

# Pest og klima: Skal vi forstå pest blant mennesker, må vi forstå hvordan pest utspiller seg i naturen

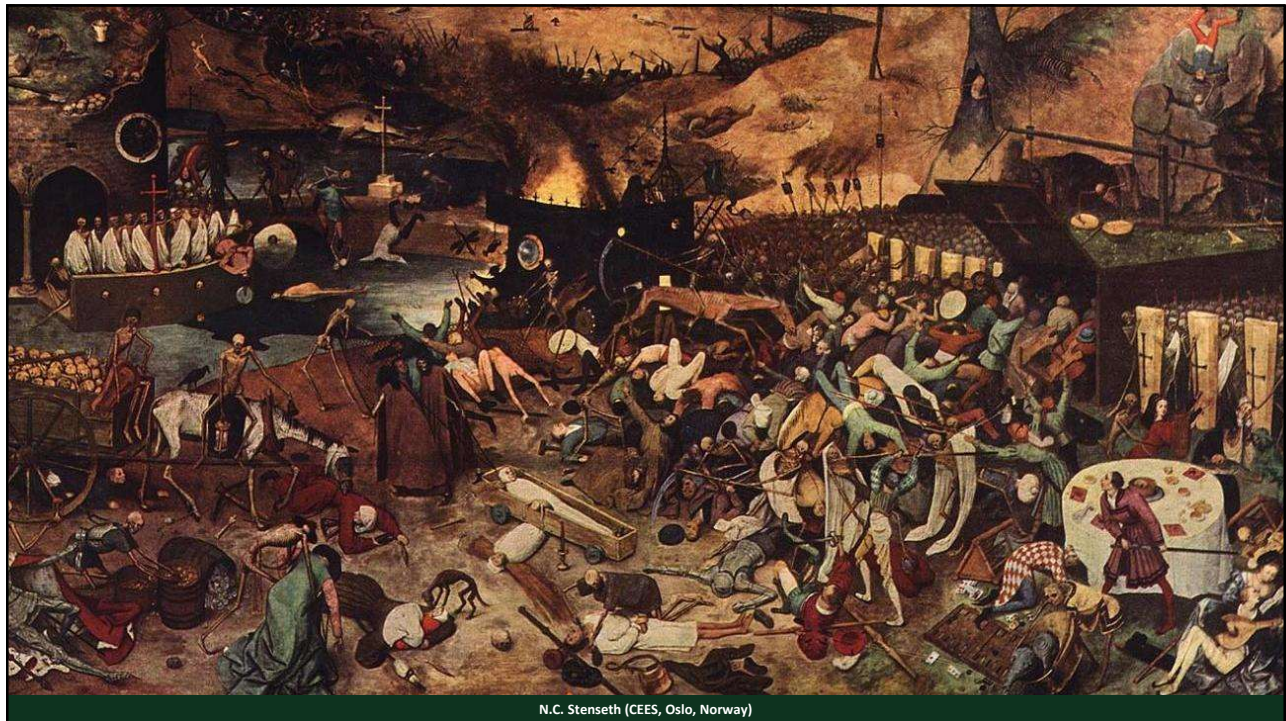
**Nils Chr. Stenseth**

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Founding and Past Chair of CEES - Centre for Ecological and Evolutionary Synthesis (CEES; [www.cees.uio.no](http://www.cees.uio.no)) at the Faculty of Mathematics and Natural Sciences,  
University of Oslo, Norway  
Deputy Chair of The Centre for Pandemics and One Health Research at the Faculty of Medicine, University of Oslo, Norway

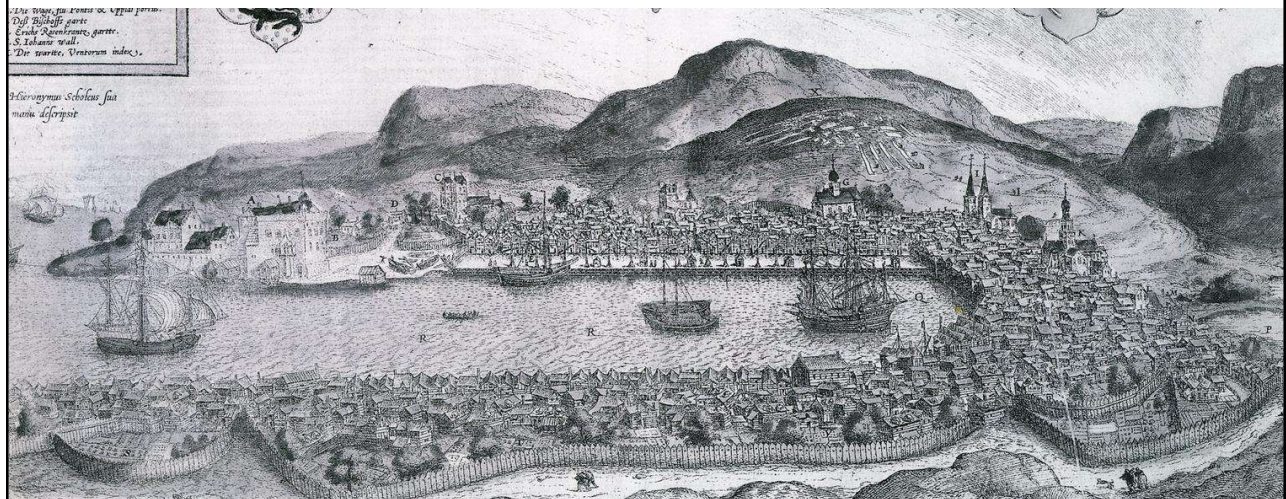
Digitalt frokost-møte i regi av CIENS.  
22.03.23 – 08:30-10:00



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## Bergen early summer 1349



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**... with a rat carrying fleas infected with plague ...**

**... after which it might have spread through the country with people and body lice and body fleas ...**

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## **Trondheim/Nidaros 1349**

**The Archbishop in Nidaros, Arne Einarsson Vade, died from plague on September 23 1349**

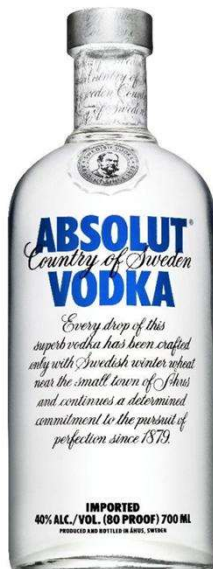


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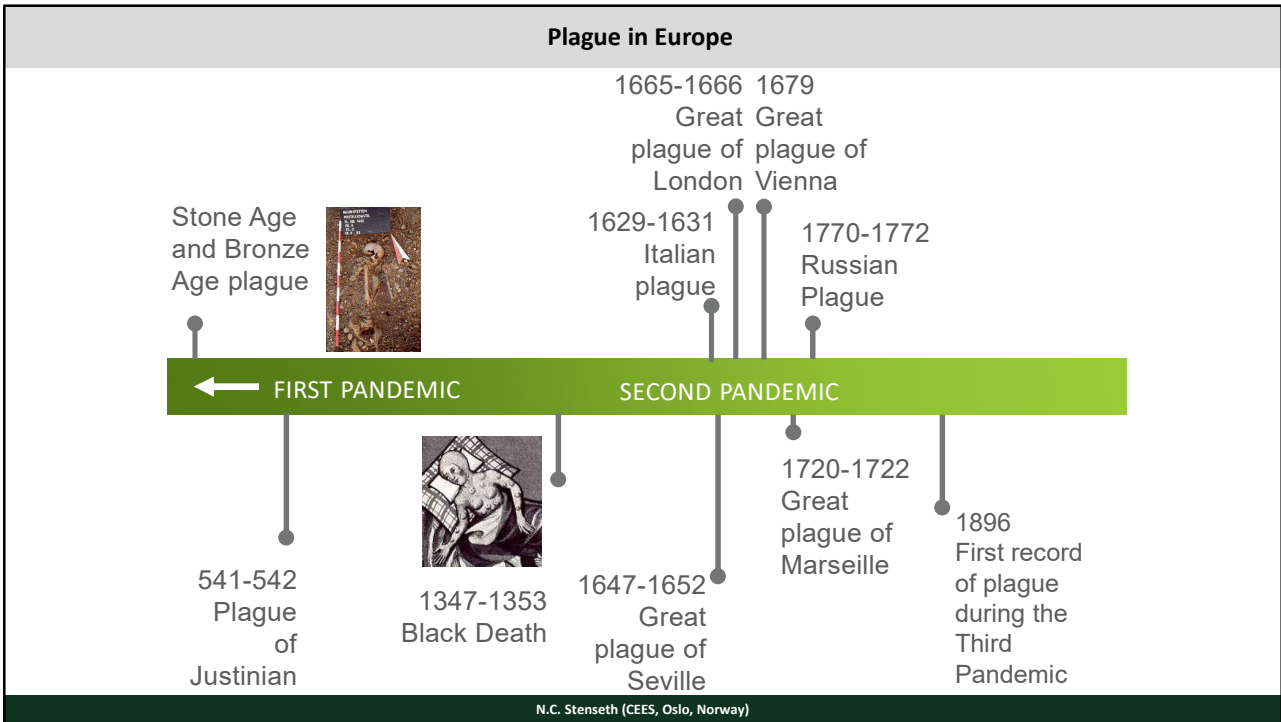
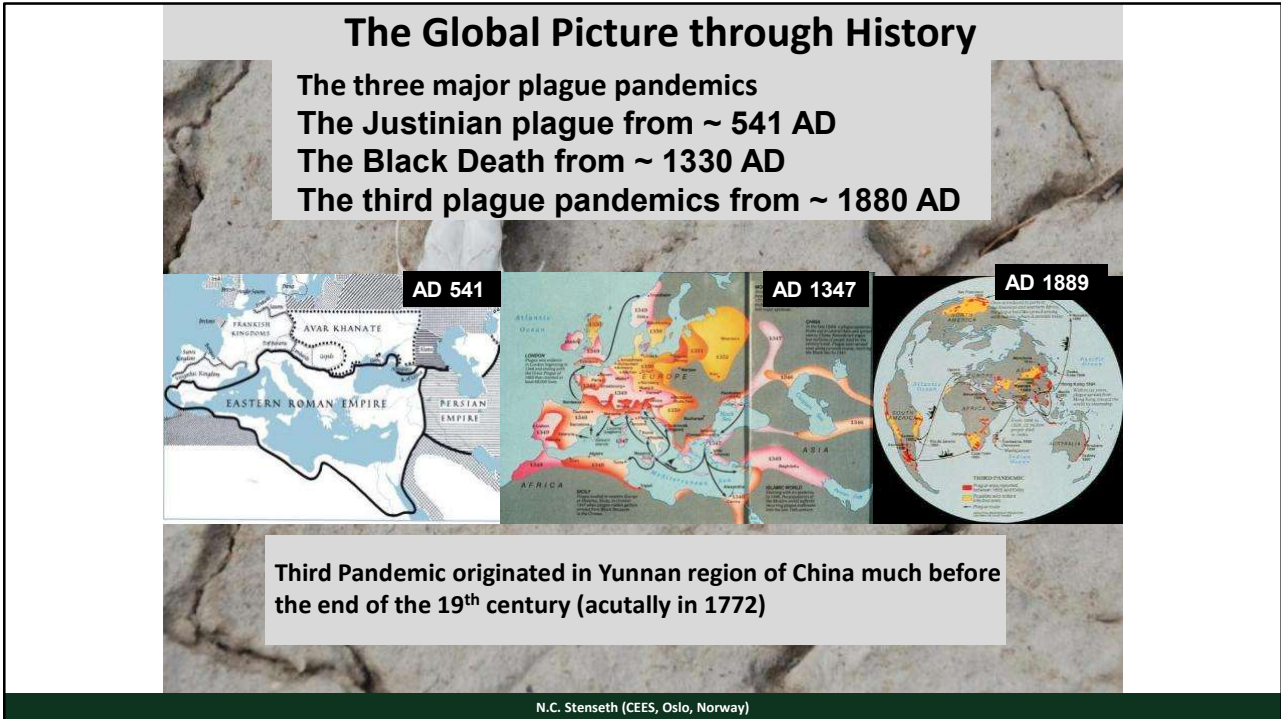
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## Negotiations



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**Today – not in Europe**

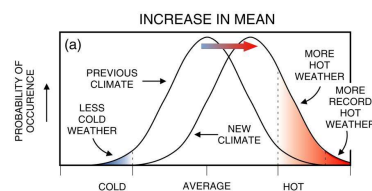


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**Outbreak of plague after a couple of years with warm (but not too hot) and humid (but not too wet) over a large area of steppes**  
**Spillover to the human population (directly or indirectly) following droughts over large areas of steppes**

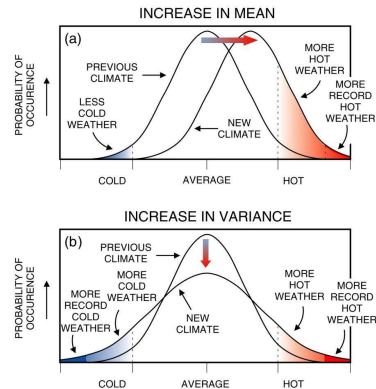
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**Climate change  
and its manifestation  
in terms of weather  
(climate extremes)**

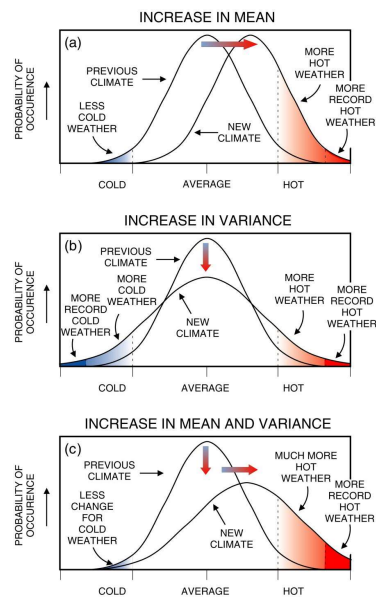
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## Climate change and its manifestation in terms of weather (climate extremes)



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## **A common claim**

N.C. Stenseth (CEES, Oslo, Norway)

### **A common claim:**

**“There must have been a wildlife-based plague reservoir in Europe (during the medieval period)”**

**BUT: Boris V. Schmid *et al.* (in *PNAS* 2015) questioned that claim “Climate-driven introduction of the Black Death and successive plague reintroductions into Europe”**

**This has later been supported by aDNA studies by the Barbara Bramanti team in Oslo**

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## Hard Tissues (Bones and Teeth)



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erc  
European Research Council  
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Supporting top researchers  
from anywhere in the world

The medieval plagues: ecology, transmission modalities and routes of the infections.



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# Plague came to Europe several times during the Medieval period



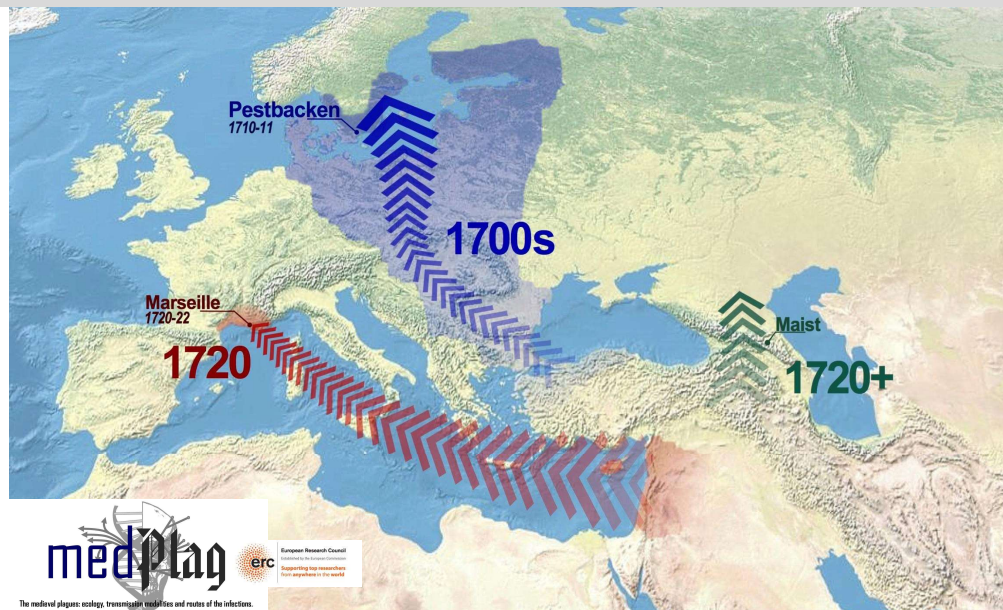
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**Two contrasting hypotheses:**

**Either the plague bacterium survived several hundred years in Europe (Hypothesis #1) or the plague bacterium was repeatedly re-introduced (Hypothesis #2)**

**Barbara Bramanti *et al.* (in *PNAS* 2021) reviewed available evidence and found Hypothesis #1 the least likely one**

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## No evidence for persistent natural plague reservoirs in historical and modern Europe

Nils Chr. Stenseth<sup>a,b,1,2</sup>, Yuxin Tao<sup>c,1</sup>, Chutian Zhang<sup>d,e,1</sup>, Barbara Bramanti<sup>a,f</sup>, Ulf Büntgen<sup>g,h,i,j</sup>, Xianbin Cong<sup>k</sup>, Yujun Cui<sup>l</sup>, Hu Zhou<sup>m</sup>, Lorna A. Dawson<sup>n</sup>, Sacha J. Mooney<sup>o</sup>, Dong Li<sup>c</sup>, Henry G. Fell<sup>p</sup>, Samuel Cohn<sup>q</sup>, Florent Sebbane<sup>r</sup>, Philip Slavin<sup>s</sup>, Wannian Liang<sup>d,e</sup>, Howell Tong<sup>t,1</sup>, Ruifu Yang<sup>u,2</sup>, and Lei Xu<sup>d,e,2</sup>

Contributed by Nils Stenseth; received June 8, 2022; accepted October 7, 2022; reviewed by Barbel Finkenstadt, Paul Slack, and David M. Wagner

Caused by *Yersinia pestis*, plague ravaged the world through three known pandemics: the First or the Justinianic (6th–8th century); the Second (beginning with the Black Death during c.1338–1353 and lasting until the 19th century); and the Third (which became global in 1894). It is debatable whether *Y. pestis* persisted in European wildlife reservoirs or was repeatedly introduced from outside Europe (as covered by European Union and the British Isles). Here, we analyze environmental data (soil characteristics and climate) from active Chinese plague reservoirs to assess whether such environmental conditions in Europe had ever supported “natural plague reservoirs”. We have used new statistical methods which are validated through predicting the presence of modern plague reservoirs in the western United States. We find no support for persistent natural plague reservoirs in either historical or modern Europe. Two factors make Europe unfavorable for long-term plague reservoirs: 1) Soil texture and biochemistry and 2) low rodent diversity. By

### Significance

Plague killed millions of people during the three pandemics in the past two millennia. Despite much research, it remains unclear whether persistent natural plague reservoirs existed in Europe. To examine this question, we have developed a statistical model based on high-resolution and

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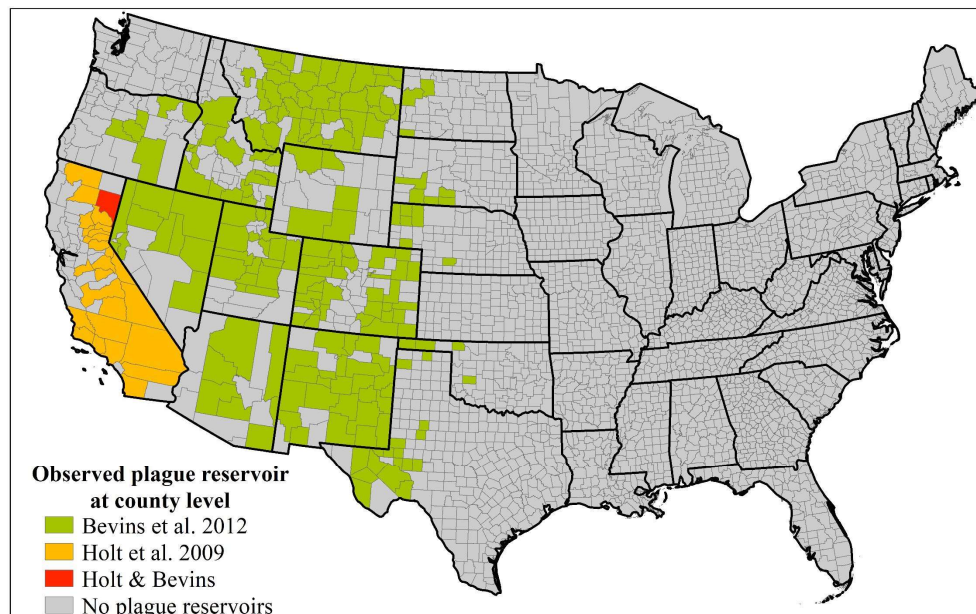
## The basic idea of this PNAS paper

N.C. Stenseth (CEES, Oslo, Norway)

**The basic idea of this PNAS paper is:**

- 1. Develop a statistical model describing the environmental conditions for the existence of persistent rodent-based plague reservoirs using active plague reservoirs in China**
- 2. The soil chemicals were in focus**
- 3. Tested (or validated) this Chinese-based model against US data**

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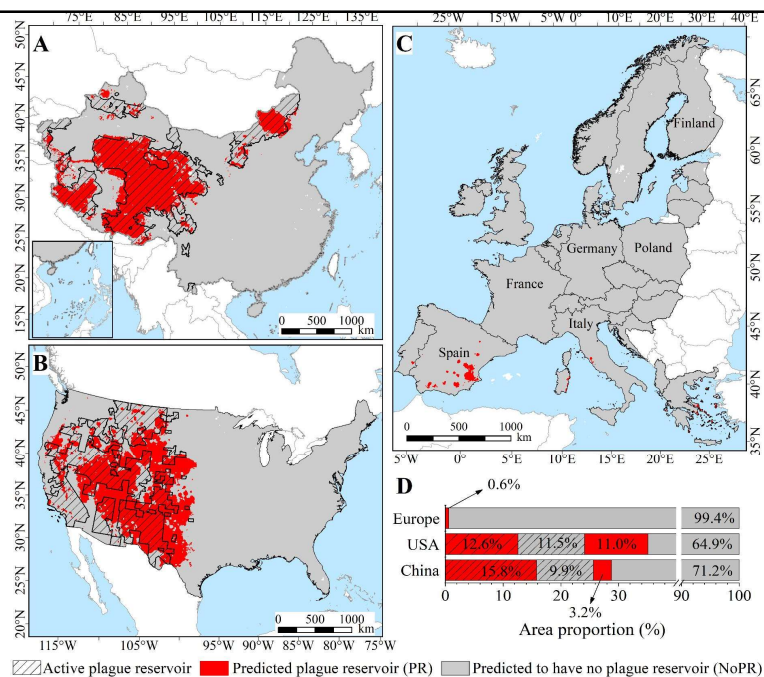


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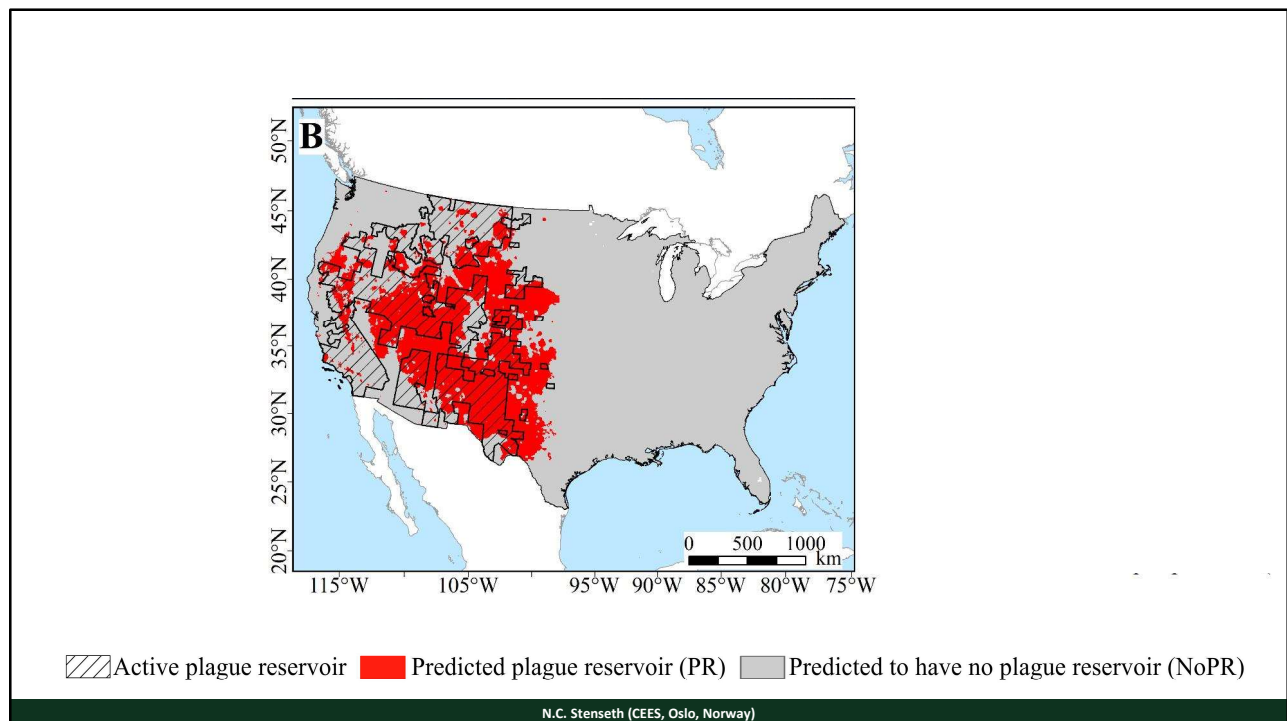
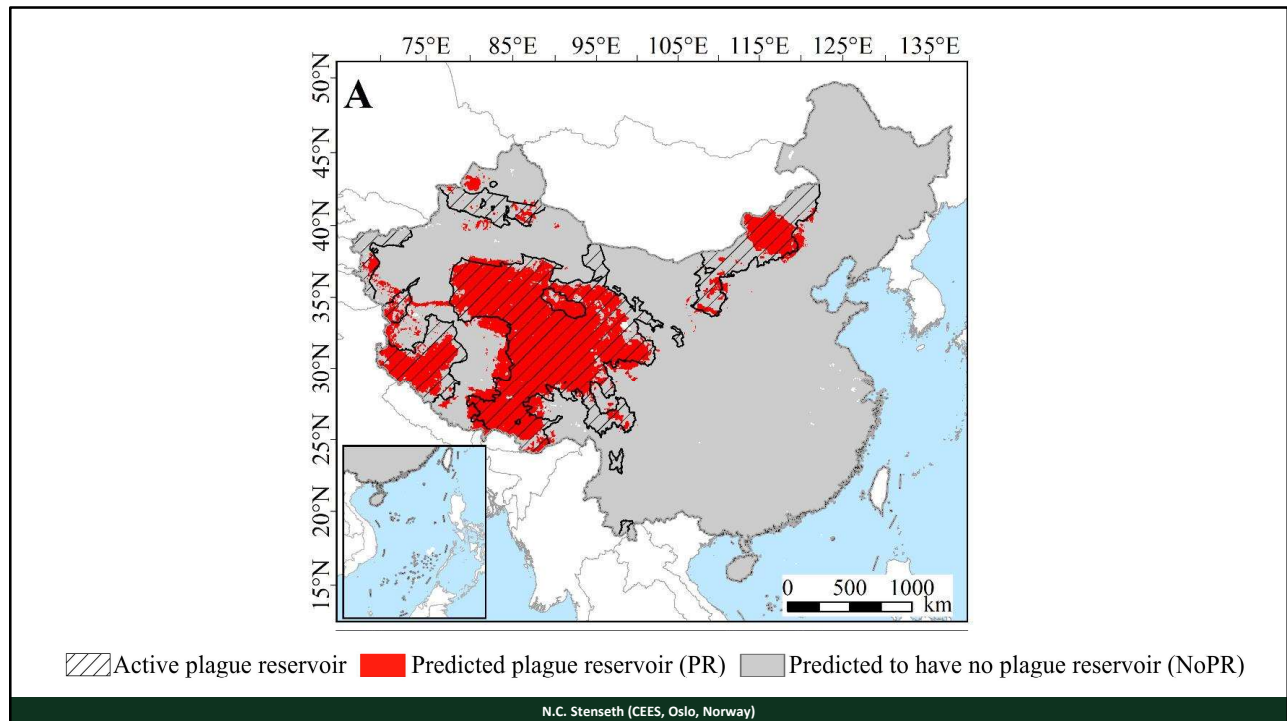
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1. Develop a statistical model describing the environmental conditions for the existence of persistent rodent-based plague reservoirs using active plague reservoirs in China
2. The soil chemicals were in focus
3. Tested (or validated) this Chinese-based model against US data
4. Used this model to ask whether there ever has been persistent rodent-based plague reservoirs in Europe

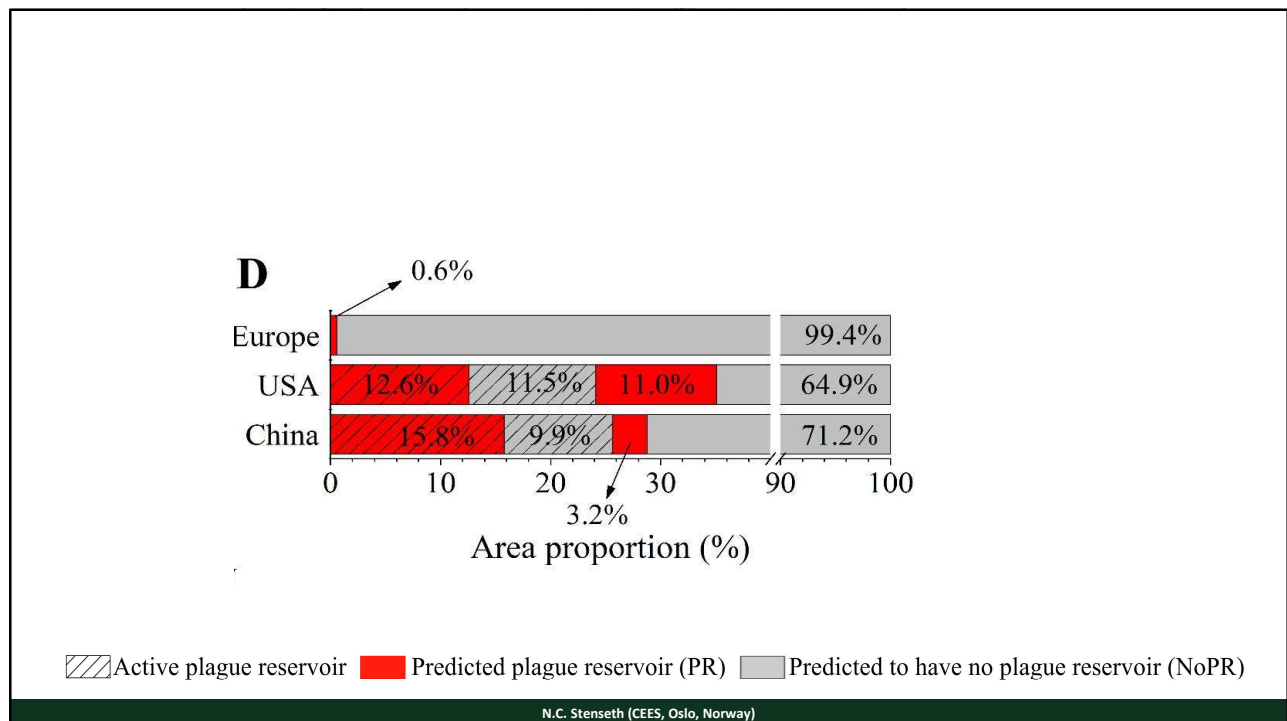
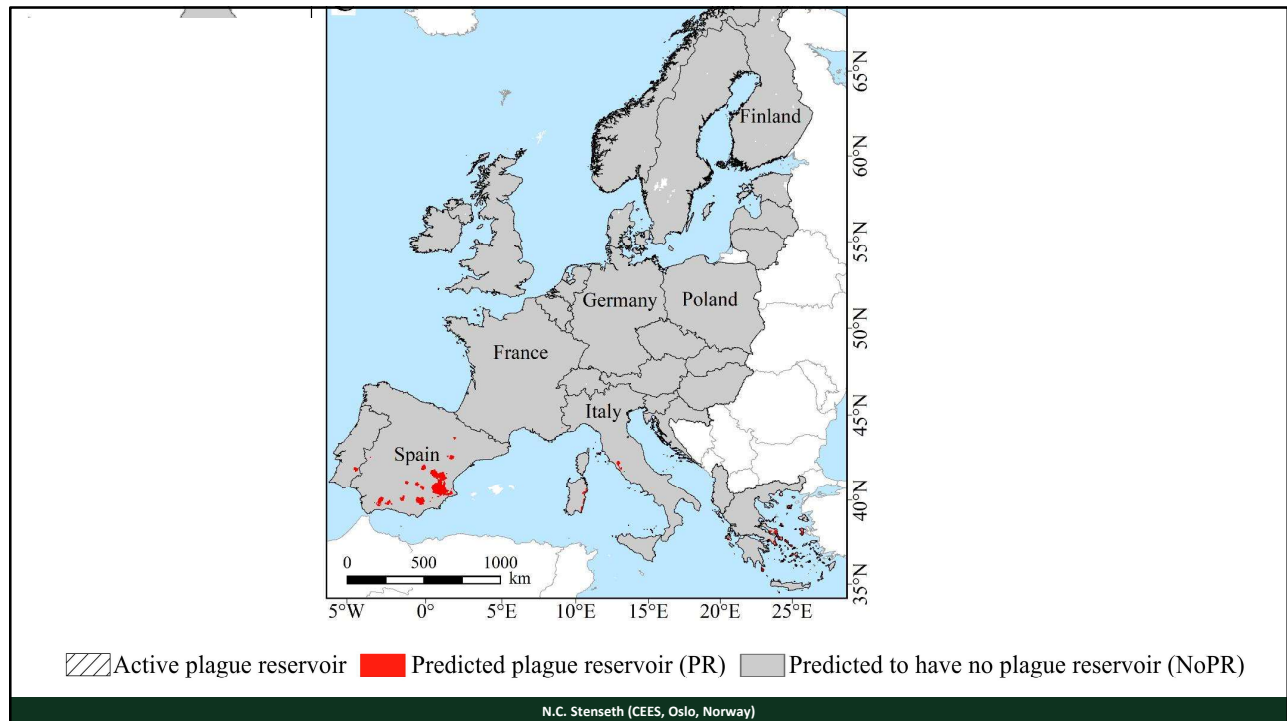
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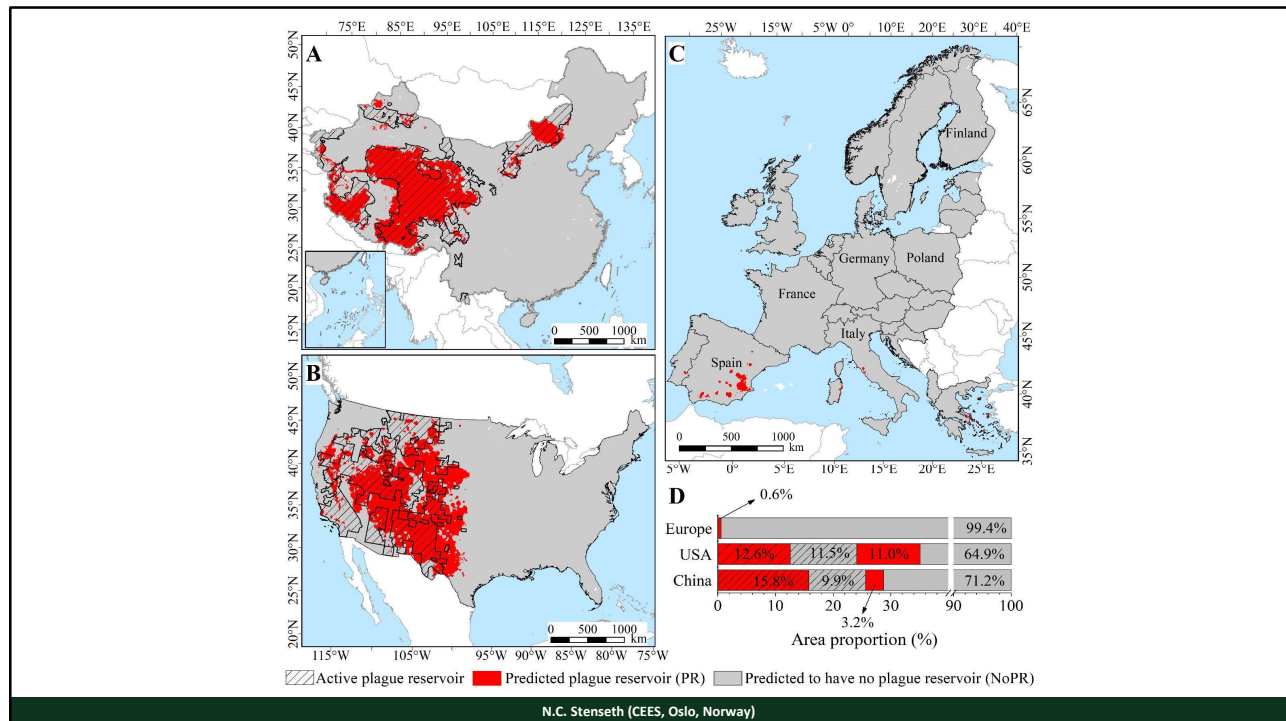


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Pandemic	Period	Place	Sources
First	660-749	Iberian Peninsula	(18)
Second	1349-c.1400	South-Central Germany	(13, 14)
Second	c.1460-1640	Central Europe	(13)
Second	1348 - 16th century	Southern Alps* & Pyrenees	(15)
Second	16 <sup>th</sup> -19 <sup>th</sup> centuries	The Balkans	(19)
Second	1348-c.1500	Temperate climate zone of Europe, including East Anglia (UK)	(16)
Third	1906-1918	East Suffolk (UK)**	(16, 20)

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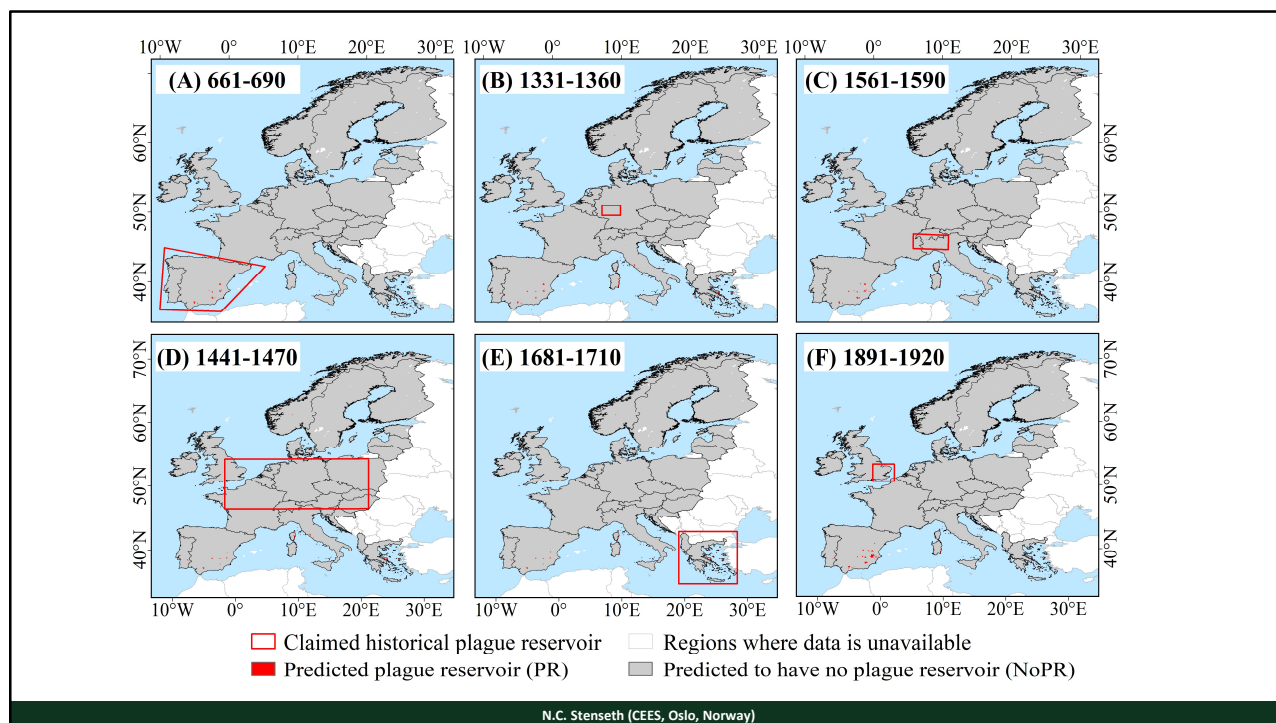


Table 1. Main differences between the two competing hypotheses proposed to explain the phylogeny of *Y. pestis* of the second plague pandemic; genomic and evolutionary, historical and archaeological, and ecological arguments are considered

	Hypothesis 1	Hypothesis 2
Main differences		
Origin of the outbreaks	Plague established in Western European reservoirs (for example, marmots in the Alps) (3, 4, 8)	Plague was repeatedly imported from Eastern European or Asian reservoirs (6, 7, 9, 11, 13)
Transmission	Mediated by rats infected by wild rodents, as in China during the Third Pandemic (3)	Imported by rats, humans, and goods and subsequently spread by chains of human transmission, as in Europe during the Third Pandemic (17, 22)
Vector	<i>Xenopsylla cheopis</i> and other rodent fleas	Any ectoparasite, including <i>Pulex irritans</i> , and body lice (14, 30)

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Supporting information		
Population genomics	Western European strains (the Alpine clade) are basal in the subbranch (although of different eras). A model proposes Western European strains as ancestral sources for the transmissions (SI Appendix, Fig. S1)	The oldest (LAI009) and the most recent strains, in addition to Bolgar, are all from Eastern Europe (Russia) as well as all the strains of the 18th century; the majority of the Western European strains in the phylogeny come from ports
History and archaeology	A hypothesis (16) suggests that the plagues from the 16th century in the Alps were not imported by major trade centers	Multiple historical records assert that plague was imported for outbreaks associated with the Black Death strains (partially reviewed in refs. 6, 7, 11, 13) for BRA (4), SPN (in the Alps), PEB10 (7), and OBS (5). Multiple records of importation are historically attested (18), particularly in harbors
Climate	No climatic signal in support, although four datasets of climatic proxies were from the Alps (13)	Strong signals of climate-driven introductions of plague from Asia (13)
Evolution	<i>Y. pestis</i> developed in Western European reservoir strains <i>pla+/pla-</i> and Delta49kb, possibly as a form of adaptation to the local host (rodents)	<i>Y. pestis</i> developed <i>pla+/pla-</i> and Delta49kb strains possibly as a form of adaptation to the new host (humans) and/or new vectors (fleas or body lice)

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## No evidence for persistent natural plague reservoirs in historical and modern Europe

Nils Chr. Stenseth<sup>1,2</sup>, Yuxin Tao<sup>1</sup>, Chutian Zhang<sup>1,2</sup>, Barbara Bramanti<sup>3,4</sup>, Ulf Büntgen<sup>5,6,7</sup>, Xianbin Cong<sup>8</sup>, Yujun Cui<sup>9</sup>, Hu Zhou<sup>10</sup>, Lorna A. Dawson<sup>11</sup>, Sacha J. Mooney<sup>12</sup>, Dong Li<sup>13</sup>, Henry G. Fell<sup>14</sup>, Samuel Cohn<sup>15</sup>, Florent Sebbane<sup>16</sup>, Philip Slavini<sup>17</sup>, Wannian Liang<sup>18</sup>, Howell Tong<sup>19</sup>, Ruifu Yang<sup>2</sup>, and Lei Xu<sup>2,4,20</sup>

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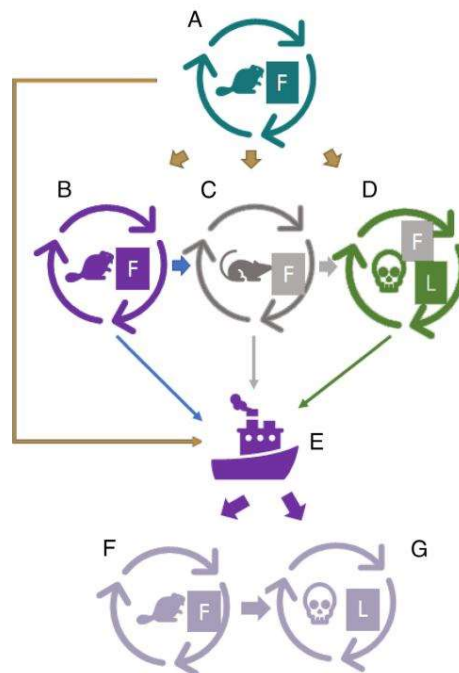
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**Indeed there is no evidence for persistent natural plague reservoirs in  
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**There is no evidence for persistent natural plague reservoirs in neither historical nor modern Europe**

**This remains a hypothesis**

**Hopefully to be tested within and ERC Synergy project**

**Reconstructing the environmental, biological, and societal drivers of plague outbreaks in Eurasia between 1300 and 1900 CE**

**cPI:** Prof. Nils Chr. Stenseth

**cHI:** University of Oslo, Norway – epidemiology and plague ecology

**PI:** Prof. Philip Slavin; **HI:** University of Stirling, UK – environmental history and geo-archaeology

**PI:** Prof. Ulf Büntgen; **HI:** University of Cambridge, UK – paleoclimatology and -ecology

**PI:** Dr. Florent Sebbane; **HI:** INSERM, Lille, France – experimental biology and infectious epidemiology

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