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PATRIK KLINGBORG

The development of the water supply on the Peloponnese in Greco-Roman times

Abstract
It has long been clear that the water supply in ancient Greece was transformed over time, with the relative number of various types of water sources varying in time and space. Yet, what patterns this produced has never been explored, and the degree to which trends suggested by local or qualitative studies are representative for larger areas and patterns is unknown. The root of this uncertainty lies largely in the difficulty assembling an extensive and representative material beyond individual sites or cities. Following this, the present article has two aims. The first is to test and evaluate a method for collecting an extensive and (more) representative material for the investigation of the water supply in ancient Greece on a regional scale, based on a systematic review of the material from the Peloponnese published in *Archaeological Reports* 1887–2012. The second aim is to discuss how the collected data can be used to explore the transformations of the water supply systems on the Peloponnese in the period 900 BC–AD 300. Together the results are intended to develop further the *WaterWorks* project, which aims to create a better understanding of the development of the ancient water supply. The method produced a considerably better dataset than previously available. The dataset, recorded in an Access database, suggests that some hitherto acknowledged trends are probably valid for larger areas while others are less prominent than previously believed. However, in the end, the dataset is too limited to allow firm conclusions concerning how, and to a larger degree why, the water supply system was transformed over time. The dataset will be made publicly accessible in an open access repository.*

Keywords: climate, diachronic, Peloponnese, percipiation, water supply

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Introduction

It has long been known that the composition of the ancient Greek water supply changed over time, but so far the phenomenon remains unexplored based on a relevant empirical material. Early scholars noted, using literary accounts, that many fountains were constructed during the Late Archaic period.[1] While it was not discussed at the time, the notion of these fountains as a new and increasingly important component of the water supply implied that the system as a whole, regardless of its previous composition, was transformed. Implicitly, this would have allowed new habits of accessing and using water to develop. Similarly, large-scale aqueducts have always been associated with Imperial Roman times, again often perceived as fundamentally changing the basic access to fresh water in innumerable cities in the Mediterranean and beyond.[2]

The same phenomenon has also been acknowledged for less monumental structures such as regular wells and cisterns since the late 1970s through John Camp's Ph.D. thesis *The water supply of ancient Athens from 3000 to 86 B.C.* In this, Camp highlighted that new wells in the area of the Athenian Agora became deeper over time until the 4th century BC when suddenly almost no new wells were constructed and, instead, cisterns rapidly became common.[3]

Importantly, Camp engaged in explaining *why* cisterns in the early 4th century BC largely replaced wells. Based on the

* I would like to thank Enboms Donationsfond for the generous funding that made the data collection for this study possible. I am also grateful for the encouraging comments by Erika Weiberg, Anton Bonnier and Martin Finné during their 2022 Navarino Environmental Observatory workshop, the feedback from Irene Vikatou, comments by the Higher Seminar in Classical Archaeology in Uppsala and in particular the detailed feedback on a draft version of this paper by Roser Marsal and Filmo Verhagen. A link to the dataset will be made accessible through the author's ORCID-profile (https://orcid.org/0000-0002-2146-3659).

[1] Late 6th century BC until 480 BC. See e.g., Richardson 1900, 471; Elderkin 1910, 19.

[2] See e.g., S. Kerschbaum (2021, 18) who assumes that aqueducts provided a previously unknown volume of high-quality water.

[3] Camp 1977.

incrementally increasing depth of the wells and supported by a small number of literary and epigraphic texts, he concluded that this change was caused by a 4th-century BC drought.[4] In Camp's model, cisterns were thus constructed to compensate for the lack of new wells, as well as a replacement for wells that dried up. While Camp's hypothetical 4th-century BC drought has come under critique and may not have existed,[5] he posed and explored two important, and intertwined, questions: 1) how the water supply system in ancient Athens was transformed over time, and, 2) in particular, *why* it was transformed.

As regards the first question, while several overviews of ancient water supply systems have been published since Camp's study, these have either taken a wide perspective such as the entire Greek world based on a limited material, or a more restricted local focus, usually on a specific site.[6] This has produced excellent insights into local trends but contributed little to our overall understanding of how the water supply systems were transformed on a regional or wider scale. Ultimately it is unclear how representative the development of the water supply at sites such as Athens, Pergamon or Miletos is for overall tendencies in the Greek world.

Furthermore, the results of these locally focused studies have rarely had a major impact on larger overviews which have remained generalizing, based mainly on a small number of well-known installations and developments.[7] Here the key issue has been that it is difficult to collect a large enough dataset to produce an overview even for smaller areas, not to mention larger ones. For example, for his Ph.D. thesis, Mark Landon initially intended to investigate all of the water infrastructure in ancient Corinth, but after a year of going through the available material, he concluded that it was far too vast.[8] As a result, he limited himself to the unpublished fountains in the city and its immediate surroundings.[9]

The result of the difficulty collecting larger datasets has been that the second question posed above, *why* the water supply was transformed, remains largely unexplored beyond a local scale. It is, therefore, difficult to evaluate if local developments correspond to larger overarching trends or not. Are developments in Athens and Pergamon driven by the same mechanisms? What impact did the climate have on the choice of water source? What influence did the local geophysical landscape have? To what degree were social factors decisive?

While this article cannot deal with the second question in detail, as a considerably larger investigation would be required, it can begin to move in this direction through two goals. The first goal is to test a method for collecting an extensive and representative dataset for the investigation of the water supply on a regional scale in Greece, using the Peloponnese as a testbed. This region was chosen due to its large but relatively manageable size, well-explored archaeology, and varied natural conditions in terms of geology, landscape, climate and population density. The second goal is to discuss how the collected data can be used to explore the transformations of the water supply systems on the Peloponnese from 900 BC to AD 300. This chronological framework was suitable due to the nature of the material collected, which has been shaped by the interest of modern scholars, who largely focused on Archaic–Roman times while paying less attention to Byzantine and Ottoman remains. Together the results are intended to further develop the *WaterWorks* project, which aims to create a better understanding of the development of the ancient Greek water supply.

MATERIAL COLLECTION METHOD

When performing a regional study on the water supply in ancient Greece, exploring material site by site is not a suitable strategy, both for practical and methodological reasons. In terms of the former, it is not possible to examine all the relevant literature for even a small number of sites in a region to provide an overview. This approach would, therefore, necessarily lead to a selection of sites (presumably primarily thoroughly explored and well-published ones), thus creating

4 Camp 1977, 147–148, 156–157; 1982. J. Camp cites Dem. 34.37, 50.61; *Olynthic.* 3.29, as well as several inscriptions concerned with the supply of grain, which is interpreted as a reaction to failing crops due to the posited drought. This hypothetical drought is commonly, and often uncritically, viewed as a fact in Classical scholarship; see e.g., Crouch 1993, 66; Oliver 2007, 41–42; Christaki *et al.* 2017; Kerschbaum 2021, 140; Stroszeck 2021, 110–111.

5 Sallares 1991, 392–393; Holloway 2004, 49; Klingborg 2017, 129–131. See Finné & Labuhn 2023 for a recent overview of climate data from ancient Greece and how to interpret it.

6 For overviews, see e.g., Tölle-Kastenbein 1990; Wikander 2000. For specific sites see e.g., *AvP* I:4; Tuttahs 2007; Wellbrock 2016. In other cases, the sheer volume of material has overwhelmed scholars, prompting a narrower focus, see e.g., Landon 1994, 2–4. Additionally, in a parallel track, there have been studies focusing on specific types of water sources, primarily fountains and nymphaea (e.g., Aristodemou & Tassios 2018), but also aqueducts (e.g., Rogers 2015; Aristodemou & Tassios 2018) and recently cisterns (e.g., Brinker 1990; Klingborg 2017; 2019; 2021; 2023; Stroszeck 2023; Commito 2024; Millar Tully 2024) and to some degree wells (e.g., Kimmey 2017; 2023; Stroszeck 2017; Millar Tully 2024). For a regional level study, see Kaiafa-Saropoulou 2008 who discusses the water supply in Macedonia during Hellenistic and Roman times.

7 Tölle-Kastenbein 1990.

8 Landon 1994, 2–4.

9 This further shows how there has been a tendency within the study of the ancient water supply to focus on monumental structures.

methodological issues.[10] Another issue is that at most sites, only monumental structures have been systematically published.[11] Therefore, using a selection of sites—in practice presumably a selection of large urban sites and sanctuaries—is not suitable when investigating what water sources were used over a large region over time.

As an alternative, a systematic inventory of all water sources and bath complexes on the Peloponnese reported in *Archaeological Reports* (henceforth *AR*) by the British School at Athens between 1887 and 2012 was performed for this study.[12] Bath complexes were included because while they are not water sources they can be viewed as a proxy for water consumption due to their thirsty nature and, consequently, the need for water sources.[13] Due to the format of *AR* with brief reports on a large number of fieldwork projects on an annual basis presented per region, it was possible to tap into a considerable and diverse material.[14] At the same time, using *AR*, it was accepted that the level of detail would not correspond to that of a qualitative study focusing more closely on one or a small number of sites. Because of the method, the terminology for the material was also somewhat inconsistent, and some installations had to be redesignated. For example, water-tanks, often reported for Roman contexts, have been relabelled cisterns when interpreted as functioning as such. Aqueduct has been used for all long-distance conduits leading water from a source to a use point regardless of period and architectural form in order to avoid a fractured dataset. Similarly, fountains and nymphaea were combined.[15]

Each installation was recorded first by sub-region (Corinthia, Argolis, Laconia, Messenia, Elis, Achaia and Arcadia), then site and finally specific location (*Fig. 1*).[16] Chronologically, the centuries during which it operated were recorded.[17] The chronology often caused difficulties, since in many cases there was no such data available. As a result, many installations were not included in the analysis. In other cases, only a fill date, or date of construction, was given, limiting the attested period of use for the installations.[18] For Roman era installations, a general date was often provided, commonly Roman or Late Roman. In the absence of more exact information, Roman has been interpreted as 1st–3rd centuries AD, Early Roman as the 1st century AD, Middle Roman as the 2nd–3rd centuries AD and Later Roman as the 3rd century AD onwards. The latter was used in order to distinguish it from early the Byzantine period, sometimes viewed as beginning in the 4th century AD.[19] That being said, many Late Roman installations were likely constructed, or at least continued to be in use, during the 4th century AD.

Lastly, it was critical to define the terms for the various water installations.[20] In the dataset, seven types of water sources (i.e., any natural or man-made feature producing water) are included: wells, cisterns, fountains, reservoirs, aqueducts, springs and "waterworks".[21] Wells are artificial water sources—usually shafts—dug into the ground until they reach the water table, from which they are fed. This means water is con-

[10] For example, using such a method, the 240 wells at Olympia, mainly dating to Archaic times, would effectively overshadow the material from all other sites during the period. This does not mean that these wells are not important when discussing the Archaic water supply, but Olympia is not representative of the general development at sites or sanctuaries at the time. See *OlBer* 11, 195, fig. 112; Kyrieleis 2011, 114.

[11] For example, in Corinth, the fountains are almost without exception published (*Corinth* I:6; Landon 1994). On the other hand, the roughly 600 other water installations at the site are only sporadically treated and rarely in detail (Landon 1994, 3).

[12] The series was transformed from 2012 onwards "into a review of new discoveries and trends [which] gives greater scope for the BSA Director's introduction to focus on the climate in which the past year's research has been conducted" (*AR* 2012, 1). While the traditional format largely still exists in an online version (now found under https://chronique.efa.gr), with benefits such as a search function, the move from a long-standing format made 2012 a suitable year to end the material collection. As stated above, the dataset used in this study will be published separately, and accessible via a link at the author's ORCID-page (https://orcid.org/0000-0002-2146-3659).

[13] For the relationship between aqueducts and monumental water structures, see Richard 2012, 60–80; Oulkeroglou 2018.

[14] The *Chronique* by the French School at Athens, similar in scope and format to *AR*, would have been equally suitable. Drawing data from both series was deemed too work intensive considering their overlapping nature. Using *Αρχαιολογικόν Δελτίον*, which also reports annually on excavations but in much greater detail, would have provided a considerably better source material. However, the massive effort required to collect the data made this impossible for the present study. Based on the results of this article the material in *Αρχαιολογικόν Δελτίον* is currently being collected for the more extensive *WaterWorks* project.

[15] For the difficulties using the terms fountain and nymphaeum, see Ginouvés 1998, 92–100; Agusta-Boularot 2001, 168–170; Dorl-Klingenschmid 2001, 18–20; Richard 2012, 7–34; Rogers 2015, 13; 2018, 173–174.

[16] The extent of the sub-regions is never specified in *AR* and do not fully overlap with modern notions.

[17] For example, a water source dated to 350–150 BC has been recorded for the 4th–2nd centuries BC.

[18] E.g., nos **1**, **133**, **462**. Throughout, numbers given in bold refer to the entries in the Access database.

[19] E.g., Baldwin 1982, 1, with discussion.

[20] For previous discussions on the terminology for water sources, see Bonnie & Klingborg 2024, 2; Klingborg 2017, 4; Ginouvés 1998, 92–100.

[21] Watercourses were not included as they are few and the degree to which they contributed to the water supply is practically unknown due to a lack of evidence.

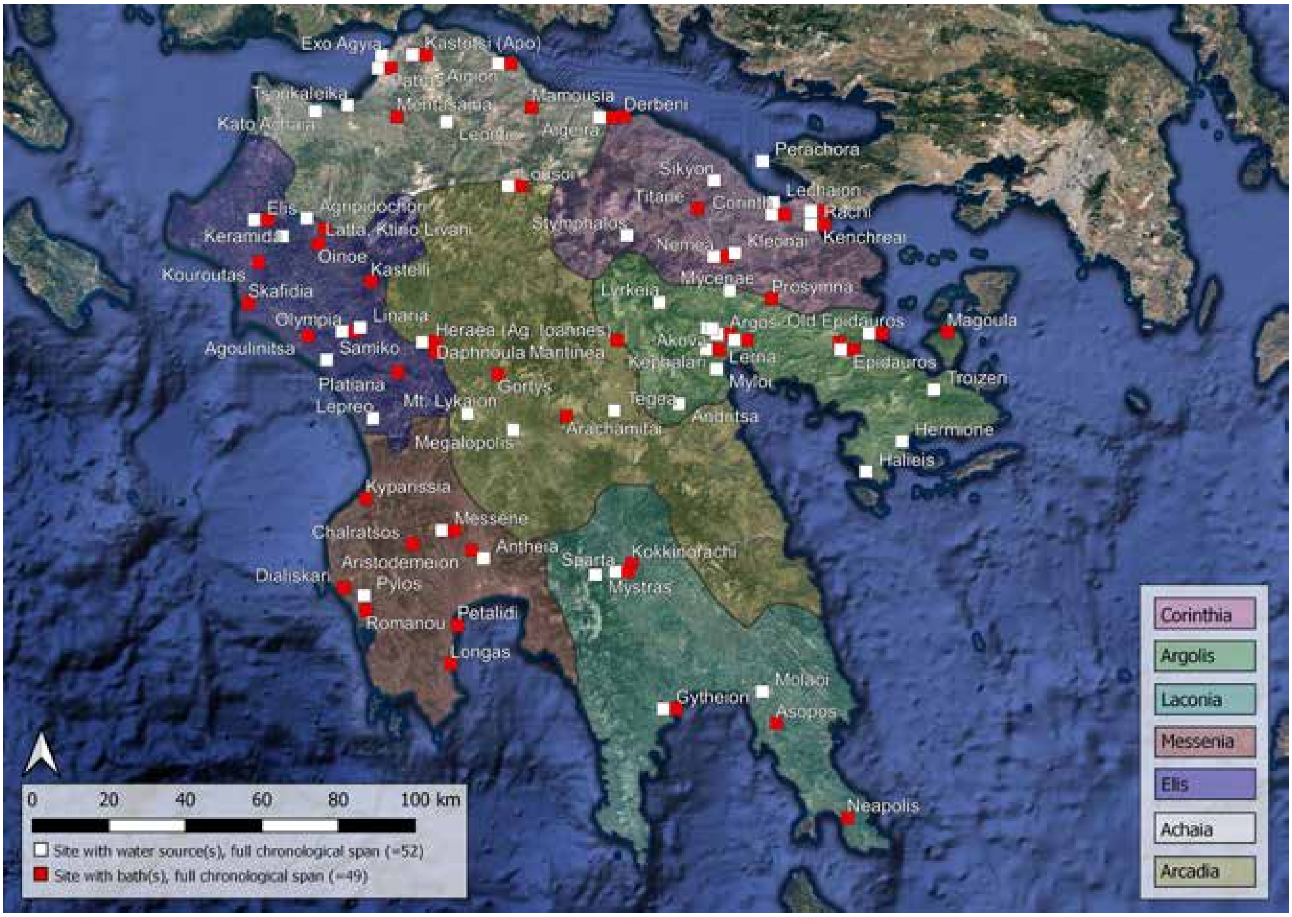

Fig. 1. Sites with water source(s) and bath(s), full chronological span, with the approximate extent of the regions. Illustration: Patrik Klingborg.

stantly "produced", although the water level may rise or recede over time. The water tends to be drawn from one, or in rare cases several, delimited horizontal openings. Wells may be interconnected with other wells or cisterns, e.g., for receiving overflow.[22] Cisterns, on the other hand, are statically situated waterproof containers constructed above or below ground to store water.[23] Cisterns hold water received from an external source—usually rainwater—and are not intended to receive a constant inflow or facilitate constant outflow. Installations with a constant inflow and outflow may instead be referred to as reservoirs, usually receiving water from an aqueduct. Aqueduct designates systems of conduits transporting water from a (distant) source to the point of use or distribution.[24] The exact type of conduit used is irrelevant, as regardless of the scale or construction technique the basic function of moving running water is the same.

The term fountain (including nymphaea here), describes a built structure with running water, usually called κρήνη in ancient Greek.[25] While a *krene* often resembled what is today called a fountain, the two are not always identical. Instead, *krene* designated an artificially modified water source with added and more monumentalized features (although they are often quite modest in practice), such as a basin, roof or staircase. Whether the water originated from a spring, stream or well was not a concern. On the other hand, a spring (πηγή

[22] Klingborg 2023, 13–14.

[23] Klingborg 2017, 5–6; 2023, 11–13. This definition is mostly in agreement with W. Brinker's definition (1990, 3–4). See also Hellmann 1994, 273. For a less exact definition, see Biernacka-Lubańska 1977, 27.

[24] Definition adapted from Hodge 2000, 40. This gives the curious result that there is a 9th-century BC aqueduct in the current material.

[25] Wycherley 1937; Tölle-Kastenbein 1985. For an extensive study of Greek fountains and nymphaea, see Aristodemou 2012. For the terminology of nymphaea, see *Note 15* above.

in ancient Greek) is a naturally occurring, unmodified source where water naturally streams from the ground or bedrock. Occasionally human intervention increased the output of fountains and springs by excavating tunnels to get better access to the water table. The geological reasons behind springs vary, but on the Peloponnese, it is often due to karst formations.[26]

Finally, "waterworks" is an often un- or ill-defined term used in modern literature for a small number of extensive water sources, usually consisting of several shafts interconnected by tunnels, that cannot be classified within the other groups.[27] Often these structures seem to have provided direct access to the water, while the origin of this is unknown in most cases.[28]

DATASET

Following the above outlined methodology, 985 installations, composed of water sources, bath complexes and other water supply structures, were recorded.[29] Of these 35 were located on islands which are not included in the current study.[30] A further 281 were identified as duplicated recordings of the same structures.[31] This results in a total of 671 unique installations.

Of these 671 unique installations, 467 are water sources, 174 are bath complexes, and 30 are other water supply installations. However, not all of these can be used. Many lack chronological information[32] and some reports are too generalizing.[33] This reduces the useful number of installations to 477 from 81 sites, of which 332 are water sources from 52 sites and 145 bath complexes from 49 sites (*Figs 1–3*, *Tables 1–3*).

Table 1. Distribution of the 950 entries.

	Entries	Unique	Used in dataset
Water sources	597	467	332
Baths	319	174	145
Other	34	30	0
Total	**950**	**671**	477

METHODOLOGICAL STRENGTHS AND CHALLENGES

The *AR* material presents a number of strengths and weaknesses. Some of these can be evaluated internally, i.e., based on the material itself, such as its quantity and temporal resolution.[34] Other aspects, particularly how good the coverage is per site, require comparative material. Fortunately, such comparative materials exist for specific types of water sources or sites, collected to be either exhaustive (collecting, as far as possible, all examples of one type of water source)[35] or qualitative (a more in-depth study of a type from one or a number of sites).[36] Notably, the detail in which each installation is recorded is usually higher in both exhaustive and qualitative studies than in the present one.

The method used to collect the material had three important strengths. First, it made it possible to review systematically an extensive material in terms of sites, including otherwise unpublished or largely unknown excavations. It also eliminated the need to select which sites to include, preventing a bias towards well-known water supply systems. Second, while difficult to quantify, it was clear that the process was very time efficient compared to traditional qualitative approaches where sites are explored exhaustively, often requiring months or years.[37] Third, it recorded a substantially larger number of non-monumental water supply installations than in previous studies.[38]

[26] Crouch 1993, 64.

[27] While the term "waterworks" is in many ways confusing, it is used here as it appears in the modern literature. Changing it would only make the situation even more complex.

[28] See e.g., the interconnected system of so-called wells in the South Stoa at Corinth (no. **904**), *Corinth* I:4, 12–17, and the so-called waterworks at Perachora (no. **805**), Tomlinson 1969; 1976.

[29] As noted above, numbers given in bold refers to the entries in the Access database. Four entries (nos **38**, **391**, **648**, **649**) are blank as a closer reading showed that the installations were the result of misinterpretation of the text in *AR*. The total number of entries in the database is thus 989.

[30] Overall, it was difficult to determine which islands should be considered as belonging to the Peloponnese, as well as ensure that the material from these was systematically recorded due to the format of *AR*.

[31] E.g., no. **1** also being recorded in entries **11**, **61**, **68**, **78**, **91**, **162**, **212**, **324**, **372**, **441**, **483**, **875, 879**.

[32] E.g., nos **24**, **75**, **298**.

[33] E.g., no. **140** which refers to bath complexes found in Sparta.

[34] For a discussion on the benefits and drawbacks of long-term perspectives, see Weiberg & Finné 2022, 232–233.

[35] E.g., Glaser 1983 who aimed to catalogue all Greek fountains, Lolos 1997 who lists known Roman aqueducts in modern Greece.

[36] E.g., Klingborg 2017 which collected a large, but far from complete, number of cisterns from 49 sites or Kimmey 2023, investigating all the known wells at the Sanctuary of Zeus at Nemea.

[37] Compare to F. Glaser (1983, 5–6) spending considerable time cataloguing 95 ancient fountains in Greece, M. Landon (1994) who dedicated a year to recording the water installations only in Corinth, and the present author's (Klingborg 2017) four-year project required to catalogue and analyse 410 cisterns in ancient Greek areas.

[38] In comparison, my study of cisterns in the Greek world (Klingborg 2017) was based on 410 cisterns collected through a qualitative method. Of these, 61 cisterns were from 10 sites on the Peloponnese, the majority being from Corinth (70%, n=42). With the current

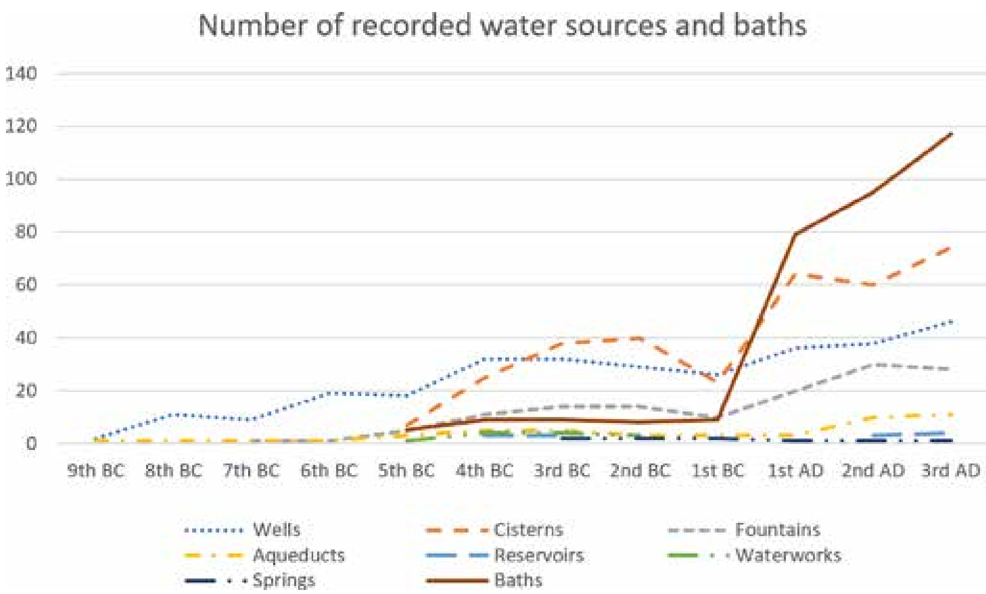

Fig. 2. The recorded number of water sources and baths per century on the Peloponnese. Graph: Patrik Klingborg.

Table 2. The recorded number of water sources and baths per century on the Peloponnese.

Number of recorded water sources and baths													
	BC									AD			
	9th	8th	7th	6th	5th	4th	3rd	2nd	1st	1st	2nd	3rd	Total
Cisterns					7	25	38	40	23	64	60	74	331
Wells	2	11	9	19	18	32	32	29	26	36	38	46	298
Fountains[I]			1	1	5	11	14	14	10	20	30	28	134
Aqueducts	1[II]	1	1	1	3	5	5	3	3	3	10	11	47
Reservoirs						3	3				3	4	13
Waterworks					1	4	4	3					12
Springs							2	2	2	1	1	1	9
Total	**3**	**12**	**11**	**21**	**34**	**80**	**98**	**91**	**64**	**124**	**142**	**164**	**844**
Baths					5	9	9	8	9	79	95	117	331
Overall total	**3**	**12**	**11**	**21**	**39**	**89**	**107**	**99**	**73**	**203**	**237**	**281**	**1,175**

[I] Including Nymphaea.
[II] This is Carl Blegen's Mycenaean aqueduct at Pylos (no. ***420****), also dated to Geometric, Hellenistic and medieval times in* AR*. The same is true for the lone aqueduct in the 8th, 7th, and 6th centuries BC.*

Thus, while qualitative methods record additional water sources per site, this considerably less work-intensive quantitative approach more than doubled the usable material. As importantly, the current material was considerably more widely distributed over the area.

The chronological resolution and monumental bias were two other important aspects. Overall, the chronological data was better than expected. Out of the 671 recorded unique installations, 15% (n=101) did not have any chronological information and could not be used in this study.[39] While the number of excluded installations is substantial, the undated share of the material is surprisingly low, considering how often wells and cisterns are published without chronological data. This suggests that excavators have been prone to primarily report datable material in *AR*.

It is also clear that monumental structures are better represented than less monumental installations. There can be little

methodology, 227 cisterns were recorded on the Peloponnese, out of which 210 were unique installations, and 133 could be placed chronologically. The data also came from a larger number of sites, 30 in total (*Fig. 4*). Corinth was considerably less dominant, representing only 17% (n=23) of the total number of cisterns. Note that the chronological scope of the current study is not identical to that of my 2017 study, which also was not intended to be exhaustive. Presumably, a similar coverage can be expected for wells, although there are no comparative studies available to confirm this.

[39] Other installations were not included in the final material as they were outside the chronological scope or insufficiently well identified.

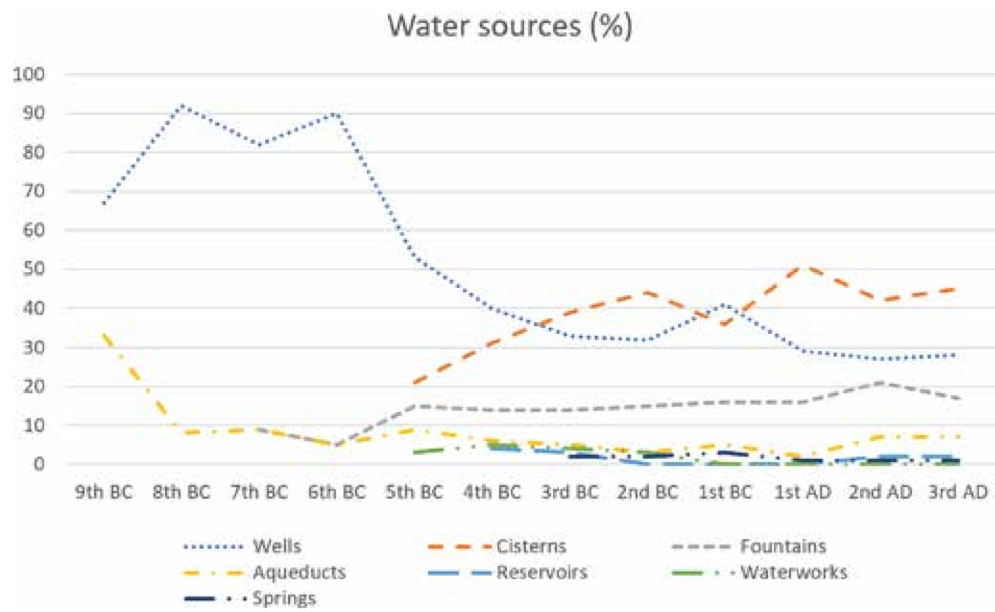

Fig. 3. The relative number of water sources per century on the Peloponnese. Graph: Patrik Klingborg.

Table 3. The relative number of water sources per century on the Peloponnese.

Water sources (%)												
	BC									AD		
	9th	8th	7th	6th	5th	4th	3rd	2nd	1st	1st	2nd	3rd
Cisterns					21%	31%	39%	44%	36%	51%	42%	45%
Wells	67%	92%	82%	90%	53%	40%	33%	32%	41%	29%	27%	28%
Fountains			9%	5%	15%	14%	14%	15%	16%	16%	21%	17%
Aqueducts	33%	8%	9%	5%	9%	6%	5%	3%	5%	2%	7%	7%
Reservoirs						4%	3%				2%	2%
Waterworks					3%	5%	4%	3%				
Springs							2%	2%	3%	1%	1%	1%

doubt that bath complexes (n=145) do not outnumber wells (n=130) on the Peloponnese. Baths are simply more likely to be discovered due to their size and reported upon because of their impressive architecture, ornamentation and associated status. We should expect a similar effect for fountains and nymphaea. However, while impossible to quantify, it seems likely that this skewing is considerably less prominent here than in previous studies.

Two other aspects offered greater challenges: 1) pin-pointing the exact location of many installations and 2) the size of the dataset. Concerning the first, in many cases, the exact location remains unknown. Overall, this was problematic because it made it difficult to account for repeated records of the same feature. A second effect was that because of this, each installation was recorded only at the level of sub-region and site, not its exact location in the landscape, making more detailed analysis impossible.

Finally, while the method produced a substantially larger dataset than previous studies, the material was still too limited for analysis at a sub-regional level where the sample size becomes unsustainably small. In two out of seven regions, the number of water sources is in single digits, while only 50 or fewer were recorded in five regions.[40] Hardly any reliable conclusions can be drawn from such a small sample.

REPRESENTATIVITY

Two critical aspects are how representative the dataset is in regards to what segment of the ancient population had access to the recorded water sources, and how many of the known once-available water sources are reported in *AR*. The first question is important because the overwhelming number of water sources excavated have been discovered in urban settings. For example, 50% (65 out of 130) of the wells in the

[40] Water sources per region: Corinthia 112; Achaia 99; Argolis 50; Laconia 32; Elis 22; Messenia 9; Arcadia 7.

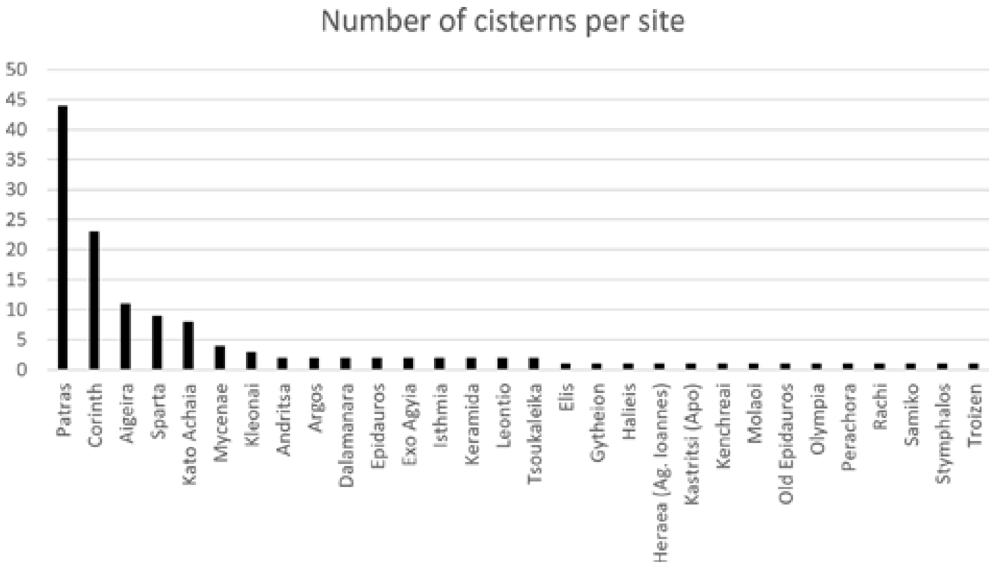

Fig. 4. The number of cisterns per site in the dataset. Graph: Patrik Klingborg.

dataset are located in central Corinth, Argos and Patras, and most others are from other urban sites (*Fig. 5*). At the same time the majority of the ancient population would have lived in the countryside or in villages.[41] It is thus important to remember that the material primarily reflects urban water supply systems, and, to a certain degree a limited number of extensively excavated sites. In contrast, it does not reflect the water supply of the rural population, which presumably relied to a larger degree on natural water sources (springs foremost) and non-monumental installations.

The second aspect is relevant in order to better understand how the current dataset reflects the known water infrastructure. Fortunately, this can be explored as we know how many installations have been found on the Peloponnese (fountains, aqueducts) and at specific sites (wells, cisterns) through previous studies. Concerning fountains, 38 installations from 16 sites were recorded on the Peloponnese by Franz Glaser.[42] The current method recorded slightly more installations (n=39) from 14 sites. However, only 18 fountains are found in both collections (47% of Glaser's material);[43] while the material largely overlaps in some cases, such as at Sikyon, it diverges significantly in others.[44] At Corinth, Glaser recorded 14 fountains, and 10 are mentioned in *AR*. Yet, only seven are included in both datasets.[45] This is unexpected as all of the fountains were excavated by the time of Glaser's study.[46] Some fountains at other sites are not represented either in Glaser or *AR,* such as the one at the Asklepieion in Messene. The relatively equal number of fountains is also a result of twelve installations being discovered in Patras and Sparta and subsequently reported in *AR* but not included in Glaser's study. In comparison, Roman aqueducts are underrepresented in the *AR* material. Only 26% (n=5) of Yannis Lolos' 19 aqueducts on the Peloponnese are mentioned in *AR*.[47] Possibly this is because while Roman aqueducts are monumental, they remain poorly explored in Greece.[48]

Concerning the non-monumental material, as related above, more than twice as many cisterns are recorded using

[41] J. Ober (2015, 86–88) estimates that around 30% of the Greek population in the 4th century BC lived in towns with a population larger than 5,000 inhabitants. Note that this is considerably more than the 10–12% estimated for the Roman imperial world.

[42] Glaser 1983, nos 5, 7, 10–12, 16–17, 23–25, 29–32, 35, 39–46, 52–57, 60–61, 66–67, 75–76, 86, 92, 94.

[43] Nos **2**, **12**, **219**, **402**, **469**, **566**, **612**, **684**, **696**, **728**, **740**, **815**, **914**, **917**, **921**, **923**, **930**, **971**.

[44] Four installations recorded in Glaser 1983 (nos 25, 39–40, 92), three in *AR* (nos **917**, **923**, **971**). F. Glaser no. 25 is not recorded in *AR*.

[45] Glaser 1983, with catalogue numbers: 5 The Cyclopean Fountain, 10 Upper Peirene, 11 Lerna, 16 The fountain on the Agora, 17 In the Abaton of the Asclepieion, 29 Roman South Stoa, 31 The Gymnasium bath, 41 The wall of the ramp of the Asclepieion, 52 Glauke, 54 Peirene, 55 Lerna, 56 Sacred Spring, 61 The East Basin at the Asclepieion, 86 The Fountain of Poseidon. *AR*: nos **2** Peirene, **566** Glauke, **612** The Fountain of Poseidon, **728** The Sacred Spring, **815** The Gymnasium Bath, **816**, Second Gymnasium Fountain, **821** Fountain of the Lamps, **921** The Lerna Fountain, **925** The Cheliotomylos Fountain House, **930** Upper Peirene. F. Glaser and *AR*: Peirene, Glauke, The Fountain of Poseidon, The Sacred Spring, The Gymnasium Bath, The Lerna Fountain, Upper Peirene.

[46] However, many lacked proper publications when F. Glaser undertook his study, see Landon 1994.

[47] Lolos 1997. Nos **255** (Gytheion), **296** (Argos Northern Aqueduct), **320** (Patras), **327** (Sparta), **676** (Corinth).

[48] With the exception of Crete, see Kelly 2004; 2006; Kelly & O'Neill 2023. See also contributions to Aristodemou & Tassios 2018.

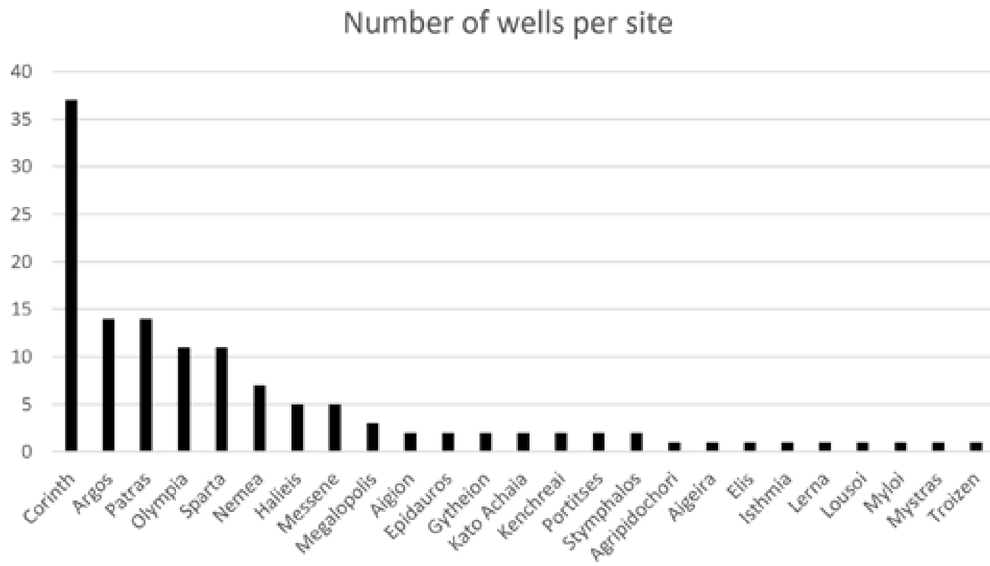

Fig. 5. The number of wells per site in the dataset. See Note 55 *for the low number of wells given for Olympia here. Graph: Patrik Klingborg.*

the current method than in my previous qualitative study (see *Fig. 4* for cisterns per site in this dataset).[49] However, it is also notable that while providing more installations overall, the number of cisterns from specific sites was lower. For example, at Corinth, the number of recorded cisterns was reduced to 23 from 42 analysed by the present author in 2017. While the terminological difficulties when dealing with the water supply installations in Corinth makes it difficult to interpret these figures,[50] they do suggest that the new methodology managed to record about 50% of the installations here compared to a qualitative study. This is significant considering that the previous material collection required a considerably larger effort which could not have been extended to the rest of the Peloponnese.[51] However, at other sites, none of the extant material was recorded, e.g., at Hermione in the Argolid.[52]

The number of wells is more difficult to explore as almost no qualitative or exhaustive studies exist.[53] However, at the Sanctuary of Zeus at Nemea, 12 wells have been excavated, 58% (n=7) of which are mentioned in *AR*.[54] This is comparable to Olympia, with at least 100 wells (42% of a total excavated number of 240 wells) mentioned in *AR*.[55] In this latter case, the sheer number of wells at the site likely prohibited detailed reporting.

The development of the water supply: interpreting the data

The dataset suggests a number of tendencies concerning the general development of the water supply system. The most notable is that the number of water sources identified per century increases constantly with the exception of the 2nd–1st centuries BC (see below, *Fig. 8*).[56] The material also suggests that this growth was largely determined by the number of active wells and cisterns—these consistently represent 70% or more of the available sources. Fountains and nymphaea, on the other hand, represent about 10–15% of the material before Early Imperial times and 15–20% from this point onwards. This is significant because it is likely that these structures are still overrepresented. Consequently, these monumental structures were rare in comparison to less monumental, and usually domestic or private, wells and cisterns.[57]

Presumably many, often interconnected, reasons (that cannot be further explored here) are responsible for this near constant growth of the water supply. That being said, an accumu-

[49] Klingborg 2017. See also *Note 38* above.
[50] Klingborg 2023, 11.
[51] Including a month working with the primary excavation records at Corinth.
[52] Gell 1810, 130; Klingborg 2021.
[53] The lack of studies is noted e.g., in Foxhall *et al*. 2012, 96.
[54] Kimmey 2023, 114.
[55] Note that these wells are only accounted for as 11 entries in the dataset, as the figures given in *AR* for nos **732** ("Wells were found in the EC and LA levels"), **856** ("Forty more of these were cleared and a few have still to be examined") and **862** ("some fifty wells have now been found and of these twenty-five have so far been excavated") are inexact. See Kyrieleis 2011, 114 for the number of wells in Olympia.
[56] A smaller decrease in the 7th century BC, 11 recorded sources, compared to 12 in the 8th century BC, is hardly significant due to the small sample.
[57] Around 85% of the 410 cisterns in the catalogue of P. Klingborg (2017, 108, 110) were located in domestic contexts.

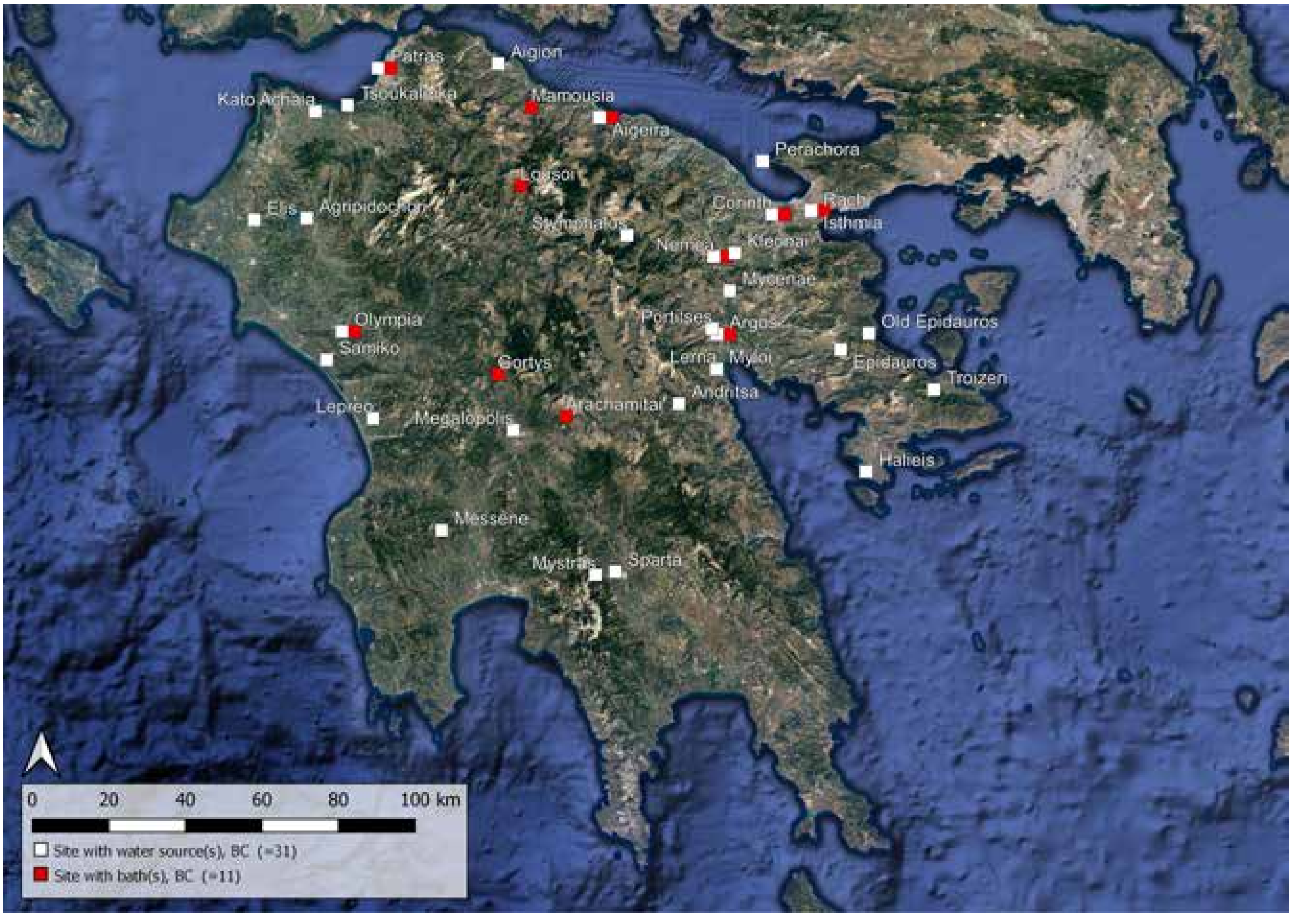

Fig. 6. Site(s) with water sources and/or baths, 9th–1st centuries BC. Illustration: Patrik Klingborg.

lation of water resources is not unexpected considering that these structures were often used for several centuries. Consequently, it is possible that this phenomenon, in terms of an overarching framework, can be viewed from the perspective of *landesque* which argues that humans, even those in the remote past, create enduring values in landscapes that are inherited by later generations.[58] Another important aspect is that wealth and infrastructure accumulated over time likely freed up resources for improving the water supply.

The decline in active water sources during the 2nd–1st centuries BC is also notable; comparing the 3rd century BC to the 1st century BC the number of water sources falls by more than 30% (from n=98 to n=64). In particular, the number of cisterns falls by almost 40% at this time (from n=38 to n=23).[59] To a certain degree, this can be explained by the destruction on the Peloponnese during the final conquest of Greece by the Romans. Particularly in Corinthia, with 44% of the available water installations in the 1st century BC (n=16) compared to the 2nd century BC (n=36), there can be little doubt that the destruction of the city of Corinth itself in 146 BC was an important factor. The large number of cisterns recorded at the site clearly contributes to the larger picture. But a significant dip is also seen in the Argolid, although the sample size is considerably smaller, with more than a 30% decline in water sources in the same period (from n=12 to n=8). In fact, while the small sample size makes any conclusions uncertain, the same phenomenon, albeit to a smaller and varying degree, is visible in all sub-regions except Laconia. One possible explanation is that the destruction of Corinth and the establishment of Roman rule caused ripple effects in terms of material wealth over the peninsula, affecting all areas to some degree. This interpretation, however, also suggests that the economic and political vacuum created by the destruction of Corinth was not filled by other actors during the next century.

[58] See e.g., Morrison 2014.

[59] Compare to wells which fall by about 20% (from n=32 to n=26) between the 3rd and 1st centuries BC.

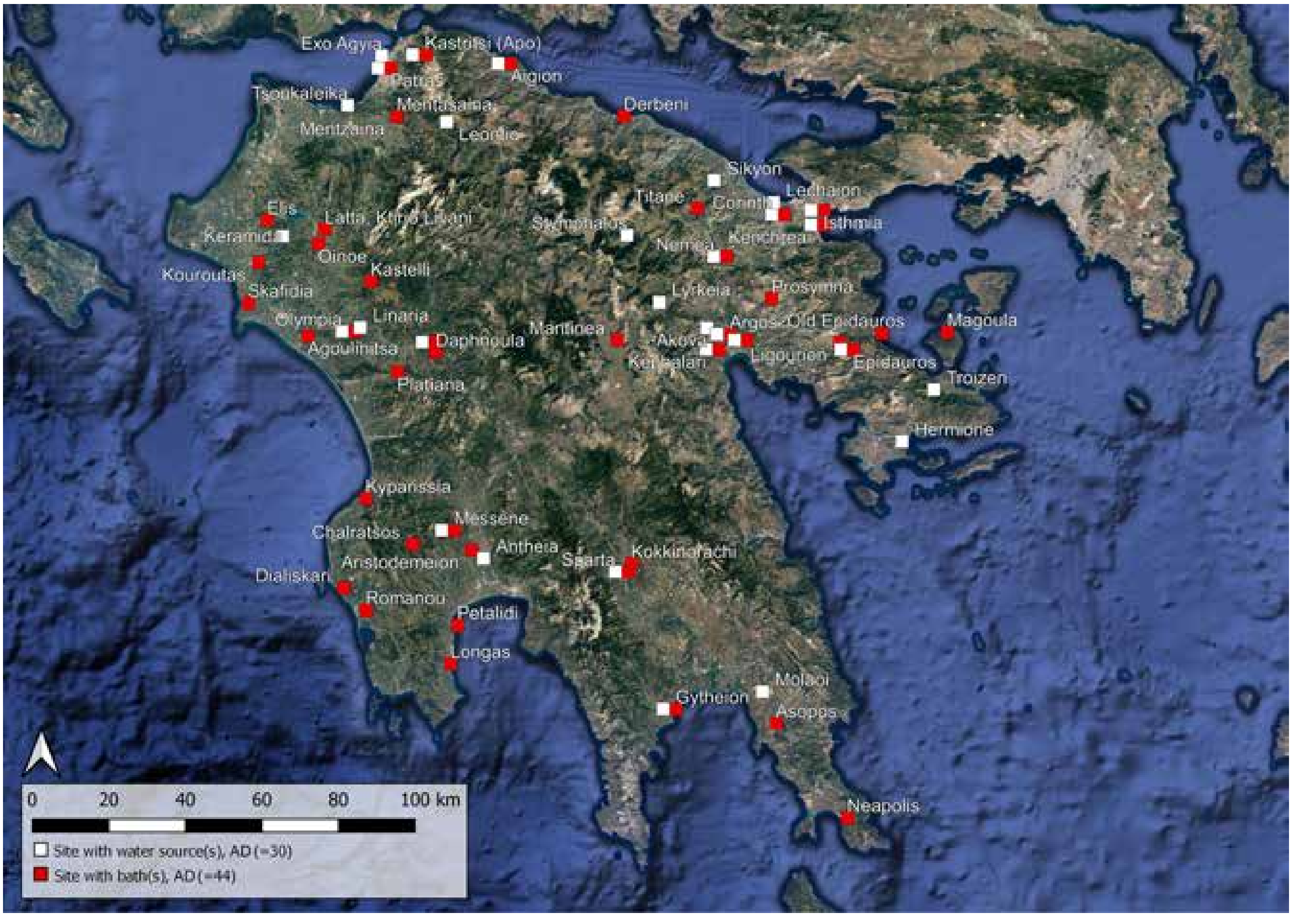

Fig. 7. Site(s) with water sources and/or baths, 1st–3rd centuries AD. Illustration: Patrik Klingborg.

Following Hellenistic times, a sharp increase in water sources is visible during the Roman Imperial period (*Figs 6–8*). However, the dataset suggests that the development was not even over the region (*Fig. 9*). In Arcadia, the number of water sources falls to the lowest level since the early Classical period, while in Corinthia there is an increase compared to the 1st century BC but the same heights as during the 3rd century BC are not reached again. In Messenia and Elis, the number of water sources increases compared to the 1st century BC and remains fairly stable compared to pre-2nd century BC levels. Finally, in three sub-regions the number of water sources increases more significantly in Roman times: in the Argolid and Laconia we see a moderate but clear increase, while in Achaia the number multiplies several times (from n=15 in the 1st century BC to n=62 in the 1st century AD). All in all, the data, therefore, suggests a significant increase in the number of water sources throughout the Peloponnese in Roman times compared to the previous two centuries. Because of this, it is reasonable to assume that whatever factor(s) caused the construction of water sources must have been in play over almost the whole peninsula.

One important contributing factor to this increase is a very significant uptick in the number of water sources in Patras during Roman times. This is to be expected considering the growth of the city during the period. The same phenomenon is also visible to a smaller degree in Laconia, in particular in Sparta. It is significant here that the number of sites with water sources remains quite stable at 25–32 between the 4th century BC and the 3rd century AD. This suggests that the increase in water sources is not the result of an increase in the number of sites at which they have been found. This is confirmed by the trend for the number of water sources per site, increasing practically every century (*Table 4*).

Yet, as suggested above, this development is, at least in Roman times, largely driven by the expansion of Patras. A more realistic image is therefore provided if the two major outliers (*Table 4*), Patras (for the Roman period) and Corinth (before the 2nd century BC), are not included in this analysis. Using this method, the number of water sources per site is more or less stable from the 4th century BC to the 3rd century AD. It, therefore, seems clear that the increase of the water supply

Number of sites with recorded water sources											
BC									**AD**		
9th	8th	7th	6th	5th	4th	3rd	2nd	1st	1st	2nd	3rd
3	5	6	10	15	27	32	28	25	26	29	32
Average number of water sources per site											
BC									**AD**		
1.00	2.40	1.83	2.10	2.27	2.96	3.06	3.25	2.56	4.77	4.90	5.13
Average number of water sources per site (excluding Corinth and Patras)											
BC									**AD**		
0.67	1.40	1.33	1.60	1.60	2.22	2.19	2.29	2.12	2.00	2.24	2.44

Table 4. Water sources per site.

infrastructure in Roman times attested in this study is, to a large degree, driven by the rapid growth of a small number of (well-excavated) sites.

There is also a remarkable increase in baths from the 1st century AD, many within domestic complexes. Almost ten times as many baths are recorded in the 1st century AD (n=79) compared to the 1st century BC (n=9).[60] Notably, while it is almost always unclear how these baths were fed, all of them must have had access to a reasonably reliable water supply. In general, Roman baths tend to be supplied by running water, not by wells or cisterns, although exceptions exist, in particular for private baths.[61] A strong connection between the increase in wells and cisterns during Roman times and the rapidly increasing number of baths is, therefore, unlikely. It is also unclear if the increase in baths can be linked to the increase in aqueducts from the 2nd century AD.[62] Certainly, aqueducts in many cities during Roman times enabled the construction of baths, but there are also far more sites with baths (n=44) than aqueducts (n=11 here; Lolos 1997 gives 19).[63] Overall, the water supply of Roman baths in Greece is a field which deserves more attention.[64] Either way, the large number of baths shows how deep the Roman cultural influences were in many areas of the Peloponnese, particularly in Patras and Sparta.

The dataset also confirms some previously known developments. For example, it has long been known, based on qualitative studies, that cisterns were rare before the Classical period.[65] In the current material, no cisterns are assigned to the 6th century BC and only seven to the 5th century, albeit the dating is weak in all of these cases (see *Figs 2–3* and *Tables 2–3*). Following this, the number almost quadruples in the 4th century BC. In comparison, the number of wells is remarkably stable between the 6th and 5th centuries BC while increasing, albeit at a considerably slower rate, not quite doubling, during the 4th century BC. In conclusion, this study strongly suggests that while it has been shown that a small number of cisterns were constructed in the 5th century BC or even earlier, e.g., in Athens, overall, there is no evidence for the widespread use of cisterns before 400 BC. The reasons for this are still debated, but can probably not be attributed to single factors such as technological innovations.[66]

Another notable aspect about the development of the use of cisterns is that the number increased significantly, almost tripling, from the 1st century BC to the 1st century AD. This is largely caused by new types of cisterns being constructed in Roman times, often above ground level and partly or completely using distinctly Roman building techniques such as bricks and cement. Overall, the material also gives the impression that the intended function of these cisterns differed from those of earlier periods. While most Classical and Hellenistic cisterns are found in domestic contexts, many of their Roman counterparts are associated with workshops and baths. While

[60] This corresponds largely to the peak in new baths in Asia Minor during the 2nd century AD (Nielsen 1990, 98). See also Kerschbaum 2021, 323. For an overview of the spread of baths in the provinces, see Maréchal 2023, 30–32.

[61] Manderscheid 2000, 484–490, but see also Kerschbaum 2021, 96–97 and Gerrard 2024, 180–190.

[62] As insinuated by Kerschbaum 2021, 323, 352–353.

[63] Aigion (**329**), Akova (**345**), Argos (**730**), Corinth (**676**, **719**), Gytheion (**255**), Kephalari (**296**), Linaria (**361**), Lyrkeia (**22**), Patras (**320**), Pylos (**420**), Sparta (**327**).

[64] See, however, Oulkeroglou 2018 for Roman and Early Byzantine Macedonia; Kelly 2004, for Crete.

[65] There are some exceptions, e.g., the Pre-Mnesiclean Cistern on the Athenian Acropolis (see Klingborg 2017, 57, no. 157. See also Doerpfeld 1886, 333; Tanoulas 1992; 2017). Furthermore, J. Stroszeck (2023, 95) has noted a small number of examples from the mid-5th century BC at Kerameikos (discussed, along other examples, in Klingborg 2017, 59–61). For a discussion on early cisterns, see Klingborg 2017, 57–59. Note that a number of publications have consistently claimed that cisterns were in widespread use at an earlier point without sound empirical basis (most recently Angelakis *et al.* 2023 [2.2.2], but see also Yannopoulos *et al.* 2017, 1024; Mays *et al.* 2013, 1917–1919; Mays 2008, 475).

[66] Klingborg 2017, 122–138; Stroszeck 2023, 107–108. It is often stated that cisterns were used by the Minoans (e.g., Mays *et al.* 2013), but the current evidence is unclear.

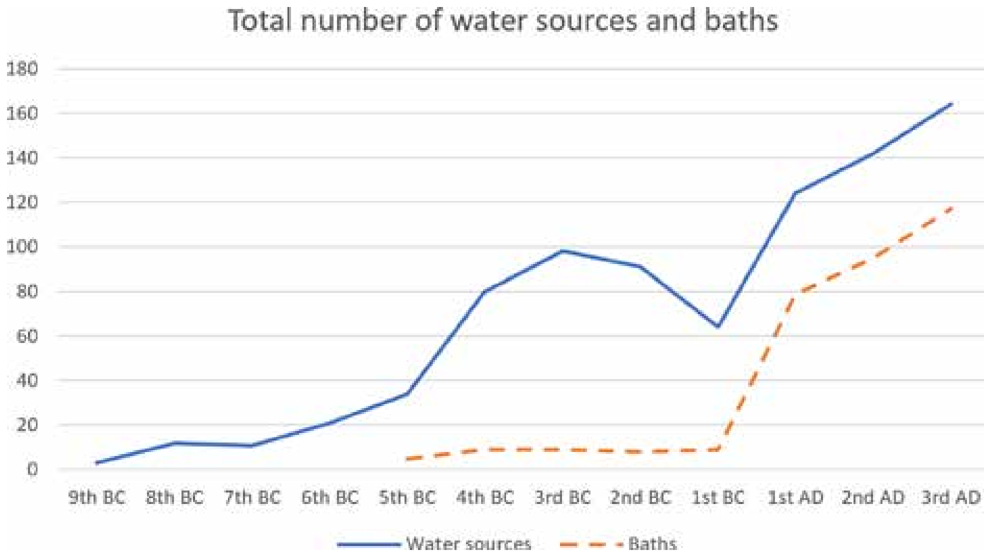

Fig. 8. Recorded number of water sources and baths per century. Graph: Patrik Klingborg.

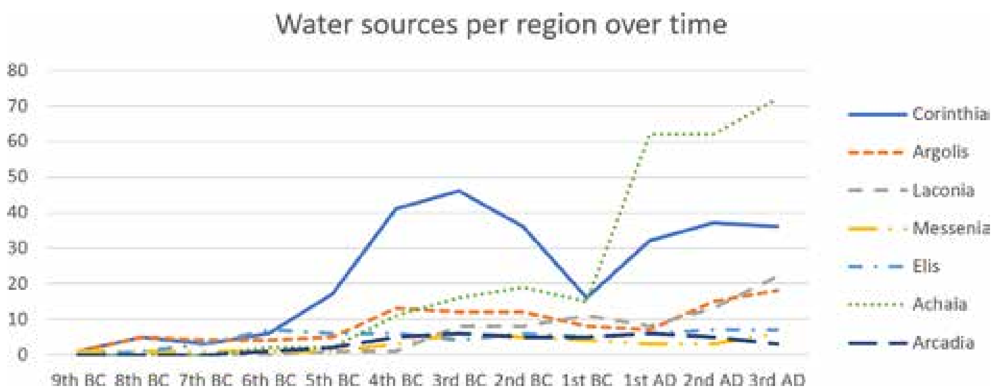

Fig. 9. Recorded number of water sources per region and century. Graph: Patrik Klingborg.

more detailed studies are necessary to establish this point further, the evidence thus seems to suggest that the use of cisterns differs in the two periods. It may even be worth considering the use of cisterns in these two periods as so fundamentally different that they practically constitute different phenomena, despite similarities in terms of collecting and making.

Fountains (including nymphaea) exhibit another interesting pattern. Usually, the construction of fountains is presented in terms of peaks during specific periods, such as Late Archaic times under various tyrants, the 4th century BC and Roman times.[67] However, the material collected here shows no such pattern. Rather, there is a steady increase of active fountains over time, with slightly fewer during the 2nd–1st centuries BC dip.

REGIONAL DIFFERENCES IN RELATION TO PRECIPITATION

While it is beyond the scope of this article to discuss subregional differences due to the relatively small dataset, some preliminary observations of the development of the water supply can be made. Overall, the Peloponnese is well suited for such inquiries because different areas exhibit different local conditions characterized by, for example, rocky terrain or plains, low or high elevation, and low or high precipitation.[68] For the current study, the precipitation pattern, often viewed as a key factor for water supply systems, is informative as it

[67] Although not presenting explicit chronologies, see Tölle-Kastenbein 1990, 134–143; Glaser 2000, 420–431 in particular. Notably, the material from Athens largely contributes to the way the material is presented.

[68] For a similar argument, but for Asia Minor, see Kerschbaum 2021, 104–105.

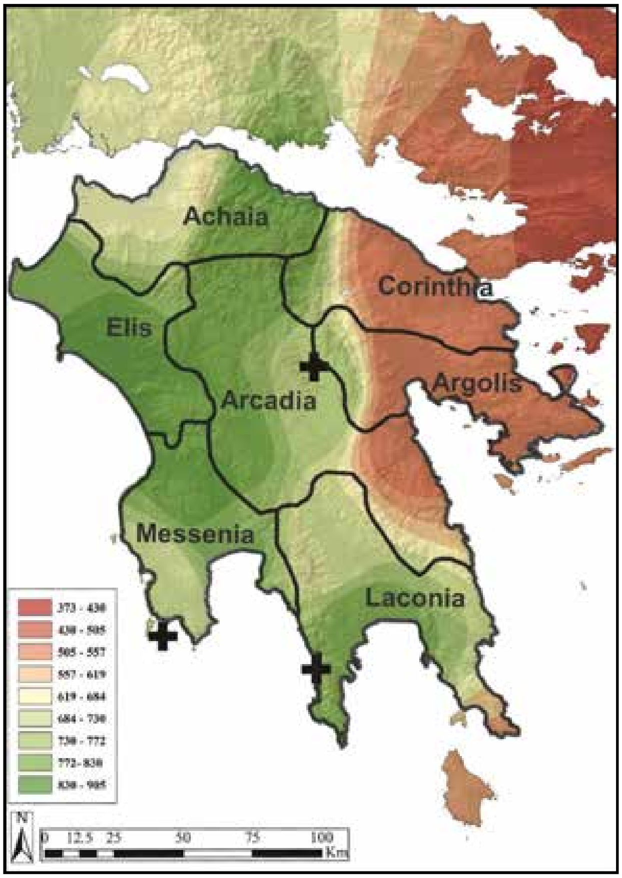

Fig. 10. Precipitation (in millimetres) on the Peloponnese (Bonnier & Finné 2020, fig. 3), where the crosses indicated the caves they explored). Published with permission, modified by Patrik Klingborg.

is characterized by a stark east–west divide (*Fig. 10*). Because of this we can compare two relatively dry regions in the east (Corinthia and Argolis) with the wetter western ones (Laconia, Messenia, Elis, Achaia and Arcadia). By doing so, it is possible to create two sub-regions with larger sample sizes, 162 water sources in the east and 169 in the west.[69]

Initially, both regions relied largely on wells, and once cisterns were introduced in the 5th century BC they quickly became popular in both areas (*Figs 11–14*). From the 4th century BC, however, the developments diverge. In the drier east, cisterns continued to increase until they account for 50% (n=24) of the water sources in the 2nd century BC and wells only for 23% (n=11). In the wetter west, on the other hand, the number of cisterns and wells remains fairly even at about 40% during the same period (cisterns, n=16 and wells, n=18). The dip of the 2nd–1st centuries BC also affects the areas differently. In the east, 60% fewer water sources are recorded in the 1st century BC than in the 3rd century BC (from n=58 to n=24). In the west, on the other hand, there is no decline. From early Roman Imperial times, water sources increased rapidly again in both regions. However, in one respect, the situation is the reversed of that during Late Classical and Hellenistic times. During the 1st century AD, in the east wells (44%, n=17) significantly outnumber cisterns (23%, n=9), while in the west, cisterns dominate, accounting for 64% (n=55) of the water sources and wells only 23% (n=19). The same pattern then continues during the 2nd and 3rd centuries AD.

These developments are interesting because they raise questions concerning the degree to which higher or lower precipitation affects the composition of the water supply system. Is it a critical factor or of secondary importance? In previous scholarship, prolonged droughts have been associated with the construction of cisterns.[70] The current material suggests that precipitation is not a central factor, considering no major east–west shift in rainfall patterns is known on the Peloponnese between Hellenistic and Roman times. It also puts other overarching theories, such as cisterns as a way to mitigate perceived risk, into question.[71] Yet, this question requires more detailed studies, in particular, since it seems likely that cisterns were utilized in different ways during different periods.

Conclusions

This paper had two goals. The first was to test a systematic method to collect an extensive and representative material for the investigation of the water supply on a regional scale on the Peloponnese. The second was to use this dataset to discuss the transformations of the water supply systems in that region in the period 900 BC–AD 300.

The dataset was collected through a systematic inventory of all water sources and baths on the Peloponnese reported in *AR* between 1887 and 2012. The analysis showed that more water sources were recorded from a larger number of sites than what would be possible through qualitative or exhaustive studies without an unrealistically large project. In two cases, the current material (wells at the Sanctuary of Zeus at Nemea and fountains on the Peloponnese) represents roughly 50% of that catalogued through exhaustive studies. While the material is less complete for other sites, such as Hermione, the method also recorded a large num-

[69] Cf. contributions in Kefalidou 2022 for the impact of rivers and local climate in the formation of the cities in Thrace.

[70] Camp 1977, although drought is not defined by the author. See Stroszeck 2023, 107–109 for an overview concerning why cisterns decreased in popularity during the Late Hellenistic period based on material in Athens.

[71] Klingborg 2017, 122–138.

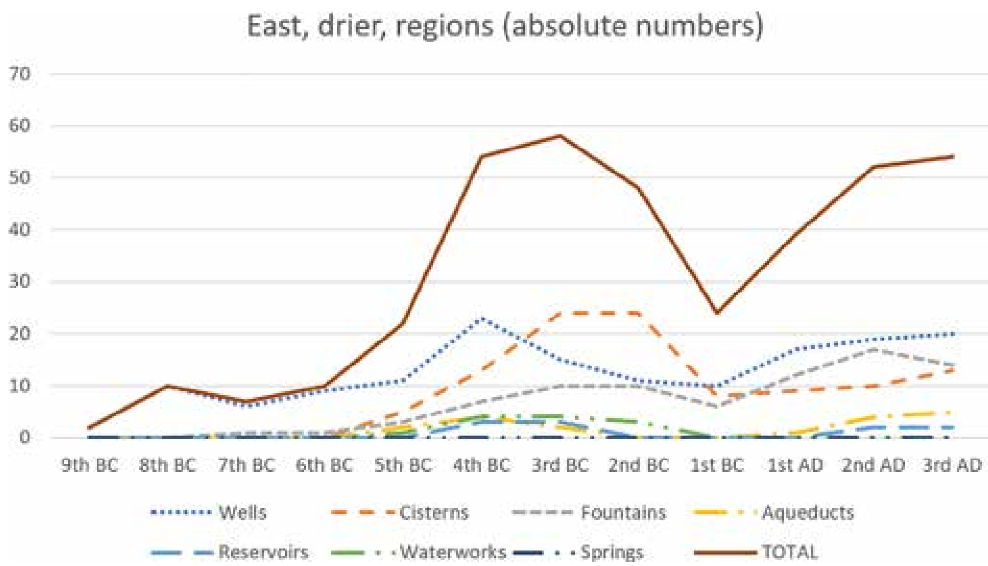

Fig. 11. Number of water sources in the drier eastern part of the Peloponnese (Corinthia and Argolis). Graph: Patrik Klingborg.

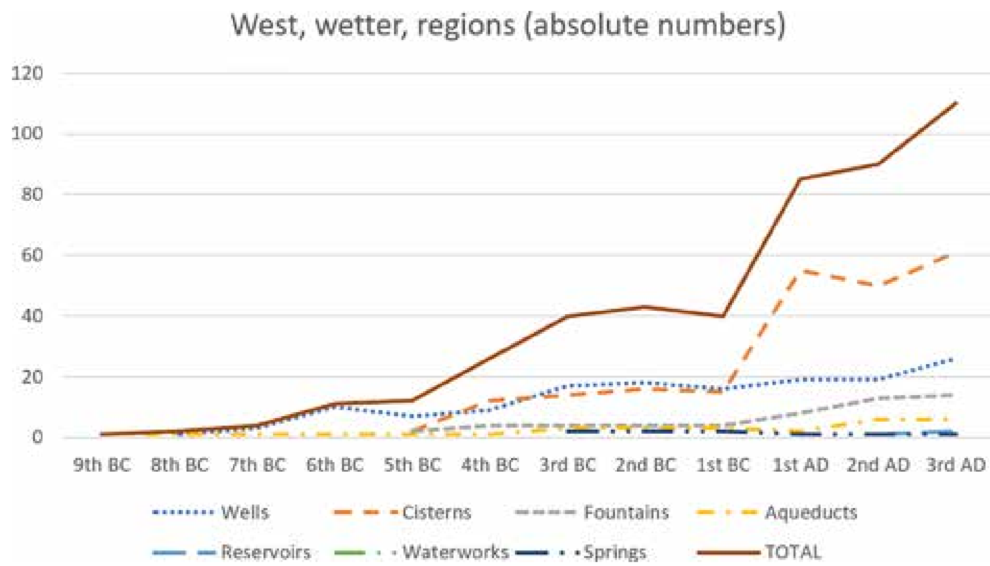

Fig. 12. Number of water sources in the wetter western regions of the Peloponnese (Laconia, Messenia, Elis, Achaia and Arcadia). Graph: Patrik Klingborg.

ber of installations previously not published systematically. Overall, there can be little doubt that the method used in this paper produced a unique and useful body of evidence. However, it is also clear that particularly the size of the dataset makes it difficult to go beyond general trends for the region. Overall, monumental water sources and baths are still over-represented, a major problem in previous studies, but to a lesser degree than expected.

Despite being difficult to use for smaller areas, it seems reasonable that some of the larger trends in the material accurately reflect changes to the development and composition of the water supply. For example, there can be little doubt that the overall number of active water sources increases over time with the exception of a period of maybe a century between the late 2nd and 1st centuries BC. The reasons for this increase are presumably multifaceted. One important factor is probably that water sources tended to be used for long periods, in many cases several centuries. This allowed an accumulation of water sources to be formed and testifies to the sustainability and robustness of the overall system. An increase in material wealth over time may also have played a role, in particular, during Roman times.

A decline in the number of active water sources during the 2nd–1st centuries BC also seems to be securely attested, although a more extensive dataset is needed in order to explore this in detail. In contrast to the uncertainties regarding the constant increase in water sources, this dip can reasonably be connected to the Roman conquest of the Peloponnese. However, while Corinth and the

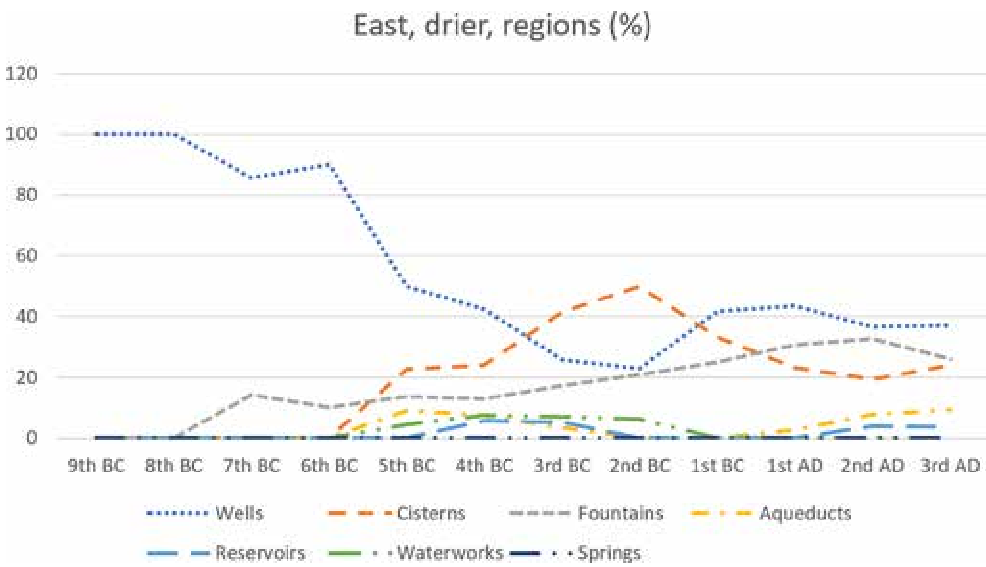

Fig. 13. Relative number of water sources in the drier eastern part of the Peloponnese (Corinthia and Argolis). Graph: Patrik Klingborg.

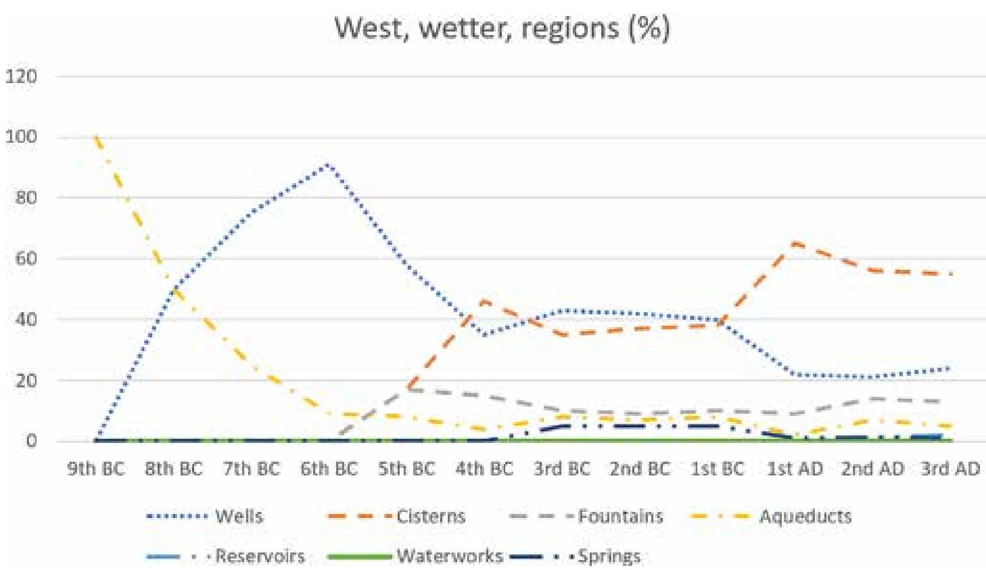

Fig. 14. Relative number of water sources in the wetter western regions of the Peloponnese (Laconia, Messenia, Elis, Achaia and Arcadia). Graph: Patrik Klingborg.

region around the city was certainly affected by this, the effect on the rest of the peninsula is less certain.

Finally, the material confirms that the locally observed introduction and rapid adoption of cisterns also took place on the whole Peloponnese in the late 5th or early 4th century BC. The reasons for this have been much discussed on a local level, but one of the main results of this study is that such explanations must move beyond individual sites and ask why cisterns were introduced in larger areas?

In the end, the results of this paper lead back to the simple question of what factors cause a water source to be constructed? Is an increase in the number of water sources a reflection of an increased need for water (physically through population growth or culturally) and/or an accumulation of wealth which enabled the construction of more water sources (essentially assuming that there was always a desire for better access to water)? What effect did new techniques and materials have, allowing new types of constructions to be built? Were changing environmental circumstances critical? Presumably, all these factors played a role to some degree, perhaps even an important one. To further explore this, however, further studies, and in particular the collection of large and (as far as possible) representative materials, are imperative. Only then can we begin seriously to disentangle why the water supply was transformed over time, allowing us to improve our understanding of this aspect of the ancient world and the long-term challenges of modern society in the face of climate change and economic development.

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