Relationship between El Niño/South Oscillation (ENSO) and population outbreaks of some lemmings and voles in Europe

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Abstract Ecologists have been puzzled by population cycles of lemmings and voles for the over 70 years. At present, our understanding and explanation to this phenomenon remain controversial. Recently, El Niño/South Oscillation has attracted attention of ecologists on its links with population outbreaks of terrestrial animals. This paper aims to investigate the statistical relationship between outbreaks of microtine rodents and ENSO events by scanning available literature. During 1862—1894, outbreaks of Norway lemmings in Norway tended to occur in the Southern Oscillation Index (SOI) peak years or 1 year after the SOI peak years with an approximate significance level ($p = 0.057$). During 1885—1931, outbreaks of voles in France tended to occur 1 year before the SOI peak years ($p = 0.01$). During 1946—1993, outbreaks of lemmings and voles in North Finland tended to occur 1 year before the SOI peak years with a significant level ($p = 0.022$); the peaks of population abundance corresponded well to the SOI trough years (equal to 1 year before the SOI peak years). Outbreaks of common voles in Poland during 1946—1975 tended to occur in the SOI peak years or 1 year before the SOI peak years ($p = 0.011$), and also tended to occur 1 year before the SOI peak years ($p = 0.030$). It was also found that the rodent outbreaks in Norway and France, rodent outbreaks in Finland and Poland synchronized well. It was suggested that the ENSO-related climate or food were key factors in causing outbreaks of microtine rodents in Europe.

Keywords: lemmings, voles, microtine, Europe, population outbreaks, El Niño/South Oscillation (ENSO), Southern Oscillation Index (SOI)

The population cycles of lemmings (Lemmus spp.) and voles (Microtus spp.) have attracted the attention of population ecologists for the over 70 years, but our understanding and explanation to this phenomenon remain controversial[1,2]. At least 22 hypotheses have appeared to explain this problem[3]. Recent reviews indicated that predation, food and social behavior were generally believed to be the most likely factors causing population cycles[4,5]. Fennoscandians generally emphasize the impact of predation, while scientists in North America tend to emphasize the role of social factors[3,4]. There were increasing reports on positive correlation between food or associated favorable climates and population outbreaks of rodents, especially in the arid or semi-arid areas, in Africa[6—8], Australia[9,10], South America[11,12] and Asia[13,14]. Recently, the El Niño/South Oscillation phenomenon has been the focus of attention as a factor of global climatic change. Many studies suggested that the strong ENSO episodes resulted in abnormal change of global climate and atmosphere circulation[13]. Many of extreme anomalies, such as severe droughts, flooding and hurricanes, have strong teleconnections to ENSO events. During an ENSO events, researchers found the strongest connection between ENSO and intense drought in Australia, India, Indonesia, the Philippines, Brazil, parts of east and south Africa, the Western Pacific Islands (including Hawaii), Central America, and various parts of the United States[14,15].

Although biological consequences of ENSO events on marine life, including marine birds, have been more revealed[16], there are only few studies on relationship between ENSO and terrestrial animals. Many studies indicated that ENSO was much associated with outbreaks of several insects, including planthoppers, Nilaparvata lugens STL and Sogatella furcifera Horvath in Japan[17], Migrant monarch butterfly (Danaus plexippus) in America and Mexico[18]. Zhang suggested that ENSO would also play an important role in population outbreaks of some rodents, and a new ENSO-related Outbreak Hypothesis was proposed to explain the population fluctuation of rodents[19—21]. Since then, Zhu et al. reported that the outbreaks on planthoppers in South China were associated with ENSO[22]; Jaksic et al. and Lima et al. found that the El Niño-driven rainfall facilitated rodent outbreaks in semi-arid regions of South America through producing abundant seeds of grass[9,10]. Zhang and Li reported outbreaks of the Oriental migratory locust (Locusta migratoria manilensis) in China tended to occur in or after El Niño years[22]. Thus, as predicted by the new hypothesis, population outbreaks of more animals (including rodents) should be discovered to have close links with ENSO events.

It is well known that Europe has long historical records as well as recent long-term data on outbreaks of lemmings and voles. It is chosen for looking for links between ENSO and lemmings or voles in this study. This paper emphasizes the statistical relationship between outbreaks of microtine in Europe and ENSO by scanning available literature, and the discussion of the mechanism of population cycle of lemming and voles in this region.

1 Methods

(1) El Niño/La Niña episodes. El Niño is used to describe the appearance, around Christmas, of a warm ocean current off the South American coast, adjacent to Ecuador and extending into Peruvian waters. Nowadays,
The term El Niño refers to a sequence of changes in circulation across the Pacific Ocean and Indonesian archipelago when warming is particularly strong (on average every 2—7 years). La Niña refers to the cold equivalent of El Niño when the sea surface temperature (SST) becomes usually cold. El Niño or La Niña often starts in October and ends next October, lasting 12 months. However, this duration varied from several months to 2 years.


(ii) SOI. El Niño is closely related to a global atmospheric oscillation called the Southern Oscillation. During El Niño episodes, lower than normal pressure is observed in the eastern tropical Pacific and higher than normal pressure is found over Indonesia and northern Australia. These conditions characterize the warm phase of the SO, which is often referred to as an El Niño/Southern Oscillation. During the periods when ocean SST are colder than normal (the colder phase of SO), lower than normal pressure is found over Indonesia and higher than normal pressure is observed over the eastern tropical Pacific.

The SOI is calculated from the monthly or seasonal fluctuation in the air pressure between Tahiti and Darwin. Large negative values of the SOI are usually associated with warm events. In this study, we calculated the SOI values based on two SOI data sources provided by Shi and Wang [26] and provided by the Queensland Department of Primary Industry (QDPI). The former SOI includes the four seasonal SOI values during 1860—1987 based on data of the US Climate Analysis Center (CAC), and the latter provides 12 monthly SOI values from 1900 to 1998. In this study, the yearly SOI value was used, and was the average value of the four seasonal SOI values provided by Shi and Wang (1989) or the 12 monthly SOI values provided by QDPI. We defined a year with locally maximum SOI value as a SOI peak year, and a year with locally minimum SOI value as a SOI trough year.

(iii) Population data of rodents and definition of outbreak-year. We collected population data of lemmings or voles in Europe by scanning the published literature. Only irruptive rodents with relatively long-term data were chosen for analysis. For qualitative data, we define outbreak-years by simply following description by authors in the references; for quantitative data with abundance or densities, we define outbreak-years with maximum values of population abundance or densities in an obvious irruption cycle. Since populations of the selected rodents oscillated greatly, it is not difficult to identify the outbreak-years. If there are more than two successive outbreak-years, only the first outbreak-year is used for analysis.

(iv) Statistics. The 2×2 contingency table was used to test whether rodent outbreaks are associated with SOI peak or trough years, by using Chi-square or Fisher’s exact probability test method. The distance of an outbreak to the nearest SOI peak (or trough) years is calculated by the difference of SOI values between in the outbreak-year and in the nearest SOI peak (or trough) year. If outbreaks occur in the SOI peak or trough year and with two same nearest peak or trough SOI years, only the shortest distance was used. 2-tailed paired t-test was used for identifying whether outbreaks tend to occur in years close to SOI peak years or trough years. The Pearson or Spearman correlation method was used to analyze the relationship between rodent density and SOI. The computerized statistical software (SPSS for Windows 8.0) was employed for running the statistical analysis.

2 Results

We did not find any significant correlations between rodent outbreaks and El Niño or La Niña episodes. However, significant correlations between rodent outbreaks and SOI peak years, and synchrony of outbreak in four countries of Europe were revealed.

(i) Lemmings in Norway. Outbreak-years of Norway lemmings (L. lemmus), identified by following Myers and Krebs [27], are 1862, 1866, 1868, 1871, 1875, 1879, 1883, 1887, 1890, 1894, 1897, 1902, 1906 and 1909. The outbreak-years, identified by following Elton [28], are 1879—1980, 1883—1984, 1887—1988, 1890—1991, 1894—1995, 1897, 1902—1903, 1906, 1909, 1918, 1920, 1922—1923, 1926—1927, 1930, 1933—1934, 1938 (fig. 1). We did not find any significant correlation between lemming outbreaks and ENSO events during the whole