DEMOGRAPHIC CONSEQUENCES OF SUDDEN GLOBAL COOLING IN THE "YEAR WITHOUT A SUMMER" AS DOCUMENTED BY 19TH-CENTURY ADMINISTRATIVE RECORDS OF AN ITALIAN TOWN.

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INTRODUCTION

The year 1816 has been described alternatively as the "Year Without a Summer" or "Eighteen hundred and froze to death." Both descriptions are telling of the climate conditions that people were experiencing in this year. Research on this period (1810-1820) has focused on the causes of these extreme climatological conditions and the natural ecological destruction that occurred; less has been focused on the demographic consequences, particularly to rural regions. Historically, these rural regions relied upon an agricultural economic base for the subsistence of its population. In addition, many of rural communities were quite isolated. Climatic instability had serious consequences for the demography and the social stability of such rural communities. Bell (1979: 8) wrote that variations in physical features such as altitude, climate, soil conditions and physical accessibility (to name a few), "affect every aspect of rural Italians' lives and cause discernible fluctuations in rates of birth, marriage, and death." Using administrative records for a small mountain town in the Abruzzi region of Italy – Pettorano-sul-Gizio, this paper will examine the demographic consequences during the decade that includes the "Year Without a Summer."

This paper will be structured as follows; first there will be a description of the data and methodology that will be used to examine the demographic consequences to the community of Pettorano-sul-Gizio. Administrative data from other neighboring communities in this region have also been collected (although not with the same amount of detail) and will be used to show that the demographic consequences were not limited to this one community. In addition there will be a brief description of the physical setting of this community. Finally, the results will be examined and summarized, with suggestions as to what the next steps in this research should be.

DATA AND METHODOLOGY

Data Sources

The primary data for this examination comes from civil registration records for the period 1809 to 1865. Before 1806, the Church kept many of the earliest vital records. Starting in 1806 many parts of Italy came under the control of the Napoleonic Code. Under this Code, the keeping of birth, death, and marriage records was initiated as a secular responsibility rather than an ecclesiastical responsibility. Each comune in Italy was made responsible for maintaining a registration of all births, deaths, and marriages occurring within its boundaries. After Napoleon's defeat in 1815, some regions and provinces of Italy relinquished their civil registration system duties back to the Church. However, the Kingdom of Naples (which controlled the Abruzzi region) continued to keep civil registration system after Napoleon's defeat and the Bourbon's regained control (renamed as the Kingdom of Two Sicilies). More recently, the civil registration records for the period 1809 to 1865 have been microfilmed and are available in the United States for the comune of Pettorano-sul-Gizio (Pettorano-sul-Gizio (L'Aquila), 1982-83). This data was transcribed into a database for analysis and evaluation of the pre-unification period 1809 to 1860.

Data on volcanoes and historic volcanic eruptions come from the Smithsonian database on volcanoes (Siebert & Simkin, 2002). In addition, data on calculated dust veil index (DVI) came from Lamb (1970). Lamb (1970, 1977, and 1983) developed the Dust Veil Index (DVI) to

> quantify the impact on the Earth's energy balance of changes in atmospheric composition due to explosive volcanic eruptions. The DVI is a numerical index that quantifies the impact of a particular volcanic eruptions [sic] release of dust and aerosols over the years following the event. (Lamb, 1985).

Such releases of dust and aerosols have been shown to generate significant climatic changes through the obscuring of "solar radiation from reaching the Earth's surface" (Simkin, 1994: 913). To calculate the DVI for a particular volcanic eruption, data from observational, empirical, and theoretical studies of an individual eruption are reviewed for "possible impact on climate of volcanic dust veils" (Lamb, 1985) and then an estimate is calculated in reference to the Krakatoa eruption of 1883 – measured at 1000.[1]

Methodology

Demographic rates were not able to used to analyze consequences because this would require population totals that were not generally available until 1861 when the first modern census took place in the unified Kingdom of Italy. Further, patterns of in- and out-migration and population growth in the pre-unification period (thru 1860) mean that the 1861 census may not represent a good proxy for this decade 1810 to 1819. While the comune was somewhat isolated, there are indications that individuals from the comune did out-migrate for various purposes, and there was in-migration from surrounding communities.

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[1] The Krakatoa eruption of 1883 was used as the reference point for measuring against as it was one of the most historic explosive volcanic eruptions and had the most modern measurements available. The benefit of referencing to Krakatoa is that one can compare all other volcanic eruptions with a single numerical index. The DVI for Tambora, which erupted in April 1815, has been estimated to be 3000.

To account for the underlying trend and overcome the problem of population size, Z-scores were calculated using the equation below for the comune during the decade of 1810 to 1819.

$$Z - score = \frac{E - \overline{E}}{\sigma}$$

In the equation above, E designates the observed number of registered events (births, deaths, or marriages) for the particular year; while $\overline{E}$ is the annual mean number of registered events; and σ is the standard deviation of the number of registered events in the period 1809 to 1865 for the comune. Z-scores were calculated using data for the whole period available from 1809 to 1865. The whole data series was used in these calculations for two important reasons. First, the use of the whole data series (1809 to 1865) to calculate the mean and standard deviation removes the long-term trend in changing number of events that influenced population increase during the period. Second, by using the whole data series, short-term fluctuations in the annual recorded vital events should not influence the calculation of the mean and standard deviation.

As a first step in the analysis, yearly totals of registered births, deaths and marriages for the decade 1810 to 1819 will be examined and a Z-score will be calculated to indicate which year(s) were most different from the mean yearly totals. The interpretation of these scores with respect to deaths is that positive Z-scores demonstrate higher registered deaths than the mean and negative scores indicates below average deaths. Consistent with other historical demographic research, we will interpret Z-scores for deaths of greater than 2 to represent a crisis year, while for births and marriages, Z-scores of less than –2 to represent a crisis year.

To determine the relationship between the environment and these recorded vital events, correlation coefficients will be calculated between annual dust veil index and the three types of events: births, deaths, and marriages.

To account for patterns of seasonality of deaths within each year, the next step of the analysis will examine monthly totals of registered deaths similarly through calculated Z-scores. An examination of the monthly totals of registered deaths will give an indication of which months contributed most to the crisis year. Since the number of deaths occurring within a month at in the 19th century varies naturally and significantly with season this is an important feature to know.

Finally since the probability of death is not distributed evenly across the life course and the impact of sudden global cooling could also impact different age groups differently, the last examination will be with respect to the age distribution of annual total deaths during the decade.

The Setting

No exact date is known for the origin of the comune of Pettorano-sul-Gizio, except that it was sometime in the Middle Ages that the name Pectoranum began appearing in documents (Abruzzo2000). Later, beginning in the 1500s thru to the end of the 1700s, the comune of Pettorano-sul-Gizio experienced “a period of economic and cultural splendor” (Abruzzo2000). Summary population data (primarily from post-unification thru to the latest census in 2001) are shown in Table 1.

Table 1: Population from Censuses and other Sources 1813 to 1931 for Pettorano-sul-Gizio

Year	1813	1843	1851	31 Dec 1861	31 Dec 1871	31 Dec 1881	10 Feb 1901
Population	2,840	3,646	3,886	4,624	4,577	4,764	5,161

DATA SOURCES: Martuscelli, S. (1979) p. 180, 200, XCI for 1813; Bonitatibus, M and Carrara, A. (1990), Table 1, page 5 for 1843 and 1851; and Istituto Centrale di Statistica (1985), Table 3, p. 250-251 for 1861 thru 1901.

Pettorano-sul-Gizio is located in the province of Aquila in the region of Abruzzo. Ecologically, it is located in the Abruzzo highlands of the Appenine Mountains. The Appenine Mountains are high and rugged. The originating rock formation is dominated by limestone. Further, tectonic movements have played an important role in the geology of the environment. Tectonic movement has been an important isolating factor for the Abruzzo highlands due to "severe faulting longitudinally and transversely…" (Walker, 1967: 180). The elevation of the principle intermontane basin in the Abruzzo highlands are, for the most part, "higher than their Umbrian counterparts" (Walker, 1967:181). (Figure 1 has map locating the region of Abruzzi and the comune of Pettorano-sul-Gizio.)

The two features (elevation and location in the interior of Italy) "combine to give the Abruzzi highlands the severest winters of the peninsula, snow lies for five months on the summits and the higher roads are frequently impassable" (Walker, 1967: 181). Because of the alignment of the Appenine Mountains is on a Northwest-Southeast axis, the geographical position of the Abruzzi highland region is poorly positioned with respect to main roads that connect the northern and southern parts of Italy. In addition, the Abruzzi highland region lacked (historically) connecting roads to plain zones, as well as a lack of access to mineral resources. All of these issues combined have been obstacles for the population and economic development of the Abruzzi region, as well as isolating in times of distress.

Pettorano-sul-Gizio is placed upon the southern boundary of the Peligna Valley. It is located between the Gizio and Riaccio rivers. The town fulfilled a strategic position in the medieval period – an important strategy of town/village protection was to keep to the highest ground.

RESULTS

For rural regions, such as the Abruzzi region of Italy, which historically relied upon an agricultural economic base for the subsistence of its population and somewhat isolated, climatic instability had serious consequences for the demography of the community, and in turn the social stability of the community.

Figure 2 shows the time series of births, deaths and marriages for the period 1809 to 1865 for Pettorano-sul-Gizio. Without any other information regarding the community and some basic European history, one notes the extreme fluctuation in deaths between 1816 and 1818. The first explanation that comes to mind would be that this is a period of political instability after the downfall of Napoleon. The Kingdom of Naples (which controlled the region of the Abruzzi) was returned to Bourbon-control. Since the recording of births, deaths, and marriages was initiated as a secular responsibility under the Napoleonic Code, the transition back to Bourbon-control may have made the responsibility of such record keeping confused in this period. However, historians of this period note that unlike other states on the Italian peninsula, the Bourbon King did not have give the responsibility of administrative record back to the Church, but left the responsibility with each of the municipalities in the Kingdom. Thus, there is a continuity of the data collection. In addition, an evaluation of the data with respect to coverage completeness concluded that the fluctuations of the data were not due low quality (Condon, 2006).

Ruling out low quality record keeping due to political instability, a more detailed explanation of the reasons for such an extreme fluctuation in this 3-year period had to be investigated. It was then that I chanced to find some research by Webb (2002: 2092S) regarding a little known famine crisis (1816-1817), that "…was born of a combination of multiple harvest failures (the most precipitous decline in production since the mid-1700s), coupled with a rapid erosion of purchasing power among the poor who faced a loss of income, coupled with rising food prices."

Yet, what was causing these multiple harvest failures? This question led me to examine climatic instability in this period. One drawback for examining climatic instability in this period is that it is somewhat before much of the scientific instrumentation and measurement of weather was well known. However, what can be said about the year of 1816 is that it is "the locus of a period of natural ecological destruction not soon to be forgotten" (Soon & Yaskell, 2003). A number of factors played into the extreme climatic conditions that occurred in 1816, some of which are still not well understood as to the exact mechanism of impact.

Before proceeding, it is important to note that Europe and much of North America had been experiencing for the last 400 years what has been known as the Little Ice Age – which lasted from about the 14th century to the mid- to late-19th century. Two other naturally occurring cosmic factors that were occurring within this decade of 1810-1820 were: (1) an extended period of low magnetic activity which lasted from about 1795 to the 1820s and known as the Dalton Minimum; and (2) the shifting of the place of the sun in the solar system, "…something it does every 178 to 180 years" (Soon & Yaskell, 2003) and is known as "inertial solar motion."[2] In addition to these cosmic factors, in April 1815 a major volcanic eruption occurred – Tambora. This by far was the most important event that created the extreme weather conditions in the Northern Hemisphere.

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[2] Soon & Yaskell (2003), state that "Scientists have not yet confirmed whether or not inertial solar motion affects Earth's climate directly, but it remains a possibility." While no plausible physical mechanism has been identified, the hypothesis is intriguing, since "one solar inertial motion model predicts that a prolonged solar magnetic activity minimum will occur somewhere between 1990 and 2013… [and] is expected to end around 2091" (Soon & Yaskell, 2003).

The 1815 eruption of Tambora volcano on Sumbawa Island, Indonesia expelled great quantities of magma and ash fallout.[3] This volcanic eruption blanketed much of Europe and North America with volcanic dust during the summer of 1816 (Webb, 2002, Oppenheimer, 2003). It was blamed for the below normal daily temperatures.[4] In addition, the below normal daily temperatures came at critical times for agriculture production which in turn caused many crops to fail, leading to famine and increased mortality. Not only did these climatic instabilities lead to famine, it produced widespread outbreaks of epidemic typhus (1816-1818) and thus leading to much social instability in the late 1810s and 1820s.

Most of the higher latitude temperate zones were blanketed by volcanic dust during the summer 1816 from a major volcanic eruption in 1815 in Indonesia" (Webb, 2002: 2092S-2093S). Stothers (1984) states that for Europe and North America that, "daily temperatures (especially the daily minimums) were in many cases abnormally low from late spring through early fall, …. Many crops failed to ripen and the poor harvest led to famine, disease, and social distress compounded by the aftermath of the Napoleonic wars." The decade 1810-1819 also witnessed several other smaller volcanic eruptions, in addition to Tambora, which increased overall volcanic air pollution in this decade. Research has found that volcanic ash fallout (measured by dust veil index developed by Lamb (1970)) can "… remain trapped for a long time in the stratosphere, affecting the earth's climate" (Camuffo and Enzi, 1995). Not surprisingly, Pisek & Brázdil (2006) also found that the relationship between volcanic eruptions on temperature fluctuations was more significant when the erupting volcano was closer to the region or location for which the temperatures were being measured. Yet, volcanic ash fallout trapped in

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[3] It is estimated that about 12 cubic miles of dust and ash were ejected into the upper atmosphere.
[4] "Global temperatures dropped by 3°C and the following year was known as the 'year without a summer'." (Kennedy, 2006).

the stratosphere regardless of the origin does have an overall impact of the earth's climate, which in turn can dramatically impact the ability for a rural community to sustain itself.

Turning back to the demographic data available for the community of Pettorano-sul-Gizio, Figure 3 shows the distribution of Z-scores of annual registered births, deaths and marriages by year of occurrence during the period 1809 to 1820. The importance of examining births and marriages is that while deaths are the most extreme reaction to climatic instability, births and marriages can also be used to examine the impact of climatic instability. Individuals within a community in response to limited resources or unstable economic environment thru poor harvests can voluntarily adjust to such events by delaying marriages and thus in turn delaying fertility. Climatic instability during the agricultural growing season would contribute significantly to an unstable economic environment as described by Stothers (1984) through limited resources and rising prices of foodstuffs. In Figure 3, there is only one year in which the Z-score is above 2 for deaths. This occurs in 1817. In addition in 1817, the Z-score for births is below –2. For marriages, the Z-score for marriages is not below –2 in 1817. The Z-score for births continues to be below –2 in 1818, while both deaths and marriage Z-scores are within "normal" ranges.

To connect these demographic events to the sudden global cooling event as measured by the dust veil index (DVI), correlation coefficients were calculated between DVI and each of the demographic events – births, deaths, and marriages. The correlation coefficient for the period 1809 to 1821 between the DVI and marriages was quite highly negatively correlated without any lag (R=-0.668). However, recorded births and deaths were best correlated with a 2-year lag to DVI (R = -0.703 and 0.607, respectively). This is not surprising since as previously mentioned a marriage can be delayed in response to limited resources or an unstable economic environment, which in turn would delay couples beginning families (i.e., fertility delay). With respect to the 2-year lagged relationship between DVI and deaths, the climate of Italy (as well as Europe and northeastern North America) was not immediately impacted by the eruption of Tambora in April 1815. It was the 1816 agricultural cycle that was most impacted with unusually cold periods at critical points in the agricultural season. The extreme food shortfall through the harvest failure of 1816 would have been felt in 1817. Although it cannot be examined in this paper because the data is not directly available, the morbidity of the community could also have been impacted during this time with respect to chronic respiratory health issues from the volcanic air pollution as represented by DVI (Durand and Grattan, 2001; Grattan, Durant, et al., 2003; Pope III and Dockery, 2006). However, researchers studying the health impacts of the Laki fissure eruptions (Iceland) in 1783-84, found contemporary descriptions of morbidity such as "headaches, eye irritation, decreased lung function, and asthma" (Grattan, et al., 2003).[5] In addition to respiratory impacts, there were descriptions of cardiovascular health impacts, as well as general comments of fevers and epidemics. In northern Italy the following description was found following,

> A phenomenon of prolonged and very dense fog, which completely hid the sun, and at night made the moon appear reddish and murky. This fog caused, moreover, many illnesses and putrid and acute fevers, so that many people died. (Fajonio, cited in Camuffo & Enzi, 1995)

The Laki fissure eruptions in 1783-84, while closer to Europe/Italy, was of a much smaller magnitude than Tambora. Thus, if we were able to find contemporary writings on the morbidity experience during the years following Tambora in the rural communities of Italy such as Pettorano-sul-Gizio, we would probably find similar descriptions.

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[5] Contemporary writers described "dry fog" as the origin of these health impacts, but modern researchers would know as the suite of gases and aerosols emitted from volcanic eruptions.

Figure 4 shows the Z-score distribution of registered deaths by month and year of occurrence during the period 1815 to 1819. As a rule for this community, deaths seem to occur most often in August for this community. Yet for the year 1817, we see a sustained higher number of deaths (i.e., Z-score above 2), beginning in April and going through September, as well as in January 1817.

Figure 5 shows the distribution of deaths by selected age groups. All age groups except for the age group under 1 year, show higher than average number of deaths in 1817. This indicates that the crisis that occurred in 1817 impacted the whole community, no one age group was more vulnerable and most probably through an extreme famine event and the type of respiratory health impacts described above. In addition, individual level data collected shows that 1817 is also a year in which the greatest number of individuals were reported to have died outside the comune.

SUMMARY AND FUTURE RESEARCH

While this paper is in no way the definitive document regarding the demographic consequences of sudden global cooling, it does show that death is not the only indicator that can be used to document the demographic consequences of climate change on a community. It is also important to note that the results shown in this paper do not appear to be unique for rural communities in Italy. I have done some preliminary data collection of administrative records in other communities in rural Italy and found similar results during this period. While certainly one of the largest eruptions experienced, Tambora was not the only volcanic eruption that has had demographic consequences on rural communities. As noted above, research on the health and mortality consequences of the Laki eruption (Iceland) in 1783-1784 found similar consequences of mortality crises for communities in England and France, as well as Europe – where data was available (Grattan, et al., 2005, Grattan, Durand and Taylor, 2003; Grattan, et al., 2003; Witham and Oppenheimer, 2005).

For the future, I would like to do a more systematic collection of community data in Italy, as well as examine the data available for England and France at the community level for this particular decade (1810-1820). For the data that I do have for Pettorano-sul-Gizio, I would like to expand the time period of examination to see whether there were other periods that showed demographic consequences of climatic instability linked to other volcanic eruptions. One such example would be with respect to the eruption of Krakatoa 1883 and whether there was climatic instability after this eruption. If so, could there be a connection between the volcanic-influenced climatic instability and the start of the great out-migration from Italy in the late 19th-century?

REFERENCES

Abruzzo2000. "Pettorano-sul-Gizio" – http://www.abruzzo2000.com/abruzzo/laquila/pettorano.htm

Bell, Rudolph M. 1979. *Fate and Honor, Family and Village: Demographic and Cultural Change in Rural Italy since 1800*. Chicago and London: The University of Chicago Press.

Bonitatibus, Marcello and Carrara, Antonio. 1990. "Pettorano, Paese di Emigranti" Associazione Culturale "Pietro De Stephanis" http://www.pettorano.com/index.php?option=com_docman&task=doc_details&gid=56

Camuffo, D. and Enzi, S. 1995. "Impact of clouds of volcanic aerosols in Italy in the past centuries." *Nat. Hazards*. 11:135-161.

Condon, K. M. 2006. "Evaluation of Historical Civil Registration Records for Demographic Research: A Case Study of the Records in an Italian Comune in the Nineteenth-century." Presented at the annual meeting of the Southern Demographic Association, Durham, North Carolina.

Durand, M. and Grattan, J. 2001. "Effects of volcanic air pollution on health." *The Lancet.* 357(9, 251): 164.

Grattan, John; Rabartin, Roland; Self, Stephen; and Thordarson, Thorvaldur. 2005. "Volcanic air pollution and mortality in France 1783-1784." *C. R. Geoscience*. 337: 641-651.

Grattan, J. P.; Durand, M. and Taylor, S. 2003. "Illness and elevated human mortality coincident with volcanic eruptions." *Geol. Soc. Spec. Publ.* 213: 401-414.

Grattan, J. P.; Durand, M.; Gilbertson, D. D.; Pyatt, F. B. and Taylor, S. 2003. "Long-range transport of volcanic gases, human health and mortality: A case study from eighteenth century Europe." In H. Catherine, W. Skinner, and A. Berger (eds.). *Geology and Health: Closing the Gap*. Pp. 19-31. Oxford: Oxford University Press.

Istituto Centrale di Statistica. 1985. *Popolazione residente e presente dei comuni: censimenti dal 1861 al 1981*. Roma, Italy.

Kennedy, A. 2006. Correspondence regarding article "Climate change and health" in *The Lancet*. 367:1977.

Kington, J. A. 1998. *The weather of the 1780s over Europe*. Cambridge, England: Cambridge University Press.

Lamb, H. H. 1970. "Volcanic Dust in the Atmosphere with a Chronology and Assessment of Its Meteorological Significance." *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences*. 266(1178: 425-533.

Lamb, H. H., 1977: 'Supplementary Volcanic Dust Veil Assessments.' *Climate Monitor*, 6:57-67.

Lamb, H. H., 1983: 'Update of the Chronology of Assessment of the Volcanic Dust Veil Index.' *Climate Monitor*, 12:79-90.

Lamb, H. H. 1985. “Volcanic Loading: The Dust Veil Index.” NDP-013. Carbon Dioxide Information Center, Information Resources Organization, Oak Ridge National Laboratory.

Martuscelli, S. 1979. *La popolazione del Mezzogiorno nella statistica di Re Murat*. Guida: Naples.

McMichael, Anthony J.; Woodruff, Rosalie E.; and Hales, Simon. 2006. “Climate change and human health: present and future risks.” *The Lancet*. 367: 859-869.

Newhall, C. G. and Self, S. 1982. “The volcanic explosivity index (VEI): an estimate of explosive magnitude for historical volcanism.” *Journal of Geophysical Research (Oceans and Atmospheres)*. 87: 1231-38.

Oppenheimer, C. 2003. “Climatic, environmental and human consequences of the largest known historic eruption: Tambora volcano (Indonesia) 1815.” *Progress in Physical Geography*. 27(2): 230-259.

Pettorano-sul-Gizio (L’Aquila) Ufficio dello stato civile, 1982-83. *Registri dello stato civile, 1809-1865*. Microfilm of the original registers in the State Archives, L’Aquila – Births, deaths, marriages, banns, marriage documents, miscellaneous documents, including annual indexes. Salt Lake City, UT: Filmati dalla Genealogical Society of Utah.

Písek, J. and Brázdil, R. 2006. “Responses of Large Volcanic Eruptions in the Instrumental and Documentary Climatic Data Over Central Europe.” *International Journal of Climatology*. 26: 439-459.

Pope III, C. A. and Dockery, D. W. 2006. “Health Effects of Fine Particulate Air Pollution: Lines that Connect.” *Journal of Air and Waste Management Association (1995)* 56(6): 709-742.

Post, J. D. 1970. “The Economic Crisis of 1816-1817 and its Social and Political Consequences.” *The Journal of Economic History.* 30(1): 248-250.

Post, J. D. 1974. “A Study in Meterological and Trade Cycle History: The Economic Crisis Following the Napoleonic Wars.” *The Journal of Economic History*. 34(2): 315-349.

Post, J. D. 1976. “Famine, mortality, and epidemic disease in the process of modernization.” *Economic History Review*. 29: 14-37

Post, J. D. 1983. “Climatic change and subsistence crises.” *Journal of Interdisciplinary History* 14: 153-160.

Post, J. D. 1990. “The Mortality Crises of the Early 1770s and European Trends.” *Journal of Interdisciplinary History*. 21(1): 29-62.

Siebert, L. and Simkin, T. (2002-). *Volcanoes of the World: an Illustrated Catalog of Holocene Volcanoes and their Eruptions.* Smithsonian Institution. Global Volcanism Program Digital Information Series, GVP-3 (http://www.volcano.si.edu/world/).

Simkin, T. 1994. “Distant Effects of Volcanism – How Big and How Often.” *Science* New Series. 264 (5161): 913-914.

Simkin, T. and Siebert, L. 1994. *Volcanoes of the World*. 2nd edition. Geoscience Press in association with the Smithsonian Institution Global Volcanism Program, Tucson, AZ.

Soon, Willie and Yaskell, Steven H. 2003. "Year Without a Summer." *Mercury*. 32(3): 13.

Stothers, R. B. 1984. "The Great Tambora Eruption in 1815 and its Aftermath." *Science*. New Series. 224 (4654): 1191-1198.

Stothers, R. B. 1999. "Volcanic Dry Fogs, Climate Cooling, and Plague Pandemics in Europe and the Middle East." *Climatic Change*. 42(4): 713-724.

Walker, Donald Smith. 1967. *A Geography of Italy*. 2nd ed. London: Methuen.

Webb, P. 2002. "Emergency Relief during Europe's Famine of 1817 Anticipated Crisis-Response Mechanisms of Today." *Journal of Nutrition*. 132: 2092S-2095S.

Witham, C. S. and Oppenheimer, C. 2005. "Mortality in England during the 1783-4 Laki Craters eruption." *Bulletin of Volcanology*. 67: 15-26.

Wrigley, E. A. and Schofield, R. S. 1981. *The Population History of England 1541-1871*. London: Edward Arnold.

Figure 1: Location of the region of the Abruzzi and the comune of Pettorano-sul-Gizio.

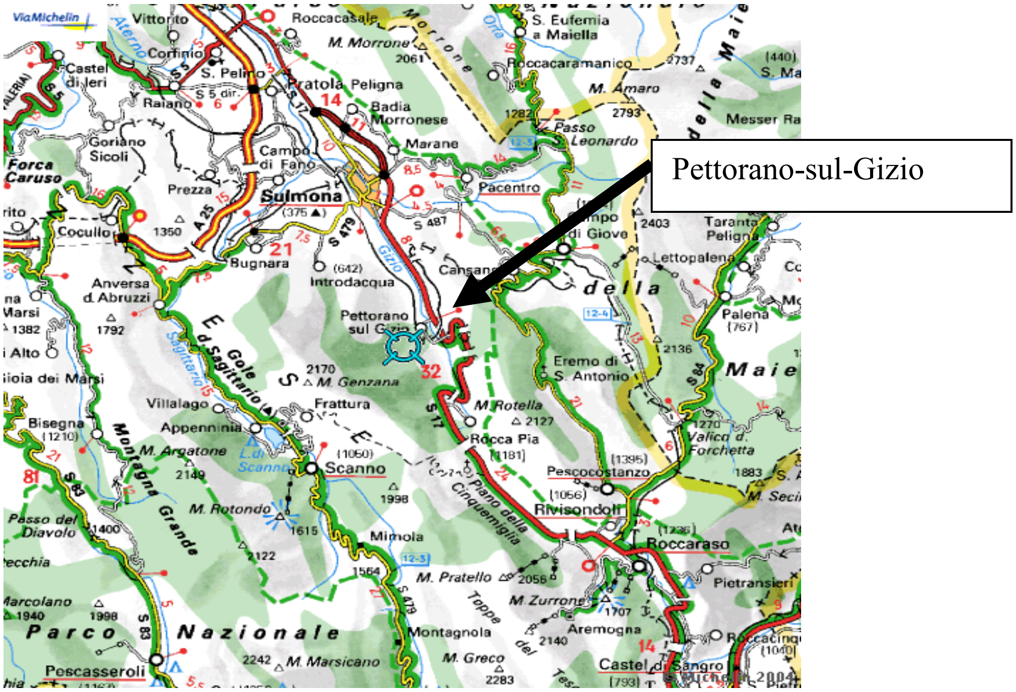

Figure 2: Births, Deaths, and Marriages in Pettorano-sul-Gizio: 1809-1860

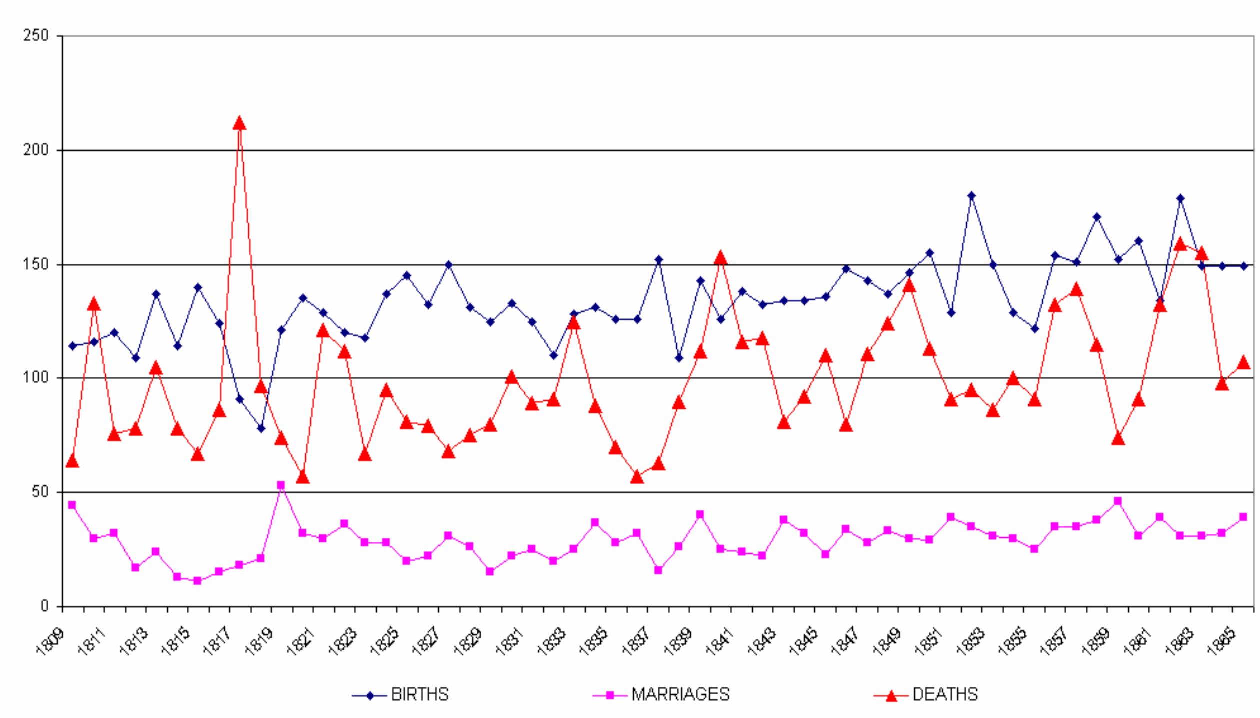

Figure 3: Distribution of Annual Z-scores for Births, Deaths, and Marriages (1809-1820)

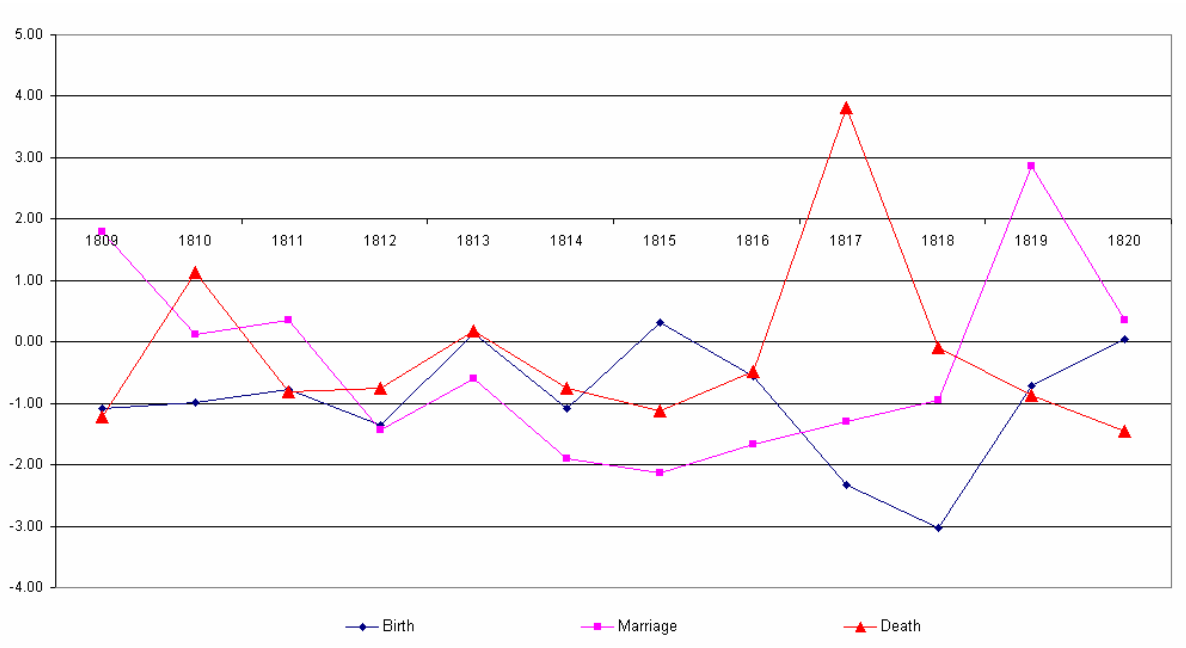

Figure 4: Distribution of Monthly Z-score for recorded Deaths (Jan 1815 – Dec 1819)

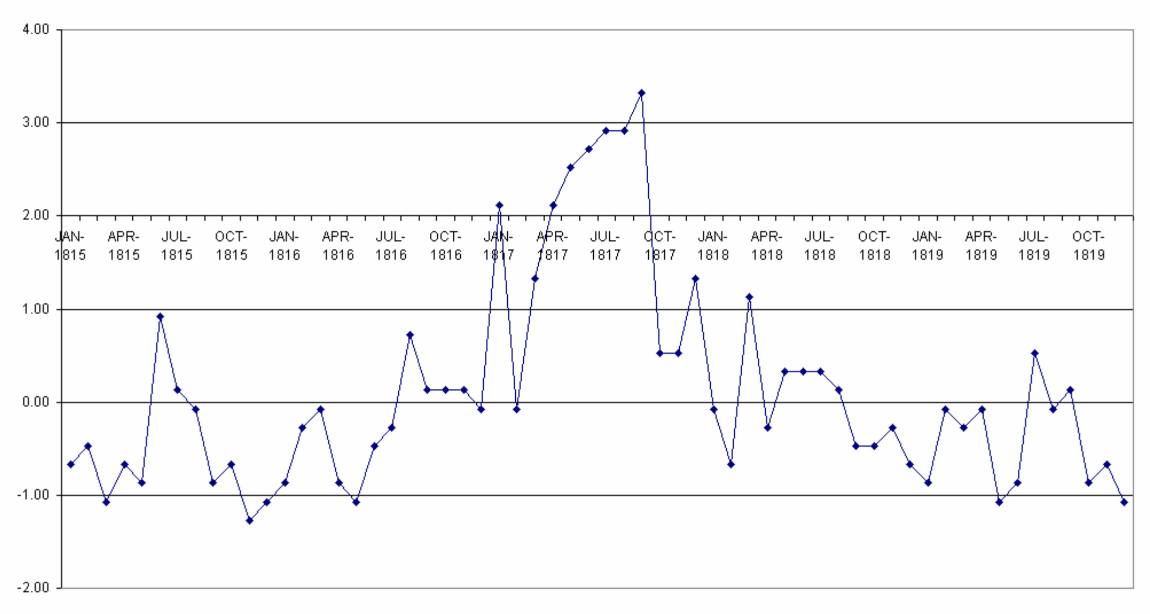

Figure 5: Z-score distribution of annual number of deaths by grouped ages (1809-1820)