



# The disappearance of malaria from Denmark, 1862–1900

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## Abstract

The reason for malaria's disappearance from northwestern Europe in the early twentieth century has long been discussed but remains an unresolved conundrum. This is partially due to a previous focus on the early modern era, and partially because various theories have never been tested against each other. In this study, we test some of the proposed hypotheses using nineteenth-century Denmark as a case. We found that the accelerating agricultural improvements with drainage and increasing livestock per km<sup>2</sup> explained much of the declining incidence rates, whilst other factors such as household size, temperatures, and precipitation did not seem to matter. Increased drainage meant dryer surface environment, and this led to a reduced size of the mosquito populations and therefore fewer malaria infections, and increased access to livestock led to changes in the mosquitoes' feeding preferences. Whilst drainage may have played a key role, it is possible that improvements in housing and clothing materials as well as use of quinine could also have affected malaria trends, although this could not be tested. We conclude that the disappearance of malaria was likely an unanticipated benefit of the agricultural developments related to the modernization of rural Denmark during the nineteenth century.

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## KEYWORDS

malaria, drainage, disease, agriculture

Until the first half of the twentieth century, malaria was endemic in northern Europe as far north as Finland. Isolated outbreaks continued to take place in Britain, Poland, Russia, Finland, and Germany during the two world wars, and in Russia, malaria elimination was first achieved in the 1970s.<sup>1</sup> Although it remains unclear when malaria was first introduced into the temperate climate in northern Europe, scholars agree that it was common in the early modern period. It has furthermore been suggested that it underwent a substantial decline in lethality in Scandinavia in the late eighteenth century, possibly due to changes in the parasite.<sup>2</sup> Whilst its disappearance from southern Europe in the mid-twentieth century has been attributed to anti-malarial interventions, the reasons for its far earlier disappearance in places such as Scandinavia and Britain in the late nineteenth century remain unclear.<sup>3</sup> There are several reasons for this. Firstly, malaria in northern Europe has primarily been studied in Britain, Sweden, and Finland, leaving us with a limited body of knowledge about its epidemiology elsewhere.<sup>4</sup> Secondly, since much of the literature has focused on the early modern era, studies of malaria in the nineteenth century are complicated by the absence of malaria as a cause of death in this period. The avid Danish tradition for keeping health and agricultural statistics from the nineteenth century can, however, contribute to understanding the role of societal developments in the disappearance of malaria. From 1803, the Danish Royal Board of Health required all physicians and surgeons to submit an annual medical report, wherein they described epidemic diseases, harvest outcomes, vaccination, maternal and infant mortality, accidents, general practitioners' conditions, midwives' conditions, legal cases against quacks, and chemists' conditions. From 1803 to 1861, the medical reports were qualitative, but from 1862, they also provided the number of diagnosed illnesses from a list of pre-defined notifiable diseases for the entire country. *Koldfeber*, the historical Danish-language diagnosis which is now associated with malaria, and its Latin synonym *Febris intermittens*, was one of the disease conditions included in this scheme.<sup>5</sup> The meaning of *koldfeber* and its association with malaria has been disputed in the medical historical literature. Until the first half of the nineteenth century, *koldfeber* was used frequently, including during epidemics, where both symptoms and mortality clearly were not consistent with modern malaria.<sup>6</sup> This has led some historians to dismiss the association between malaria and *koldfeber*.<sup>7</sup> The debate echoes a broader debate about the meaning of 'ague', the English-language equivalent of *koldfeber*.<sup>8</sup> During the second half of the century, however, *koldfeber* and *Febris intermittens* became synonyms for a disease condition with clinical symptoms and a seasonality such as that of malaria.<sup>9</sup> The motivation

<sup>1</sup> A review of the history of malaria in each country can be found in Bruce-Chwatt and de Zulueta, *The rise and fall of malaria in Europe*.

<sup>2</sup> Studies are published in medical journals: Hulden and Hulden, 'The decline of malaria in Finland'; Chen et al., 'The spatiotemporal distribution'; Horstmann, 'Malariaens forsvinden fra Danmark'.

<sup>3</sup> Bruce-Chwatt and de Zulueta, *The rise and fall of malaria in Europe*, pp. 4–6.

<sup>4</sup> Dobson, *Contours*; Hulden and Hulden, 'The decline of malaria in Finland'; Chen et al., 'The spatiotemporal distribution'.

<sup>5</sup> Ingholt, 'An ordinary malaria?'.

<sup>6</sup> Ingholt, 'An ordinary malaria?'.

<sup>7</sup> Nyland, *De praktiserende læger*, p. 235.

<sup>8</sup> For the international historiographical debate, see Ingholt, 'An ordinary malaria?', pp. 57–60.

<sup>9</sup> Manniche, 'En dansk malariaepidemi?', pp. 172–4; Ingholt, 'An ordinary malaria?'.



for this article is to investigate the possible link between changes in agriculture and society and the disappearance of malaria in Denmark using the Royal Board of Health's morbidity statistics.

## I | MALARIA

Malaria is caused by parasites of the genus *Plasmodium*. The *Plasmodium* species endemic to northern Europe was a now-extinct *P. vivax* strain with an approximately 9-month incubation time, which allowed it to survive the winters inside the human host.<sup>10</sup> The case fatality rate of *P. vivax* malaria in the late nineteenth century has previously been measured to be 0.2 per cent, meaning that it was not a particularly acute cause of death in this period.<sup>11</sup> Nevertheless, it has been argued that constant exposure to malaria could lead to infant malnourishment, because mothers were unable to provide sufficient breast milk due to frequent bouts of fever paroxysms, and adults constantly exposed to malaria were more likely to die from other infections.<sup>12</sup>

For malaria to be endemic in temperate climates such as Denmark, the *Plasmodium* parasite had to survive the fall and winter. In mosquitoes, the parasitic development of *P. vivax* ceases when temperatures fall below  $\sim 16^{\circ}\text{C}$ .<sup>13</sup> When an infected mosquito bites a human, the *Plasmodium* parasites are transferred into the human blood stream and invade the liver cells. Here, they start a process of maturing. In northern Europe, the immature *P. vivax* parasites entered a stage of dormancy, and only reactivated in the spring, when they caused clinical malaria relapses.<sup>14</sup> Only mosquitoes of the *Anopheles* species can host *Plasmodium* parasites, and in northern Europe, two *Anopheles* mosquitoes are known to be able to transmit the parasite. These belonged to a group known as the *A. maculipennis complex*. In southern Sweden, Denmark, England, and the Netherlands, the *A. atroparvus* and *A. messeae* mosquitoes – two sub-species in this group – were the main malaria vectors.<sup>15</sup> *A. atroparvus* preferably breeds in relatively still-standing bodies of brackish water found in marshes and river deltas, and *A. messeae* breeds in freshwater sites such as lakes, creeks, and ponds.<sup>16</sup> The *A. atroparvus* mosquito resided mainly indoors, and preferred dark and humid environments, meaning that people were most at risk of being infected indoors rather than near bogs or wetlands.

## II | STATE-OF-THE-ART AND THEORETICAL FRAMEWORK

The debate over the disappearance of malaria from northern Europe had already begun starting in the late nineteenth century, and multiple explanations have since been put forth. The explanations have only rarely been evaluated in relation to each other, and they are often situated in individual countries' own contexts. The explanations can roughly be grouped into two theoretical frameworks presented in figure 1. The first framework dictates that malaria disappeared for

<sup>10</sup> Ingholt et al., 'Temperate climate malaria'.

<sup>11</sup> Ingholt et al., 'Temperate climate malaria'.

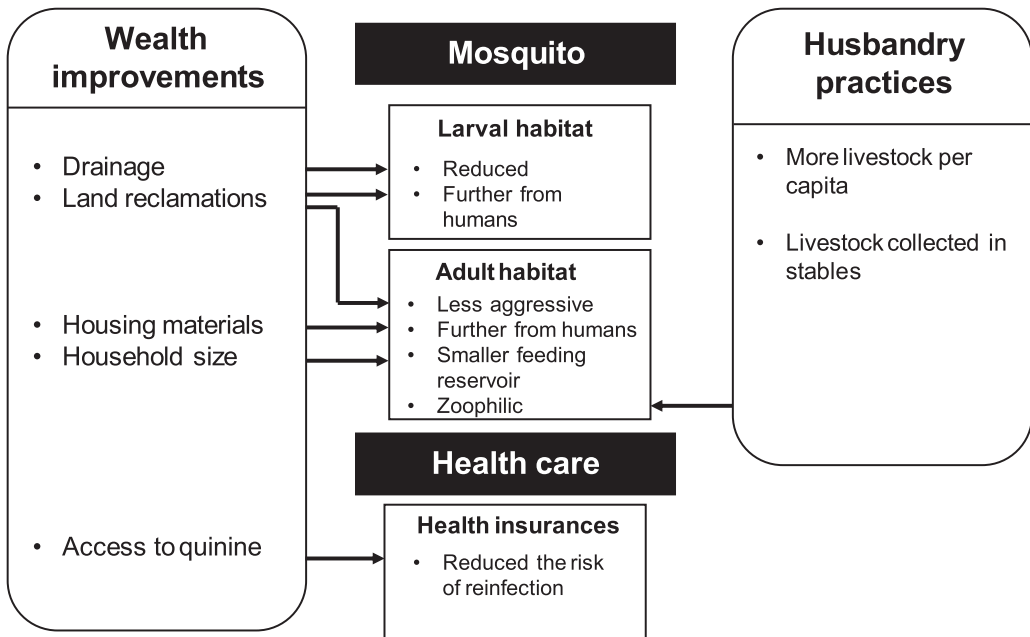
<sup>12</sup> Dobson, *Contours*, pp. 340–50.

<sup>13</sup> Petersen, Severini, and Picot, 'Plasmodium vivax malaria'.

<sup>14</sup> Dobson, *Contours*, p. 310; White, 'The rise and fall'.

<sup>15</sup> Jetten and Takken, *Anophelism without Malaria in Europe*, p. 1.

<sup>16</sup> Jetten and Takken, *Anophelism without Malaria in Europe*, pp. 29–30; Ramsdale and Wilkes, 'Some aspects'.



**FIGURE 1** Illustration of the two theoretical frameworks in previous literature for the disappearance of malaria from northern Europe.

various reasons related to wealth improvements in the second half of the nineteenth century. Indeed, one epidemiological study concluded that a growth in gross domestic product (GDP) was the main cause of malaria's disappearance in all of Europe.<sup>17</sup> Here, drainage and land reclamations have been suggested as the most important factor. Wealth improvements allowed farmers to drain their fields more efficiently, to sponsor land reclamation projects, where larger tracts of land were reclaimed from the sea and turned into farmland, and to replace dark and humid cottages with large brick houses with drier indoor environments. Finally, health insurance became common from the second half of the nineteenth century and allowed the rural population to treat themselves with the anti-malarial drug quinine. The second framework does not place emphasis on wealth improvements, but rather on the growing role of livestock in agriculture. In the final part of this paper, we will test for the influence of drainage and livestock using statistical modelling. Because of limitations in data availability, the other potential factors mentioned here will be discussed. Below, we discuss both the different proposed explanations and the potential factors that could influence the malaria burden in detail.

The oldest and most cited explanation is that agricultural improvements with embankments and soil drainage led to the disappearance of malaria.<sup>18</sup> Farmland improvements in northern Europe began with the agricultural revolution in the second half of the eighteenth century, and the wetland coverage was reduced considerably during the nineteenth and twentieth centuries. In Denmark, open field farming was replaced with enclosure in a series of comprehensive national agrarian social reforms that began in the 1770s and ended roughly in the 1830s. A reform act from

<sup>17</sup> Zhao, Smith, and Tatem, 'Exploring the spatiotemporal drivers'.

<sup>18</sup> Det kongelige Sundhedskollegiums Aarsberetning for Aaret 1874, 354; Hansen, *Epidemiologiske Undersøgelser*, p. 21; Dobson, *Contours*, pp. 351–4; Nicholls, 'Fenland ague'.



1790 required landowners to drain their enclosed fields and clean up creeks and bogs.<sup>19</sup> In this period, fields were drained by digging open ditches that led stagnant water away from the surface of the fields, thereby reducing the groundwater mirror.<sup>20</sup> This was a primitive system that had several disadvantages. Firstly, the ditches are believed to have taken up 10 per cent of the total field area. Secondly, the ditches needed to be kept clean. Thirdly, both humans and livestock were in risk of falling into the ditches. Despite the act of 1790, less than 2 per cent of Denmark is believed to have been drained by the middle of the nineteenth century. Following the invention of the cylindrical clay pipe in the 1840s, the major drainages of Denmark, however, intensified rapidly, and in this period considerable efforts to dry out bogs also began to take shape. The cylindrical clay pipes were dug into the soil 10–20 meters apart to form underground channels that led the underground water away and lowered the groundwater mirror. Following a drainage act in 1859, drainage was required to take place through cylindrical clay pipes.<sup>21</sup> During the period 1860–1900, drainage was done on a local level, and only in the twentieth century did the Danish state support drainage schemes financially.<sup>22</sup> Drainage can affect mosquitoes' ecology and thereby the malaria burden in several ways. It reduces the number of bodies of water where mosquitoes can lay eggs, which reduces the size of mosquito populations. A drier surface environment may also have reduced the mosquitoes' biting rates, since mosquitoes exhibit more aggressive behaviour under humid conditions.<sup>23</sup> Intensified drainage finally increased the distance between humans and mosquitoes, since mosquitoes rarely fly further than 500 meters from where they hatch, and the increased distance between humans and mosquitoes would have led them to feed on other mammals and birds, which led to zoophilic feeding preferences.<sup>24</sup> The drainage explanation was, from early on, also criticized for being too simplistic and not considering that mosquitoes of the *A. maculipennis complex* still exist in malaria-free areas today.<sup>25</sup>

The disappearance of malaria has also been explained by various social improvements. Improvements in housing conditions has been proposed as the cause in England and Italy.<sup>26</sup> Since *A. maculipennis* mosquitoes prefer dark and humid indoor environments such as stables and cowsheds, leaving only to breed and lay eggs, improvements in housing conditions with drier and better ventilated indoor environments would have caused a more hostile indoor environment for the mosquito.<sup>27</sup> In Denmark, housing conditions improved during the nineteenth century. Windows became larger, which allowed for more sunlight and better indoor ventilation, and in a study from 1921, Danish entomologist [Wesenberg-Lund](#) found that the mosquitoes were not present in farmhouses after these improvements had taken place.<sup>28</sup> The importance of housing materials has also been documented in studies from England and the Netherlands, where it was shown

<sup>19</sup> Forordning angaaende skadeligt Vands Aflledning til Agres, Enges og Mosers Forbedring i Danmark, 17 June 1790.

<sup>20</sup> [Bjørn et al.](#) *Det Danske Landbrugs Historie*, pp. 17–20.

<sup>21</sup> [Breuning-Madsen](#), 'Drænrørets indførelse', pp. 158–161. [Stenak](#), *De inddæmmede landskaber*, p. 103.

<sup>22</sup> [Breuning-Madsen](#), 'Drænrørets indførelse', p. 160.

<sup>23</sup> [Nicholls](#), 'Fenland ague'; [Patz et al.](#), 'Predicting key malaria transmission'.

<sup>24</sup> [Nicholls](#), 'Fenland ague'.

<sup>25</sup> [Nuttall](#), [Cobbett](#), and [Strangeways-Pigg](#), 'Studies in relation to malaria'; [Wesenberg-Lund](#), *Contributions*, p. 178; [James](#), 'The disappearance of malaria'.

<sup>26</sup> [James](#), 'The disappearance of malaria'; [Hackett and Missiroli](#), 'Housing'.

<sup>27</sup> [Wesenberg-Lund](#), *Contributions*, p. 171.

<sup>28</sup> [Wesenberg-Lund](#), *Contributions*, pp. 164–5.



that humid indoor environments allowed for continuous malaria transmission on the individual household level for years, even after community transmission had ceased.<sup>29</sup>

A study of malaria in Finland concluded that a reduction of the average household size to below four individuals ceased continuous malaria transmission, as the reservoir of susceptible individuals to the parasites became too small.<sup>30</sup> The study considered the period 1750–1950 and captured outbreaks in the twentieth century that were related to World War II. Malaria had already declined steeply in the late nineteenth century, and the new outbreaks took place because of exogenous factors such as war. Moreover, the study did not consider the development of medical diagnoses during the eighteenth and nineteenth centuries and did not correct for population size either.

The introduction of health insurance funds in the middle of the nineteenth century provided people with better opportunities to treat themselves with the anti-malarial drug quinine.<sup>31</sup> Like the other explanations, this one has received criticism. Dobson argued that whilst access to quinine could have had local effects on the malaria burden, the large-scale disappearance of malaria cannot have taken place solely due to better access to quinine.<sup>32</sup> There are no figures on the prices of quinine in Denmark. The earliest health insurance funds in Denmark date back to the 1840s, and the number of funds accelerated during the 1870s. A survey from 1885 concluded that there were 986 health insurance funds with 118,000 members by then. Nevertheless, it has been argued that there were disparities between rural and urban funds. Rural health insurance funds very often struggled to provide the help the members needed and relied heavily on donations from benefactors.<sup>33</sup> More widespread access to healthcare in rural and poorer parts of Denmark came with the Health Insurance Law of 1892, but by then, malaria had already ceased to be a major problem in Denmark.<sup>34</sup> Moreover, local practices and different perceptions of health and treatment preclude large regional scale effects, especially in rural areas where malaria was most present. In Finland, for example, many farmers did not treat themselves with quinine, even when offered, and instead relied on folk remedies for malaria treatment.<sup>35</sup>

All the proposed explanations – housing conditions, drainage, declining family size, and better access to treatment – are related to increasing wealth and a changing society, and several of the mentioned studies have indeed proposed that malaria disappeared due to a combination of social and agricultural improvements.<sup>36</sup>

The second strain in the literature connects the disappearance of malaria with the economic crisis that western European farmers underwent in the 1870s. From the 1840s, the European market for food products globalized. Improvements in transportation, which included railways and steam ships, soon meant that the European market was flooded with cheap crops from the United States, Argentina, and the Russian Empire. In Denmark, this forced farmers to focus attention on the production of animal products such as dairy and bacon, which was targeted at the

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<sup>29</sup> Hackett, *Malaria in Europe*, pp. 74–8; Swellengrebel, de Buck, and Kraan, ‘Mechanisms of malaria transmission’; James, ‘The disappearance of malaria’.

<sup>30</sup> Hulden and Hulden, ‘The decline of malaria in Finland’.

<sup>31</sup> Swellengrebel and de Buck, *Malaria in the Netherlands*, pp. 23–30; Hansen, ‘Den lollandske feber’; Porter, *Health, Civilization and the State*, pp. 144–5, 202.

<sup>32</sup> Dobson, *Contours*, pp. 358–9.

<sup>33</sup> Feldbæk et al., *Drømmen om tryghed*, pp. 179–80.

<sup>34</sup> Løkke, ‘State and insurance’, pp. 16–7.

<sup>35</sup> Hulden and Hulden, ‘The decline of malaria in Finland’.

<sup>36</sup> Nuttall, Cobbett, and Strangeways-Pigg, ‘Studies in relation to malaria’; James, ‘The disappearance of malaria’; Dobson, *Contours*, pp. 352.



British market.<sup>37</sup> This led to an increase in livestock herds, and livestock was collected in stables rather than grazing in the open. *A. maculipennis* mosquitoes naturally prefer feeding on livestock and are attracted to stables.<sup>38</sup> Wesenberg-Lund speculated that changing husbandry practices in Denmark, and the collection of livestock in stables, created stable food reservoirs for mosquitoes, which he argued resulted in mosquitoes preferentially biting animals and becoming exclusively zoophilic.<sup>39</sup> A more recent study of England indeed concluded that the combination of increasing cattle density and declining wetland coverage explained the disappearance of malaria there.<sup>40</sup>

### III | THE DECLINE OF MALARIA IN DENMARK

The main source material for this study is the Danish Royal Board of Health's annual medical reports for the period 1862–96. Until 1876, they were published as a supplement to the annual proceedings of the Danish Medical Association, and from 1877, they were published in separate books. The published medical reports from after 1862 contained statistics on the monthly number of notified cases by medical region, and from 1871 with rural and urban distinctions. At the time, Denmark was divided into 12 medical regions. The borders of the medical regions followed the borders of the Danish counties, for which reason, we could estimate the medical regions' populations using the county populations from the censuses of 1860, 1870, 1880, 1890, and 1901.<sup>41</sup>

Between 1862 and 1896, there were 167,746 notified cases of malaria in all of Denmark. This figure is, however, likely to be an underestimate of the true disease burden. The national figures are based on reported cases by district physicians and general practitioners, and although all physicians were required to send in reports, many either sent in very short reports, or did not do so at all. Rural medical coverage was poor, and some rural physicians did not keep records of treated patients, which could have led to further underestimation of the actual number of patients.<sup>42</sup> Finally, because treatment was not free of charge, patients did not consult licensed physicians for treatment and instead obtained prescriptions for quinine treatment elsewhere.<sup>43</sup> Nevertheless, the annual variation that is observed was likely not affected by the lower counts of patients. Figure 2 shows the declining malaria incidence in the medical regions. Two epidemic years stand out: 1862 – the reasons of which are still unknown—and 1873, which followed a storm surge in November 1872 that caused flooding in Lolland-Falster and the southern part of Funen.

Geographically, the lowest malaria burden was in western Jutland (the combined regions of Ribe, Ringkøbing, and Viborg), and the greatest burden was in the south-eastern medical region Lolland-Falster.<sup>44</sup> Lolland-Falster consists of the two main islands Lolland and Falster, but also includes the three small islands Askø, Fejø, and Femø. Lolland was mainly flat and low lying,

<sup>37</sup> Lains and Pinilla, *Agriculture and economic development*, pp. 11–2; Lampe and Sharpe, *A land of milk and butter*, p. 151.

<sup>38</sup> Hackett, *Malaria in Europe*, p. 80.

<sup>39</sup> Wesenberg-Lund, *Contributions*, pp. 182–184; Bjørn et al. *Det Danske Landbrugs Historie*, pp. 370–4.

<sup>40</sup> Kuhn et al., 'Malaria in Britain'.

<sup>41</sup> Census lists for Maribo county before 1850 are found in Danish National Archives, Rentekammeret (1787), Rentekammeret Danske Afdeling, Dansk-Norsk Tabelkontor (1801), Rentekammeret Danske Afdeling, Tabelkommissionen (1834–45). Census lists for 1850–1901 are found in Danish National Archives, Danmarks Statistik.

<sup>42</sup> The flaws of the medical reporting system were already noted before its conception. Uldall, 'Bemærkninger', pp. 180–2.

<sup>43</sup> Det kongelige Sundhedskollegiums Aarsberetning for Aaret 1863, 363, 377.

<sup>44</sup> Ingholt et al., 'Temperate climate malaria'.

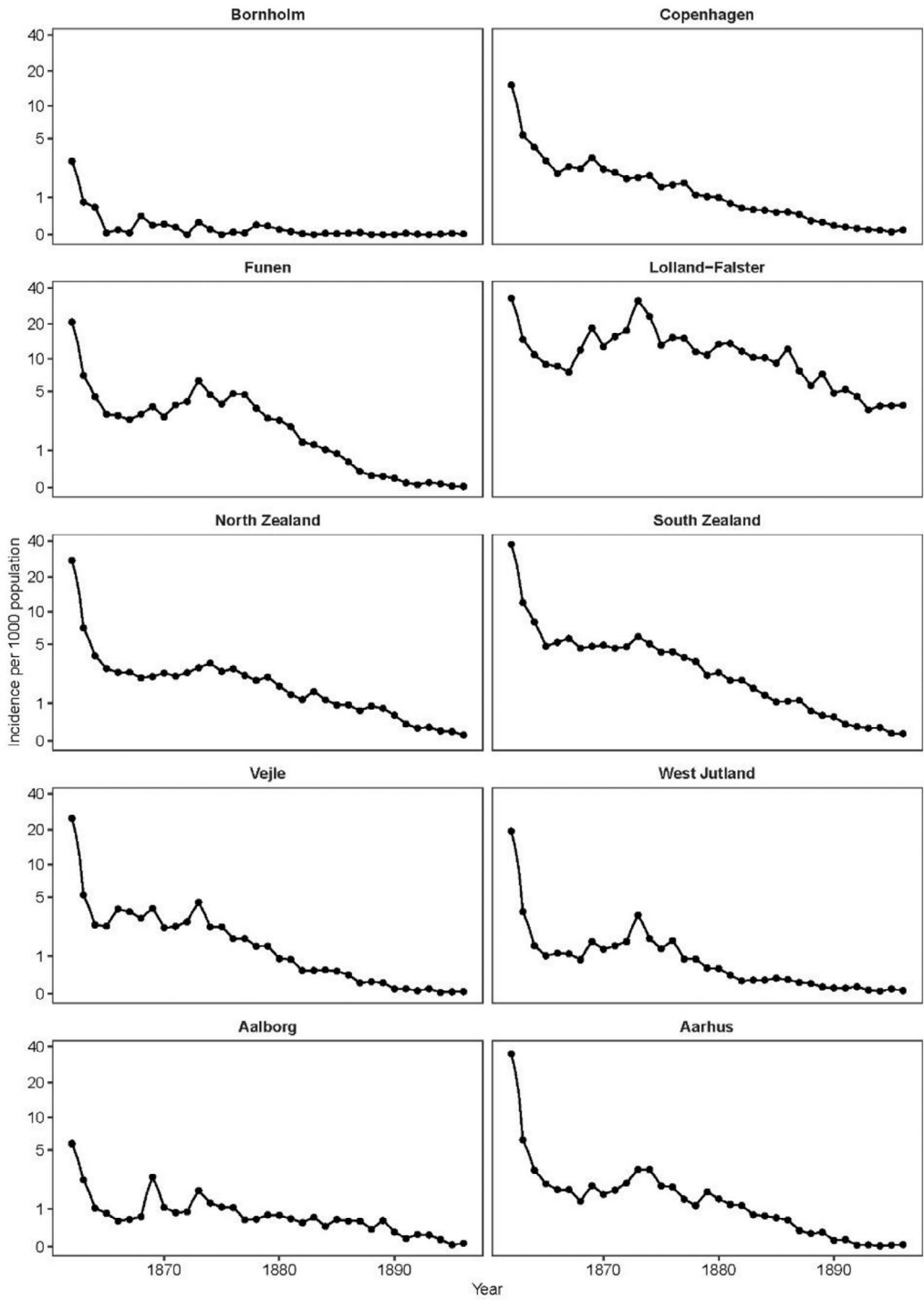


FIGURE 2 Malaria incidence per 1000 population in the Danish medical regions, 1862–96.



with coastal wetlands in the western part and with dense clay soil. Moreover, substantial agricultural production and high rural population density in this part of Denmark meant that there were both livestock herds for the mosquitoes to feed on and many human hosts for the *Plasmodium* parasites. Western Denmark, on the contrary, provided poorer conditions for both parasite and mosquito vector, as it was characterized by sandy moor with less agricultural production and a low rural population density. Sand-based soil types generally drain better, whereas moraine clay drains poorly, leading to a concentration of stagnant water bodies, where the *Anopheles* mosquitoes can lay eggs. This probably explains a large part of the geographical disparities in morbidity. In addition, the clay soils of eastern Denmark meant that this part of the country was more arable, and economic inequality was higher during the period in question.<sup>45</sup> Malaria is known as having been a poverty-related disease in Europe historically.<sup>46</sup> This may, in conjunction with natural geography, explain the higher malaria incidence rates in eastern Denmark. Finally, malaria was not endemic on the island of Bornholm in the Baltic Sea (figure 2).<sup>47</sup>

#### IV | THE FACTORS RESPONSIBLE

To investigate the factors responsible for the disappearance of malaria, we studied the roles of livestock and drainage on malaria incidence in the medical regions. Analysing the role of changes in housing materials was not possible, as no such regional statistics exist. A sample of 236 fire insurance records from six randomly selected parishes in Lolland-Falster during 1840–1929 showed that the known transition from houses being built in clay till to brick houses to some extent followed the disappearance of malaria. In the decade 1840–9, none of the recorded housing materials were brick walls, whilst this was 36 per cent in 1910–9 and 25 per cent in 1920–9, competing against half-timbering and wood. In 1840, none of the recorded roofs were tile. In 1909 that number was 31 per cent and in 1929 it was 6 per cent, when roofing felts became more common. In the 1870s and 1880s, when malaria began to decline, the most common building materials were timber-framed houses with bricks between the timber logs and timber-framed houses with clay. The most common material for roofs were thatched roofs. During the period 1840–1929, the number of additional buildings to the farmhouse rose from 1.7 to 4.8.<sup>48</sup> Regarding quinine treatment, no official records documenting the amount of quinine sold to Danish consumers exist, and as already discussed, much of the population may not have had access to quinine due to the poor health insurance funds. Therefore, we left both building materials and quinine treatment out of the statistical analysis.

<sup>45</sup> Boberg-Fazlic, Lampe, Lasheras and Sharp, 'Winners and losers' p. 14.

<sup>46</sup> Buonnano, P., Esposito, E., and Gulino, G., 'Social adaptation to diseases and inequality' p. 8.

<sup>47</sup> Ingholt et al., 'Temperate climate malaria'.

<sup>48</sup> Danish National Archives, Landbygningernes alm. Brandforsikring, Lollands Branddirektorat: Forsikringsprotokol, Lollands Nørre Herred (1853–1858) 2: B Nakskov Landsogn mm, Forsikringsprotokol, Nakskov Landsogn (1858–1950) 1; Forsikringsprotokol, Fuglse Herred (1858–1874) 1: A Bursø mm., B Skørringe mm., Forsikringsprotokol, Bursø, Holeby og Krønge Sogne (1870–1956) 1, Forsikringsprotokol, Skørringe og Tirsted Sogne (1870–1956) 1; Forsikringsprotokol, Musse Herred (1858–1874) A: Hunseby, Forsikringsprotokol, Hunseby Sogn (1870–1956) 1; Landbygningernes alm. Brandforsikring, Nykøbing Falster Branddirektorat: Forsikringsprotokol, Falster Nørre Herred (1858–1868) 1: B-L, Forsikringsprotokol, Falster Nørre Herred (1868–1882) 1: B-L, Sognevurderingsprotokol, Gundslev Sogn (1897–1942) 1: 1897–1942; Forsikringsprotokol, Falster Sønder Herred (1858–1868) 2: Karleby-Væggerløse, Forsikringsprotokol, Falster Sønder Herred (1868–1882) 3: Nykøbing-Væggerløse, Sognevurderingsprotokol, Sønder Kirkeby Sogn (1876–1954) 1: 1876–1952.

We analysed which of the associated factors – livestock density and drainage – had the strongest statistical association with the malaria trends. We followed a hypothesis put forth by [Randall Packard](#) that there may have existed a threshold for drainage above which the mosquitoes have limited breeding grounds around human populations, which would have led to the demise of malaria.<sup>49</sup> We hypothesized that increases in the livestock density over time in a similar fashion could have led to a preference of mosquitoes to bite livestock rather than humans. The existence of such thresholds would show in malaria incidence as breakpoints in the time series: points in time related to the developments in these factors, after which the decline in malaria accelerates. Our hypotheses can therefore be formulated as follows:

1. Does a threshold value exist for drainage and livestock density after which its effect on the decline of malaria becomes apparent?
2. If so, to what extent can the decline in rates of malaria be associated with increases in drainage and livestock density?

The variables included in the analyses are described below, and the statistical modelling framework is outlined.

From 1861, the Danish Bureau of Statistics published agricultural surveys in 5-year intervals.<sup>50</sup> These surveys contained statistics on the size of the cultivated land, the types of crops, the size of pastures and fallow, the *tønder land* (0.55 ha) drained by clay pipes, and the total landmass in *tønder land* for all parishes, hundreds, and counties in Denmark. The Bureau of Statistics also published livestock censuses in the same years, which contained statistics on the number of cattle, swine, sheep, and horses per parish.<sup>51</sup> The surveys and livestock censuses were conducted by parish councils, who had detailed knowledge about the parish and were familiar with the local conditions.<sup>52</sup> There was a little development in horse density in most regions towards the 1890s (supplementary figure 1), which is likely due to horses having been used for work and transportation rather than food production. Therefore, we did not include horse density in our statistical framework. Because the medical regions' borders follow those of the counties, we re-estimated the *tønder land* drained and size of the livestock herds from county level to medical region level for the surveys between 1861 and 1896. The survey and livestock census of 1888 were excluded due to changes in drainage registration in this survey and changing county borders in the livestock census.

The natural drainage efficiency varies by soil type, and whilst sand is highly drainable, water has difficulties penetrating soil with high clay content, leaving more stagnant surface water. For this reason, the parts of Denmark with high clay concentration in the soil also needed more artificial drainage with clay pipes.<sup>53</sup> To assess the historical need for drainage, we combined a modern soil texture map of Denmark with a map of the Danish medical regions as they were in 1880 in the Quantum Geographical Information System (QGIS) using the Union function.<sup>54</sup> We then estimated the percentage of each medical region that was moraine clay soil. The administrative

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<sup>49</sup> [Packard](#), *The making of a tropical disease*, p. 52.

<sup>50</sup> Arealets Benyttelse i Danmark Den 17de Juli 1876, 1878.

<sup>51</sup> Kreaturholdet Den 17de Juli 1876, 1878. In some censuses, donkeys, geese and beehives were counted as well.

<sup>52</sup> Arealets Benyttelse Og Størrelsen Af Udsæden Den 15de Juli 1881, 1884, ii.

<sup>53</sup> [Breuning-Madsen](#), 'Drænrørets indførelse', p. 160.

<sup>54</sup> The soil map was produced by the Geological Survey of Denmark and Greenland (GEUS).



boundary map and soil texture map by Geological Survey of Denmark and Greenland (GEUS) all have size information in  $\text{m}^2$ . To test whether the geographical size in the two maps align, we tested the sizes on the island of Bornholm. The GEUS map showed that Bornholm was roughly  $583 \text{ km}^2$  in size, and the medical region map showed that Bornholm was  $587 \text{ km}^2$  in size. The size of Bornholm in the Bureau of Statistics' surveys is  $582 \text{ km}^2$ , for which reason we found the GEUS map most reliable for this study. We then recalculated the land size measured in *tønder land* drained from the surveys into  $\text{km}^2$  and estimated the proportion of clay soil drained in percentages. We found that the medical regions in Zealand, Funen, and Lolland-Falster were drained more intensively than in western Jutland and Aalborg medical regions. These differences can be attributed to differences in the texture of the soil. As mentioned in part 3, the eastern part of Denmark – North and South Zealand, Lolland-Falster, and Funen – all had high clay concentration, whereas western Jutland and Aalborg medical regions had higher proportions of sand-based soil. Despite a low percentage of clay soil in the 'drier' medical regions, malaria was still a local problem here. In Aalborg medical region, it caused outbreaks in settlements along the saline Limfjord, and in western Jutland, malaria was endemic in settlements on clayish soil along the saline Skjern river delta.<sup>55</sup>

Livestock density per  $\text{km}^2$  was estimated using the number of cattle, swine, and sheep per county independently and the county's overall land area, converted from *tønder land* to  $\text{km}^2$ . We estimated the proportion land drained and the livestock density in the years between the surveys described above using linear interpolation.

As previous studies have demonstrated an association between high malaria incidence and warm summer temperatures,<sup>56</sup> we also included the previous year's average summer temperature and precipitation as covariates. Monthly mean temperatures and precipitation have been measured in Copenhagen since 1768.<sup>57</sup> Observations for other regions were not available in the study period. The mean temperatures and mean precipitation from June, July, and August were selected as the independent variables representing summer temperatures and summer precipitation.

In all medical regions, the average household size did not reach the four-person threshold during the study period, as has been previously observed in Finland.<sup>58</sup> The household size first slightly declined to then increase towards the 1880s and then declined again (figure s2). Funen, Lolland-Falster, and North Zealand, regions where the malaria incidence was also high, showed high household sizes, with average household sizes higher than the European average for the nineteenth century, which ranged between four and five individuals per household. The declining household size in the nineteenth century has been explained by the disappearance of extended families and the overall fertility decline.<sup>59</sup> Extended families were primarily found in pre-industrial agrarian societies such as Lolland-Falster – which, due to rich clay soil, was one of Denmark's most densely cultivated regions – which might explain a part of the large household size.<sup>60</sup> Lolland-Falster had one of the highest concentration of manors in all of Denmark. Manors counted on the labour of many servants, which may partially also explain the high average household size. Since the same household sizes were both observed in time periods and regions

<sup>55</sup> Det kongelige Sundhedskollegiums Aarsberetning for Aaret 1863, 365–68, 377–78.

<sup>56</sup> Ingholt et al., 'Temperate climate malaria'; Chen et al., 'The spatiotemporal distribution'.

<sup>57</sup> Cappelen, *DMI Historical Climate Data*.

<sup>58</sup> Hulden and Hulden, 'The decline of malaria in Finland'.

<sup>59</sup> Rothenbacher, *The European population* pp. 50–2.

<sup>60</sup> Rothenbacher, *The European population* p. 54.



with high and low incidence of malaria, we did not consider this variable in our statistical analysis.

We investigated the existence of threshold values for each of the explanatory variables, drainage, cattle density, swine density, and sheep density, using negative binomial regression models, which is a standard approach in epidemiology. We excluded Bornholm and Copenhagen from the analysis as malaria incidence was very low on Bornholm, and patterns in livestock and drainage we inconsistent over time in Copenhagen, probably due to the city's rapid expansion in the second half of the nineteenth century (figure 2 and supplementary figure 1). Ribe, Ringkøbing, and Viborg medical regions, all of which had low incidence rates, were combined into a single region called 'West Jutland'. Their combination resulted in more robust statistical models.

The model had the following general form:

$$\mu_i = \exp(\ln(t_i) + \beta_1 T_{i-1} + \beta_2 P_{i-1} + \beta_3 D_{1,i} + \beta_4 D_{2,i} + \beta_5 I + V_{j,x,i})$$

where  $\mu_i$  is the expected number of malaria cases in year  $i$ ,  $T_{i-1}$  and  $P_{i-1}$  are the lagged time series for temperature and precipitation, respectively,  $D_1$  and  $D_2$  are dummy variables for the years 1862–3 and 1873–4, respectively, to capture known disruptions to the long-term trend,  $t_i$  is the population size as an offset,  $I$  is the temporal trend, and  $V_{j,x,i}$  is an explanatory variable in year  $i$  and can either be percentage of clay soil drained, or swine, sheep, or cattle. These explanatory variables are tested using a change point approach, where there is assumed to be a threshold. Below the threshold, drainage, cattle density, and swine density, which were increasing over this time period, had no effect, and above the threshold, the variable had a linear effect. For sheep density, the opposite was modelled since it was decreasing over the study period. The livestock variables were first centred on the overall mean and scaled by the overall standard deviation. If the value of  $V$  at time  $i$  is larger (or smaller in the case of sheep) than a threshold value  $x$ ,  $V_{j,x,i}$  is equal to the difference, or 0 otherwise. This generates a series of linear splines. For example, if  $x = 0.1$  and drained clay soil is 0.2, then  $V_{\text{drainage},0.1,i} = 0.2 - 0.1 = 0.1$ , but if drainage is 0.05,  $V_{\text{drainage},0.05,i} = 0$ . The latter variable tests the hypothesis of the existence of a threshold value, as well as its contribution to malaria incidence. Its coefficient can be interpreted as the linear association between the covariate and malaria incidence beyond a certain threshold. We used the `glm.nb()` function from the MASS package (version 7.3–60) in R to run these models. The model is run for every region separately and for a range of values for  $x$  for each of the explanatory variables (from lowest to highest value over the time series range). At the lowest value, this is equivalent to assuming that the association between the covariate and  $\text{Log}(\text{incidence})$  is linear over the full range of the variable. The best-fitting model for each region and each explanatory variable was selected on the basis of Akaike information criterion (AIC). This resulted in a list of threshold values ( $x$ ), when they occur, and fit statistics for each explanatory variable and for each region. After selecting the best-fitting model, we estimated the predicted malaria cases, as well as a counterfactual scenario where the explanatory variable was set to 0, meaning that any change beyond the threshold did not impact malaria incidence. We calculated the difference between the counterfactual and real-world situation to get an idea of the attributable decline in malaria incidence.

Overall, the analysis showed a mixed result: sheep showed the least evidence of contributing to the decline of malaria, whilst there was best support for an effect of drainage on Funen and in West Jutland, cattle density on South and North Zealand and Lolland-Falster, and swine density in Aalborg. However, the strength of evidence varied between locations, and some models were close in their fit statistics. A mixture of effects could therefore not be excluded.

**TABLE 1** Results from the threshold analysis.

Medical region	Drainage		Cattle		Sheep		Swine	
	Threshold, in % (year)	AIC	Threshold, animals per km <sup>2</sup> (year)	AIC	Threshold, animals per km <sup>2</sup> (year)	AIC	Threshold, animals per km <sup>2</sup> (years)	AIC
South Zealand	0.39 (1881)	387.1	44.3 (1876)	374.7	20.4 (1886)	409.1	24.3 (1878)	377.3
Lolland-Falster	0.34 (1881)	463.0	34.4 (1873)	459.9	37.0 (1885)	491.3	17.5 (1882)	473.7
Funen	0.23 (1878)	381.3	-46.8 (1877)	397.7	35.9 (1885)	456.6	20.7 (1883)	411.5
Aalborg	0.12 (1888)	363.1	35.6 (1889)	363.0	46.2 (1877)	384.6	16.7 (1887)	358.9
Vejle	0.05 (1865)	328.7	66.4 (1881)	331.7	62.0 (1878)	343.6	24.0 (1884)	337.8
West Jutland	0.04 (1877)	346.6	27.4 (1877)	377.0	48.9 (1873–1873)	388.8	8.2 (1882)	378.0
Aarhus	0.02 (1864)	362.4	25.3 (1862)	410.9	33.8 (1890)	401.3	15.7 (1896)	417.5
North Zealand	0.01 (1862)	401.1	43.1 (1877)	388.0	21.7 (1887)	414.1	34.5 (1887)	428.6

Note: Threshold values and associated years in which they occur are shown on the basis of the best-fitting model for each of the explanatory variables and each medical region. AIC values are also given. Parameter estimates are given in table [s1](#).

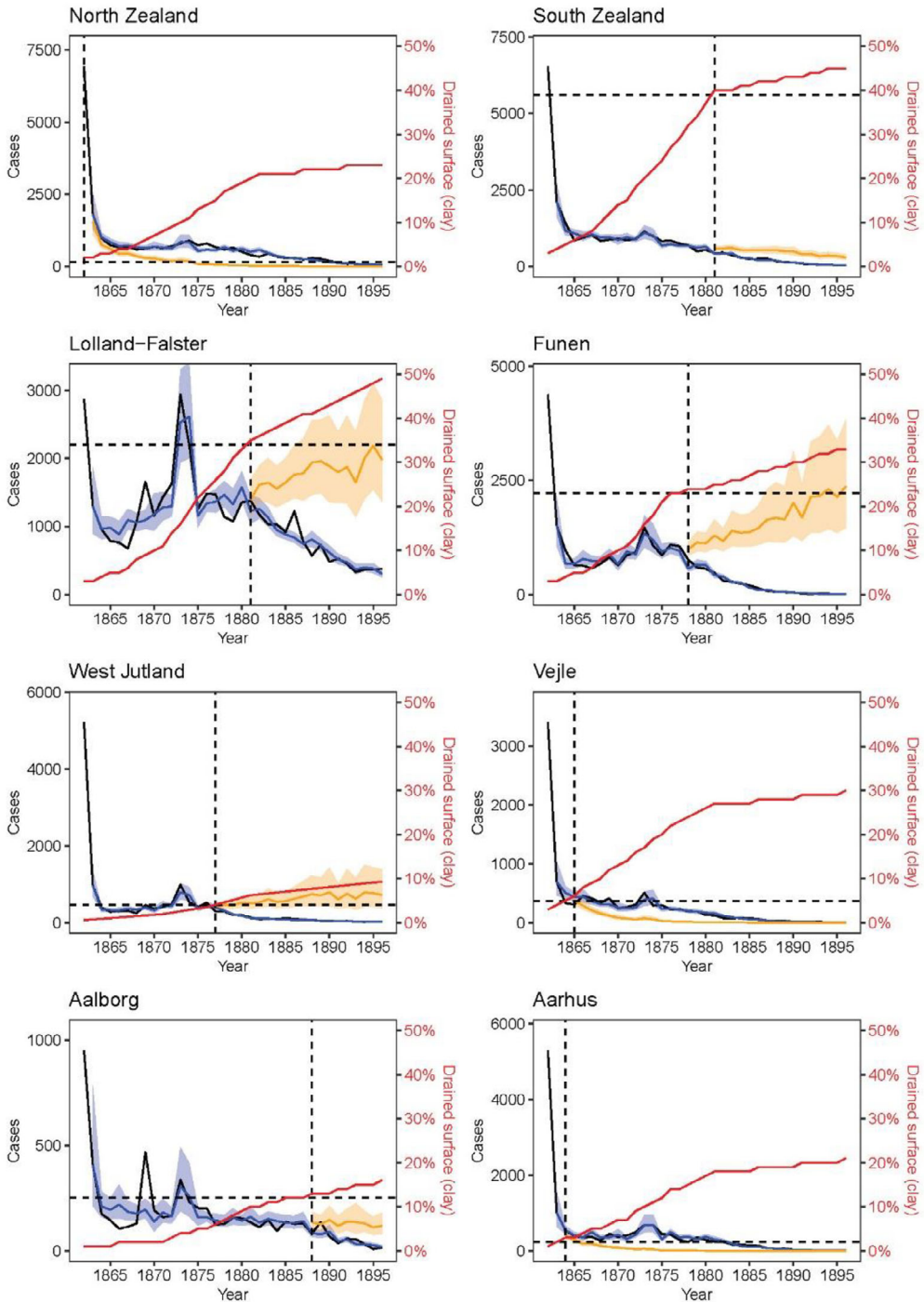
In most regions, 0–3 per cent was drained with clay pipes by 1862 (figure 3). By 1896 however, the percentage of land drained with clay pipes ranged from 9 per cent in the driest regions (West Jutland) to <40 per cent in the wettest regions (South Zealand and Lolland-Falster). Most regions experienced a linear growth in drainage until the late 1870s, after which the trend broke. This has previously been explained by a rural economic crisis,<sup>61</sup> but an alternative and appealing explanation is that most of the land suitable for draining had already been drained. The threshold analysis estimated a statistically significant change in slope associated with drainage in all medical regions in the 1870s and early 1880s, apart from North Zealand, Vejle, and Aarhus medical regions, where drainage was associated with malaria incidence already in the 1860s (table 1 and table [s1](#)). In these latter medical regions, the best fit effect estimate was positive, indicating that drainage was likely not responsible for the decline in malaria there. In Lolland-Falster and South Zealand, the threshold values for drainage were roughly similar, between 34 per cent and 39 per cent, respectively, and occurred at approximately the same time, between 1880 and 1883, respectively, whilst on Funen and in West Jutland this was estimated at 23 per cent and 4 per cent, respectively.

Like drainage, livestock densities varied considerably between the regions (figure [s1](#)). Sheep densities declined in all regions, whilst cattle and swine densities increased dramatically. In Lolland-Falster, North and South Zealand, and Funen, the number of cattle per km<sup>2</sup> rose dramatically, and South Zealand also saw a dramatic increase in the swine density during the study period. This has been explained with the rise of animal production in Denmark during the 1880s.

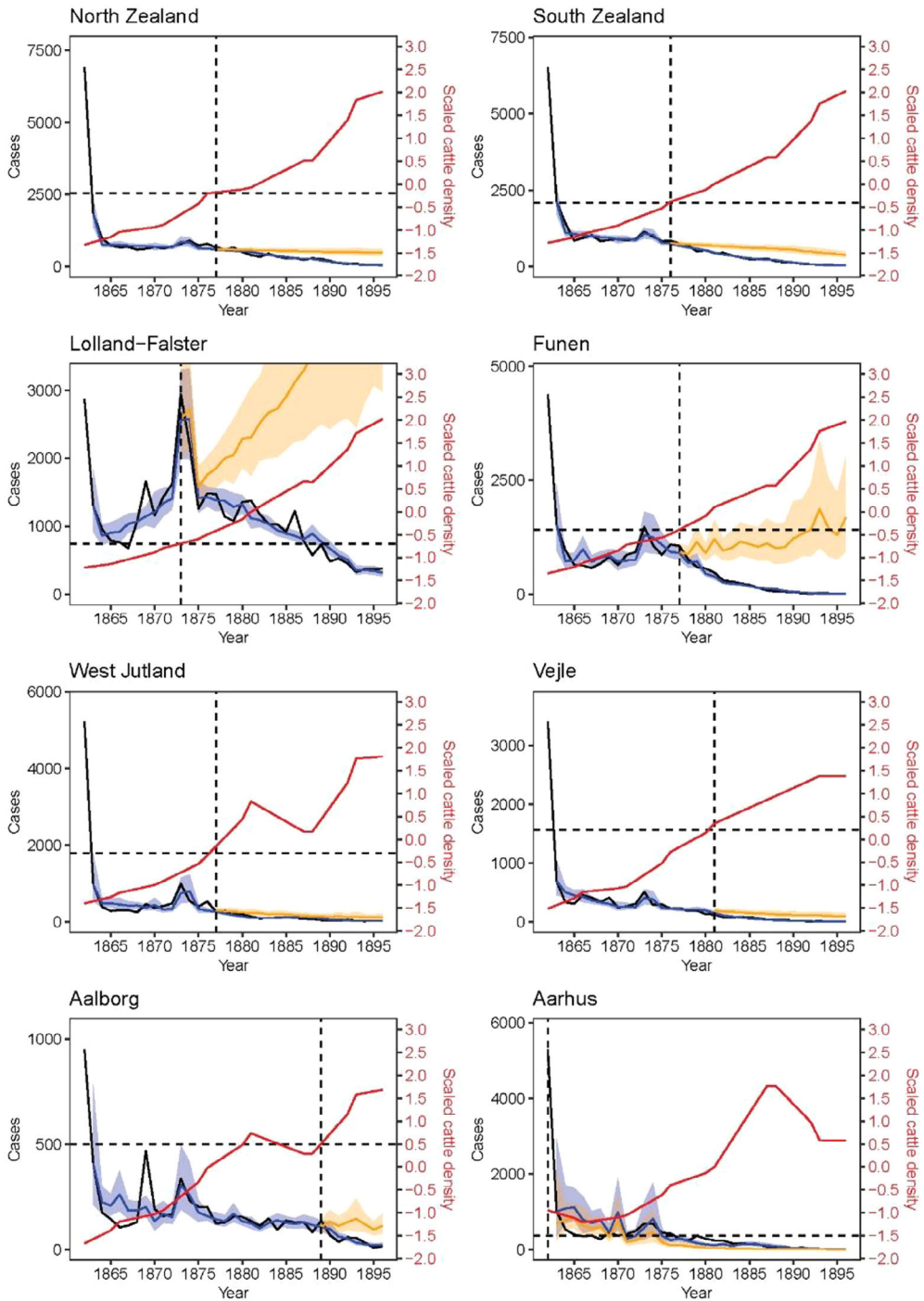
The threshold analysis showed that cattle density was the best predictor of malaria decline in Lolland-Falster, North Zealand, and South Zealand, whilst swine density performed best in Aalborg (table 1; best model fits are shown in figures 3–4 and supplementary figures 3–4). The association between livestock and malaria remains disputed in modern epidemiological studies. Whilst some argue in favour of a prophylactic relationship, others have concluded that livestock could potentially have increased the risk of malaria for those living close to the livestock.<sup>62</sup> Our analysis only showed positive parameter estimates for cattle density in Aarhus and sheep density in West Jutland (neither were the best fits), indicating that if anything, that livestock was likely

<sup>61</sup> Bjørn et al. *Det Danske Landbrugs Historie*, pp. 234.

<sup>62</sup> Hasyim et al., 'Does livestock protect'; Loha, 'Association between livestock ownership and malaria incidence'.



**FIGURE 3** Observed and predicted malaria incidence in the Danish medical regions between 1862 and 1896 along with drainage levels. Observed malaria incidence is shown in black, the model-predicted malaria incidence in blue with 95% confidence interval, the dashed lines indicate the estimated threshold level, and the red line indicates the drainage levels and their interpolation. In orange are the number of cases that would have been predicted if there had been no increase in drainage, with 95% confidence intervals.



**FIGURE 4** Observed and predicted malaria incidence in the Danish medical regions between 1862 and 1896 along with cattle density. *Notes:* Observed malaria incidence is shown in black, the model-predicted malaria incidence in blue with 95% confidence interval, the dashed lines indicate the estimated threshold level, and the red line indicates the cattle density levels and their interpolation. In orange are number of cases that would have been predicted if there had been no increase in cattle density, with 95% confidence intervals.



**TABLE 2** Attributable decline in Malaria Percentage decline attributable to each explanatory variable is shown. Model for the counterfactual is the best fit model where the explanatory variable is set to zero. Only declines are shown.

Medical region	Attributable decline in % (95% confidence interval)			
	Drainage	Cattle	Sheep	Swine
South Zealand	59.27% (57.17–61.23%)	48.73% (46.93–50.54%)	51.28% (48.02–54.06%)	52.33% (50.43–54.25%)
Lolland-Falster	59.47% (56.15–62.19%)	67.66% (64.53–70.55%)	54.23% (50.4–57.62%)	54.46% (50.91–57.9%)
Funen	87.64% (86.5–88.89%)	79.48% (77.47–81.55%)	85.59% (83.72–87.21%)	83.43% (81.4–85.39%)
Aalborg	58.26% (52.98–63.27%)	58.05% (52.05–63.8%)	23.4% (13.34–32.57%)	49.67% (44.47–54.17%)
Vejle	–	68.13% (65.01–70.72%)	73.99% (71.56–76.41%)	50.83% (46.68–54.47%)
West Jutland	83.97% (81.97–85.87%)	44.56% (39.71–49.13%)	38.08% (31.46–43.69%)	60.03% (55.38–64.4%)
Aarhus	–	–	83.82% (81.49–86.17%)	–
North Zealand	–	44.43% (42.43–46.78%)	54.09% (51.05–56.87%)	26% (20.64–31.24%)

negatively associated with malaria incidence (table s1). To what extent the mosquitoes exhibit zoophilic behaviour also depends on what animals are available. Little is known about the feeding preferences of *Anopheles* mosquitoes, but the few modern studies that have been conducted found that *A. maculipennis* mosquitoes prefer to feed on swine and sheep over cattle.<sup>63</sup> Although none of the regions showed a good fit for the decline in sheep density, in Aalborg, the best-fitting model was for swine density. The increase in the number of swine there suggests that they could have acted prophylactic against mosquitoes. Our analysis did show negative and statistically significant associations with swine density in all regions except Aarhus, where no good model could be fitted.

We also estimated how much of the decline in malaria was attributable to drainage and cattle, sheep, and swine density in a counterfactual scenario, where these variables played no role (table 2 and orange areas in figures 3–4 and figures s3–s4). These results generally mirror the main analysis, and the attribution estimated for the various variables were rather similar within regions. The main outlier was in West Jutland, where we estimated an attributable proportion of 84 per cent (82–86 per cent) for drainage, compared with 45 per cent, 38 per cent, and 60 per cent for cattle, sheep, and swine, respectively (note that drainage was also the best-fitting model for West Jutland).

Lastly, average summer temperature and precipitation were not statistically significantly associated with the decline in malaria ( $p$ -values > 0.01; see table 1). The finding of malaria not being associated with temperature and precipitation has also been reproduced in both England and Finland.<sup>64</sup>

The disappearance of malaria may have been driven by agricultural improvements with differences in timing and intensity. The fact that not one single variable explained the disappearance across all regions illustrates the complexity. Comparing the model fits and coefficients across explanatory variables, only Funen and West Jutland showed the best performance for drainage, whilst North and South Zealand and Lolland-Falster had the best fit with cattle density, and Aalborg with swine density. These regional differences cannot be explained with some regions, for example, being more intensely drained than others – South Zealand had both intensive drainage,

<sup>63</sup> Sousa, *Malaria vectorial capacity*, p. 114; Danabalan et al., ‘Occurrence and host preferences of *Anopheles maculipennis*’, p. 176; Puente et al., ‘Effect of blood meal digestion’.

<sup>64</sup> Hulden and Hulden, ‘The decline of malaria in Finland’; Kuhn et al., ‘Malaria in Britain’.



high livestock density, and a high malaria burden. The historical geographer [Stenak](#) has argued that the technologies used for drainage in the nineteenth century – clay pipes, steam pumps, and windmills for pumping away water – were not sufficient to dry out wetlands. Instead of being turned into arable soil, they were often left as bog or pasture in the nineteenth century.<sup>65</sup> Our analysis is limited by its geographical scale. As already mentioned, low-lying settlements in some low-incidence regions did indeed experience outbreaks of malaria, and due to the absence of parish-level malaria statistics, we were not able to assess the impact of drainage on the malaria burden at local scale.

There are likely additional factors that we did not test. As already noted, housing materials improved, and even though physicians still noted a large presence of humid and dark houses,<sup>66</sup> the gradual transition away from clay tiled houses may still have improved the indoor conditions. Changes in sleeping habits could also have played an important additional role. In the second half of the nineteenth century, curtains around beds became common in Danish farmhouses. These curtains shielded the sleeping person from insects and mice during the night,<sup>67</sup> and could also have prevented mosquito bites. People started sleeping clothed instead of naked, which offered them additional protection against mosquitoes.<sup>68</sup> From the 1880s, health insurances became increasingly common in Denmark, but as already discussed, this may not have played a large role before the Health Insurance Law of 1892.

The disappearance of malaria from Denmark is best explained by a combination of regional factors, and drainage and changes in husbandry practices may have played a simultaneous role in its disappearance. We could not study the likely effect of other societal changes, such as housing and changing sleeping habits, however, these developments may also have contributed locally. The disappearance of malaria thus appears to have been related to the agricultural developments in the modernization of rural Denmark.

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## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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<sup>65</sup> [Stenak](#), *De inddæmmede landskaber*, pp. 227–33.

<sup>66</sup> Det kongelige Sundhedskollegiums Aarsberetning for Aaret 1864, 417–8; Det kongelige Sundhedskollegiums Aarsberetning for Aaret 1865, 357; Det kongelige Sundhedskollegiums Aarsberetning for Aaret 1870, 540; [Hansen](#), *Epidemiologiske Undersøgelser*, p. 30.

<sup>67</sup> [Venborg Pedersen](#), *I søvnens favn*, pp. 81–2.

<sup>68</sup> [Andersen](#), *Danske bønders klædedragt*, pp. 108–28, 257–70.

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**REFERENCES**

- Andersen, E., *Danske bønders klædedragt* (Copenhagen, 1960).
- Bjørn, C, Dahlerup, T., Jensen, S.P., and Pedersen, E., eds., *Det Danske Landbrugs Historie*, (Odense, 1988) 3, pp. 1810–1914.
- Boberg-Fazlic, N., Lampe, M., Lasheras, P.M., and Sharp, P., ‘Winners and losers from agrarian reform: Evidence from Danish land inequality 1682–1895’, *Journal of Development Economics*, 155 (2022), pp. 1–20.
- Breuning-Madsen, H., ‘Drænrørets indførelse og betydning i et landbrugs- og miljømæssigt perspektiv’, in M.A. Nielsen, ed., *Det fremmede som historisk drivkraft: Danmark efter 1742: et festskrift til Hendes Majestæt Dronning Margrethe II ved 70-års fødselsdagen den 16. april 2010* (Copenhagen, 2010), pp. 158–165.
- Bruce-Chwatt, L. and de Zulueta, J., *The rise and fall of malaria in Europe* (New York, 1980).
- Buonanno, P., Esposito, E., and Gulino, G., ‘Social adaptation to diseases and inequality: historical evidence from malaria in Italy’, no. 1755. Economics Working Paper Series (Barcelona 2020).
- Cappelen, J., ‘DMI Report 19-02 Denmark—DMI Historical Climate Data Collection Colophon’, (2019), pp. 1–112.
- Chen, T.T., Charpentier Ljungqvist, F., Castenbrandt, H., Hildebrandt, F., Ingholt, M.M., Hesson, J., Ankarklev, J., Seftigen, K., and Linderholm, H.W., ‘The spatiotemporal distribution of historical malaria cases in Sweden: a climatic perspective’, *Malaria Journal*, 20 (1), 2021, pp. 1–14.
- Danabalan, R., Monaghan, M.T., Ponsonby, D.J., Linton, Y.-M., ‘Occurrence and host preferences of *Anopheles maculipennis* group mosquitoes in England and Wales’, *Medical and Veterinary Entomology* 28 (2014) pp. 169–178.
- Dobson, M., *Contours of death and disease in early modern* (Cambridge, 1997).
- Feldbæk, O., Løkke, A., and Jeppesen, S.L., *Drømmen om tryghed. Tusind års dansk forsikring* (Copenhagen, 2007).
- Hackett, L., *Malaria in Europe. An ecological study* (1937).
- Hackett, L., and Missiroli, A., ‘Housing as a factor in malaria control,’ *Transactions of Royal Society of Tropical Medicine and Hygiene*, 26 (June 1932), pp. 65–72.
- Hansen, C.A., *Epidemiologiske Undersøgelser angaaende Koldfeberen i Danmark paa Grundlag af det kgl. Sundhedskollegiums Medicinalberetninger* (Copenhagen, 1886).
- Hansen, C. A., ‘Den “lollandske Feber”,’ *Lolland-Falsters Historiske Samfunds Aarbog* (1913), pp. 45–65.
- Hasyim, H., Dhimal, M., Bauer, J., Montag, D., Groneberg, D., Kuch, U., and Müller, R., ‘Does livestock protect from malaria or facilitate malaria prevalence? A cross-sectional study in endemic rural areas of Indonesia’, *Malaria Journal*, 17, 1, (2018), pp. 1–11.
- Horstmann, P., ‘Malariens forsvinden fra Danmark’, *Bibliotek for Læger* (March 1986), pp. 69–101.
- Hulden, L., and Hulden, L., ‘The decline of malaria in Finland—The impact of the vector and social variables’, *Malaria Journal*, 8, 1, (2009), pp. 1–9.
- Ingholt, M. M., ‘An ordinary malaria? Intermittent fever in Denmark, 1826–1886’, *Medical History* 67, 1, (2023), pp. 57–73.
- Ingholt, M.M., Chen, T.T., Hildebrandt, F., Pedersen, R.K., and Simonsen, L., ‘Temperate climate malaria in nineteenth century Denmark’, *BMC Infectious Diseases*, 22, 432, (2022), pp. 1–11.
- James, S.P., ‘The disappearance of malaria from England,’ *Journal of Royal Society of Medicine* 23, 1, (1929), pp. 71–87.
- Jetten, T.H., and Takken, W., *Anophelism without Malaria in Europe: A Review of the Ecology and Distribution of the Genus Anopheles in Europe*, Wageningen Agricultural University Papers. Vol. 94–5, (1994).
- Kuhn, K. G., Campbell-Lendrum, D. H., Armstrong, B., and Davies, C. R., ‘Malaria in Britain: Past, present, and future’, *Proceedings of National Academy of Sciences of United States of America* 100, 17, (2003), pp. 9997–10001.
- Lains, P. and Pinilla, V., *Agriculture and economic development in Europe since 1870* (2009).
- Lampe, M. and Sharp, P., *A land of milk and butter. How elites created the modern Danish dairy industry* (Chicago, 2019).
- Loha, E., ‘Association between livestock ownership and malaria incidence in south-central Ethiopia: a cohort study’, *American Journal of Tropical Medicine and Hygiene* 108, 6, (2023) pp. 1145–1150.
- Løkke, A. ‘State and insurance. The long-term trends in Danish health policy from 1672 to 1973’, *Hygiea Internationalis: an interdisciplinary journal for history of public health*, 6,1 (2007) pp. 7–24.



- Manniche, J.C., 'En dansk malariaepidemi?,' *Dansk medicinhistorisk årbog* (1997), pp. 171–205
- Nicholls, A., 'Fenland ague in the nineteenth century,' *Medical History* 44, 4, (2000), pp. 513–30.
- Nuttall, G., Cobbett, L., and Strangeways-Pigg, T., 'Studies in relation to malaria. I. The geographical distribution of anopheles in relation to the former distribution of ague in England,' *Journal of Hygiene* 1, 1, (1901), pp. 4–44.
- Nyland, N., *De praktiserende læger i Danmark 1800–1910* (Odense, 2000).
- Packard, R., *The Making of a Tropical Disease* (Baltimore, 2007).
- Patz, J.A., Strzepek, K., Lele, S., Hedden, M., Greene, S., Noden, B., Hay, S.I., Kalkstein, L., and Beier, J.C., 'Predicting key malaria transmission factors, biting and entomological inoculation rates, using modelled soil moisture in Kenya,' *Tropical Medicine and International Health* 3, 10, (1998), pp. 818–27.
- Petersen, E., Severini, C., and Picot, S., 'Plasmodium vivax malaria: A re-emerging threat for temperate climate zones?,' *Travel Medicine and Infectious Disease*, 11, 1, (2013), pp. 51–59.
- Porter, D., *Health, civilization and the state. A history of public health from ancient to modern times* (New York, 1999).
- Puente J.M., Ruiz, S., Soriguier, R., and Figuerola, J., 'Effect of blood meal digestion and DNA extraction protocol on the success of blood meal source determination in the malaria vector *Anopheles atroparvus*,' *Malaria Journal* 12, 109 (2013), pp. 1–6.
- Ramsdale, C. D., and Wilkes, T.J., 'Some aspects of overwintering in Southern England of the mosquitoes *Anopheles atroparvus* and *Culiseta Annulata* (Diptera: Culicidae),' *Ecological Entomology* 10, 4, (1985), pp. 449–54.
- Rothenbacher, F., *The European Population, 1850–1945* (New York, 2002).
- Sousa, C.A. *Malaria vectorial capacity and competence of Anopheles atroparvus Van Thiel, 1927 (Diptera, Culicidae): Implications for the potential re-emergence of malaria in Portugal* (Lisbon 2008)
- Stenak, M., *De inddæmmede landskaber* (Odense, 2005).
- Swellengrebel, N., and de Buck, A., *Malaria in The Netherlands* (Amsterdam, 1938).
- Swellengrebel, N., de Buck, A., and Kraan, H., 'Mechanism of malaria transmission in the province of north Holland,' *Journal of Hygiene* 38, 1, (1938), pp. 62–74.
- Thonning Olesen, P., 'Omlægningen fra vegetabilsk til animalsk produktion i dansk landbrug efter ca. 1850,' *Bol og By* 2,1, (1977) pp. 11–36.
- Uldall, F., 'Bemærkninger om Stiftslæge Dr. med. Mouriers Forslag til Medicinalberetningernes Forbedring,' *Ugeskrift for Læger*, 2, 12, (1859), pp. 177–186.
- Venborg Pedersen, M., *I søvnens favn: om søvn og sovevaner på landet 1600–1850* (København, 2009).
- Wesenberg-Lund, C., *Contributions to the Biology of the Danish Culicidae*, (Det Kgl. Danske Videnskabernes Selskabs Skrifter, *Naturvidenskab og Mathematisk Afd.* 8, Række VII, 1, 1921), pp. 157–95.
- White, N.J., 'The rise and fall of long-latency plasmodium vivax,' *Transactions of Royal Society of Tropical Medicine and Hygiene* 113, 4, (2019), pp. 163–68.
- Zhao, X., Smith, D.L., and Tatem, A.J., 'Exploring the spatiotemporal drivers of Malaria elimination in Europe,' *Malaria Journal* 15, 1, (2016), pp. 1–13.

## OFFICIAL PUBLICATIONS

- Det statistiske Bureau, Statistisk Tabelværk, 3. Række, 5. Bind.
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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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