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Plague Mortality in Late Medieval Cairo: Quantifying the Plague Outbreaks of 833/1430 and 864/1460

A historian of Ottoman Egypt recently posed some key questions about plague mortality in eighteenth-century Cairo. What he wanted to know was whether or not we should give credence to the historical accounts that report peak urban fatality rates (deaths per day) of a thousand for major epidemics.[1] He also wanted to know how these mortality figures were actually determined and suggested that these numbers might in fact be more symbolic in nature than statistic. Finally, he asked if we can accept the estimations of historians that place cumulative death tolls for Cairo at levels of 100,000 or higher.[2]

These are very good questions and they apply equally well to Mamluk Cairo and its forty-some plague outbreaks.[3] Michael Dols opened this same can of worms nearly four decades ago as he examined mortality from the 833/1429–30 plague outbreak in Cairo.[4] Dols expressed some dissatisfaction with his attempts, but nevertheless came up with a tentative approximation of some 90,000 for the 833/1430 outbreak's death toll. Dols clearly intended to work on the data from another major plague outbreak (864/1460) but as his career was cut short, the statistics he had gathered were left abandoned on a page of his last article on the subject.[5]

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[1]This article comes out of work conducted at the Annemarie Schimmel Kolleg of Bonn University. The authors would like to thank the Annemarie Schimmel Kolleg and its staff for their generous support that made this collaborative work possible.
[Alan] Mikhail, "The nature of plague in late eighteenth-century Egypt," *Bulletin of the History of Medicine* 82, no. 2 (2008): 260.

[2]The estimations of Ottoman-era: Daniel Panzac, *La peste dans l'Empire Ottoman, 1700–1850* (Leuven, 1985), 361; André Raymond, "Les grandes épidémies de peste au Caire aux XVIIe et XVIIIe siècles," *Bulletin d'études orientales* 25 (1972): 203–10.

[3]The most comprehensive chronology of Mamluk-era plagues is Boaz Shoshan, "Notes sur les épidémies de peste en Egypte in Démographie historique et condition féminine," in *Annales de Démographie Historique Paris* (1981): 395–400.

[4]Michael Dols, *The Black Death in the Middle East* (Princeton, 1977), 212–18; idem, "The General Mortality of the Black Death in the Mamluk Empire," in *The Islamic Middle East, 700–1900: Studies in Economic and Social History,* ed. Abraham Udovitch (Princeton, 1981), 411–14.

[5]Dols, "General Mortality," 409.

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Our goal here is to pick things up where Dols left off. We will answer these questions by studying the 833/1430 and 864/1460 plague outbreaks, investigating in detail how these Mamluk-era plague numbers were put together and determining whether or not these were bona fide statistics for the number of plague fatalities.[6] By analyzing these numbers quantitatively and performing regressions on the data, we will propose new methods for quantifying the mortality of the Mamluk-era (1347–1517) epidemics.

Plague

If we are to get a sense of whether or not these numbers bear upon reality, it makes sense to include in this discussion a clear understanding of how plague functions quantitatively. For that reason we have used a mathematical model for plague mortality and will employ this model as a guide for discussing the dynamics of the disease itself. The plague is a zoonosis spread between rats by means of the rat flea vector.[7] The rat flea spreads plague bacteria via the process of feeding on the

[6]The Mamluk-era sources we have consulted include Ibrāhīm ibn ʿUmar Biqāʿī, *Iẓhār al-ʿaṣr li-asrār ahl al-ʿaṣr,* ed. Muḥammad Sālim ibn Shadīd ʿAwfī (Cairo, 1992); Abū Bakr ibn Aḥmad ibn Qāḍī Shuhbah, *Tārīkh Ibn Qāḍī Shuhbah,* ed. ʿAdnān Darwīsh (Damascus, 1977); Ibn al-Ṣayrafī, *Nuzhat al-nufūs wa-al-abdān fī tawārīkh al-zamān,* ed. Ḥasan Ḥabashī (Cairo, 1994); ʿAbd al-Bāsiṭ ibn Khalīl, *Nayl al-amal fī dhayl al-duwal,* ed. ʿUmar Tadmurī (Ṣaydá, 2002); Maḥmūd Badr al-Dīn al-ʿAynī, *ʿIqd al-jumān fī tārīkh ahl al-zamān,* ed. Muḥammad Amīn (Cairo, 1987); Muḥammad ibn ʿAbd al-Raḥmān al-Sakhāwī, *Kitāb al-tibr al-masbūk fī dhayl al-sulūk,* ed. Saʿīd ʿAbd al-Fattāḥ ʿĀshūr (Cairo, 2002–7); Ibn Iyās, *Badāʾiʿ al-zuhūr fi-waqāʾiʿ al-duhūr,* ed. Muṣṭafá Muḥammad (Cairo, 1982); Aḥmad ibn ʿAlī al-Maqrīzī, *Kitāb al-sulūk li-maʿrifat duwal al-mulūk,* ed. Muḥammad Muṣṭafá Ziyādah (Cairo, 1956–73); Aḥmad ibn ʿAlī ibn Ḥajar al-ʿAsqalānī, *Inbāʾ al-ghumr bi-abnāʾ al-ʿumr,* ed. Ḥasan Ḥabashī (Beirut, 1969); Yūsuf ibn Taghrībirdī, *Ḥawādith al-duhūr fī madá al-ayyām wa-al-shuhūr,* ed. William Popper (Berkeley, 1930–42); idem, *Al-Nujūm al-zāhirah fī mulūk Miṣr wa-al-Qāhirah,* ed. William Popper (Cairo, 1954–57), translated by William Popper as *History of Egypt 1382–1469 A.D.,* University of California Publications in Semitic Philology, Volumes 13, 14, and 17. (Berkeley, 1954–57).

[7]That Yersinia pestis was the cause of these late medieval outbreaks was indicated in the 2010 DNA samples that confirmed that Yersinia pestis was responsible for the Black Death and subsequent plague outbreaks in Europe, the Middle East, and Asia. Stephanie Haensch et al., "Distinct clones of Yersinia pestis caused the black death," *PLoS pathogens* 6, no. 10 (2010): e1001134. Further studies, such as the examination of dental pulp from the mass graves in East Smithfield, England, produced the first draft genome sequence of the bacterium; see Kirsten I. Bos et al., "A draft genome of Yersinia pestis from victims of the Black Death," *Nature* 478, no. 7370 (2011): 507; Hinnebusch et al., "Role of Yersinia murine toxin in survival of Yersinia pestis in the midgut of the flea vector," *Science* 296, no. 5568 (2002): 733–35. Hinnebusch et al. describe how the earlier Yersinia pseucotuberculosis bacterium acquired—via horizontal gene transfer—two plasmids that effected an evolutionary change in this organism. Via the impetus of the plasmids, the bacterium evolved from a disease of mild enteritis spread through fecal-oral contact to a virulently pathogenic disease with the rat flea as the vector. See also Jarrett et al., "Transmission of *Yersinia pestis*

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blood of rats.[8] When a flea bites an infected rat, ingested plague bacilli concentrate in the flea's proventriculus, which is a kind of one-way check valve for the flea's esophagus. As a check-valve, the proventriculus allows the flea's blood meal to flow into the digestive system while at the same time preventing its reuptake.[9] What the plague bacilli do is to multiply rapidly in this proventriculus, so rapidly that they form an obstruction for this valve and the obstruction prevents the flea from ingesting blood. As a result, the flea is no longer able to feed and takes on the role of disease vector, transmitting the plague bacteria.

from an Infectious Biofilm in the Flea Vector," *Journal of Infectious Diseases* 190 (2004): 783; Verena J. Schuenemann, Kirsten Bos, Sharon DeWitte, Sarah Schmedes, Joslyn Jamieson, Alissa Mittnik, Stephen Forrest, et al., "Targeted enrichment of ancient pathogens yielding the pPCP1 plasmid of Yersinia pestis from victims of the Black Death," *Proceedings of the National Academy of Sciences* 108, no. 38 (2011): E746–E752; Mark Achtman, Giovanna Morelli, Peixuan Zhu, Thierry Wirth, Ines Diehl, Barica Kusecek, Amy J. Vogler, et al., "Microevolution and history of the plague bacillus, Yersinia pestis," *Proceedings of the National Academy of Sciences of the United States of America* 101, no. 51 (2004): 17837–42; Mark Achtman and Michael Wagner, "Microbial diversity and the genetic nature of microbial species," *Nature Reviews Microbiology* 6, no. 6 (2008): 431–40; Florent Sebbane, Clayton O. Jarrett, Donald Gardner, Daniel Long, and B. Joseph Hinnebusch, "Role of the Yersinia pestis plasminogen activator in the incidence of distinct septicemic and bubonic forms of flea-borne plague," *Proceedings of the National Academy of Sciences* 103, no. 14 (2006): 5529; Jessica M. Girard, David M. Wagner, Amy J. Vogler, Christine Keys, Christopher J. Allender, Lee C. Drickamer, and Paul Keim, "Differential plague-transmission dynamics determine Yersinia pestis population genetic structure on local, regional, and global scales," *Proceedings of the National Academy of Sciences of the United States of America* 101, no. 22 (2004): 8408–13.

[8]The bacteria's evolution was recent enough to be part of history, as the range for its evolution is two thousand to twenty thousand years. Clayton O. Jarrett, Eszter Deak, Karen E. Isherwood, Petra C. Oyston, Elizabeth R. Fischer, Adeline R. Whitney, Scott D. Kobayashi, Frank R. DeLeo, and B. Joseph Hinnebusch, "Transmission of Yersinia pestis from an infectious biofilm in the flea vector," *Journal of Infectious Diseases* 190, no. 4 (2004): 783.

[9]The proventriculus also serves as a pre-digestive system, by which the spines of the proventriculus break up the incoming food before it reaches the flea's midgut. The blocking of the flea's digestive system caused by the proliferation of masses of plague bacilli in the flea's proventriculus was first discovered and documented by Ada White Bacot and C. J. Martin, "LXVII. Observations on the mechanism of the transmission of plague by fleas," *The Journal of hygiene* 13 Suppl. (1914): 431–37. For recent research discussing this blocking of flea digestive systems, see Ellen A. Lorange, Brent L. Race, Florent Sebbane, and B. Joseph Hinnebusch, "Poor vector competence of fleas and the evolution of hypervirulence in Yersinia pestis," *Journal of Infectious Diseases* 191, no. 11 (2005): 1907–8; Rebecca J. Eisen, Scott W. Bearden, Aryn P. Wilder, John A. Montenieri, Michael F. Antolin, and Kenneth L. Gage, "Early-phase transmission of Yersinia pestis by unblocked fleas as a mechanism explaining rapidly spreading plague epizootics," *Proceedings of the National Academy of Sciences* 103, no. 42 (2006): 15380; Clayton O. Jarrett et al., "Transmission of Yersinia pestis," 785–89; Kenneth Gage and Michael Y. Kosoy, "Natural history of plague: perspectives from more than a century of research," *Annual Review of Entomology* 50 (2005): 511–14; Hinnebusch et al., "Role of Yersinia murine toxin in survival of Yersinia pestis in the midgut of the flea vector," *Science* 296, no. 5568 (2002): 733–35.

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As the blocked flea attempts to feed on the rat, its esophagus becomes enlarged as the blood is prevented from moving past the block in its proventriculus. The flea is eventually forced to relax its pharyngeal muscles and this sends blood contaminated with plague into the dermis of the rat. The blocked flea eventually dies of starvation and dehydration but not before it has had many opportunities to spread the plague bacteria in this fashion. The infected rats become the collective reservoir that transmits the bacilli to uninfected fleas. Uninfected fleas then become blocked in turn and spread the disease to uninfected rats—and so the cycle continues.

The plague outbreak that results from this interaction is initially an epizootic and not an epidemic. That is to say that the outbreak is at first confined to the rat population and has no direct impact on humans. Epidemic only occurs at the tail end of the epizootic, when the rat population crashes to such a low level that the flea numbers overwhelm the dwindling pool of surviving rats—and the flea index (the average number of fleas per rat) exceeds the flea carrying capacity by a certain margin. At this point there are too many fleas for the few remaining rat hosts, and these fleas, which usually disdain human blood, shift their focus to the human population. These hungry fleas, their feeding attempts multiplied by the blocking of their digestive systems, then move in exponentially rising numbers to humans. Thus when the rat population collapses and diminishes to a low level, there is a rapid increase in the number of infectious fleas without rat hosts.

In the graph below is one of our quantitative reconstructions of historical plague outbreaks, in which one can see the exponential rise in the number of these hungry and host-less fleas. Also shown in this graph is the sharp decline in the rat population and the ensuing rise in the rate of human fatalities (human deaths per day). When the rats die off and release massive numbers of rat fleas, the human outbreak begins. Humans comes last, and in this sense, an epidemic is simply an afterthought of epizootic. This simulation is part of our ongoing effort to assess plague mortality via an adaptation of the Keeling and Gilligan (2000) epizootic model; the numbers for the rats, fleas, and humans displayed in the graph below were generated by the simulation.[10] In these simulations we fitted the model's equations from the Keeling and Gilligan (2000) plague model to historical data sets from Mamluk Cairo. The human casualties were generated by this simulation's quantitative interpretation of this historical data; the rat and

[10] The model is that of M. J. Keeling and C. A. Gilligan, "Bubonic plague: a metapopulation model of a zoonosis," *Proceedings of the Royal Society of London, Series B: Biological Sciences* 267, no. 1458 (2000): 2219–30; idem, "Metapopulation dynamics of bubonic plague," *Nature* 407, no. 6806 (2000): 903–6. The idea of using the Keeling and Gilligan model in this manner was suggested by the work of Stefan Monecke, Hannelore Monecke, and Jochen Monecke, "Modelling the black death: A historical case study and implications for the epidemiology of bubonic plague," *International Journal of Medical Microbiology* 299, no. 8 (2009): 582–93.

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flea numbers were the program's estimation of how many of both it would take to bring this about.

We fitted seventeen parameters (bubonic) and nine differential equations (bubonic) from the Keeling and Gilligan model. To the Keeling and Gilligan model we added stochastic features which account for the very short term oscillations that can be seen in the graph below. We also analyzed hypothetical outcomes using seven parameters (bubonic and pneumonic) and three differential equations (pneumonic) from our own model. As a brief example of how the Keeling and Gilligan model works, the equation ($\lambda_H = F\,e^{(-a\,Tr)}$) expresses the proportionate rate of change in the force of the human epidemic and its integral ($\Lambda_H = \int_0^\infty \lambda_H(t)\,dt$) is proportional to the overall strength of the plague outbreak in the human population. While we ultimately used conventional SIR (Sick Infected Removed) equations for the human population, λH is a good shorthand for the manner in which epizootic becomes epidemic. (T_r) is the total number of rats at any given time, (a) quantifies the effectiveness or efficiency by which the flea searches for a host, and (F) is the number of infectious fleas that are actively searching for a new host (i.e., for their food/blood). The more infectious fleas, the more powerful the epidemic; thus F, and the equations for the epizootic that quantify (F), are the driving force of the epidemic. The second term in this equation ($e^{(-a\,Tr)}$) is in a very loose sense the timer for the human outbreak; with (a) constant, as the rat population falls to a very low level (aT_r) can approach zero and its exponent ($e^{(-a\,Tr)}$) thus rises to approach one. The equation therefore conveys the timing of swiftly rising human casualties with the mathematical demise of the rats being the signal for the human outbreak to begin.

We used the model to help us visualize and conceptualize the shapes of plague mortality curves. Pneumonic plague was used in one instance to simulate bimodal peaks of some of our plague fatality rate curves; these bimodal peaks can also be seen in other plague outbreaks, such as those of Sydney (1903), Freiberg (1613–14), Bombay (1905–6), Coventry. The notion that someone might try to explain the twin crests of plague epidemics was suggested by Monecke et al. in their adaptation of the Keeling and Gilligan plague model.[11] The Monecke et al. adaptation of the Keeling and Gilligan model to the 1613–14 plague outbreak in Freiberg inspired us to do the same for Mamluk Cairo.[12]

[11] Monecke et al., "Modelling the black death," 588.

[12] W. O. Kermack and A. G. McKendrick, "A Contribution to the Mathematical Theory of Epidemics," *Proceedings of the Royal Society of London* 115 (1927): 700–21, in Monecke et al., "Modelling," 585; Peter Curson and Kevin McCracken, *Plague in Sydney: The Anatomy of an Epidemic* (Kensington, NSW, 1990), in Keeling and Gilligan, "Bubonic," 2220; James W. Wood, Rebecca J. Ferrell, and Sharon N. Dewitte-Avina, "The Temporal Dynamics of the Fourteenth-Century Black Death: New Evidence from English Ecclesiastical Records," *Human Biology* 75, no. 4 (2003): 443.

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In this recreation, the rat population (dashed line) can be seen to be sinking to a very low level as the number of infectious fleas without hosts rises precipitously (dotted line). The human epidemic can then be seen beginning at the tail end of the rat epizootic.[13]

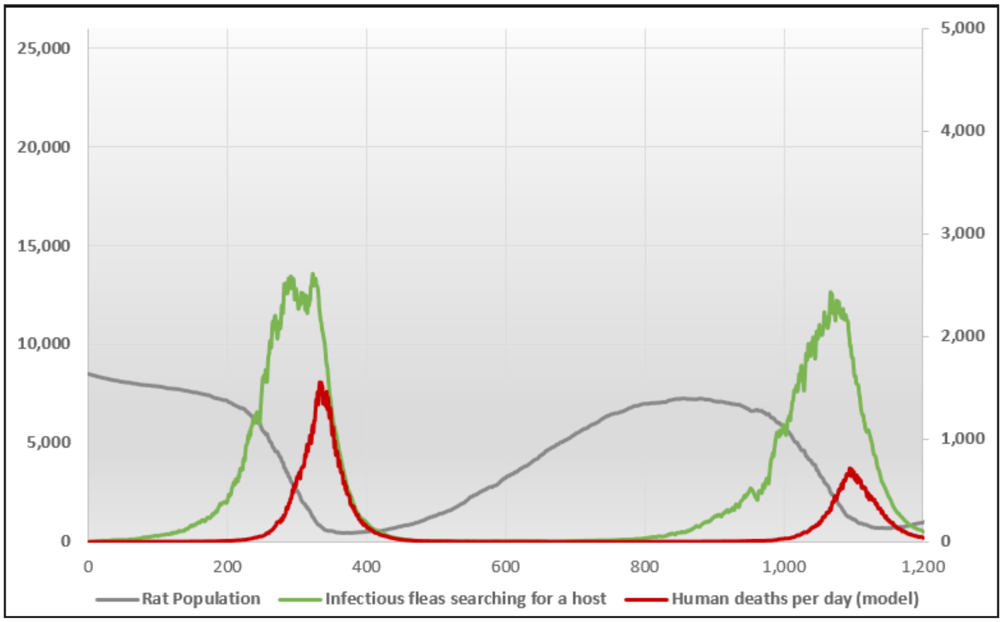

Fig. 1. Two Plague Outbreaks in Close Proximity (time in days). Keeling and Gilligan model differential equations fitted to historical data from Mamluk Cairo. Flea and Rat numbers: left Y-Axis, Human fatality rate on the right.

Regarding the point at which the rat population collapses (T_r left y-axis), which on this graph intersects (at time ~ 300 days and ~ 1100 days) the plot of the rising number of human fatalities (right y-axis), Ole Benedictow has a vivid description of this pivot point: "Epidemic diseases that spread directly between human beings produce bell-shaped development curves that reflect the pace of a disseminative process based on human contact and the slow depletion of the pool

[13] The differential equations of the Keeling and Gilligan model quantify the dynamic unfolding of epizootic. Key variables in these equations act out the parts played by susceptible rats, infected rats, infectious host-less fleas, and the flea index (the average number of fleas on a rat). These primary variables govern the way in which the human epidemic plays out quantitatively via the SIR model (SIR: Susceptible, Inflected, Removed). For our simulation, we fit the parameters of the model via the Excel program's Solver functions, which provides an iterative solution for the minimization of the squared discrepancy between the historical and predicted data. Data for plague fatalities over time (deaths per day) was simulated via nonlinear regression.

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of susceptible persons."[14] Not so with plague and its rat-and-flea underpinnings, as Benedictow points out, illustrating quantitative trajectory with detail from a plague outbreak in 1905 Bombay, "It was the very beginning of this transitional phase that the inhabitants of the plague-stricken block of tenements in Bombay had experienced, when they suddenly were so aggressively attacked by swarms of voracious rat fleas that many of them felt obliged to sleep in the veranda at night. The characteristic features of this transitional phase explain the sudden and dramatic onset of plague epidemics with abruptly skyrocketing morbidity rates and mortality rates. This dramatic and explosive type of epidemic development is in itself a clear indication of plague."[15]

The end of the outbreak, like the beginning, came with relative swiftness, via the starvation and dehydration of tens of thousands of rat fleas that could no longer ingest blood, rat or human. This final moment can be seen in the graph from our simulation as the curve for the rate of human fatalities plunges swiftly and in tandem with the expiration of these fleas—the slight lag between the two being the period of the plague's incubation and the brief (and usually fatal) course of the illness. A German research team that fitted these same equations to the historical data from a plague outbreak in early modern Freiberg concluded that the average plague outbreak lasts about forty weeks and ends rather suddenly at the limit of the fleas' endurance. That is to say that the timing of a typical plague outbreak is as follows: twenty weeks for the rat population to collapse, eighteen weeks for the flea population to starve and dehydrate to death, and another two weeks for incubation and course of illness in human hosts.[16]

For the purposes of working up scenarios and imagining quantitative possibilities, some of the parameters of the model we used were allowed to float within constraints. One of these parameters that was very responsive to environmental circumstances should be mentioned here because for this one at least we do have some data from Egypt that might apply. This is the parameter for rat-carrying capacity. Rat-carrying capacity is the number of rats that can be sustained on a given area of one kilometer squared. For our simulation, it was the rat-carrying capacity parameter that quantified the level of the rat population at time zero—and this parameter makes a big difference for the quantitative outcome.[17] On the

[14] Ole Benedictow, *The Black Death, 1346–1353: the complete history* (Rochester, NY, 2004), 18–19.

[15] Ibid.

[16] Monecke et al., "Modelling," 590; Nicolas Bacaër, "The model of Kermack and McKendrick for the plague epidemic in Bombay and the type reproduction number with seasonality," *Journal of mathematical biology* 64, no. 3 (2012): 403–22; Florent Sebbane, Donald Gardner, Daniel Long, Brian B. Gowen, and B. Joseph Hinnebusch, "Kinetics of disease progression and host response in a rat model of bubonic plague," *The American journal of pathology* 166, no. 5 (2005): 1427–39.

[17] Keeling and Gilligan, "Bubonic Plague," 2226.

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graph below we plotted the impact of raising this rat-carrying capacity in increments. What we were simulating was improving upon the rats' environmental conditions step by step, i.e., imagining a dirtier and fouler urban landscape one step at a time. One can see the effects of a higher rat population density on two key variables in the graph below: the number of infectious fleas without a host and the approximate strength of the resulting human epidemic. This scenario of rising increments and exponential results is entirely appropriate for pre-modern Egypt because indications are that environmental and architectural conditions favored an exceptionally high rat population density, and as one can see here, more rats means more infectious fleas and in the end more human lives.[18]

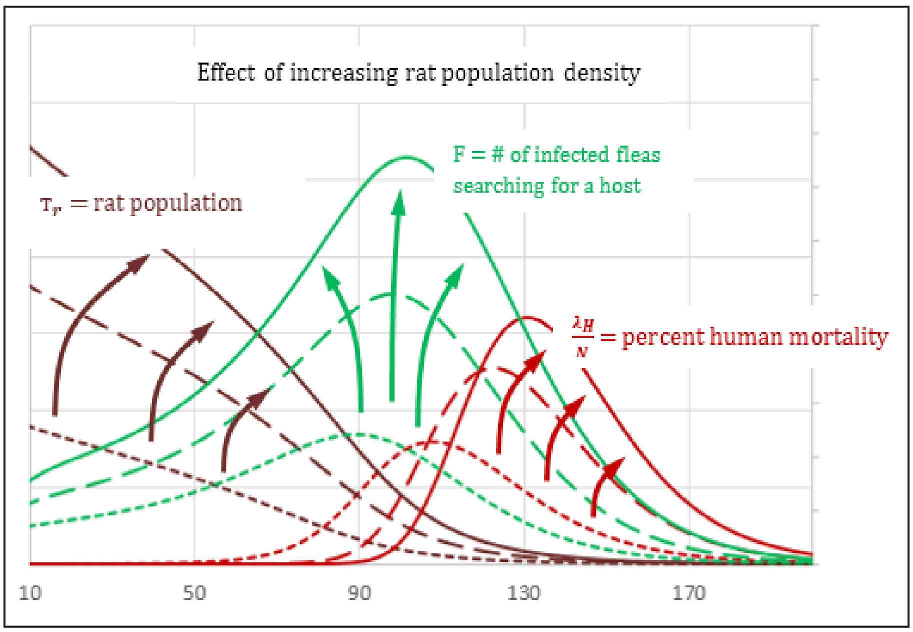

Fig. 2. The outbreak's variables under stress of rat population density

But all of this, it should be noted again, was well beyond the biological worldview of the inhabitants of Cairo. They were like those in the other cities of the Middle East, Europe, and Asia, in that they couldn't help but give scant notice to this biological drama unfolding at their feet. Any attention given in the sources to the natural world's role in plague outbreaks was given not to the sick rats and the

[18]For conditions in the early twentieth century, see A. Bacot, George F. Petrie, and Ronald E. Todd, "The fleas found on rats and other rodents, living in association with man, and trapped in the towns, villages and Nile boats of Upper Egypt," *Journal of Hygiene* 14, no. 4 (1914): 498–508 and tables II–IV.

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rising flea numbers, but rather to the myriad of nature's creatures, including the birds and the fish, who were said to be dying of plague along with the humans.[19]

Plague Narratives (833/1430 and 864/1460)[20]

Thus the two outbreaks that we are studying were described by medieval observers who were unaware that as they watched the plague march toward them from the north, from Alexandria and the Nile Delta, it was in fact already upon them and in their midst. So for the second of these two outbreaks, 864/1460, the inhabitants of Cairo waited as they received the alarming reports of a very bad plague outbreak approaching. The plague was making its way south and devastating towns and villages along the way.[21] From the reports of high fatalities in the Delta, which for provincial towns like al-Maḥallat al-Kubrá and Minūf al-Ulyá were in the hundreds per day, the inhabitants of Cairo knew this would be a

[19] Though things may have been otherwise half-a-world away. During the third global plague pandemic, Yersin noted that Chinese tradition did regard plague as a disease of rats, and some of these communities took action, i.e., flight, when observing dying rats; see Jessica Girard et al., "Differential plague-transmission dynamics determine Yersinia pestis population genetic structure on local, regional, and global scales," *Proceedings of the National Academy of Sciences of the United States of America* 101, no. 22 (2004): 8413.

[20] Al-Maqrīzī, *Al-Sulūk,* 4:822–26, is the main source for the 833/1430 plague; Ibn Taghrībirdī, *Al-Nujūm*, 16:136–47, for the 864/1460 plague. Ibn Taghrībirdī's information is the more detailed and precise of the two. Ibn Taghrībirdī (812–74/1408–69) was the son of the Mamluk amir Taghrībirdī (d. 814/1412), who had been a high-ranking military officer under the sultans al-Ẓāhir Barqūq and al-Nāṣir Faraj. Ibn Taghrībirdī learned history from al-ʿAynī and al-Maqrīzī and was well-versed in numerous subjects. Using his father's connections, he was granted access to court life and to several mid-fifteenth century sultans such as Barsbāy, Jaqmaq, and Khushqadam. His information on plague outbreaks, particularly the 864/1460 outbreak, is to be found in his works *Al-Nujūm al-zāhirah fī mulūk Miṣr wa-al-Qāhirah* (available in translation by William Popper as *History of Egypt*), and *Ḥawādith al-duhūr fī madá al-ayyām wa-al-shuhūr*. Using a manuscript of *Ḥawādith* from the Vatican Library, we were able to piece together two separate accounts that he made of this 864/1460 outbreak. The two data streams of these sources, though not at odds with one another, differ in their focus and ultimately complement one another. The account in *Ḥawādith* contains more detailed quantification of plague mortality for the outskirts *(al-ẓawāhir)* of Cairo, population centers like Miṣr (Fusṭāṭ), the old capital of Egypt, Būlāq, the shipping depot for grain on the Nile, and important residential areas such as al-Ḥusaynīyah to the north of Cairo. Together, these two narratives from Ibn Taghrībirdī make the 864/1460 outbreak the best documented of the Mamluk period. For these biographical details, see Wan Kamal Mujani, "The Mamluk Historians and their Accounts on the Economy of Egypt for the Period of 872–922 H/1468–1517 AD," *Journal of History and Social Sciences, Univ. of Karachi* 1, no. 2 (http://www.jhssuok.com) (2010): 52–54.

[21] Al-Biqāʿī, *Iẓhār,* 3:107; ʿAbd al-Bāsiṭ, *Nayl,* 6:75; Ibn Taghrībirdī, "Ḥawādith," Vatican MS 727, fol. 101; idem, *Al-Nujūm,* 16:136.

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very bad outbreak.[22] As the epidemic closed in and devastated the town of Bilbays on the edge of the eastern desert, and as it set upon the great Sufi monastery of Siryāqūs, the mood of morbid anticipation intensified.[23] Ibn Taghrībirdī noted of this nervous tension that it was a dread so powerful that people were afraid to leave their houses.[24] By early February, when the city finally became aware of the epidemic in their midst, the growing number of infections were claiming around a hundred lives a day—and this fatality rate was increasing rapidly.[25]

By the end of March, more than a thousand inhabitants of Cairo were dying of plague every day.[26] Then in mid-April following the customary responses to plague outbreaks, including supernumerary fasting and mass prayers in the desert, the outbreak reached its peak.[27] As the living could no longer match their strength to the rising number of dead, desperate people struggled and fought with each other to get proper funeral shrouds. Coffins and corpses were lined up in rows, blessed *en masse* via a very hurried *janāzah* (funeral prayer) and taken out of the city gates for hurried burial in the desert.[28] While the dictates of tradition were not overtly against such hasty funeral prayers, they were at odds with the expedient of blessing such large numbers in one collective prayer.[29] Mass blessing, like mass burial, became the rule as this outbreak was rising to its full peak.[30] And as the peak swept through, even the best attempts to remove the bodies of plague victims left a substantial number of corpses behind, which were unceremoniously deposited in urban gardens or narrow alleyways. They filled

[22] Ibn Iyās, *Badāʾiʿ,* 2:357; Ibn Taghrībirdī, *Al-Nujūm,* 16:139; Popper, *History,* 6:93.

[23] Ibn Taghrībirdī, "Ḥawādith," fol. 103.

[24] Ibn Taghrībirdī, *Al-Nujūm,* 16:136–37; Popper, *History,* 4:90–91.

[25] Ibn Taghrībirdī, *Al-Nujūm,* 16:137; Popper, *History,* 4:91; Ibn Taghrībirdī, "Ḥawādith," fol. 103a; ʿAbd al-Bāsiṭ, *Nayl,* 6:75.

[26] ʿAbd al-Bāsiṭ, *Nayl,* 6:80; al-Biqāʿī, *Iẓhār,* 3:116–17; Ibn Taghrībirdī, "Ḥawādith," fol. 104b; idem, *Al-Nujūm,* 16:141; Popper, *History,* 4:94.

[27] Dols, *Black Death,* 246–50.

[28] ʿAbd al-Bāsiṭ, *Nayl,* 6:80.

[29] Ibid.

[30] For similar details from 1791, see Alan Mikhail, "The nature of plague in late eighteenth-century Egypt," *Bulletin of the History of Medicine* 82, no. 2 (2008): 249–75. Mikhail notes, "so great a number of the soldiers and marines stationed in Old Cairo, Gīza, and Būlāq died that mass graves were dug into which their corpses were thrown without any ceremony or final rites. For those not connected to the military, their funerals also had to be done en masse, with prayers being said for up to five people at one time. Indeed, the apparatuses charged with the management of death were stretched to their limits during this spring as the demand for undertakers *(al-hawānīt)* and corpse washers *(al-mughassilīn)* far exceeded their available numbers."

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Cairo's streets with the horrible stench of human decay as the death toll finally started to fall.[31]

Looking back further in time to the first of these two outbreaks, it is clear to us that the 833/1430 plague was in fact even more severe. Ibn Taghrībirdī declared that it was the second worst epidemic to visit the Islamic world—after the 749/1348 Black Death (known to late Mamluk Cairo as "*al-wabāʾ al-ʿāmm,*" the Great Plague).[32] In this outbreak bodies were brought to a collection point at one of the main city gates, the Bāb al-Naṣr, and blessed for burial in groups of forty as bodies stretched out from this gate to the Bāb al-Wazīr gate some 2.5 kilometers away.[33] Mass burials followed in this outbreak as well and we are told that the digging of graves went on through the night, with dogs gnawing on corpses left unattended.[34] As always, the desperate attempt to dispose of bodies led to extreme practices such as simply throwing corpses into the Nile.[35]

The Dīwān al-Mawārīth and the Oratories

At the focal point of our study are the social and administrative mechanisms for processing the dead and counting the bodies. These mechanisms are the real sources of our data, the data that the fifteenth-century chroniclers analyzed in their fashion and filtered according to their own dictates of time and necessity. And as it turns out, this data was once the property of the Mamluk Sultanate, more or less. That is to say that those who did the actual counting were either bureaucrats working for the Mamluk regime or ad hoc assemblages and temporary hires supervised by government officials.[36] Most of these people were in fact directed by high-ranking amirs appointed by the sultan.[37]

There were two main agencies that brought these groups of people, clerical workers of one sort or another, together. The first of these was both formal and official and its data is central to our quantifications. It was the Dīwān al-Mawārīth

[31] Dols, *Black Death,* 238.

[32] ʿAbd al- Bāsiṭ, *Nayl,* 1:177

[33] Al-Maqrīzī, *Al-Sulūk,* 4:827.

[34] Al-Maqrīzī, *Al-Sulūk,* 4:828.

[35] Ibn al-Ṣayrafī, *Nuzhat,* 1:427

[36] Dīwān al-Mawārīth (Office of Inheritances) had official offices at al-Qāhirah (Mamluk Cairo), Miṣr (Fusṭāṭ), and Būlāq. In some cases we get first-hand information written out from these *waraqāt al-taʿrīf.* Ibn Iyās apparently had these *waraqāt* in hand as he wrote about the plague years 909, 910, and 919. Ibn Iyās also makes his own estimations of the ratios of this Dīwān count and the total number of plague fatalities. See Ibn Iyās, *Badāʾiʿ,* 4: 301–2, 308. See discussion of this office in Dols, *Black Death,* 175–78.

[37] See al-Maqrīzī, *Al-Sulūk,* 4:822–26, for sources of his data in the 1430 plague; Ibn Taghrībirdī, *Al-Nujūm,* 16:136–47, for sources of his data for the 1460 plague.

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al-Ḥasharīyah, which we might translate as "bureau of inheritances," and it had responsibility for the registration of deaths, inheritances, and the final disposal of the deceased's assets.[38] As Dols describes this agency: "The Dīwān registered only the deaths of those with taxable legacies. The government would take the entire estate of anyone dying without heirs and the residue of an estate where the heirs were not entitled to the whole inheritance. In some instances, the government would confiscate inheritances even when there were heirs. Cairo and Fusṭāṭ had separate dīwāns."[39]

As the one-time bureaucrat al-Qalqashandī informs us, the Dīwān al-Mawārīth was responsible for the registration of deaths and for the disposal of assets in cases where there were either no designated heirs or no legitimate heirs.[40] To a certain extent then this all boiled down to money, and money was the regime's main concern.[41] The sultanate monitored deaths and legacies with an eye to seizing as large a proportion of the deceased's assets as possible. Though the regime was legally limited to estates without valid heirs, the actual practice was often to seize estates, heirs or no heirs.[42] Not surprisingly, the Dīwān al-Mawārīth was particularly concerned with the deaths of the richest members of society, and these were often high-ranking members of the ruling regime, whose landed estates *(iqṭāʾ)* were eligible for transfer. But the Mamluk government was in general eager to preside over the transfer of assets from any well-to-do family.[43] With money as the object, it is clear that they were interested in only those with worthwhile assets and not with the poor and indigent. It is hard to say exactly where the Dīwān al-Mawārīth drew the line between rich and poor, but anyone with property of good value was probably fair game.

So it's clear that only part of the population counted in the eyes of the Dīwān al-Mawārīth. What this boils down to in practical terms that concern us quantitatively is that for these two outbreaks, about one-fifth to one-third of all the deaths in the population of Mamluk Cairo were registered *(taʿrīf)* by the Dīwān.[44] (The

[38]Dols, *Black Death,* 175–78.

[39]Dols, *Black Death,* 175.

[40]Aḥmad ibn ʿAlī al-Qalqashandī, *Subḥ al-aʿshá fī ṣināʿat al-inshāʾ,* ed. Muḥammad Ḥusayn Shams al-Dīn (Beirut, 1987), 4:33, 13:385.

[41]Al-Qalqashandī, ibid., 11:93, describes how they were concerned with the dying of *muqṭaʿūn* (landholders) so as to transfer their *iqṭāʾ* (their estates).

[42]The Dīwān al-Mawārīth kept detailed records of property bequests. See *Documents of the Jewish pious foundations from the Cairo Geniza,* ed. Moshe Gil, Publications of the Diaspora Research Institute, vol. 12 (Leiden, 1976), 7.

[43]See again al-Qalqashandī, *Ṣubḥ,* 11:93.

[44]Sources for Dīwān al-Mawārīth figures include, for 1430: al-Maqrīzī, *Al-Sulūk,* 4:822–26; Ibn Ḥajar al-ʿAsqalānī, *Inbāʾ,* 9:200; ʿAbd al-Bāsiṭ, *Nayl,* 267–68; Ibn Taghrībirdī, *Al-Nujūm,* 14:340–43; al-Biqāʿī, *Iẓhār;* Ibn Iyās, *Badāʾiʿ,* 2:113; Ibn Taghrībirdī, *Ḥawādith,* 14:339–43. For 1460 see Ibn

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registration was called a *taʿrīf*, which for each day was recorded on a separate document known as a *waraqat al-taʿrīf*.) This fraction of one-fifth to one-third of the total population counted by this Dīwān is a fraction central to our quantifications. What we will do is to divide the Dīwān's fatality rate by this fraction to arrive at the total fatalities per day for all of Mamluk Cairo. So this fraction, this ratio, is very important to us, but it seems that it was also very much on the minds the Mamluk-era chroniclers and, in fact, everyone who was involved in the business of counting. The chroniclers in their narratives also try themselves to work out this ratio of the Dīwān deaths to the total number of deaths. Al-Maqrīzī tried to estimate this ratio, as did Ibn Taghrībirdī—and Ibn Iyās several decades later.[45]

For our analysis, what we did was to calculate this ratio by taking cases (specific days) where we had both (1) the number of deaths from the Dīwān al-Mawārīth and (2) the total number of deaths for Mamluk Cairo as a whole. As an example for the purposes of illustrating this process, take the case of plague statistics for the 26 Jumādá I 864 (19 March 1460). On this day, the Dīwān al-Mawārīth produced a *waraqat al-taʿrīf* (death register) recording that there had been 235 deaths on that day. Yet we learn from a second count that included the entire population of Mamluk Cairo that the actual total of all deaths that day was 1153. Using these two numbers we calculate a ratio of the Dīwān to the total, which is $(\frac{235}{1153}) = .204$.[46] Then by repeating this process for other days in which we had both sets of numbers, we were able to sum up our results and calculate the average ratio for the 864/1460 plague outbreak, which turned out to be .1916, meaning that the Dīwān was only counting one-fifth of all fatalities at this time. Having determined what this ratio was (on average) we could apply it to the many cases. So we then took these isolated and partial statistics and from them computed the whole. So as another example of how this works, for 19 Rabīʿ II 864 (12 February 1460) the Dīwān al-Mawārīth recorded thirty-five deaths, and that is the only figure that we have for that day. We take this number and divide it by the average ratio of the Dīwān to the total, i.e., $(\frac{35}{.1916}) = 183$, and so by the process we get the estimated number of deaths for the many days in which we have only the figures from the Dīwān al-Mawārīth.[47] About 60% of our data is in fact the result of doing these calculations.

But there is another source of data, and the Dīwān was not the only agency that was doing the counting. From other sources we obtained the total counts for Mamluk Cairo as a whole (i.e., such as the 1153 deaths in the example above). The

Taghrībirdī, *Al-Nujūm,* 16:136–47; in translation by Popper, *History,* 4:90–100; Ibn Taghrībirdī, *Ḥawādith,* 16:130–47; Ibn Iyās, *Badāʾiʿ,* 2:357; ʿAbd al-Bāsiṭ, *Nayl,* 6:74–83.

[45] Al-Maqrīzī, *Al-Sulūk,* 4:824; Ibn Taghrībirdī, "Ḥawādith," fol. 104b.

[46] Ibn Taghrībirdī, *Al-Nujūm,* 16:141.

[47] Ibn Taghrībirdī, *Al-Nujūm,* 16:137.

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other agency that counted fatalities was the collection of what were called *muṣallāt* (oratories) around the city of Mamluk Cairo. A *muṣallá* was an open place for prayer with ceremonial scope more limited than that of a mosque. In many cases it was not a building but rather an open area that may or may not have had some kind of enclosing structure.[48] The bodies of plague victims, wrapped *(takfīn)* in simple white cloth *(kafan),* were brought to these oratories where a final blessing took place, after which the bodies were taken outside of the city gates for inhumation. This blessing itself (the *janāzah*) was in general a rather short process, a few minutes only, but at the peak of these plague outbreaks it became a very rushed and hectic affair, with bodies stacked up in rows and blessed hastily.[49] According to our sources, there were fourteen of these oratories in (Mamluk) Cairo during the early 1400s and some seventeen oratories in the late fifteenth century.[50] Most of them appear to have been located at either city gates (e.g., Bāb al-Naṣr, Bāb al-Wazīr, Bāb al-Maḥrūq, Bāb al-Qalʿah), mosques (al-Azhar, al-Ḥākim), or markets (al-Biyāṭurah, the Farriers' Market): presumably anywhere there was sufficient space not claimed by structures and crowds of people.[51] The one *muṣallá* that is most often referred to in the course of these two outbreaks was that of the Bāb al-Naṣr at the northern end of Fatimid Cairo.

Just as the Dīwān al-Mawārīth's fatality numbers were fractions of the whole, there was also a mathematical relationship—a ratio—between the individual oratories and the sum of all the oratories in Mamluk Cairo. In the same manner in which we derived ratios from partial and full counts above, we also calculated ratios for specific oratories (the Bāb al-Naṣr oratory in particular) and then applied those ratios to derive comprehensive figures for Mamluk Cairo. As was the case with the Dīwān's ratio with the whole, the bureaucrats and the chroniclers were also interested in the oratory ratios. For example, Ibn Taghrībirdī's attention was drawn to one clerical worker's fairly accurate estimation of the average ratio

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[48] R. Hillenbrand, "Muṣallā," *Encyclopaedia of Islam,* 2nd ed., 7:658–60.

[49] Ibn Taghrībirdī, *Al-Nujūm,* 14:341.

[50] Al-Maqrīzī, *Al-Sulūk,* 4:827; Ibn Taghrībirdī, *Al-Nujūm,* 16:141.

[51] Other *muṣallāt* in Mamluk Cairo included one near the mosque of Ibn Jibās (south of Bāb Zuwaylah): see Aḥmad ibn ʿAlī al-Maqrīzī, *Kitāb al-Mawāʿiẓ wa-al-iʿtibār bi-dhikr al-khiṭaṭ wa-al-āthār* (Būlāq, 1270/1853–54), 4:273; Āl Malik at Suwayqah al-Ramlah: see al-Maqrīzī, *Khiṭaṭ,* 3:192; a *muṣallá* near the Māridānī mosque: see Ibn Ḥajar al-ʿAsqalānī, *Inbāʾ,* 1:480. For areas outside of Mamluk Cairo, three *muṣallāt* are mentioned: Zāwiyat al-Khuddām in Ḥusaynīyah: see Ibn Taghrībirdī, "Ḥawādith," fol. 104b, *Muṣallá al-ʿīd,* later called *Muṣallá al-amwāt:* see Doris Behrens-Abouseif, "A Circassian Mamluk Suburb North of Cairo," *Art and Archaeology Research Papers* (Dec. 1978): 17; Khūlān in one of the two Qarāfatah: see Ibn Ḥajar al-ʿAsqalānī, *Inbāʾ,* 1:480; al-Andalus in the Qarāfah al-Ṣughrá: see al-Maqrīzī, *Khiṭaṭ,* 4:333. Ibn Taghrībirdī also notes that there were eleven *muṣallāt* inside Mamluk Cairo during the 841/1438 outbreak; see Ibn Taghrībirdī, *Al-Nujūm,* 15:104.

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of the deaths per day recorded at the Bāb al-Naṣr oratory to the deaths/day for all the dead for Mamluk Cairo.[52]

The figure calculated by this minor bureaucrat, relayed to us by Ibn Taghrībirdī, turns out to be quite precise. From the ratio it seems clear that these counters of corpses could be quite thorough. The Mamluk-era interest in ratios may be convenient for quantitative history today, but we are in the dark as to the precise motivation for counting corpses at these oratories. We do know—from evidence of the sultan's orders—that it was a high priority for the regime. Zayn al-Dīn al-Ustadār, a high-ranking amir under orders from the sultan, apparently organized the process of hiring counters and sending them out to every one of the oratories in Mamluk Cairo.[53] That someone really cared about the process of counting the dead is indicated by factors such as the use of independent witnesses, i.e., cases in which counts were made by different, independent observers and then compared with each other for accuracy.[54] Ibn Taghrībirdī notes that at an oratory count at the beginning of April 864/1460, when the plague was at its worst, there were three or more independent persons and/or groups conducting the count. Bureaucratic officialdom was also on display that day, as he describes for us the scene of bureaucrats lining up at the Bāb al-Naṣr oratory to do their counting, with tables, pens, and paper, then working away at the numbers as bodies were lined up along the gate in a low row.[55]

The Urban Setting and the Urban Boundaries

In order to estimate mortality, we first have to quantify the susceptible human population, i.e., the size of the urban population for which the dead were counted, meaning the population of Cairo. But at the outset we are faced with a problematic question: Which Cairo are we talking about? It's clear that there was more than one Cairo, and that there were in fact multiple urban entities sharing this physical and mental space in the 1400s.

Michael Dols worked on this problem and he broke the urban landscape down into three units of increasing scale: Fatimid Cairo, Mamluk Cairo, and Greater Cairo.[56] Dols' three-fold scheme is ideal for our study because Dols' purpose was the same as ours, to estimate plague mortality, and he was concerned with the reference points and demarcations used by the Mamluk-era chroniclers as they drew boundaries within which they defined the scale of human loss. The map

[52] Ibn Taghrībirdī, *Al-Nujūm,* 16:140; idem, "Ḥawādith," fol. 104b.

[53] Ibn Taghrībirdī, "Ḥawādith," fol. 104b.

[54] Ibn Taghrībirdī, *Al-Nujūm,* 16:141; Popper, *History,* 4:95.

[55] Popper, *History,* 18:71.

[56] See Dols, "Mortality," 403, and the maps he used in Popper, *Systematic Notes,* 1:19–37.

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below takes in the full compass of all three Cairos, Greater Cairo at its furthest extent, and then inside that Mamluk Cairo, within which was the smaller unit of Fatimid Cairo. Fatimid Cairo is not shown on this map, but it takes up the north-east quadrant of the space defined as Mamluk Cairo.

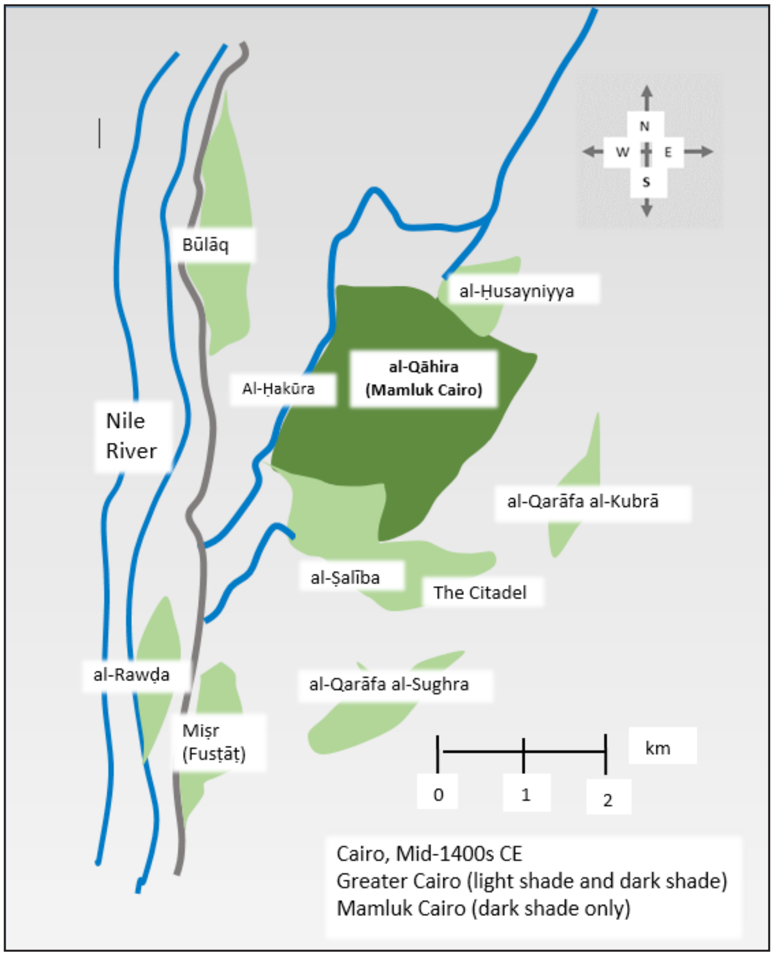

Fig. 3. Map of Greater Cairo, with Mamluk Cairo shown in the center

Greater Cairo

Greater Cairo is, in a sense, nothing more than a term of convenience used by Dols to refer collectively to the scattered and separate areas around Mamluk Cairo.[57] Whether or not the medieval inhabitants of Cairo considered these areas as a

[57] Dols, "Mortality," 403.

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single urban unit is not entirely clear in the sources, but there was at least an expression used for the area as a whole: "al-Qāhirah wa-ẓawāhirihā," Cairo and its outskirts.[58] Anecdotally, the concept of Greater Cairo as a single unit managed to capture the attention—and spleen—of the seventeenth-century Jean de Thevenot. He complains about the concept in his travelogue as he recounts walking and measuring the inner urban areas from end to end. Ridiculous, he called the idea, like lumping into his home city Paris all of her banlieues, her outlying suburbs. He launches a minor diatribe about those who use the fictive concept of Greater Cairo to boast of the city's size, noting the vast stretches of intervening and often empty spaces between the urban areas of Būlāq, Fusṭāṭ, and Cairo proper. Nevertheless, this bears on a notion of Greater Cairo in the 1400s, a concept that is very important for our analysis, as this "al-Qāhirah wa-ẓawāhirihā" is used on a number of occasions as the largest of the units for which mortality was counted. So the chronicles will at times give the largest of mortality figures and specify that this counted for this area as a whole. What we will do below is to use the plague numbers in reverse in order to use them to quantify the relative demographic concentration of this largest unit.

The following are the areas included as Greater Cairo, as mentioned for one or both of the two plague outbreaks:

1. Al-Qarāfatayn (the Two Cemeteries): al-Qarāfah al-Kubrá north of the Muqaṭṭam hills, and al-Qarāfah al-Ṣughrá, south close to Fusṭāṭ, to the east/southeast of Mamluk Cairo
2. Būlāq on the Nile northwest of Cairo
3. Miṣr (i.e., Fusṭāṭ), Old Cairo, to the south
4. Ḥusaynīyah to the north of Mamluk Cairo

Fatimid Cairo

The smallest of our three units is Fatimid Cairo, the original city founded by the Fatimids in 358/969. It was rectangular in shape, approximately 160 hectares in extent, and measured 1.45 km north to south and 1.1 km east to west.[59] Fatimid Cairo was contained within the much larger unit that Dols defined as Mamluk Cairo.

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[58] Examples of this usage can be found in Ibn Ḥajar al-ʿAsqalānī, *Inbāʾ al-Ghumr,* 9:200; Ibn Taghrībirdī, *Al-Nujūm al-zāhirah,* 14:340, 16:145; idem, "Ḥawādith," fol. 105a; al-Maqrīzī, *Al-Sulūk,* 4:826–27.

[59] Raymond, "Al-Maqrīzī's *Khiṭaṭ* and the Urban Structure of Cairo," *Institut d'Etudes et de Researches Sur Le Monde Arabe et Musulman,* 166–67, for maps, and Jean-Claude Garcin, "Toponymie et topographie urbaines médiévales à Fustat et au Caire," *Journal of the Economic and Social History of the Orient/Journal de l'histoire economique et sociale de l'Orient* 27, no. 2 (1984): 136, 145.

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Mamluk Cairo

The area for which we quantify population and plague fatalities is Mamluk Cairo, intermediate in size between Greater Cairo and Fatimid Cairo. The boundaries of this area have been studied in some detail by a number of scholars, among them William Popper, Michael Dols, Jean-Claude Garcin, Andre Raymond, and Julien Loiseau.[60] In Loiseau's maps, the area we define as Mamluk Cairo can be seen to measure some 3.25 km north to south, with a slanted and uneven east-west extent averaging about two kilometers.[61]

A digression here is essential as it brings us to the most important question about these three Cairos and that is: which one of them was al-Qāhirah, the title used in our sources?[62] Was al-Qāhirah simply the old Fatimid Cairo, or was it something larger than that? Was it Mamluk Cairo? This is a tricky question and requires some exploration of the subject. The usage of the word al-Qāhirah and the boundaries intended by the word varied not just in the long term (969–1517), but perhaps also in the short term, i.e., over the course of the fifteenth century. The Mamluk-era sources may also have intended more than one thing when they used this term, the meaning changing according to the context and subject matter of their writings. As such, it may be that the meaning of al-Qāhirah in the plague narratives was specific to plagues, and did not apply to other contexts.

When the Ayyubids replaced the original Fatimid mud-brick walls with stone, they also extended those walls to the south, stretching to the new citadel.[63] Sultan Qalāwūn extended these walls farther, and it seems that some Mamluk-era writers clearly conceived of al-Qāhirah as an urban zone larger than Fatimid Cairo, i.e., extending far beyond the original Fatimid boundaries.[64] Whether or not that was true of our 1400s sources, what is clear from al-Maqrīzī, Ibn Taghrībirdī, etc., and also from the temporal/spatial distribution of plague fatalities, is that the scope of surface area referenced by the usage of the word al-Qāhirah, which was the word they used for counting plague fatalities, was much larger than the 160 hectares of Fatimid Cairo. The apparent fact is that the boundaries of al-Qāhirah

[60] Julien Loiseau, "Reconstruire la maison du sultan," in *Ruine et recomposition de l'ordre urbain au Caire (1350–1450),* IFAO Études urbaines 8 (Cairo, 2010), 2:591–93, 600–21; Andre Raymond, "Cairo's area and population in the early fifteenth century," *Muqarnas* (1984): 21–31; Jean-Claude Garcin, "Note Sur La Population Du Caire En 1517," in *Grandes villes méditerranéennes du monde musulman médieval* (Rome, 2000), 205–13; Popper, *Systematic Notes,* Part 1, Maps 5–12.

[61] Loiseau, "Reconstruire," 2:592–93.

[62] See references to Mamluk Cairo as found in Ibn Ḥajar al-ʿAsqalānī, *Inbāʾ al-ghumr,* 9:200; Ibn Taghrībirdī, *Al-Nujūm al-zāhirah,* 14:340, 16:145; al-Maqrīzī, *Kitāb al-Sulūk,* 4:826–27.

[63] Andre Raymond, *Cairo,* trans. Willard Wood, (Cambridge, MA, 2000), 83–90.

[64] Ibn ʿAbd al-Ẓāhir, *Al-Rawḍah al-Bahīyah al-Ẓāhirah fī al-Khiṭaṭ al-Muʿizzīyah al-Qāhirah,* ed. Ayman Fuʾād Rashīd (Cairo, 1996), 19–20; Ibn Taghrībirdī, *Al-Nujūm,* 1:44.

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within which the dead were registered (by the Dīwān al-Mawārīth), collected (at the *muṣallāt* [oratories]), and counted, encompassed most of the area south of Bāb Zuwaylah and west of the Cairo Canal, al-Khalīj al-Miṣrī.

Raymond, Garcin, and Loiseau refer to the area west of the Cairo Canal as the western zone (Exterieur Ouest) and the area south of Bāb Zuwaylah as the southern zone. Raymond has studied the extent of the built-up areas (areas of high population density, ~ 400 persons per hectare) and estimated that these areas measured about 266 hectares for the southern zone and 100 hectares for the western zone.[65] If one adds to this Raymond's estimate for Fatimid Cairo's built-up area (153 hectares), the total built-up urban area of these three is 519 hectares. Excepting a couple of small subsections (al-Ṣalībah in the south, and al-Ḥakūrah to the west), these 519 hectares were the surface area intended by the word of al-Qāhirah in the plague narratives, even if al-Qāhirah meant something else (like Fatimid Cairo) in other contexts.[66] Compelling evidence makes this case. One example of this evidence is the fact that 50% of the oratories of al-Qāhirah were in fact outside of Fatimid Cairo (the Muʾminī oratory and the Biyāṭurah oratory south of Bāb Zuwaylah).

[65] In a number of studies, Andre Raymond measured the built-up area within these confines and concluded upon painstaking examination that it was about 519 hectares. His are the boundaries of the plague narratives with the only exceptions being Ṣalībah in the south and al-Ḥakūrah in the west. Our sources indicate these two areas were not included in the mortality counts of Mamluk Cairo. Al-Ḥakūrah, in the area that Raymond called the "western zone" (to the west of the Khalīj al-Miṣrī), seems to have been a non-residential area, more or less what is proposed by the meaning of this word, i.e., a garden. This area in which al-Ḥakūrah seems to be located is in what Raymond calls the "western zone" that lay between the Khalīj al-Miṣrī and the Khalīj al-Naṣirī with the observation that its built-up area measured some hundred hectares. The case of al-Ḥakūrah (the word meaning "vegetable garden") is made more difficult as its precise location is hard to identify. William Popper noted it on one of his maps as a smallish sector just west of the Khalīj al-Miṣrī. Ṣalībah, however, was a densely inhabited area, first and foremost a street, but also a neighborhood in the section of the city that Andre Raymond called "the southern zone." Ṣalībah seems to have been a subset of this southern zone, which in its largest extent was the whole area (measuring about 226 hectares according to Raymond) from Bāb Zuwaylah at the southern end of Fatimid Cairo down to the citadel in the southeast and the Qanāṭir al-Sibāʿ in the southwest. For the areas of the southern zone (266 ha) and the western zone (100 ha) see Raymond, "La Population," 206. The scope of the Ṣalībah area seems to have been relatively small, some 25 hectares to the southwest of the Muʾminī oratory in Mīdān Rumaylah across from the citadel.

[66] Al-Maqrīzī, *Kitāb al-Sulūk,* 4:826, lists al-Ḥakūrah and Shāriʿ al-Ṣalībah as being outside the bounds of the city proper: as he states, "This [death toll] did not include the people of the areas [neighborhoods/environs] outside of Cairo such as al-Ḥakūrah, al-Ḥusaynīyah, Būlāq, al-Ṣalībah, Madīnat Miṣr (Fusṭāṭ), the Cemeteries, and the desert."

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So for this article and the quantification of plague mortality, our unit of analysis is the 519 hectares of Mamluk Cairo and al-Qāhirah as used in the plague narratives, which refers to Mamluk Cairo and not just Fatimid Cairo.

Fatimid Cairo	153 hectares
Western Zone	100 hectares
Southern Zone	266 hectares
Total Surface area	519 hectares
Subtract al-Ṣalībah	- 19 hectares
Mamluk Cairo ("collection area")	= 500 hectares[67]

Given an approximate surface area of 500 hectares, we can multiply this area by Raymond's estimated population density of 400 persons per hectare, and this gives us a total urban population of 200,000 as shown in the schematic equations here.[68]

Extent of collection area (Mamluk Cairo)	500 hectares
Population density of collection area	400 persons/hectare
	$500 \text{ hectares} \times 400 \frac{\text{persons}}{\text{hectare}}$
Population within collection area:	= 200,000 persons

Lastly, what we will do with this urban population estimate is to estimate mortality. For example, if our death toll for one of these outbreaks was 50,000 then the total mortality would be:

Mortality for al-Qāhirah: $\frac{\text{number of deaths within collection area}}{\text{population within collection area}} = \frac{50{,}000}{200{,}000} = 25\%$

In reality, 200,000 is only a rounded estimate. The true population level fluctuated substantially over time and was impacted by plague depopulation itself.[69]

[67] We measured the area of al-Ṣalībah using Raymond's map ("La Population," 204) and comparing it with the details provided in Julien Loiseau, "La Porte du vizir: programmes monumentaux et contrôle territorial au Caire à la fin du XIVe siècle," *Histoire urbaine* 1 (2004): 7, to determine the approximate boundaries of the Ṣalībah area.

[68] This rounded urban population estimate is in fact the estimate of Raymond and Garcin for the year 1517 (Garcin estimates Greater Cairo's population to be 270,000; see Garcin, "Note sur," 213.) However, Raymond's figure for the early 1400s is substantially lower, in fact as low as 150,000. As a scholarly verdict on Cairo in the early 1400s, Raymond consigns to it a population of merely 150,000 to 200,000, whereas Loiseau pronounces it a ruin; see Raymond, "Cairo's Area," 30; Julien Loiseau, "Les demeures de l'empire: Palais urbains et capitalisation du pouvoir au Caire (XIVe-XVe siècle)," *Actes des congrès de la Société des historiens médiévistes de l'enseignement supérieur public* 36, no. 1 (2005).

[69] Fluctuations haven't stopped some from trying to pin down urban population with precision: Dols estimated urban population (Mamluk Cairo, roughly 300,000 and Greater Cairo, 450,000) based on William Popper's mapping of Cairo's built-up areas. See Dols, "General Mortality,"

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Quantitative Analysis (Results)

833/1430

Total deaths in Mamluk Cairo over 95 days[70]	93,040
Deaths due to natural causes[71]	-1,710
	=91,330
Population of Mamluk Cairo: 200,000	
Mortality of the plague outbreak	$(\frac{91,330}{200,000}) = 46\%$

864/1460

Total deaths in Mamluk Cairo over 117 days	83,057
Deaths due to natural causes	2,106
	= 80,951
Population of Mamluk Cairo: 200,000	
Mortality of the plague outbreak	$(\frac{80951}{200,000}) = 40\%$

422–23, and idem, *Black Death,* 193–204, which contain detailed discussions of population density whereby Dols estimates an urban population density of 348 persons per hectare. Dols compares his figure to other estimates of urban density, which range from 200 persons per hectare to 400 persons per hectare. Using Popper's *Systematic Notes,* 23, he then estimates the area of Mamluk Cairo as 864 hectares and calculates 864ha x 348 persons/ha = 300,672 concluding that this was the population of Mamluk Cairo in the 1400s; see *Black Death,* 193–204; idem, "General Mortality," 401–2. Since Dols, mapping of the urban space has been greatly revised by Andre Raymond, Jean-Claude Garcin, and Julien Loiseau. For their analyses, see Garcin, "Toponymie," 134–45. Raymond notes that much of Dols' 864 hectares was in fact not densely populated urban space but rather was composed of ponds, gardens, cemeteries, etc., and that is how Raymond arrives at the much lower figure of 519 hectares. The fact that Raymond's population density (400 persons/ha) is higher than that of Dols (348 persons/ha) makes sense if one takes into account Raymond's painstaking mapping efforts and his careful attention to what was inhabited and what was not. For additional discussion of population and population density, see Garcin, "Toponymie," 134–45. Raymond's work was based on al-Maqrīzī's fifteenth-century descriptions of Cairo's urban space. Raymond determined the relative population densities from the locations and numbers of caravanserais, markets, bath houses, mosques, and housing concentrations *(ḥārah)* in his efforts to measure the extent of built-up areas and the relative concentrations of population; see "La Population," 203, 211–12; idem, "Al-Maqrīzī's Khiṭaṭ," 146–49; idem, "Cairo's area and population," 22, 24, 29–30. In similar fashion Julien Loiseau has analyzed Cairo's urban space and measured changes in population density over time after the Black Death; see *Reconstruire,* 117–40.

[70] Chroniclers report a cumulative of 100,000 for Mamluk Cairo, which Ibn Taghrībirdī considers a realistic number. See Popper's translation of Ibn Taghrībirdī's *Nujūm* in Popper, *History of Egypt,* 18:76.

[71] CDR (Crude death rate) estimated as 32.5 out of 1000.

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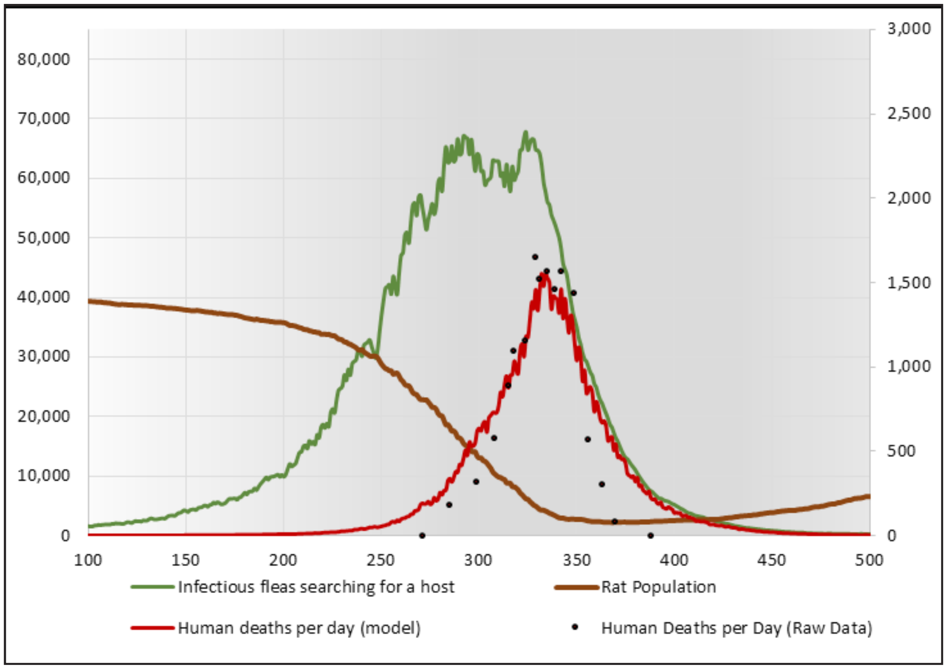

Fig. 4. 864/1460 Plague Outbreak in Cairo (rat and flea numbers estimated from human casualties).

The mortality numbers produced by these data collectors, examiners, and transmitters are shown in the tables below. Tables show the original data for the rates of fatality (deaths per day) as gathered from the two primary sources, the Dīwān al-Mawārīth and the oratories—and our methods for calculating ratios are indicated in the tables as well. We examined the data from this analysis via our adaptation of the Keeling and Gilligan plague model whereby we fit parameters of our equations for bubonic plague to the historical data provided by Ibn Taghrībirdī and others.[72] Via integration of these curves for fatality rates (deaths per day) over time in days, we computed the estimated cumulative mortality for both epidemics and from this estimated the likely mortality for both outbreaks. A plot of our simulation for the 864/1460 outbreak is shown above.

[72]Via the Solver function in Excel. See notes on the use of Solver in nonlinear regressions in Gerdi Kemmer and Sandro Keller, "Nonlinear least-squares data fitting in Excel spreadsheets," *Nature protocols* 5, no. 2 (2010): 267–81. For the use of Solver in nonlinear regression, see Daniel Harris, "Nonlinear least-squares curve fitting with Microsoft Excel Solver," *Journal of chemical education* 75, no. 1 (1998): 119–21; Angus M. Brown, "A step-by-step guide to non-linear regression analysis of experimental data using a Microsoft Excel spreadsheet," *Computer methods and programs in biomedicine* 65, no. 3 (2001): 943–44; Harvey J. Motulsky and Lennart A. Ransnas, "Fitting curves to data using nonlinear regression: a practical and nonmathematical review," *The FASEB journal* 1, no. 5 (1987): 365–74.

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Table: The 833/1430 Plague Outbreak in Mamluk Cairo

Sources for the 1430 plague: see al-Maqrīzī, *Al-Sulūk*, 4:822–26; Ibn Ḥajar al-ʿAsqalānī, *Inbāʾ*, 9:200; ʿAbd al-Bāsiṭ, *Nayl*, 267–68; Ibn Taghrībirdī, *Al-Nujūm*, 14:340–43; al-Biqāʿī, *Iẓhār;* Ibn Iyās, *Badāʾiʿ*, 2:113, Ibn Taghrībirdī, *Ḥawādith*, 14:339–43.

Date 1429/1430 CE	Fatalities registered by the Dīwān of Cairo	The ratio of the Dīwān fatalities to the total fatalities is derived here	The ratio for the Dīwān fatalities to the total fatalities is applied here	Fatalities counted at the Bāb al-Naṣr Oratory	The ratio for Bāb al-Naṣr fatalities to the total fatalities is derived here	The ratio for Bāb al-Naṣr fatalities to the total fatalities is applied here	Total Fatalities as reported by all 14 oratories	MAMLUK CAIRO	Source of the Final Result
		The average of the three calculations below is .3111	The figures below have been divided by .3111		The result of the calculation below is .3563	The figures below have been divided by .3563	Here are reports of all of Cairo		
28 Dec	12		12/.3111 = 39					39	Dīwān
11 Jan	16		16/.3111 = 51					51	Dīwān
25 Jan	48		48/.3111 = 154					154	Dīwān
26 Jan	100		100/.3111 = 321					321	Dīwān
9 Feb	300		300/.3111 = 964					964	Dīwān
24 Feb	400		400/.3111 = 1286					1286	Dīwān
28 Feb	390	390/1200 = .33					1200	1200	All Oratories
3 Mar	350	350/1200 = .29					1200	1200	All Oratories
5 Mar	400	400/1263 = .32		450	450/1263 = .3563		1263	1263	All Oratories
6 Mar				505		505/.3563 = 1417		1,417	Bāb al-Naṣr
9 Mar				800		800/.3563 = 2245		2,245	Bāb al-Naṣr
11 Mar				1030		1030/.3563 = 2891		2,891	Bāb al-Naṣr
2 Apr							0	0	

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Table: The 864/1460 Plague Outbreak in Mamluk Cairo

The primary sources for the 1460 plague are: Ibn Taghrībirdī, *Al-Nujūm*, 16:136–47, in translation Popper, *History,* 4:90–100; Ibn Taghrībirdī, *Ḥawādith,* 16:130–47; Ibn Iyās, *Badāʾiʿ,* 2:357; ʿAbd al-Bāsiṭ, *Nayl,* 6:74–83.

Date 1460 CE	**From the Dīwān of Cairo**	**Ratio of Dīwān to total (.1916) is derived**	**The ratio of Dīwān to total (.1916) is applied**	**Bāb al-Naṣr**	**Muʾminī Oratory**	**Al-Azhar Oratory**	**Biyāṭurah Oratory**	**Total Fatalities of the four main**	**Total Fatalities as reported by all 17**	**MAMLUK CAIRO**	**Source**
25 Jan										0	
12 Feb	35		35/.1916 = 183							183	Dīwān
22 Feb	60		60/.1916 = 313							313	Dīwān
3 Mar	110		110/.1916 = 574							574	Dīwān
10 Mar	170		170/.1916 = 887							887	Dīwān
13 Mar	209		209/.1916 = 1132							1,091	Dīwān
19 Mar	235	235/1153 = .2038							1153	1,153	All orato-ries
24 Mar	316		316/.1916 = 1649						1910	1,649	Dīwān
26 Mar					417/.27 = 1521					1,521	Muʾminī oratory
30 Mar	280	280/1561 = .1794	280/.1916 = 1461	380						1561	Greater Cairo
3 Apr	280		280/.1916 = 1461	570						1,461	Dīwān
6 Apr	300		300/.1916 = 1566	570		396	470			1,566	Dīwān
13 Apr				350	280	600	204	1434		1434	4 oratories
20 Apr				190	137	130	114	571		571	4 oratories
27 Apr				95	90	65	50	300		300	4 oratories
4 May				25	30	5	23	83		83	4 oratories
22 May									0	0	

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Quantitative Analysis (Discussion)

The last part of this study is our assessment of these quantifications. We have concluded that our methods have produced solid estimates of mortality and our discussion on the next few pages details the reasons and analyzes the primary facets of these results, concluding with an analysis of other plague outbreaks (one for 819/1416 and the other for 822/1419) that have a strong bearing on our case for this methodology. Our hope is to continue the work of quantifying the long series of plague outbreaks of the second plague pandemic in Egypt.

Evidence of the Relationship between Numbers (Dīwān and Oratories)

Reliable statistics like these can display consistently ordered patterns whereas unreliable estimates—or gross exaggerations—do so only rarely and by coincidence. If these chroniclers were really making wild guesses for their numbers, we should not expect to see these patterns.

Evidence that these were actual counts of plague deaths can be seen in the mathematical relationships between the data points. The ratio of the daily deaths registered by the Dīwān al-Mawārīth to the total daily deaths for Mamluk Cairo stayed more or less the same over the course of each outbreak. The best way to describe this ordered pattern is to visualize it. The graphs below compare and bring together two data streams, one from the oratories' total deaths per day and the other from the total deaths per day as derived from the Dīwān al-Mawārīth.

Ratios of the Dīwān *taʿrīf* to the count by the oratories:

833/1430:	.33	.29	.32
864/1465:	.18	.20	

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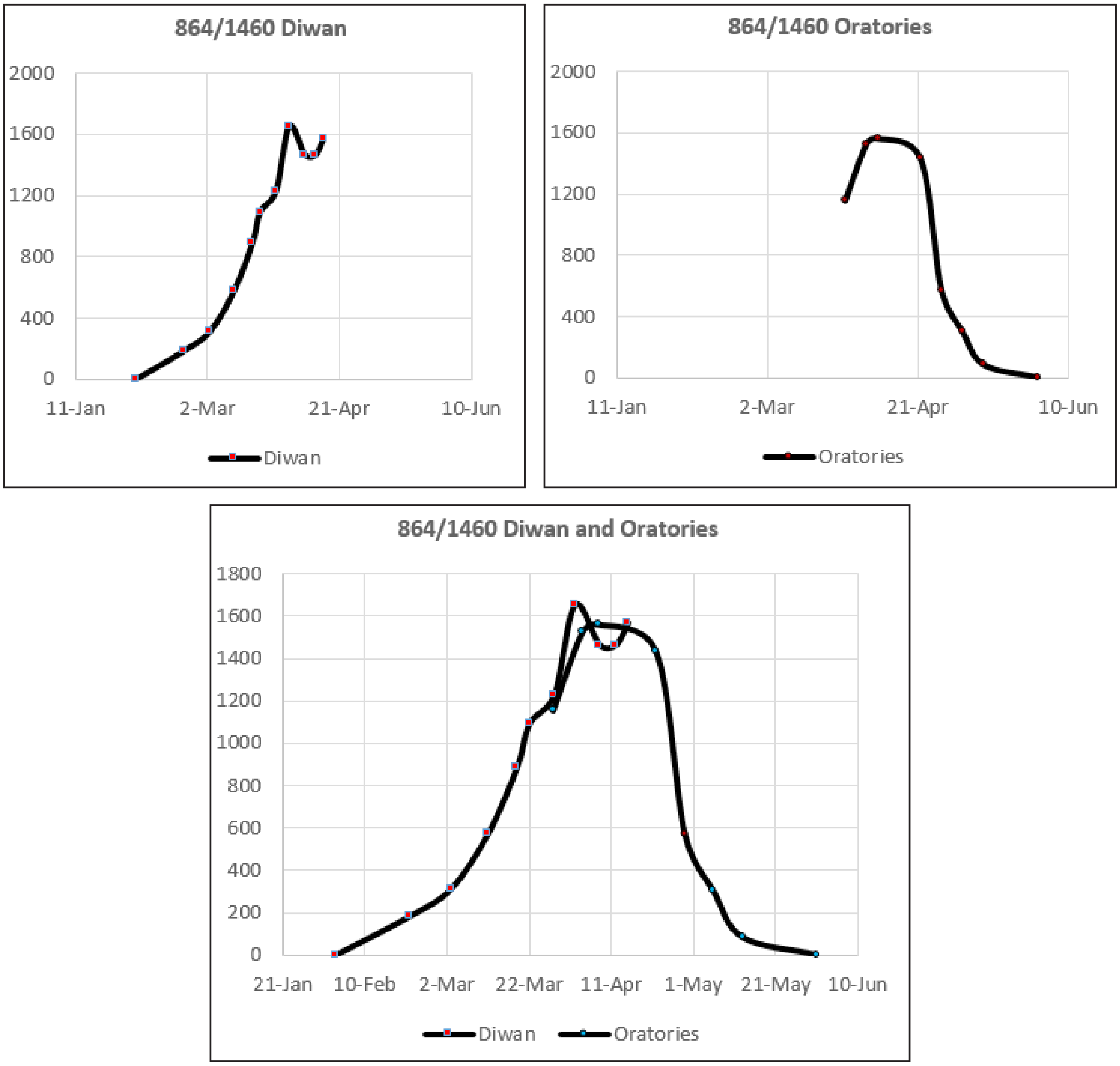

Fig. 5. Data Streams Compared

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For the most part, the same can be said of the ratios of deaths counted at individual oratories relative to the total deaths. Derived totals (from the Bāb al-Naṣr and Mu'minī oratories) and actual totals are shown in the graph below.[73]

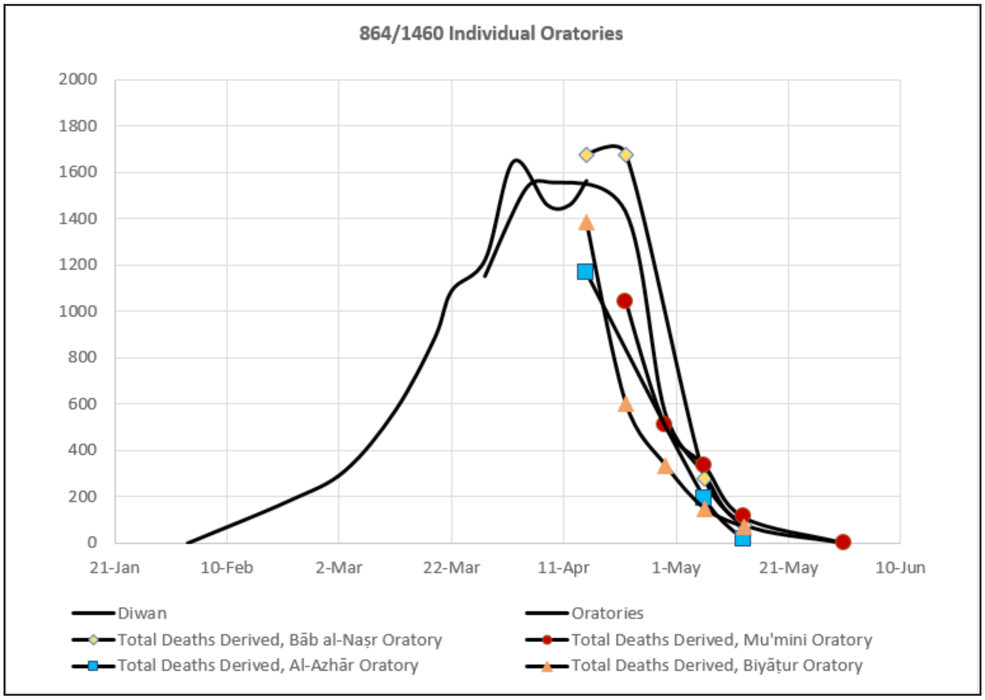

Fig. 6. Oratory Data Streams Compared

The same agreement between data streams (Dīwān al-Mawārīth derived and oratories total) was tested via the Wilcoxon Signed Ranks Test (Z-score -1.342, P-value .180). The test indicated that these two sets came from the same set of data.[74]

Test Statistic[a]

	B – A
Z	-1.342[b]
Asymp. Sig. (2-tailed)	.180

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

[73] The data point from the Bāb al-Naṣr Oratory, 29 April 1460, and the al-Azhar Oratory, 13 April 1460, were excluded as outliers.

[74] This test was performed because the sample size was small and the normality assumption not satisfied.

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Nevertheless, it should be added that as these epidemics reached their peaks, the Dīwān ceased to produce fatality numbers. Chroniclers note this phenomenon and make a logical observation: the Dīwān became overwhelmed when numbers reached a certain limit. Ibn Taghrībirdī stresses this point for the 864/1460 outbreak.[75] However, for epidemics of lesser intensity, like the 819/1416 and 822/1419 outbreaks detailed below, the Dīwān continued to count the dead through the duration of the epidemic. The oratories, in general, continued their counts. The pattern seems logical as oratories could divide the labor, the data, into a more manageable count. Yet even these were overwhelmed at the outbreak's peak in 833/1430, which was by far the more severe of the two outbreaks—a death toll of some 12,000 was a 833/1430 peak.[76]

Evidence of the Relationships between Numbers (Ratios with the Outskirts)

Broadening our scope and looking at the results for Greater Cairo (al-Qāhirah wa-ẓawāhirihā) we can see another layer of evidence that attests accuracy in the counting of the dead. Ordered relationships can be seen here as well, this time in ratios between Mamluk Cairo and Greater Cairo.[77] On two separate occasions (one for each outbreak) we have fatalities numbers for Mamluk Cairo and Greater Cairo on the same day and we can set these death tolls side by side and compare their ratios as shown here.[78]

Date	Fatality Rate	Fatality Rate	Relationship	Ratio
833/1430	1286	2100	Mamluk Cairo : Greater Cairo	(.61)
864/1460	1517	2545	Mamluk Cairo : Greater Cairo	(.60)

We can also see consistency in this ratio of Mamluk Cairo to Greater Cairo by comparing our results with data from a very different source, this time not plague statistics, but rather property assessments. These assessments were made by the European traveler Leo Africanus.[79]

[75] Ibn Taghrībirdī, "Ḥawādith," fols. 104b–105a.

[76] A guess at the peak fatality rate (12,600 deaths per day) is noted by al-Maqrīzī for 18 March 833/1430; see *Al-Sulūk,* 4:827. This seems to have been a count at the gates of the city and not just the oratories.

[77] Greater Cairo was defined above as Mamluk Cairo plus Fusṭāṭ, Būlāq, and other urban or quasi-urban spaces surrounding Mamluk Cairo.

[78] Sources: for 833/1430: see al-Maqrīzī, *Al-Sulūk,* 4:825; Ibn Taghrībirdī, *Al-Nujūm,* 14:339; idem, "Ḥawādith," fol. 104b.

[79] Garcin, "Note," 207–10; see also Raymond's discussion of these figures, "La Population," 206.

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Location	**Number of Taxable Households**
Al-Qāhirah (here, Fatimid Cairo)	8,000
Bāb Zuwaylah (southern Mamluk Cairo, possibly with part of al-Ṣalībah)	12,000
Bāb al-Lūq (western edge of Mamluk Cairo, possibly with part of al-Ḥakūrah)	3,000
Būlāq	4,000
Qarāfah	2,000
Rawḍah	1,500
Fusṭāṭ (estimated from plague data)	(5,060)
Total (Greater Cairo)	**35,560**

As explained above, Mamluk Cairo was composed of Fatimid Cairo, a southern sector, and a western sector. Here Fatimid Cairo is listed (8,000 households) while the southern area corresponds to Bāb Zuwaylah (12,000 households) and the western area to Bāb al-Lūq (3,000 households). The total for Mamluk Cairo is 23,000 and Greater Cairo totals 35,560—the figure for Fusṭāṭ is estimated from the ratio of average fatality rates (Fusṭāṭ Dīwān/Cairo Dīwān = .22) for the years 833/1430 and 1438/841.[80]

[80]Potentially one could argue that the area of the Bāb Zuwaylah sector called al-Ṣalībah and the part of Bāb al-Lūq that is called al-Ḥakūrah should both be subtracted from Mamluk Cairo's 23,000. These two subtractions would make the ratios slightly askew from one another, perhaps a ratio of .5 for the Leo Africanus Mamluk Cairo-Greater Cairo relationship. Dols, *Black Death,* 196, uses the same figure we do, 23,000 for Mamluk Cairo.

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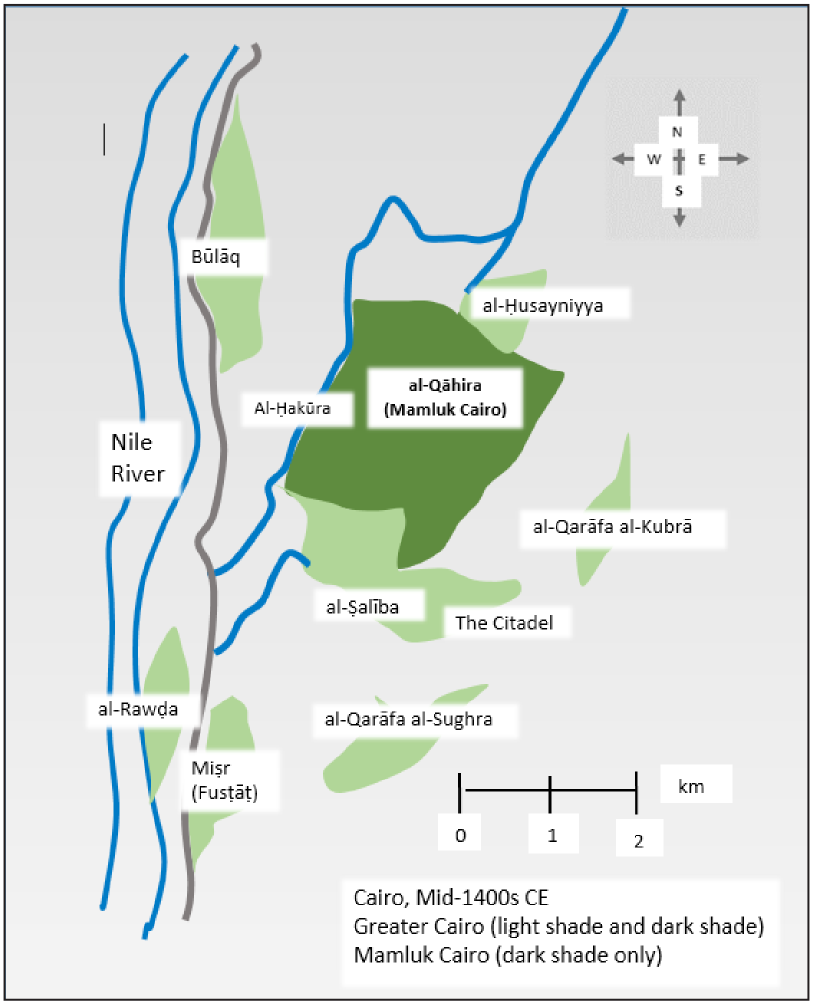

Fig. 3. (Repeated) Map of Greater Cairo, with Mamluk Cairo Shown in the Center

The closeness of the ratios (.65 to .60, less than 10% difference) indicates an ordered relationship.[81]

Count	Taxed Houses	Taxed Houses	Relationship	Ratio
922/1517	23,000	38,000	Mamluk Cairo : Greater Cairo	(.65)

[81]Parenthetically, one fatality rate (300 dead/day) from the 864/1460 data set (for the *muṣallá* Zāwiyat al-Khuddām in Ḥusaynīyah) gives us an opportunity to estimate the potential size of Ḥusaynīyah's population relative to that of Greater Cairo, which is 300/2545, roughly .12.

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Outbreak	Fatality Rate 1286	Fatality Rate 2100	Relationship	Ratio
833/1430	1286	2100	Mamluk Cairo : Greater Cairo	(.61)
864/1460	1517	2545	Mamluk Cairo : Greater Cairo	(.60)

Evidence from Earlier Outbreaks

Another way to test the validity of this historical data is to examine similar sets of data from other plague outbreaks in Mamluk Cairo. Ideal in this regard is the case of a plague outbreak in 822/1419 for which we have not only the daily record of deaths but the cumulative total deaths. As the daily rate and the cumulative deaths were recorded by the same Dīwān al-Mawārīth that provided the numbers above, this seems like a perfect way of determining whether or not our figures were based upon actual death counts. The 822/1419 outbreak allows us to see the Dīwān's written figures from its *waraqat al-taʿrīf* (daily register of deaths) from all causes plague or otherwise.[82] The total deaths are listed in categories according to the deceased's gender, age, and legal status.[83] These figures are the cumulative deaths over an interval of sixty-eight days.

Table: (a) Rate of fatalities (registered by the Dīwān al-Mawārīth)[84]

Time in days since the start of the outbreak	Deaths per day registered *(al-taʿrīf)*	Timing of registration
0	25	
5		Dīwān starts counting
15	50	
47	196	
73	77	Dīwān stops counting

[82] Al-Maqrīzī, *Al-Sulūk,* 4:492.

[83] Regarding the biological aspects of plague, note the high percentage of children on this list. Children here account for some 70% of the victims (not counting slaves). This can be compared with a general medieval average for Europe of roughly 33% of the total population, with a range in some cases as high as 40 to 45%. This high percentage for children falls in line with the latest research showing that plague was "selective with respect to frailty." Children and others with weaker immune systems were more vulnerable to plague; see Sharon N. DeWitte and James W. Wood, "Selectivity of Black Death mortality with respect to preexisting health," *Proceedings of the National Academy of Sciences* 105, no. 5 (2008): 1436–41. For percentages of children in the population, see E. A. Wrigley and R. S. Schofield, *The Population History of England, 1541–1971* (Cambridge, MA, 1989), Table A3.1, 4.

[84] Al-Maqrīzī, *Al-Sulūk,* 4:486–92.

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Table: (b) Cumulative fatalities (as registered by the Dīwān al-Mawārīth)

Category of deceased	Total deaths (from day 5 to day 73)
Men	1,065
Women	669
Children	3,969
Male slaves	544
Female slaves	1,369
Christians	69
Jews	32
Sum total	7,717

Comparison of calculated fatalities (from regression of [a] daily fatalities and registered fatalities [b]):

Source	822/1419 total fatalities
Cumulative deaths as reported by Dīwān	7,717
Cumulative obtained via regression of Dīwān fatality rates	8,454

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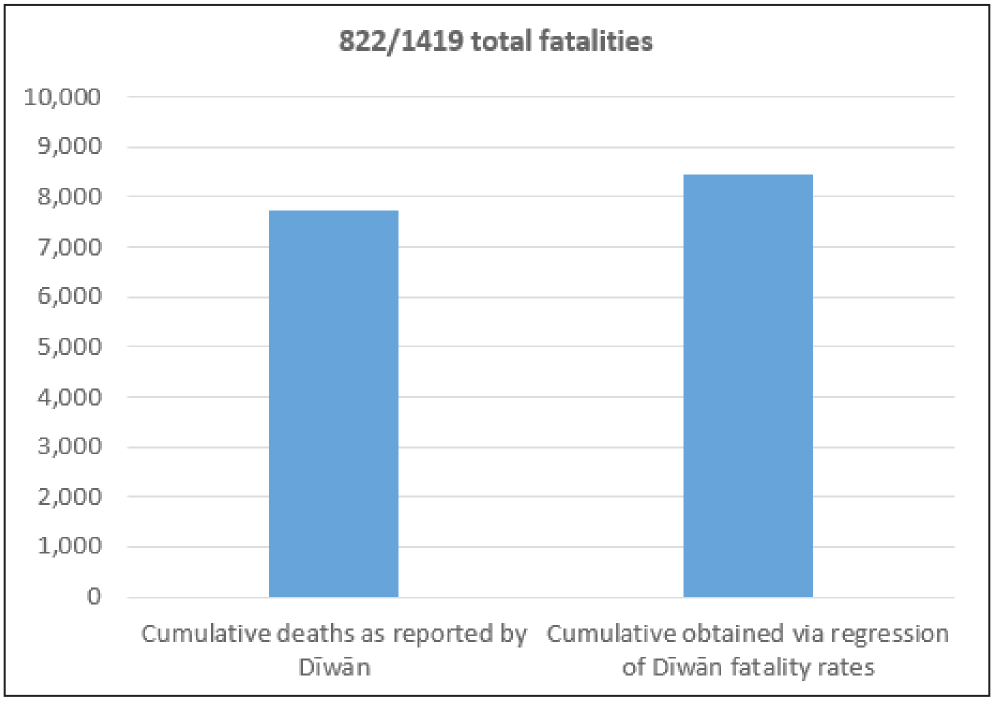

Fig. 7. Graph for 822/1419

As can be seen, the rate of fatalities yields a figure for the total deaths (7,117) that is in proximity to the recorded cumulative of fatalities. Since the fatality rate data consists of only four data points, some disagreement between the two is to be expected. From this perspective, something more can be said about the rounding of numbers. If the 822/1419 cumulative death toll is accurate enough, rounding it, even to the thousands, yields a figure that is a good indicator of mortality. Ibn Ḥajar al-ʿAsqalānī and others record a rounded figure (8,000) that indicates an important point: rounding is not in all cases a matter of loose estimation, as it is equally likely to be the product of the process of recording and copying from one text to another.[85] With a reasonable degree of skepticism, there is a basis for accepting some of the rounded figures, depending on context. Context might include whether or not the number had originated with an eyewitness and whether or not it was accompanied by other data points.

Also in the context of rounding, al-Maqrīzī notes a cumulative death toll for this outbreak of some 10,000. He clarifies that this figure is a total for all of

[85] Thus compare the Dīwān's cumulative of 7,717 with the cumulative (8,000) listed by Ibn Ḥajar and Ibn al-Ṣayrafī. These two take the number 7,717, round off the number of children to 4,000 and add 4,000 adults for an approximate total of 8,000. Rounding in this case is for convenience and not for invention. See also Ibn Ḥajar, *Inbāʾ*, 7:358; Ibn al-Ṣayrafī, *Nuzhat,* 4:56.

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Mamluk Cairo's population and not just the deaths registered at the Dīwān al-Mawārīth. From al-Maqrīzī's numbers we can calculate the Dīwān's ratio to the total as ($\frac{7,710}{10,000} = .77$) and this result matches up fairly well with al-Maqrīzī's reported ratio for the Dīwān al-Mawārīth to the total (.72).[86] Furthermore, ʿAbd al-Bāsiṭ's account for the 822/1419 outbreak includes a cumulative death total for Greater Cairo (al-Qāhirah wa-ẓawāhirihā) of approximately 20,000.[87] If we use the ratio (.605) for Mamluk Cairo to Greater Cairo (derived from 833/1430 and 864/1460) we see that the resulting figure for Mamluk Cairo (some 12,000) is close to al-Maqrīzī's reported 10,000 deaths for Mamluk Cairo.

Conclusion

The numbers we have examined for these two major outbreaks are either exact counts of plague deaths or rounded approximations of the same. Given that the population level for Mamluk Cairo was likely in the vicinity of 200,000, losses of this magnitude—some 90,000 for 833/1430 and about 80,000 for 864/1460—would surely have had a massive impact on Cairo's economy and society. Other studies are revealing that rural population losses were of a similar magnitude.[88] We hope that the results we have shown here will open the door to further studies of plague's urban and rural demography over the long term. The data is substantial enough to allow for a solid assessment of mortality over the course of the second plague pandemic.

[86]It should be noted that the ratio of the Dīwān's figures to the total falls over the course of the 1400s (from .72 here to a low of about .09 in 919/1513). For the latter figure, see Ibn Iyās, *Badāʾiʿ,* 4:301.

[87]ʿAbd al-Bāsiṭ, *Nayl,* 4:38.

[88]See Borsch, "Plague Depopulation and Irrigation Decay in Medieval Egypt," in *The Medieval Globe*: *Pandemic Disease in the Medieval World,* ed. Monica H. Green (Univ. of Western Michigan, 2014) http://scholarworks.wmich.edu/medieval_globe/1.

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