Acknowledgements

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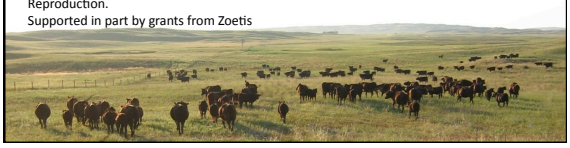
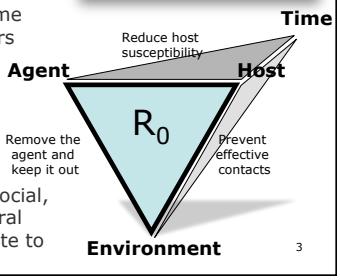
A contribution of the Beef Cattle Population Health Program at Mississippi State University.
Supported by the Mikell and Mary Cheek Hall Davis Endowment for Beef Cattle Health and Reproduction.
Supported in part by grants from Zoetis



Systems thinking in veterinary medicine

Traditionally, disease control programs have focused on agent-host interactions with some environmental factors considered.



However, political, social, economic, and cultural factors also contribute to disease ecology

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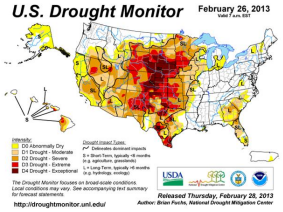
Systems thinking in veterinary medicine

The failure of disease control programs, whether at a local, regional, or global level, frequently results from not fully considering or understanding the system comprising the disease's ecology including the decisions made by people responding to factors within the system (e.g. economic factors).



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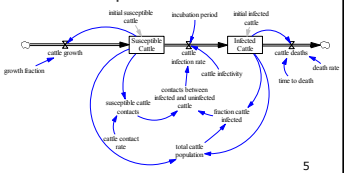
System Dynamics

- Methodology that originated from the application of feedback control theory to the study of complex systems.
- Models include:
  - Cause and effect relationships
  - Interactions
  - Time delays
  - Feedback loops



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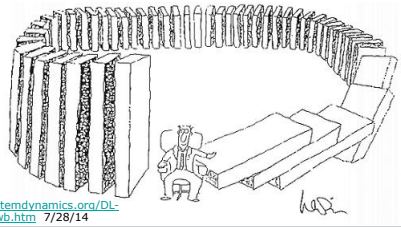
Systems thinking in livestock production systems

System dynamics models could help us understand and (at least sometimes) predict behaviors that present a risk to livestock production system health and sustainability.



http://www.systemdynamics.org/DL-IntroSysDyn/bwb.htm 7/28/14

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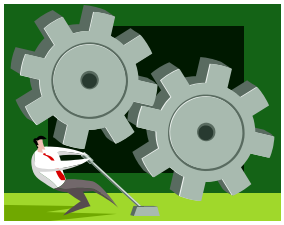
Systems thinking as an approach to problem solving

Our challenge is to recognize how the system is influencing the outcome of concern…

AND to find the leverage point for changing the system



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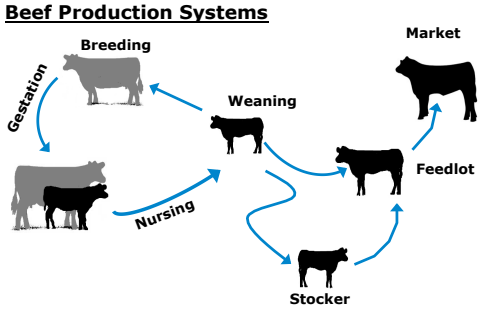
Beef Production Systems



Adapted from http://www.aps.uoguelph.ca

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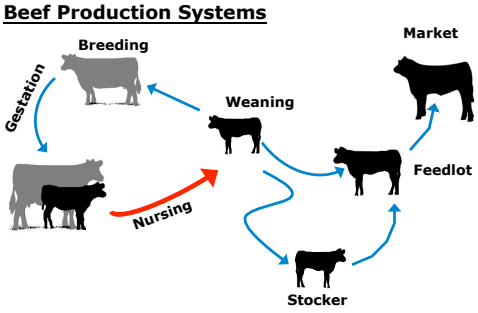
Beef Production Systems



Adapted from http://www.aps.uoguelph.ca

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Evaluating and managing risk

- What are you worried about?
- Is it serious?
- How likely is it to happen?
- How does that compare to "normal" day to day activities?

Risk Assessment

- What can be done to minimize the risk?
- Does lowering that risk increase another?

Risk Management

- Does everyone understand?
- Did we write down what we did?
- Did it work?

Documentation and Communication

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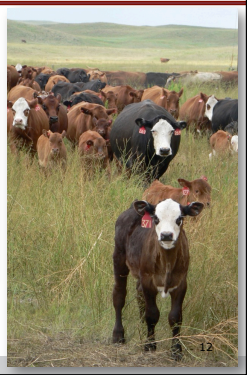
Pre-Weaning Pneumonia in Beef Calves

Host-pathogen interactions

Population dynamics



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The cost of calfhood pneumonia

Sample: Beef cow-calf ranchers with a history of pre-weaning BRD

Mail survey

Clicker survey

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Main contents of Survey

Part I General Information	Beef cow-calf producer or not State of residence Number of beef cows and replacement heifers in January, 2016
Part II Cost of BRD prevention	Beef cows and heifers Beef calves prior to weaning Cost for vaccine Time cost to vaccinate Cost for labor to vaccinate People who performed the vaccination*
Part III Cost of treatment for pre-weaning BRD	Sick beef calves Medicine cost Time cost to treat per sick calf Cost for labor to treat per sick calf People who performed the treatment*
Part IV Veterinary service cost for BRD*	Veterinary services cost (not counting vaccine, drugs) related to BRD diagnosis, prevention, and treatment to beef calves per year*

* Questions only included in the clicker survey

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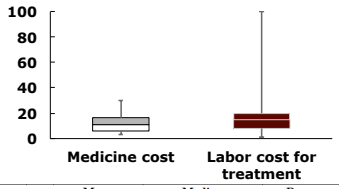
Results

Crude annual treatment costs for pre-weaned BRD
per sick calf per year ($)



Variable	n	Mean (SD)	Median (IQR)	Range (Min, Max)	LS means*
Medicine cost	36	13.00 (7.41)	11.00 (6.00-16.50)	3.00-30.00	12.95[a]
Labor cost	38	19.45 (18.12)	15.00 (8.00-20.00)	1.00-100.00	19.43[b]

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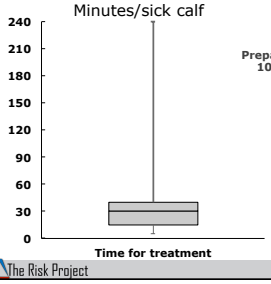
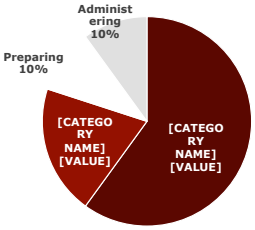
Results

Crude time spent on treatment



Percent of time spent to treat sick calves



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Total cost of BRD in beef calves prior to weaning, 2011–2015

Cost of BRD mortality

Treatment cost

Losses from lost weaning weight from BRD

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Materials and Methods

Data

- USDA reports
  - NAHMS 2007-2008, NASS 2011-2015, and AMS 2011-2015
- Survey
  - 43 beef cow-calf ranchers from Nebraska, South Dakota, and North Dakota
- Peer-reviewed papers
  - Data directly from the paper
  - Simulation of the data from the paper

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Materials and Methods

Monte Carlo Simulation Model

Risk analysis to estimate the uncertainty and variation of the cost of BRD in pre-weaning calves

- 10,000 iterations
- Sensitivity analysis

@RISK
Advanced Risk Analysis for Spreadsheets

Excel

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$165 million per year

Total cost of BRD in US beef calves prior to weaning

Outputs	Median (5%–95% CrI)		
	National cost (Million $)	Cost/cow ($)	Cost/Sick calf ($)
Cost of BRD mortality ($C_{MortalityBRD}$)	126 (92–200)	4.30 (3.08–6.70)	165.70 (110.25–268.95)
Death loss due to BRD less than 3 weeks ($C_{DeathBRD<3w}$)	44 (29–72)	1.48 (0.96–2.42)	56.23 (34.79–94.72)
Death loss due to BRD ≥3 weeks of age to weaning ($C_{DeathBRD\geq3w}$)	84 (57–138)	2.87 (1.93–4.65)	109.84 (69.31–183.67)
Cost to treat pre-weaning BRD ($C_{TreatBRD}$)	25 (20–32)	0.86 (0.67–1.09)	32.45 (27.18–37.71)
Cost for medicine to treat pre-weaning BRD ($C_{MedineBRD}$)	10 (8–13)	0.34 (0.27–0.43)	13.00 (10.96–15.04)
Cost for labor to treat pre-weaning BRD ($C_{LaborBRD}$)	15 (11–20)	0.51 (0.37–0.69)	19.45 (14.61–24.28)
Losses from lost weaning weight from BRD ($C_{LossWBRD}$)	15 (9–25)	0.50 (0.31–0.83)	18.49 (12.41–29.35)
Total cost of BRD in beef calves prior to weaning ($C_{TotalCostBRD}$)	165 (129–246)	5.63 (4.33–8.26)	215.74 (158.41–325.66)

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Conclusions

- **Pneumonia in calves prior to weaning is costly**
- Between 2011 and 2015 BRD in pre-weaned beef calves most likely cost US cattle ranchers:
  $165 million per year
  $5.63 per US cow…. $28 per cow in affected herds
  $216 per sick calf
- **Death loss** was the largest cost component representing 76% of the total cost, and calf death loss among calves ≥ 3 weeks of age to weaning was 50% of the total cost
- **Not** including the cost of vaccines or other prevention practices

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Agent factors

population dynamics of BRD pathogens in cow-calf systems are poorly understood

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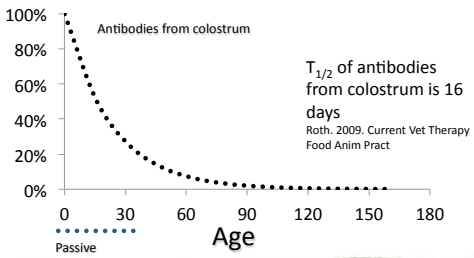
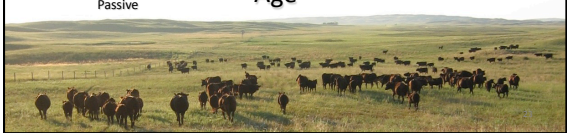
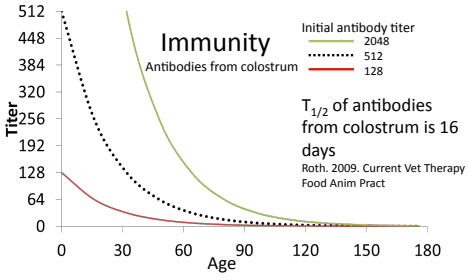
Host factors: Immunity



$T_{1/2}$ of antibodies from colostrum is 16 days

Roth. 2009. Current Vet Therapy Food Anim Pract





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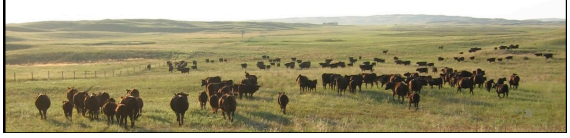

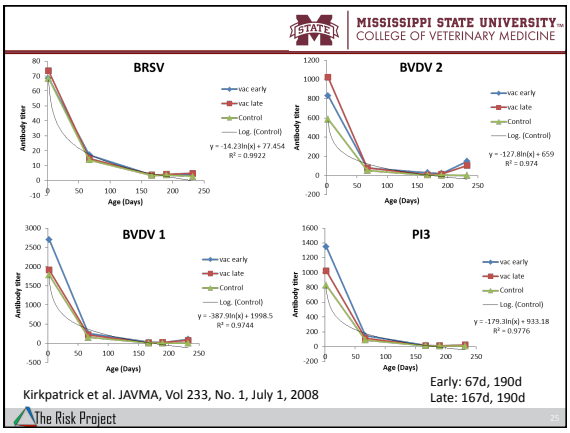
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BRSV
BVDV 2
BVDV 1
PI3
vac early
vac late
Control
Log. (Control)
Antibody titer
Age (Days)
Kirkpatrick et al. JAVMA, Vol 233, No. 1, July 1, 2008
Early: 67d, 190d
Late: 167d, 190d
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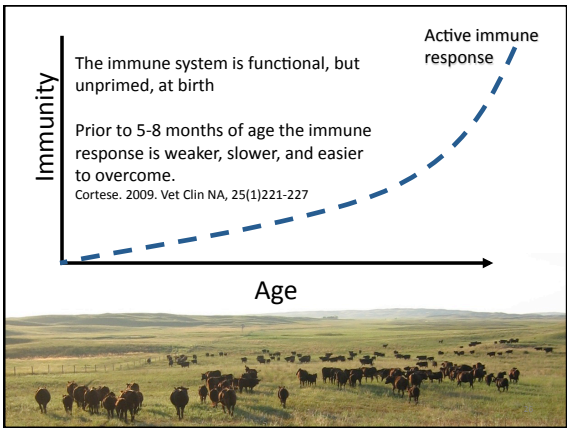
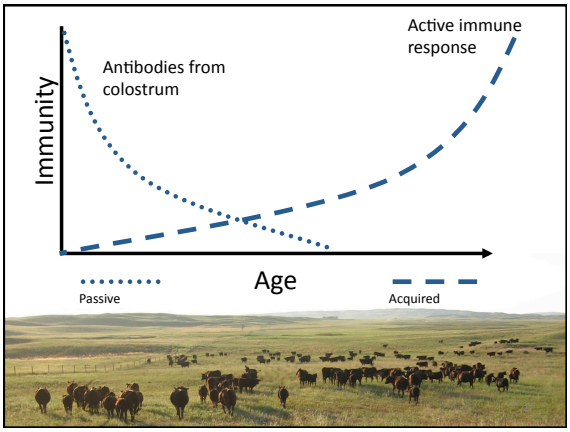
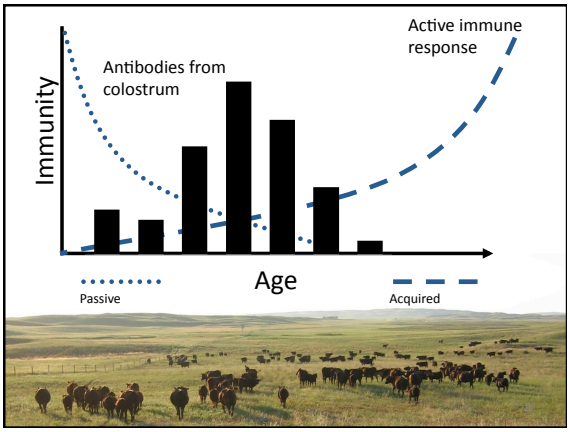

Immunity
The immune system is functional, but unprimed, at birth
Prior to 5-8 months of age the immune response is weaker, slower, and easier to overcome.
Cortese. 2009. Vet Clin NA, 25(1)221-227
Active immune response
Age


Immunity
Antibodies from colostrum
Active immune response
Age
Passive
Acquired


Immunity
Antibodies from colostrum
Active immune response
Age
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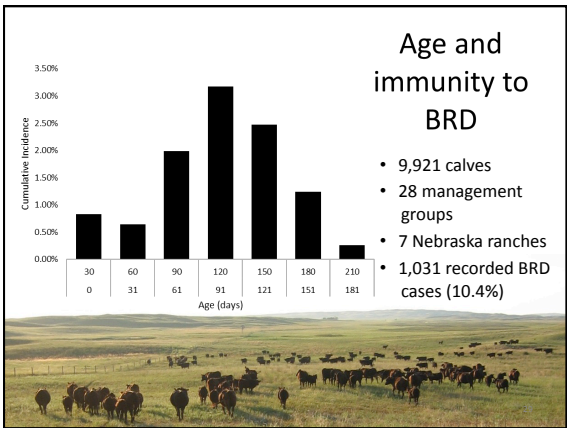
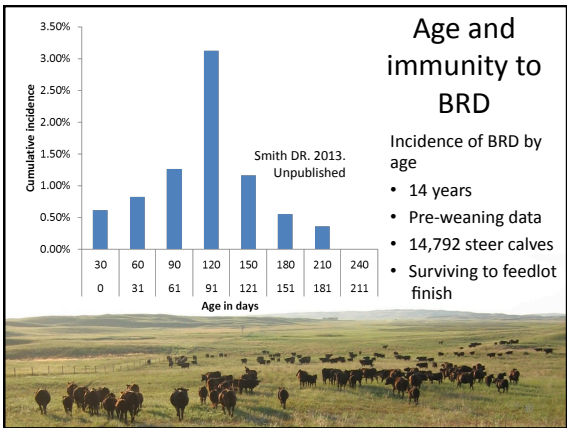

Age and immunity to BRD
• 9,921 calves
• 28 management groups
• 7 Nebraska ranches
• 1,031 recorded BRD cases (10.4%)
Cumulative incidence
Age (days)


Age and immunity to BRD
Incidence of BRD by age
• 14 years
• Pre-weaning data
• 14,792 steer calves
• Surviving to feedlot finish
Smith DR. 2013. Unpublished
Cumulative incidence
Age in days

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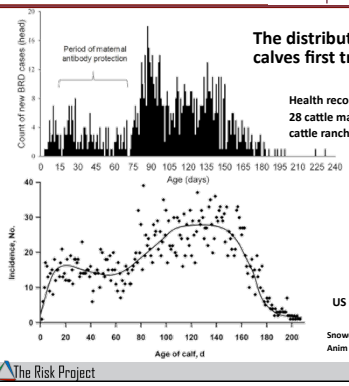

The distribution of the number of calves first treated for BRD by age

Health records representing 9,921 calves from 28 cattle management groups within 7 beef cattle ranches with BRD in Nebraska

110,412 calves
20 years
US Meat Animal Research Center

Snowder GD, et al. Anim Sci. 2005, 83(6):1247-61

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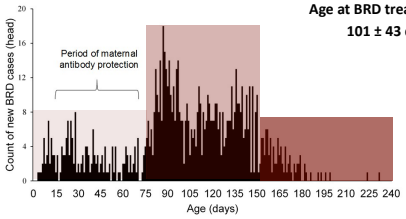
Different risk periods?

Age distribution for 877 of 9,582 calves with BRD



Age at BRD treatment
101 ± 43 d

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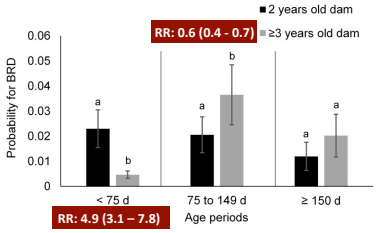
Results and discussion



Separate models adjusted probability for BRD by age of age in different age periods
(Differing superscripts within age periods are significantly different)

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Passive transfer of maternal antibodies

1,671 calves with health records from a single ranch with 4 management groups

56 recorded cases of BRD (3%)

- 384 calves from 3 management groups tested for IgG passive transfer
  - Radial immunodiffusion (adequate ≥ 1,600 mg/dl)
- 36 of 384 calves (9%) had inadequate passive transfer

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Passive transfer of maternal antibodies

21 of 384 calves (5%) with IgG data were treated for BRD

Calves with inadequate passive transfer were 3.4 times more likely to be treated for BRD than calves with adequate transfer (p=0.03)

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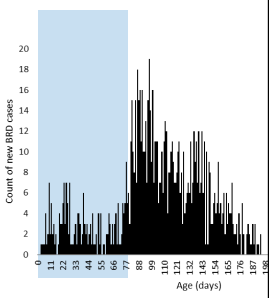
Passive transfer of maternal antibodies

21 calves treated for BRD had IgG data

- Calves with inadequate passive transfer were 3 times more likely to be treated for BRD in the first 80 days of age
- Fisher's exact p-value =0.08



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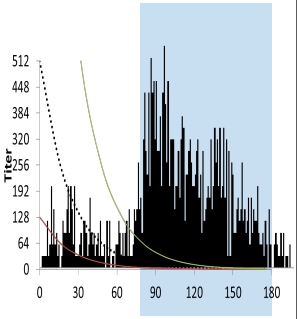
Discussion

- Failure to receive colostrum puts those calves at risk for pneumonia prior to 75 days of age
- **What explains the larger number of cases after 75 days of age?**



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Herd immunity

- Transmission is hindered because a majority of animals are immune –inefficient transmission means the pathogen may "die out" (R_0 <1) before everyone is exposed
- Results in protection of susceptible animals within the group
  - Better to be the susceptible calf within a pen of well-immunized cattle, than the only one vaccinated
  - For this reason successful vaccine programs are "group-based"

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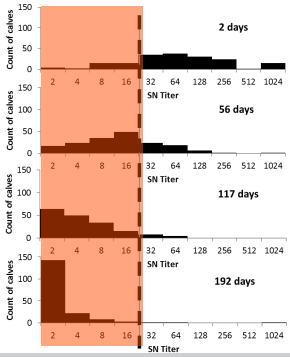
BRSV SN titers
179 calves serially sampled

As calves in the population age the distribution of titers shifts to the left

Leaving a smaller proportion of calves protected and a larger proportion of calves susceptible

Data provide by Dr. Amelia Woolums



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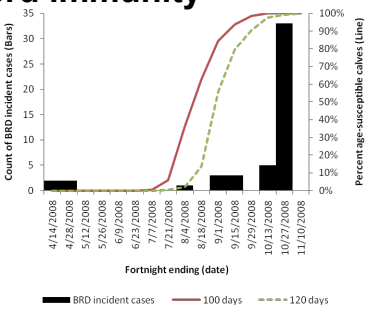
Loss of herd immunity

When a large portion of the calves have lost immunity from colostrum the group loses herd immunity and outbreaks of disease may occur



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Conclusions from ranch BRD outbreak investigations

- The two epidemic patterns may be related to factors of immunity:
  - **failure of passive transfer** resulting in **sporadic cases** of pneumonia in very young calves (<75 days)
  - **Loss of herd immunity** resulting in **outbreaks** of pneumonia in older calves (75-150 days of age) that are more rapid in onset and of higher incidence.

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Environmental factors

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JAVMA, Vol 243, No. 4, August 15, 2013 538-547

Producer survey of herd-level risk factors for nursing beef calf respiratory disease

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Objective—To identify herd-level risk factors for bovine respiratory disease (BRD) in nursing beef calves.
Design—Population-based cross-sectional survey.
Sample—2,600 US cow-calf producers in 3 Eastern and 3 Plains states.

Results –Bovine respiratory disease had been detected in at least 1 calf in 21% of operations

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"Detection of BRD in calves was
- Positively associated with **large herd size**, detection of BRD in cows, and diarrhea in calves. Calving season length was associated with BRD in calves in Plains states but not Eastern states.

Cumulative incidence of BRD treatment was
- Negatively associated with **large herd size** and examination of cows to detect pregnancy
- Positively associated with calving during the winter, introduction of calves from an outside source, offering supplemental feed to calves, and **use of an estrous cycle synchronization program for cows**."

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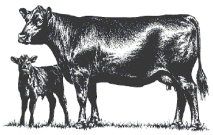
Understanding Herd Level Risk Factors for Pneumonia in Calves Prior to Weaning



- **Case-control study** of herd level risk factors for nursing calf BRD
- Phone interviews of producers
  - case herds: treated ≥ 5% of nursing calves for BRD
  - control herds: treated ≤ 0.5% of nursing calves for BRD
  - 2 control herds enrolled for each case herd
- Herds in SD, ND, and NE (30 case herds, 54 control herds)

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Management practices:
- Cow numbers
- Were cows and calves managed in more than one group?
- Was intensive grazing used?
- Did cattle have fence-line contact with other herds?
- Were cows or calves given supplemental feed?
- Were any cattle brought onto the farm from outside sources?
- Were cows synchronized after calving?
- Were cows checked for pregnancy?
- Were cattle tested for bovine viral diarrhea (BVD) virus?
- Were cows and calves ever moved more than one mile on foot?
- Length of calving season?
- Did any calves develop diarrhea?
- Were respiratory vaccines given to cows and/or calves?
- Were any cows/heifers treated for respiratory disease?

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Management practices:
- **Cow numbers**
- Were cows and calves managed in more than one group?
- **Was intensive grazing used?**
- Did cattle have fence-line contact with other herds?
- Were cows or calves given supplemental feed?
- Were any cattle brought onto the farm from outside sources?
- **Were cows synchronized after calving?**
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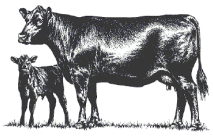
Herd Level Risk Factors, Case-Control Study



Significant risk factors:
- **Number cows/heifers calving**
  - **Versus herds with < 150 cows**
  - If 150 – 499 cows: OR = 7.9 (2.0 – 31) *P* = 0.03
  - If ≥ 500 cows: OR = 12 (2.0 – 70) P = 0.02
- **Intensive grazing**
  - **Versus not:** OR = 3.3 (1.2 – 9.2) *P* = 0.05
- **Cows or heifers synchronized**
  - **Versus not:** OR = 4.5 (1.5 – 14) *P* = 0.02

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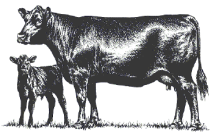
Pneumonia in calves prior to weaning



- A "childhood disease" of cattle due to age-related susceptibility and loss of herd immunity
- Parodoxically associated with practices of highly managed herds!
- A "systems" problem

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Attributable fraction

The **impact** of the exposure on the exposed. (e.g. What proportion of an individual's disease is explained by the exposure?)

- Herd size
  - AF (150-499) = 71%
  - AF (≥ 500) = 74%
- Intensive grazing
  - AF = 60%
- Estrus synchronization
  - AF = 64%

Each of these factors contributes meaningfully to disease risk for the herds that have them

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Population attributable fraction

The **impact** of the exposure on the population (e.g. what proportion of the disease in the population is attributed to the factor?)

- Herd size (4% of herds 150 -499 cows; 1% of herds 500 cows or greater)
  - pop AF (150-499) = 9%
  - popAF (≥ 500) = 3%
- Intensive grazing (30% of herds)
  - popAF = 31%
- Estrus synchronization (8% of herds)
  - popAF = 13%

These 3 factors may explain more than half of the occurrence of calfhood BRD

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Larger herds, intensive grazing, and estrus synchronization increase the rate of effective contacts

An **effective contact** is defined as any kind of **contact** between two individuals such that, if one individual is infectious and the other susceptible, then the first individual infects the second

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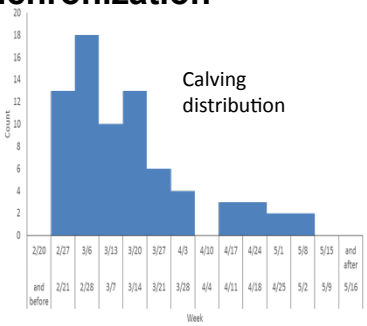
Estrus synchronization

Shorter calving seasons means the loss of herd immunity is more abrupt –a large portion of the calves lose immunity at the same time.



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Estrus synchronization

The cost in affected herds:

$28/cow x 64% (AF) = $18 / cow

= 10-15 lbs/calf

= 5-7 days shift in median day of calving

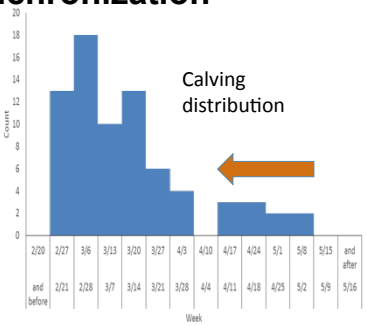
The benefits:

Total lbs marketed

Uniformity/ marketing

Days to breeding

Genetics



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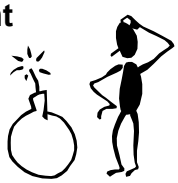
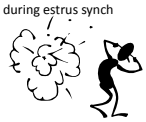
Risk Management

Manage BRD risk by:

- Age of vaccination
  - twice before 90 days of age
  - some evidence of success!
  - Bovine coronavirus?
- Age of exposure
  - commingling early or late
  - merging groups during estrus synch is probably not good
  - Minimize crowding (effective contacts) and stress during estrus synch
- Age of stressors
  - Wean early or late
  - Trailing or transportation
- Monitor calves during high risk ages





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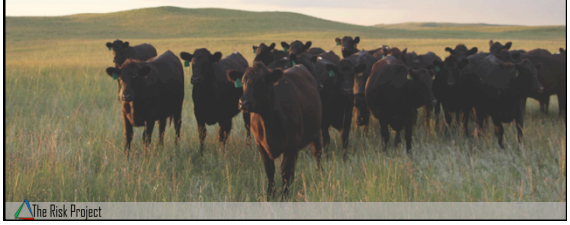

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Applying risk-based strategies to solve everyday problems in animal populations

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