# NAEMS: National Air Emissions Monitoring Study

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# Over the Past Decade….

- Public complaints over air emissions from large animal feeding operations (AFOs)
- National Research Council report (2003)
  - Insufficient scientific data to regulate air emissions from AFOs
  - Comprehensive emission study needed (NAEMS)


Newsweek

National Affairs

The Smell Of Success

Hog farms stink. But the neighbors are rising up.

BY DIRK JOHNSON AND VINCE KUPPIG

IT STARTED AS A JOYOUS Easter egg hunt on the Nebraska prairie. But when the winds shifted, it stunk so badly of hog manure the kids ran indoors. "Oh Grandma," one of the little girls cried

July 12, 2004


The New York Times

The Huge Flow of Animal Waste

Much of U.S. livestock is raised in industrial operations that produce many times their animals' weight in manure. Immense lagoons used to store waste can degrade the surrounding air and water.

U.S. livestock produces perhaps 900 million tons of waste annually, about **3 tons of manure** for each American.

A 1,100-pound beef cow can produce manure at a clip of about **14.6 tons annually.**

Iowa's hogs produce at least 50 million tons of waste annually, about **16.7 tons of manure** for each of the 2,988,000 residents of the state.

Weight equivalent of that manure as measured in Toyota Priuses: 2 cars.

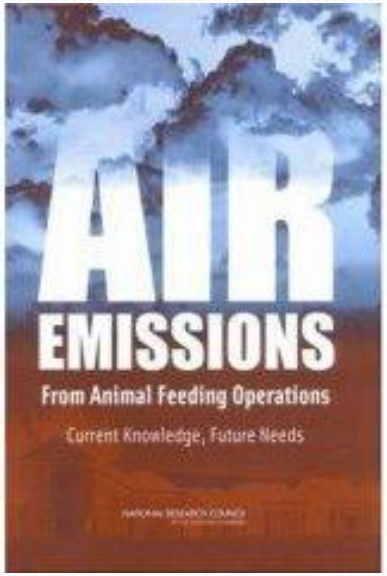
That's the weight equivalent of 10 cars.

That's the weight equivalent of 11.4 cars.

Sources: David Pimentel, Cornell Univ.; Ohio State Univ.; Iowa State Univ.

BILL MARSH/THE NEW YORK TIMES

January 26, 2008



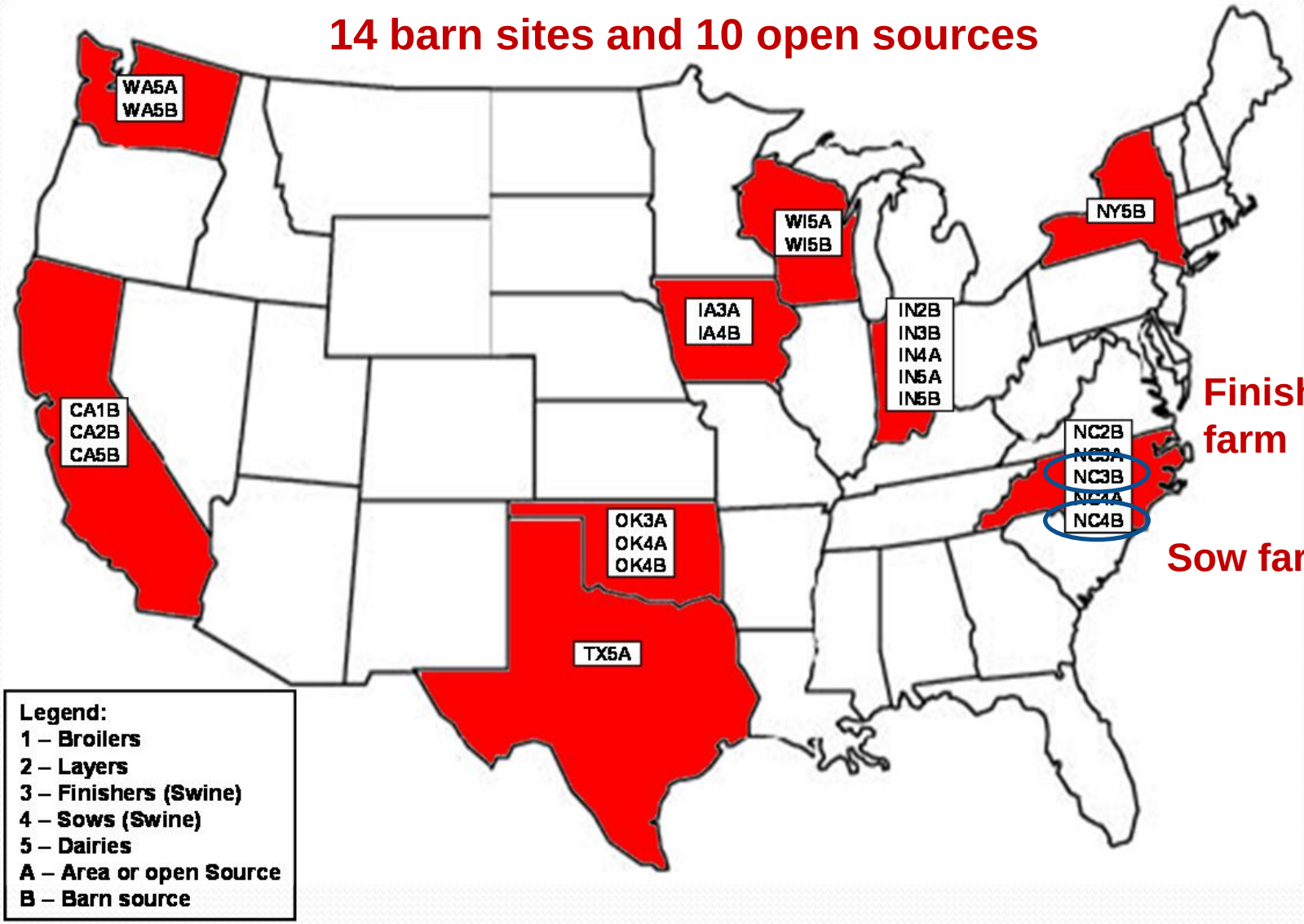
# NAEMS

- Established in 2006 by a voluntary Air Compliance Agreement between the EPA and the pork, dairy, egg and broiler industries.
- Addresses lack of data cited in NRC report.
- Livestock producers provided financial support to obtain emissions data to:
  - 1) accurately assess emissions from livestock operations and compile a database for estimation of emission rates;
  - 2) promote a national consensus for emissions-estimation methods/procedures from livestock operations.

# NAEMS

- Funding: National Pork Board, National Chicken Council, National Milk Producers Federation, American Egg Board
- EPA Office of Air Quality Planning and Standards (OAQPS)
- Lead institution Purdue University (Dr. Al Heber)
- Site PIs from Cornell Univ., Iowa State Univ., NCSU., Texas A&M University, Univ. of California-Davis, Univ. of Minnesota, Washington State Univ.

# National Air Emissions Monitoring Study



# What emissions are regulatory concern and monitored?

- Ammonia, $NH_3$
- Hydrogen Sulfide, $H_2S$

EPCRA (Emergency Planning and Community Right-to-know Act)

- Particulate Matter, PM (Dust)
- Volatile Organic Compounds (VOCs)

Clean Air Act

- Greenhouse Gases
  - Carbon dioxide, $CO_2$
  - Methane, $CH_4$ (dairy only)
  - Nitrous oxide, $N_2O$ (restricted to few sites)

# Governing equation of air emissions from ventilated building

$$[ER_G]_t = \sum_{e=1}^{n}[Q_e]_t\left([G]_e - \frac{\rho_e}{\rho_i}[G]_i\right)\times 10^{-6}\times\frac{w_m}{V_m}\times\frac{T_{std}}{T_a}\times\frac{P_a}{P_{std}} \quad [1]$$

$$[ER_{PM}]_t = \sum_{e=1}^{n}[Q_e]_t\left([PM]_e - \frac{\rho_e}{\rho_i}[PM]_i\right)\times 10^{-6}\times\frac{T_{std}}{T_a}\times\frac{P_a}{P_{std}} \quad [2]$$

where
- $[ER_G]_t$ = Gaseous ER of the source during sample integration time t, (g house$^{-1}$ t$^{-1}$)
- $[ER_{PM}]_t$ = PM emission rate of the house (g house$^{-1}$ t$^{-1}$)
- $[Q_e]_t$ = Average ventilation rate of the house during sample integration time t under field temperature and barometric pressure (m$^3$ house$^{-1}$ t$^{-1}$)
- $[G]_i$,$[G]_e$ = Gaseous concentration of incoming and exhaust ventilation air, ppm$_v$
- $[PM]_i$ = PM concentration of incoming ventilation air (ug m$^{-3}$)
- $[PM]_e$ = PM concentration of exhaust ventilation air (ug m$^{-3}$)
- $w_m$ = molar weight of air pollutants, g mole$^{-1}$
- $V_m$ = molar volume of the gas under consideration at standard temperature (0°C or 20°C) and pressure (1 atmosphere) (STP), 0.022414 m$^3$ mole$^{-1}$ (0°C) or 0.024055 m$^3$ mole$^{-1}$ (20°C)
- $T_{std}$ = standard temperature, 273.15 K (or 293.15 K)
- $T_a$ = absolute house temperature, (°C+273.15) or (°C+293.15) K
- $P_{std}$ = standard barometric pressure, 101.325 kPa

Xin et al. (2010) Mythologies and Protocols for Analysis of Raw data to minimize uncertainties of resultant aerial emissions estimation (In Press).

# Aerial emissions from swine buildings

- Emission rate = concentration x ventilation rate
- Emissions are a mass per unit time
  - g/d/$m^{-2}$, per surface area
  - g/d/AU (per Animal Unit, AU = 1000 lb = 500 kg)

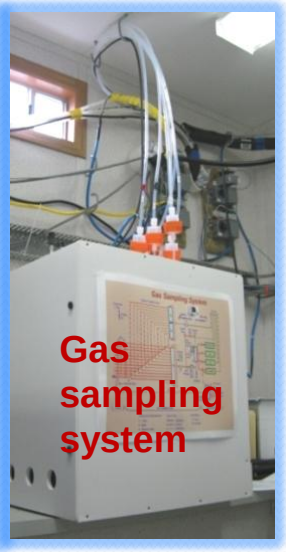




NH3 analyzer

Barn PM controller


Gas diluter



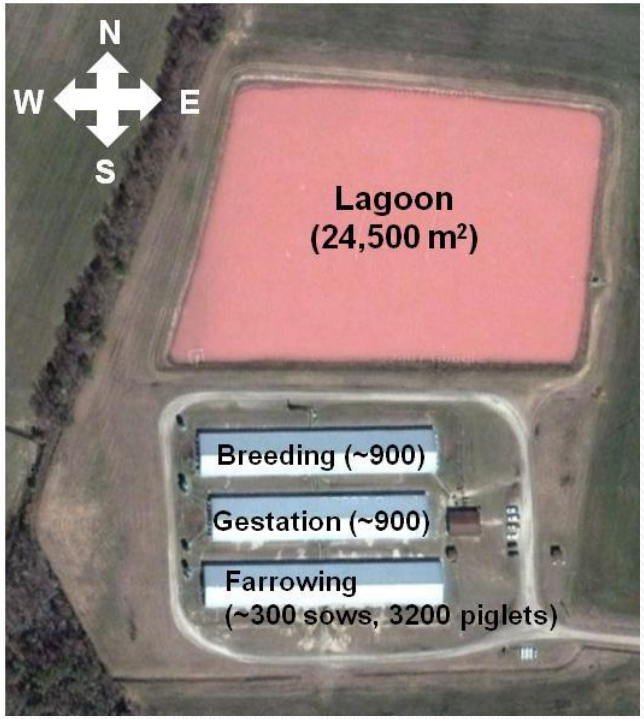
Gas sampling system

Ambient PM controller

H2S analyzer

# Finishing farm (NC3B)

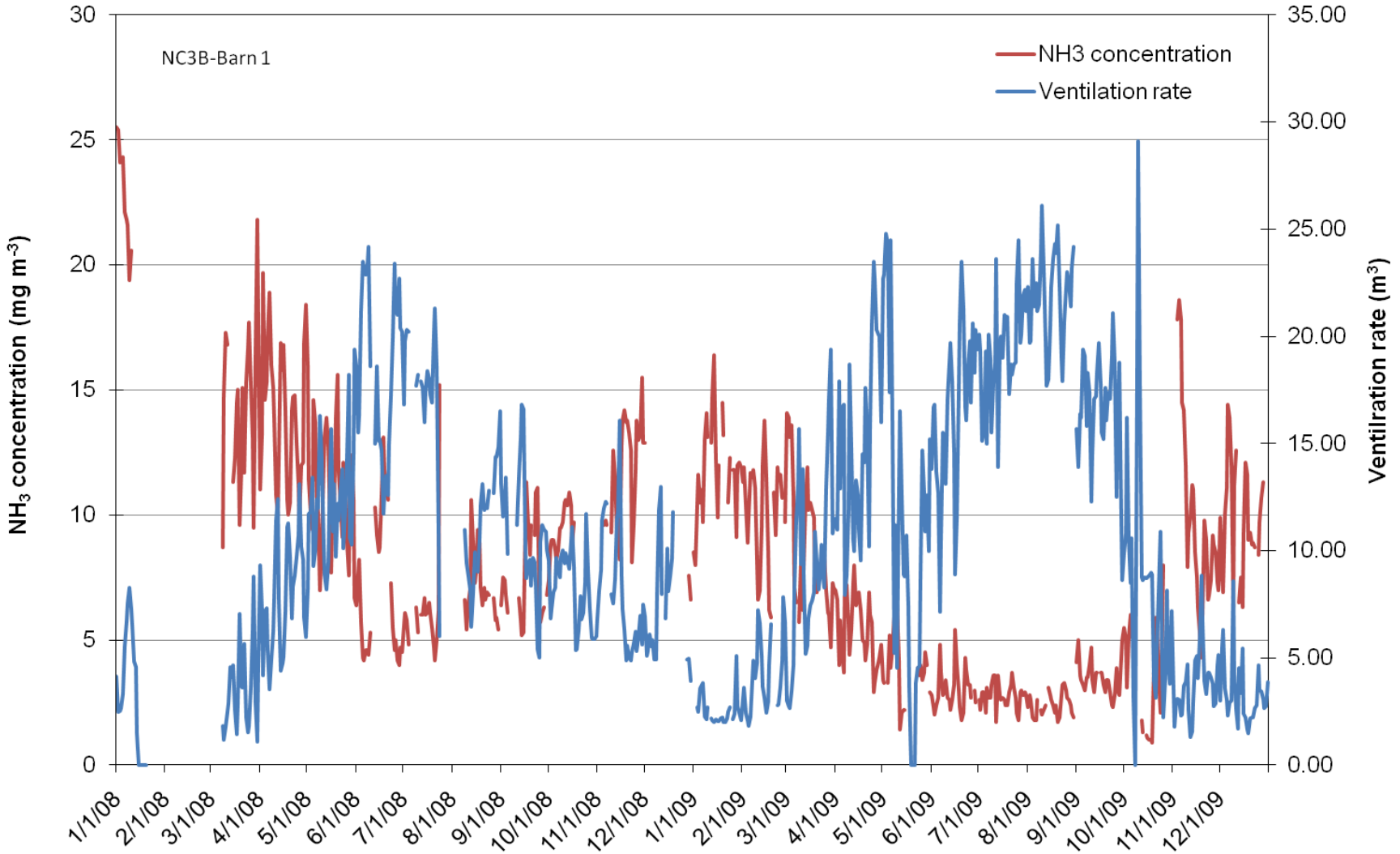

# Sow farm (NC4B)



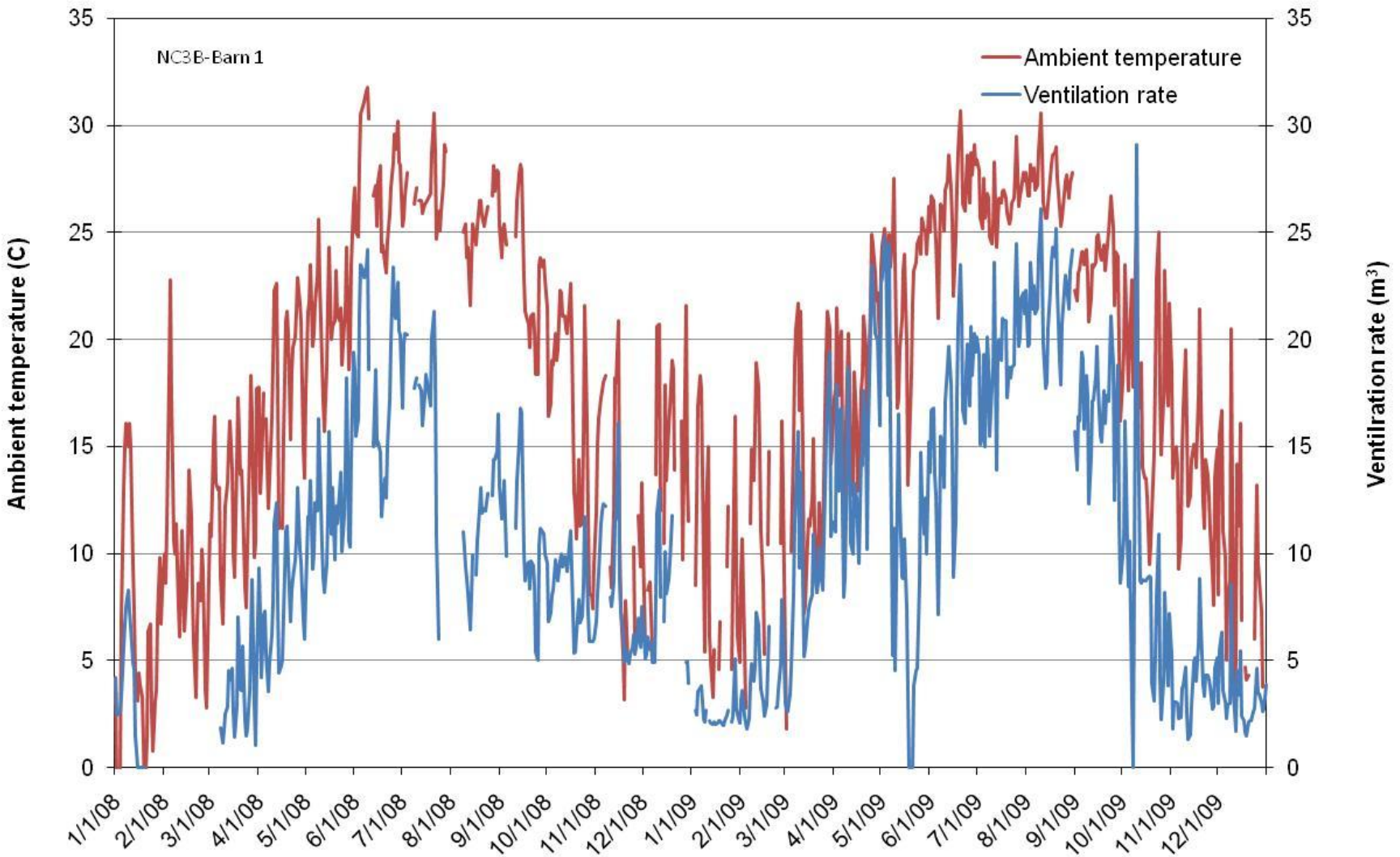

F1
F2
F3
F4
F5
F6
6 Ventilation stage
5
3
1-2
4
7
Fan number
Instrument shelter
(Breeding, 17 m × 153 m)
F1
F2
F3
F4
F5
F6
F7
F8
3
4
5
1 & 2
8
7
6
tation,18 m × 138 m)
1 & 2
3 & 4
5
F1 F2 F3
(Farrowing, 17 m × 152 m)
Activity sensor
Air sampling
Anemometer
Cooling cel
Exhaust fan
Gas heater
port
Wind se
RH/T sensor
Solar sensor

# Ammonia

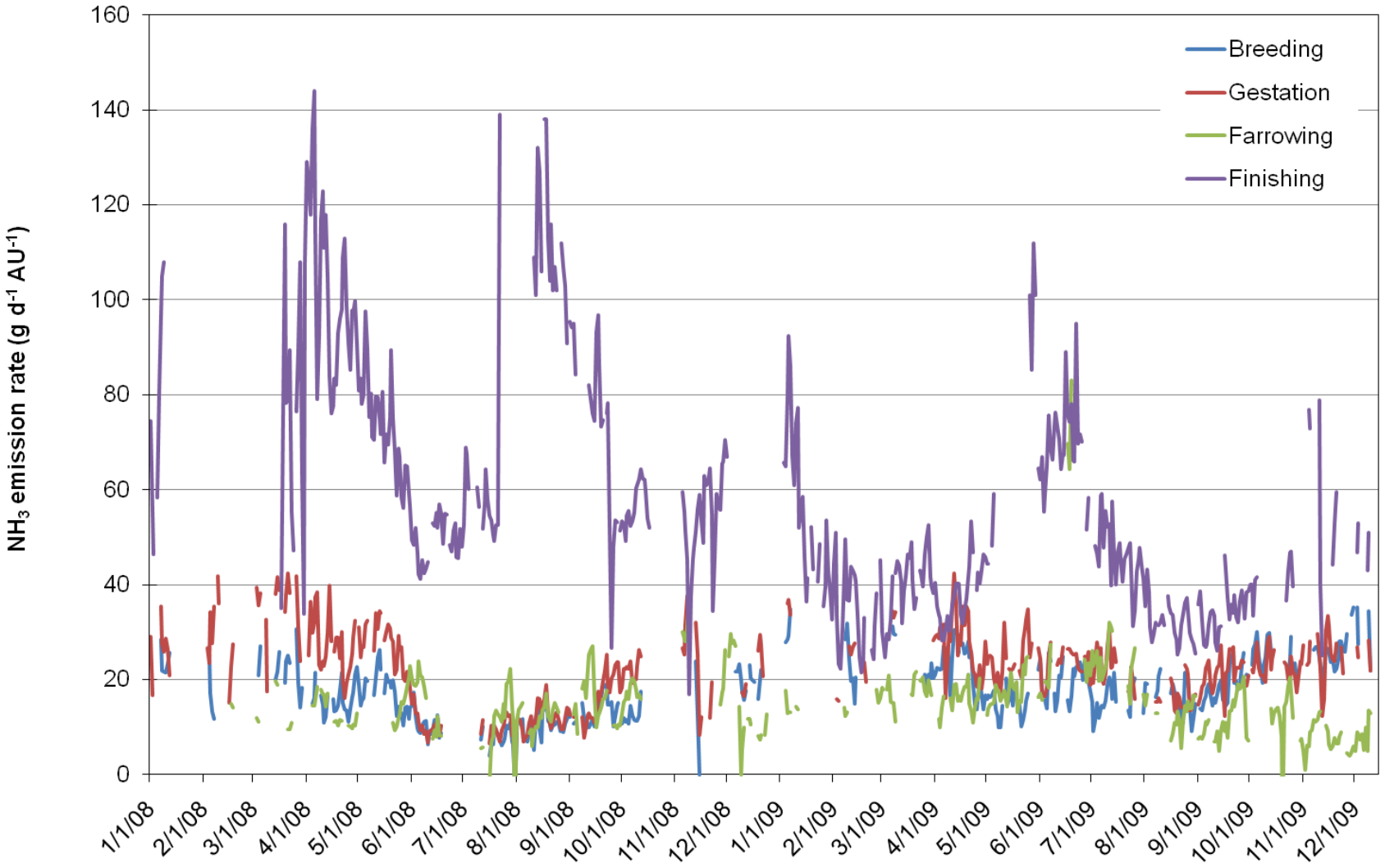
# Concentration vs Ventilation



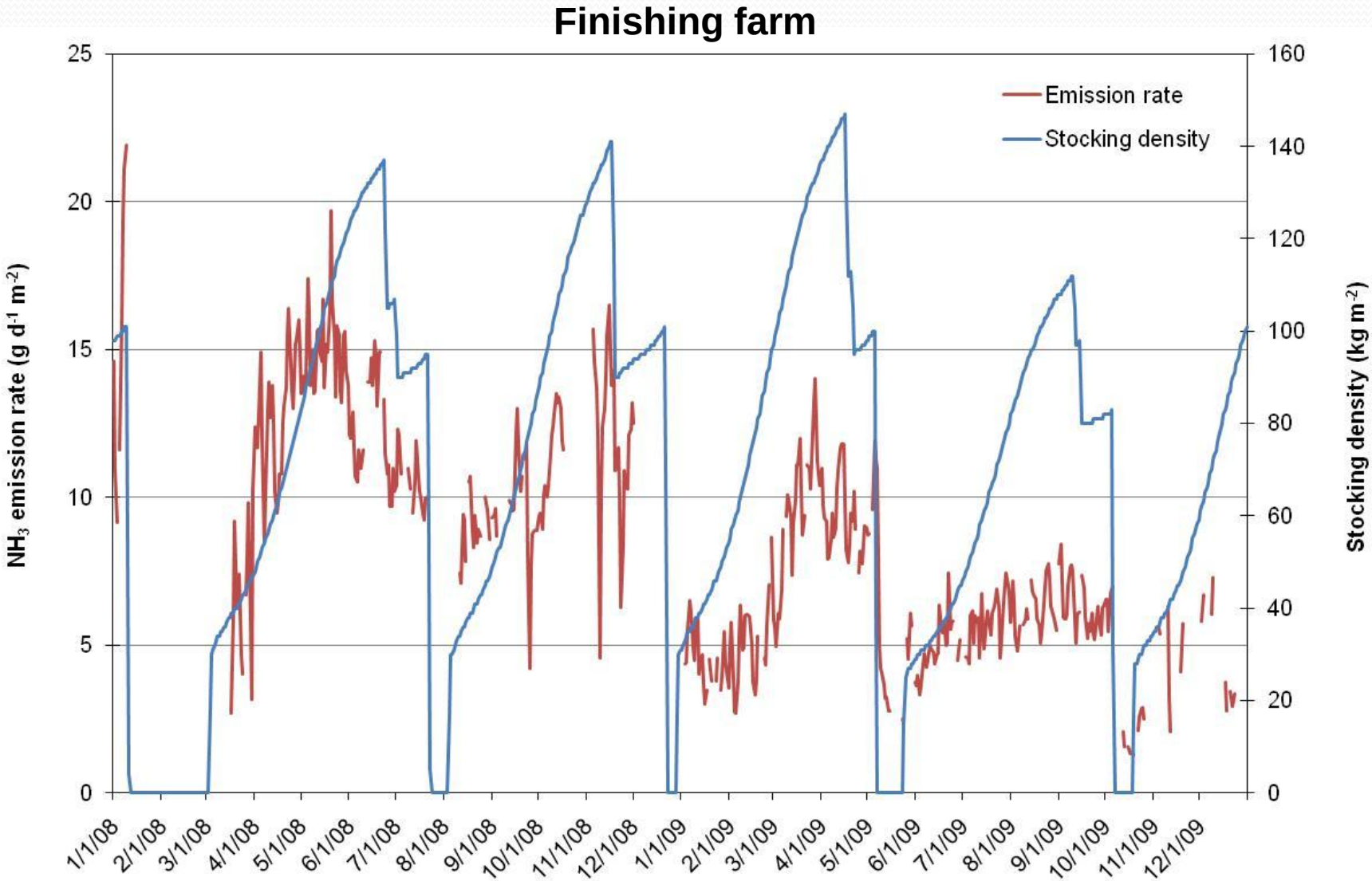
# Ambient temperature vs Ventilation



# NH3 emission rate across farm operations

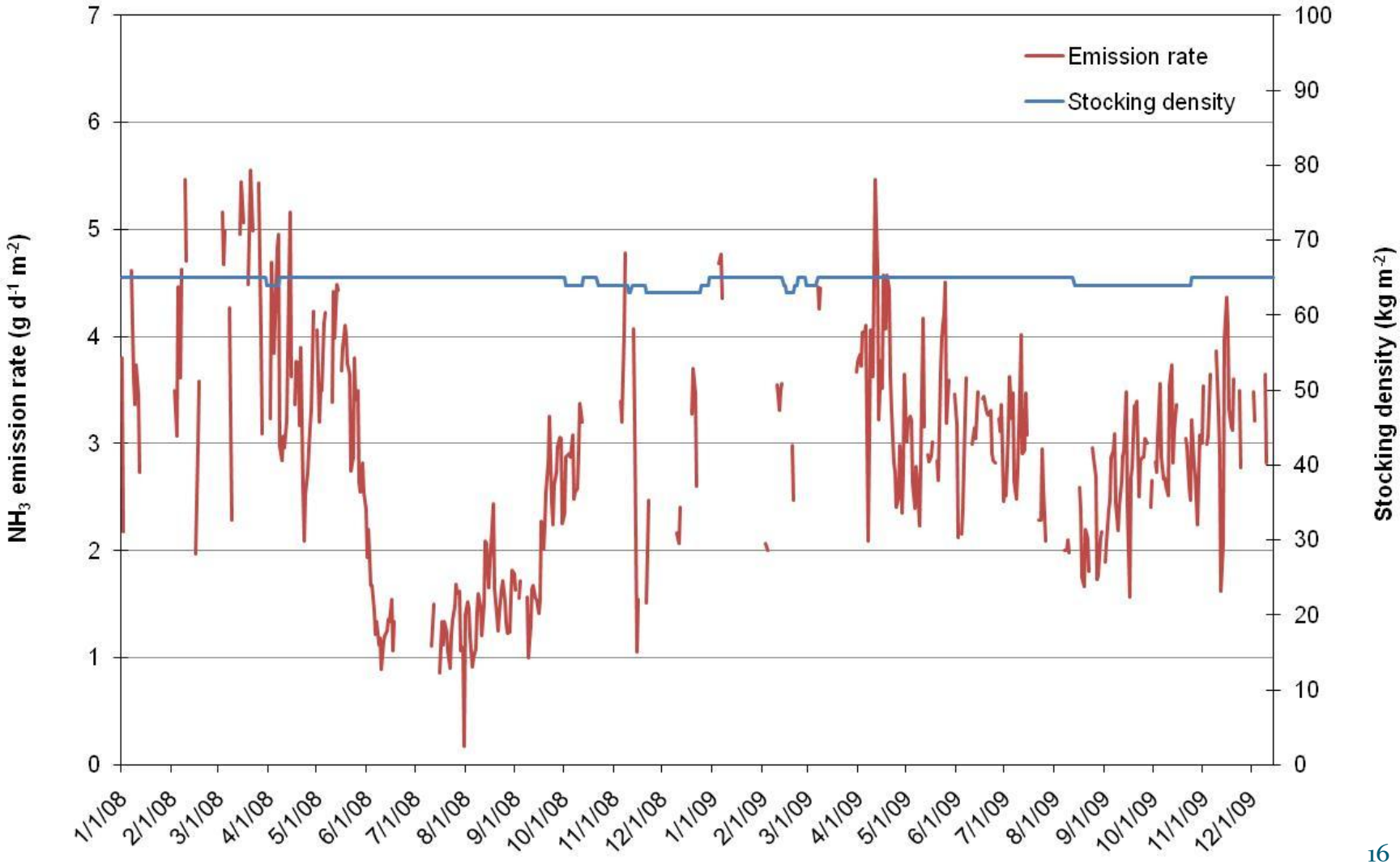


# NH3 emission rate vs Animal density



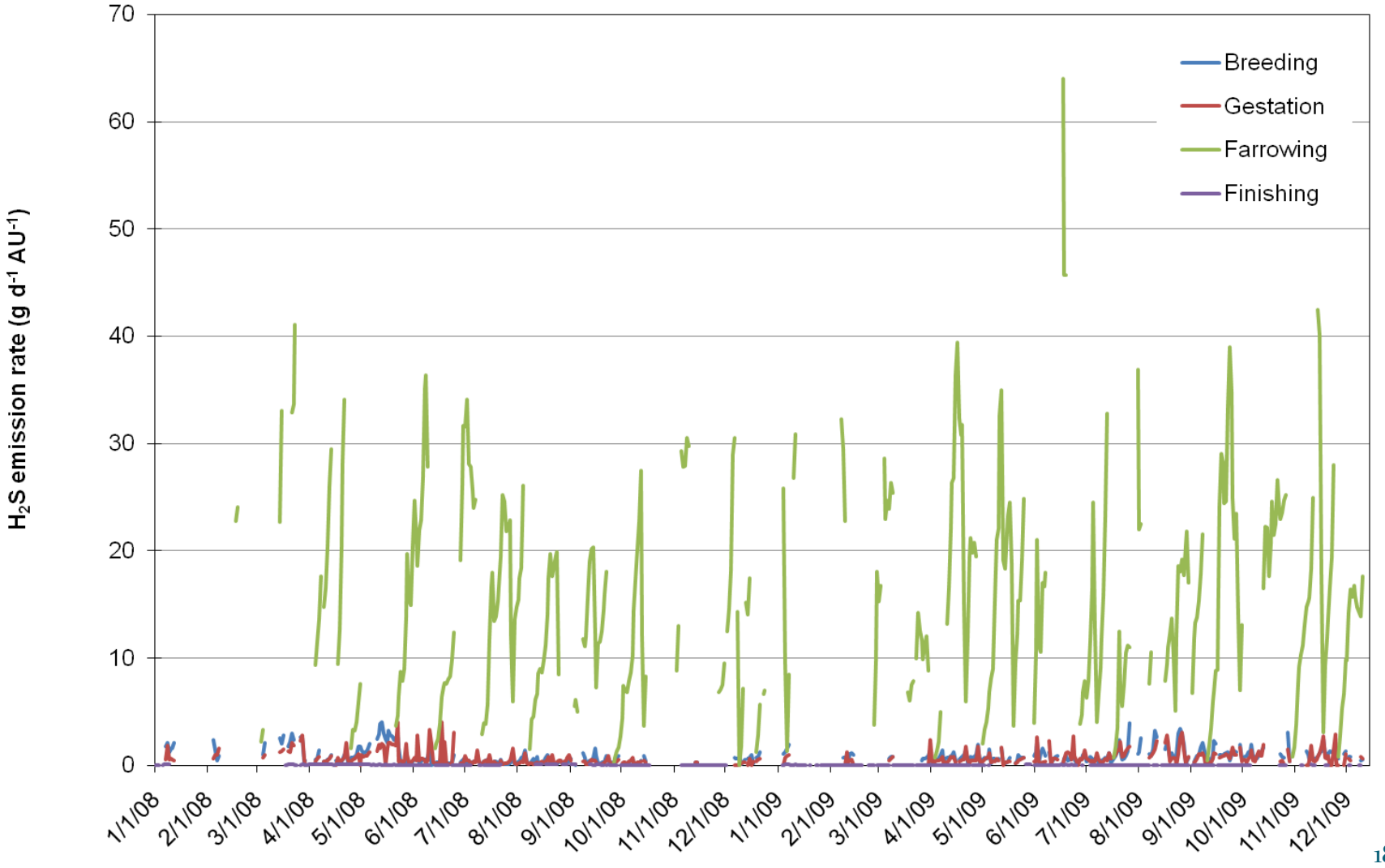
# NH3 emission rate vs Animal density

**Sow Farm (Gestation)**



# Hydrogen Sulfide

# H2S emission rate across farm operations



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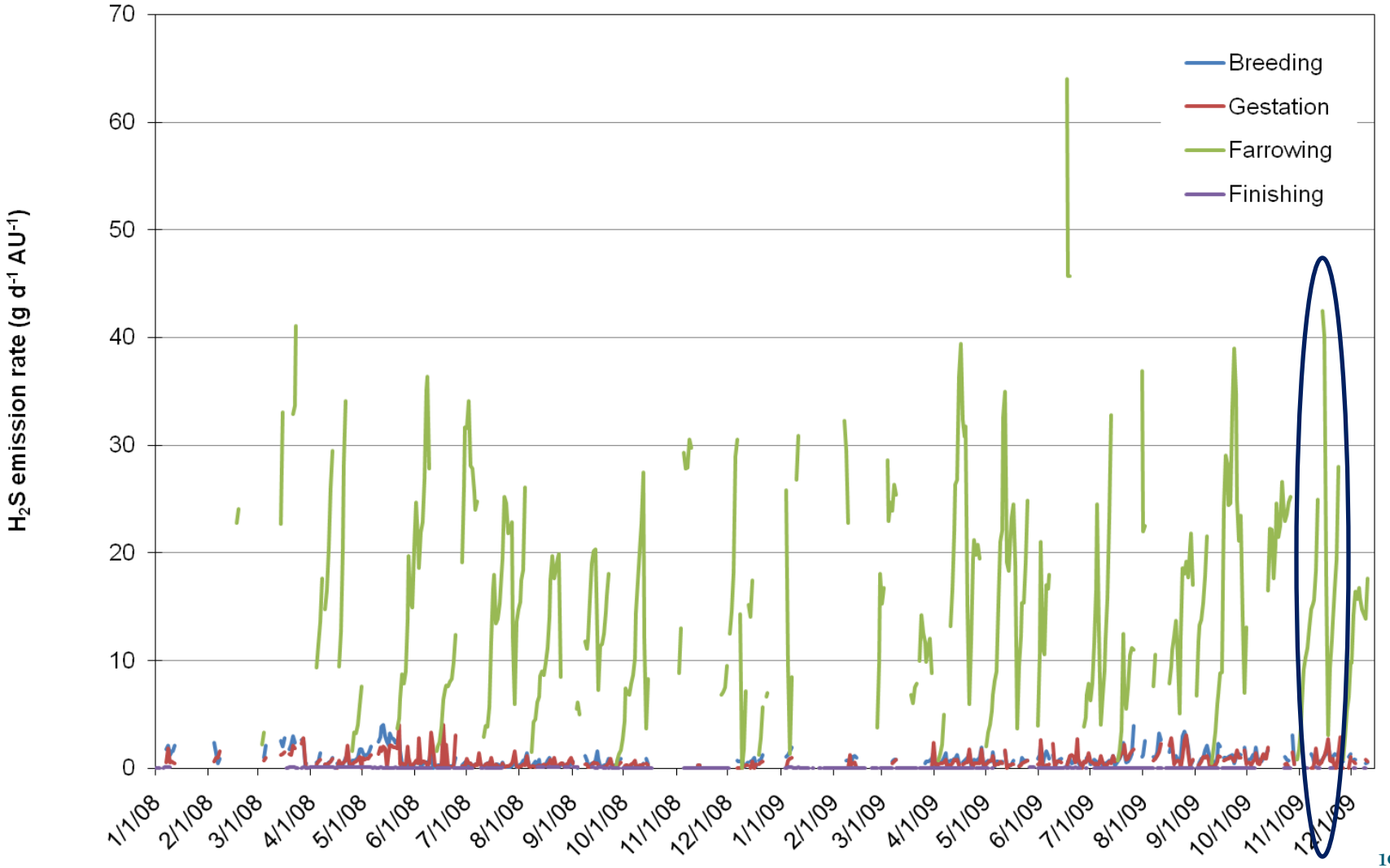
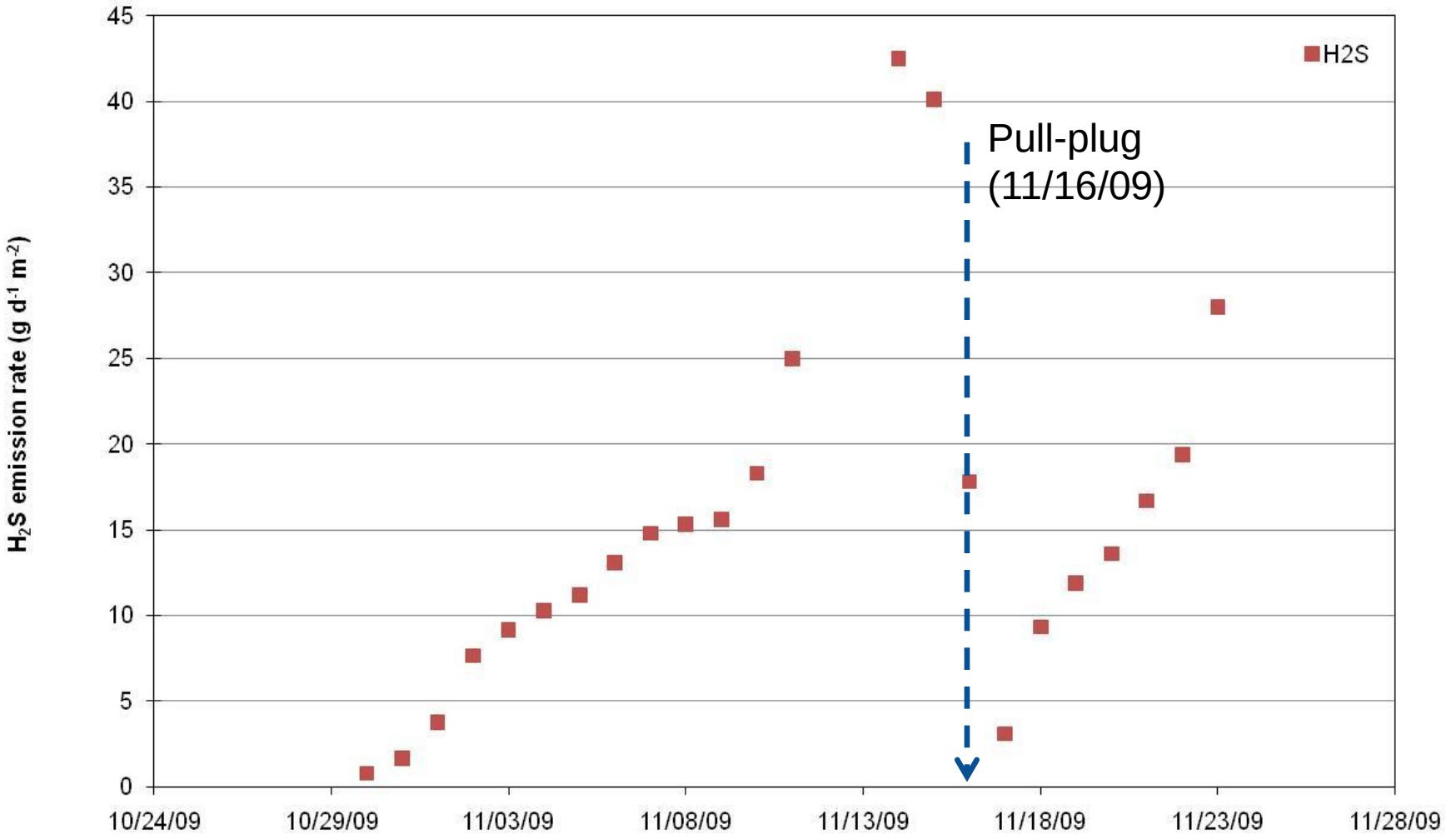
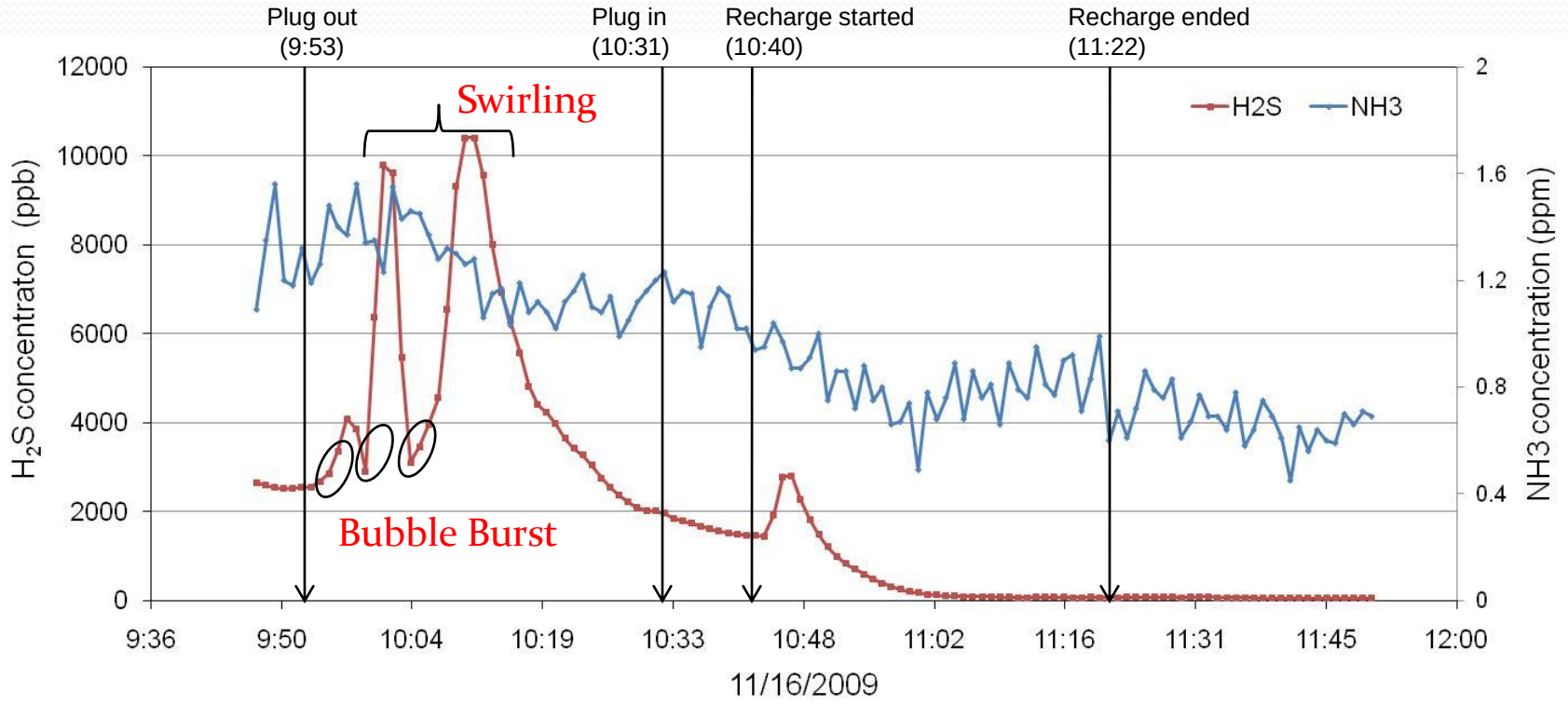


# H2S emission rate during a farrowing cycle (10/28/09 to 11/24/09)



# Gas concentrations during pit drainage and recharge





Before Drainage


Bubble Burst


Swirling


After Recharge

# *Ancillary Information*

- Feed Inputs and Composition
- Analyses of pit liquid and pit sludge
- Animal numbers and live weight changes during rotation
- Observation of pit recharge events
- Management differences/styles
- Foundation for additional work/studies:
  - Development of process-based models
  - Reduction in emissions through changes in existing management practices

# Summary and Conclusion

# Ammonia Emission

**Breeding (17.8 g/d-AU)**

**Gestation (22.6 g/d-AU)**

**Farrowing (15.1 g/d-AU)**

**Finishing (57.4 g/d-AU)**

- Per barn basis, 5 kg /d from finishing operation
- Nine barns at finishing farm emit close to 100 lb $NH_3$ $d^{-1}$ (45.4 kg $NH_3$ $d^{-1}$).
- Per N feed consumed at finishing operation, about 10 % of N was emitted as $NH_3$ (45 kg N/barn-day vs 5 kg $NH_3$/barn-day).

# Hydrogen Sulfide Emission

**Breeding (0.9 g/d-AU)**

**Gestation (0.7 g/d-AU)**

**Farrowing (15.5 g/d-AU)**

**Finishing (2.1 g/d-AU)**

- Farrowing operation - could be a potential hazard to pigs and farm workers
- Not close to 100 lb $H_2S$ $d^{-1}$ (45.4 kg $d^{-1}$, EPCRA threshold)

**Collaborators:**

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Erin Cortus (SDSU)
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# Thank you
# Question?

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PURDUE UNIVERSITY
PAAQL
Purdue Agricultural Air Quality Laboratory
PURDUE AGRICULTURE

This project was supported by the Agricultural Air Research Council and the National Pork Board.