GENETIC SOLUTIONS FOR LIVESTOCK ADAPTABILITY IN A CHANGING CLIMATE

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ADAPTABILITY CHALLENGES

- May be different in different industries and regions of the country
  - Elevation
    - Obviously won’t change much, but best grasses might change in distribution along elevation
  - Feed quality/availability
  - Disease challenges
  - Heat stress
  - Water quality/availability

- Secondary challenges for genetics studies
  - Accurate definition of phenotypes
  - Accurate and easy data collection methods (at least for some industries)
  - The bad news: Productivity vs adaptability-incompatible?
    - See this also in developing countries with native vs introduced animals
    - The good news: The correlations are not one!

- I will put in information on all livestock where I have it, but I will mostly focus on cattle due to time constraints
DISEASE CHALLENGES

- Indirect effects due to spreading of vector-borne diseases (Rojas-Downing et al. 2017)
  - Temp increase accelerate growth of pathogens
  - Disease transmission between hosts
- Change in ranges for many parasites like ticks (Sonenshine 2018)
- Genetic technologies like DNA fingerprinting, genome sequencing, and tests for resistance may be key mitigation or monitoring strategies
  - Some indication that resistance to internal and external pests is a moderately heritable trait (reviewed by Morris 2007), little work done in this area due to difficulty in collecting large numbers of phenotypes
  - Disease resistance heritability ranges from low to moderately heritable for diseases like pinkeye, Johne’s and BRD (Morris 2007 and BRD CAP)
- Manage with coordinated selection programs-phenotypes?
  - Management practices will still be critical
Example: Brisket disease (Dropsy, up to 30% death loss)

- Measured using PAP testing (resistance to blood flow in the lungs at high altitude) on acclimatized animals at high altitude (usually at least 6000 ft)
- Age is a significant factor (PAP score increases with age)
- Moderately heritable-0.34 (Shirley et al. 2008)
- Phenotypically unrelated to birth or weaning weights, genetically correlated (unfavorably) 0.49 for birth, 0.50 for weaning
- Selection for increased growth at low altitude makes cattle less suited to high altitude

### Pulmonary Arterial Pressure (PAP) scores

<table>
<thead>
<tr>
<th>Age Months</th>
<th>&lt; 12</th>
<th>12 - 16</th>
<th>&gt; 16</th>
<th>&lt; 35</th>
<th>36 - 39</th>
<th>40</th>
<th>41 - 44</th>
<th>45 - 40</th>
<th>&gt; 49</th>
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<tbody>
<tr>
<td></td>
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<td>Good</td>
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<td>Caution</td>
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</tbody>
</table>

**Interpretation of PAP scores**
Reliability of scores depends on age, altitude, time for acclimation, and outdoor temperature.

<table>
<thead>
<tr>
<th>Altitude</th>
<th>&gt; 6000</th>
<th>6000 - 6500</th>
<th>5500 - 6000</th>
<th>5000 - 6000</th>
<th>&lt; 5000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acclimation</td>
<td>&gt; 8 weeks</td>
<td>5 weeks</td>
<td>4 weeks</td>
<td>3 weeks</td>
<td>&lt; 3 weeks</td>
</tr>
</tbody>
</table>

**Temperature**
Freezing temperatures can increase pulmonary arterial pressure so all tests should be performed well above freezing.
Association of a variant in EPAS1 in Angus cattle with high-altitude pulmonary hypertension (HAPH)

- Variant present in lowland cattle (41% carriers in one herd of 32 animals)
- Phenotype only expressed at high altitude

A different perspective: Grazing distribution

- Presumably elevation won’t change with the climate much, but the distribution of grasses may change, making elevation an important consideration.
- No phenotypic relationship between terrain use and performance (Bailey et al. 2001).
- But…Poor grazing distribution results in localized overgrazing and need to reduce stocking rates.
- Cattle often avoid: steep slopes, high elevation, areas away from water.
- Can track using GPS collars (expensive and not accessible for producers) for at least 2 months.
- Can summarize into average slope, elevation, and distance to water of positions to get a phenotype or combine into an index of all 3.
- Hill climbers and bottom dwellers.

HEAT STRESS

- Can lead to massive economic losses across entire industries (St-Pierre et al. 2003)
  - 3 sources of losses modeled: decreased performance, increased mortality, and decreased reproduction
  - Without heat abatement, total losses across dairy, beef, swine, and poultry systems average $2.4 billion annually
  - Even with optimum heat abatement, still $1.7 billion annually
  - Dairy: $897 million, Beef: $369 million, Swine: $299 million, Poultry $129 million
Fig. 2. Genetic differences in the deleterious effects of elevated culture temperature on subsequent embryonic development. Embryos >8 cells at day 4 after insemination were cultured at either 38.5°C continuously (solid bars) or at 41°C for 6 h followed by 38.5°C thereafter (open bars). The proportion of embryos that became blastocysts was determined at day 8 after fertilization. Data from Experiment 1 are redrawn from Paula-Lopes et al. (2003) and data from Experiment 2 are redrawn from Hernández-Ceron et al. (2004).
IMPORTANT FOR GENETIC SELECTION ON ALL TRAITS!

- Improve genetic merit for heat tolerance by selecting within a breed
  - Simulated selection scheme by Nardone and Valentini (2000) compared selection for heat tolerance within a high-milking breed and milk production within a highly adapted breed
    - Selection for heat tolerance within the high-milking breed was more efficient, adapted breed needed 20+ generations to reach comparable levels of milk production.

- Goal: Develop cattle to perform in diverse environments, maintain high productivity, possess superior carcass attributes (Scharf et al. 2010).

- Heat tolerance exhibits genetic antagonisms with other economically important traits
  - Correlations of BVs calculated across different THI diverge when THI is high
    - Animal performance reranks in hot environments
  - Genetic correlation between milk production and heat tolerance in dairy cattle is approximately -0.3 (Ravagnolo and Misztal 2000)
  - Genetic corr for non return rate at 90 days and heat tolerance is -0.95 (Ravagnolo and Misztal 2002)
  - Continual selection for increased performance without regard to heat stress actually reduces heat tolerance (Ravagnolo and Misztal 2000; Dikmen et al. 2012)
UNFORTUNATELY, WE CAN’T JUST DO THIS….

Correlation is small in some cases so can make progress in both if we have the right tools!
MITIGATION STRATEGIES

- Management interventions (shade, water availability, sprinkling, etc.)
- Decision support tools that can help
  - Cattle comfort Advisor

http://cattlecomfort.mesonet.us/

**Calculated Cattle Comfort Level**

- Using 100% Solar Radiation
- Using 60% Solar Radiation
- Using 20% Solar Radiation
Genetic Selection can help also!

Current tools:

- Selection for coat color/breed (lighter colored hide and hair colors)
  - Black absorb more solar radiation, so spend more time in shade and dark hided 25% more stressed at temps above 25 C
  - Simply-inherited, so easy to select for this!
- Selection for slick hair coats
  - Slick hair gene in Senepol on Chromosome 20
- Hair shedding

Other approaches?

- Heat tolerance is a heritable trait (Ravagnolo and Misztal 2000)
- Can select for heat tolerance, particularly in environments with high average THI
Brown-Brandl et al. 2006

- 2 summers, 256 feedlot heifers (32/breed/yr) from 4 breeds in NE
  - Angus-Black Skin, Black Hide
  - MARC III-Dark Red Skin, Dark Red Hide (Small number were black)
  - Gelbvieh-Tan Skin, Tan Hide
  - Charolais-Pink Skin, White Hide

- Breed had a significant effect on respiration rate and panting score (p<0.0001)
HAIR SHEDDING

- Cows that don’t shed winter hair coat quickly show more signs of heat stress (Gray et al. 2011)
- Heritable trait, can be altered through selection
  - 0.63 (Turner and Schleger 1960)
  - 0.35 (Gray et al. 2011)
- Score cows in May on a 1-5 scale (3= start of shedding)

<table>
<thead>
<tr>
<th>Hair shedding score</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>Full winter coat</td>
</tr>
<tr>
<td>4</td>
<td>Coat exhibits initial shedding</td>
</tr>
<tr>
<td>3</td>
<td>Coat is halfway shed</td>
</tr>
<tr>
<td>2</td>
<td>Coat is mostly shed</td>
</tr>
<tr>
<td>1</td>
<td>Slick, short summer coat</td>
</tr>
</tbody>
</table>

- Impacts 205d adj. WW
  - Cows with score of ≤3 on June 1 had calves that weighed ~11 kg heavier at weaning
  - Does not impact BCS
  - Moderate genetic correlation with 205d adj. WW (-0.58)
HAIR SHEDDING RESULTS

LS Means of Adjusted WW

March  a
April  a,b
May    b,c
June   c,d
July   d

Different letters indicate significant differences Gray et al. 2011
HEAT STRESS

- Selection for other traits is possible, but what is the right trait???
- Body temperature regulation (tympanic, vaginal, surface, or internal)
  - Heritable trait-estimates range from 0.11-0.44 (Burrow 2001; Da Silva 1973; Dikmen et al. 2012; Mackinnon et al. 1991; Seath and Miller 1946, Turner 1982)
  - Respiration rate
    - Heritability estimates 0.76-0.84 (Seath and Miller 1946)
- Panting score
- Others?
WE CAN USE GENOMIC TOOLS TO HELP

- If we can decide on a trait and agree to measure it in an industry, genomic testing can help
- Rectal Temperature GWAS in Dairy (Dikmen et al. 2013)
  - Afternoon rectal temp when THI ≥78.2 (n=1,440 w/ SNP50 genotypes)
  - Single step GBLUP (3 SNP moving windows)
BEEF BODY TEMPERATURE

- Howard et al. 2013
  - Various percentages of Angus, Simmental, and Piedmontese with unknown pedigree and breed fractions
  - Body temperature regulation: 5 days in summer area under curve (AUCS5D), same in winter (AUCW5D)
  - AUCS5D heritability 0.68 using GenSel (Bayes)
  - AUCW5D heritability 0.21 using GenSel (Bayes)
  - Correlations between S and W DGV were 0.40
    - Small number of the top 5% 1MB windows were in common (9%)
    - Different sets of genomic regions involved, so could select for both heat and cold tolerance mostly independently


**WATER QUALITY AND AVAILABILITY**

- What are the 6 essential nutrients?
- Water shortages in some areas
  - Little rainfall
  - Water rights issues
  - Drought
  - Competition from other ag (irrigation, crop production)
  - Competition from wildlife
  - Competition from humans
- Has been tied to performance (weight gain and ability to deal with heat stress) in the literature
  - Specific mechanisms are less well defined
  - Little exploration from a genetics standpoint outside of model organisms and some specific water conditions (i.e. high sulfur, Kessler et al. 2013)

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**Demand from power, ag, and municipalities as a percentage of available water**

![Water Stress in the U.S.](image)

**Projected decline in water supplies accounting for GHG emissions**

![Water Supply Stress Index](image)

![Water Supply Sustainability Risk Index (2010)](image)

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Anim Phys and Anim Nutr 97:838-845)
EXACERBATED BY NATURAL DISASTERS

U.S. Drought Monitor

September 11, 2018
(Released Thursday, Sep. 13, 2018)
Valid 8 a.m. EDT

Drought Impact Types:
- Delineates dominant impacts:
  - S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)
  - L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://droughtmonitor.unl.edu/
WHAT DO WE KNOW ABOUT WATER INTAKE?

- Breed differences (Winchester and Morris 1956)
- Group-based Measurements
    - Affected by environmental conditions
  - Average intakes of 32.4 and 17.3 L/day in summer and winter, respectively (Arias and Mader 2011)
  - 40.9/L/hd/d in Texas panhandle (Parker et al. 2000)
- Voluntary water restriction when quality is poor
  - Some restriction even w/ chemically treated vs not (Lardner et al. 2013)
  - Up to 22% with high salt (Lopez et al. 2016)
  - Water restriction impacts body temperature regulation (Finch 1986)
- Can be impacted by water temperature

Figure 1. Water intake expressed as a function of dry matter consumption and ambient temperature.
Now have the technology to collect large numbers of WI phenotypes on individual animals

- GrowSafe and Insentec systems
  - Meyer et al. 2004 (60 lactating dairy cows)
    - WI range from 14-171 kg/day (Mean 81.5 kg/day)
  - Meyer et al. 2006 (62 Holstein bulls on finishing ration)
    - WI range 0 to 78.7 kg/day (mean 17.8 kg)
  - Brew et al. 2011 (146 growing beef cattle)
    - Mean WI of ~30 L/head/day
    - Brahman and Romosinuano cattle drank less than British and Continental cattle
    - No difference between bulls, steers, and heifers

No heritability estimates or genomic studies of water intake in beef cattle

- Heritable in mice (Bachmanov 2002), successful selection experiments

Influence of breed composition on water intake of growing beef cattle (source: Brew et al. 2011)

<table>
<thead>
<tr>
<th>Breed Composition</th>
<th>Gross WI, L/head/d</th>
<th>WI/kg metabolic BW, L/head/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charolais X Angus</td>
<td>42.8a</td>
<td>0.58a</td>
</tr>
<tr>
<td>Angus X Brangus</td>
<td>30.8b</td>
<td>0.42b</td>
</tr>
<tr>
<td>Brangus</td>
<td>30.8b</td>
<td>0.32c,d</td>
</tr>
<tr>
<td>Charolais X Brangus</td>
<td>29.7b</td>
<td>0.38c,b</td>
</tr>
<tr>
<td>Brangus X Romosinuano</td>
<td>24.1c</td>
<td>0.28d</td>
</tr>
<tr>
<td>Charolais X Romosinuano</td>
<td>20.7d</td>
<td>0.32c,d</td>
</tr>
</tbody>
</table>
Conclusions:
-WI and water efficiency measures are heritable
-Genetic correlations were low to moderate with DMI and RFI, high between WI and water efficiency traits, no correlation with ADG
-What about other ERT?
ACKNOWLEDGEMENTS:

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THANK YOU!

“Everybody has to change to compete.”

“What if we don’t change at all ... and something magical just happens?”

Of course some species have proved more able to adapt to changing climate conditions than others!