Genetics and economics of a feed efficiency breeding value for New Zealand dairy cattle

Mark D. Camara[1], Jeremy R. Bryant[1], Kevin A. Macdonald[1],

Muyiwa Olayemi[1,2], Peter Amer[3]

[1]DairyNZ /New Zealand Animal Evaluation Ltd., Hamilton, New Zealand
[2]Current Address: Sugar Research Australia, Queensland, Australia
[3]AbacusBio Ltd., Dunedin, New Zealand

DairyNZ AE

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LIC

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ABACUSBIO LIMITED

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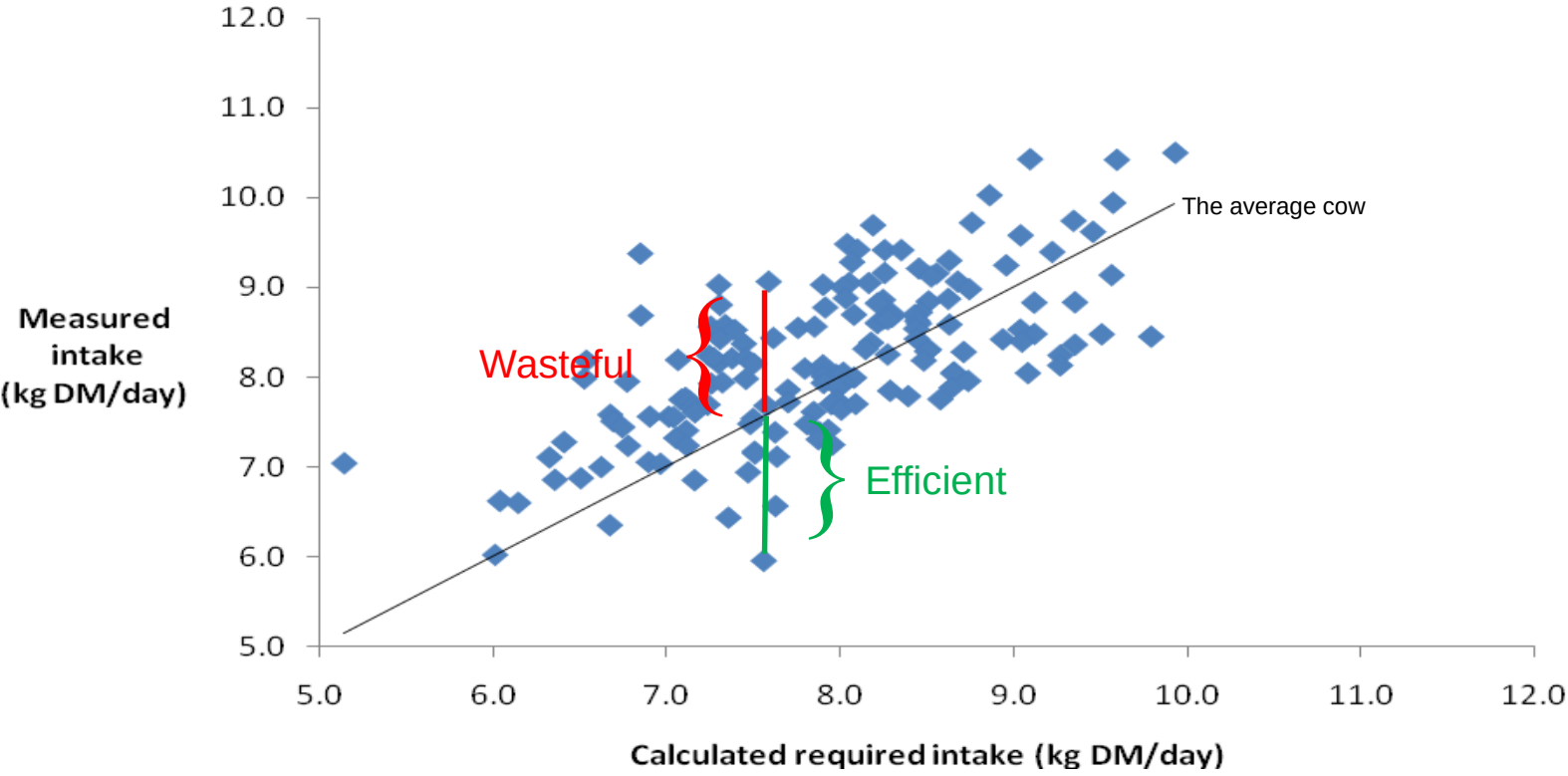
- Barbara Dow

Outline of talk

- Phenotypes: RFI & Infrared Thermography
- 2 Trials
  - Young Friesian bulls & heifers
  - Friesians vs. Jerseys
- Combined genomic analyses
- Economic value estimation
- Prospects for implementation

How does RFI measure efficiency?



Phenotyping Facility in Taranaki

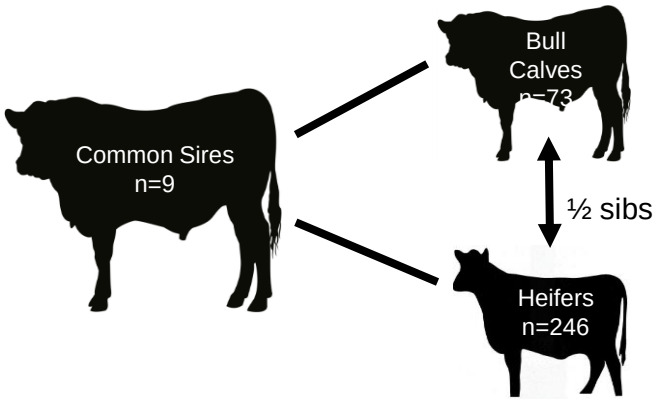
Video

Infra-red thermography as a low-cost predictor?

A. Thermal data: Importance of all PCs								
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Standard deviation	3.057	1.281	1.166	0.743	0.645	0.523	0.436	0.358
Proportion of Variance	0.672	0.118	0.098	0.040	0.030	0.020	0.014	0.009
Cumulative Proportion	0.672	0.790	0.888	0.928	0.957	0.977	0.991	1.000

B.Thermal Data: Loadings of PCs onto original variables								
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Eye max	0.165	-0.106	0.170	-0.086	0.418	-0.115	0.255	-0.820
Eye avg	0.253	-0.162	0.199	-0.112	0.723	0.387	-0.216	0.373
Eye Corner max	0.362	-0.283	0.385	-0.090	-0.139	-0.331	0.609	0.364
Eye Corner avg	0.433	-0.176	0.427	-0.149	-0.490	0.237	-0.483	-0.219
Cheek max	0.375	0.589	0.196	0.683	0.044	0.048	0.062	0.003
Cheek avg	0.284	0.636	-0.101	-0.654	0.053	-0.256	-0.072	0.063
Muzzle max	0.419	-0.308	-0.438	0.228	0.117	-0.571	-0.382	0.030
Muzzle avg	0.440	-0.081	-0.600	-0.059	-0.158	0.527	0.360	-0.063

Trial 1: Holstein-Friesian heifers & bull calves



- Separate-sex pens to prevent bullying
- 2 temporal “cohorts” due to capacity limits
  - 29 Jan ->16 March
  - 10 April -> 20 May
- Heritability?
- Across-sex r_g
- Value of thermal data?

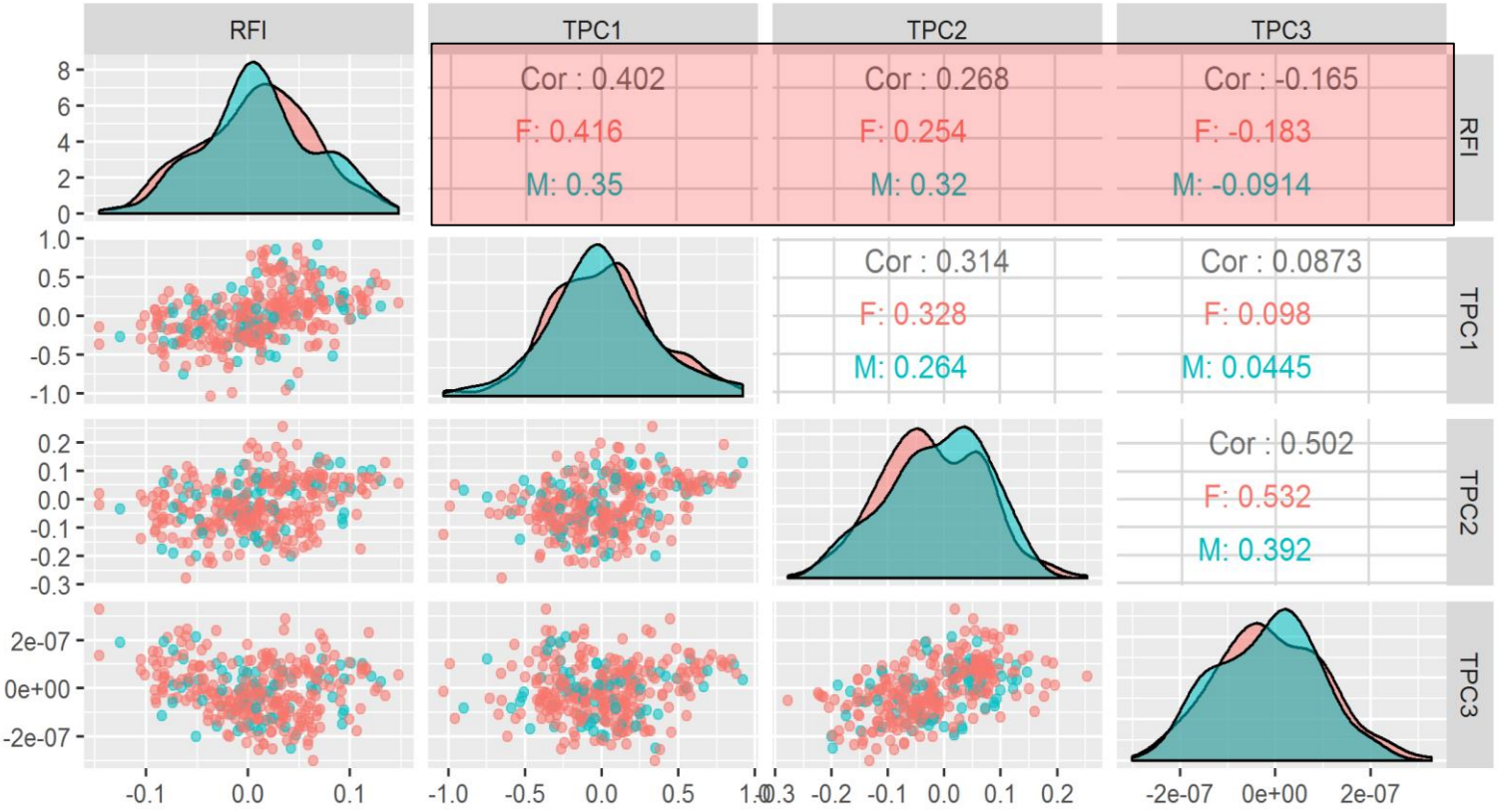
Bivariate animal-model

- Bull and heifer RFI treated as **separate traits**.
- Complex fixed effects model to account for separate pens, source farms, etc.
- Pedigree-BLUP
- ASReml
- 3 generation pedigree

Gender	Heifer	Bull
Heifer	0.14 ± 0.01	0.93 ± 1.46
Bull	0.15 ± 0.23	0.19 ± 0.04

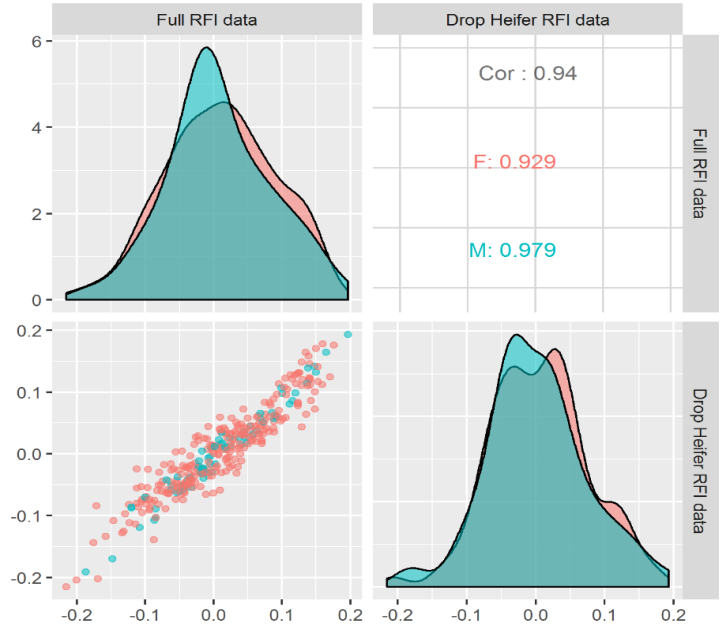
Heritabilities (diagonals) and correlations (genetic above; phenotypic below) between residual feed intake (RFI) in Friesian heifer and bull calves

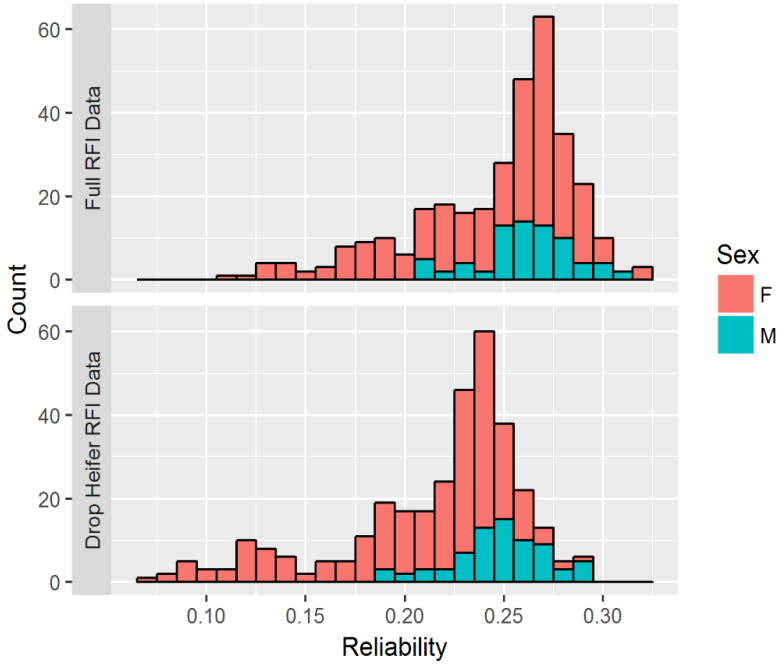
BV correlations (univariate models)



Reasonably high correlations between EBVs for RFI and PC's

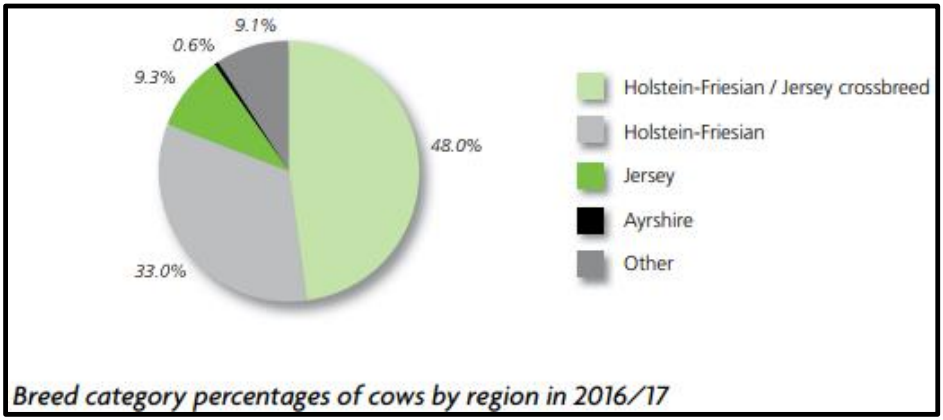
A thought experiment





Trial 2: Holstein-Friesians vs. Jerseys

- 110 Jerseys
- 162 More Friesians
- 18-21 months old
- Breed differences?
- More thermal imaging
- Genomic analysis



Breed category percentages of cows by region in 2016/17

Phenotypic-level breed differences?

Recall: Feed Intake= Intercept + β_1(Met Wt) + β_2(Wt Gain) + Residual

Add terms to model:

- Breed
- Breed x MetWt
- Breed x ADG

Interactions test for heterogeneity of slopes

=

breed effects on DMI required for maintenance and weight gain

Cohort 1

Source	df	MS	F	p
Mid-trial Metabolic Wght	1	336.74	136.53	0.001
Daily Weight Gain	1	18.84	7.64	0.007
Breed	1	2.21	0.86	0.355
Metabolic Wt x Breed	1	2.66	1.08	0.301
Weight Gain x Breed	1	0.00	0.00	0.994
Residual	128	2.47		

Cohort 2

Source	df	MS	F	p
Mid-trial Metabolic Wght	1	159.98	109.53	0.001
Daily Weight Gain	1	4.30	2.94	0.089
Breed	1	0.01	0.01	0.922
Metabolic Wt x Breed	1	0.24	0.16	0.689
Weight Gain x Breed	1	0.21	0.15	0.703
Residual	128	1.46		

Combined Genomic Analyses

50K Genotypes & RFI phenotypes available from 366 animals:

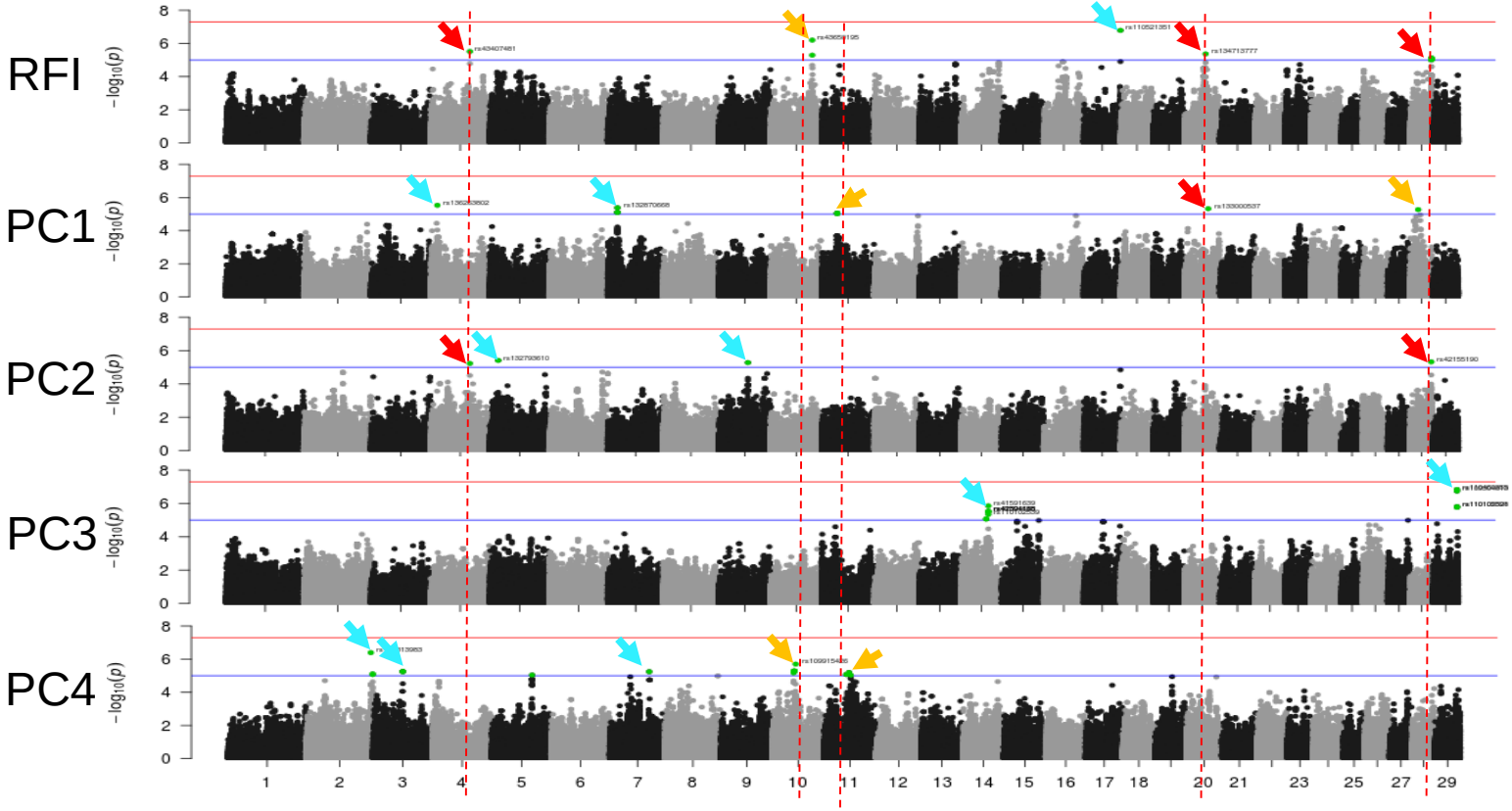
- Most Trial 1 heifers (re-located for tissue sampling)
- Almost all animals from this trial (some missing RFI due to equipment failures)
- Imputed to ~650K

Linear mixed models on RFI, PC1-PC4

- Univariate GWAS (GEMMA)
- Bivariate variance component estimation (GCTA): RFI vs, PCs

Model Terms

- **Fixed Effects**: Breed (F,J), Age at test (days), Cohort (1-4), North American Holstein (%)
- **Random Effect:** Genomic Relationship Matrix


RFI
PC1
PC2
PC3
PC4
$-\log_{10}(p)$
0
2
4
6
8
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
21
23
25
27
29

Genomic parameter estimates

	RFI		PC1		PC2		PC3		PC4	
VAR(G)	0.068	(0.029)	7.402	(1.593)	0.389	(0.170)	0.058	(0.064)	0.174	(0.068)
VAR(ENV)	0.433	(0.028)	2.283	(0.028)	1.034	(0.157)	0.762	(0.081)	0.260	(0.056)
V(P)	0.502	(0.020)	9.685	(0.829)	1.423	(0.109)	0.820	(0.061)	0.434	(0.035)
Heritability	0.136	(0.057)	0.764	(0.122)	0.274	(0.112)	0.071	(0.077)	0.401	(0.142)
COV(G) w/ RFI			0.119	(0.169)	-0.026	(0.056)	0.015	(0.039)	0.029	(0.035)
COV(ENV) w/RFI			-0.127	(0.141)	0.052	(0.053)	0.006	(0.040)	-0.013	(0.031)
rG w/ RFI			0.167	(0.238)	-0.157	(0.345)	0.244	(0.608)	0.270	(0.320)

How to build RFI into NZ's "Breeding Worth" index?

Weightings in NZ's National Breeding Objective are **data-derived** economic values based on current market conditions.

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Assumptions & methods

- **Assume:**
  - RFI is only measured on non-lactating animals (heifers)
  - Genetic correlation btwn RFI of heifers & lactating cows = 0.4
  - Genetic correlation btwn 3 relevant life stages for heifers = 1
    - stage 1 = 3 to 9 months
    - stage 2 =10 to 22 months
    - stage 3 = 23 to 24 months of age
  - Energy requirements according to standard tables

- **Methods:**
  - Quantify impact of unit change in RFI BV on feed consumption for all life stages and seasons
  - Quantify savings in feed costs at different times of the year and duration of life stages
  - Account for changes in stocking rate
  - Re-scale for “discounted genetic expressions”

The “nitty gritty”

Life stage/season	Period length (days)	Ave feed cost ($/kg DM)	Maintenance DMI (kg DM/day)	Genetic regression	Economic value component ($)
Heifers					
Calves, weaning to R1 in May	180	0.22	2.1	0.47	-18.84
R1 May-May	390	0.17	3.3	0.73	-49.70
May to 2yo. at 1st parturition	65	0.35	4.1	0.92	-21.01
Heifer total					-89.54
Lactating cows					
Early spring	48	0.44	4.7	0.73	-15.55
Late Spring	61	0.21	4.8	0.75	-9.66
Summer	91	0.29	5.1	0.79	-20.74
Autumn	70	0.34	5.1	0.79	-19.04
Dry cows					
Autumn	10	0.34	5.1	0.80	-2.74
Winter	60	0.35	5.0	0.78	-16.48
Early spring	25	0.44	4.9	0.76	-8.51
Cow total					-92.71

Adjust for changes in stocking rate

- A 1kg increase in RFI would increase DMI requirement per cow on the milking platform andrequire a 5.3% reduction in stocking rate
- A 5.3% reduction in stocking rate would mean a 5.3% reduction in the margin and change economic value of -$10.01, from -92.71 to -102.72.

Discounted Genetic Expressions

- Relative to cows, the discounted number of expressions of heifer traits is 0.27 based on annual age statistics for herd tested dairy cows and assuming a discount rate of 5% per annum.

EV= -89.54 x 0.27 + -102.72 x 1 = -$126.90

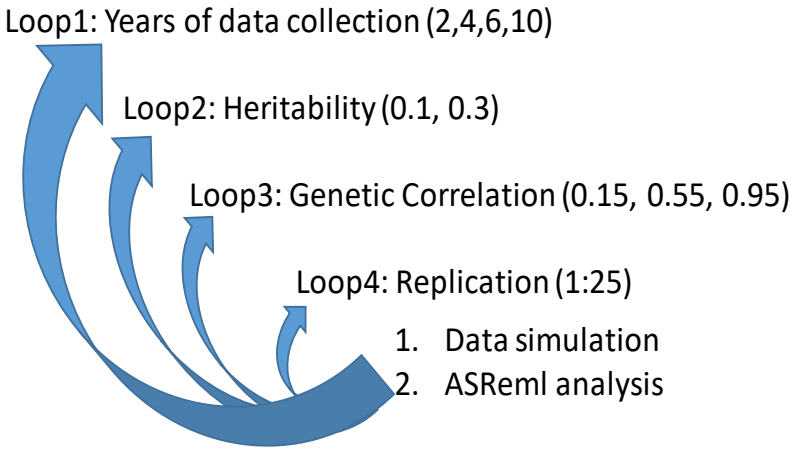
Prospects for implementation

- Several “issues”:
  - RFI phenotyping is **very costly** (NZ$1500/animal)
  - Small sample size
    - Large SE’s for genetic parameters
    - Need to validate value of thermal images

- How much more data required to generate confidence?
  - Low SE’s for genetic parameters (including thermography)
  - Adequate reliabilities for EBVs

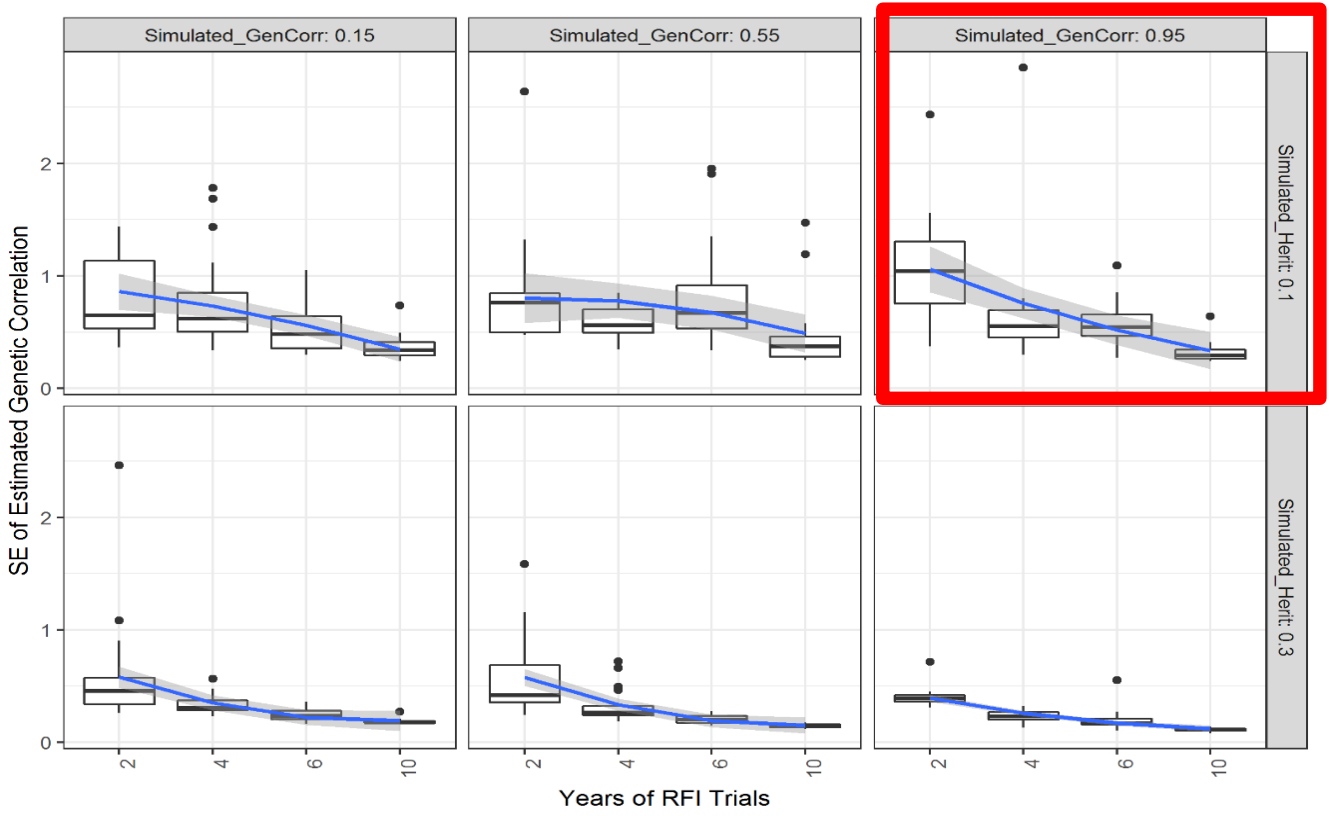
Simulation study

- Realistic pedigree structure
- Range of underlying genetic architectures
- Test approximately 325 animals/yr
  - newly born progeny of 35 most influential sires recruited for RFI trials

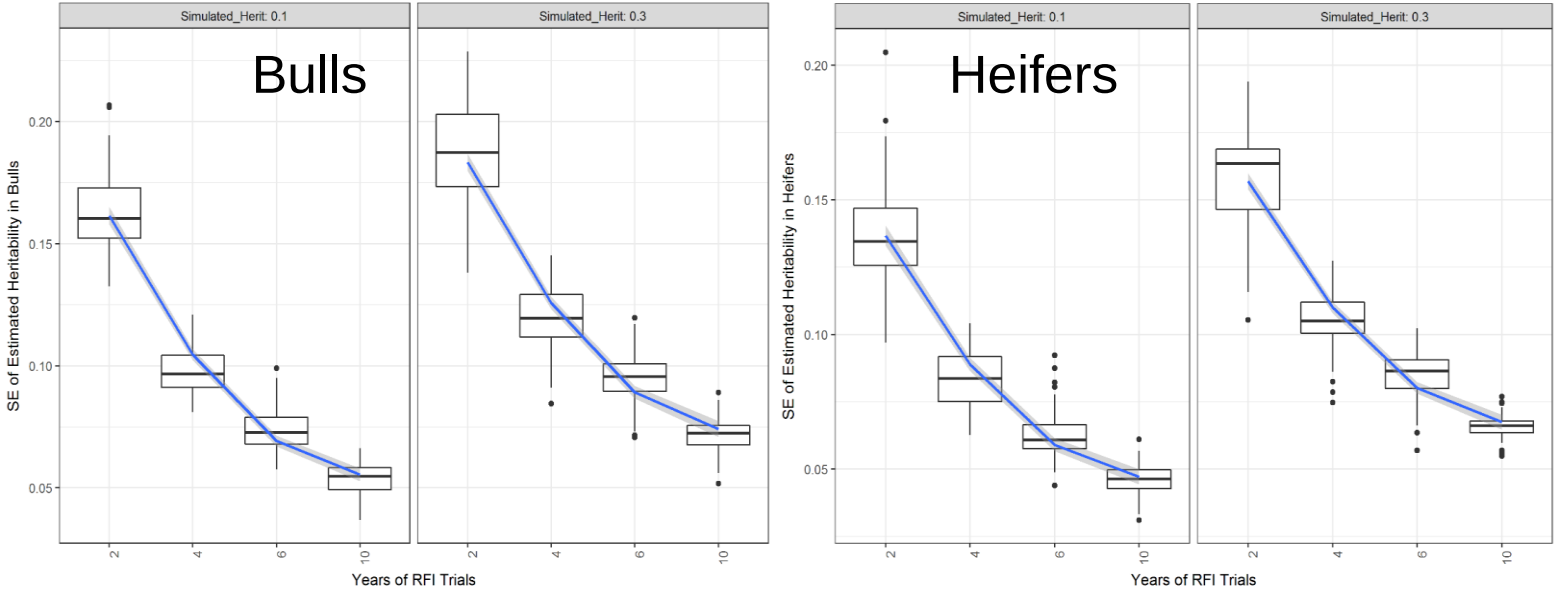


	Sires	Bulls	Heifs	Total
	4	8	10	72
	4	6	8	56
	5	5	7	60
	5	5	6	55
	8	3	3	48
	9	2	2	36
TOTALS	35	148	179	327

SEs for cross-sex r_g



SEs for heritability vs. years of trials



$NZ1500/animal x 325 animals/yr ~ $NZ0.5 M/yr (Phenotyping only)

Summary & Conclusions

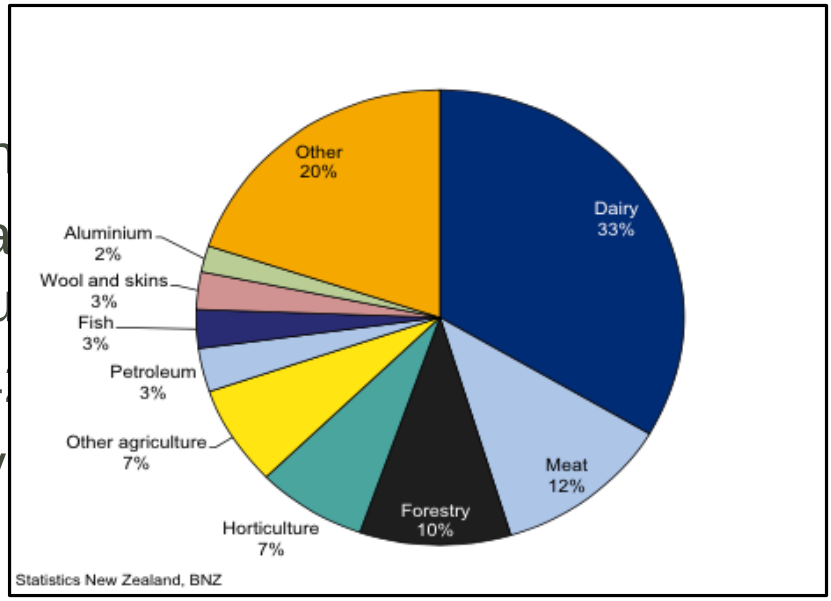
- Sufficient genetic variation to support selective breeding
- Across-sex genetic correlation for (probably) very high in young animals
- No evidence for strong breed differences
- Thermal imaging potentially useful predictor
- **BUT**
  - available data has limitations,
  - no funding for additional trials
  - implementation uncertain

Questions?

DairyNZ

Quick Facts about the NZ Dairy Industry

- Pasture based w/ high
- Feed-limited w/ annua
  exploit seasonal pastu
- ~ 12,000 herds w/ ~ 4
- NZ's largest export by



Reliabilities

Bivariate mixed-model

Bivariate Mixed Model Terms	Type	Effect
Intercept	Fixed	Overall mean
Cohort	Fixed	Two time-based groups
Female Pens	Fixed	Female - specific pens nested w/in cohorts
Male Pens	Fixed	Male - specific pens nested w/in cohorts
Female Owners	Fixed	Female contemporay group (if >2 from one farm)
Male Owners	Fixed	Male contemporary group (if >2 from one farm)
Age	Fixed	Animal age in days
Eczema	Fixed	Binary variable indicating symptoms of facial eczema
Animal	Random	Pedigree-based additive genetic relationships

Calf	Heifer	Bull
Heifer	0.14 ± 0.01	0.93 ± 1.46
Bull	0.15 ± 0.23	0.19 ± 0.04

Heritabilities (diagonals) and correlations (genetic above; phenotypic below) between residual feed intake (RFI) in Friesian heifer and bull calves

Univariate QQ Plots

- All look pretty reasonable