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Patterns in the Population Distribution of Lower Egypt from the Predynastic to the Ptolemaic Period as Estimated from Archaeological Evidence

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Abstract

Karl Butzer (1976) introduced a methodology for calculating local population sizes for ancient Egypt based on archaeological remains and textual sources and focused its application on the nomes (i.e. provinces) of Upper Egypt. Although textual sources are still scant for the Delta, an increasing amount of data on settlement remains has become available in recent years and here we apply Butzer's demographic approach to Lower Egypt. Like Butzer, we focus on the timespan from the Predynastic to the Ptolemaic Period (ca. 5300–30 BC), but unlike Butzer, we analyse population densities separately for six distinct time slices. Our results suggest the population concentration was generally skewed towards the eastern sector, and the central sector was least densely settled, but there were notable temporal fluctuations, with the western sector gaining increased importance during the Ptolemaic Period when new cities were founded. However, gaps in the archaeological record due to poor preservation mean that the results should be treated cautiously.

Keywords

Nile Delta – population size – demography – settlement archaeology – hydrology – carrying capacity

1 Introduction

Changes in population distribution offer critical insights into how societies develop in response to environmental, economic and political forces and are therefore of key

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interest to archaeologists. However, from most ancient societies, written records are scarce and producing even rough estimates of population densities can be challenging (Hassan 1981; Zorn 1994). For Egypt, most studies have so far focused on providing population estimates for specific sites and time periods, based on comprehensive site surveys to determine the area of occupancy and the number and sizes of houses, and making assumptions about household sizes (Kraus 2004; e.g. Kemp 1981 and Strudwick 1995 for New Kingdom Amarna and Thebes, respectively). An exception is Karl Butzer's classical study of population sizes across the entire country from Predynastic and Pharaonic times: he used specific features of sites as indicators of relative population sizes, which were then converted to absolute numbers based on country-wide population estimates based on estimated carrying capacity (Butzer 1976). However, Butzer treated the Nile Delta as a black box due to lack of data at the time. Relying heavily on the progress made by the Delta Survey in recent decades (Spencer 2024), we here complement Butzer's study by presenting estimates of population distribution within the Nile Delta, applying a modification of his approach that allows relative population sizes to change over time.

1.1 *Environmental Setting*

To understand the demographic changes in the Nile Delta in a wider context, we will first provide an overview of environmental changes in Northeast Africa during the Holocene. In their 2006 study, Kuper and Kröpelin identified key periods of environmental changes which they argue affected the movement and settlement of populations at the time and contributed to the emergence of the pharaonic state. These are the Early Holocene reoccupation (8500–7000 BC), the Mid-Holocene formation (7000–5300 BC), the Mid-Holocene regionalisation (5300–3500 BC), and the Late Holocene marginalisation (3500–1500 BC) (Kuper & Kröpelin 2006: 805–806). Although falling before the time period of our study (i.e. 5300–30 BC), the Mid-Holocene formation is relevant because domestic species first appear in Egyptian archaeological contexts towards the end of this period (Fayum: 5673–4700 BC, Sodmein Cave: ca. 6109–4727 BC, Tree Shelter: ca. 5700–3700 BC, Eastern Desert and Dakhla: ca. 5400–3700 BC; Churcher 1999; Linseele & van Neer 2008; Linseele et al. 2010; Vermeersch et al. 2015; Linseele et al. 2016; Holdaway et al. 2017). Husbandry of domestic livestock ties human populations to ecological niches that allow livestock grazing, and these differ from those allowing hunting-fishing-gathering. Finding suitable habitats became an increasing challenge during the Mid-Holocene regionalisation due to gradual aridification caused by decreasing northern hemisphere insolation and concomitant reduced northern reach of the Intertropical Convergence Zone (Williams 2009). Inhabitants of today's Eastern and Western Deserts were forced to retreat closer to the Nile and adopt a more sedentary lifestyle as environmental conditions became less compatible with pastoral nomadism (Kuper & Kröpelin 2006: 805–806). As for the Nile itself, a decrease in monsoon intensity over the Ethiopian highlands caused lower sedimentation rates at the time (Pennington et al. 2017).

The Mid-Holocene regionalisation coincides with Egypt's Predynastic Period, when the earliest archaeological evidence for domestic species emerges from the Delta at sites such as Merimde Beni Salama (ca. 5200–4100/3800 BC), Tell el-Samara (ca. 4500–4000 BC), and Maadi (ca. 4100–3350 BC) (Hecker 1982; von den Driesch & Boessneck 1985; Hawass et al. 1988; Rowland & Bertini 2016; Rowland 2020; Guyot et al. 2022), as well as in the Farafra oasis (Gautier 2014). Later in the Predynastic Period, archaeological evidence for domestic livestock appears in Upper Egypt at Maghar Dendera 2 (ca. 4400–4250 BC), Hierakonpolis (ca. 4000–3600 BC), and Adaima (ca. 4000–2686 BC) (Midant-Reynes et al. 1993; Hendrickx et al. 2001; van Neer et al. 2005). The Late Holocene marginalisation covers the time period from just before the emergence of a fully unified pharaonic state to the beginning of the New Kingdom. During this time, rains ceased in the present-day deserts, restricting any permanent occupation there (Kuper & Kröpelin 2006: 806). By contrast, the Nile Valley and Delta – turning less marshy – became more favourable for settlement.

But the environment by the Nile differed substantially between Lower and Upper Egypt. The hydrological changes of the Nile had a more dramatic impact on the habitability of the Delta in Lower Egypt, which was a vast dynamic mosaic of floodplains, 'turtlebacks' or *geziras* (i.e. islands), marshes and multiple moving river channels; by contrast, the Nile Valley in Upper Egypt was dominated by a single river channel flanked by floodplains. Especially, the transition of the Delta from a so-called 'Large-Scale Crevassing' (LSC) landscape to a 'Meandering' landscape around the time of the Predynastic Period is likely to have had a pervasive effect on the suitability of the Delta for human habitation (Pennington et al. 2017). The LSC landscape was a consequence of high sea-levels which reduced the gradient of the river and slowed down the transport of sediment. LSC was associated with multiple anastomosing river channels frequently bursting their

banks, channel superelevation, widespread crevassing and higher rates of floodplain aggradation, resulting in the repression of soil formation in a landscape dominated by swampy wetlands (Pennington et al. 2016: 195–196; Pennington et al. 2017: 213). The switch to a Meandering landscape occurred when the sea-level rise attenuated and aggradation rates decreased, which resulted in fewer river channels with more stable banks, although these channels migrated laterally (i.e. east-west) over time; crucially, these conditions enhanced soil formation (Pennington et al. 2016: 196).

The LSC–Meandering transition of the Nile Delta thus had a major effect on the availability of key resources as well as the potential to control the river network at strategically placed nodes (Pennington et al. 2016). A LSC landscape favours settlements that are connected both longitudinally and transversely, without any single settlement being able to control the movement of goods in the network. Such an environment does not promote the development of large population centres. By contrast, the Meandering landscape, characterised by fewer river arms, opened up for the possibility of controlling the distribution of goods at nodes situated at key locations, allowing larger population centres to develop (Pennington et al. 2016).

1.2 *Estimating Local Population Sizes: the Methodology of Karl Butzer*

Information about the size and distribution of the human population in the Delta can offer important insights into how societies responded to this dramatic environmental context. But how do we approach the thorny issue of estimating the actual changes in human population densities in the dynamic environment of the Nile Delta during the mid- to late Holocene? In his 1976 publication *Early Hydraulic Civilization in Egypt*, Karl Butzer laid out a methodology for estimating population sizes of ancient Egypt based on archaeological evidence and textual sources. This study remains widely cited as a rare attempt at estimating spatial patterns in population densities during predynastic and pharaonic times. Butzer provided broad estimates of population sizes for all of Egypt, but his focus was on the population of the 22 Upper Egyptian nomes (i.e. provinces/governorates), the first Lower Egyptian (Memphite) nome, and the Fayum. He presumably excluded the Delta nomes due to the scant evidence available at the time (Christaller 1966: 187; Butzer 1976: Table 3). However, since the 1970s, a wealth of evidence has accumulated from increased archaeological activity in the Delta. A valuable source is the survey by the Delta Survey project of the Egyptian Exploration Society (EES), which provides co-ordinates and details of physical remains for 786 sites from the Predynastic to Islamic Period (Spencer 2024). Using this information as a starting point, we here apply Butzer's methodology to evaluate its usefulness in assessing population fluctuations in the 2nd–20th Lower Egyptian nomes (henceforth referred to as 'the Delta'; Fig. 1). Like Butzer, we consider the timespan from the Predynastic through to the Ptolemaic Period (ca. 5300–30 BC); however, unlike Butzer, we divide this extensive period into six time slices to investigate temporal changes in population patterns (we already here note that the application of the Butzer approach reduced the number of sites to 122; for further details see 'Dataset and Analytical Approach' where the time slices are also defined).

To calculate local population sizes for Upper Egypt, Butzer began with a list of place names and details derived from two ancient Egyptian texts: the *Onamasticon of Amenemope* and the *Papyrus Wilbour* (Gardiner 1947, 1948), and he then added sites which were known from archaeological evidence only. For each site, he recorded features that he considered to be indicators of population size; these included the presence of various structures, such as temples, cemeteries, and fortresses, and administrative characteristics, such as the presence of a mayor or the status as a district capital (see Table 1 for details). He assigned a numerical score to each of these features and added them together to provide a total score indicative of the relative population size of each site. He used this site score to categorise the sites into his hierarchy of size-ranked population centres, namely – from smallest to largest – 'large village', 'small centre', 'large centre', and 'city' (Butzer 1976: Table 2; he excluded 'small villages' which he considered unlikely to leave any archaeological evidence). By adding the site scores for each site within a nome, Butzer then calculated an initial population index for each of the Upper Egyptian nomes, which indicated its relative population size.

However, Butzer was conscious of the potential for bias due to gaps in the archaeological record. He therefore sought to compensate for underrepresentation of sites in certain size categories by applying a 2:1 median bifurcation ratio to standardise his data (Butzer 1976: 72). A median bifurcation ratio is a basic method within Central Place studies in Geography, where the number of sites in different size categories are assumed to follow a regular numerical pattern due to key economic principles underlying trade, notably the dependency of costs and benefits on distance (Butzer 1976: 72 note 1; see also Johnson 1975). Specifically, the 2:1 ratio (i) predicts the number of small settlements as no less than double the

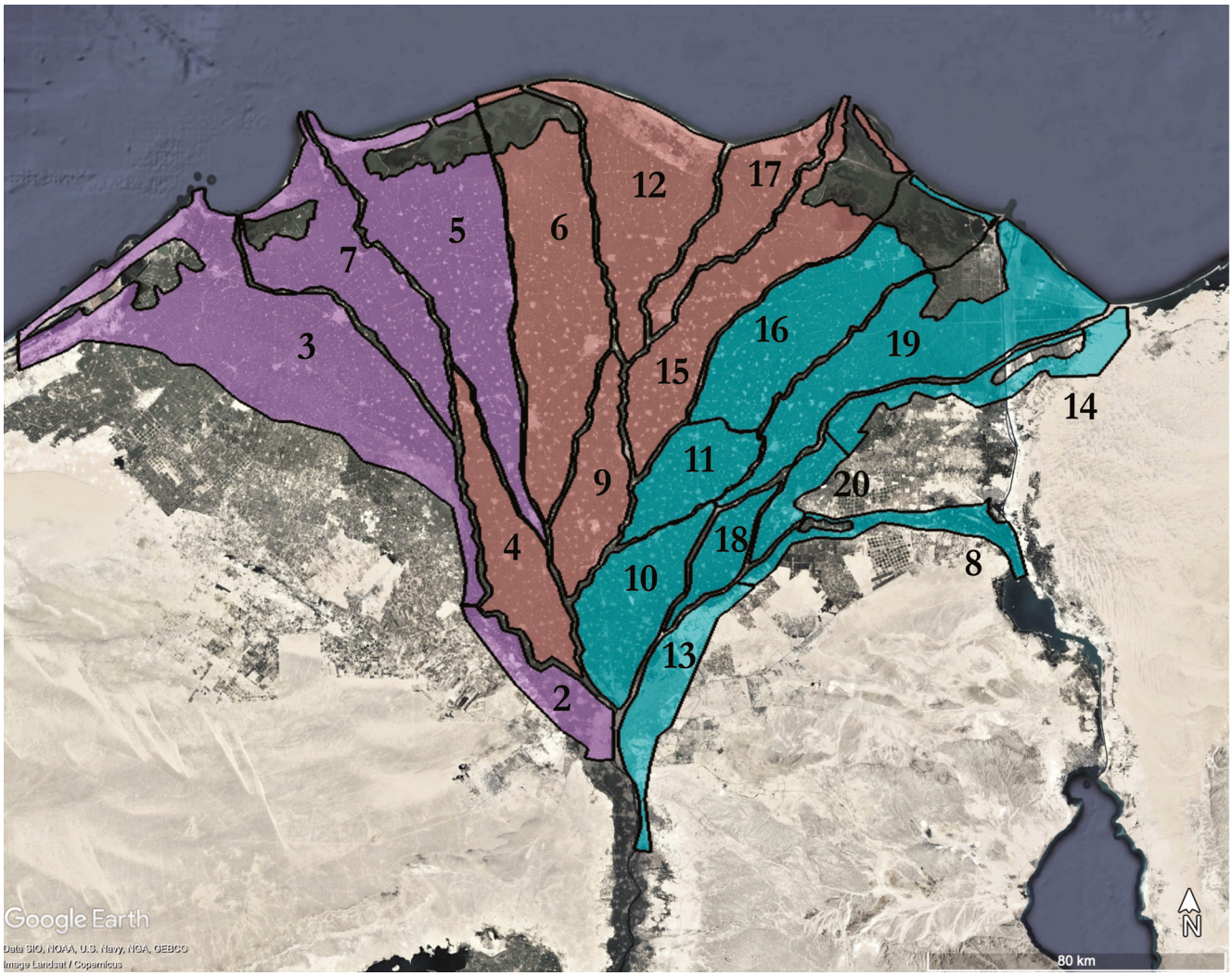

FIGURE 1 The 2nd–20th nomes of Lower Egypt. The colours indicate our division of nomes into similar-sized western (purple), central (red) and eastern (turquoise) sectors of the Delta.
BASE MAP FROM GOOGLE EARTH PRO, NOME BOUNDARIES AFTER BAINES & MÁLEK 1980, 15

number of large settlements and cities combined, and (ii) predicts the number of large villages as no less than double the number of small settlements. After applying the bifurcation ratio, Butzer updated the population indices for the nomes by multiplying the number of extra sites predicted for each nome by the mid-value score for the given settlement category, i.e. 5 for small centres and 2 for large villages. These totals were then added to the initial population index.

Butzer found that if he multiplied the total population index for the entire Nile Valley and Fayum for the Ramesside Period (ca. 1295–1069 BC) by 1,000, he would coincidentally arrive at a total population size that was consistent with a population estimate derived independently by Klaus Baer from ecological carrying capacity (Butzer 1976: 76). Based on this, he used the factor 1,000 to convert population indices to population sizes in general. Butzer's method thus allows population density to be estimated without relying on full site surveys to estimate local population sizes directly from archaeological evidence. Butzer did state that his absolute population sizes should not be "taken literally" (1976: 76) and, arguably, the main strength of the method is in estimating relative population densities based on the indices.

In his work, Butzer makes the simplifying assumption that the relative population densities of Upper Egypt remained constant throughout the predynastic and pharaonic times, i.e., that only the total population size changed, not the distributional pattern. To approximate this general population distribution, he again used data from the Ramesside Period, where he relies heavily on the aforementioned *Onomasticon of Amenemope* (Butzer 1976: 73; Gardiner 1947). We found that the assumption of relative population densities remaining unchanged over the study period is especially problematic for the Delta where settlement dynamics – apart from political and economic

TABLE 1 Butzer's (1976) criteria for assigning site scores

Category	Butzer's criteria	Denoted by	Score given
A	Nome capital	X	3
	Royal residence	X *	6
	Alternative nome capital	(X)	1
B	Tombs of elite or royalty	X	3
	Both royal and elite	X *	4
C[a]	Mayor (HAty-a)	X	2
D	Temple	X	2
	Temples	X *	3
E	Settlement	X or [X][b]	1
F	Fortress or keep	X	1
G	Villa, estate, or suburb	X	1
H	Quarry linked to site	X	1
I	Cumulative rating	N/A	Sum of scores for A–H: 1–3 = Large village; 4–6 = Small centre; 7–10 = Large centre; 10+ = City
J	Overall hierarchical category	N/A	Large village = 1 Small centre = 2 Large centre = 3 City = 4

a Excluded from this study due to the absence of written records.
b [X] indicates settlements inferred from the presence of a temple/cemetery.

factors – are likely to have been particularly affected by changes in the environment caused by the dynamics of the Nile, as we outlined above. In contrast to Butzer, we therefore incorporate a temporal dimension by analysing physical remains by date interval, which enables us to estimate fluctuations in relative population densities of the Delta over the period studied.

A final debatable point is that Butzer makes a few small adjustments of settlement numbers in the different categories when he applies the bifurcation ratio. For example, he maintained that there was a 'surfeit of mortuary complexes' (1976: 73) in the Memphite nome, and on that basis he reassigned settlements that had been designated as a 'large centre' according to his criteria to a 'small centre'. However, we are sceptical about some of these adjustments. With regards to Memphis for instance, it is clear from its long-term status as capital and an administrative centre that it was an exceedingly important population centre, and mortuary temples are known to have had administrative roles in this context (Muhs 2016). Because such adjustments entail a degree of subjectivity, we have chosen to refrain from any similar modifications in the present study.

2 Methods

2.1 *Dataset and Analytical Approach*

Table 1 presents the criteria that Butzer used to assign sites to the size-based hierarchy which he used to calculate population indices for individual nomes, all except one in Upper Egypt. We here apply these criteria to sites in the 19 Lower Egyptian nomes of the Delta, following Butzer in using nome boundaries as defined during the Ptolemaic Period (Fig. 1). The initial identification of sites came from the comprehensive Egyptian Exploration Society (EES) Delta Survey database (Spencer 2024; https://www.ees.ac.uk/alphabetical-index). Additional data was obtained from Abd el-Alim (2022), Abd el-Maksoud et al. (2014), Adam (1958), Bajeot et al. (2017), Ballet (2022), Debono & Mortensen (1990), Dhennin & Redon (2013), Dhennin & Somaglino (2022), Fischer (1976), Ghattas (1989), Grajetski, et al. (2002), Hasegawa & Nishimoto (2022), Helck (1974), Herbich (2009), Hendrickx & Vermeersch (2000), Leclère (2007; 2014), Maksoud (1989), Porter & Moss (1934), Rizkana (1989), Rowland (2007, 2012), Rowland & Strutt (2011), Snape (1986), Spencer & Herbich (2009), S. Thomas

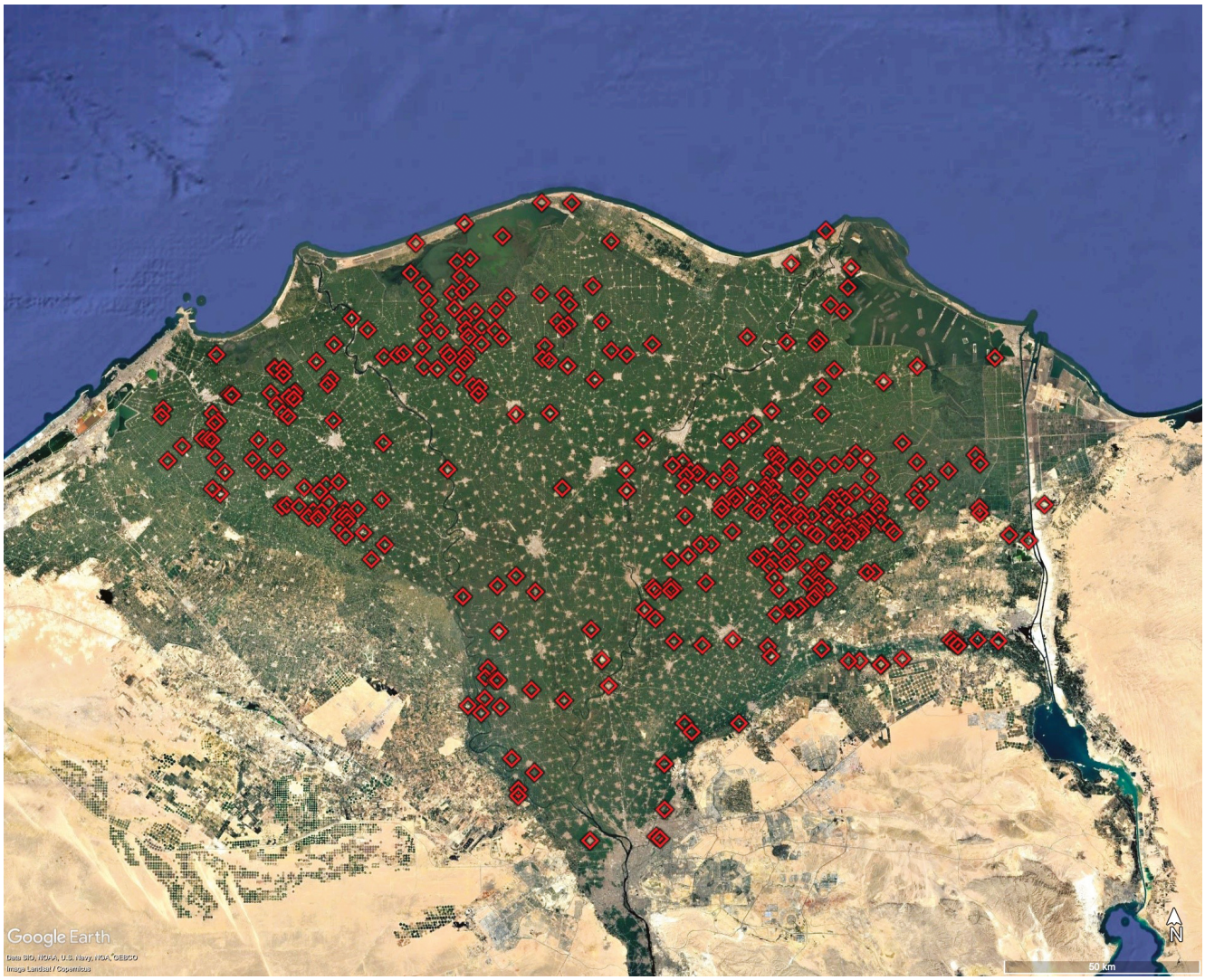

FIGURE 2 Location of EES Delta Survey sites with datable material from the Predynastic to the Islamic Period
BASE MAP FROM GOOGLE EARTH PRO

(2011), R. Thomas (2014), Wahby et al. (2022), Wenke et al. (2016), Wilson (2006a, 2012) and Wilson et al. (2014). It is worth noting that although the compiled list of sites reflects primary evidence, it is inevitably affected by various biases, such as skew in survey work, loss of sites due to land management projects and natural disasters (e.g. sea incursions); we will return to the impact of such potential biases in the Discussion below. The application of the Butzer approach reduced the number of sites from 786 to 122 because only 348 sites had datable material, of which only 245 dated to the interval from the Predynastic to the Ptolemaic Period, and of these only 122 had evidence of the features that Butzer used to score settlement size (the remaining sites were overwhelmingly represented by ceramic sherds; Fig. 2).

We divided the archaeological data into six time slices: Predynastic Period (PD) (ca. 5300–3000 BC), Early Dynastic Period (ED) and Old Kingdom (OK) (ca. 3000–2160 BC; 1st–6th Dynasty), First Intermediate Period (FIP) and Middle Kingdom (MK) (ca. 2160–1650 BC; 7th-early 13th Dynasty), Second Intermediate Period (SIP) and New Kingdom (NK) (ca. 1650–1069 BC; late 13th–20th Dynasty), Third Intermediate Period (TIP) and Late Period (LP) (ca. 1069–332 BC; 26th Dynasty–31st Dynasty), and Ptolemaic Period (PP) (332–30 BC). These time slices are aligned with Butzer's hypothetical population estimates (see below) and reflects key changes in Egyptian history. We assigned the origin of a site to a time slice by using the first attestation of any feature defined by Butzer. Two approaches were then used to calculate Butzer's index for the individual time slices: (i) a conservative approach assuming that sites were only active during time slices from which archaeological evidence is present, and (ii) a liberal, or 'cumulative', approach calculating a cumulative score based on the assumption that site features generally remained active after their first documented presence, even in the absence of archaeological evidence of later

additions. This provided us with two extreme estimates of densities, in between which the actual pattern is likely to fall. Similar to Butzer's study of Upper Egypt, we applied a bifurcation ratio of 2:1 (see Introduction for details) but made no further adjustments.

2.2 *Calculation of Population Indices and Estimated Population Sizes and Densities*

Following Butzer, the population index for each nome was calculated by adding the scores for all sites within the nome; however, in contrast to Butzer, we calculated separate indices for each time slice as mentioned above. The population size of each nome for each time slice was then approximated by distributing the total population size in the Delta for the time slice in question, as provided by Butzer, between the nomes according to each nome's proportion of the total population index calculated for the Delta. As the population index for a given time slice includes all site features dated up to the end date of that time slice, we found the population size at the end of the time interval was most appropriate for those time intervals where Butzer suggested an increasing trend in population size, i.e., for the PD and the TIP–LP. However, as Butzer assumed decreases in population sizes during the intermediate periods and at the end of the PP, we found that the peak population estimated for the time slice was more appropriate in these cases since site features from this peak were included in the calculation of the index, i.e. for the ED–OK, FIP–MK, SIP–NK and PP. For five time slices, Butzer presents hypothetical population estimates for the Delta in his Table 4, i.e. 210,000 for 3000 BC for PD, 540,000 for 2500 BC for ED–OK, 750,000 for 1800 BC for FIP–MK, 1,170,000 for 1250 BC for SIP–NK, and 2,160,000 for 150 BC for PP. For TIP–LP, we approximated his population estimate for 332 BC by extracting his combined population estimates for the Delta, Fayum and the Desert from his Fig. 13 and then subtracting his population estimates for the Fayum and the Desert obtained by interpolation of hypothetical population values given in his Table 4. Therefore, any absolute population numbers used in this study are derived from Butzer's own 'guesstimates'. We furthermore calculated nome-specific estimates of population densities by dividing the estimated population sizes by the area of each nome. For this purpose, we calculated the area of each of the 19 Delta nomes in km² based on a 1:1,800,000 map (Baines & Málek 1980, 15) using the GIS software Google Earth Pro. Finally, we divided the nomes of the Delta into a western, central and eastern sector of roughly equal sizes (Fig. 1 and Table 2) and calculated the proportion of the Delta population settled in each sector for each time slice.

TABLE 2 Assignment of Delta nomes into western, central, and eastern sectors

Delta sector	Nomes	Total area (km²)
Western	2, 3, 5, 7	6,962
Central	4, 6, 9, 12, 15, 17	7,196
Eastern	8, 10, 11, 13, 14, 16, 18, 19, 20	6,733

3 Results

The overall results are presented in Tables 3–7. Table 3 shows an overview of the features documented for sites in nomes 2 to 20 of the Delta for the entire timespan from the Predynastic to the Ptolemaic Period; additional breakdown of results by time slice is provided in the Supplementary Material using both the conservative approach (Tables S1–S6) and the cumulative approach (Tables S7–S10). Table 4 presents the population indices, estimated population sizes and estimated population densities for each nome in the Ptolemaic Period using the cumulative approach; additional breakdown of results by time slice is provided in the Supplementary Material using both the conservative approach (Tables S11–S16) and the cumulative approach (Tables S17–S20). Tables 5a and 5b summarise the estimated population distribution across western, central and eastern sectors of the Delta over time, and Figs. 3a and 3b show the estimated population densities for each nome using the conservative and cumulative approach, respectively. Tables 6 and 7 present relative population indices and relative population densities – and their ranking – for individual nomes over time.

Using the conservative approach, the Delta population appears to have been somewhat concentrated in the eastern sector from the Predynastic until the Late Period, although the distribution was more even during the Early Dynastic Period/Old Kingdom and again during the Third Intermediate Period/Late Period (Table 5a; Fig. 3a). The more even pattern during the Third Intermediate Period/Late Period bridged a shift in concentration to the western sector of the Delta in the Ptolemaic Period (Table 5a). Inspection of the maps suggests that the northern part of the central sector in particular may have been only lightly settled until later pharaonic times (Fig. 3a). The cumulative approach suggests a far more stable pattern in the relative distribution over time, with most of the population in the eastern sector, the central sector being the least

TABLE 3 Overview of first attestation and features considered by the Butzer methodology (Table 1) for sites in nomes 2–20 of the Delta from the Predynastic to Ptolemaic Period (for additional breakdown of results by time slice, see Tables S1–S10). Modern name in small letters; ANCIENT NAME in capital letters

Nome 2	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
El-Qatta	Middle Kingdom		X			[X]				4	2
Ausim KHEM/ LETOPOLIS	Old Kingdom	X			X	X				6	2
Abu Roash	1st Dynasty		X			[X]				4	2
Merimde Beni Salama	Neolithic (5000 BC) (Predynastic Period)		X			X				4	2
Wardan	26th Dynasty		X			[X]				4	2
Merimde Abu Ghalib	Middle Kingdom					X				1	1
Total										23	

Nome 3	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Alexandria	Ptolemaic Period	X*	X		X*	X				14	4
Tell el-Abqa'in	19th Dynasty (Ramses II)				X	X	X			4	2
Kom Firin	Middle Kingdom		X		X	X				6	2
Kom el-Hisn IMU	5th Dynasty	X	X		X	X				9	3
Tarrana/Kom Abu Billo TERENUTHIS	6th Dynasty		X		X	X				6	2
El-Niqrash NAUKRATIS	ca. 625 BC		X		X	X				6	2
Kom Metawah	Late Period		X		X	X				6	2
Kom Trugi	Ptolemaic Period				X	X				3	1
Abusir Mariout TAPOSIRIS MAGNA	Ptolemaic Period		X		X					5	2
Kom el-Nugus PLINTHINE	Ramesside Period		X		X	X	X			7	3
MAREA	Ptolemaic Period					X				1	1
Kom el-Akhdar	Ptolemaic Period				X	[X]				3	1
Kom el-Hamam	Ptolemaic Period					X				1	1
Kalabt Shafiq	Ptolemaic Period		X			[X]				4	2
Kom el-Kharaz	Ptolemaic Period		X			[X]				4	2
Silvagou	26th Dynasty		X			[X]				4	2
Kom el-Qadi	Ptolemaic Period		X			[X]				4	2
Kom Kortas	First Intermediate Period					X				1	1
Total										88	

TABLE 3 Overview of first attestation and features considered by the Butzer methodology (*cont.*)

Nome 4	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
El-Barnugi	11th Dynasty		X			[X]				4	2
Ashmun	New Kingdom						X			1	1
Menouf/Kom el-Ahmar PA-IW-NEFER/ONOUPHIS	Late Period?					X				1	1
El-Nahhariya	Late Period				X	[X]				3	1
Tanta PTKHEKA	Late Period	X				X				4	2
Total										13	

Nome 5	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Sa el-Hagar SAU/SAIS	Late Neolithic (5000–4800 BC) (Predynastic Period)	X*	X*		X*	X				14	4
Tell Mutubis	Ptolemaic Period		X			X				4	2
Tell el-Farain PER-WADJET/BUTO	Final Neolithic (4000 BC) (Predynastic Period)	X	X		X	X				9	3
Bendariya	20th Dynasty		X			[X]				4	2
Total										31	

Nome 6	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Sakha XOIS	Ptolemaic Period	X			X*	X				7	3
Kom el-Daba	Late or Ptolemaic Period				X	X				1	1
Kom el-Ganayin	Ptolemaic Period					X				1	1
El-Mahalla el-Kubra	Late Period				X	[X]				3	1
Ibshan	Ptolemaic Period		X			[X]				4	2
Total										16	

Nome 7	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Damanhur HERMOPOLIS MAGNA	Late Period	X				X				4	2
Abu Qir CANOPUS	Ptolemaic Period				X	[X]				3	1
Kom al-Diba'	Ptolemaic Period				X	X				3	1
Rosetta	Late Period				X	[X]				3	1
THONIS/HERAKLEION	Ptolemaic Period				X*	X				4	2
MENOUTHIS	Ptolemaic Period?					X				1	1
Kom Aziza	Old Kingdom		X			[X]				4	2
Kom el-Ghuraf	Ptolemaic Period					X				1	1
Kom el-Nuss el-Sahgir	Ptolemaic Period					X				1	1
Total										24	

TABLE 3 Overview of first attestation and features considered by the Butzer methodology (*cont.*)

Nome 8	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Tell el-Retaba	18th Dynasty or earlier				X	X	X			4	2
Tell el-Maskhuta TJEKU/ PITHOM	ca. 1900 BC	X			X	X				6	2
Tell Abu Suweir	19th Dynasty		X			[X]				4	2
Ezbet Rod Iskander	Late Period		X			[X]				4	2
Kafr Hassan Daoud	Predynastic Period		X			[X]				4	2
Tell el-Manshiya	Second Intermediate Period		X			[X]				4	2
Sheikh Shaeib	?		X			[X]				4	2
Total										30	

Nome 9	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Abusir Bana DJEDU/ BUSIRIS	Predynastic Period	X			X	X				6	2
Tell Umm Harb/Tell Mustai	Ramesside Period				X	[X]				3	1
Quesna	Old Kingdom		X			[X]				4	2
Total										13	

Nome 10	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Benha/Tell Atrib HUTHERIB/ATHRIBIS	4th Dynasty	X	X		X	X				9	3
Total										9	

Nome 11	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Tell el-Muqdam TAREMU/ LEONTOPOLIS	Ramesside Period	X*	X		X	X				12	4
Mit Ya'ish	Ptolemaic Period		X			X				4	2
Tell Fauziya	Second Intermediate Period					X				1	1
Kufr Nigm	Early Dynastic Period		X			[X]				4	2
Total										21	

TABLE 3 Overview of first attestation and features considered by the Butzer methodology (*cont.*)

Nome 12	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Bahbit el-Higara ISEUM	Late Period				X	[X]				3	1
Sammanud TJEB-NETJER/ SEBENNYTOS	Late Period?	X*	X		X*	X				13	4
El-Kafr el-Sharqi PACHNAMUNIS	Ptolemaic Period				X	X				3	1
Behbeit PER-HEBYT	Ptolemaic Period?				X	[X]				3	1
Ma'sara	Saite Period								X	1	1
Kom Yetwal wa Yuksur	Late Period		X			[X]				4	2
Total										27	

Nome 13	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
El-Gebel el-Ahmar	Ramesside Period								X	1	1
Matariya/Tell Hisn IUNU/ HELIOPOLIS	Predynastic Period	X*	X		X*	X				11	4
Kheraha	Old Kingdom?				X	X				3	1
Maadi	Final Neolithic 4000 BC (Predynastic Period)		X			X				4	2
El-Marq	Saite Period		X			[X]				4	2
Tell el-Yahudiya NAYTAHUT	Middle Kingdom		X		X*	X				7	3
Bilbeis	Late Period				X	[X]				3	1
El-Khanka	Late Period?					X	X			2	1
Gebel Abu Hassa	New Kingdom				X	[X]				3	1
El-Omari	Final Neolithic 4600–4350 BC (Predynastic Period)		X			X				4	2
Total										42	

Nome 14	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Tell Heboua I-II TJARU/ SILE	Middle Kingdom?	X	X		X	X	X			10	3
Khata'na	Middle Kingdom				X	[X]				3	1
Tell Dafana TJEBNET/ DAPHNAE	26th Dynasty (Psamtik I)		X		X	X	X			7	3
El-Qantara/Tell Abu Seifa	19th Dynasty (Ramses II)		X		X	X	X			7	3
Tell Farama PELUSIUM	Before 720 BC		X		X	X	X	X		8	3
Tell el-Balah/Sfeira	Ptolemaic Period					X	X			2	1
Ezbet Heimi DJADU?	12th Dynasty	X*				X				7	3
Total										44	

TABLE 3 Overview of first attestation and features considered by the Butzer methodology (*cont.*)

Nome 15	Date attested first	A	B	C	D	E	F	G	H	I	J
El-Baqliya/Tell el-Naqus BA'H/TEHUTI/ HERMOPOLIS MAGNA	Before Old Kingdom	X	X		X	X				9	3
Tell Tambul	Saite Period		X			[X]				4	2
Damietta/Tell el-Deir	26th Dynasty		X			[X]				4	2
Shubra Hor	Late Period				X	[X]				3	1
Total										20	

Nome 16	Date attested first	A	B	C	D	E	F	G	H	I	J
Tell Rub'a PERBANEBDJEDET/ MENDES	Late Predynastic Period	X*	X*		X*	X				17	4
Tell el-Timai THMUIS	After New Kingdom				X	X				3	1
Tell el-Farkha	Predynastic Period		X			X				4	2
Tell Balala/Tell Tebilla	Old Kingdom		X		X*	X				7	3
Tell Abu Husa	Naqada IIC		X			[X]				4	2
Tell Buweib	New Kingdom				X*	[X]				4	2
Tell Daba	Predynastic Period		X			[X]				4	2
Tell Ginidba	Early Dynastic Period					X				1	1
Tell Samara	Predynastic Period		X			X				4	2
Kom el-Khilgan	Predynastic Period		X			X				4	2
Minshat Ezzat	Predynastic Period		X			[X]				4	2
Total										56	

Nome 17	Date attested first	A	B	C	D	E	F	G	H	I	J
Tell el-Balamun SMA-BEHDET/ PA-IW-N-IMN	New Kingdom	X	X		X*	X				10	3
Total										10	

TABLE 3 Overview of first attestation and features considered by the Butzer methodology (*cont.*)

Nome 18	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Tell Basta BAST/BUBASTIS	Predynastic Period	X*	X		X*	X				13	4
Tukh el-Qaramus	18th Dynasty?		X		X	X	X			7	3
Tell Miniet el-Habib/ Shagamba	19th Dynasty					X	X			2	1
Tell Awiad Daoud	Predynastic					X				1	1
Total										23	

Nome 19	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Horbeit SHEDNU/ PHARBAITOS	30th Dynasty (Nectanebo II or earlier)	X	X		X	X				8	3
Qantir PIRAMESSES	19th Dynasty (Ramses II)	X*	X		X*	X	X			15	4
Tell Nebesha/Tell Farun IMET	Naqada III	(X)	X		X*	X				8	3
Gumaiyima	Ptolemaic Period				X	[X]				3	1
San el-Hagar DJA'NET/ TANIS	Unknown before 19th Dynasty	X*	X		X*	X				13	4
Tell el-Dab'a HUT-WARET/ AVARIS	Early 12th Dynasty (Amenemhat 1)	X*	X		X	X	X			13	4
Tell el-Iswid (N)/Tell el-Abbassiya/Tell el-Nashed	4th Millennium BC (Predynastic Period)					X				1	1
Tell el-Iswid (S)	Predynastic Period					X				1	1
Tell Belim SETHROE/ HERAKLEOPOLIS PARVA	New Kingdom				X	[X]				3	1
Geziret el-Nisf	Ptolemaic Period		X			[X]				4	2
Geziret Sineita /Tell es-Sunaytah	New Kingdom or Late Period		X			[X]				4	2
Tell Ibrahim Awad	Predynastic Period		X		X*	X				7	3
Tell or Kom Mara	Naqada III		X			X				4	2
Tell el-Mashala	Late Predynastic Period		X			[X]				4	2
Minshat Abu Omar / Tell es-Sabaa Banat	Predynastic Period		X			[X]				4	2
Total										92	

Nome 20	**Date attested first**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Saft el- Hinna/Suwa PER-SOBDU	New Kingdom	X	X (Suwa)		X	X				9	3
Tell el-Maghud /Tell Farasha	Second Intermediate Period		X			X				4	2
Total										13	

TABLE 4 Settlement patterns in nomes 2–20 of the Delta (cumulative score for the PD-PP, see Tables S11–S20 for additional breakdown of results by time slice). Modern name in small letters; ANCIENT NAME in capital letters

Nome	Capital	Cities	Large centres	Small centres	Large villages	Population Index	Small centres: Predicted	Large villages: Predicted	Corrected population index	Area (km²)	Estimated population	Population density (/km²)
2	Ausim KHEM/LETOPOLIS			5	1	23	5	10	41	484	87,857	182
3	Kom el-Hisn IMU	1	2	10	5	88	10	20	118	3,200	252,857	79
4	Tanta PTKHEKA			2	3	13	2	4	15	888	32,143	36
5	Sa el-Hagar SAU/SAIS	1	1	2		31	4	8	57	1,927	122,143	64
6	Sakha XOIS		1	1	3	16	2	4	23	1,939	49,286	25
7	Damanhur HERMOPOLIS MAGNA			3	6	24	3	6	24	1,349	51,429	38
8	Tell el-Maskhuta TJEKU/PITHOM			7		30	7	14	58	387	124,286	322
9	Abusir Bana DJEDU/BUSIRIS			2	1	13	2	4	19	708	40,714	58
10	Benha/Tell Atrib HUTHERIB/ATHRIBIS		1			9	2	4	27	908	57,857	64
11	Tell el-Muqdam TAREMU/LEONTOPOLIS	1		2	1	21	2	4	27	616	57,857	94
12	Sammanud TJEB-NETJER/SEBENNYTOS	1		1	4	27	2	4	32	1,528	68,571	45
13	Matariya/Tell Hisn IUNU/HELIOPOLIS	1	1	3	5	44	4	8	55	578	117,857	193
14	Tell Heboua I-II TJARU/SILE		4		3	44	8	16	130	592	278,571	472
15	El-Baqliya/Tell el-Naqus BA'H/TEHUTI/ HERMOPOLIS MAGNA		1	2	1	20	2	4	26	1,392	55,714	40
16	Tell Rub'a PERBANEBDJEDET/MENDES	1	1	7	2	56	7	14	80	1,379	171,429	125
17	Tell el-Balamun SMA-BEHDET/ PA-IW-N-IMN		1			10	2	4	28	740	60,000	81
18	Tell Basta BAST/BUBASTIS	1	1		2	23	4	8	55	324	117,857	364
19	Qantir PIRAMESSES , San el-Hagar DJA'NET/TANIS	3	3	5	4	92	12	24	167	1,688	357,857	213
20	Saft el-Hinna/Suwa PER-SOBDU		1	1		13	2	4	26	261	55,714	214
Total									1,008	20,891	2,160,000	NA
Average density (overall)												103

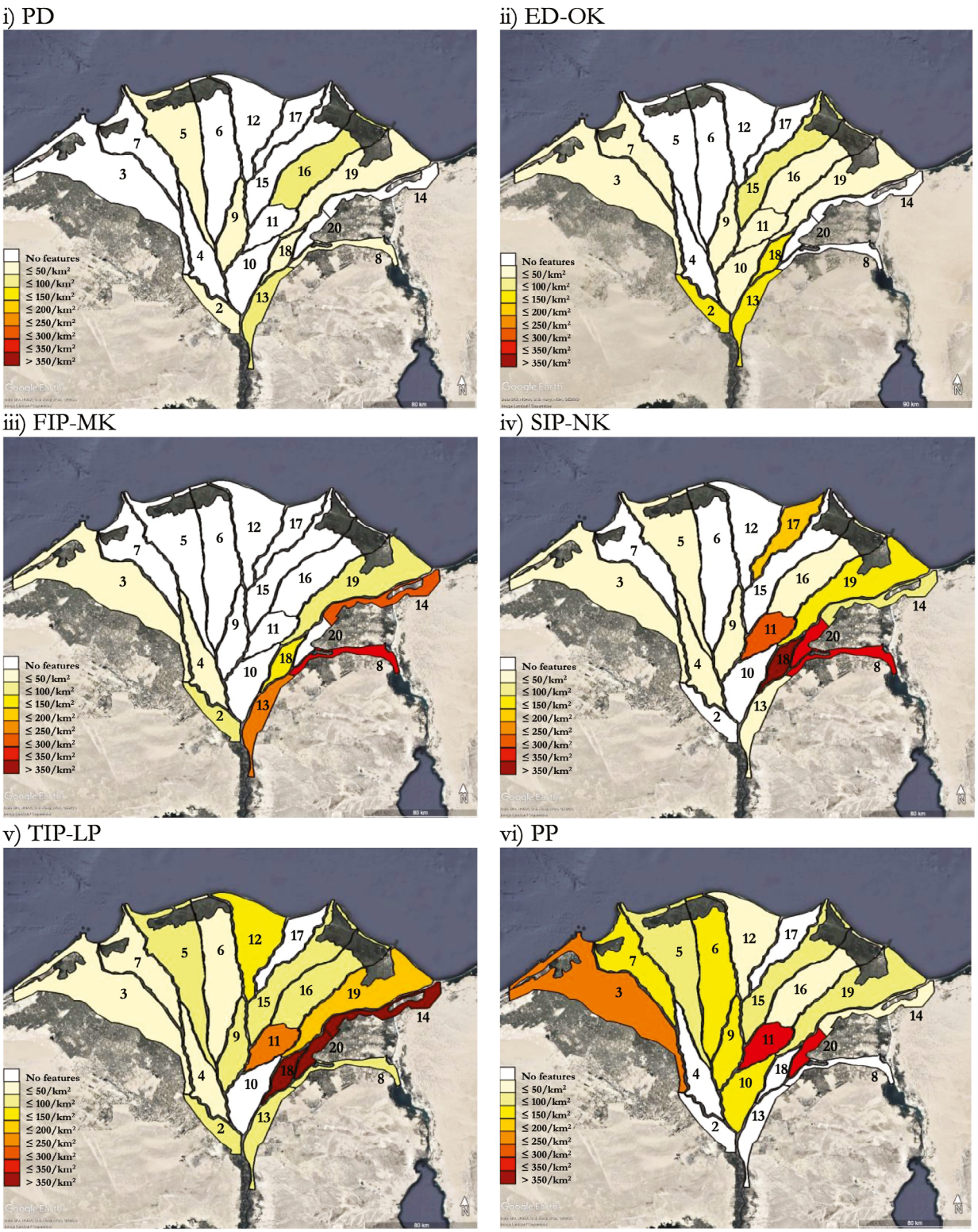

FIGURE 3A Estimated population density (people/km²) of the Delta using the conservative approach
BASE MAP FROM GOOGLE EARTH PRO, NOME BOUNDARIES AFTER BAINES & MÁLEK 1980, 15

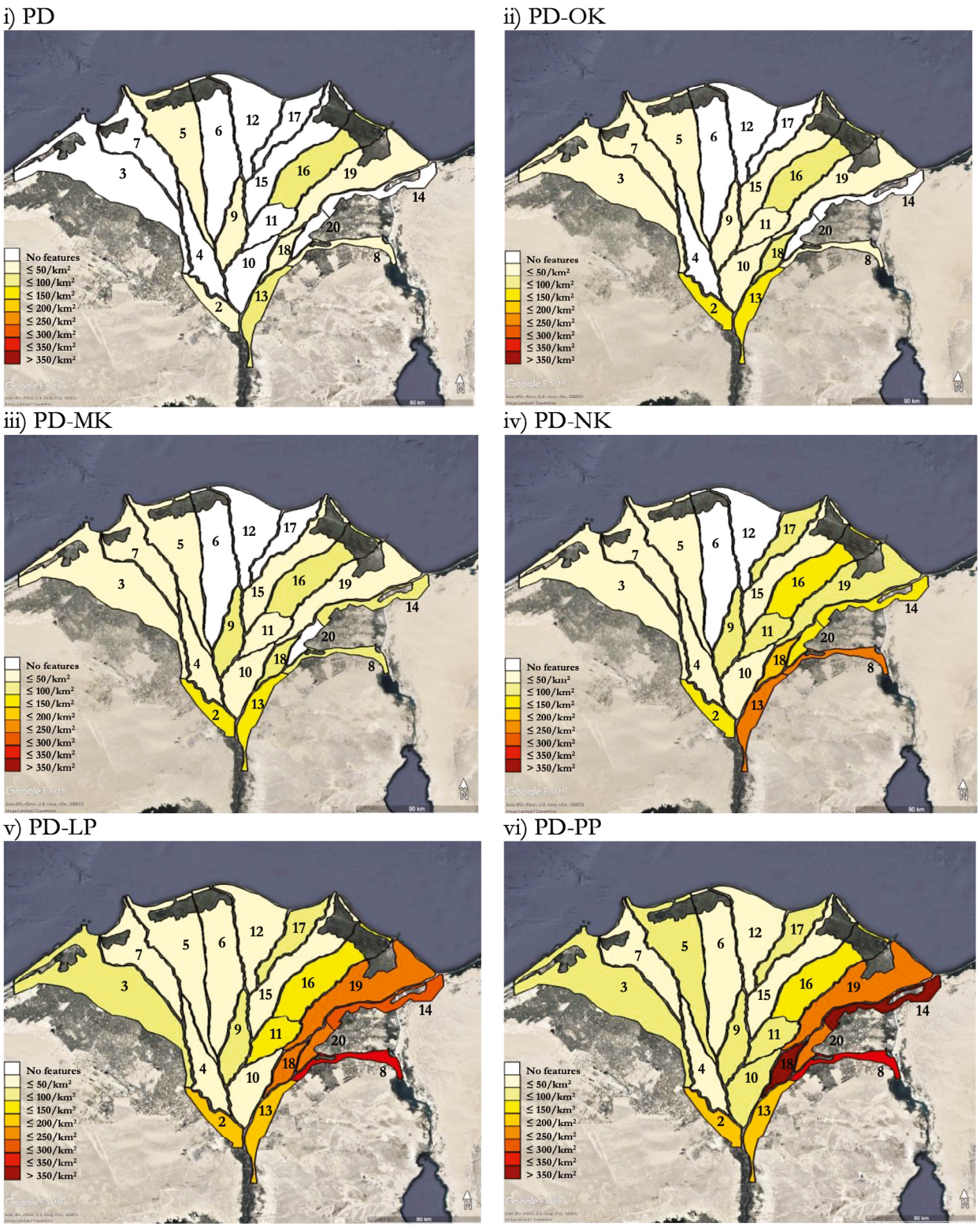

FIGURE 3B Estimated population density (people/km²) of the Delta using the cumulative approach
BASE MAP FROM GOOGLE EARTH PRO, NOME BOUNDARIES AFTER BAINES & MÁLEK 1980, 15

TABLE 5A Relative population sizes (in %) for the western, central, and eastern sectors of the Delta using the time slice approach

	Sector of the Delta	Western	Central	Eastern
Time slice	PD	21	6	73
	ED–OK	26	25	49
	FIP–MK	20	6	74
	SIP–NK	14	15	71
	TIP–LP	18	21	61
	PP	51	24	25

TABLE 5B Relative population sizes (in %) for the western, central, and eastern sectors of the Delta using the cumulative approach

	Sector of the Delta	Western	Central	Eastern
Time period	PD	21	6	73
	PD–OK	26	16	58
	PD–MK	26	14	60
	PD–NK	22	15	63
	PD–LP	21	17	62
	PD–PP	24	14	62

populated, a pattern that was particularly pronounced during the Predynastic Period (Table 5b, Fig. 3b).

4 Discussion

4.1 *Drivers of Settlement Patterns in Time and Space*

To what extent can we understand the broad shifts in the population distribution in the Nile Delta suggested by this study as the outcome of a combination of socioeconomic, political and environmental changes in Northeast Africa and the Levant? The settlement in the Delta during the Predynastic Period was undoubtedly related to the transition from a LSC to a Meandering landscape around 4000–3000 BC, when a swampy environment was replaced by a landscape of floodplains with well-drained soils that allowed subsistence based on crop cultivation and livestock in addition to fishing. In the earlier LSC landscape, settlements would have developed primarily on the turtlebacks (Tristant 2004), with fishing a primary source of protein (Pennington et al. 2016: 204–205) and interconnected river channels facilitating transport (Pennington et al. 2016: 203). Larger settlements at this time are likely to have been positioned in the area with the highest density of available resources, which may explain the emergence of sites such as Buto and Sais in nome 5 in the west, and Minshat Abu Omar and Tell el-Iswid in nome 19 in the east (Pennington et al. 2016: 206). However, the population concentration in the Eastern Delta during the Predynastic Period may also be related to its proximity to growing urban centres in Mesopotamia and, especially, the Levant in the Late Neolithic/Early Bronze Age (Wengrow 2006).

The subsequent Meandering landscape, by contrast, was characterised by fewer defined river branches, which allowed settlements strategically placed to control trade to flourish. A prime example is the site of Memphis, a major administrative centre and capital (Pennington et al. 2016: 205–206). Proximity to Memphis may explain the population concentration observed in nome 2 to the north of this city during the Early Dynastic Period/Old Kingdom. Imperial expansion from Memphis into the Delta during the Early Dynastic Period and especially the Old Kingdom may furthermore explain a more even settlement pattern across the Delta at this time as central and western areas of the Delta were 'colonised'. A key example is Kom el-Hisn, a centre of cattle-rearing activities in the western sector of the Delta (Redding 1992; Warden et al. 2023), situated in nome 3 which was estimated to have the third largest population in the Delta at the time. Conceivably, a contributing factor promoting such settlements in the central Delta was a decrease in Nile floods from the late 4th Dynasty to the First Intermediate Period, which may have affected the Delta edges disproportionately; the fluctuations in Nile floods are evidenced from historical records and boring at Birket Qarun, a lake in the Fayum fed by the Nile (Hassan 1997: 2). Although a reduction in the deposition of sediment meant that the turtlebacks in the Delta were now shrinking, they were still the favoured sites for settlements (Pennington et al. 2017: 226).

Compounding the effect of decreasing Nile floods, climatic aridification at the end of the Old Kingdom particularly affected the north of Egypt, as evidenced by the incursion of dune sands around Memphis (Hassan 1997: 6; Bunbury et al. 2017: 81; however, the severity of desertification was also felt further south, e.g. in Gilf el-Kebir in the Western Desert, which was abandoned by nomadic cattle herders around 2350 BC; Hassan 1997: 15). From the Eastern Desert, evidence suggests that the area around Wadi Deir was abandoned from around 2150–1920 BC,

TABLE 6 Relative population index (in %; dark grey: highest; light grey: second highest; -: no sites recorded)

	Time slice/period																					
Nome	**PD**	**Rank**	**ED–OK**	**Rank**	**PD–OK**	**Rank**	**FIP–MK**	**Rank**	**PD–MK**	**Rank**	**SIP–NK**	**Rank**	**PD–NK**	**Rank**	**TIP–LP**	**Rank**	**PD–LP**	**Rank**	**PP**	**Rank**	**PD–PP**	**Rank**
2	5	5	13	2	9	4	5	7	9	4	-	-	6	4	2	7	6	4	-	-	4	7
3	-	-	8	4	4	6	15	4	7	6	6	6	10	2	5	6	9	2	33	1	12	3
4	-	-	-	-	-	-	6	6	2	8	< 1	11	1	10	2	7	2	7	-	-	1	10
5	16	2	-	-	9	4	-	-	7	6	8	5	5	5	8	3	4	5	9	4	6	5
6	-	-	-	-	-	-	-	-	-	-	-	-	2	7	1	8	12	2	2	9		
7	-	-	5	7	3	7	-	-	2	8	-	-	1	8	2	7	2	7	8	5	2	9
8	5	5	-	-	3	7	17	3	5	7	12	4	8	3	2	7	7	3	-	-	6	5
9	6	6	5	7	7	5	-	-	5	7	1	10	4	6	2	7	3	6	4	5	2	9
10	-	-	6	6	3	7	-	-	2	8	-	-	1	8	-	-	1	8	5	6	3	8
11	-	-	6	6	3	7	-	-	2	8	14	2	5	5	7	4	4	8	10	3	3	8
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	3	4	8	3	8	3	8
13	16	2	13	2	11	2	18	2	13	2	2	9	10	2	2	7	7	3	-	-	5	6
14	-	-	-	-	-	-	20	1	8	5	4	7	5	5	13	2	9	2	1	10	13	2
15	-	-	19	1	10	3	-	-	7	6	-	-	5	5	6	5	4	5	4	7	3	7
16	36	1	12	3	24	1	-	-	18	1	3	8	13	1	7	4	9	2	2	9	8	4
17	-	-	-	-	-	-	-	-	-	-	13	3	5	4	-	-	4	5	-	-	3	7
18	2	7	7	5	3	7	6	6	2	8	13	3	5	8	8	3	4	5	-	-	5	6
19	14	3	6	6	11	2	13	5	11	3	16	1	13	1	14	1	19	1	5	5	17	1
20	-	-	-	-	-	-	-	-	-	-	8	5	3	7	7	4	3	6	4	7	3	7

TABLE 7 Relative population density (in %; dark grey: highest; light grey: second highest; -: no sites recorded)

	Time slice/period																					
Nome	**PD**	**Rank**	**ED–OK**	**Rank**	**PD–OK**	**Rank**	**FIP–MK**	**Rank**	**PD–MK**	**Rank**	**SIP–NK**	**Rank**	**PD–NK**	**Rank**	**TIP–LP**	**Rank**	**PD–LP**	**Rank**	**PP**	**Rank**	**PD–PP**	**Rank**
2	9	4	21	1	17	1	6	5	15	2	-	-	9	4	3	7	9	4	-	-	7	5
3	-	-	2	9	1	10	3	8	2	8	1	9	2	9	1	9	2	8	13	3	3	7
4	-	-	-	-	-	-	4	7	2	8	< 1	10	1	12	2	8	2	8	-	-	1	9
5	8	5	-	-	4	7	-	-	3	7	2	8	2	11	3	7	2	8	6	6	2	8
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	9	< 1	10	8	4	1	9
7	-	-	3	8	2	9	-	-	1	10	-	-	1	12	1	9	1	8	7	5	1	9
8	12	3			7	5	28	1	11	3	18	2	15	1	4	6	14	1	-	-	12	3
9	8	5	6	6	8	4	-	-	6	4	1	9	4	9	2	8	3	7	8	4	2	8
10	-	-	5	7	3	8	-	-	2	9	-	-	1	12	-	-	1	9	7	5	2	8
11	-	-	7	5	4	7	-	-	3	7	13	4	6	7	9	4	5	5	19	1	3	7
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	6	2	8	3	8	2	9
13	25	1	18	2	17	1	20	3	18	1	2	8	13	2	3	7	9	3	-	-	8	4
14	-	-	-	-	-	-	22	2	11	3	4	7	6	7	16	3	11	2	2	9	17	1
15	-	-	11	4	6	6	-	-	4	6	-	-	3	10	3	7	2	7	4	7	1	9
16	24	2	7	6	16	2	-	-	11	3	2	8	7	6	4	6	5	5	1	10	5	6
17	-	-	-	-	-	-	-	-	-	-	11	5	5	8	-	-	4	6	-	-	3	8
18	7	6	17	3	9	3	12	4	6	4	23	1	11	3	18	2	10	3	-	-	13	2
19	7	6	3	8	6	6	5	6	5	5	6	6	6	7	6	5	9	4	4	7	8	4
20	-	-	-	-	-	-	-	-	-	-	17	3	8	5	19	1	9	4	18	2	8	4

i.e. around the time of the First Intermediate Period and Middle Kingdom (Hassan 1997: 15; Kuper & Kröpelin 2006: 806). The decrease in game populations and the reduced potential for livestock herding in the deserts may have driven populations to settle in the margins of the Delta at this time, with the central Delta being less compatible with a nomadic lifestyle relying on pastoralism and hunting of open plains game.

Our data suggest that from the First Intermediate Period to the New Kingdom, the Eastern Delta again became significantly more densely populated than areas further west. During the First Intermediate Period, and especially the Middle Kingdom and the Second Intermediate Period, an influx of Asiatics into Egypt is well documented. The logical point of contact for migrants from Asia was the Eastern Delta, where evidence of Levantine influence includes architectural features of buildings and burials from the late 12th Dynasty (Moeller 2016). These settlements eventually coalesced into the dominant presence of the Hyksos and other groups from the Levant in the Second Intermediate Period. Although the absolute numbers of these immigrants among the indigenous Egyptian population probably remained low, the developments can help explain that our findings suggest a general population skew towards the east, a pattern consistent with the description of the Western Delta as a sparsely populated area at the time, with abundant grazing for pastoral populations (Moreno Garcia 2014).

The concentration in the eastern sector of the Delta may also, as Bietak (2017: 53) points out, be partly due to the physical geography of the Delta in the Middle Kingdom. At this time, the eastern sector had higher rates of sediment accumulation than the western and central sectors and offered more stable ground on which to settle (Pennington et al. 2016; Bietak 2017: 55). Bietak further maintained that the eastern sector, together with the western edge of the Delta, would have provided 'the most suitable water courses also for harbours' (Bietak 2017: 55). Harbours are hubs for movement of both goods and people and thus enables control over key networks and permits the establishment of major settlement centres that are conveniently connected to both the Nile Valley and the sea (Bietak 2017: 57). Those state-planned settlements which were founded in the Delta before the Late Period were primarily in the East, most notably at Tell el-Dab'a/Avaris in the Middle Kingdom, Pi-Ramesses in the New Kingdom and Tanis in the Third Intermediate Period.

Our findings suggest that the northern part of the central sector was only scantly populated until around the Third Intermediate Period. The reason for this is also likely to be environmental. The analysis of the fluvial environment of the Nile Delta by Pennington et al. (2017) indicates that much of the northern part of the central sector of the Delta was, for most of the period studied here, either inundated or marshlands and thus unsuitable for sustained habitation (see also Stanley & Warne 1998). The lack of donation stela for land in the central sector has also been interpreted as evidence that it was not desirable (Meeks 1979). Again, it may also be expected that nomadic populations would preferentially settle around the edges of the Delta in the east and west, rather than in the interior Delta. It is, however, also true that marshlands are not favourable for the survival of archaeological remains, especially the temporary structures which may be expected in an unstable environment where water courses frequently change. We therefore suggest that although the population densities in the northern nomes in the central sector are indeed likely to have been low until the first millennium BC, the impression that significant parts of the central sector were more or less empty is misleading, resulting from poor survival of less-permanent structures and the absence of written records.

Whilst the dynamic geography of the Delta was likely advantageous in promoting the establishment, growth, and expansion of sites in the Eastern Delta during the Middle and New Kingdom as explained above, it was also a risk factor: due to hydrological changes, the easternmost river channel, the Pelusiac branch, began to silt up as Egypt entered the Third Intermediate Period (Sneh & Weissbrod 1973), and the conditions that had allowed settlements here to function as major centres of economic and administrative control were no longer present. These changes may have contributed to a more even settlement pattern across the Delta again at later times, as may the management of river avulsions in the Western Delta to enhance channels for irrigation and transport benefits, starting under Shoshenq III of the 22nd Dynasty (Bennet 2019: 53–54). Thus, the location of the capital shifted from the east (Pi-Ramesses during the 19th and 20th Dynasty, Tanis during the 21st Dynasty, Bubastis during the 22nd Dynasty) to further west (Sais during the 26th Dynasty, Mendes during the 29th Dynasty, and Sebennytos during the 30th Dynasty). Also an increased number of refugees arrived from the Western Desert during the Third Intermediate Period (Bennett 2019: 191), and e.g. from Tanis and in particular Bubastis, evidence shows an influx of Libyans (particularly Libu, Meshwesh), a trend which started already during the 19th Dynasty (Snape 2012; Bennett 2019). The high population density in the eastern

nome 8 in particular may be related to the construction during the 26th Dynasty of a canal linking the Nile Delta to the Red Sea, facilitating trade (Bunbury 2019: 122).

The higher population concentration in the west during the Ptolemaic Period is likely to be strongly connected also to the foundation of a new capital in Alexandria and the settlements developing in its hinterland (Kenawi 2014). That proximity to dynamic centres could promote growth of adjacent settlements is also exemplified by Kom Firin, a New Kingdom fort site, which underwent a revival during the Late Period and continued to thrive during the Ptolemaic Period because of its proximity to Sais and Naukratis, a state-controlled Greek colony (Spencer 2014; Bunbury 2019: 100, 126–127).

4.2 *Methodological Considerations*

In our study, we recorded 122 sites, which are fewer than the 217 Upper Egyptian sites recorded in Karl Butzer's study. A contributing factor to our lower number of sites may be that for most of the period considered here large parts of the Delta region were hydrologically more unstable than the Nile Valley and thus less suitable for agriculture (Bunbury 2019). However, the main factors behind the more limited archaeological record from the Delta are likely to be poorer site survival and a preference for excavation sites in the Nile Valley among archaeologists. In particular, Delta sites may have been more susceptible to destruction resulting from large-scale mining for *sebakhin* (decomposed mudbricks from archaeological sites used as organic fertilizer), urban growth, and agricultural expansion in later times. In addition, older sites and site levels are often further below the modern water table in the Delta than in the Nile Valley, which complicates excavation, often with pumps required to reach the earliest settlements (Borghouts 1988: 4; Bunbury 2019: 97), e.g. predynastic levels of Sa el-Hagar (Sais) and Kom el-Khilgan (Wilson 2006b; Buchet & Midant-Reynes 2007). Also, some sites that were attractive for settlement in antiquity, remain so today, making it impossible to excavate without moving the modern population. Furthermore, as mentioned above, Butzer was at an advantage to counter biases in the settlement remains because he benefitted from ancient literary sources on population settlements in the Nile Valley, which allowed him to identify sites no longer visible on the ground, with no equivalent information available for the Delta (although the most important sites are mentioned in texts such as the Piankhy stela and the records of the Assyrian kings Esarhaddon and Assurbanipal, in these cases emphasising militarily significant localities; Bennett 2019: 33–34).

These biases have the potential to affect the total estimates of population sizes in the Delta relative to the Nile Valley. However, they are less likely to affect estimates of relative population densities *within* the Delta, which is what we focus on here, as we simply rely on Butzer's regional population estimates for Upper and Lower Egypt to convert the relative measures into absolute numbers. Within the Delta, we note that the Eastern Delta has traditionally been the focus of archaeological activity in Lower Egypt (e.g. see the overview of EEF/EES activity in the Delta between 1882–1982 by Spencer 1982), with a particular gap in evidence from the more central and southern sectors (Fig. 2); however, to what extent this constitutes a bias or appropriately reflects settlement density is currently unclear.

A final consideration is that there is a certain degree of arbitrariness in Butzer's selection of criteria for scoring settlement size. For example, one may argue that features such as harbours, animal cemeteries, workshops, and canals are also suitable indicators of population size and should be included as well. However, we decided to use Butzer's scoring criteria for site features without modification to generate results for the Delta that are comparable with his from the Nile Valley, resulting in a comprehensive proposition of possible spatiotemporal changes in population distribution in ancient Egypt.

5 Conclusions

The data presently available indicate that while the population in the Delta was generally skewed towards the eastern sector, and the central sector was least densely settled, there were notable temporal fluctuations, with the western sector gaining increased importance during the Ptolemaic Period. Initial settlement predominantly in the eastern sector (with prominent exceptions including Buto, Sais and Merimde Beni Salama) may be influenced by proximity to the Fertile Crescent and environs in the Levant. During the Old Kingdom, increasing settlement in the central sector may be related to colonisation from the centralised power in Memphis. Eastern concentration from the Middle Kingdom onwards may be explained by land stabilisation as well as incursions of settlers from Asia. Finally, from the late Third Intermediate Period onwards, a westward shift in population density may be associated with hydrological changes, including the silting up of the Pelusiac Nile branch and improved management of irrigation and transport further west, as well as increased influx of Libyans.

Some of these suggested patterns and drivers remain tentative, but a convenient feature of Butzer's method is that it is relatively straightforward to add new archaeological discoveries to update the population indices and this study is to be viewed as the template for future work. As more evidence accumulates, estimates of population changes within and between individual nomes are likely to become more accurate and nuanced, allowing more refined assessment of demographic changes in the Delta as a function of climatic, environmental and sociocultural factors. We hope that this will contribute to our understanding of the stresses and opportunities that shaped the life of people in ancient Egypt from the Predynastic through to the Ptolemaic Period.

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