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Using Historical Storms for Flood Risk Management: The 1872 Storm in South Sweden

Risk analyses aim at answering three principal questions:[1] What can happen? What is the probability that it will happen? If it happens, what are the consequences? Even though it is both practically and theoretically impossible to map all the events that can possibly occur, referring to historical storm events when assessing coastal flood risk can bring us closer to the answers to those three questions, all of which are critical for planners and policymakers.

Risk is commonly defined as the product of probability and consequence. To determine the probability of flooding, knowledge of extreme water levels, the frequency of their occurrence, storm duration, and simultaneous wave climate is required. The probability of extreme events is typically determined by statistical extreme-value models. However, wave and water-level data series are often short compared to the frequency of occurrence of interest, limiting the accuracy and applicability of model results. Therefore, information about historical storm events that occurred before data measurements started is an important complement to these analyses.[2]

Historical storm events also provide knowledge about impact, and thus the second component of risk: consequence. In risk analysis, the state of the system is an essential aspect.[3] The state of the system changes over time, implying that observed consequences of historical events are not directly transferable to present or future societies. Studying how the consequences of flooding change over time can provide insight into how the state of the system has evolved. The collective memory of storm events is commonly a trigger to improve flood risk management in affected areas. Absence of memory may instead lead to unsustainable development of flood-prone areas and thereby increased risks.

1 Stanley Kaplan and B. John Garrick, "On the Quantitative Definition on Risk," *Risk Analysis* 1, no. 1 (1981): 11–27.
2 Paolo Ciavola, M. D. Harley, and C. den Heijer, "The RISC-KIT Storm Impact Database: A New Tool in Support of DRR," *Coastal Engineering* 134 (*April* 2018): 24–32.
3 Yacov Y. Haimes, "On the Complex Definition of Risk: A System-Based Approach," *Risk Analysis* 29, no. 12 (December 2009): 1647–54.

This paper discusses the relation between flood risk management and collective memory using the 1872 storm in the Baltic Sea as a case study; how did the affected countries respond to the disaster and how did risk awareness evolve over time in the flood-prone areas of Sweden?

The 1872 Storm

On 13 November 1872, an extreme storm surge in combination with large waves caused large-scale devastation on the Danish, German, and Swedish Baltic Sea coast (figure 1). In total, about three hundred people died and more than fifteen thousand lost their homes.[4] At that time, it was more common that people lost their lives at sea, due to unsafe boats and lack of meteorological warning systems, whereas coastal flooding was rare in this area, which has no astronomical tide. Still, about one hundred people drowned on land in Denmark, 63 in Germany, and five in Sweden, making this event one of the major natural disasters in the South Baltic Sea.[5]

The water level was measured to 3.4 meters above normal in Travemünde, Germany, and similar water levels were observed on the Danish southeast coast.[6] On the south coast of Sweden, the water level is estimated to have been a maximum of about 2.4 meters above normal.[7] These water levels are about 1 meter higher than the maximum water levels observed during the last one hundred years on these coasts.

In Sweden, where there are no water-level records from that time, extreme value analysis of the 1872 storm results in a return period of seven thousand years, which is an unrealistically high value. If it were not for the historical observation of the storm, it

4 Dennis Feuchter, Christof Jörg, Gudrun Rosenhagen, Renate Auchmann, Olivia Martius, and Stefan Brönnimann, “The 1872 Baltic Sea Storm Surge,” in *Weather Extremes During the Past 140 Years*, eds. Stefan Brönnimann and Olivia Martius (Bern: Geographica Bernensia, 2013).

5 Kjeld Ejdorf, *Stormfloden Den 13. November Danmarks Störste strandingskatastrofe* (Copenhagen: Skib Forlag, 2002); Caroline Fredriksson, Beate Feldmann Eellend, Magnus Larson, and Grit Martinez, “The Role of Historical Storm Events in Risk Analysis: A Study of the Coastal Flood Events in 1872 and 1904 Along the South and East Coast of Scania, Sweden,” *VATTEN – Journal of Water Management and Research* 73 (2017): 93–108.

6 Jürgen Jensen and J. H. Müller-Navarra, “Storm Surges on the German Coast,” *Die Küste: Archive for Research and Technology on the North Sea and Baltic Coast* 74 (2008): 92–124.

7 Caroline Fredriksson, Nader Tajvidi, Hans Hanson, and Magnus Larson, “Statistical Analysis of Extreme Sea Water Levels at the Falsterbo Peninsula, South Sweden,” *VATTEN—Journal of Water Management and Research* 72 (2016): 129–42.

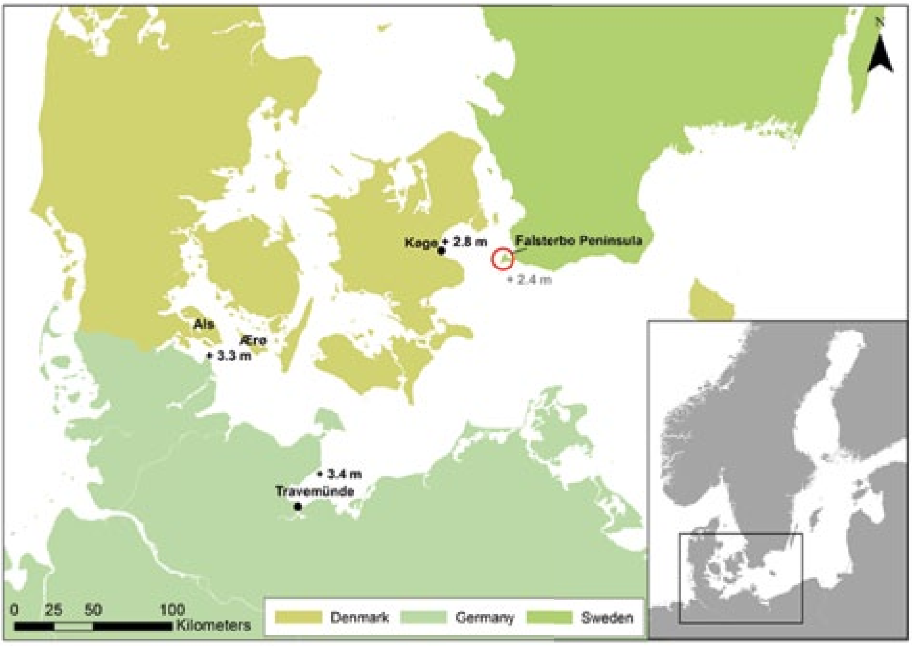

Figure 1: Map of the impacted area with observed and estimated storm surge still-water levels (m above normal). Source: the authors

would seem to be an almost impossible event. Interestingly, historical documents from Germany describe a storm surge of the same magnitude occurring in 1320, and two slightly smaller events in 1625 and 1694, which are mentioned in both Danish and German records,[8] suggesting a much shorter return period for the 1872 storm, in the order of three hundred to five hundred years. Similar results have been found when comparing eighteenth-century storm-surge data to estimated return periods along the Dutch coast.[9] In these cases, where extreme value models underestimate the probability of the most extreme events, historical observations can be used to identify possible events—answering the question of what *can* happen. If included in statistical models, they can also improve estimations of probability.

8 Jensen and Müller-Navarra, "Storm Surges on the German Coast"; Thade Petersen, "Stormfloden 1872," *Geografisk Tidsskrift* 27 (1924): 16–24.

9 Fedor Baart, Marcel A. J. Bakker, Ap van Dongeren, C. den Heijer, Sytze van Heteren, M. W. J. Smit, Marke van Koningsveld, and A. Pool, "Using 18th Century Storm-Surge Data from the Dutch Coast to Improve the Confidence in Flood-Risk Estimates," *Natural Hazards and Earth System Science* 11, no. 10 (2011): 2791–2801.

Flood Risk Awareness in South Sweden

Natural disasters contribute to increased risk awareness in society; also, the collective memory of a disaster or accident can provide knowledge about events that are not self-experienced. Flood events are often followed by technical developments and improved coastal protection, decreasing the flood risk.[10] In fact, risk awareness in itself leads to decreased risks.[11]

There are several indicators of societal risk awareness in south Sweden before the 1872 storm and in the immediate response to the event. The low-lying Falsterbo Peninsula in the southwest of Sweden has been described as flood prone in documents dating back to the eighteenth century.[12] In 1872, the two cities Skanör and Falsterbo were located on the most elevated part of the peninsula (figure 2). Seaweed dikes reaching 1.65 meters above ground surrounded the cities and their pasture, serving both as fencing and flood protection.[13] The storm damaged the dikes, but they were quickly rebuilt by the local associations responsible for their maintenance. Houses in need of repairs after the storm were reinforced, with the flood-resistant bases of the walls built higher to withstand future floods.

The presence of dikes before the 1872 storm indicates that the population of the Falsterbo Peninsula was aware of the flood risk and had taken measures to prevent flooding. The 1872 storm exceeded the design conditions for which the dikes were built, and further measures were taken, such as improving house construction to reduce the damage in case of a new storm event of comparable magnitude.

The flood risk on the Falsterbo Peninsula has subsequently increased due to the extensive development of low-lying flood-prone areas (figure 2). Meanwhile, the dikes have not been maintained and there is no longer a coherent flood protection strategy for the cities; therefore, both the probability and the consequences of flooding have increased. In many places along the south Swedish coast, vulnerability has increased through de-

10 Franz Mauelshagen, "Disaster and Political Culture in Germany since 1500," in *Natural Disasters, Cultural Responses: Case Studies toward a Global Environmental History*, eds. Christof Mauch and Christian Pfister (Lanham, MD: Lexington Books, 2009).
11 Kaplan and Garrick, "On the Quantitative Definition of Risk."
12 Albert Eskeröd, *Skånes kust* (Stockholm: LT förlag, 1960).
13 Lars Dufberg, *Skanör och Falsterbo efter "sillatiden"* (Skåne län: Vellinge kommun, 1994).

velopment without sufficient flood protection. At the same time, vulnerability has decreased due to higher insurance cover and less dependency on fishing as livelihood.

In 1904, another storm caused flooding in the same area, and documentation from this event reveals that the 1872 storm was still in the collective memory and had an impact on people's reaction to this storm.[14] Since then, however, the 1872 storm has been forgotten by successive generations of coastal dwellers in Sweden. The extensive migration to coastal areas by people working in other parts of the country, and the absence of flood markers—in the whole of Sweden there is only one such marker—may help to explain the lack of any collective memory.

Figure 2: Areas flooded on the Falsterbo Peninsula in 1872 and today. ©Lantmäteriet [I2014/00579]

During the late nineteenth century, a large part of the population along the coast made a living from fishing or shipping. On the Swedish coast, more than one hundred fishermen's houses were destroyed during the 1872 storm and a large proportion of their boats and fishing equipment were wrecked, leaving the already poor coastal population without possessions and the means to earn an income. However, harbors and boats were quickly restored by local associations. Private donations, both local and national, helped to rebuild the coastal societies, which in some cases led fairly quickly to flourishing local economies.[15]

A society's ability to bounce back after a disaster is commonly described in terms of resilience. In Sweden, different forms of the coastal societies' resilience have developed over time. In 1872, the local communities had stronger social bonds than today because

14 Frans Löfström, *Kring Sandhammare*n (Lund: Gleerups: 1946).
15 Anne Asplund, *Abbekås—i forna dar* (Skurups kulturnämnd, 1988).

the citizens were more dependent on one another. These social structures facilitated a quick restoration of houses and infrastructure. The citizens of today rely to a greater extent on the municipality, the government, or their insurance companies to provide support after a disaster. The economy is stronger overall, and also today, private donations and voluntary labor are commonly organized in response to disasters.

The experience of the 1872 storm shows that through cooperation and benevolent donors, the basic functions of society can recover quickly. However, human lives can never be recovered. In south Sweden today, thousands of houses have been built in flood-prone areas, and if the 1872 storm were to repeat itself, many more lives would be at risk. It is perhaps not necessary to build physical structures to protect dwellings against a similar event, but prognosis and warning systems together with evacuation/action plans are required to ensure safety in the lowest-lying areas.

The Collective Memory of the Storm in Sweden, Denmark, and Germany

In Sweden, the 1872 storm has more or less been forgotten. In Denmark and Germany, collective memory and awareness of the storm are much greater. In those countries, there are many more publications about the storm and, even today, the storm is often used as a design criterion for coastal protection measures.

Several explanations could account for these differences in collective memory between the countries. Firstly, storm damages were less extensive in Sweden compared to the other countries; the number of casualties, including those deceased at sea, is estimated to be 23, and only about one hundred houses were destroyed. Secondly, Denmark and Germany also have coasts on the North Sea, and have thereby experienced worse storms and coastal flooding that have led to increased risk competence, in which memory and measurements play a central role. Thirdly, in Denmark and Germany there are multiple memory markers from storms (figure 3). The flood level is carved out in stones at public places. In Sweden, there is only one such stone that is known of, at the Falsterbo Peninsula, and it has been moved several times from its original position. Last, the organization of coastal management differs between the countries. In the case of Germany, the transformation of coastal protection duties from private initiatives to government strategies is coupled with the foundation of the German Empire in 1871. The 1872 storm accelerated the turning point in coastal flood management. After 1872, storm-surge public-defence programs were systematically planned and implemented by the Prussian authorities along the German Baltic Sea coast. In Sweden, the responsibility for coastal protection is unclear and there are no national or state policies and guidelines as in Denmark and Germany.

Figure 3:
Flood marker from the 1872 storm in Wismar, Germany. Photo: Caroline Fredriksson.

Late-nineteenth-century society in Sweden faced different risks compared to those it faces today. For example, the city of Skanör was almost completely devastated by fire in 1874, and again in 1885. The threat of city fires has significantly decreased and, in the process, the 1872 storm has become relatively significant as a past disaster that could strike again. Also, the risk has increased in terms of more damaging consequences due to the development of low-lying areas. With sea-level rise, the probability of flooding will also increase, and events similar to that of 1872 will occur much more frequently. Therefore, the collective memory of the 1872 storm is more important today than before. In Sweden, numerous public talks, articles in the media, and radio documentaries have served as a reminder of the 1872 storm.

Climate change adaptation work has also put a new focus on flood risk and contributed to increased risk awareness. The water level during the 1872 storm in south Sweden corresponds to the estimated extreme water level with a one-hundred-year return period in the year 2100. Research on the 1872 storm reveals that what planners are currently assuming to be an extreme event some decades into the future had already happened 150 years ago— and it is something that we should be prepared for today. Policy needs to be informed not just by statistical models, but also by the lessons of history.