Researching Genetic Components of Environmental Impacts

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Genetic Components of Environmental Impacts

- Methane production
- Water use
- Adaptability
- Existing tools

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Methane production

- Methane production critically important, really hard to measure
  - Many different methane prediction models that are pretty accurate on average
  - They are functions of DMI, so they are unable to find differences in methane production between animals independent of differences in DMI
  - Selection for decreased predicted methane is equivalent to selection for decreased DMI
    - A by-product of selection for feed efficiency should be a decrease in methane production

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Methane production

- Methane production critically important, really hard to measure
  - Respiration chambers = gold standard, one animal at a time, virtually impossible to measure enough animals for genetic evaluation
  - SF_6 (sulfur hexafluoride) tracer technique = bolus SF_6 placed in rumen, animal wears gas collection halter, very labor intensive, only used for a short duration on a few animals

Herd et al. 2014

Hegarty et al. 2007

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Methane production

- Methane production critically important, really hard to measure
  - –Open circuit gas quantification system–entices animals with feed to put heads in a hood that measures gas flux, can measure more animals in feedlot or grazing situation

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Methane production

- Relationship between RFI and methane production SF_6 measurement in 76 Angus steers (Hegarty et al, 2007)
  - Methane collection technique decreased DMI
  - 1 kg/day reduction in RFI EBV associated with 13.4 g/d reduction in methane production
  - Ten lowest RFI steers emitted 25% less methane per day than ten highest RFI steers, had 24% less methane per unit of ADG
  - Simulation of selection for low RFI over 20 years showed a 3% decrease in methane production by national herd (Alford et al., 2006)

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Methane production

- Relationship between RFI and methane production (respiration chamber), crossbred cattle (Nkrumah et al., 2006)
  - Low RFI steers (n=8) produced 28% less methane per day than high RFI steers (n=11)
    - Approximately 16,100 less L/yr/animal for low RFI steers
  - Phenotypic correlations between daily methane production and RFI (0.44), DMI (0.32), ADG (0.05)

Methane production

- 1046 Australian Angus cattle in respiration chambers for methane measurement (Donaghue et al. 2016)
  - Heritabilities on diagonal, r_g above and r_p below

	DMI	MP	MY	RMP*
DMI	0.46 (0.08)	0.84 (0.06)	-0.04 (0.18)	-0.25 to 0.10
MP	0.71 (0.02)	0.27 (0.07)	0.50 (0.14)	0.32 to 0.63
MY	-0.01 (0.04)	0.68 (0.02)	0.22 (0.06)	0.99
RMP*	-0.14 to 0.08	0.60 to 0.76	0.96 to 0.97	0.09 (0.06)

DMI=dry matter intake, MP=methane production, MY=methane yield (MP/DMI), RMP*=residual methane production, with expected calculated by 4 different eqn's

Methane production

- 1046 Australian Angus cattle in respiration chambers for methane measurement (Donaghue et al. 2016)
  - Genetic correlations of methane measurements with production traits

	DMI	MP	MY	RMP*
Birth weight	0.54 (0.14)	0.36 (0.18)	-0.01 (0.21)	-0.12 to 0.03
Weaning weight direct	0.84 (0.06)	0.84 (0.09)	0.27 (0.21)	0.18 to 0.45
Weaning weight maternal	0.50 (0.12)	0.32 (0.19)	-0.21 (0.30)	-0.41 to -0.25
Yearling weight	0.94 (0.03)	0.86 (0.06)	0.21 (0.18)	0.07 to 0.38
Final weight	0.95 (0.03)	0.79 (0.08)	0.05 (0.17)	-0.11 to 0.18

DMI=dry matter intake, MP=methane production, MY=methane yield (MP/DMI), RMP*=residual methane production, with expected calculated by 4 different eqn's

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Methane production

- 1046 Australian Angus cattle in respiration chambers for methane measurement (Donaghue et al. 2016)
  - Genetic correlations of methane measurements with ultrasound measured carcass traits

	DMI	MP	MY	RMP*
Rib fat	0.20 (0.13)	0.11 (0.16)	-0.14 (0.17)	-0.11 to -0.06
Rump fat	0.20 (0.13)	0.10 (0.15)	-0.14 (0.16)	-0.13 to -0.07
Ribeye area	0.55 (0.12)	0.40 (0.16)	-0.09 (0.19)	-0.18 to -0.03
IMF	0.28 (0.14)	0.36 (0.16)	0.10 (0.18)	0.13 to 0.21

DMI=dry matter intake, MP=methane production, MY=methane yield (MP/DMI), RMP*=residual methane production, with expected calculated by 4 different eqn's

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Methane production

- 1046 Australian Angus cattle in respiration chambers for methane measurement (Donaghue et al. 2016)
  - Low to moderate h^2 on methane production and yield
  - Selection should be on methane yield or residual methane production because of r_g with production traits

- What about a properly weighted index?

Methane production

- Continuation of Donoghue et al. (2016), 1043 Angus cattle (Hayes et al., 2016)
  - Cattle genotyped on 50K or 770K, GBLUP and BayesR analyses
  - Heritability of methane production and yield similar to pedigree BLUP
  - Accuracies of genomic EBV for methane traits 0.26-0.38 depending on methodology
  - Proportion of genetic variance in methane traits explained by SNP
    - Dry matter intake 0.49
    - Methane production 0.67
    - Methane yield 0.59
    - Residual methane production 0.41 to 0.49

Methane production

- Continuation of Donoghue et al (2016) Australian Angus cattle in respiration chambers (Manzanilla-Pech et al. 2016); compared to Holstein methane production
  - Heritability new trait methane intensity (methane per kg weight) 0.25 ± 0.06
  - Genetic correlations
    - Methane production and methane intensity 0.18 ± 0.16
    - Methane yield and methane intensity 0.86 ± 0.05
  - 165 SNPs significant for methane production in Angus population
  - Significant SNPs different in Angus and Holstein populations

Methane production

- General conclusions
  - Methane production highly correlated to DMI
  - Methane production and methane yield have low to moderate h^2
  - Methane production genetically correlated to production traits
    - Methane yield and residual methane less correlated
  - Methane traits appear to be good candidates for genomic selection
- Questions
  - What measurement is most useful?
  - What is the economic value of methane production?

Genetic Components of Environmental Impacts

- Methane production
- Water use
- Adaptability
- Existing tools

Water Intake

- Very little work on water intake in beef cattle
  - Heritable in mice
  - Breed differences (Brew et al. 2011)

Breed Composition	Gross WI, L/head/d	WI/kg metabolic BW, L/head/d
Charolais X Angus	42.8[a]	0.58[a]
Angus X Brangus	30.8[b]	0.42[b]
Brangus	30.8[b]	0.32[c,d]
Charolais X Brangus	29.7[b]	0.38[c,b]
Brangus X Romosinuano	24.1[c]	0.28[d]
Charolais X Romosinuano	20.7[d]	0.32[c,d]

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

Water Intake

- Ahlberg et al. measured water intake on 579 feedlot steers
  - Heritabilities on diagonal, r_p below diagonal, r_g above diagonal

	WI	DMI	ADG	RWI	RFI
Water Intake	0.39 (0.14)	0.34 (0.27)	0.05 (0.05)	0.88 (0.33)	0.33 (0.11)
DMI	0.37	0.67 (0.16)	0.68 (0.01)	-0.10 (0.10)	0.68 (0.02)
ADG	-0.09	0.53	0.37 (0.15)	-0.17 (0.16)	-0.03 (0.01)
Residual WI	0.60	0.00	0.05	0.37 (0.15)	-0.57 (0.17)
RFI	0.26	0.60	0.00	-0.03	0.65 (0.17)

Water Intake

- Ahlberg et al. measured water intake on 579 feedlot steers
  - Carcass traits relationship with water intake

Trait	r_p	r_g
HCW	0.17	0.38 (0.49)
REA	-0.03	0.08 (0.07)
BFAT	0.22	0.36 (0.36)
MARB	0.18	0.17 (0.97)
YG	0.22	0.29 (0.40)
Final weight	0.18	0.29 (0.41)

Water Intake

- General Conclusions
  - Water intake is heritable
  - Low r_g of water intake and DMI or gain; some animals eat and gain on less water
  - No relationship of water intake on carcass traits
- Questions
  - Is there potential for selection for reduced water consumption without affecting other traits?
  - What is the value of animals that drink less water?

Genetic Components of Environmental Impacts

- Methane production
- Water use
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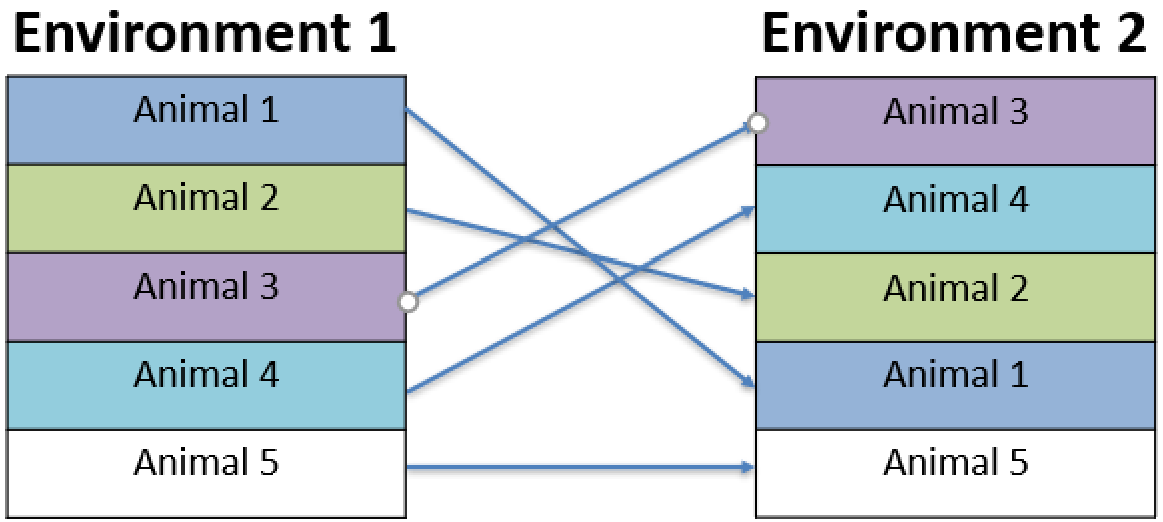
Adaptability

- Adaptability = Phenotypic plasticity –ability of an animal to maintain production over a range of environments
- One way to measure adaptability is to look at correlation between a trait measured in 2 different environments



Adaptability

- Adaptability = Phenotypic plasticity –ability of an animal to maintain production over a range of environments
- One way to measure adaptability is to look at correlation between a trait measured in 2 different environments
  - r_g between Limousin BW (mean 0.81, range 0.55-1.00) and WW (mean 0.69, range 0.53-0.99) in different regions (Bertrand, 1987)
  - r_g between Red Angus stayability in different regions ranged from 0.32-0.87 (Fennewald et al., 2018)
  - r_g between Angus WW in different regions ranged from 0.85-0.87, (Durbin et al., 2020)

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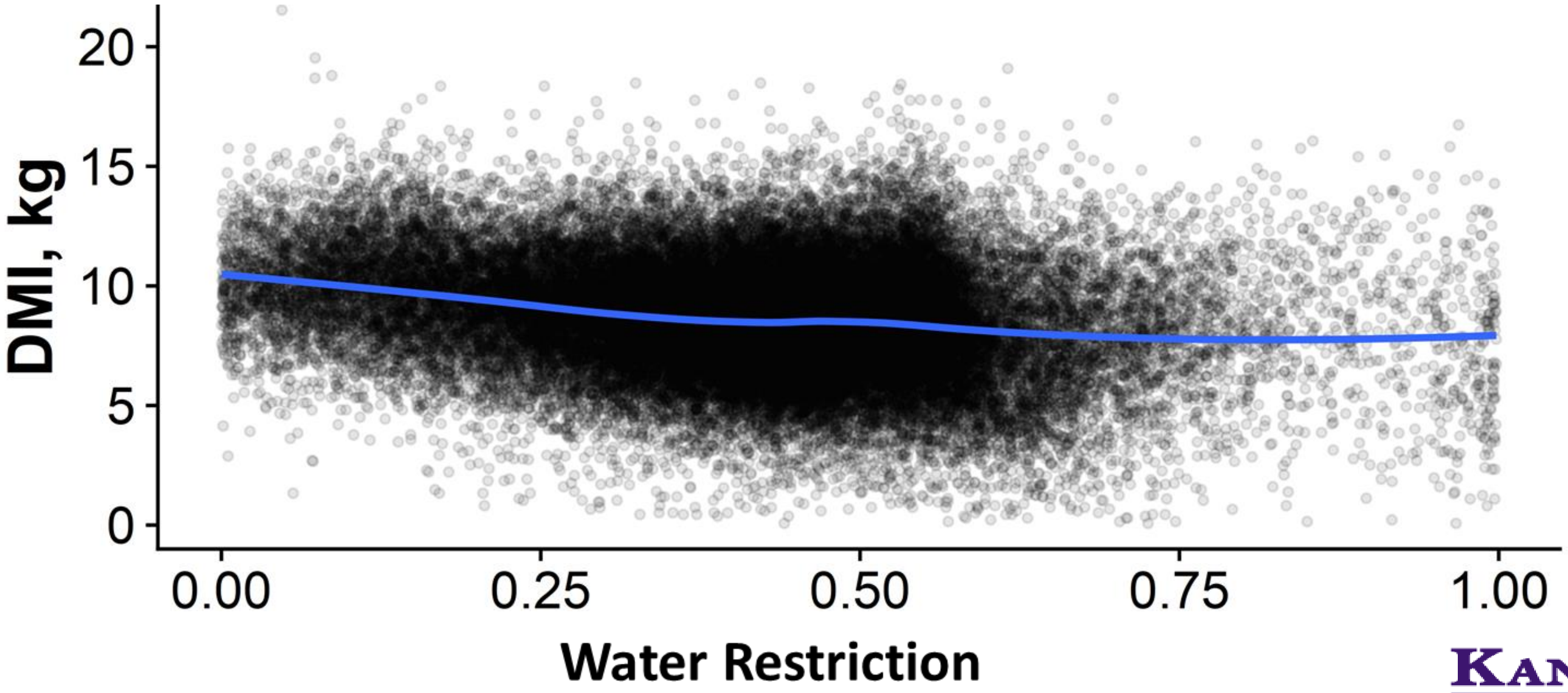
Adaptability

- Adaptability = Phenotypic plasticity –ability of an animal to maintain production over a range of environments
- Another method is to model performance over range of environments using random regression
  - Bradford et al. (2016) Angus field data
  - h^2 decreased for WW and YW at higher levels of heat stress
  - positive correlations between slope and intercept
    - higher performing animals under minimal environmental stress continued to be higher performing under heat stress
    - some re-ranking of animals at extreme heat stress

Adaptability

- Shaffer et al continuation of Ahlberg et al. 587 feedlot steers
  - Ad lib water intake for each steer determined over 70 days, then gradual restriction up to 50% of ad lib water intake



Adaptability

- Shaffer et al continuation of Ahlberg et al. 587 feedlot steers
  - Ad lib water intake for each steer determined over 70 days, then gradual restriction up to 50% of ad lib water intake
  - Correlations between DMI measured at ad lib (0), 25%, and 50% water restriction

	0	0.25	0.50
0	Genetic ->	0.96 (0.94, 0.99)	0.78 (0.65, 0.91)
0.25	0.96 (0.94, 0.98)		0.92 (0.87, 0.97)
0.5	0.80 (0.69,0.90)	0.92 (0.88, 0.97)	<- Spearman

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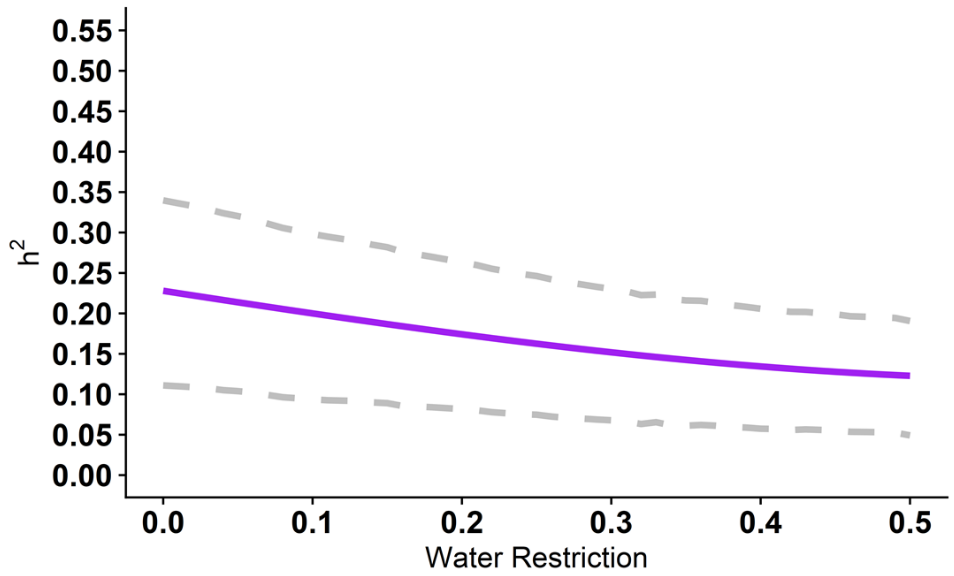
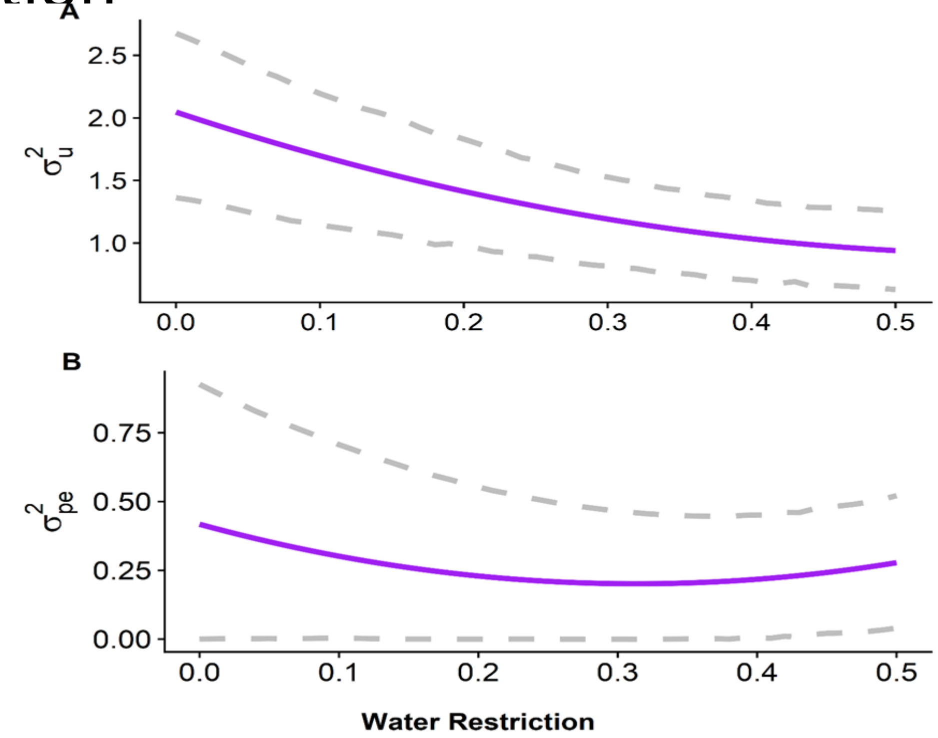
Adaptability

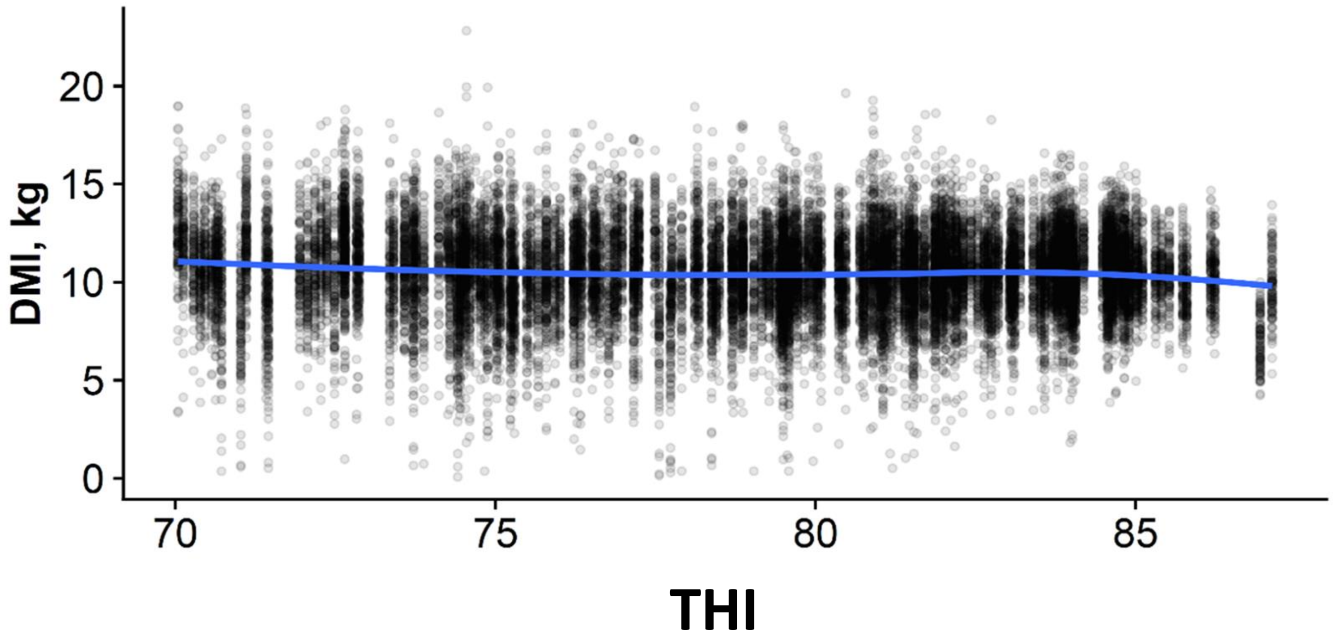
- Shaffer et al continuation of Ahlberg et al. 587 feedlot steers
  - Ad lib water intake for each steer determined over 70 days, then gradual restriction up to 50% of ad lib water intake
  - h^2 of DMI decreases under water restriction





Adaptability

- Shaffer et al continuation of Ahlberg et al. 587 feedlot steers
  - Temperature humidity index (THI) calculated



Adaptability

- Shaffer et al continuation of Ahlberg et al. 587 feedlot steers
  - Temperature humidity index (THI) calculated
  - Correlations between DMI measured at increasing THI

	70	75	85
70	Genetic ->	0.92 (0.89, 0.95)	0.42 (0.26, 0.57)
75	0.96 (0.95, 0.98)		0.73 (0.65, 0.82)
85	0.39 (0.26,0.52)	0.60 (0.50, 0.69)	<- Spearman

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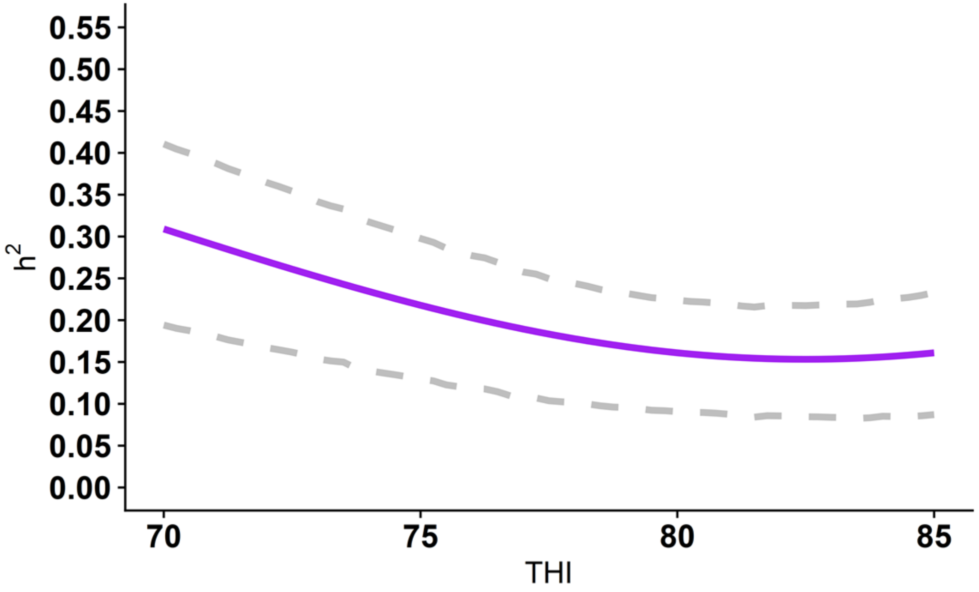
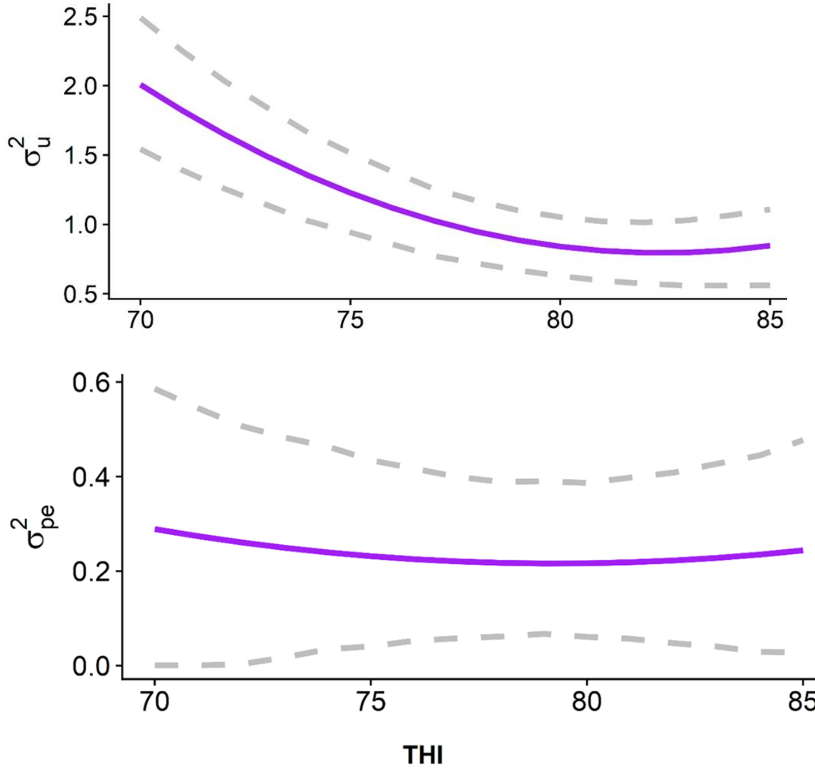
Adaptability

- Shaffer et al continuation of Ahlberg et al. 587 feedlot steers
  - Temperature humidity index (THI) calculated
  - h^2 of DMI decreases with increasing THI





Adaptability

- Shaffer et al continuation of Ahlberg et al. 587 feedlot steers
  - Random regression of DMI on either water restriction or THI
  - Negative correlation indicated that higher performing animals at non-stressful environments decrease performance more when under stress

	slope	Corr between slope and intercept
Water restriction	-4.10	-0.74
THI	-0.05	-0.78

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Adaptability

- General Conclusions
  - h^2 goes down as environmental stress goes up
  - Higher performing animals in non-stressed environments seem to have increased environmental sensitivity
- Questions
  - If h^2 is lower in stressed environments, does that limit the ability to make selection in those environments?
  - Are higher performing animals less adaptable to environmental stressors?

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- Water use
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Existing Tools

- Matching cows to environment
  - Recent simulation work models land and water use by cows of varying mature size and milk production in Great Plains (Lakamp et al. 2021)
    - Large cows required more land than small cows regardless of lactation potential
    - High lactation animals required the most supplement (couldn’t meet requirements with forage alone)
    - Total water required driven by lactation potential (irrigation for supplemental feeds)
    - Methane production higher for large cows (increased forage intake)

Existing Tools

- Matching cows to environment
  - Recent simulation work models land and water use by cows of varying mature size and milk production in Great Plains (Lakamp et al. 2021)
  - Environmental footprint scaled by weaning weight of calves:
    - Small, high milk cows were most efficient users of grazing land, total land, drinking water, and produced the least methane/lb weaned calf
    - Small, low milk cows used less cropland and irrigation water
    - Large, low milk cows had largest environmental impact/lb weaned calf

Existing Tools

- Matching cows to environment, use terminal sires
  - Create market progeny with sires very different than the optimal cow
- Best system for complementarity is static terminal
  - Purchased F1 maternal line females crossed to terminal breed sire, all offspring sold as feeders

Purchased maternal line cows

X

Terminal sire

→ All offspring sold as feeder calves

Existing Tools

- Matching cows to environment, use terminal sires
  - –Create market progeny with sires very different than the optimal cow
- Example: roto-terminal system
  - –Breed ≈ half of cows to maternal bulls and only keep heifers from that portion; breed ≈ half of cows to a terminal sire and keep no heifers

Maternal sire

X

½ of maternal line cows

½ of maternal line cows

X

Terminal sire

Replacement heifers retained, cull heifers and steers sold as feeder calves

All offspring sold as feeder calves

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Existing Tools

- Improved reproduction and stayability
  - Keep a higher percentage of total herd productive
  - Depending on region and year, weaning rate (number of calves weaned per cow exposed the previous year) somewhere around 80-90%
    - 10-20% of resources used to maintain nation's cowherd does not produce any beef each year
  - Depending on year and cattle cycle, replacement rate is roughly 15-20%
    - Developing a heifer takes 2 years of inputs with no beef produced

Existing Tools

- General Conclusions
  - We have good tools available to make genetic improvement that can translate to decreased environmental impact
    - Modeling to determine optimum cow size and lactation potential by region
    - Crossbreeding systems
    - EPD’s for reproductive traits and stayability and indexes that include them
- Questions
  - What other currently existing technology can be employed to make improvements in environmental impact of beef production?

Questions?

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