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Farmers ́ sense of the biological impact of extreme heat and seasonality on Swedish high-yielding dairy cows – A mixed methods approach

Lena-Mari Tamminen [a,*], Renée Båge [a], Maria Åkerlind [b], Gabriela Olmos Antillón [a,*]

[a] Department of Clinical Sciences, Swedish University of Agricultural Sciences, Uppsala 75651, Sweden
[b] Växa Sverige, Uppsala 751 05, Sweden

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ABSTRACT

Supporting dairy farmers in becoming resilient towards extreme weather requires a broad understanding of the experiences and perceived risks associated with these events from those who undergo them. We used a mixed methods approach to explore national trends of biological consequences on dairy cow udder health and fertility, combined with in-depth farmer conversations around extreme weather events, focusing on heat. The aim is to provide a comprehensive picture of how dairy farmer perceptions, priorities and decision-making are related to the season and extreme weather to identify preventive pathways that can reduce biological costs of heat stress on Swedish dairy cattle during summer. Data collected monthly at cow and farm level between 2016–2019 as part of the Swedish milk and disease recording system confirm seasonal trends and show increased somatic cell counts (SCC) and negatively impacted fertility during summers. In addition, transcriptions of 18 interviews with dairy farmers across the country and seasonal variations of SCC and fertility were thematically analysed. The results suggest that farmers have a broad definition of extreme weather and are aware of the negative impacts. Yet handling of extreme weather events can mainly be classified as reactive. Nevertheless, there are long-term effects on the farm economy, health and herd dynamics. Swedish dairy farmers are currently showing resilience, albeit a fragile one. The capability to ensure sufficient feed production in extreme weather is critical for farm self-perceived resilience. However, acknowledging the long-term biological costs related to fertility, currently not perceived by farmers, has the potential to support proactive planning and improve farm resilience and profitability.

1. Introduction

Extreme weather (EW) events are increasing globally because of climate change, especially rain, droughts and hot spells. In Sweden, the summer of 2018 saw weather conditions that were extreme, due to long periods of unexpected high temperatures and little rain (Sjökvist et al., 2019). These events had significant effects on the overall society. For instance, wells went dry, wildfires increased, the health of elderly people was impaired and farming was negatively affected (Johnsson et al., 2019). Heat is an important threat to dairy production as dairy cows are highly sensitive to heat stress which has tremendous biological cost to them (Fabris et al., 2019; Guzmán-Luna et al., 2022). Heat stress will not only decrease milk production but also reduce health and welfare (Polsky and von Keyserlingk, 2017). Heat stress cause general discomfort and alterations in dairy cows' physiological parameters, such as immune response (Bagath et al., 2019; Turk et al., 2015), and increased incidence of clinical mastitis has been observed during summers (Vitali et al., 2016). In addition, heat negatively impacts fertility, for example, through disrupted follicular development or embryonic losses, and indirectly disrupting oestrus cycles and reducing the expression of oestrus behaviour (Sammad et al., 2020).

Temperature humidity index (THI) is a commonly used indicator for when a cow can experience heat stress (Hoffmann et al., 2020). For temperate regions, a THI of 65 (i.e. 25 °C +20% humidity or 22 °C + 50% humidity) is considered a critical threshold (Pinto et al., 2020). Nonetheless, dairy cows change their behaviour already at a THI of 56 (Hut et al., 2022) (Pinto et al., 2020). In Sweden, the maximum average THI reaches well above 65 during ordinary summers and in the summer of 2018, the hottest summer so far recorded (since 1951), the maximum THI was between 78–80 in the south and 72–78 in the north (SMHI,

* Corresponding authors.
E-mail addresses: lena.mari.tamminen@slu.se (L.-M. Tamminen), renee.bage@slu.se (R. Båge), maria.akerlind@vxa.se (M. Åkerlind), gabriela.olmos.antillon@slu.se (G. Olmos Antillón).

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2021). In a recent study we have shown that temperatures from 20 °C are associated with reduced milk production and increased economic costs to the Swedish dairy industry (Ahmed et al., 2022). While it is clear that heat can pose problems for the high-yielding cows in Swedish dairy production, the biological costs related to fertility and SCC and how these are perceived by the herd managers have been less explored. An important difficulty for evaluating any connection between heat stress and biological costs in the Swedish dairy herds are the between- and within-herd management practice changes occurring during the warmest months. For example, a key change across the country is the mandatory provision of access to pasture (60–120 days) during spring/summer (SJVFS, 2019). This means that estimating the impact of heat stress by correlating the differences observed with THI or comparing the summer and winter season, using for example summer to winter ratios (Flamenbaum and Ezra, 2007), will be confounded with the effect of seasonal changes in management. The close correlation between heat (i.e. THI ≥65) and the summer months in Sweden means that separating the effects of heat and seasonal changes in a field study is difficult. However, the warm temperatures during the summer of 2018 differed from other years and comparing this year to other years provides an opportunity to study the effect of adding additional heat. This effect is important because the temperatures observed in 2018 match the predictions of what to expect of future summers in Sweden as climate change progresses (Sjökvist et al., 2019). However, simply estimating the impact at a population level does not automatically lead to improvements in dairy farm resilience. While it is acknowledged that the identification of a problem is the first step towards acting, the performed action is a result of a series of decisions that are impacted by perceived threats, barriers and susceptibility (Janz and Becker, 1984). Swedish dairy farmers' sense making of EW events is currently undescribed, although it is assumed that it is complex and dependant on associations and experience-based knowledge (Asplund, 2014). Thus, while the extremely hot and dry summer of 2018 has steered the national debate to EW events related to heat and droughts in Sweden, other EW events may also provide significant challenges to agriculture and animal production and thus be perceived as of greater importance by farmers. Additionally, there are other recurring seasonal challenges associated with the warm summer period that may take precedence over heat related EW events.

In addition to the perception of the problem and the risk, the perceived efficacy of different measures, in combination with barriers and capability of the farmers, will steer if and which preventive measures are implemented (Janz and Becker, 1984; Robert et al., 2016; Svensson et al., 2019). However, the efficacy of specific measures is not constant. For example, the most efficient measure for handling climate change and sudden stressors, like EW events, depends on whether the measure is taken reactively, i.e. during or after an event, or proactively, i.e. taken before the event (Stewart, 2009). In addition, the efficiency of preventive actions can also differ depending on whether short or long-term effects are considered and on which following decisions are made over time (Robert et al., 2016). This complexity should be considered when exploring the decision-making process for handling different types of extreme weather on farms. Yet, gaining knowledge of such complexity demands a multidisciplinary approach.

To support dairy farmers in becoming resilient towards EW in general, a broad understanding of farmers perceptions is needed. But currently little is known about how dairy farmers' perceive EW events and the impact on their animals now and in a warmer future. In this study a mixed methods approach is used to jointly explore the national trends and farmers' perceptions of the biological consequences on dairy cow udder health and fertility during a "normal" vs an extremely hot summer (2018). Moreover, we explore how such consequences are perceived by farmers, with a contextualized focus on heat and its potential biological impacts to their herds. The aim is to provide a comprehensive picture of how dairy farmer perceptions, priorities and decision-making are related to seasonal weather changes, heat and EW events to identify preventive pathways that can reduce the biological costs of heat stress on Swedish dairy cattle during summer.

2. Materials and methods

Our study follows an explanatory mixed methodology design (Creswell and Clark, 2017). First quantitative data from the Swedish national milk and disease recording scheme (SMDRS) were analysed to identify national trends of SCC and fertility variables under normal and abnormal summer conditions (2018) and to identify cases (i.e. farms that manage the summer period without changes in udder health and fertility and farms that experience negative impact) for the qualitative phase. In-depth semi-structured interviews with the identified Swedish dairy farmers were then performed, and the results were integrated and summarized as themes. An overview of the different parts of the study is presented in Fig. 1.

For the interaction, integration and synthesis of quantitative and qualitative phases we followed a meta-theoretical perspective of Scott́s critical realism where ontology (the way things are) determines epistemology (the way things are known) leading to an epistemic relativism embraced by using an inductive/deductive analytical approach (Scott, 2007). A critical realism perspective allows combining quantitative and qualitative data sets, methods and analytical frames at the ontological level (thought and reality are fused), allowing the exploration of diverse perspectives and uncovering relationships that exist in multifaceted research challenges. Here the qualitative component focuses on deep and detailed descriptions of experiences, actions, practices, activities and interpersonal interactions from fieldwork and it is analysed jointly with the national trends for the interpretation of the meaning of a situation (i.e. EW events) from the decision maker (i.e. farmer).

2.1. Ethical statement

In consultation with the ethics and legal department at the Swedish University of Agricultural Sciences university, in agreement with the Swedish Ethical Authority, the study did not require a special provision or permit according to Swedish law (SFS 2003:460). Nonetheless, a strict code of conduct as set out by the Swedish Research Council (Swedish Research Council, 2017) was followed; including gaining informed consent by all the participants and guaranteeing the pseudoanonymisation of their responses and herd registry data. Furthermore, no sensitive personal information was discussed nor collected during the process. No financial incentive was offered to farmers in exchange for their participation. Nonetheless, the results of the project (e.g. their fertility variables and SCC) were presented at a later occasion and discussed with each farmer over the phone or on the farm. Additionally, a paper copy was sent by email.

2.2. Overarching study population and measures for descriptive and quantitative analysis

This study includes data from the SMDRS from 2016 to 2019. Details on data used can be found in Anonymous et al. (2022). Farms with a minimum of 50 calvings per study year, participating in the SMDRS, were included in the study. Somatic cell counts (SCC) were retrieved from monthly test-day milk records and summarised at herd level (Table 1). To study seasonal deviations during the years, the herds' average monthly SCC was calculated based on individual test results. In addition, the deviation and proportional deviation of monthly SCC to the yearly herd average SCC for each study year was also calculated.

The SMDRS also collects fertility parameters like inseminations and calvings. Firstly, average number of expected calvings per month, assuming an evenly distributed calving pattern over the year, was calculated by dividing the total number of calves born per year by 12. Then the proportional deviation from herd average for each month was calculated. Secondly, the pregnancy rate within 30 days after the herd-

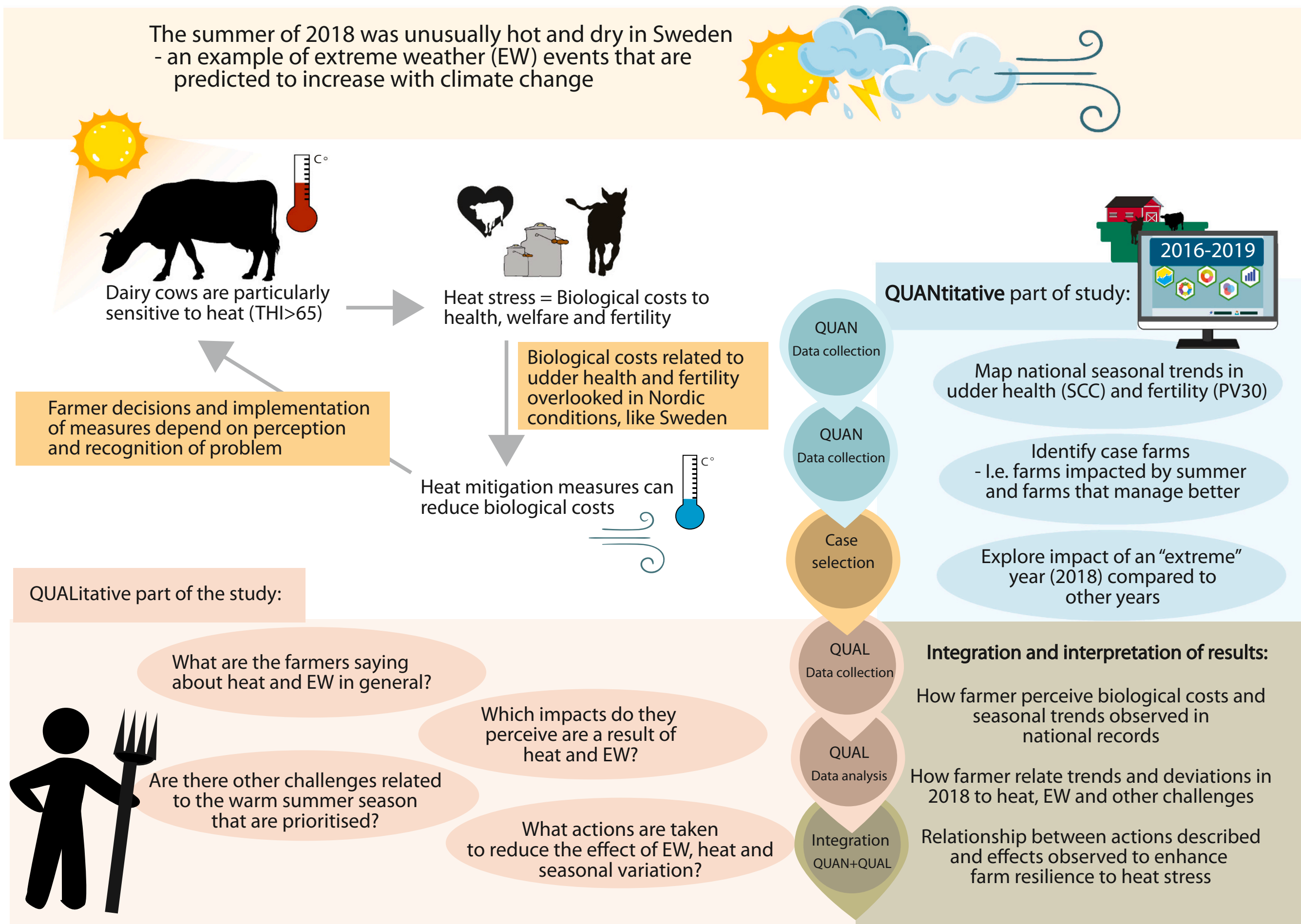

Fig. 1. Visualisation of the quantitative and qualitative part of the study and how the results were integrated in the analysis.

Table 1
Summary statistics of herds participating in the monthly trial milking between 2016–2019. SD=Standard deviation.

	2016	2017	2018	2019
Number of farms	1235	1251	1252	1258
Average Somatic Cell count *[x10^3 cells/mL milk]* [SD]	223.0 (86.8)	243.8 (82.1)	253.4 (85.6)	261.3 (89.9)
Average kg milk/ cow and day (SD)	32.9 (3.8)	31.07 (3.63)	31.0 (3.8)	31.4 (4.0)

specific voluntary waiting period (PV30), a composite reproductive performance indicator showing the proportion of eligible cows identified in oestrus, being inseminated and becoming pregnant, was calculated (Löf, 2012). PV30 includes both the animal's biological ability to get pregnant and the reproductive management, like oestrus detection and insemination skills, on farm (Löf, 2012). The herd specific voluntary waiting period (VWP) used in the calculations was estimated by identifying number of days after calving at which 10% of the animals had been inseminated. PV30 on a herd level was calculated for each calendar month and the yearly farḿs averages. Then the monthly deviation of each farm from this average was calculated. Successful pregnancies were identified as insemination periods followed by a calving or a confirmed, positive, pregnancy check. Data from 2019 was only used to identify calvings following inseminations and not included in the analysis of farḿs deviation in PV30.

Descriptive and quantitative analysis was performed in R (R Core Team, 2018) and visualised using ggplot2 (Wickham, 2016) and ggeffects (Lüdecke, 2018). Significance of seasonal trends in monthly average SCC, proportional deviation from expected number of calvings as well as deviation of the farms' average PV30 were explored using generalized additive models for large datasets (Wood, 2011). Models were fitted with fast REML computation and fitted with a "scat" distribution developed for heavily tailed response variables (Wood et al., 2016). Month was modelled with a cubic cyclic spline by year (allowing different smooth terms for different years). Herd was included as a random effect in all models to account for clustering. When modelling SCC the farmś monthly average days in milk, average milk production (kg) per cow and average lactation number from each trial sampling were included to account for confounding. Initially as non-parametric coefficients with smooths but after evaluation of linearity all except average days in milk were included as parametric variables. Biologically plausible interactions were evaluated using AIC. Normality, heteroscedasticity were evaluated using residual plots and model residuals were evaluated for remaining autocorrelation (Van Rij et al., 2022). Final model setups are described in Table 2.

2.3. Qualitative component

2.3.1. In-depth interviews participantś selection

The study sought to attain a theoretical maximal variation of experiences on the impact of yearly heat events on SCC and fertility of a dairy herd. For that, we actively sought participants that showed an increase in SCC, a decrease milk production or fertility. Equally, farms that did not show such variation during summer months. Data from the overarching study population was used to estimate impact of summer on SCC and fertility at farm level. This was estimated by calculating the average

Table 2
Overview of models fitted to describe seasonal deviations in somatic cell counts and fertility (pregnant within voluntary waiting period plus 30 days and monthly calvings). NP = Modelled with non-parametric thin plate regression spline, CC = Modelled with cyclical cubic spline, P = no smooth applied, F = Factor, ECM = Energy corrected milk.

Outcome	Explanatory variables	Deviance explained
Somatic cell count (SCC)		
Deviation of SCC from yearly herd average (%)	Season: Month (CC), Year (F) Average of sampled cows: kg ECM/cow (NP), days in milk (NP), lactation number (NP) Farm: Herd id (random effect), Average yearly SCC (NP) Interactions: Month x year, Month x kg milk/cow, Month x Yearly SCC, Yearly SCC x kg milk/cow	8.36%
Average SCC (1000 cells/mL)	Season: Month (CC), Year (F) Average of sampled cows: kg ECM/cow (NP), days in milk (NP), lactation number (NP) Farm: Herd id (random effect) Interactions: Month x year, kg milk/cow x days in milk, days in milk x month, kg milk/cow x month	32.4%
Fertility		
Deviation from expected calvings (%)	Season: Month (cc), Year (F) Farm: Herd id (random effect) Interactions: Month x year	9.1%
Monthly deviation from yearly herd average PV30 (%)	Season: Month (cc), Year (F) Farm: Herd id (random effect) Interactions: Month x year	3%

summer deviation in SCC and fertility estimates (PV30) from the yearly farm average for 2016 to 2018. From this a list of 100 farms with the smallest and largest deviation in SCC as well as the 100 farms with smallest and largest deviations in PV30 was created. Farms from such list with more than 50 dairy cows were purposively recruited to achieve variation in seasonal impact as well as geographical spread via the leading dairy farm advisory company VÄXA Sverige, which has a well-established trust relationship with dairy farmers (Fig. 2). The purposive sampling from the identified farms was performed with the aim of providing contrast in the participating voices and increase the opportunity to identify differences in the experiences arising from farms with large and little impact. Informed consent was gained from all participating farms ahead of the interview process taking place. The characteristics of the farms participating in the in-depth interviews are presented in Table 3. The selection consisted of 18 farms, including 6 cases and 9 controls for mastitis (Case = Large, consistent seasonal deviations in SCC, Control = Small seasonal deviations in SCC) and 7 cases and 3 controls for metritis (Case = large, consistent seasonal deviations in PV30, Control: Small seasonal deviations in PV30). Several farms were combinations, for example 3 were cases for both mastitis and fertility (Table 3).

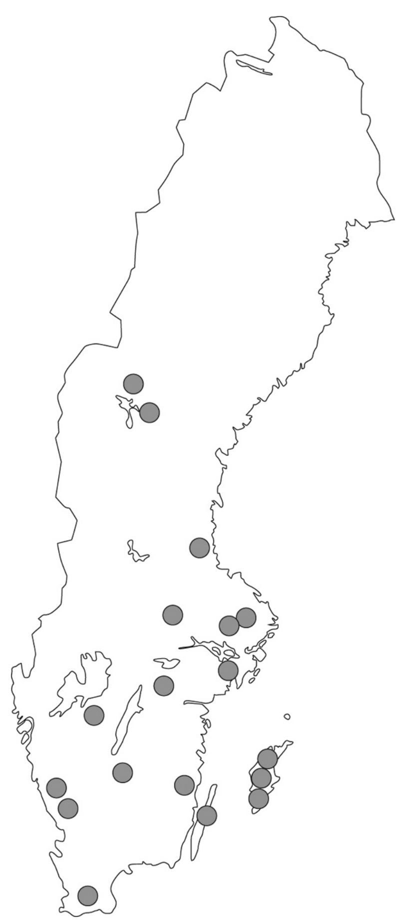

Fig. 2. Geographical location of the 18 participating farms for in-depth interviews. Location is an approximation so to maintain participants' privacy.

Table 3
Description of farms participating in the in depth interviews and farmer's perceived impact of heat on cows. AMS =Automatic milking system. ECM = Kg Energy corrected milk. M Case = Large, consistent seasonal deviations in SCC, M Control = Small seasonal deviations in SCC, F Case = Large, consistent seasonal deviations in PV30, F Control: Small seasonal deviations in PV30.

ID	Average kg ECM/cow and day (2018)	Average SCC ($x10^3$ cells/ mL milk) (2018)	Dairy cows (no.)	Milking system	Barn type	Perceived impact of heat on cows and the barn
111223 M: ControlF: Case	28.8	216.0	120	AMS	Insulated new barn (2020) with fans and adjustable walls.	Less impact in new barn. Mainly relates problems to ensuring good feed hygiene and fetching animals on pasture (although not such a big problem).
111509 M: Control	30.2	362.0	130	AMS	Insulated barn (2004) that opens at the gable. Plans to install fans the coming year.	Experiences that animals gather in specific places (with better airflow) during hot days. Experiences reduced feed intake and reduced activity.
111733 F: Case	29.7	344.0	60	AMS	Insulated barn from 2014. Cannot open up sides of barn.	Experiences that hot days are a problem because cows reduce activity and feed intake.
111756 M: Case F: Case	24.5	248.0	78	Milking parlour	Insulated barn from 2007. Gables can be opened to increase wind flow.	Describes signs of severe heat stress and that animals are lying down during hot days. Uses a hose to cool individuals in severe cases.
111842 M: Case	29.8	268.0	220	Milking parlour	Insulated barn from 2008 with fans.	Main problem is increased somatic cell counts and drop in milk production. Puts cows to pasture during cooler hours to avoid heat stress.
112094 M: CaseF: Case	36.4	254.0	60	AMS	Barn from 2001 with insulated roof.	Only experiences problems with heat a few days per year. Connects reduced production and poor health and fertility with pasture.
112116 M: Control	26.9	197.0	120	AMS	Older, rebuilt barn (1994) without insulation and some opportunities to open up windows and doors. However, ventilation could be better according to farmer.	Mainly impacted by heat and drought in 2018. Traffic goes down every summer, relates this to pasture. Animals change their daily pattern and eat during evening/early morning during hot days.
112606 M: Case	30.3	275.0	240	AMS	Relatively new barn (2017) with good cooling opportunities.	Experiences high impact of heat, lost animals because of mastitis related to hot spells in 2018 and struggles with feed hygiene.
112700 M: CaseF: Case	27.1	350.0	65	AMS	Insulated barn from 2009. Ventilation that adapts to wind and temperature by adjusting wind flow.	Experience a drop in milk, increased cell counts and that cows are inactive and panting during hot days. Tries to cool animals with water hose during warm days.
113064 F: Control	27.8	276.0	220	Milking parlour	Barn from 1999. Experimented with sprinkler cooling during 2018.	Has less problems after installing fans 2019. Before animals would reduce activity during warm days.
113198 M: Control	22.0	293.0	130	AMS	Barn from 2009 with insulated roof and adjustable curtains on the side.	Has experienced problems with droughts and poor feed availability as a result of weather.
113268 M: Control	24.8	297.0	130	AMS	Non-insulated old barn with high ceiling. Open sides and two fans over cubicles. Cows feed outside under shade.	Experiences negative impact shorter periods during summer. Cows drop in activity, milk and more difficult to get pregnant.
114258 M: Control F: Case	27.6	304.0	95	Milking parlour	Insulated barn from 2007. Extra fans after summer of 2018. Experiments with pasture at night and a homemade sprinkler system.	Experiences that cows reduce activity and feed intake during hot days.
114490 F: Control	29.7	89.5	105	AMS	Insulated barn built 2000. Windows along the sides that open and good natural ventilation.	Experiences that the barn remains cool during warm days. Allows cows to pasture at nights during the warm periods to avoid exposing them to heat.
114546 M: Control	31.8	130.0	125	AMS	Barn from 2011 with insulated roof, curtains that can be opened and fans.	Experiences that cows are suffering because of the heat and that mastitis is more common. Also that fat content drops in milk.
115843 M: Case	28.7	253.0	170	AMS	Non insulated barn from 2012 with curtains that open on sides.	Experiences problems with reduced cow activity leading to longer milking intervals during summer. Also problems with feed hygiene.
115939 M: Control F: Case	23.6	289.0	58	AMS	Non-insulated barn built 2008. Fans installed after 2018.	After fans were installed cows prefer to stay indoors in warm weather. Less problems with reduced activity.
115997 M: Control M: Control	26.5	228.0	243	AMS	Insulated barn built 2011. Limited opportunities to open up to ensure wind flow through barn.	Experiences that heat causes problems in activity and cow traffic but also indirectly through negative effects on feed, which in turn causes health problems.

2.4. Interview process, qualitative analysis and mixed methods integration

The interview guidelines were developed by the last (GOA) and first authors (LMT) in consultation with the co-authors (RB, MÅ) and other field advisors working closely with Swedish dairy farmers during 2018 events. Interviews were structured around four topics; a) the general health situation of the farm, b) their definition/experiences of EW, c) a description of any on-farm challenges associated with weather events and specific challenges related to animals and heat/the summer season. Lastly, d) they described the current/future perspectives on how to cope with the challenges. Farm interviews were done in Swedish either on-farm face-to-face (n = 11), via videoconference (n = 2) or over the phone (n = 5) during spring 2021 by the first (LMT) and last author (GOA). When conducting these interviews, we adhered to an interview agenda to ensure each of the topics was addressed. Yet, the pace and flow of the interview was guided by what we as interviewers interpreted as meaningful to the interviewee, thus weaving in and out of topics as necessary (i.e. semi-structured). The interviews lasted on average one hour and they ranged from 40 min to 1.5 h. The interviews were followed by a short survey section (data not shown here) and a walk on the farm when interviews were done on site. At the end of each interview LMT and GOA discussed their impressions and took reflective notes that were later revised when themes were constructed. All interviews were voiced recorded and manually transcribed verbatim in Swedish. Only representative phrases for exemplification of the identified themes were translated into English by LMT. The transcriptions, field notes and post-interview notes (memoing),were open-coded with the aid of Dedoose application for managing, analysing and presenting qualitative and mixed methods research data (Version 9.0.85, 2021; Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com) by the last and first authors. A Reflexive Thematic Analysis (Braun and Clarke, 2022, 2019; Byrne, 2022) was used meaning the qualitative data set was analysed predominantly inductively within one inductive/deductive continuum where quantitative phase results were part of the analytical process. Thus, the qualitative dataset was open-coded, and farmers' meanings were emphasised around central themes arising from the data, curated according to relevance of the research questions. Coding went beyond the descriptive level of the data in an attempt to identify meanings, underlying assumptions and ideas of farmers around EW, heat and seasonal changes and its impact to their animals. For this analytical process, the first and last authors familiarized themselves with the field notes and transcribed text independently generating initial codes capturing the salient features of the dataset. Through jointly interactive discussions that included the third author comments, initial themes were drafted and later on revised for a final selection.

The final detailed themes were jointly constructed by LMT and GOA. Themes integrated the qualitative and quantitative phases/datasets of the study following a meta-theoretical critical realist stance (Scott, 2007) where synthesis and contextualisation of the data are reported as a joint section (Braun and Clarke, 2022, 2019; Byrne, 2022). This is a significant departure from the traditional reporting convention followed by research with either a positivist or deductive-oriented thematic analysis stance inconsistent with the framework and methodology of our study.

2.4.1. *Authors' positionality statement*

All authors of this paper have experience in and connections to the dairy sector in Sweden and abroad. LMT, GOA and RB have a veterinary degree. MÅ works as an expert cattle nutritionist at Växa Sweden and has a graduate degree in animal nutrition and management. RB holds a professorship in domestic animal reproduction and is a European Diplomate in animal reproduction, subspecialty ruminant reproduction and herd health, LMT has a graduate degree in epidemiology and GOA a graduate degree in applied animal behaviour and welfare; all fields traditionally quantitatively oriented. However, LMT and GOA regularly conduct social enquiries or mixed methods research guided by different paradigms. Moreover, GOA holds additional training in social sciences connecting traditional epidemiological research with qualitative approaches to enhance understanding of stakeholders' decision-making related to animal welfare. Her broad aim is to bridge scientific understanding of risk factors of poor health and welfare to contextualized practical solutions by highlighting contested knowledge among animal caretakers and a way forward. LMT is a postdoctoral fellow aiming to improve the welfare of dairy cattle by conducting research with people who care for animals. RB acknowledges the need to investigate dairy producer and animal caretakers perspectives through interviews, to facilitate a better uptake of scientific evidence and reducing the practical know-how gap in Sweden and internationally. All authors believe there

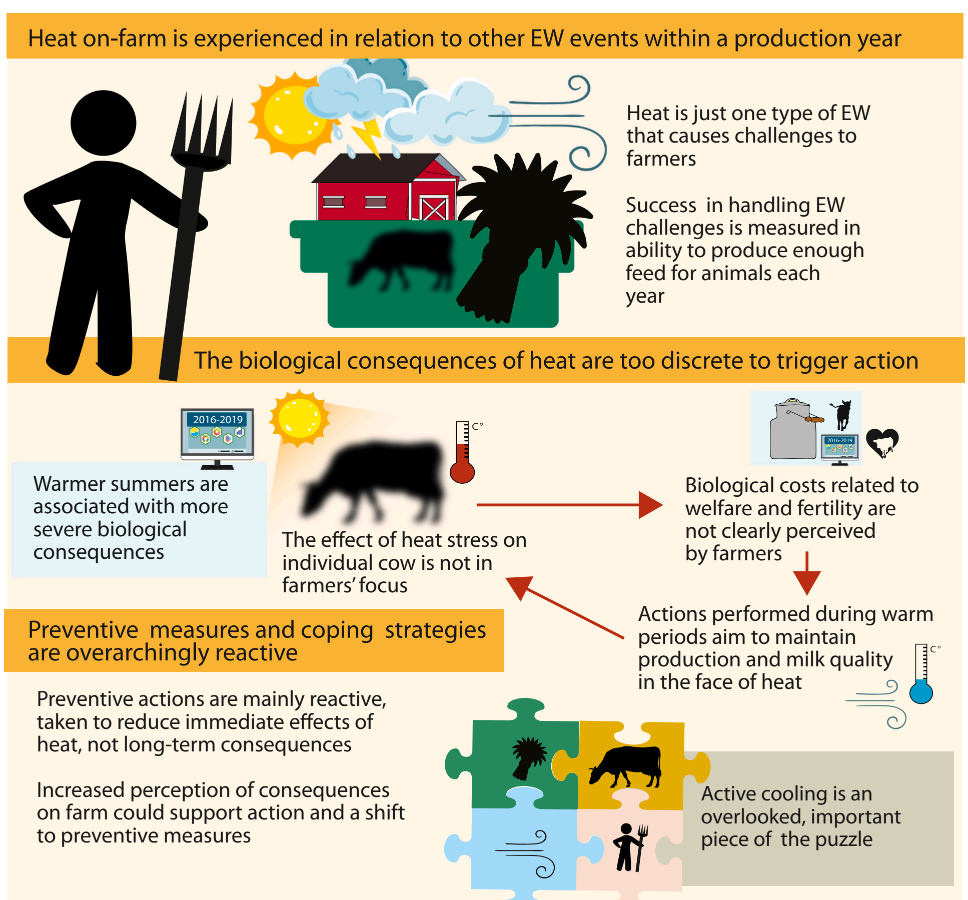

Fig. 3. Thematic map visualising the three prominent themes derived from analytical integration of quantitative and qualitative results.

are no irrational farmers but a lack of contextualized understanding of their needs and aim within their farm.

3. Results and discussion

Our aim was to provide a comprehensive picture of how Swedish dairy farmers' experience extreme heat and other EW events. Moreover, by exploring the unusually hot and dry year of 2018 in particular, we aim was to identify if farmers are aware and if so enact any preventive pathways to reduce the biological cost that heat stress can cause to dairy cattle when faced with hot weather. From the analytical integration of quantitative and qualitative results three prominent themes were constructed that summarise the main topics from the national statistics in light of farmers' experiences from extreme weather events. The three themes are presented in Fig. 3 and revolve around how: 1) heat on-farm is experienced in relation to other EW events within a production year, 2) the biological consequences of heat on the herd have too discrete consequences to trigger action and 3) preventive measures and coping strategies are overarchingly reactive. We develop these ideas further in the next paragraphs and discuss the consequences and way forward.

3.1. Heat on-farm is experienced in relation to other EW events within a production year

Conversations highlighted that heat is not the only experienced EW that has affected Swedish farms in recent years (recalled events between 2014 to 2019 included). Although dairy production in Sweden is an all-year round feature, it was clear that participants discussed on-farm events like harvest, silage production, winter feed usage as a circle of yearly events (e.g. 2018 harvest/silage production vs. 2017) where each year needed to have certain success for the year to be recalled as good or poor (Holland and Kensin, 2010). Farmers' memory of the last few years, including the dystopic summer of 2018, conveyed an overarching positive resilience towards the EW events experienced based on their ability to resolve difficulties faced and their prognosis to continue doing so individually or as a community. A farm's ability to solve difficulties was linked to their capacity to feed their animals, a priority for maintaining milk production and financial stability. Thus, feed production on-farm was a key priority over other events in the herd as well as a barometer of success. The construction of the theme is supported by two key ideas:

3.1.1. Heat is just one type of EW that causes challenges to farmers

Although farmers generally considered heat and drought as important types of EW their definition of EW is considerably broader than this. Farmers often mentioned examples of how rain, heavy wind and snow fall affected their farm routines within a year thus, also being considered extreme events. Thus the EW experiences are marked by how they occur in relation to other events in a year and across the years.

> *"Yes, there are different kinds of extreme weather. It can be drought and it can be rain, but also snow. Wind. We rarely have snow, we're getting less and less problems with that. But wind, rain and drought are causing the most problems for us" (F111509)*

> *"In 2014 …there was this big forest fire. As it often is when these things happen, it doesn't feel like it's real in any way, it just happens…a powerful experience, absolutely! But it went well. It's extreme weather that has created these scenarios anyway. And then. well, when we get to the drought of 2018 that also has. it has long-term consequences, even if you sort it out for the moment." (F111509)*

> *"…when you can't even go out in the fields [referring to heavy rain], then I would say that's extreme…if it's so dry that there's no grass to pick up when you're going to do the second harvest, then that's also extreme, it seemed to me… I guess it's up to each person how sensitive they are to what they think is extreme…Now you know that it almost always works out somehow at some point. But it doesn't have to be good, but it will… yes, but somehow it will work" (F115939)*

3.1.2. EW impacts feed production but farmers experience a fragile resilience

While farmers recalled various type of EW events, droughts due to heat, like those recorded during the summer of 2018, stand out in farmers' memory as extra challenging for them. These EW events are perceived as more severe or having more long-lasting consequences. But as described before, there appears to be an overarching confidence towards the described EW events, often referring to how everything *"worked out in the end"* despite the circumstances observed. This indicates that the farmers had been buffering their problems within their farm means. The recurring statements of confidence reflect a certain positive resilience to what farmers perceived as EW, albeit a fragile status. The fragility of such resilience is based on individual farm ability to produce feed (i.e. excess land) or buy it (i.e. savings) despite the EW demands. Thus, the farmer's capacity to absorb the disturbance in feed production resulting from EW events was key to the perceived farm stability in the long term.

> *". There are consequences in the economy that you have to buy in feed. You don't have the room to not manoeuvre that. you might be able to buy feed, but is it financially worth it? You judge. Of course it has consequences and it has consequences for those who work here too [referring to the cows]. It can be anything. If you have problems with feeding" (F115843)*

> *"[referring to the summer 2018]. We were behind with feed, … So that's when you buy grass from everywhere of varying quality. then the third crop was probably the best quality we got then, so I could give it to the dairy cows, but by then there were other consequences. The animals had been a bit heat stressed and we had problems with pregnancies and things like that" (F111509)*

That feed is a prioritised area for Swedish farmers has been previously suggested (Barth and Melin, 2018). Animal production in Sweden has been classified as having a relatively low vulnerability to climate change and Northern Europe has been identified as a region where crop yield may increase with climate change (EEA, 2017; Horn et al., 2022). Yet, the farmers in the study were already expressing challenges with securing animal feed and associate the shifting weather patterns with problems. This suggests that the vulnerability of Swedish dairy producers may be underrated and more comparable to the medium vulnerability projected for production of grains (Horn et al., 2022).

3.2. The biological consequences of heat on the herd are too discrete to trigger action

While farmers described how EW events, specially droughts due to heat, had negative consequences at farm level; there was little discussion over the biological cost these events may have on their animals. If so, this was stated in terms of productivity and milk quality (i.e. increased SCC) rather than physiological or welfare impacts to their animals (e.g. reproduction success). Nevertheless, national herd statistics confirms that extreme heat (i.e. 2018 spring/summer) had an impact that can be separated from cyclical management changes related to spring/summer months. This period was recognized by farmers as the busiest periods on-farm and they described trade-offs as well as in adverted consequences to the herd. This theme acknowledges that such circumstances shade farmers' ability to promptly detect and act to mitigate the effects of heat on the herd. In particular fertility aspects that generate the negative consequences expressed by farmers (i.e. disrupted calving patterns and stressful workflow).

This theme is constructed around five subheadings illustrating SCC and fertility national trends and farmers interpretations of heat stress in cows and milk quality and fertility consequences on their herds.

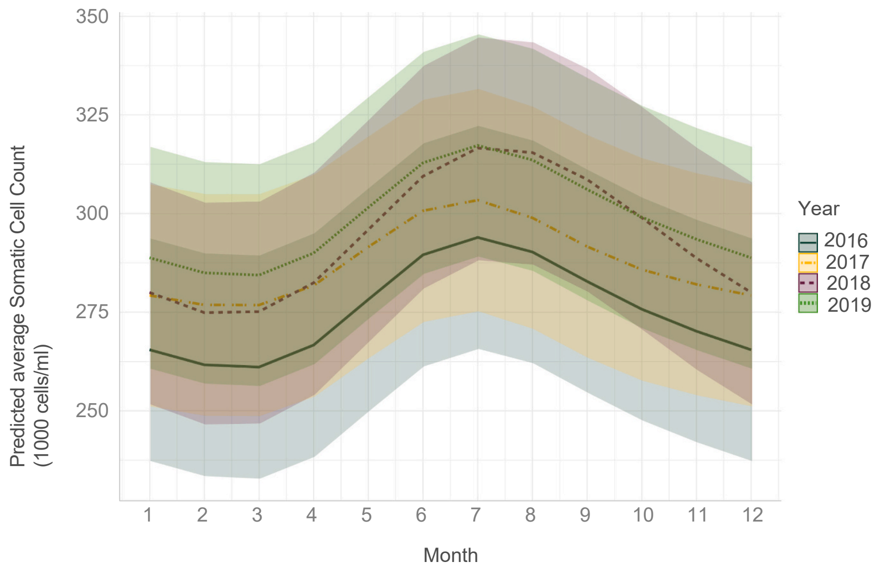

Fig. 4. Predicted herd average somatic cell count by month and year according to Generalized additive model by month ($p < 0.001$). Shaded areas represent 95% confidence intervals.

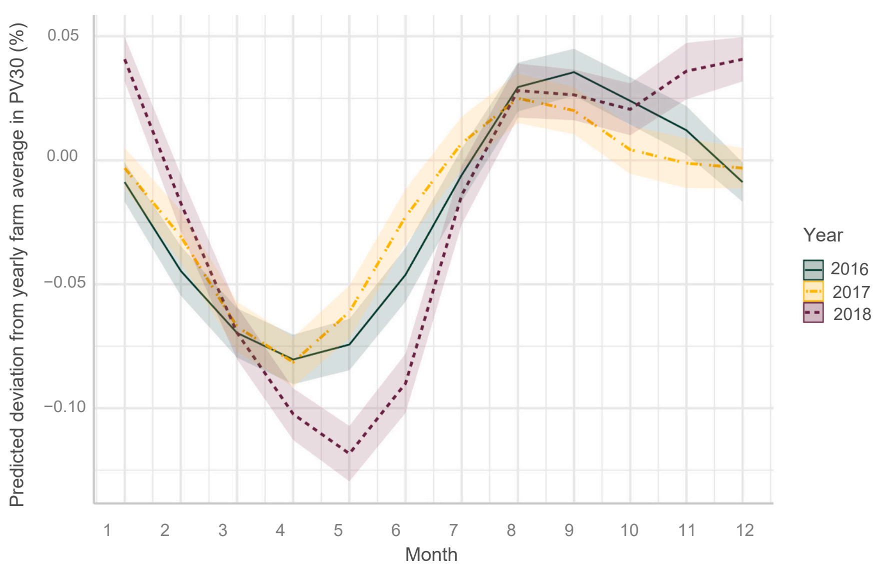

Fig. 5. Predicted seasonal deviation (%) from farm average of pregnancy rate within 30 days after the voluntary waiting (PV30) according to Generalized additive model by month ($p < 0.001$). Shaded areas represent 95% confidence intervals.

3.2.1. *National trends and impact of the summer of 2018*

While ensuring feed availability was the priority when facing EW-events, farmers expressed that they perceived negative impacts of on herd profitability during warm periods in general and 2018 in particular. Exploring the seasonal pattern in Sweden using national data from SMDRS confirms a recurring negative impact on udder health and fertility during summer. For SCC a seasonal trend where the average SCC is lowest in March to peak in August was found (Fig. 4). The proportional deviation in SCC to yearly farm average followed the same pattern (S1, Table 1). Modelling of seasonal deviation in the cows ability to conceive at the expected time point, using the key performance indicator PV30, shows that a smaller proportion of animals that are inseminated during the summer months become pregnant within the herd specific voluntary waiting period (Fig. 5). For both average SCC and deviation in PV30 there was a significant interaction between month and year ($p < 0.001$). SCC was higher during the summers of 2018 and 2019 (Fig. 4) and fertility was more severely impacted the unusually warm summer of 2018 compared to 2016 and 2017 (Fig. 5). It should be remembered that PV30 is a composite measure combining management and physiologic factors. Thus, the deviation observed can be a result of either unsuccessful inseminations, missed inseminations or inseminations at suboptimal times, all to which heat stress can contribute (Rhoads, 2023). On the other hand, the difference between 2018 and the other years may not only be related to heat. For example active decisions to not inseminate animals due to feed shortages may have contributed to the observed reduction in fertility. For SCC on the other hand it is likely that feed shortages would have led to increased culling of animals with poor udder health. This would decrease SCC compared to other years but instead the SCC remain higher in 2019. As heat stress in late lactation can have carry over effects to the coming lactation, both in terms of productivity as well as health status, there is likely some lingering effects from the summer of 2018 (Dado-Senn et al., 2019).

Other interactions included in the final models on SCC suggested that farms with lower average production per cow and higher average of days in milk during summer generally had larger deviations compared to other farms. Yet, these effects were small compared to the effect of month and year (S1, Fig. 1). Model residuals showed no signs of autocorrelation when month and year were included and residuals were normally distributed and heteroscedastic. However, the predictive capabilities of the models were relatively poor indicating that there is unexplained variation in the data (Table 2). As both fertility and udder health are complex and management-dependent it is not a surprise that the models are not able to explain all variation. Thus, models should be interpreted with caution as they indicate seasonal trends in the population and do not represent accurate predictions for individual farms. Full details of the models outputs can be found in the supplementary material (S1, Table 1-4).

3.2.2. Farmers clearly perceive the connection between heat and SCC

In discussion with the farmers, a clear link between summer and hot spells on SCC was expressed. However, while all farmers recognised the impact, their perceptions of control differed. On one hand we had farmers that expressed the situation as an unavoidable effect of summer:

> *"Yeah, It's inevitable. it's. summer cells [referring to SCC] - we've had that as our big dilemma" (F111842)*

Others discussed an active engagement in the challenge of keeping cell-counts down by naming the many reasons why this could happen as well as potential areas of action associated with varying degrees of success.

> *"Interviewer: You say it's hard to keep low cells during the summer and feed hygiene was one reason. What else? Farmer: There are a lot of small streams. We get a little less cow traffic in the summer, always have. Usually drop down there to 2.3–2.4 milkings per day. And it goes without saying, the [milking] interval gets longer …that's where you get the big problems [referring to SCC] or challenges with it" (F115843)*

> *"Interviewer: When you notice the reduced cow traffic to the milking robot and reduced feed intake. What do you do? Farmer: If I do something? Interviewer: Yes, to improve traffic… Farmer: No it is more about making sure that they have fresh feed inside and not old, disgusting… Feed quickly becomes warm when it's hot. So it is better to provide less more often. During winter we feed once a day, in summer you can give… If it is warm and they do not want to eat outside they get fresh feed in the morning and afternoon. And maybe you clean in between. During winter we clean every third or fourth day" (F112700)*

Also on a national level a variation in impact on SCC across farms can be observed (Fig. 6). The negative effect of summer on SCC was mainly observed as a shift in the population of farms with higher SCC also in winter, while the distribution of farms with lower SCC in winter appeared to experience smaller differences throughout the year (Fig. 6). This uneven impact on SCC indicates that there are farms that manage to avoid negative consequences during summer and future studies should look deeper into differences between these two types of farms. However, August 2018, an unusually hot month, stands out from the general pattern and a higher proportion of farms appear to have been affected by higher SCC. Thus, farms that are currently managing may need to adapt to face increasing number of heat waves in the future.

3.2.3. Perception of biological consequences of heat related to fertility

Compared to the impact on SCC, where the link to an increase during the summer season was quickly recognised by all farmers, negative impacts on fertility often required targeted elicitation before being acknowledged. Here farmers described and confirmed problems associated with poor oestrus expression in cows, linked to difficulties in getting cows pregnant during summer. The consequences of impaired fertility during hot spells/summer were associated with difficulties in recruiting enough animals and in some cases added costs of buying new animals. In particular fertility problems and consequences were mentioned in relation to the summer of 2018, which also stands out as a deviating year according to national data (Fig. 6), but also in relation to warmer periods during ordinary summers.

> *"The number of inseminations per pregnancy went up a lot [referring to summer of 2018]. Then we had… Well, specifically heifers that did not show any signs of heat at all. But we bought some new material, then. You want to avoid that, but that's what we did anyway" (F111509)*

> *"No, they don't show any heat [referring to summer]. And it is harder to get them pregnant when it is very hot" (F111223)*

> *"All aspects of fertility are affected [referring to producing dairy cows]. The oestrus behaviour is weak and often they do not get pregnant during the hot period. You can see that clearly nine months after that yes, that was the hot weeks in July. That's why we do not have any calvings right now." (F113268)*

The difficulty to get cows pregnant in summer can be related to the cows expressing poor oestrus behaviour and warm temperatures having negative effects on the oocyte development, implantation as well as uterine environment (Sammad et al., 2020). Separating these effects is not possible in this study but the discussions with farmers suggest that they face a combination of problems. However, previous literature suggests that inseminations per cow start decreasing when daily average THI is above 57 while successful pregnancies per insemination decrease at higher temperatures (THI 68) (Gernand et al., 2019). When daily

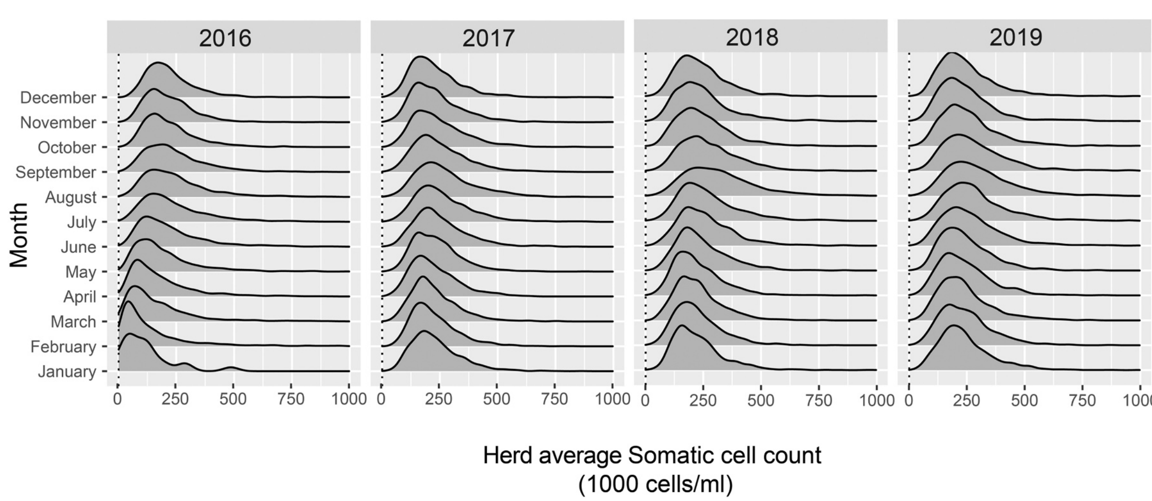

Fig. 6. Distribution of average herd somatic cell counts from the 1262 farms participating in the Swedish Milk and Disease Recording System between 2016–2019.

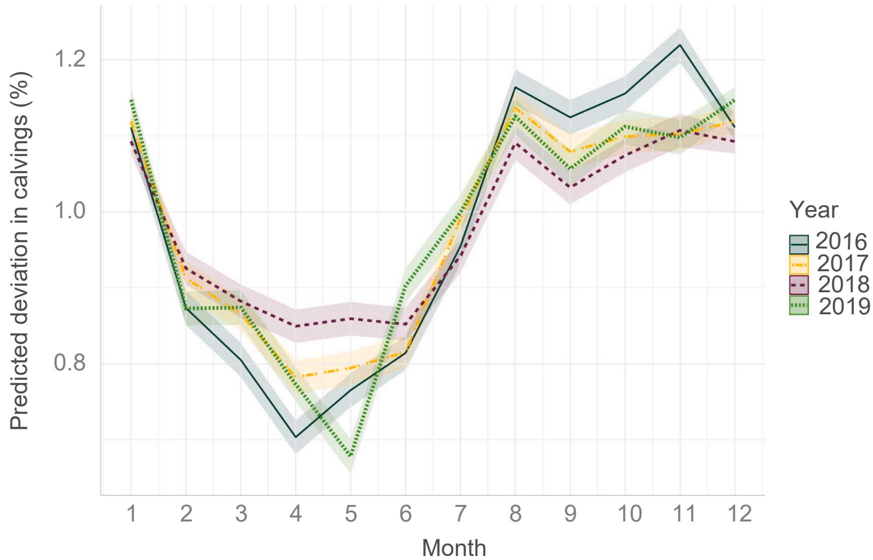

Fig. 7. Predicted deviation (%) from expected average farm calvings recorded in the Swedish milk and disease recording scheme between January 2016 to December 2019.

average THI is 73 the conception rate falls drastically (Schüller et al., 2014). Thus, it is possible that the unusually warm months of 2018 caused additional challenges beyond the difficulties of observing oestrus behaviour which led to the observed deviation.

3.2.4. The long term consequences of reduced fertility are recognised but not connected to heat

Looking at the deviation from expected number of calvings (based on monthly average of total calvings) on a national level, there was a clear seasonal trend where the farms have fewer calvings in spring, with some variation between years (Fig. 7). One of the participants made a clear connection on how the difficulties during summer lead to problems down the line:

"*Interviewer: How did it work with pregnancies and inseminations during that period [referring to 2018]?*

Farmer: Yes, well that is the problem then, that they don't become… they don't show heat [referring to the animals]. And when we approach the winter, or fall and winter, then they are all in heat so to speak. And this leads to an uneven flow. But you don't want to… prefer not to… When you are on the borderline with numbers of animals you don't want to lose a single one which means that you keep inseminating and it becomes a vicious circle… Then they all [referring to calves] come in the wrong month so to speak, all of them" (F112606)

However, these type of observations that linked/discussed the long-term consequences of summer/heat on calving patterns were rare. Nevertheless, calving patterns was a recurrent topic, where most farmers mentioned how uneven calving patterns was a challenge to their farm in general.

"No, I don't experience any [referring to fertility/health issues] as problem, but a little uneven calving. When there are 30–35 calving in a month, and then there are only 10 the month after. That's a challenge. Last autumn and up until the turn of the year here now, we had such a huge peak with a lot of calvings. And then you get to a different infection pressure in calves…" (F111223)

"You get out of that swing [referring to calving pattern], you might only have two or three calving one month, and then the next month you might have 20. And that means we can't have a full stocking, we get disruption. works much better with the flow, with calves and weaning everything becomes much easier" (F111509)

Uneven calvings do not only impact the number of young calves on the farm, it also has an impact on the entire cattle herd dynamics, lactation patterns of the cows and the flow of milking animals in the barn. Especially in farms with automatic milking systems (AMS) this even flow is important.

"In the conventional system, it did not matter so much if ten cows calved in a few days. But with the milking robots it much more sensitive and you want to have an even flow and try to match the cows that calve with the number of cows that are dried off" (F113268)

The seasonal shift, leading to a peak in calvings in late summer/early fall, means that a high proportion of animals are at the final stages of pregnancy during the warmest months. Heat stress during this period is associated with long term effects on both dam and calf, for example reduced production in subsequent lactation and changes in immune responses (Dado-Senn et al., 2019; Dahl et al., 2020, 2019). Thus, while farmers focused on the immediate, recoverable impacts of heat stress on profitability, the long term consequences of reduced fertility in summer can impact farm profitability for many lactations and across generations.

3.2.5. The challenges for fertility are multifactorial

Farmers reflected on heifers in particular and as a separate entity from the multiparous cows, especially in relation to insemination and fertility routines during summer. This group of animals was associated with additional practical challenges in addition to difficulties in observing oestrus or achieving pregnancy. The farmers also reflect around unevenly distributed calving patterns and connect it to fewer heifers getting pregnant in summer.

"Yes it is a little easier [referring to fertility of dairy cows]. You see the cows more than you see the heifers in summer" (F112700)

"You should have the same number of calvings every month all year round. We don't really have that… Well, it's better to have few cows in the summer than in the winter. But the best thing would be to have full all year round. But then it has to do with this then that you are inseminating less. Fewer heifers get pregnant from May to October or September " (F.115939)

"It is difficult to say but heat makes it more difficult [referring to inseminations]. That is clear. And then it does not help that we cannot keep an eye on them, since they are outside. [….] For the heifers we use a bull, since we can only keep them inside for two weeks" (F112116)

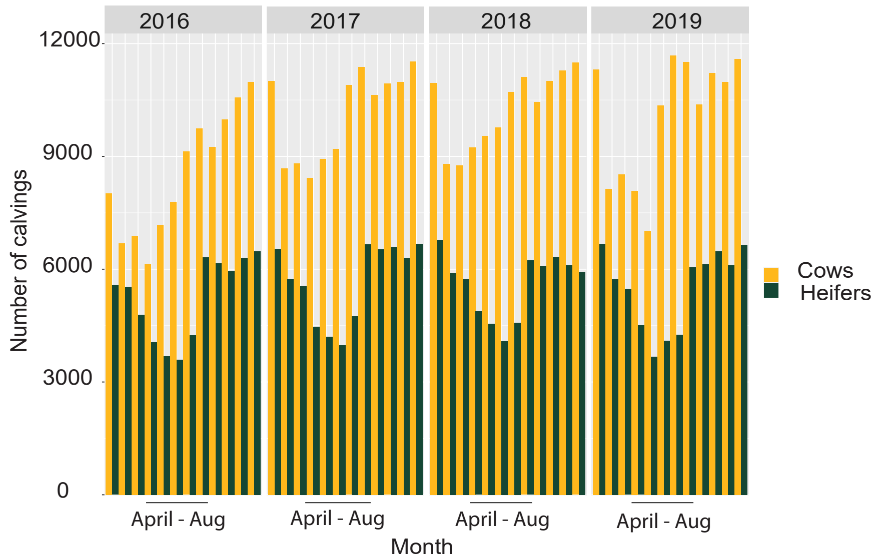

Fig. 8. Number of calvings recorded in the Swedish milk and disease recording scheme between January 2016 to December 2019.

Calving patterns on a national level confirm farmers' experiences through a recurring pattern where the number of heifers calving decreases from February and remains low until June (which corresponds to becoming pregnant between May and September) (Fig. 8). This pattern is highly consistent throughout the 4 years, which supports that there are recurring important management related factors unrelated to weather that influences it. For the multiparous cows on the other hand, a less consistent pattern was observed. This suggests that there is more variation between years for the multiparous cows, possibly a result of the variation in temperatures across years and the build-up of previous years that remain unseen/unremarked to farmers.

3.3. Preventive measures and coping strategies are overwhelmingly reactive

Participants' described actions to reduce the impact of heat (i.e. heat stress) on farm are overwhelmingly a reaction to an immediate reduction in profitability, reinforcing that the long-term biological costs are not visible or attracting attention. Furthermore, conversations also highlight some farmers with a self-believed inability to act on the impact of seasonal heat has on their herd. Altogether we characterize current Swedish farmer coping strategies as reactive. Yet, pro-active changes are slowly gaining traction derived by a collective memory of heat waves and belief they will recur in the future. The question remains if such changes are enough for the events to come.

3.3.1. Current control of heat among participating farms

Although the number of participants in the qualitative part of the study is too small to draw quantitative conclusions, some interesting general trends were observed in the farm characteristics and farmers' perception of the impact of heat (Table 3). The majority of the barns on the participating farms were insulated (only roof or roof and walls) and heat was generally controlled by natural ventilation. However, the newer barns (e.g. 111223) were built with cooling in mind as they had curtains that can be opened. In addition, the most modern barns had fans and some farmers with older barns had invested in fans after 2018. In most of the barns, farmer stated that the airflow could be modified to some extent by opening windows or doors, but to which extent this was possible varied. Selection of study participants was performed to achieve variation in the impact of summer/heat as well as geographical variation and not farm characteristics. Thus, it is positive to see that variation in farm characteristics, reflecting the general large variation observed in Swedish dairy production, was achieved in the study.

All farmers participating in the study stated that heat has had an impact on their animals (Table 3). The majority discussed the effects as behavioural changes, especially related to reduced activity, while others also described panting and other severe signs of heat stress. Biological costs such as decreased production, decreased udder health and immediate impact on fertility were recognised but sometimes connected to management changes (pasture and feed hygiene). It is interesting to notice that two of the farmers (112700, 111756) described severe symptoms of heat stress and that they used a water hose to cool the cows that were affected. By the signs described the cows on these farms experienced severe heat stress and farmer reactions were clear examples of reactive handling of heat. However, there were also examples of proactive handling. Farmer 113064 had experimented with sprinkler systems and purchased fans. Farmer 115939 made the decision to purchase fans after the summer of 2018 and saw smaller effects of summer on his animals. Thus, from what the farmers describe, heat is impacting dairy cows in Sweden on a regular basis although 2018 was more severe. However, the large variation in what is perceived as problematic is noteworthy and suggests that there is considerable variation in how heat stress is perceived among Swedish farmers.

3.3.2. Differences in perception of biological costs influence coping strategies and decision-making

Ensuring feed was farmers' first priority when facing heat waves and other EW events and in discussions farmers described a mix of both reactive and proactive actions. Reactive measures were described especially in relation to 2018 and farmers described new, proactive strategies for ensuring feed security in a long term perspective being implemented after 2018. Some farmers also described how they actively worked to try to prevent the seasonal increase in SCC. The actions described were mainly reactive, handling the situation as it arose, and were connected to what farmers perceived to be the underlying reason for the seasonal increase in SCC. For fertility few actions to prevent the negative effects were described, although farmers are aware of the immediate negative impacts.

According to the Health Belief model, adoption of proactive behaviours is connected to the perceived threat and susceptibility as well as the perceived benefits and barriers (Janz and Becker, 1984). As the focus of farmers was securing feed for the animals it is not surprising that this area was also connected with preventive behaviours. Regarding the biological costs the conversations suggest farmer perception of consequences of reduced fertility is more indistinct than for the SCC issue, possibly because of the time lag between heat event and consequences.

Whereas the increase in SCC is relatively immediate, the consequences on fertility do not materialise until long after summer. Therefore the consequences (and severity of the consequences) may be more difficult to perceive. An inability to see the consequences may impact the perceived benefits of acting to control a threat which, in combination with perceived barriers, are an important part of how effectiveness of preventive measures are perceived (Janz and Becker, 1984; Svensson et al., 2019). In addition, the practical barriers associated with fertility may also contribute to why farmers choose to focus on SCC instead. Another possible explanation of the differentiation of perception of consequences and actions towards of SCC vs. fertility is related to the emotional content attachment (Holland and Kensin, 2010). Such attachment may influence the way in which the event is remembered in relation to the past and present goals. This influences the recall of the event (i.e. memory), the believed consequences and can thereby impact future goals. SCC is linked with milk quality and it is a constantly monitored key indicator of the industry. As such, SCC variations can have direct short-term consequences on the financial stability of a farm. Thus variation SCC during a stressful year, such as 2018, could easily affect a farmer's ability to cope with other stressors (i.e. buying feed) and future reinvestment on-farm for self-improvement (i.e. a new barn). This is similar to how the consequences of reduced feed availability was described. Variation in fertility on the other hand lacks direct industry penalty and recognising the negative impact on the farm requires follow-up of long-term consequences. Therefore, emotional attachment is presumed higher for SCC variations compared to fertility variations in a given year.

3.4. Moving forward – coping strategies and decision-making needs to include biological costs

Our assumption that fertility is linked with a reduced emotional attachment, and thus less prioritised, is substantiated in the fewer solutions to reduce negative effects described by the participants. Instead, costs of additional recruitment of cows was discussed. Overall, this suggests that fertility is currently the least prioritised area and to a large extent handled reactively with little thought to long-term effects. This is problematic as good reproductive performance does not only enhance management control, but is also an important factor for herd profitability (Gröhn and Rajala-Schultz, 2000).

While the observed shift in calving intervals may increase risk of long term consequences for productivity and health there may be other effects that support heat mitigation in practice. For example, fewer calvings in spring could lead to fewer animals in the barn which can decrease the risk of heat stress the sequent summer (Noordhuizen and Bonnefoy, 2015). However, reduced animal density only occurs if animals in late lactation are also removed and some participants suggested the opposite, thereby also exacerbating the risk of increased SCC during summer by retaining late lactation animals or animals with high cell counts. Similarly a low number of recruitment heifers may lead to farmers keeping older cows which are, according to national animal health statistics at higher risk of developing mastitis (van den Borne et al., 2010). Thus, proactive handling of fertility and animal flow on farm could potentially also decrease the negative impact on SCC.

With increasingly warm summers that pose challenges on maintaining dairy cow fertility, awareness of seasonal trends on the farm and their long term consequences are important to highlight in order to prevent further escalation as well as preventive work to minimise effects. Therefore there needs to be an increased awareness of how an uneven calving patterns develops on farm and the consequences it has. Developing tools that aid farmers visualise long-term effects on fertility and herd dynamics as a result of heat stress, may aid to create the necessary emotional attachment for farmers to re-evaluate the prioritisation of actions and promote proactive planning to enhance future on-farm resilience by integrating fertility measures for decision making. We also propose that fertility decision making should not be blind to the fact that cows should live in cooled environments. As seen in Table 3 all farmers described episodes of heat stress, thus the necessity to preventively cool the cows also in the northern hemisphere, where the collective norm that cows do not need cooling is stronger compared to tropical areas, should be recognized. As farmers describe heat stressed animals in all kinds of barns it appears that what has been seen as optimized design for Sweden may no longer be enough.

The aim of this study was to increase understanding of how dairy farmers perceive and act in the face of climate change, increasing risk of heat waves and other types of EW. To identify how farmers perceive yearly as well as extreme challenges a mixed methodology where the individual farm and national patterns were integrated and understood in relation to each other was necessary. This approach complements existing literature of the effects of heat stress in dairy cows with new perspectives and insight into the needs to act also in areas where heat has not been considered the main challenge historically. However, the study design also has limitations. For example the 18 farms participating are too few for identifying successful coping strategies on a national level. Future studies including a larger sample size should focus on for example identifying which types of barns and cooling systems work best under Swedish conditions. In addition, the potential of adding water based cooling systems should be explored.

4. Conclusion

Overall, conversations with farmers indicate a broad definition of extreme weather, where its handling is reactive and the memory of the events do not trigger a big concern for the biological cost of the events to the cows. There is a perceived lack of control of the events, i.e. something that happens and must be handled as it comes but cannot be planned for. However, at a national level, long-term effects on the farm economy, health and herd dynamics indicate that attention must be given to heat waves normally seen during the spring and summer season in Sweden. While Swedish dairy farmers are aware of negative impacts of heat in particular, mainly expressed in production and SCC, they show fragile resilience. Their resilience is built and expressed around their capability to ensure sufficient feed when extreme weather events hit the farm. Yet, the currently unacknowledged long-term biological costs related to fertility has the potential to visualise the need for proactive planning and thus improve farm resilience and profitability based on efficient farm dynamics in addition to feed supply. This might imply a re-design of current and future barns for better and active cooling.

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CRediT authorship contribution statement

Olmos Antillón Gabriela: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Åkerlind Maria:** Conceptualization, Funding acquisition, Resources, Writing – review & editing. **Båge Renée:** Conceptualization, Funding acquisition, Resources, Writing – review & editing, Formal analysis. **Tamminen Lena-Mari:** Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing, Conceptualization.

Declaration of Competing Interest

The authors declare no conflicting or competing interests.

Data availability

The datasets for this article are not publicly available because of privacy and confidentiality reasons. Requests to access the datasets should be directed to the corresponding author and Växa Sverige (info@vxa.se), respectively.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2024.106131.

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