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Disturbing the dead: Climate change and the potential relocation of Swedish cemeteries

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ABSTRACT

This study focuses on the contradiction of mobility and immobility in relation to interred human remains. While society generally embraces human mobility, once individuals pass away and are disposed of, mobility ceases to be the norm. Some counties, like Sweden, has a rigid burial legislation that prohibits the re-location of interred human remains. However, both society- and climate-related events are increasingly affecting the eternal rest of the deceased. Utilizing quantitative data on all cemeteries in Sweden, this study aims to assess and analyse the potential magnitude of future large-scale moves of human remains due to expected impacts of climate change, and to put this into a relational context of norms and laws. Results show that climate change poses an apparent risk to cemeteries in Sweden, especially in the south-west of the country, and that this is mainly caused by increased risk of landslides and erosion, as a result of expected increased precipitation. A low estimate state that by the end of this century, some 30.000 interred remains and some 146.000 living survivors will likely be affected by climate-related risks.

1. Introduction

Societies in a globalised world are highly influenced not only by place and human place making, but also by human mobility. In this context, studies in social science have made a mobility turn in recent decades and placed human mobility at centre stage (Urry, 2007). Local everyday mobility within modern society, such as commuting or grocery shopping, has been highlighted (Hannam et al., 2006), but today climate change accelerates mobility at increasing higher speed (de Certeau, 2002). Even after individuals pass away, they do not stop being mobile. Rather, death is a trigger for a final act of mobility, from the place of death to a place of final rest (Marjavaara, 2012; Rowles & Comeaux, 1986, 1987). However, once the human remains are buried, mobility often ceases to be, and immobility becomes the norm. The idea that deceased individuals should *"rest in peace"* and not be disturbed prevails in western society (Hockey et al., 2010; Prendergast et al., 2006). In several countries this is manifested through legislation (e.g. Sweden) and buried remains should not be relocated once disposed of in a cemetery. Exceptions might be made due to external events, such as exploitation or climate impacts.

Individuals do not cease to be important for others just because they happen to die (Maddrell, 2013). According to Walters (2009) the dead are not banished from the lives of the living. Rather, the living and the dead are connected by "*continuing bonds*" (Klass et al., 2014), meaning that living individuals can experience that they still have relation to the deceased. In relation to death, place is of importance to activities such as mourning, honouring or remembrance (Maddrell & Sidaway, 2010). Through these activities, cemeteries (as well as places for scattering ashes in nature) gain special significance for both individuals and society as a whole, as places for identification and belonging (Petersson & Wingren, 2011; Spirn, 1998). This means that death and disposal are essentially a geographical phenomena. Not only in the places where death is most intensified but unfolds and have consequences in multiple other (Maddrell & Sidaway, 2010). Therefore, death as well as cemeteries could not be seen as a separated phenomenon, but instead as intertwined with the mobile society and societal life both physically and culturally. This is often overlooked in a planning context, especially in relation to new cultural situations and new cemetery practices (Maddrell et al., 2022). In Sweden, Church of Sweden takes care of most cemeteries on delegation from the state with the implication to facilitate any cultural or religious need or difference. This means a co-existence of majority and minority death rituals, enhancing possibilities for fusing social

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boundaries (Reimers, 1999).

Francis (2003) and Francis et al. (2000) argue that places for burial are of ever-greater importance in modern societies, where mobility has become the norm, due to their role as anchors for families and as a link in a chain of generations. Further, Mueller and Meindl (2017) argue for the longevity of cemeteries, noting that they are rooted in the notion of never being disturbed. Additionally, cemeteries are seen as sacred spaces, indicating that a disturbance of cemetery areas and practices also challenge and question actual forms, geographies and identities (Maddrell, 2016). Hence, the place of final rest (cemeteries) could be seen as static, non-mobile entities in an otherwise mobile world, and as such regarded as permanent and securing (Basmajian & Coutts, 2010). Cemeteries act as stable places that give meaning, roots and memory to living survivors.[1] Marschall (2012) makes a similar argument, emphasising the importance of seeking *"personal memory spaces"*', which might also incorporate returning to places of loss. Hence, cemeteries where close kins, friends and other important individuals are interred become a node in a social network that has individual importance for survivors, and at times is manifested through visits and corporal proximity (Walters, 2009).

Norms, practices and legislations are different within different countries, even between culturally similar countries in the European North (Nordh et al., 2021). In Sweden, the immobility of interred human remains is greatly emphasised in the burial legislation (Sveriges Riksdag, 2022a), which states that the relocation of already buried or disposed human remains is not generally allowed, even if reuse of graves is permitted after 25 years. Exceptions can be granted on rare occasions due to special reasons, but the overall attitude is that the deceased should *"rest in peace"*. Even though Sweden is one of the most secular countries in the world, disturbing the dead is still something that is viewed as undesirable (Marjavaara, 2017). Compared to many other countries, the Swedish legislation is rather rigid. For example, in the UK the removal of ashes is permitted by law, meaning that remains can be hypermobile, and the ashes can be kept, buried or scattered in one or more significant places (Prendergast et al., 2006). In the Netherlands the practice of exhumation and second burial is allowed (Heessels & Venbrux, 2009). Given the burial legislation in Sweden, the place of final rest becomes even more important (Marjavaara, 2012), especially when proximity to the deceased is important for survivors.

In today's society, macro-level societal and environmental changes are challenging the conventions and norms regarding death and mobility (Kohn et al., 2019). Around the globe, many examples can be found in which the relocation of cemeteries and other places for the disposal of human remains is necessary. One reason for this is competition for space in and around growing urban localities for purposes other than for cemeteries (Coutts, Basmajian, & Chapin, 2011; Kay, 1998). Older cemeteries have come to be centrally located in expanding cities, meaning that their land value is high, and the alternative land use is present. Another reason for relocating cemeteries can be industrial development or expanding infrastructure or mining, which often has a long and important heritage as well as economic value for many countries, and often involves spatial expansion for the further extraction of minerals. In many cases, this leads to the destruction of nearby settlements, both those for the living and for the dead (Bora & Voiculescu, 2021; Saccaggi & Esterhuysen, 2014). Currently, the city of Kiruna in Sweden is being moved and a total of 5000 human remains is to be relocated due to the expanding iron ore mine (Wingren, 2024). Another reason is climate change, which is causing increased risks of erosion, flooding and sea level rise. This puts pressure on responsible authorities to take preventive action to protect cemeteries, and in worst case relocate parts of (or whole) them. This has already been highlighted in the coastal area of Louisiana (USA), where a general sea level rise in combination with storm surges has led to extensive damage to cemeteries (Schexnayder & Manhein, 2017). From the Caribbean, Mueller and Meindl (2017) report that some 23% of surveyed cemeteries are at risk of sea level rise and storm surges, and that severe damage has already been reported in some localities. Čakar et al. (2018) report from Bosnia and Herzegovina that torrential rainfall during 2014 caused more than 3000 landslides, inflicting severe damage, including cemeteries. In Fiji, Charan et al. (2017)report, erosion caused by sea level rise is threatening coastal cemeteries and leaving them to be washed out to sea is not an option, as these places are important to the local communities. In Alaska, Tran et al. (2021) describe that a general concern for the local community of St. Paul is the potential erosion damage to the local cemetery, as this cemetery holds important meaning as a place of heritage, culture, religion, and personal identity.

Given this background, there is a clear relationship between cemeteries and mobility, and therefore it seems important to highlight the conflicting interests between a possible accelerating need to move human remains and the societal norms, conventions and legislation that prioritize the static in relation to funeral landscapes, at least in Sweden. It is unknown how much of a threat climate change-related risks are to the *"eternal rest"* among the interred, and how many survivors might be affected. In general, there is limited research on climate change impacts on historically and culturally important areas such as cemeteries (Mueller & Meindl, 2017). Previous studies have mostly focused on limited types of climate-related risks and often also limited geographical spaces. Hence, the aim and purpose of this study is to make a nationwide assessment and analysis of the potential magnitude of possible future large-scale moves of human remains in Sweden, due to expected impacts of climate change. Therefore, the specific research questions addressed in this study are: (1) What kinds of possible climate-related problems will affect cemeteries in the future? (2) Which impact will this have, where and on whom?

2. Methods

In the first part, using geographical information systems, the study adopts an explorative quantitative approach, scrutinising cemeteries in Sweden and assessing their possible vulnerability to climate change-related impacts. In the second part, an assessment of the number of affected human remains and living survivors is made. Multiple data sources from public authorities and private firms, concerning all active cemeteries in Sweden in 2010, are used. The data is then processed and analysed using a geographical information system (GIS). This approach enables a nationwide study of the impact on funerary services and sites and offers insight especially regarding the vulnerability of individual cemeteries. The work flow process is presented in Fig. 1.

First, a register of all (1) active cemeteries in Sweden in 2010 was retrieved from the Swedish Mapping, Cadastral and Land Registration Authority (Lantmäteriet, 2022). This georeferenced data specifies the location and detailed layout of each cemetery in the country, 2822 cases in total. Active cemeteries are defined here as being in use and accepting new remains, and not defined as cultural heritage sites. These cemeteries serve as the input to an overlay analysis conducted in GIS. The variables used for the overlay analysis represent climate change-related processes that are assessed to be of specific importance in creating hazardous conditions for cemeteries. The input variables are: (2) erosion potential due to soil type and slope; (3) documented scars from previous landslides; (4) existing landslide scars in fine-grained stratified sediments; (5) annual current and predicted future precipitation; (6) future flooding scenarios; (7) average sea level change; (8) storm surge levels in the sea; (9) beach erosion potential; and (10) erosion potential in proximity to water. These data sources (see Table 1) were collected from public authorities in Sweden: the Swedish Geological Survey (SGU); the Swedish

[1] In this study the term; "Survivor(s)" is used as a collective term for friends and relatives outliving the deceased. This is a frequently used term in the scientific literature within deathscapes, geographies of death and necrogeography. It is also the term used in early works within the field by for example Rowles and Comeaux (1986; 1987), and therefore applied.

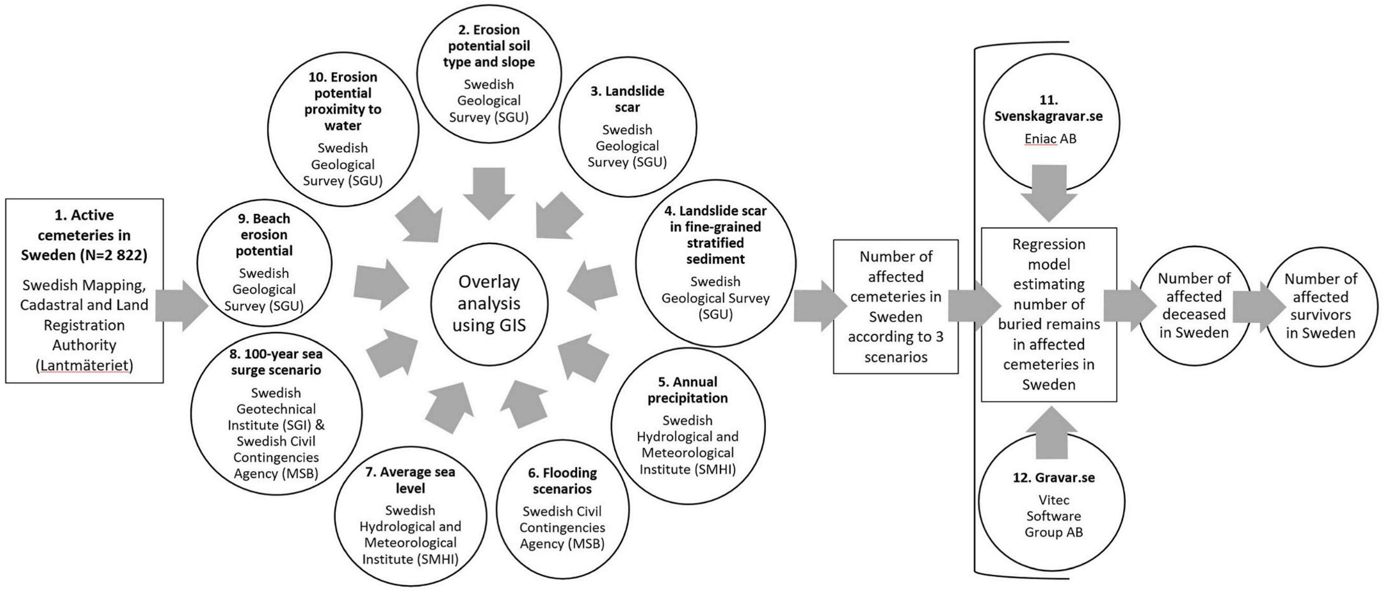

Fig. 1. The work-flow process.

Hydrological and Meteorological Institute (SMHI); the Swedish Geotechnical Institute (SGI); and the Swedish Civil Contingencies Agency (MSB).

The calculations of the impact of climate change-related problems are based on three different future climate RCP (Representative Concentration Pathway) scenarios adopted by the IPCC (2014). These scenarios are based on the level of greenhouse gases emitted in the future, up to the year 2100. RCP 2.6 implies that greenhouse gases decline from 2020 and go to zero emissions by 2100; RCP 4.5 that greenhouse gases peak around 2040 and start declining around 2045; and finally, RCP 8.5 predicts that greenhouse gases will continue to rise throughout the 21st century (IPCC, 2014).

The average sea level rise (taking into consideration the prevailing effect of land rise in Sweden) and a 100-year sea surge (only available for RCP 4.5) cover impacts on the entire Swedish coastline (SMHI, 2022a; 2022b; SGI & MSB, 2021). Further, different flooding scenarios were used for 100-year floods, 200-year floods and calculated highest flows (CHFs), covering 83 major lake and river systems in Sweden (MSB, 2022). A 100-year flood means that these levels has been seen as likely to occur once every 100 years by the year 2100, but recent events during the last decades indicates that a 100-year flood is probably occurring more often today than when these classifications were done. A 200-year flood statistically occurs once in a 200-year period, and the CHF is a scenario in which multiple factors co-occur, e.g. snow melting, precipitation and water saturation in the ground (MSB, 2022). Additionally, data from the Swedish Geological Survey (SGU) includes areas

Table 1
Data sources, data type and format.

#	Source	Data	Extent	Geometry
1.	Swedish Mapping, Cadastral and Land Registration Authority (Lantmäteriet)	Feature files on mapped cemeteries and religious buildings in Sweden. Last updated in 2010.	2822 cemeteries and 13 449 buildings for organised religious activities, such as churches, chapels, mosques, synagogues, monasteries, mortuary chapels etc.	Polygons
2-4.	Swedish Geological Survey (SGU)	Feature files on areas subjected to landslides, landslips and erosion	230 000+ areas defined as hazardous based on soil type, slope and proximity to water. 1843 landslide scars and 50 684 landslide locations.	Polygons and polylines
5.	Swedish Hydrological and Meteorological Institute (SMHI)	Precipitation level annual average for years 1991–2013 and by the year 2100, according to RCP 4.5 and RCP 8.5	Entire Sweden aggregated on 4 km*4 km squares.	Polygon
6.	Swedish Civil Contingencies Agency (MSB)	Feature files for flooding predictions in lakes and rivers according to 100-year and 200-year flooding scenarios, and highest calculated levels by the year 2100	83 lake and river systems in Sweden	Polygons
7.	Swedish Hydrological and Meteorological Institute (SMHI)	Feature files for average sea level predictions by the year 2100 according to RCP 2.6, RCP 4.5 and RCP 8.5 scenarios	Entire Swedish coastline	Polygon
8.	Swedish Geotechnical Institute (SGI) & Swedish Civil Contingencies Agency (MSB)	Feature file for 100-year sea surge prediction according to RCP 4.5	Entire Swedish coastline	Polygon
9-10.	Swedish Geological Survey (SGU)	Feature files on areas subjected to landslides, landslips and erosion	800 000+ stretches of beaches classified according to assessed erosion potential. 36 000+ areas classified based on proximity to water.	Polygons and polylines
11.	Eniac AB (Svenskagravar.se)	Public database run by Eniac Data AB	Burial registers for 84 burial administrations in Sweden, with information on 3 266 860 buried individuals	–
12.	Vitec Software Group AB (Gravar.se)	Public database run by Vitec Software Group AB	Burial registers for 1860 cemeteries in Sweden, with information on 2 570 522 buried individuals	–

specifically vulnerable to landslides, landslips and erosion (SGU, 2022). Based on an overlay analysis, the location, size and number of likely affected cemeteries in Sweden were identified, as was the reason for their predicted future vulnerability.

Since we do not have access to information regarding the total number of disposed human remains in each individual cemetery in Sweden, a figure was estimated for the cemeteries lacking this information, based on a random sample of cemeteries that do have this information. A sample was drawn from the list of cemeteries, and the number of interred was noted based on information from two databases that provide this information publicly on the Internet. These databases (11) Svenskagravar.se (Eniac AB, 2022) and (12) Gravar.se (Vitec Software Group AB, 2022) – contain detailed, updated information on who is buried in what grave in individual cemeteries, together with a total count. Svenskagravar.se covers 86 burial administrations in Sweden, with information on 3 311 178 human individuals (Eniac AB, 2022), while Gravar.se (Vitec Software Group AB, 2022) covers 1838 cemeteries throughout Sweden, including 2 480 148 human remains.

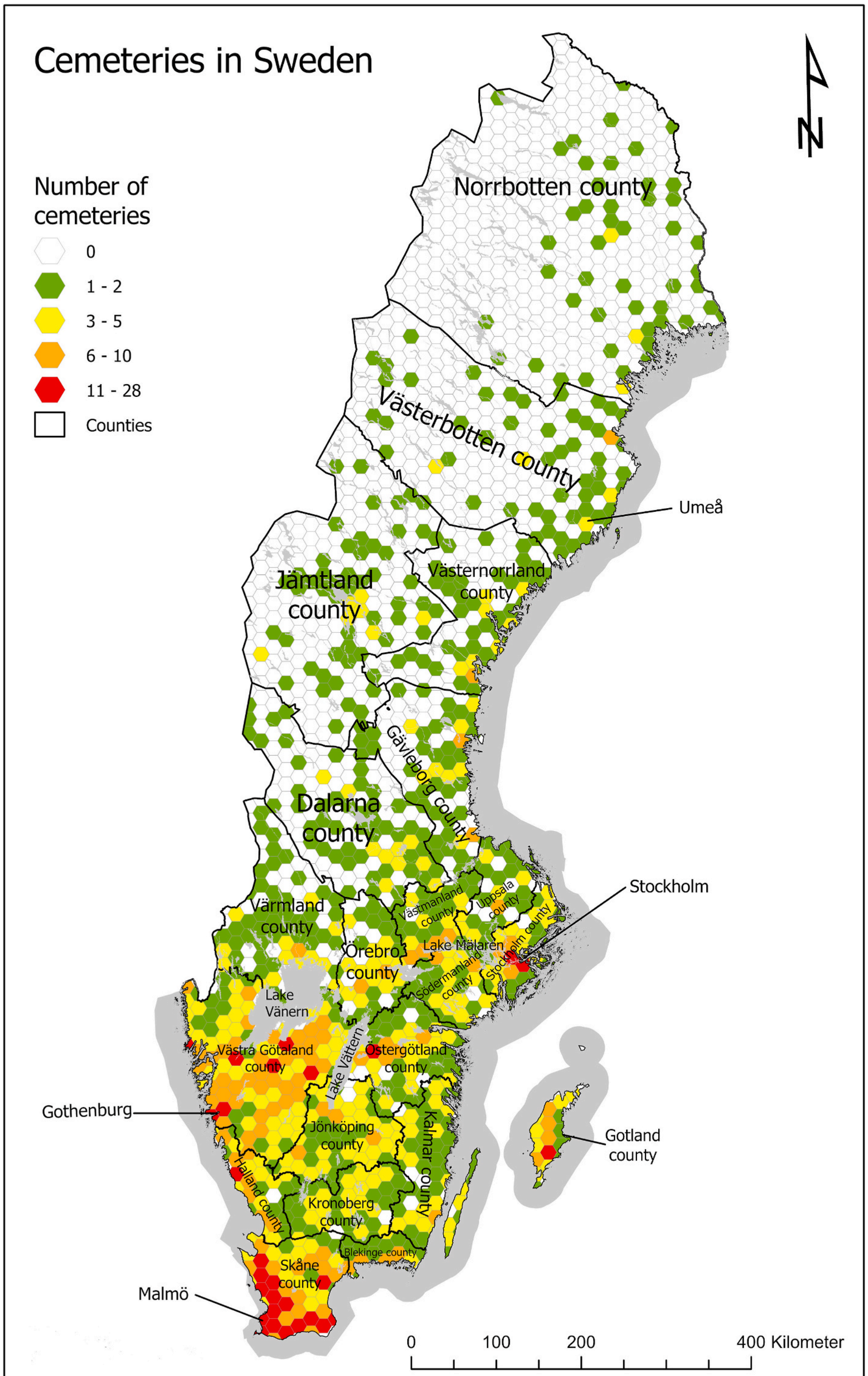

Fig. 2. The spatial distribution of Swedish cemeteries. Summary of the number of cemeteries within hexagons (250 km2 in size). Total number of hexagons: 2046. Own elaboration based on information from the Swedish Mapping, Cadastral and Land Registration Authority (2022).

The two databases do not overlap each other. Based on the identified cemeteries and their size, an expected number of buried individuals was calculated using a linear regression model. In this way, estimated values were created for cemeteries lacking information on the number of buried human remains there. Finally, based on the calculated number of affected human remains, the number of affected survivors was assessed through an extrapolation based on information from previous studies. In this way, using multiple input data, the nationwide magnitude of the associated problems can be addressed. Combining all data in an overlay analysis, the number of affected cemeteries in Sweden was calculated based on three scenarios: low, medium and high. The low scenario is rather strict and narrow in terms of climate change-related impacts, providing a low estimate. However, these cemeteries will most definitely run into problems in the future. The medium scenario is broader, incorporating more extensive problems due to climate change and therefore a higher number of affected cemeteries. This scenario also includes a flooding variable for the sea (only available for the RCP 4.5 scenario). The high scenario incorporates CHFs for flooding and the highest sea level rise according to the RCP 8.5 scenario.

Naturally, there are limitations in the data and methodology. First, the list of cemeteries provided by the Swedish Mapping, Cadastral and Land Registration Authority (Lantmäteriet, 2022) is somewhat incomplete; this was detected during the empirical work. However, it is hard to assess how many active cemeteries are missing in the data. Our view is that this is of minor importance, since there is only a small number of detected missing cases and the missing cemeteries are small, with a limited number of interred human remains. Second, not all layers provided by the Swedish authorities have nationwide coverage, for example different flooding scenarios or beach erosion. This means that the number of affected cemeteries is likely higher than the assessment made in this study. Further, torrential rainfall is also not included here. Fourth, cemeteries defined as heritage sites - i.e., decommissioned cemeteries constructed before 1940 (Sveriges Riksdag, 2022b) - are not included in this study as there are likely very few living relatives. However, these cemeteries might be of interest in future studies, since they are of public interest and might be of importance in the shaping of local and national culture and identity. Fifth, the number of interred human remains that may be impacted was calculated based on the total number of interred in each cemetery, not taking into consideration an uneven distribution of graves within cemeteries or the specific parts of cemeteries that may be impacted. Sixth, the so-called Bruun's rule (Bruun, 1962), used for calculating coastal erosion inland, has not been taken into consideration, meaning that the problems could potentially be even greater. Therefore, the results from this study are not to be regarded as a detailed assessment of individual cemeteries throughout Sweden. To do this, one would need to undertake detailed and individual onsite risk assessments. Instead, this study provides an initial nationwide assessment of the expected magnitude of cemeteries that are at risk due to climate change.

3. Results

Most of the cemeteries in Sweden are located in the south of the country (see Fig. 2). Naturally, there is a correlation between larger population concentrations and the number of cemeteries. However, rural areas with a long history of agricultural production also have many cemeteries. Examples include the island of Gotland (Gotland county) (N = 69), the county of Skåne (N = 455) in the south, the agricultural plains of Västra Götaland (N = 623) in the southwest. Here, small villages typically have their own village church, with an attached churchyard.

Next, an overlay analysis was conducted using three different scenarios (see Table 2), a low-, medium- and high scenario, based on the expected impacts. The different scenarios are divided into variables related to impacts of erosion/landslides and flooding.

To assess the risk of erosion and landslide in individual cemeteries, five different GIS layers were applied in a two-stage process. First, cemeteries overlapped by areas with fine-grained soil combined with

Table 2
Scenarios and variables.

#	Variables	Scenario: Low	Medium	High
Erosion/Landslide				
2.	Fine-grained soil with steep slope	Area covered (%)	Area covered (%)	Area covered (%)
3-4.	Landslide scars	Intersect of perimeter length (%)	Intersect of perimeter length (%)	Intersect of perimeter length (%)
5.	Precipitation	Annual average 1991–2013 (mm)	Annual average RCP 4.5 (mm)	Annual average RCP 8.5 (mm)
9.	Beach erosion level	Intersect level 4 of perimeter length (%)	Intersect level 3 to 4 of perimeter length (%)	Intersect level 1 to 4 of perimeter length (%)
10.	Fine-grained soil with shore proximity	Area covered (%)	Area covered (%)	Area covered (%)
Flooding				
6.	Flooding (lakes & rivers)	100-year flood area covered (%)	200-year flood area covered (%)[a b]	CHF flood area covered (%)[a]
7.	Sea level (average)	RCP 2.6 area covered (%)	RCP 4.5 area covered (%)	RCP 8.5 area covered (%)
8.	Flooding (sea level)	N/A	100-year flood RCP 4.5 area covered (%)	N/A

+Overlapping cases occur.
[a] Excluding Lake Mälaren.
[b] Limited number of scenarios provided.

steep slopes (#2) and with shore proximity (#10) were assessed according to the total area covered by these attributes, measured in percentage. The same applies to existing landslide scars (#3–4), with the total length of the scar measured as a percentage of the total perimeter length of the cemetery. These three variables are the same regardless of the scenario. The beach erosion variable (#9) is different, as the low scenario includes only the beach stretches with the highest risk class (Level 4) and the most sensitive. The risk assessment was done according to a percentage of the total perimeter length of individual cemeteries, in order to assess the impact. The medium scenario contains risk Levels 3 and 4, and the high scenario contains all levels, 1 to 4 for beach erosion. This means that the low scenario cemeteries are those that have a high likelihood of being affected, by the year 2100. Finally, all cemeteries with at least one of the above-mentioned features prevalent within the perimeters of the cemetery were then further selected if they are in an area with an expected level of yearly precipitation (#5) of over 1000 mm/year. In the low scenario this applies to the current situation (1991–2013), and in the medium scenario it applies to a projected situation by the end of this century according to RCP 4.5 estimations. The high scenario is based on the RCP 8.5 predictions. The risk of erosion and landslides is an effect of long periods of high levels of precipitation (MSB, 2018), stressing the importance of monitoring precipitation.

The flood risk was assessed based on floods in lake and river systems (#6), the average sea level rise (#7) and temporal storm surges in the sea (#8). These are different depending on the level of the scenario. Flooding in lake and river systems was based on 100-year floods in the low scenario, 200-year floods in the medium scenario and the CHF in the high scenario. Individual cemeteries were assessed according to the total area covered by this attribute. For the change in average sea levels, the different scenarios include predictions for RCP 2.6 (low), RCP 4.5 (medium) and RCP 8.5 (high) and were assessed according to the percentage covered in individual cemeteries. Finally, flooding in the sea (storm surges) was also included but was only available for RCP 4.5 predictions, then included in the medium scenario.

A bivariate regression was conducted in order to be able to extrapolate and estimate the number of individuals buried in Swedish cemeteries. Using an online number randomiser, cemeteries were selected by serial numbers from a list of cemeteries. Information on the number of interred human remains was then looked up using data from www.svenskagravar.se (Eniac AB, 2022) and www.gravar.se (Vitec Software Group AB, 2022). Occasionally, the selected cemeteries were not in the websites' records; then a new random selection was made until the total number added up to 141 (n), equal to 5% of the total. A scatterplot showed a positive correlation between the area (m^2) and the number of interred remains and was statistically significant: $r(139) = 0.858$, $p < .001$. The linear regression equation for predicting the number of interred human remains based on the area was $\hat{Y} = 433.82 + 0.104x + \varepsilon$. ($r^2$ 0.736). This equation was then used to predict the number of interred for all cemeteries in Sweden Using the linear regression, the predicted number of affected interred human remains was calculated. Finally, an extrapolation was made based on previous findings of the estimated number of affected living survivors. According to Krull (2022), each death leaves behind five grieving people. Other studies (Verdery et al., 2020), calculate that every death translates into 8.91 surviving individuals. In this study we use Krull's numbers for a moderate assessment.

In order to differentiate between cemeteries that are only marginally affected the cases were further divided into three levels of impact. The first contains all cemeteries affected, regardless of the extent (>0% of their area covered). The second contains all cemeteries with at least 50% of the cemetery covered, and the third contains cemeteries with at least 75% of their area at risk. As indicated in Table 3, the low scenario includes 195 cemeteries that are affected more than 0%, meaning from minor to substantial levels. A total of 114 cemeteries are affected by erosion and landslide-related risks, and 88 are at risk of flooding. In the medium scenario the same number of cemeteries is affected (195), however with one more affected by landslide/erosion. Here as well, a majority of the cases are related to landslides and erosion. In the high scenario the number of cases dramatically increases to 326. Almost an equal number of cases is affected due to landslide/erosion and flooding. This is of course due to the CHFs in the flooding scenarios and the sea level rise according to RCP 8.5.

The total area affected ranges from 5.3 to 9 million m^2 of cemetery space, with about the same volume for both forms in the low- and medium scenarios. In the high scenario, cemeteries affected by flooding dominate. The number of affected interred human remains is estimated to be between 600 000 (low scenario) and around a million (high scenario). About an equal number of human remains, around 300 000, are

Table 3
Calculations of the number of cemeteries, number of human remains and number of affected living survivors, according to different scenarios and extents.

	Scenario		
>0% of area affected	Low	Medium	High
Total no. cases	195[c]	195[c]	326[c]
Erosion/Landslide	114	115	178
Flooding	88	88[a b]	164[a]
Total area covered (m^2)	5 343 487[c]	5 547 270[c]	9 084 587[c]
Erosion/Landslide	2 990 717	3 022 542	4 356 016
Flooding	2 915 326	3 111 987[a b]	5 463 220[a]
Total estimated no. deceased	640 318[c]	661 511[c]	1 086 222[c]
Erosion/Landslide	360 490	364 234	530 246
Flooding	341 370	361 823[a b]	639 321[a]
Total estimated no. survivors	3 201 590[c]	3 307 555[c]	5 431 110[c]
Erosion/Landslide	1 802 450	1 821 170	2 651 230
Flooding	1 706 850	1 809 115[a b]	3 196 605[a]
No. overlapping cases	7	8	16
Minimum 50% of area affected			
Total no. cases	33	35	72[c]
Erosion/Landslide	28	28	46
Flooding	5	7[a b]	28[a]
Total area covered (m^2)	421 652	489 458	923 663[c]
Erosion/Landslide	365 892	365 892	503 043
Flooding	55 760	123 566[a b]	431 839[a]
Total estimated no. deceased	58 168	66 088	127 296[c]
Erosion/Landslide	50 200	50 200	72 272
Flooding	7968	15 888[a b]	57 058[a]
Total estimated no. survivors	290 840	330 440	636 480[c]
Erosion/Landslide	251 000	251 000	361 360
Flooding	39 840	79 440[a b]	285 290[a]
No. overlapping cases	0	0	2
Minimum 75% of area affected			
Total no. cases	17	16	41
Erosion	13	13	18
Flooding	4	3[a b]	23[a]
Total area covered (m^2)	211 183	184 915	574 088
Erosion	169 369	169 369	188 428
Flooding	41 814	15 546[a b]	385 660[a]
Total estimated no. deceased	29 338	26 172	77 492
Erosion	23 254	23 254	27 405
Flooding	6084	2 918[a b]	50 087[a]
Total estimated no. survivors	146 690	130 860	387 460
Erosion	116 270	116 270	137 025
Flooding	30 420	14 590[a b]	250 435[a]
No. overlapping cases	0	0	0

[a] Excluding Lake Mälaren.
[b] Limited number of scenarios provided.
[c] Overlapping cases occur.

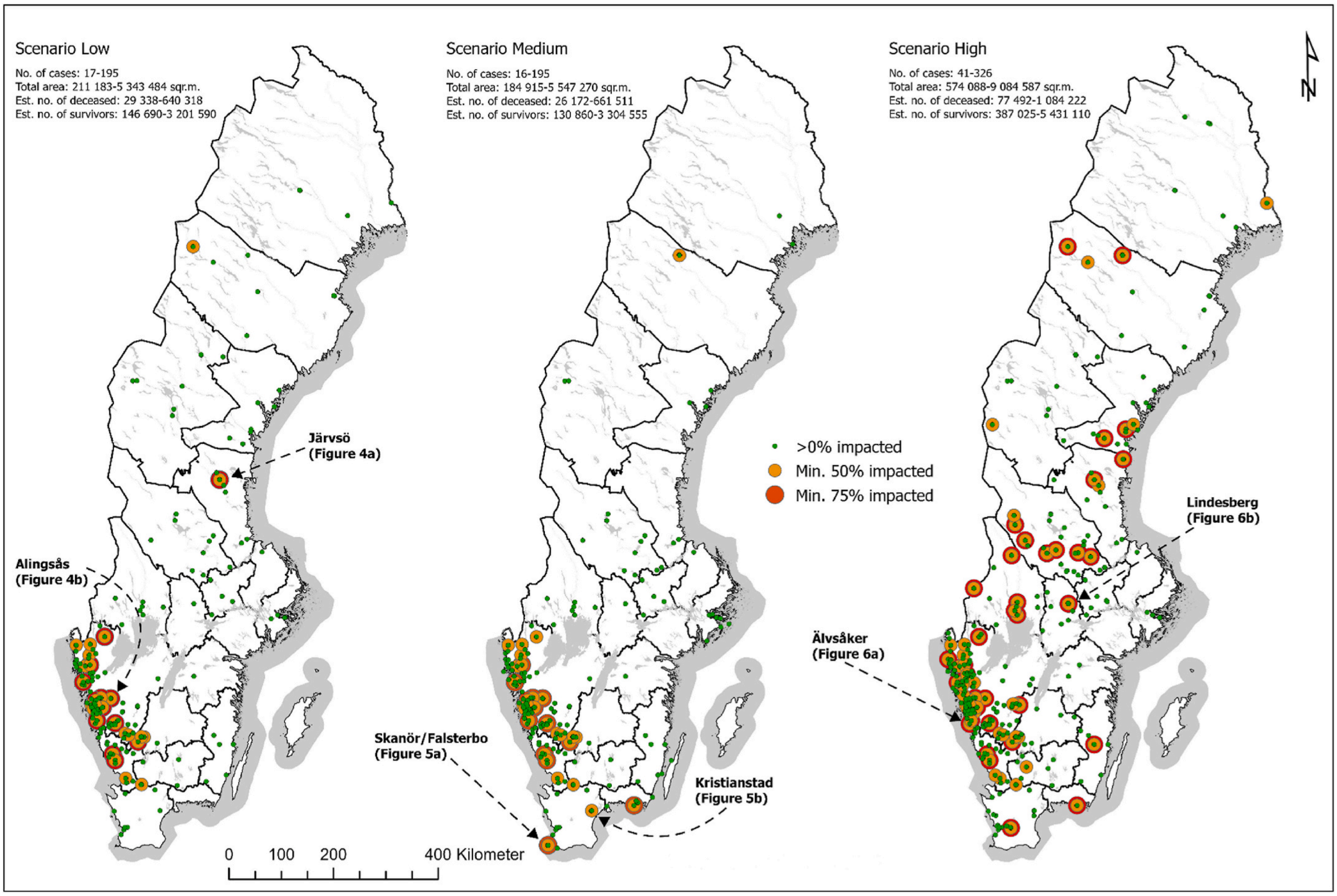

Fig. 3. Distribution of Swedish cemeteries impacted in different scenarios (low, medium and high) and share of cemetery affected (over 0%, minimum 50% and minimum 75%).

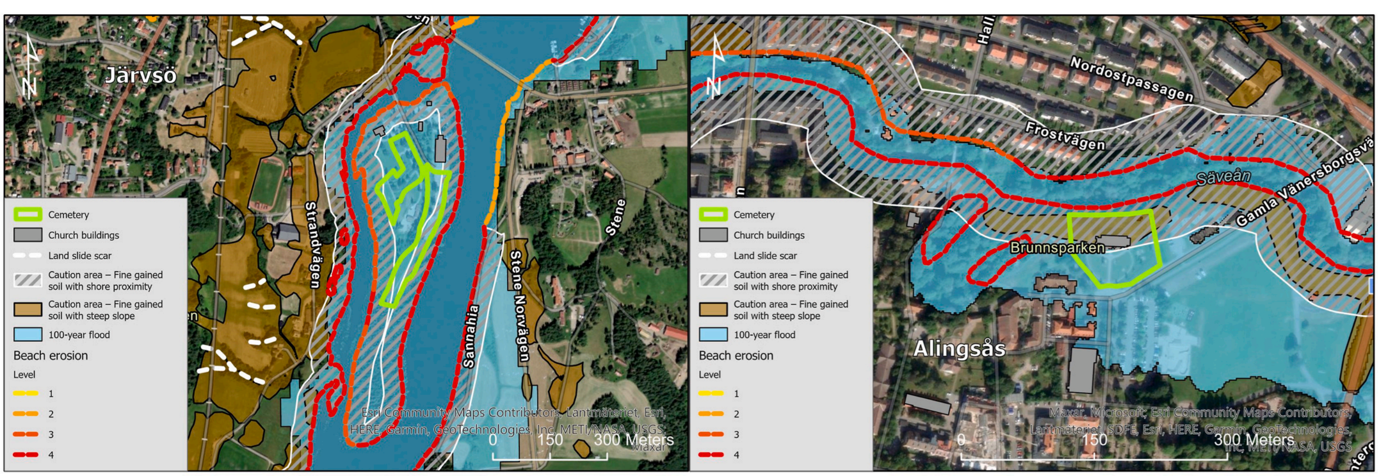

Fig. 4a and b. Low scenario and impacts on cemeteries in Järvsö and Alingsås. For reference concerning locations, see Fig. 3.

affected by both landslides/erosion and flooding in the low- and medium-scenarios. In the high scenario the number of human remains rises, especially due to flooding. The extrapolation of the number of living survivors (based on Krull, 2022) reveals that it ranges from 3.2 to 5.4 million.

Perhaps it is more logical to focus only on cemeteries that are impacted to a higher degree? Hence, on the second level, cemeteries with a minimum of 50% of the area covered were included. The number of impacted cemeteries naturally decreases. 33 cemeteries are impacted in the low scenario, 35 in the medium and 72 in the high scenario. Most cemeteries are impacted by erosion or landslides. The area varies from 420 000 m^2 to some 920 000 m^2. The number of interred human remains impacted is 58 168 in the low scenario, 66 088 in the medium and 127 296 in the high scenario. The number of impacted survivors ranges from 290 840 to 636 480. In a final simulation, only cemeteries impacted on a severe level were included. This applies to cases impacted to a minimum

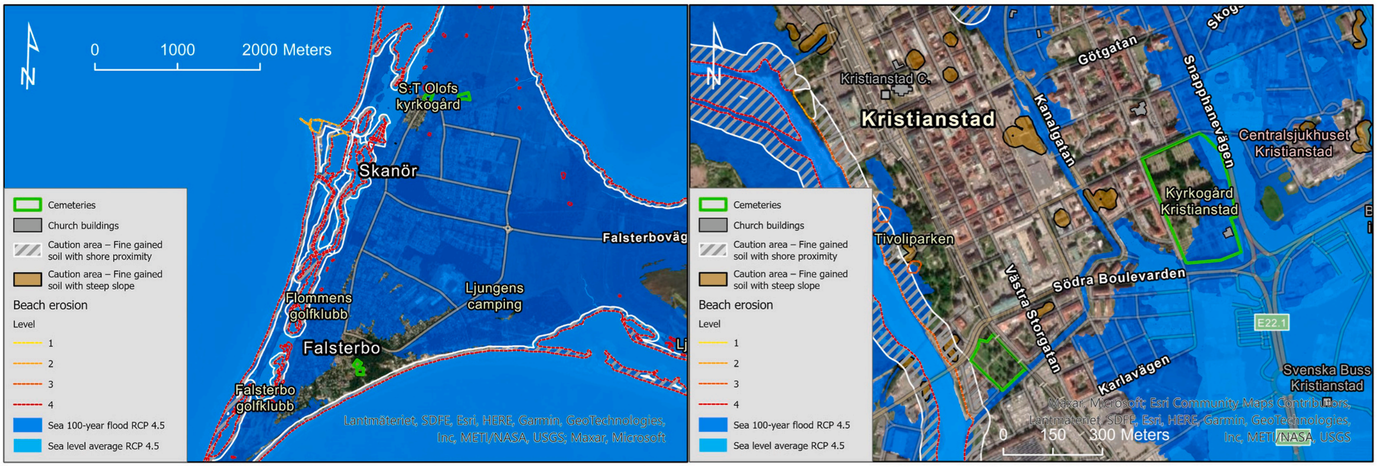

Fig. 5a and b. Medium scenario and impacts on cemeteries in Skanör/Falsterbo and Kristianstad. For reference concerning locations, see Fig. 3.

Fig. 6a and b. High scenario and impacts on cemeteries in Älvsåker and Lindesberg. For reference concerning locations, see Fig. 3.

of 75%. Here we are down to 17 cases in the low scenario, 16 in the medium and 41 in the high. Some 26 000 to 77 000 interred human remains, and between 130 000 and 387 000 survivors, are impacted.

The geographical distribution of impacted cemeteries varies throughout Sweden (Fig. 3). Some areas are more vulnerable than others due to variations in precipitation, type of soil, elevation and sea level rise. This applies especially to southwestern Sweden, and typically the counties of Västra Götaland and Halland (see Fig. 2 for orientation). Here, specific types of fine-grained soil occur in conjunction with hilly landscapes and high precipitation levels; creating preconditions for landslides and erosion. For cemeteries in the low scenario with at least 75% of the area impacted, 14 (82%) are in these counties. Cemeteries outside these counties are mostly impacted on low levels. The only cases with more severe impacts in the low scenario are in the village of Järvsö in Gävleborg county (see Fig. 4a below), where the close proximity to the river is hazardous. In the medium scenario there is a spread of affected cemeteries in other counties as well, mainly in southern Sweden. This is greatly due to a sea level storm surge scenario is available. Examples of this are cemeteries in Skanör/Falsterbo and in the city of Kristianstad (see Fig. 5a & b below). The high scenario includes many more affected cemeteries, notably in Värmland, Dalarna, Gävleborg and Västernorrland counties, and to some degree in Västerbotten and Närke (see Fig. 6a & b. Fig. 2 for reference). Hazardous localities are mainly river valleys with a steep inclination, increasing the risk of not only erosion and landslides but also flooding. Interestingly, the sea level rise and storm surges in the sea have minimal impact on Swedish cemeteries. Only seven cemeteries are affected by an average sea level rise in the low scenario, with the most extreme case only involving 7% of the cemetery's area. In the medium scenario, which includes the storm surge simulation, the number increases: 35 cemeteries are affected, but most of them with only minor impact. Only 11 of them are impacted with over 10% of their area affected. Only eight cemeteries are affected by the average sea level rise (RCP 4.5), with the most extremely affected case having 22% of its area impacted.

In the high scenario a total of 310 cases are distributed throughout the country. Cases are added, especially to southwestern Sweden, where the annual precipitation levels are expected to increase the most and where the number of cemeteries is high. Cases are almost evenly distributed between the problem categories. According to the different climate-change scenarios presented in this study, the low scenario incorporates cemeteries where these problems will appear first, especially those that are impacted the most (more than 75%). The case of Alingsås, depicted in Fig. 4b, is the most severely impacted cemetery in Sweden according to this scenario, with multiple risks present.

4. Discussion and conclusion

As argued by Mueller and Meindl (2017), previous research has examined climate change impacts and adaptation in relation to infrastructure and ecosystems but focused only to a limited extent on historic and culturally important places. The results of this study show that expected climate change in Sweden will have profound effects, not only on the living and mobile society of today, but as well on: cultural and memorial sites and places for remembrance, the relation between the living and the dead, and the possibility for eternal rest. It is also evident that this is not a marginal phenomenon, as it will impact thousands of interred human remains and thousands of living survivors. Our results confirm that similar problems associated with climate change, as described in other studies, are likely to occur in Sweden as well (c.f. Schexnayder & Manhein, 2017; Mueller & Meindl, 2017; Čakar et al., 2018; Tran et al., 2021). Given the estimated magnitude, this needs attention in order to mitigate the risks and, in some severe cases, perhaps involving relocation from places that in the future are deemed unsuitable for cemetery purposes.

This study has focused on climate change and involves several insecure presumptions about the importance of different effects of erosion, flooding or sea level rise (Fig. 1), but as it builds on established national data, it can be used (and transformed if necessary) to indicate a change that will come, and that society needs to prepare for. The results of this study can be used for different aims: One could be as a basis for discussions about the stringency of Swedish burial legislation, which is also challenged by cultural factors related to migration, new cultural influence etc. Another use, both at short and long term, is as a basis for cemetery location to avoid risk factors for future cemeteries.

Looking at the importance of different climate effects in this study, on conclusion is that the estimated impacts of sea level rise and associated problems are of minor importance, compared to those of landslides and erosion. This is partly due to the existing land rise in many parts of Sweden, but relates also to the application of a rather modest and low estimate of the potential impacts that we have used in this study. For example, we do not apply Bruun's rule (Bruun, 1962) in our risk assessment of shoreline erosion. The number and extrapolation of affected survivors should also be commented as we have chosen to use a rather low estimates for the number of survivors affected. On cemeteries as physical and cultural landscapes, the need for relocation (or abandon) of human remains, and on the possibility for continuing bonds in relation to individual, religious and cultural aspects, should be taken into account in any discussion of future societal planning.

When it comes to the consequences of this likely future, many questions arise. The numerous human remains at risk of being relocated, is of course neither intentional (see Swedish burial legislation) nor expected among individuals before they pass away. Interesting is how Swedish legislation that supports eternal rest, the practiced guarantee for a minimum of grave right of 25 years (Sveriges Riksdag, 2022a), will cope with new knowledge about the impact of climate change on Swedish cemeteries among individuals and in society. How will the knowledge of vulnerable cemeteries affect the process of selecting places of burial for family members and people's possibility to be buried adjacent to a close family member? In addition, how will it affect the feeling of security and well-being when buried kin are at risk for disturbance or relocation, and thereby will lose the permanent rest that was the chosen option? A violation of legislation and norms, at least in Sweden, which could not be considered before the actual knowledge about climate effects. On the other hand, the possibility to relocate interred kin due to climate-related or other impacts, might give new and unique possibilities for survivors in Sweden to reconnect to their kin by moving the remains to a more secure and maybe even closer place.

This paper focus on the aspect of Swedish cemeteries as a place for burial and mourning, but stretches out also towards the issue of cemeteries as public green space, appreciated for their greenness and maintenance (Grabalov, 2018; Nordh et al., 2017, 2023; Nordh & Wingren, 2023). Hence, the relocation or disturbance of cemeteries, for whatever reason, is an issue that relates to most individuals in society. Therefore, the results generated here offer the opportunity to investigate, plan and prepare for new cemetery situations, not only in relation to the cemetery administrations of identified vulnerable cemeteries but also for society as a whole. The study can be used to develop a *"best practice"* and for being pro-active in relation to landscape changes related to climate change, both at a local and national level.

We acknowledge that predicted climate change scenarios are highly uncertain regarding how they will play out. The same applies for local geographies. However, this study is based on the knowledge we have today and can as such be developed further in future. It should be seen as a starting point for further studies, on how the relation between climate change and the (re-)location of cemeteries can be looked at. But as well in a prolongation, it can be used for other threats like exploitation, mining etc. Taking on a national perspective, this study shows that utilizing multiple data sources, in conjunction with GIS-analysis, we can move forward from occasional case studies and make assessments of the problem on a higher aggregate level, regardless of national contexts.

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Roger Marjavaara: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Wingren Carola:** Writing – original draft, Validation, Investigation, Conceptualization.

Declaration of competing interest

The authors report there are no competing interests to declare.

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