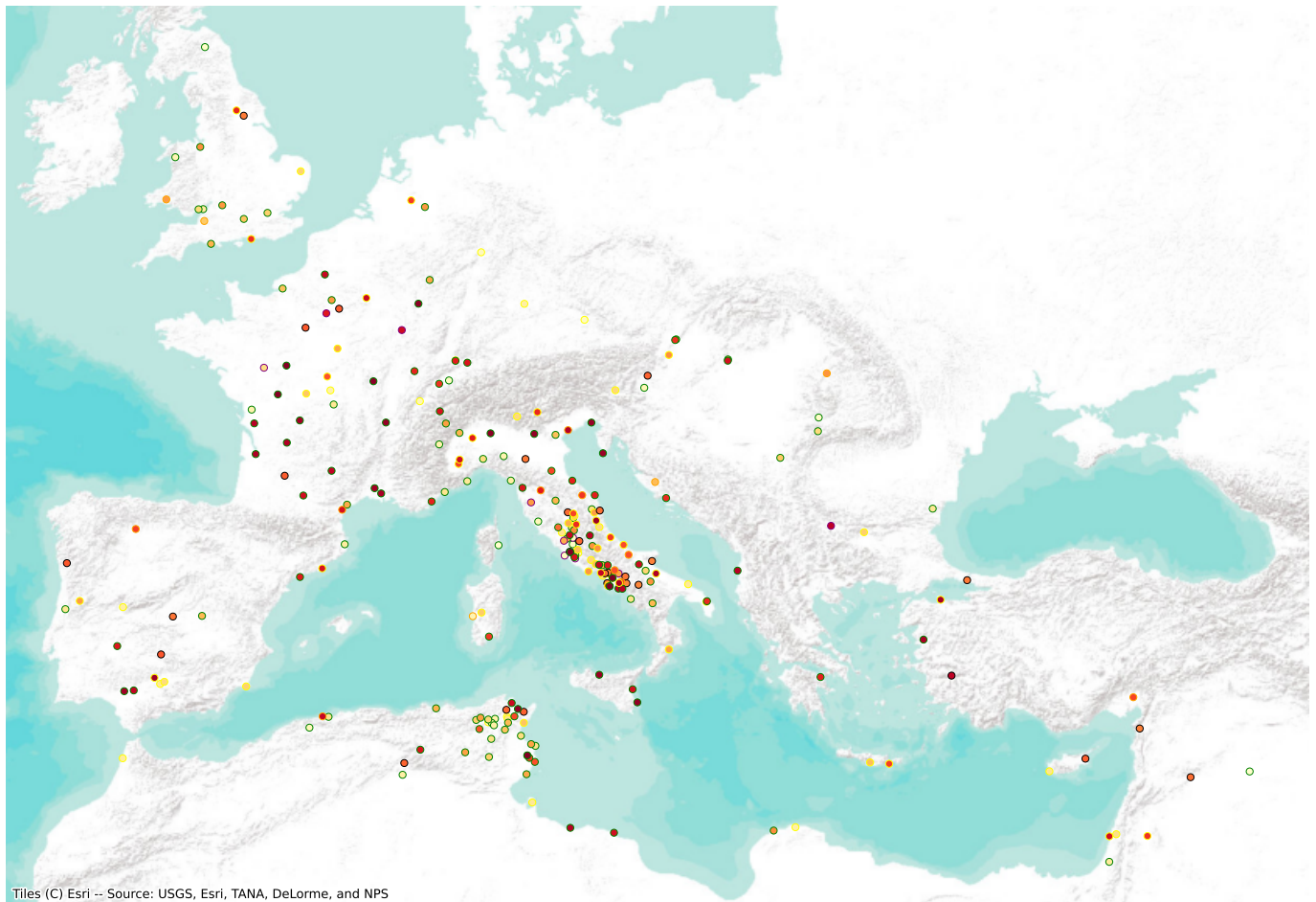
For readers comfortable with ancient geographic nomenclature, Figure 5 and Table 2 present seating capacity grouped by either the Augustan regions of Italy or by Roman provinces. The provincial divisions adapt the list of provinces as known for the second century. Figure 5 cannot be read as only a more detailed version of figure 4 as the regions here are not simple subdivisions of modern countries. It is instead an alternate view with its own strengths and weaknesses. In this rendering, it is Regio I (*Latium et Campania*) that stands out, with 14 percent of all seating capacity. Permanent amphitheaters were first built in the southern part of Regio I and that is where seating was always most numerous. Proconsularis, or North Africa, came to have many seats, but not more than Regio I. The numbers keep falling after

these two. Aquitania and Lugdunensis are both relatively large areas of Gaul and their size must be accounted for when noting the seating capacity in each. Looking at either of the maps in this article (figs 1 and 6) shows that the density of amphitheaters is very low in comparison to the densest parts of Italy and Africa. Regio II (*Apulia et Calabria*) and Regio X (*Venetia et Histria*) continue to demonstrate this relatively high concentration of seating capacity in Italy. For the latter, it is the large amphitheater at Pula (in modern Croatia) that moves it into sixth position.²⁶

MAPPING

Figure 6 renders the estimated capacities as a map. It uses a yellow to red colormap for the markers in which the lightest yellow is used for 1000 seats and darkest red for 50,000. The edges of each marker are colored according

²⁶ A convenient reference map for the Augustan regions of Italy is at https://en.wikipedia.org/wiki/Roman_Italy under the heading "Augustan Italy".



Tiles (C) Esri -- Source: USGS, Esri, TANA, DeLorme, and NPS

Fig. 6. Map with amphitheater locations colored by estimated seating capacity. Lightest yellow indicates 1,000 seats, darkest red indicates 50,000. Only the Flavian Amphitheater is that large.

to the scheme used in figure 3 (this detail may be more apparent in the high-resolution PDF that accompanies this article). As a reminder, green - the most common color - means that all four measurements are known, and an estimated seating capacity based on prior scholarship is recorded. There are, of course, many ways of rendering the spatial element of the quantities given in the bar charts shown as figures 4 and 5. And many of those renderings would communicate the same basic point: Modern Italy or Roman Italia (particularly Campania) contained a relatively great concentration of amphitheater seats, often in relatively large structures. North Africa - especially the central part of Proconsularis - also is an area of greater seating, but not to the extent that Italy is given that it has nearly 120,000 fewer seats than Regio I when that Augustan region is taken on its own.²⁷ The fall away after that is sharp. Britannia, Gaul along with a few structures in Germania, and Hispania are correctly recognized as areas that have greater access to the experience of sitting in an amphitheater than do most regions of the Eastern Mediterranean, but that access is observably and demonstrably less than in Latium and Campania or in Proconsularis. These observations are by design qualitative. Any writing of just a few sentences can only hope to communicate a big picture that is a background

²⁷ LAURENCE/CLEARY/SEARS 2011, Ch. 10.

to closer examination of one particular region or even any single structure.

CONCLUSION

All of the above is meant to communicate a reproducible and adaptable approach to characterizing the distribution of amphitheater seats at large geographic scale and without chronological specificity. This last qualification is important.²⁸ There is no single point in time - no year, decade, nor even century - when all of these amphitheater seats were in use simultaneously. The amphitheater at Pompeii had been buried under the ashes of Vesuvius by the time that the Flavian Amphitheater in Rome came to be in regular use in the 80s CE. At Puteoli, Capua, and then later at Thysdrus, large amphitheaters more or less directly replaced smaller earlier structures. The large amphitheater at Thysdrus (modern El Djem) is a late example of this change in that it was built in the early third century CE. Any map or characterization of earlier distributions of seating needs to exclude it. These are specific instances. More generally, to the extent that the largest number of amphitheaters was in use at some point in the second century CE, there are already signs of structures falling out of use for reasons that are often not fully known but presumably reflect some combination of changing local behaviors and historical

²⁸ HEATH 2023.

circumstance. The re-used neolithic ring at Maumbury in England is an unusual case for being a much earlier feature repurposed as an amphitheater and for the relatively short period of time that it functioned as such. By the late second it may well have reverted to being a feature of the landscape, though perhaps a sacred one, rather than a special purpose venue for violent entertainment.²⁹

As fundamental as the uncertainty that attaches to any one structure are the uncertainties that attach to all of them. How often were they used to stage events? How many spectators actually attended any one event?³⁰ These questions are not answerable with any great and universally applicable specificity. Accordingly, the maps and figures here can only be a starting point for discussion. This is particularly the case because work on the dataset is ongoing. Seeing big history, or any history, in these visualizations requires nuance. While amphitheaters are properly understood as an important aspect of the Roman Empire, the unequal distribution of seating shown here emphasizes variability throughout Roman territory.³¹ Therefore, no single narrative is offered. Instead, I mean this article as a shared stopping point along many paths of inquiry, including those that integrate digital resources in a reproducible fashion.³²

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²⁹ WILMOTT 2008, 107.

³⁰ HANSON/ORTMAN 2020, 425; GUTIERREZ *et al.* 2007, 185.

³¹ e.g. NOREÑA 2010, 541; GARNSEY/SALLER 2015, 218.

³² BAGNALL/HEATH 2018.

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