75th EAAP Annual Meeting

Kiel University
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Use of an outdoor run by group-housed sows in the mating area depending on weather conditions

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Project manager
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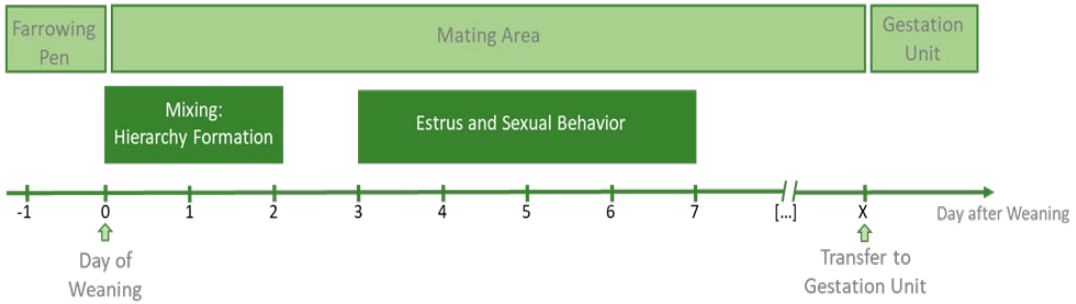
Current Research Question

Transformation process in animal husbandry

- MEPs support EU citizens' call to phase out permanent fixation of farm animals (EP, 2021)

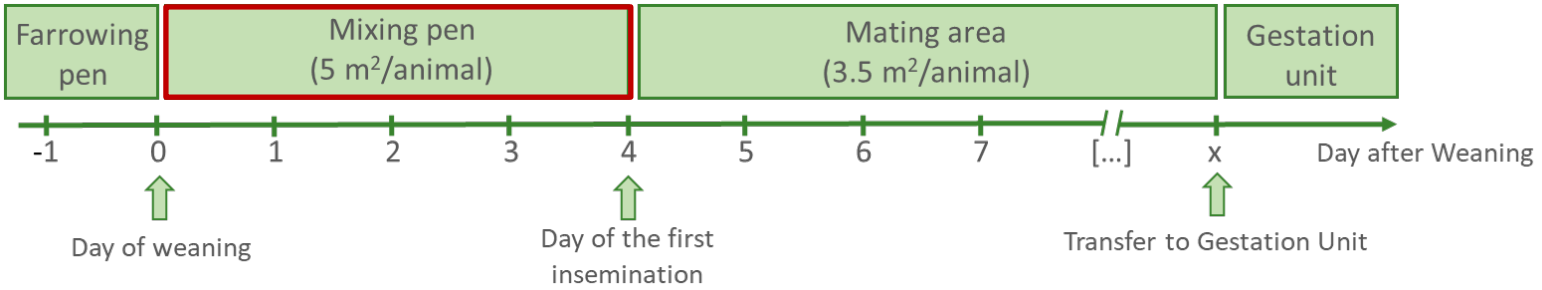
- For the mating area (in Germany):
  - Group housing system with short-term fixation (FLI, 2022)
  - Space allowance: 5 m^2/ sow until first insemination (FLI, 2022)

How can we meet future legal requirements in the mating area?



Current Research Question

Easy-to-implemtent modification:



- Sufficient space positively impacts sows' socialisation and welfare (HEMSWORTH et al., 2013)
- But, mixing after weaning results in higher stress than mixing after insemination (RAULT et al., 2014)
- Therefore, addition of an outdoor run within the mixing pen to improve animal welfare
  - structuring the pen and enabling functional areas (MCGLONE et al., 2021; HÖNE et al., 2023)
  - providing environmental enrichment and exposure to different climate zones (HÖNE et al., 2023; VERMEER et al., 2015)

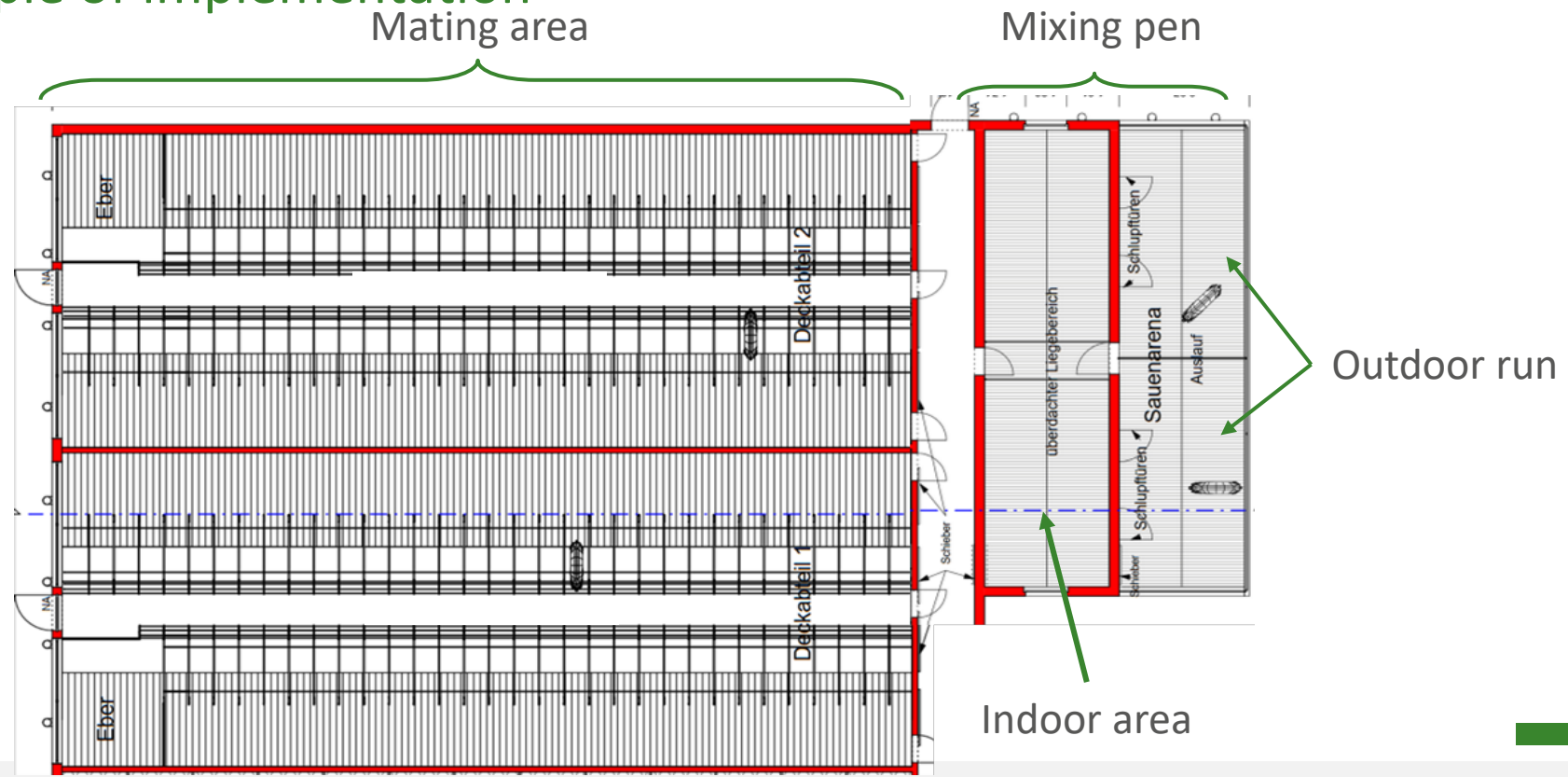
Current Research Question

Use of an outdoor run by group-housed sows in the mating area depending on weather conditions

- How do sows use the outdoor run during the day?
- What is the impact of local weather conditions on the behavior of sows?

Material & Methods

Example of implementation



Example of implementation

Indoor area of the mixing pen

Free access outdoor run of the mixing pen

Data Collection

Weather data

Video observation:
Animal behavior

Data Collection

Weather data

- Outdoor temperature [°C]
- Humidity [%]
- Windspeed [m/s]
- Precipitation [mm]
- Solar radiation [W/m²]
- Indoor temperature [°C]
- Temperature difference in - out [°C]

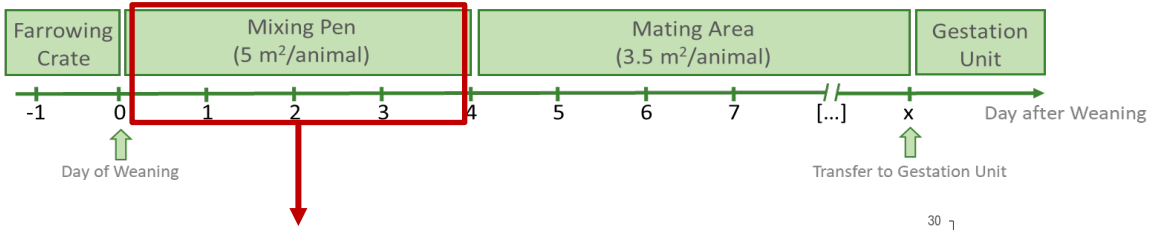
Animal behavior

(at 14 observation days)

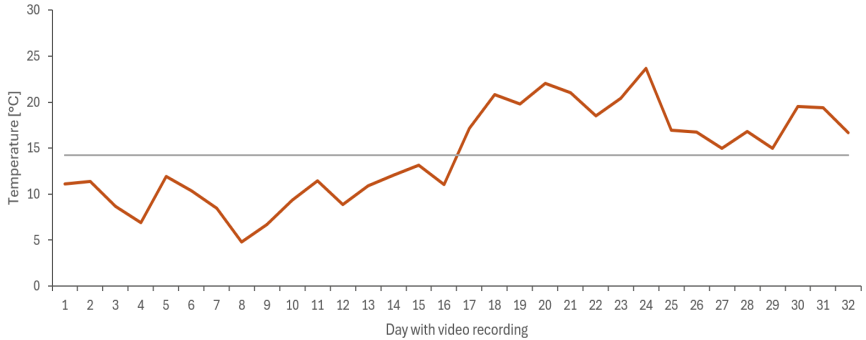
- 24 hr observation
- N = 94 sows
- In 10-minute interval (3804 images)
  - Number of sows in the outdoor run
  - Individual sow ID
  - Sow lying / sow not lying

- Heat stress index: Equivalent Temperature Index for Sows (ETIS) (Cao et al., 2021)
  → includes temperature, humidity, windspeed and their interaction

Observation days



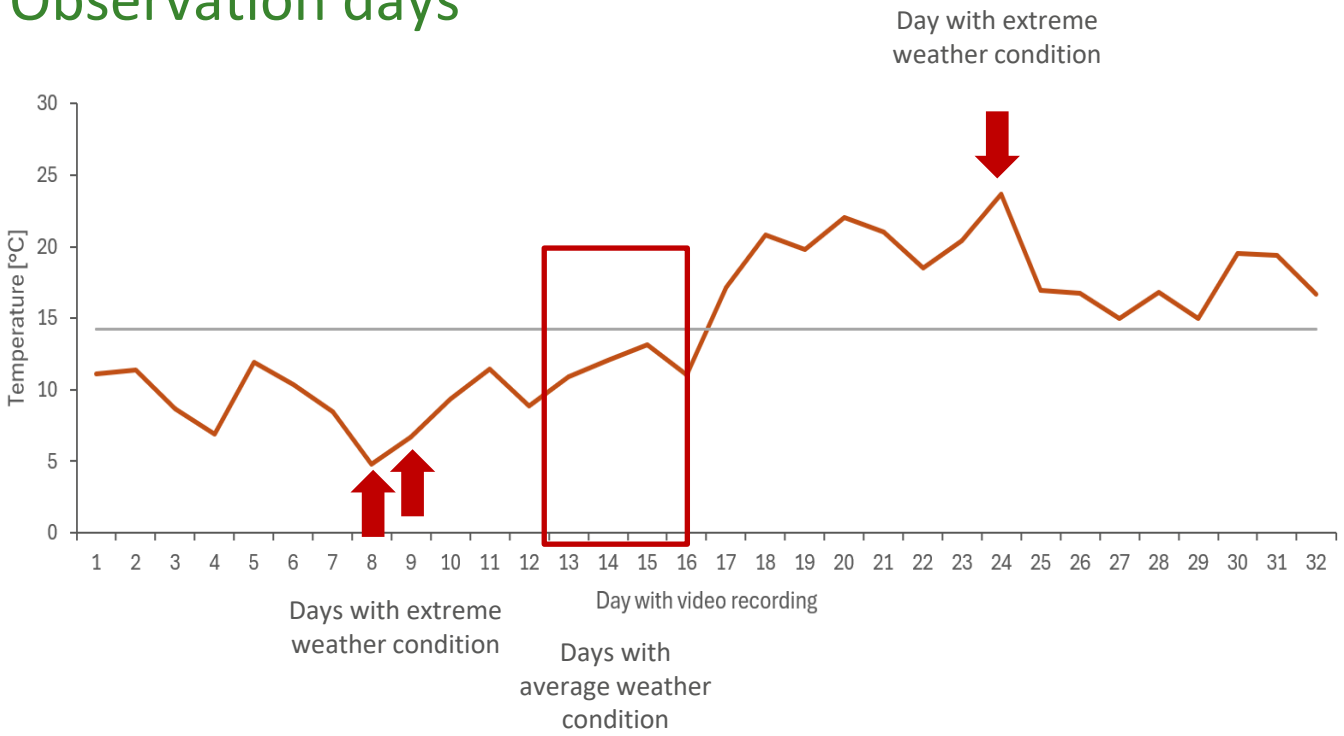
Data collection
2023/03 – 2023/08
in 8 batches (32 days)
and two groups



14 observation days

- 4 d = average weather conditions
- 10 d = extreme weather conditions

Observation days



Mean temperature across video days	14.8 °C
Max. mean daily temperature	23.6 °C
Min. mean daily temperature	4.8 °C

Statistical Analysis

→ Multiple linear regression with linear mixed model (LMM)

- Model objective: investigate the **influencing factors** on the **relative number of sows** in the outdoor run per group in 10-minute intervals
  - Response variable: **relative number of sows** in the outdoor run (10-minute interval) per group
  - Fixed effects: **time of day** (night, morning, noon, evening), **group** (1,2)
  - Covariates-candidates: temperature, humidity, wind speed, precipitation, solar radiation, indoor temperature, temperature difference, heat stress index (ETIS)
  - Random effect: **observation day**

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  - Covariates: ~~temperature~~, ~~humidity~~, ~~wind speed~~, **precipitation**, **solar radiation**, ~~indoor temperature~~, ~~temperature difference~~, **heat stress index (ETIS)**
  - Random effect: **observation day**

First Results

Estimation of the effects on the relative number of sows

	Effect ± SE	P-value
Intercept	0.213 ± 0.026	***
Daytime_noon	0.096 ± 0.01	***
Daytime_morning	0.108 ± 0.013	***
Daytime_night	-0.097 ± 0.012	***
Group2	0.038 ± 0.006	***
Precipitation	-0.017 ± 0.003	***
Solar radiation	0.0002 ± 0.000	***
ETIS	-0.003 ± 0.0007	***

*P < 0.05, **P < 0.01, ***P < 0.001

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- Random effect: observation day

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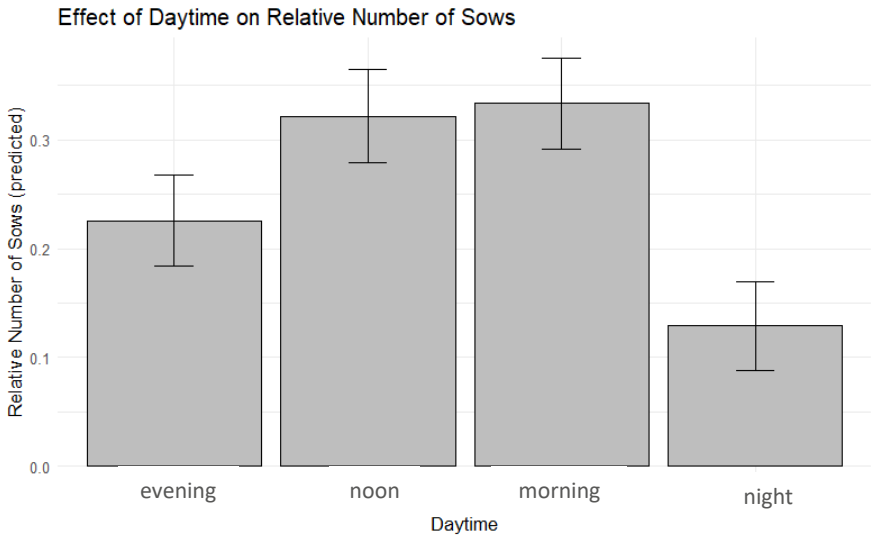

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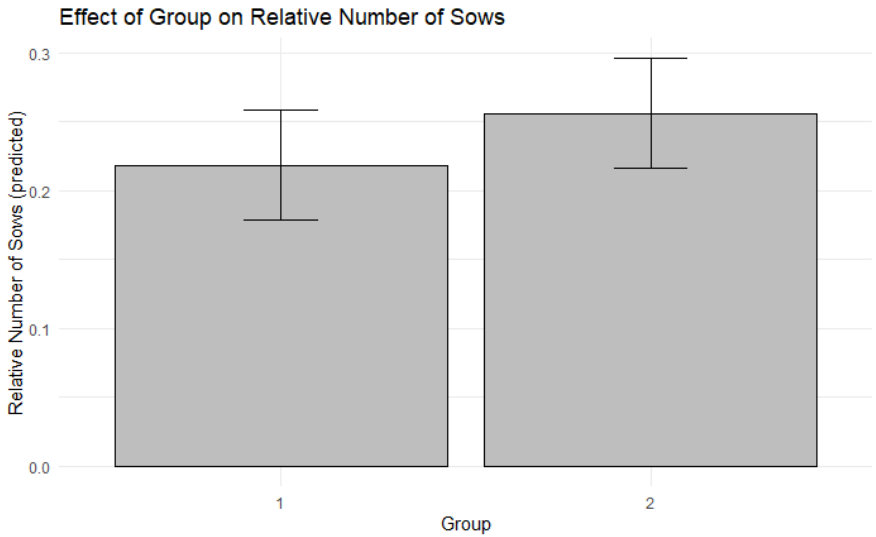

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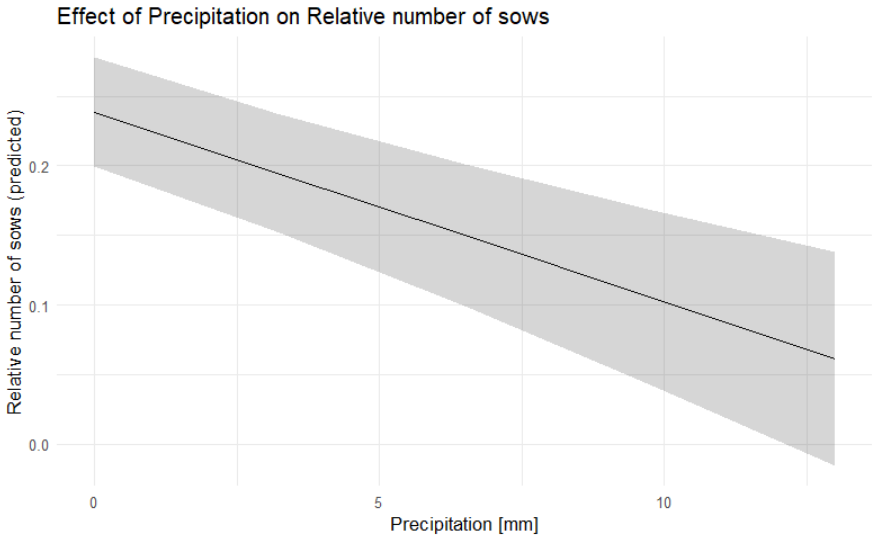

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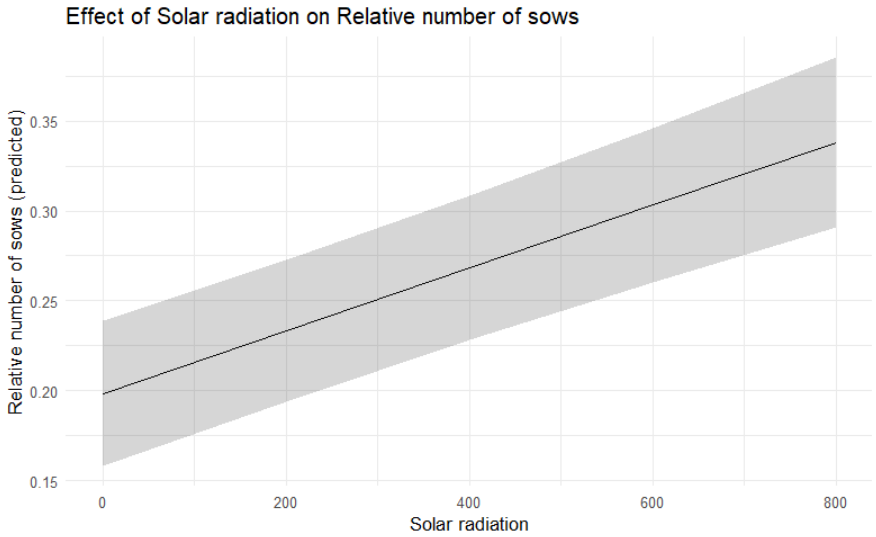

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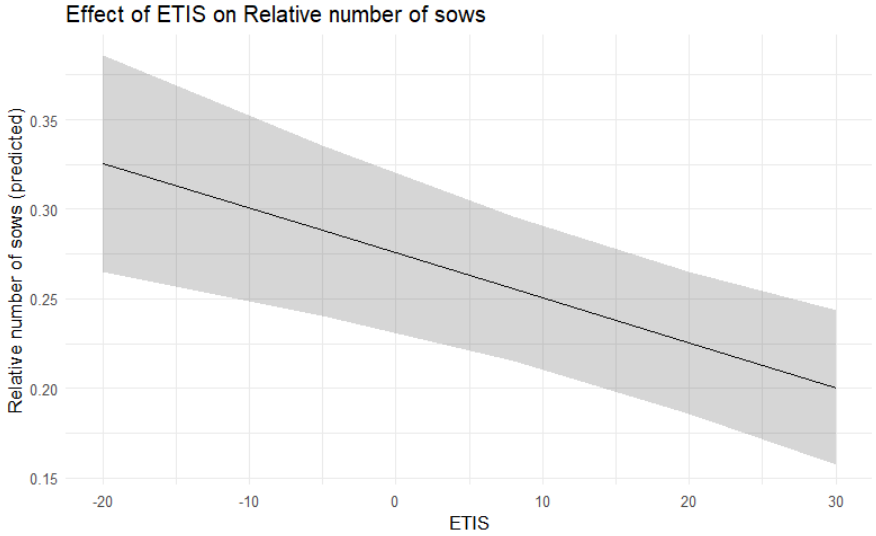


Estimation of the effects with daytime interaction

	Effect ± SE	P-value
Intercept	0.25 ± 0.032	***
Daytime_noon	0.232 ± 0.026	***
Daytime_morning	0.046 ± 0.022	*
Daytime_night	-0.112 ± 0.021	***
Group2	0.036 ± 0.006	***
Precipitation	-0.018 ± 0.005	***
Solar radiation	0.0003 ± 0.000	***
ETIS	-0.006 ± 0.007	***

*P < 0.05, **P < 0.01, ***P < 0.001

	Effect ± SE	P-value
Precipitation*daytime_noon	-0.125 ± 0.024	***
Precipitation*daytime_morning	0.001 ± 0.001	n.s.
Precipitation*daytime_night	0.01 ± 0.007	n.s.
Solar radiation*daytime_noon	-0.0003 ± 0.000	***
Solar radiation*daytime_morning	-0.000 ± 0.000	n.s.
Solar radiation*daytime_night	0.0002 ± 0.000	*
ETIS*daytime_noon	-0.002 ± 0.001	*
ETIS*daytime_morning	0.007 ± 0.001	***
ETIS*daytime_night	0.002 ± 0.001	*

*P < 0.05, **P < 0.01, ***P < 0.001

Conclusion

- Time of day significantly affects sow visiting behavior:
  - Increased sow presence in the outdoor run in the morning (30 % of the sows) and at noon (48 % of the sows).
  - Decreased sow presence at night (14 % of the sows).
- Weather events influence visitation patterns, with time-of-day interactions:
  - Precipitation ↑ = Number of sows in the outdoor run ↓
  - Solar radiation ↑ = Number of sows in the outdoor run ↑, except at noon
  - Heat stress conditions significantly reduce outdoor run use.

Good acceptance of the outdoor run → potential strategy to enhance environmental enrichment and improve sow welfare

Thank you for your attention !

This work is funded by the German Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany, granted by the Federal Office for Agriculture and Food (BLE; grant number 28N305603).

References

Cao M.; Zong, C.; Wang, X.; Teng, G.; Zhuang, Y.; Lei, K. (2021): Modeling of heat stress in sows-part 1: Establishment of the prediction model for the equivalent temperature index of the sows. In: *Animals*, **11** (5).

Friedrich-Loeffler-Institut (FLI) (2022): Ausführungshinweise TierSchNutztV (Schwein). Anlage 2 zum Handbuch.

European Parliament – Directorate General for Communication (2021): MEPs endorse EU citizens' call for gradual end to caged farming. Press release.

Hemsworth, P. H.; Rice, M.; Nash, J.; Giri, K.; Butler, K. L.; Tilbrook, A. J.; Morrison, R. S. (2013): Effects of group size and floor space allowance on grouped sows: aggression, stress, skin injuries, and reproductive performance. In: *Journal of Animal Science*, **91** (10): 4953–4964.

Höne, U.; Krause, E. T.; Bussemas, R.; Traulsen, I.; Schrader, L. (2023): Usage of outdoor runs and defaecation behaviour of fattening pigs. In: *Applied Animal Behaviour Science*, **258**: 105821.

McGlone, J. J.; Aviles-Rosa, E. O.; Archer, C.; Wilson, M. M.; Jones, K. D.; Matthews, E., M.; Gonzalez, A. A.; Reyes, E. (2021): Understanding sow sexual behavior and the application of the boar pheromone to stimulate sow reproduction. In: Aral, F., Payan-Carreira, R. & Quaresma, M. (Hrsg.): *Animal Reproduction in Veterinary Medicine*, **6**: 37-58.

Rault, J.-L.; Morrison, R. S.; Hansen, C. F.; Hansen, L. U.; Hemsworth, P. H. (2014): Effects of group housing after weaning on sow welfare and sexual behavior. In: *Journal of animal science*, **92** (12): 5683–5692.

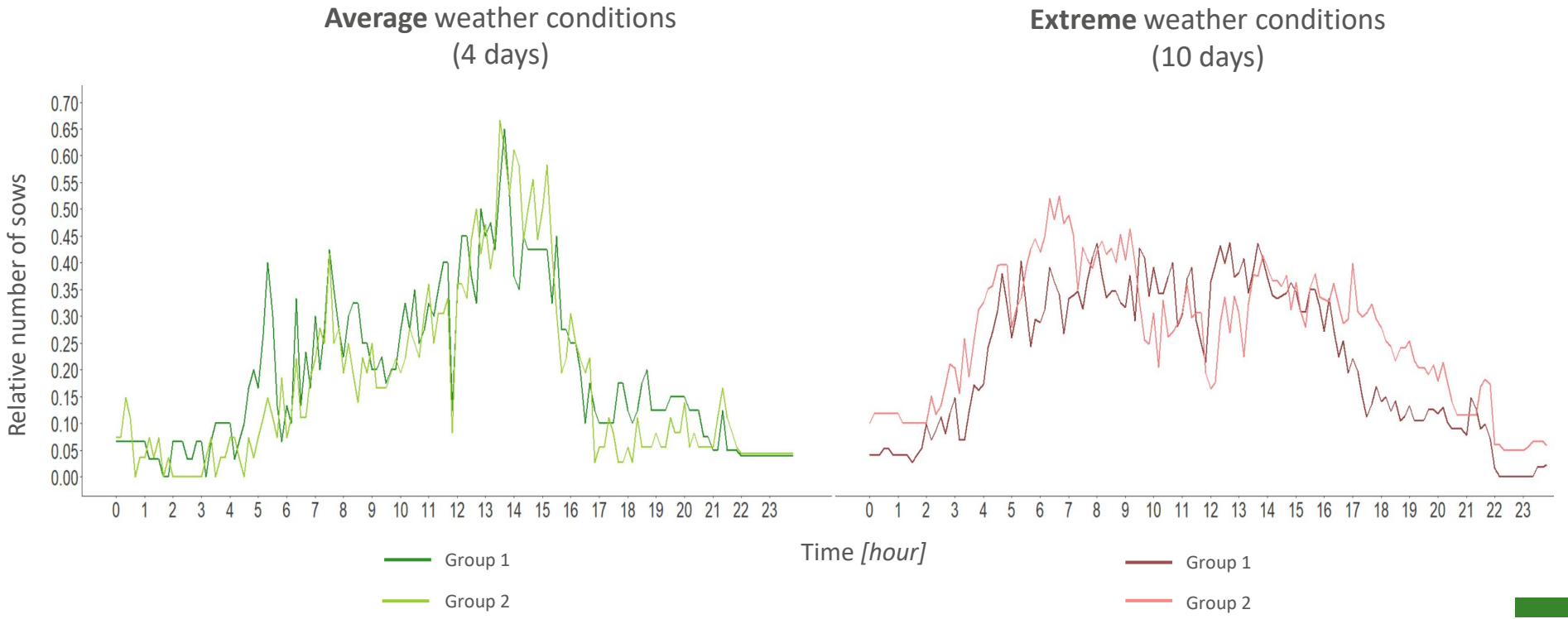
Vermeer, H. M.; Altena, H.; Vereijken, P. F. G.; Bracke, M. B. M. (2015): Rooting area and drinker affect dunging behaviour of organic pigs. In: *Applied Animal Behaviour Science*, **165**: 66–71.

Appendix I: Farm with outdoor run

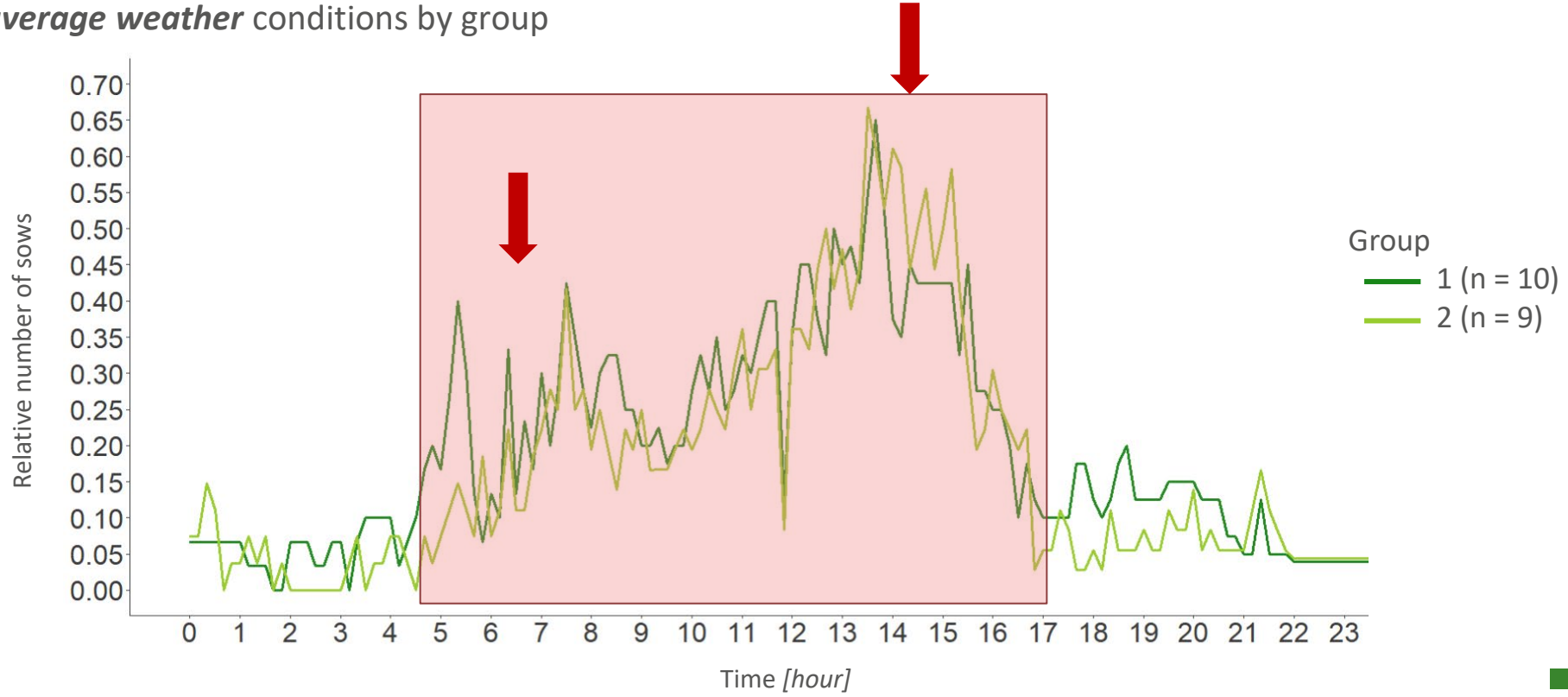
- 500 sows (DanZucht)
- 20 sows (in two groups) are weaned every week
- 5 m^2 /animal mixing pen with indoor and outdoor area
- 3.5 m^2/ animal mating area with free access feeding stalls (short-term fixation for insemination)

Appendix II: Daily course of visits under weather conditions

Relative number of sows in the outdoor run (10-minute interval) during the day over the observation period by group and weather conditions

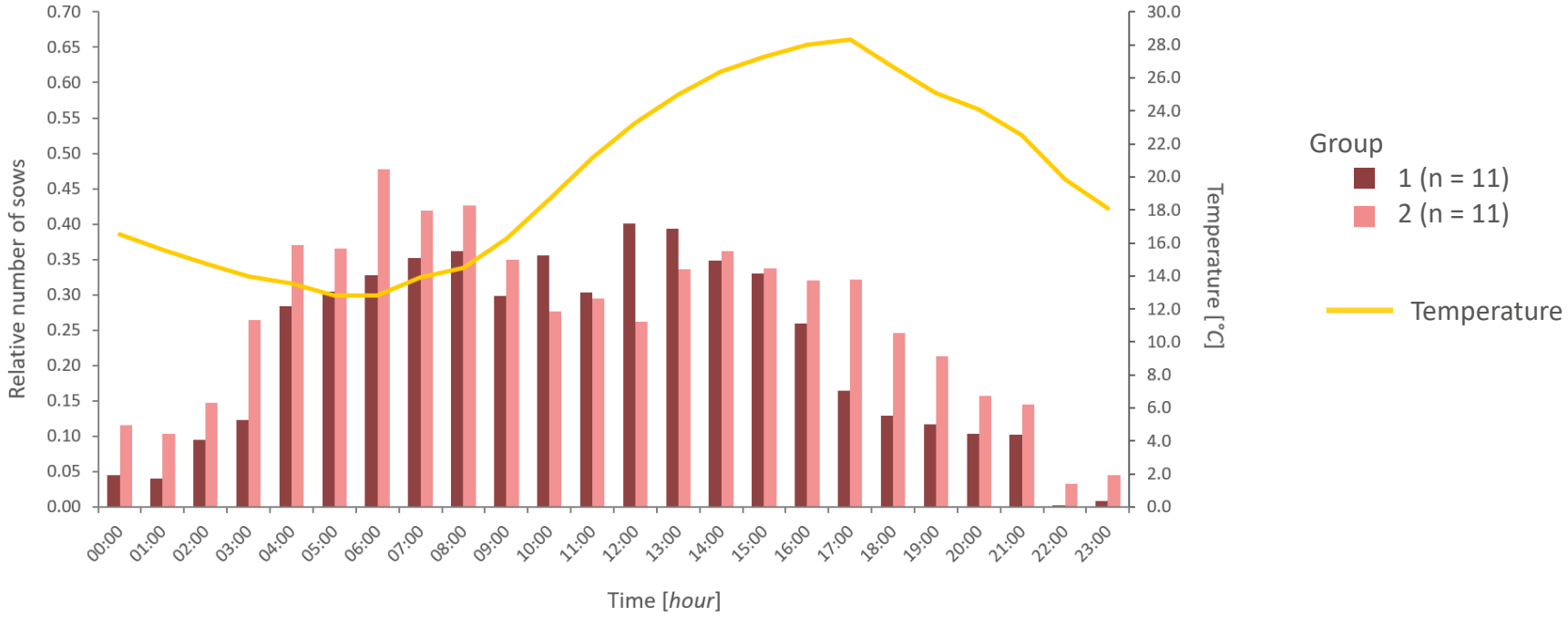


Relative number of sows in the outdoor run (10-minute interval) during the day under ***average weather*** conditions by group



Appendix III: Visits under hot weather conditions

Average relative number of sows in the outdoor run during days (n= 4) with high temperatures



Appendix IV: Daily course of visits over the observationdays

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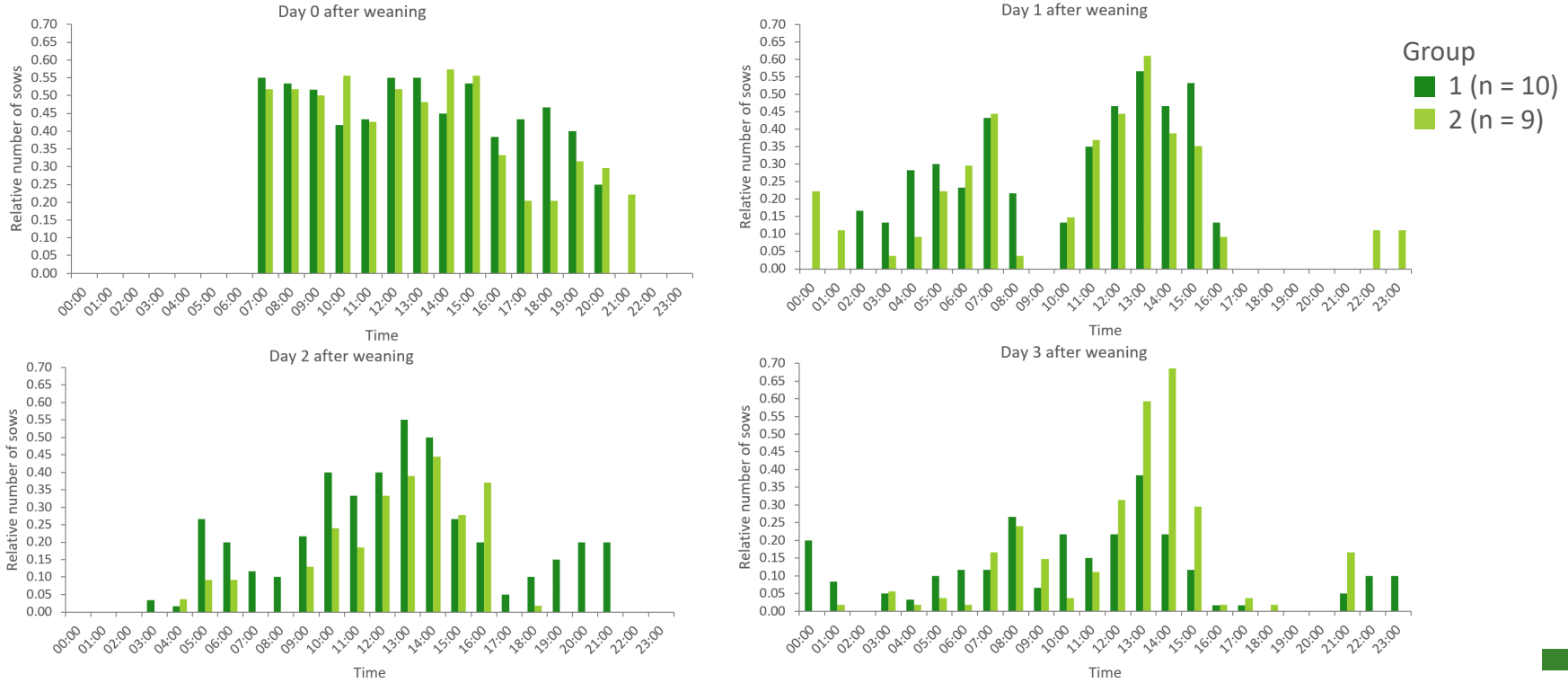
Appendix II: Average relative number of sows in the outdoor run during the day at days with ***average weather*** conditions by group



Appendix V: LMM without Heat Stress Index

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	Effect ± SE	p-value
Intercept	0.422 ± 0.06	***
Daytime_noon	0.061 ± 0.011	***
Daytime_morning	0.071 ± 0.013	***
Daytime_night	-0.104 ± 0.012	***
Group2	0.037 ± 0.006	***
Temperature	-0.015 ± 0.002	***
Humidity	-0.032 ± 0.041	n.s.
Windspeed	-0.011 ± 0.004	*
Precipitation	-0.017 ± 0.003	***
Solar radiation	0.0002 ± 0.000	***

α-Signifikanzniveau: *p < 0.05, **p < 0.01, ***p < 0.001

Model objective: investigate the **influencing factors** on the **relative number of sows** in the outdoor run per group in 10-minute intervals

- Response variable: *relative number of sows in the outdoor run (10-minute interval) per group*
- Fixed effects: *time of day, group*
- *Covariates: **temperature**, **humidity**, **windspeed**, precipitation, solar radiation, ~~heat stress index (ETIS)~~*
- Random effect: *observation day*

Appendix VI: ETIS as an Indicator of heat stress

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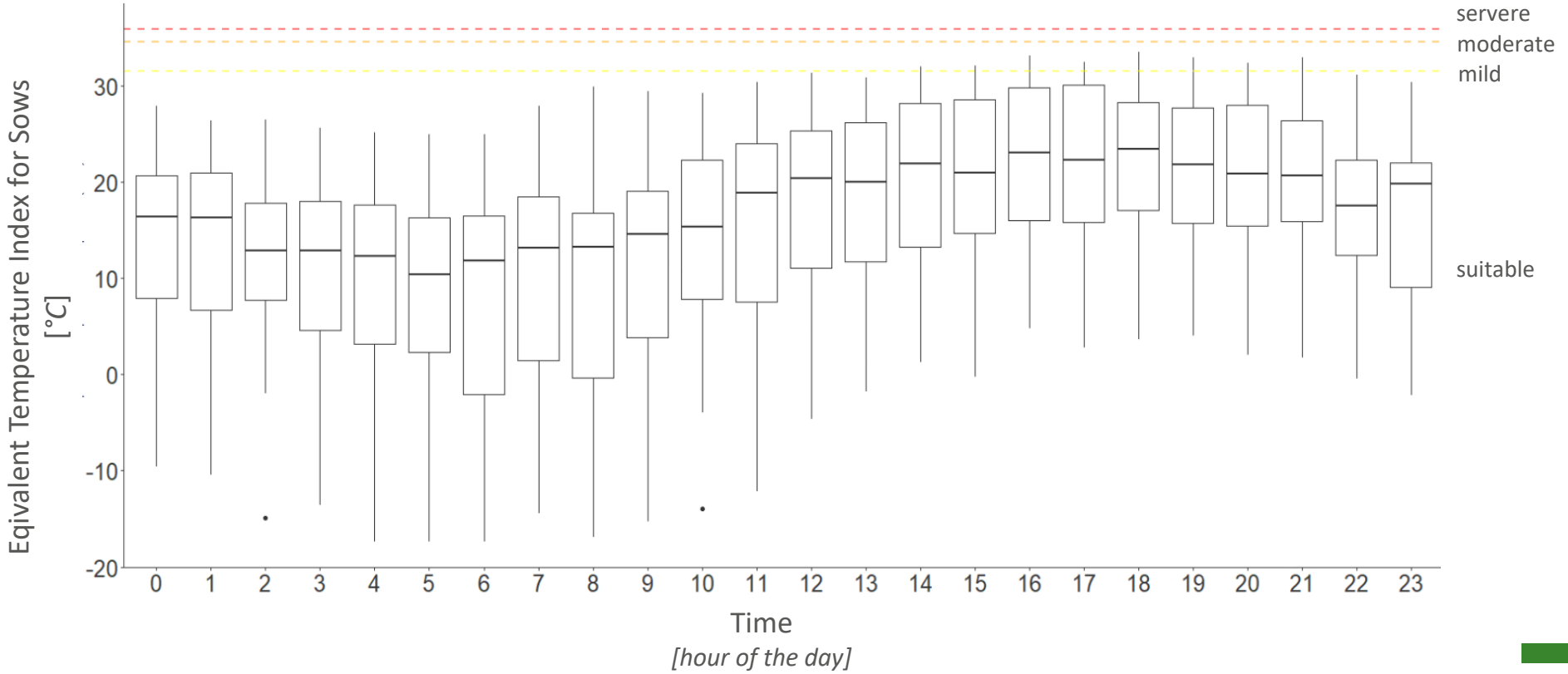

Appendix VII: Comparison of Heat Stress Index Fit Accuracy

Table 3. Pearson correlation coefficient between the thermal index and physiological responses (skin temperature) (all p-values < 0.0001). The thermal index and the skin temperature are positively correlated. When the Pearson correlation coefficient R is closer to 1, the correlation is stronger.

Thermal Index	Equation	Skin Temperature Correlation (R)
ETIS	$\mathrm{ETIS} = \mathrm{T} + 0.0006\cdot(\mathrm{RH}-50)\cdot\mathrm{T} - 0.3132\cdot u^{0.6827}\cdot(38-\mathrm{T}) - 4.79 \cdot(1.0086\cdot 38-\mathrm{T}) + 4.8957\cdot 10^{-8}\cdot\left((38+273.15)^4-(\mathrm{T}+273.15)^4\right)$	0.82
THI [9]	$\mathrm{THI} = \mathrm{T} + 0.36\cdot\mathrm{T}_{wb} + 41.5$	0.78
THI [10]	$\mathrm{THI} = 0.8\cdot\mathrm{T} + \left(\frac{\mathrm{RH}\cdot(\mathrm{T}-14.4)}{100}\right) + 46.4$	0.79
THI [11]	$\mathrm{THI} = 0.65\cdot\mathrm{T} + 0.35\cdot\mathrm{T}_{wb}$	0.79
THI [12]	$\mathrm{THI} = \mathrm{T}^{\circ} - (0.55-0.0055\cdot\mathrm{RH})\cdot\left(\mathrm{T}^{\circ}-58\right)$	0.79
THI [13]	$\mathrm{THI} = 0.72\cdot\mathrm{T} + 0.72\cdot\mathrm{T}_{wb} + 40.6$	0.78
THI [16]	$\mathrm{THI} = (1.8\cdot\mathrm{T}+32) - \left[0.55\cdot\left(\frac{\mathrm{RH}}{100}\right)\right]\cdot[(1.8\cdot\mathrm{T}+32)-58]$	0.69
THI [14]	$\mathrm{THI} = \mathrm{T} - (0.55-0.0055\cdot\mathrm{RH})\cdot(\mathrm{T}-14.5)$	0.79
THI [15]	$\mathrm{THI} = 0.27\cdot\mathrm{T} + 1.35\cdot\mathrm{T}_{wb} + 34.07$	0.73
BGHI [17]	$\mathrm{BGHI} = \mathrm{T}_g + 0.36\cdot\mathrm{T}_{dp} + 41.5$	0.71
ET [19]	$\mathrm{ET} = \mathrm{T} + 0.0015\cdot(\mathrm{RH}-50)\cdot\mathrm{T} + \left[-1.0\cdot 42 - \mathrm{T}\cdot\left(v^{0.66}-0.2^{0.66}\right)\right]$	0.75
H [21]	$\mathrm{H} = 1.006\cdot\mathrm{T} + \frac{\mathrm{RH}}{\mathrm{Pm}}\cdot 10^{\left(\frac{7.5\cdot\mathrm{T}}{273.3+\mathrm{T}}\right)}\cdot(71.28+0.052\cdot\mathrm{T})$	0.68

Note: ETIS is the equivalent temperature index for sows. THI is temperature and humidity index. BGHI is the globe-humidity index. ET is the effective temperature. H is the enthalpy ($\mathrm{kJ\cdot kg^{-1}}$). T is the dry bulb temperature (°C). T° is the dry bulb temperature(°F). $\mathrm{T_g}$ is the black globe temperature (°C). $\mathrm{T_{wb}}$ is the wet bulb temperature (°C); $\mathrm{T_{dp}}$ is the dew point temperature (°C). RH is the relative humidity (%). $\mathrm{P_m}$ is high mercury of barometric pressure (mmHg).

Reference:
CAO et al., 2021

Appendix VIII: Local weather conditions -

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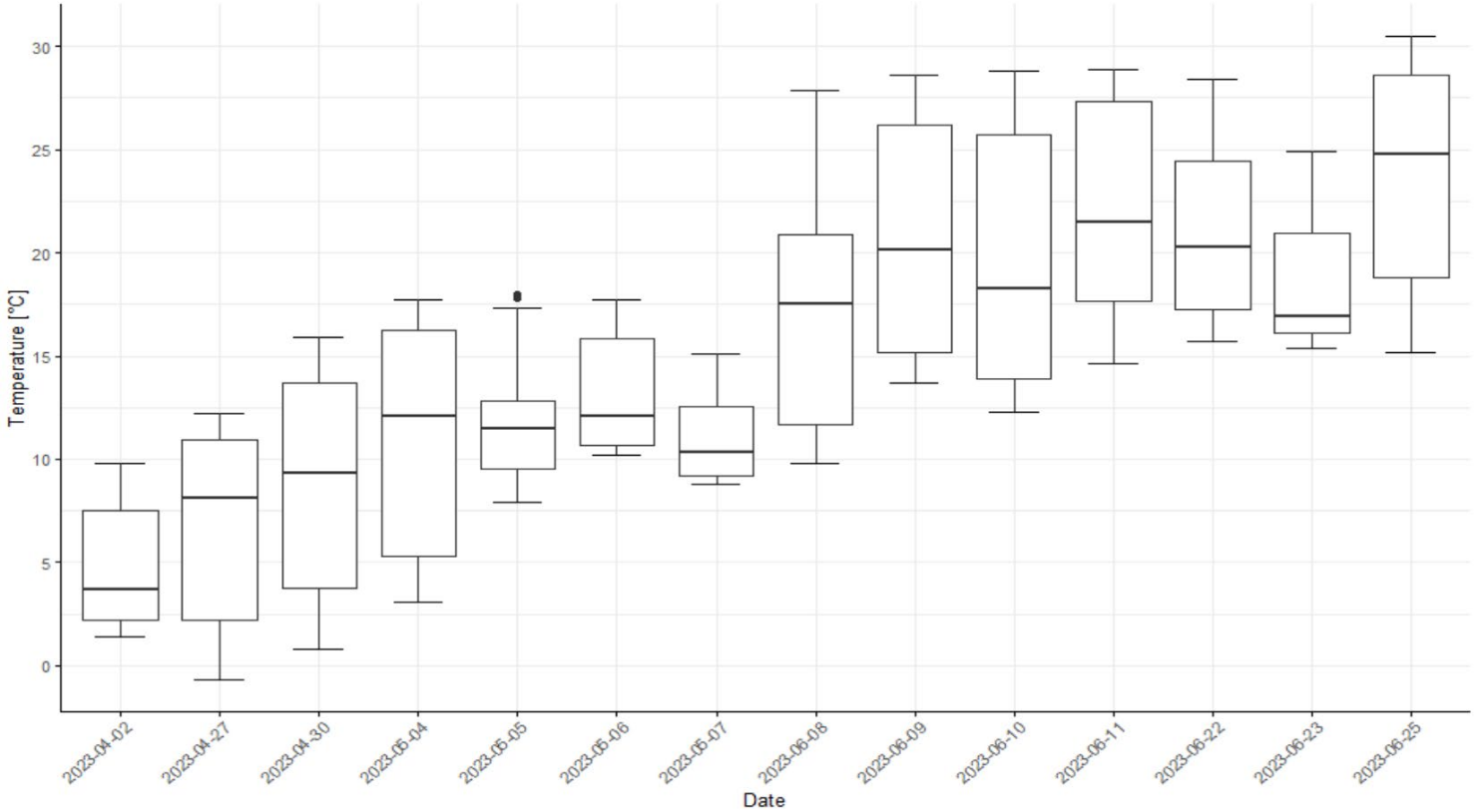

Appendix IX: Local weather conditions - Humidity

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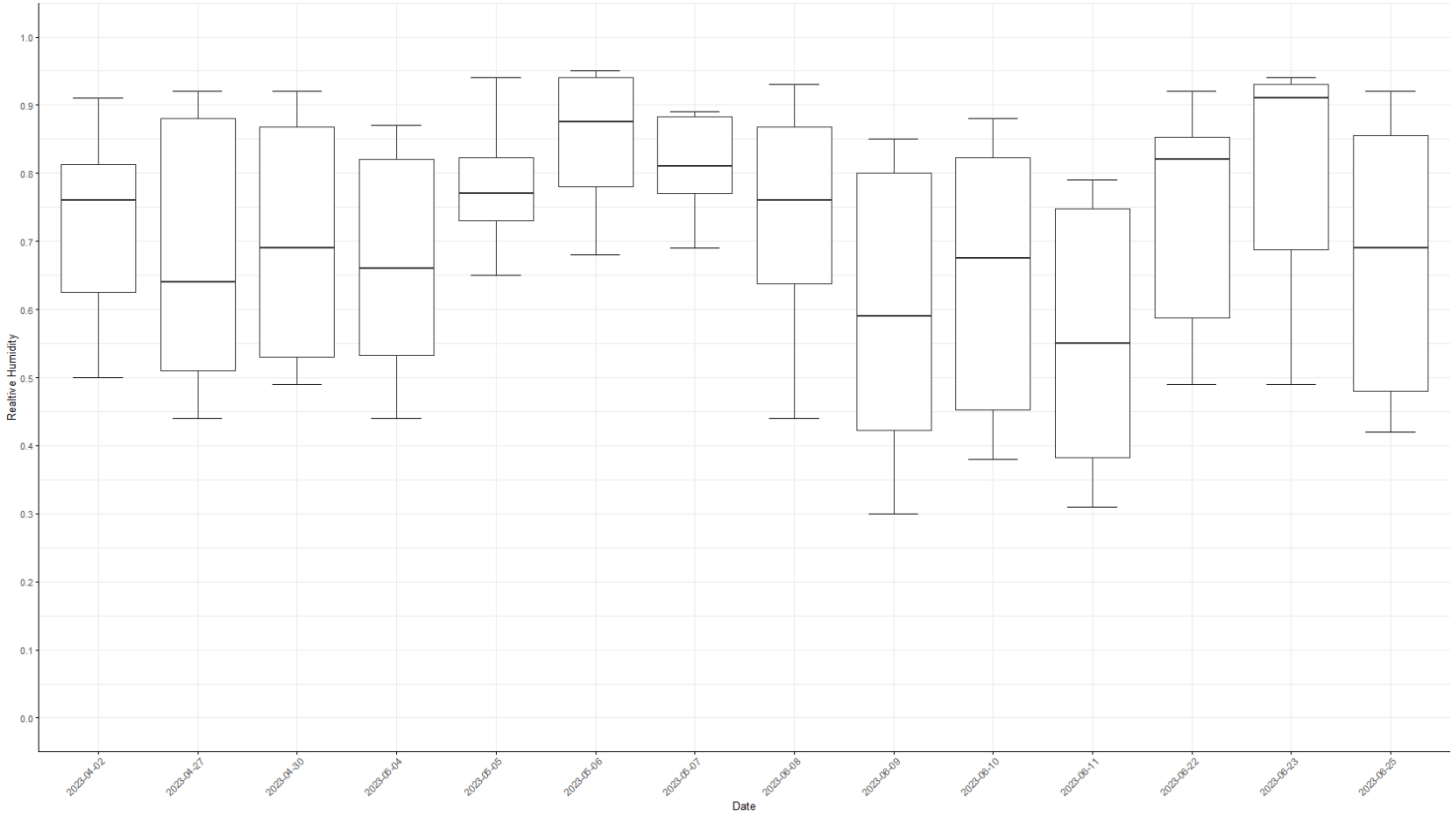

Appendix X: Local weather conditions - Precipitation

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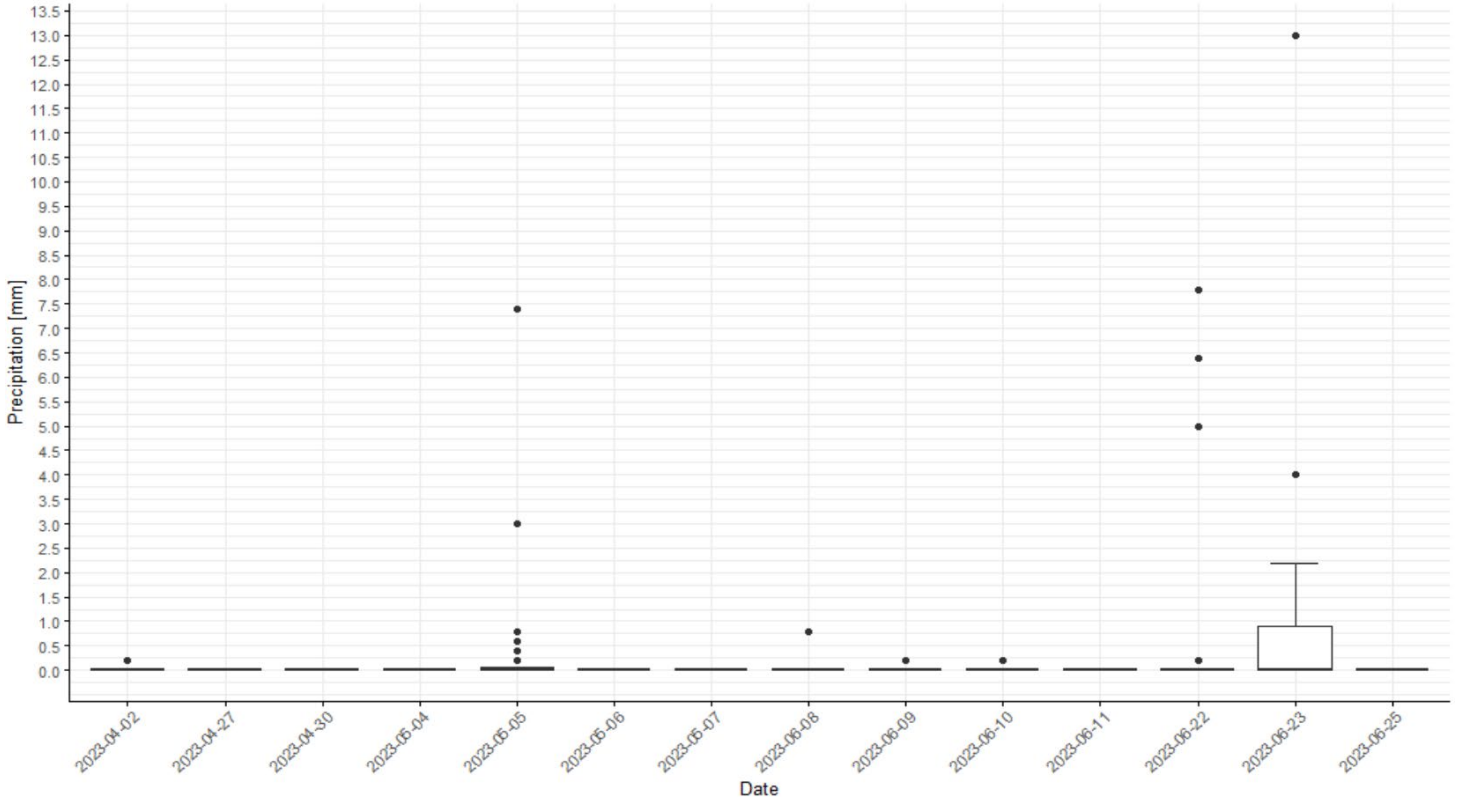

Appendix XI: Local weather conditions – Solar radiation

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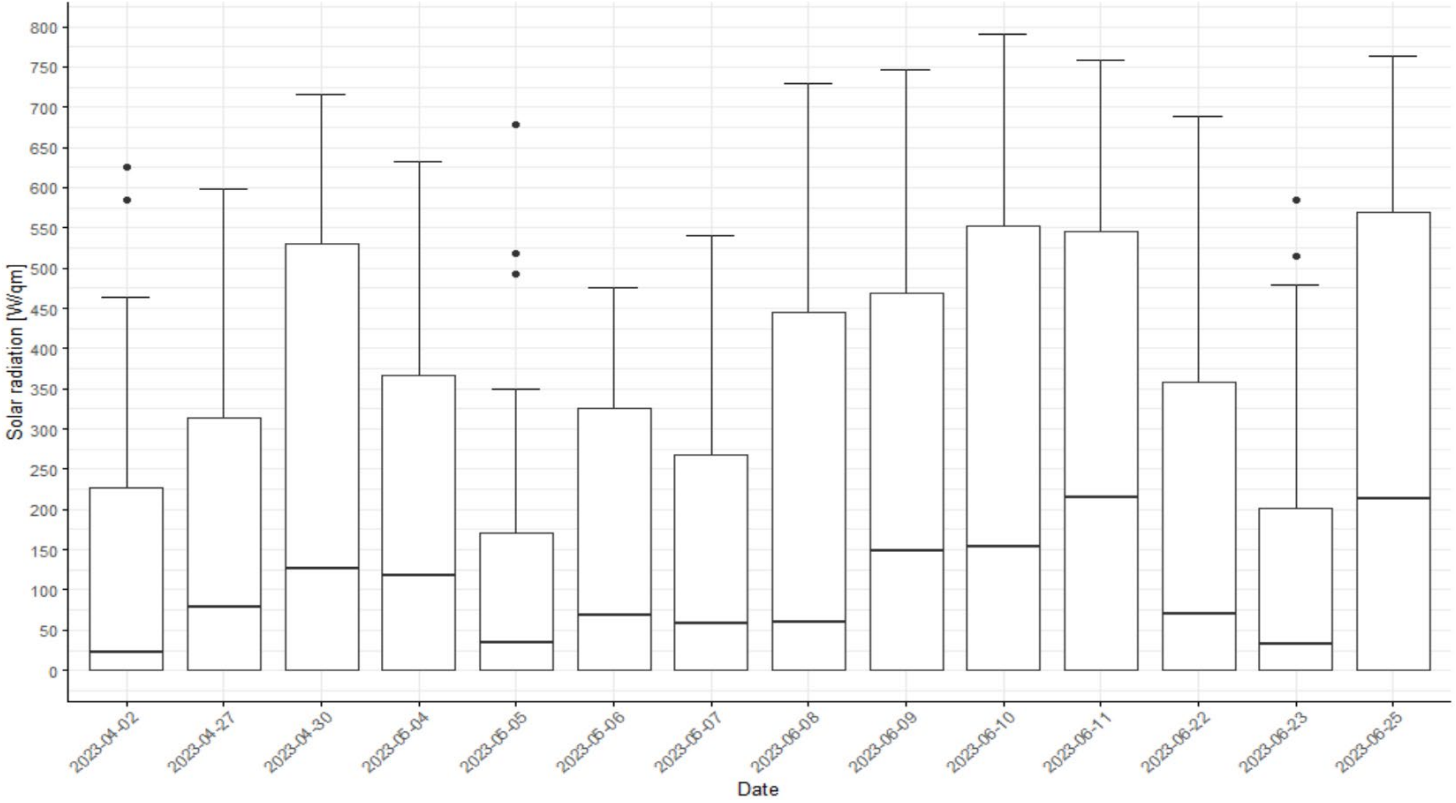

Appendix XII: Local weather conditions – Windspeed

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