Genetic improvement strategies for better fertility in dairy cattle

Improving the reliability of fertility breeding values

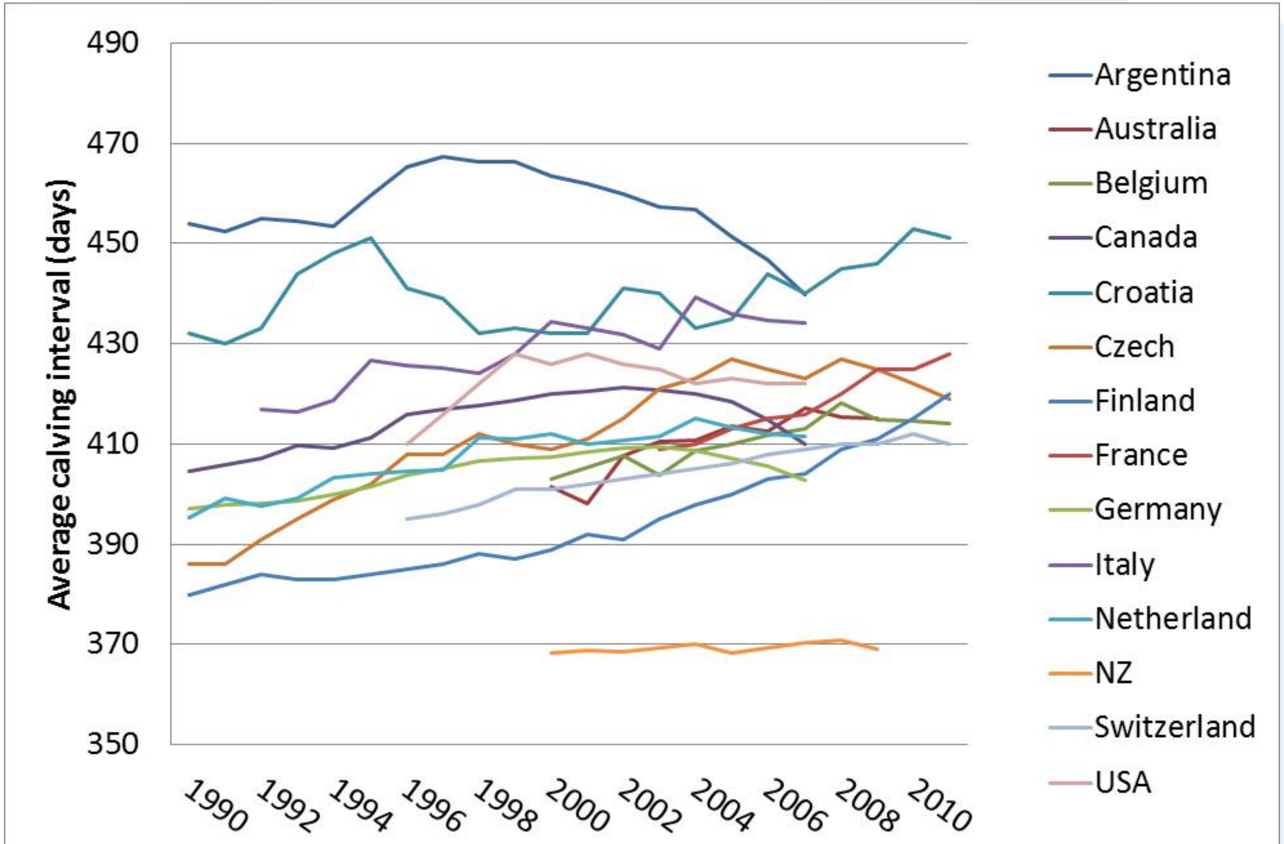
Jennie Pryce

DairyFutures CRC

Outline

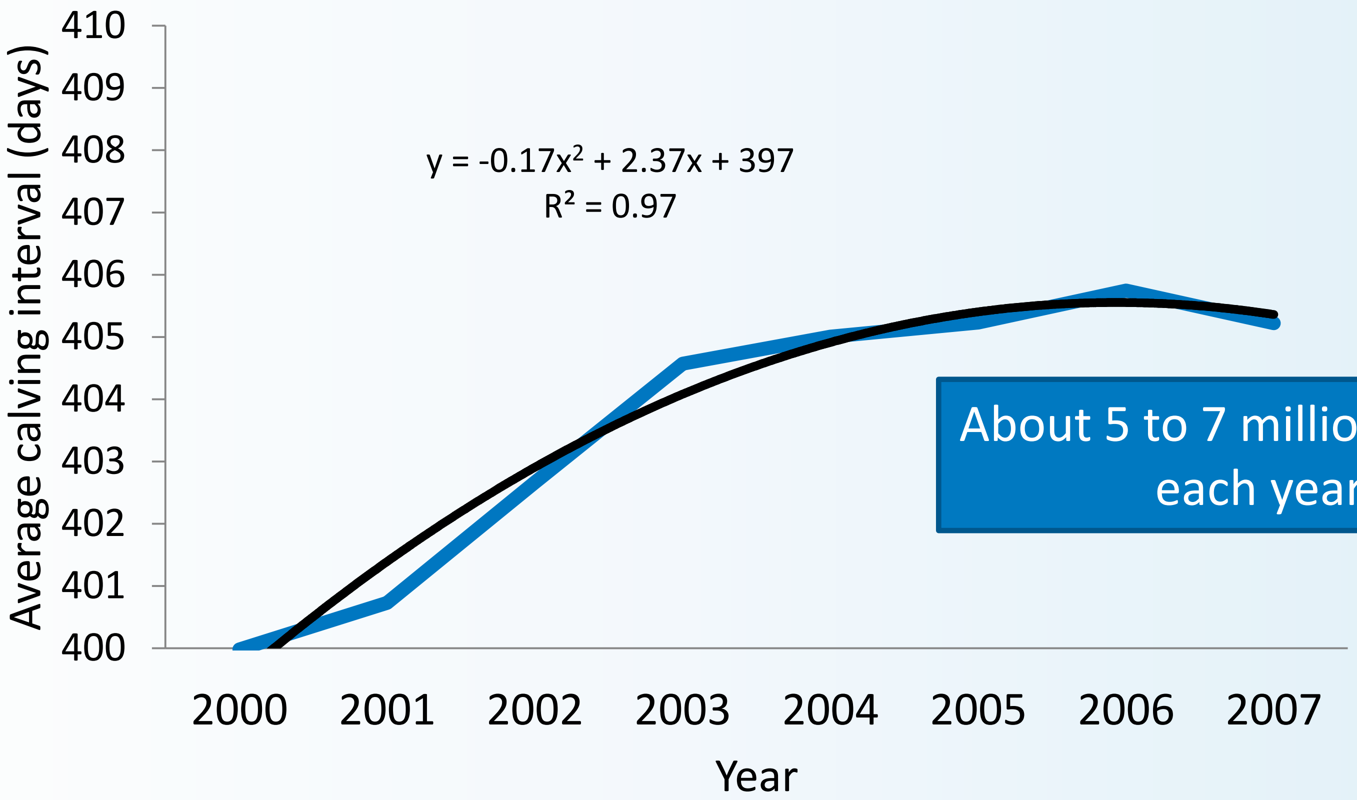
- Trends in fertility around the world
  - Genetics (additive and non-additive)
- Improving the reliability of fertility breeding values
  - Genomics and an information nucleus
  - Multi-trait fertility model
  - How collecting more data can help

Calving interval for 15 countries (phenotypic trend)



Woolaston et al. (2012)

Calving interval for 15 countries (weighted phenotypic trend)



About 5 to 7 million cows in each year

Genetic Trend for Holstein cows by year of birth

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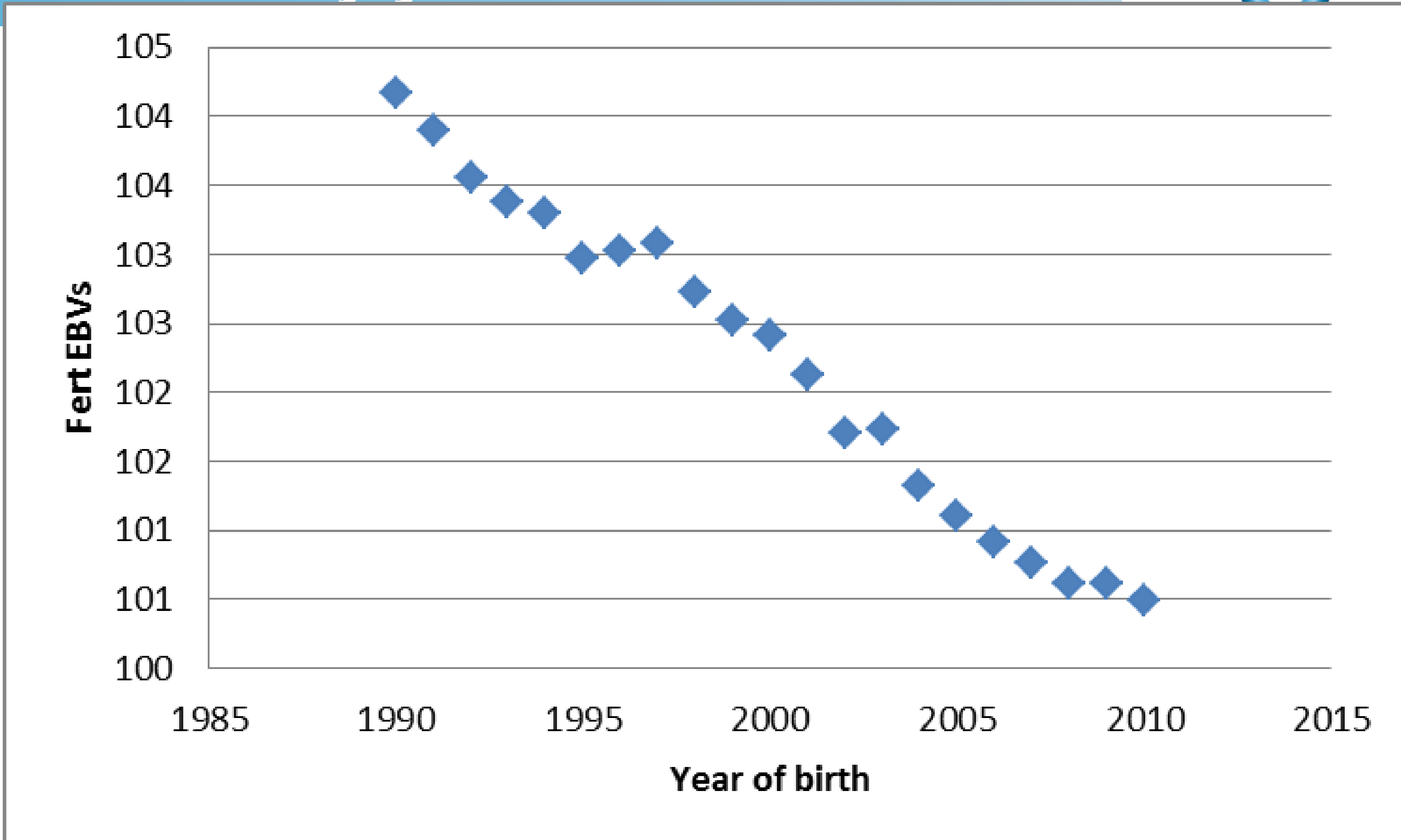

Summary of worldwide snapshot of fertility

- Evidence for phenotypic trend in calving interval starting to improve
- Variable evidence for genetic trend in females born
  - Some countries seeing an improvement in the trend between 2000-2005
  - Not consistent in all countries

Other genetic effects

- Non-additive (or inbreeding and crossbreeding)
- Lethal mutations: fertility "haplotypes" associated with lower (3.1% to 3.7%) conception rates and lower (1.1% to 3.7%) non-return rates

Heterosis effects (calving rate)

Cross	Effect (%)
NZ Holstein x Jersey	+2.2%
N. American Holstein x Jersey	+2.9%
NZ x N. American Holstein	+0.9%

(Pryce et al., 2007: Proc NZSAP)

Reduction in fertility of progeny of non-inbred half-sibs (12.5% inbreeding)

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Study	Country	Measure	Effect
Hudson and Van Vleck (1984)	USA	Calving interval	+1.2 d
McParland et al (2007)	Ireland	Calving interval	+8.8 d
Gonzalez-Recio et al. (2007)	Spain	Pregnancy rate	-1.7%*
Hoeschele (1991)	USA	Days open	+1.5 d
Wall et al (2005)	UK	Calving interval	+2.9 d
Pryce et al (2013)	Australia	Calving interval	+2.5 d

* For cows with F between 6.25 and 12.5%

Rate of inbreeding

Study	Country	Breed	Rate of inbreeding/year
McParland et al (2007)	Ireland	Holstein	+0.10%
Wiggans et al (1995)	USA	Holstein	+0.20%
Wiggans et al (1995)	USA	Jersey	+0.22%
Haile-Mariam et al	Australia	Holstein	+0.17%
Haile-Mariam et al	Australia	Jersey	+0.25%

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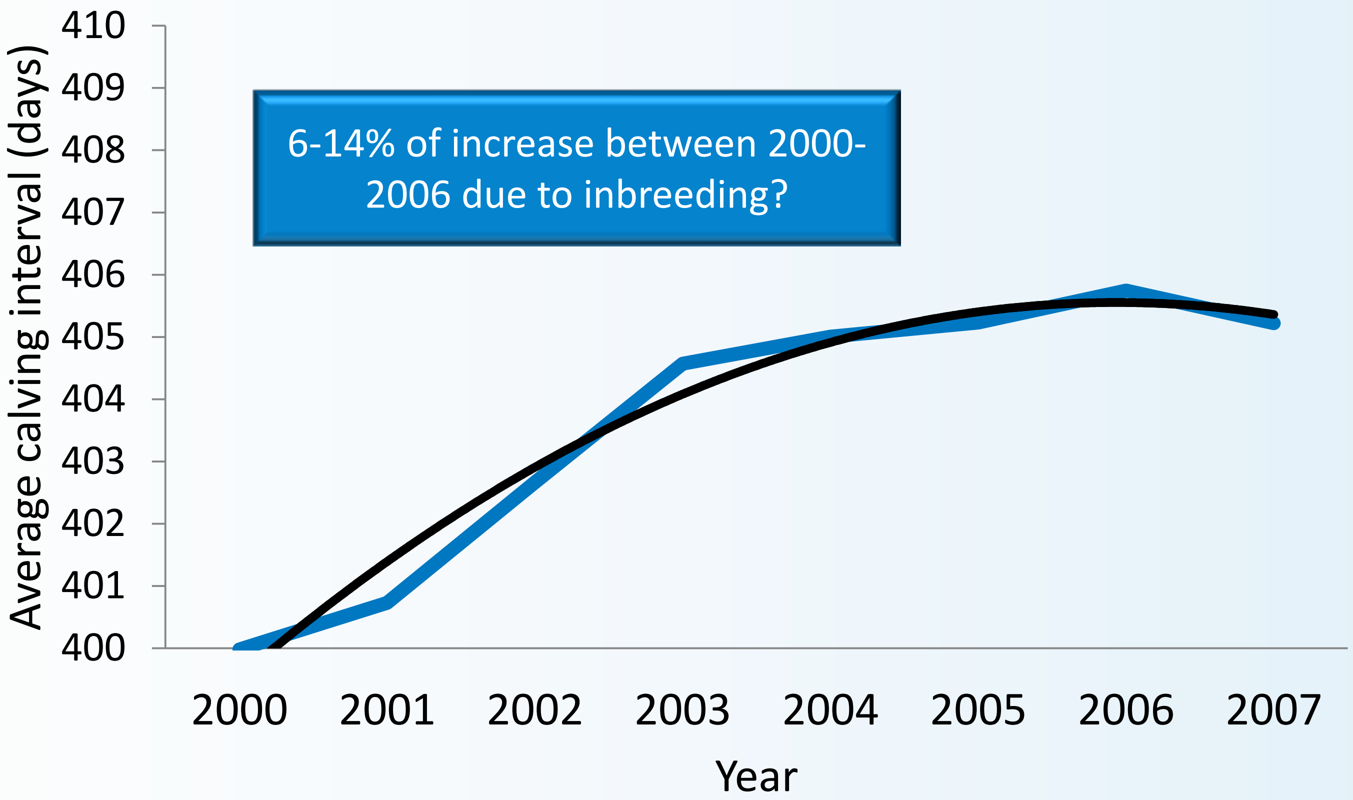
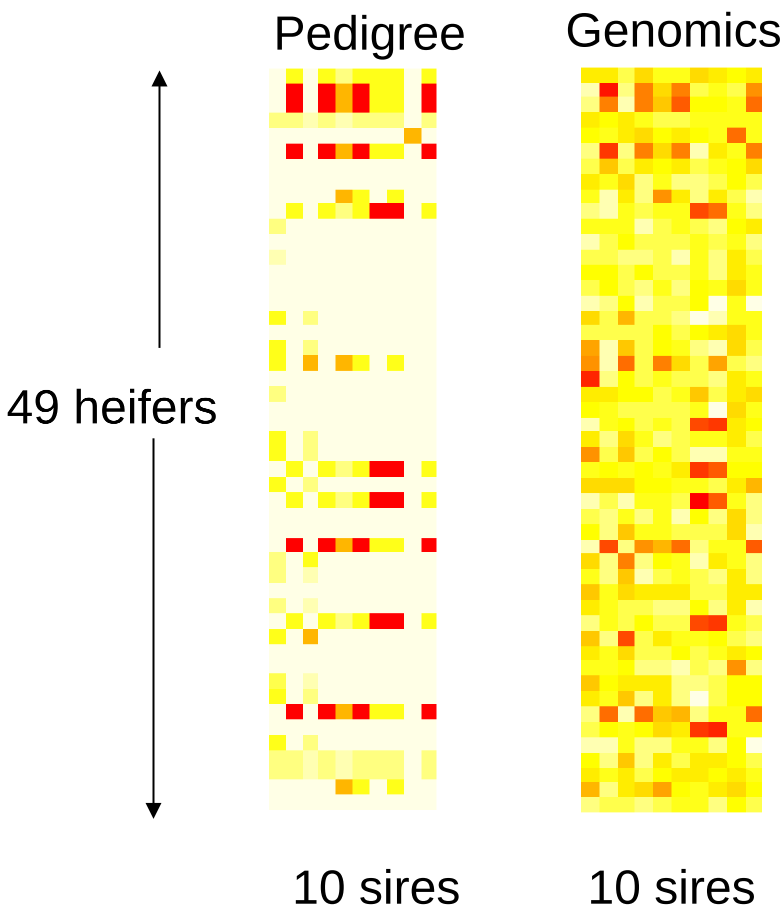
Contribution of inbreeding to phenotypic trend



MATING PLANS



- Each square represents the degree of relationship
- Darker orange/red indicates closer relationships

Australian strategy to genetically improve fertility

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- Australian Profit Ranking index
- Genomics and an information nucleus
- Multi-trait fertility model
- How collecting more data can help

Development of Australian fertility BVs

2003 Fertility ABV Developed – Calving interval

2003

Fertility Added to Australian Profit Ranking (APR)

Australian Profit Ranking (APR)

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Profit-based selection index

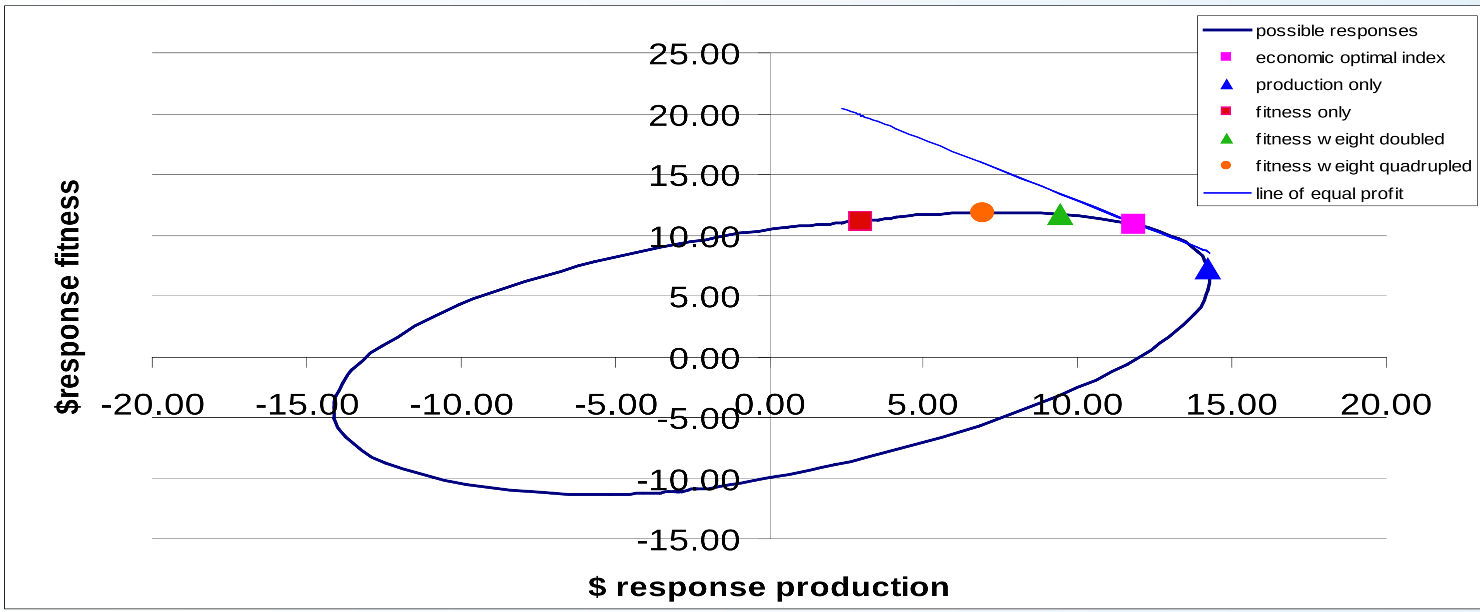
- Efficient production
- Survival
- Milking speed
- Temperament
- Fertility
- Cell Count

– Farmers use the APR when selecting bulls

Australian Dairy Herd Improvement Scheme

Direction of APR

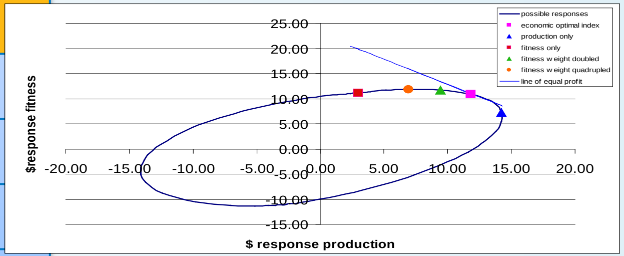
- Industry criticism that there is “insufficient” weight on fertility in the APR index
- A new approach to selection index.
- What’s the cost?



Annual response to selection (unit of measure)

	Economic Index	APR
Milk Yield (kg)	62.00	53.52
Protein Yield (kg)	2.30	2.02
Fat Yield (kg)	2.72	2.40
Survival (longevity)	1.07	1.10
Fertility (%)	0.25	0.51
SCC (Mastitis Resistance)	2.31	2.86
Liveweight (kg)	1.00	1.20
Milking Speed	0.16	0.17
Temperament	0.37	0.35

Difference between Economic index and APR worth $0.83 (<4%)



Improving reliability

Development of Fertility ABVs

2003 Fertility ABV Developed – Calving interval

2003

Fertility Added to APR

2010 Increased emphasis on fertility in APR

2011 Introduction of genomics. Genomic data improves reliability of Fertility ABVs for young bulls

Impact of genomics on reliability of fertility EBVs (young bulls with no progeny)

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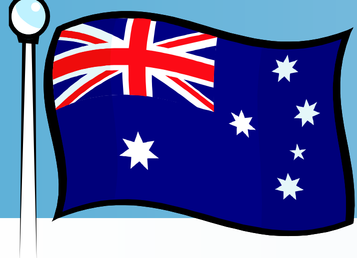
Country	Pre Genomics	Post Genomics	Change
Australia	16	38	22
Canada	33	60	27
D/S/F			28
Germany	25	43	18
Italy			38
UK			29
USA	31	72	41

World Holstein Friesian Federation WHFF



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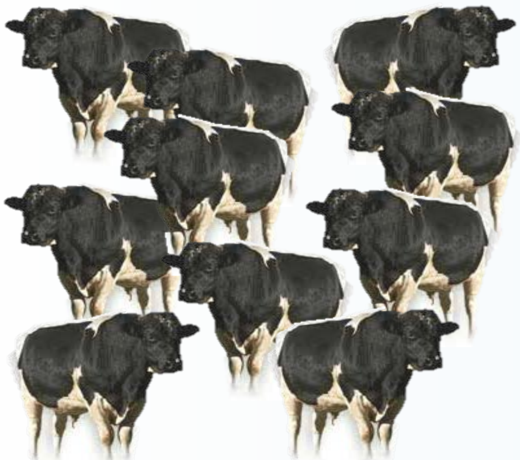
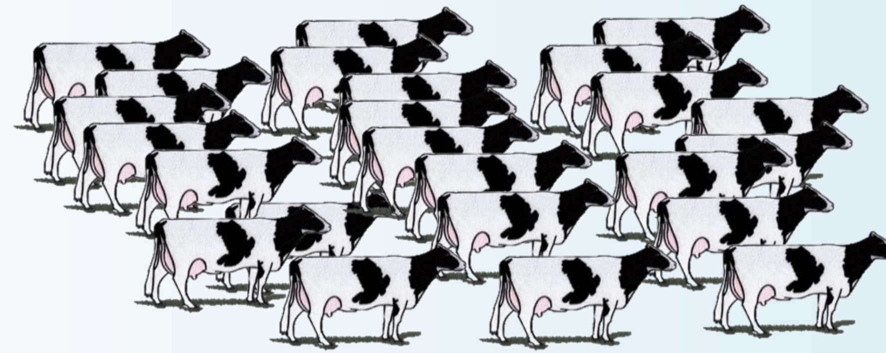


3571 bulls with
Australian daughters



8716 cows
deliberately selected

Australian national DNA reference set

917 bulls with
Australian daughters

Australian national DNA reference set

3995 cows
deliberately selected

Ginfo

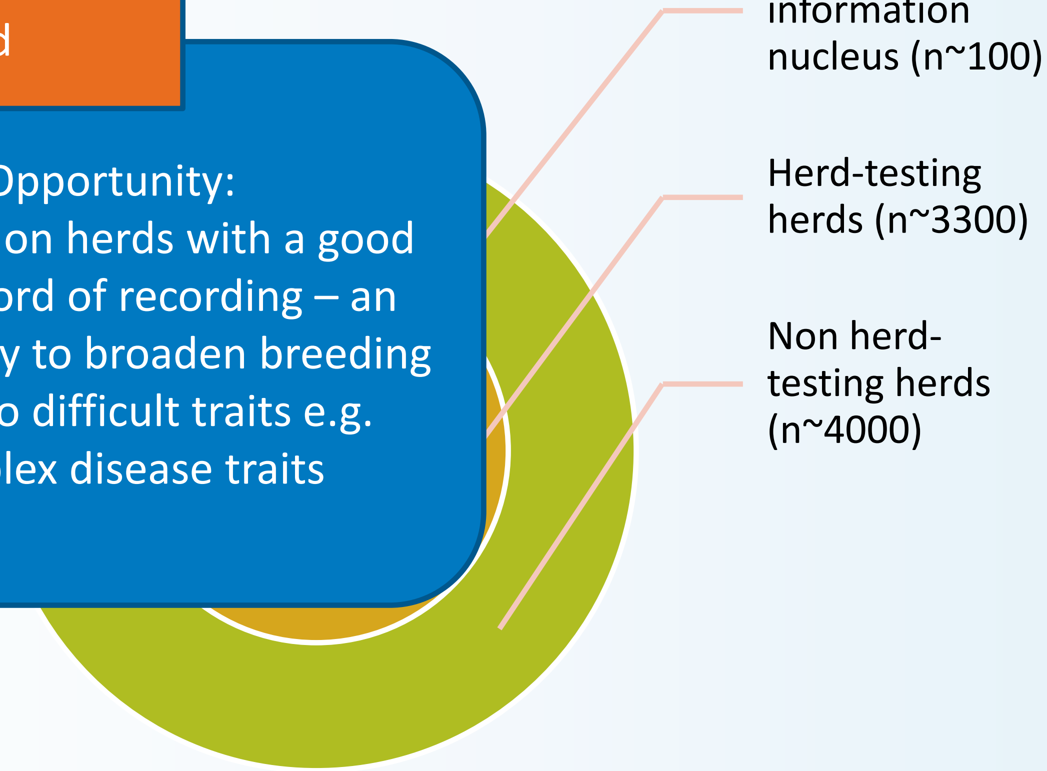
Genomic information nucleus

- 10,000 Holstein genomes and Jernomics captured 1 time-point, *Ginfo* is designed to be on-going
- Work with herds with great data, rather than cows with great data
- The reference population needs updating, predictions of genomic breeding values deteriorate as the reference population differentiates from the general population
- Focus on fertility!

Genomic information nucleus

Recruiting of herds started

Opportunity:
Focussing on herds with a good track record of recording – an opportunity to broaden breeding values to difficult traits e.g. complex disease traits



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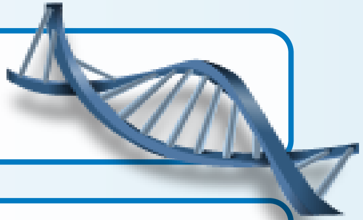
Ginfo process

Contact

- 50 herds in phase 1
- Individual farm visits

DNA

- Tail hair collection (farmer or HAA)
- Lab extract DNA



Phenotypes

- Farmers continue to collect high quality phenotypes
- Type and additional phenotypes collected

ABVg

- Better genomic breeding values

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Development of Fertility ABVs

2003 Fertility ABV Developed – Calving interval

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Fertility Added to APR

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2013 multi-trait model (5 predictors)

Multi-trait fertility model

Bulls born since 2000:
Fertility breeding values

Breed	Number	Reliability OLD	Reliability NEW	Change
Holstein	2421	61.9	68.3	6.5
Aussie Red	29	62.1	70.8	8.7
Jersey	498	62.4	70.0	7.6

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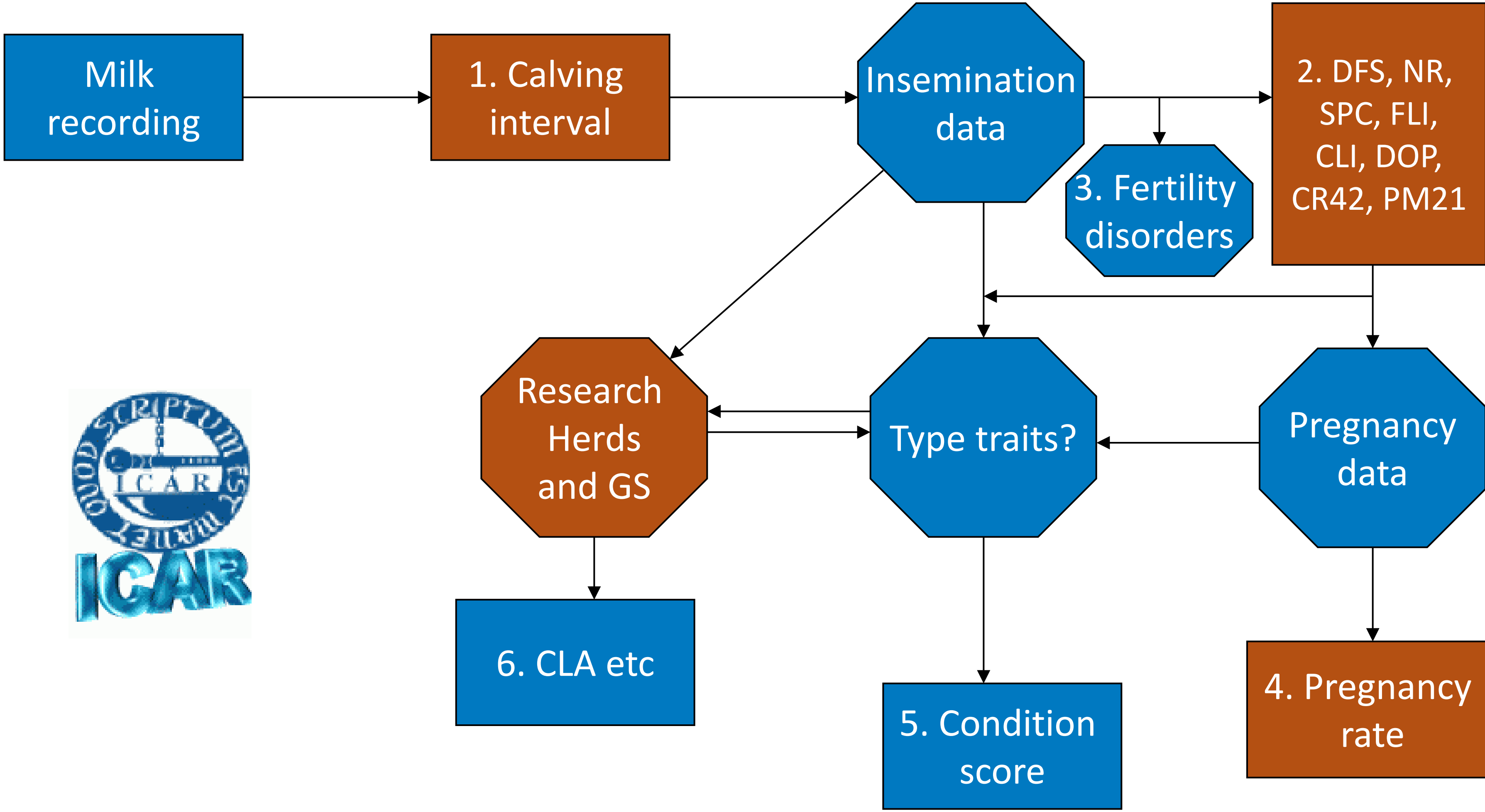
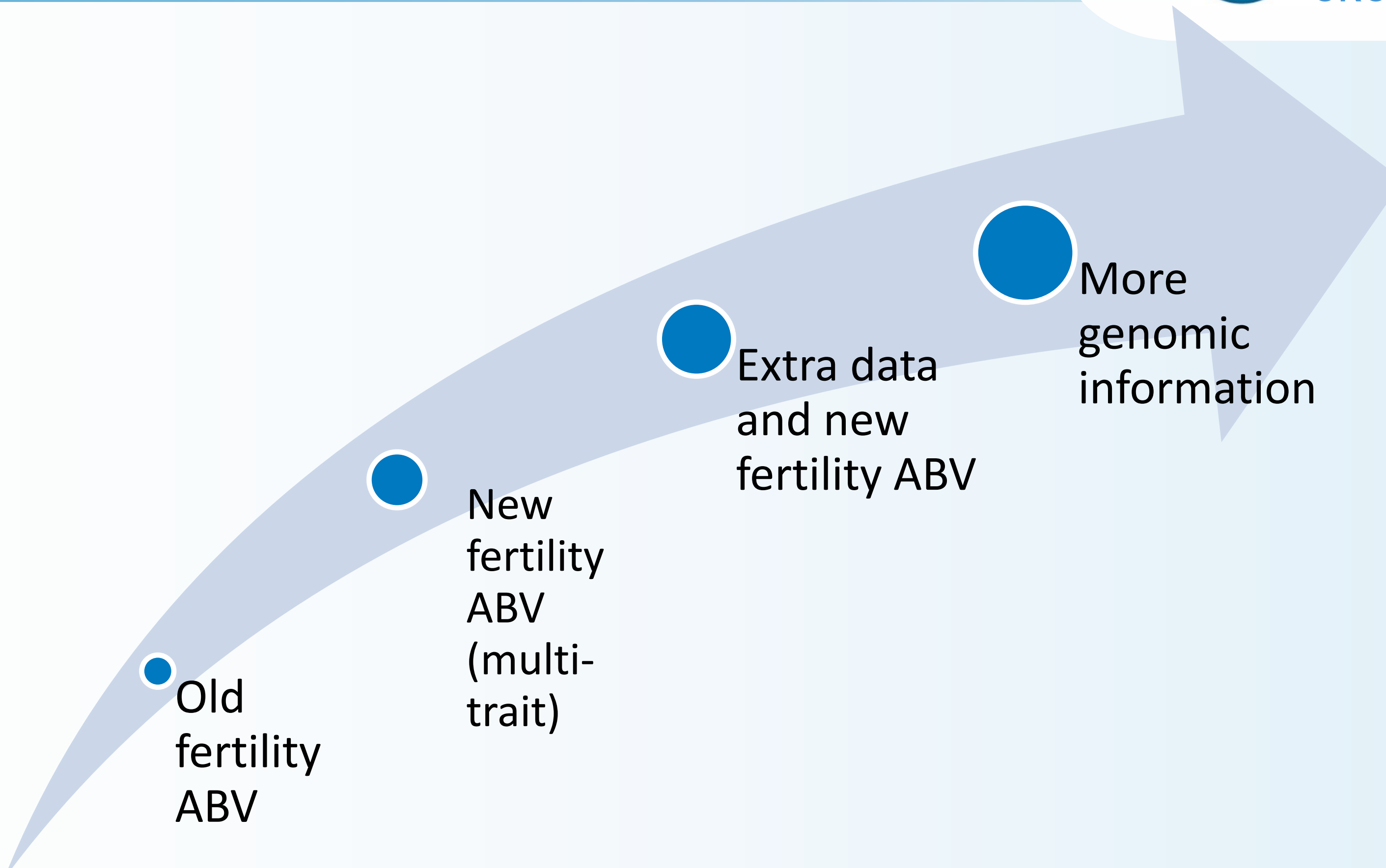

Milk recording
1. Calving interval
Insemination data
2. DFS, NR, SPC, FLI, CLI, DOP, CR42, PM21
3. Fertility disorders
Research Herds and GS
Type traits?
Pregnancy data
6. CLA etc
5. Condition score
4. Pregnancy rate
ICAR

Increasing the reliability of fertility breeding values



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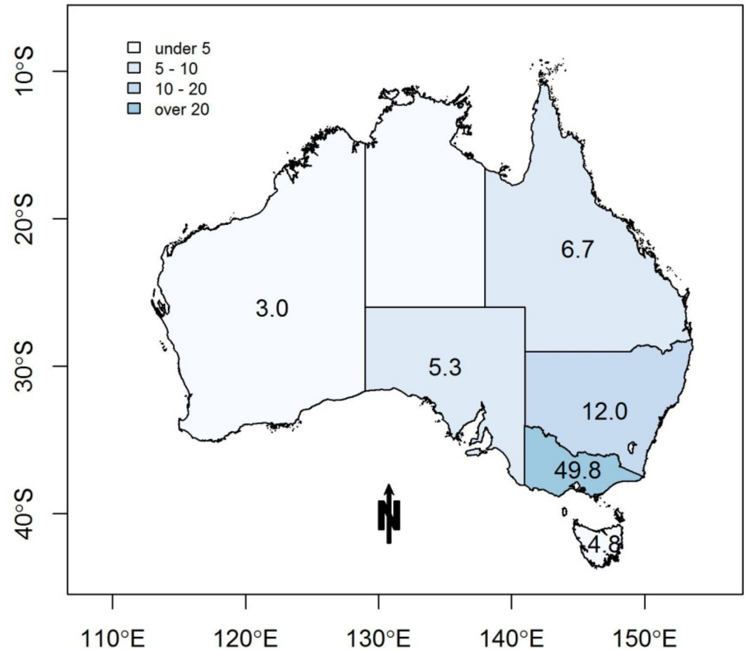
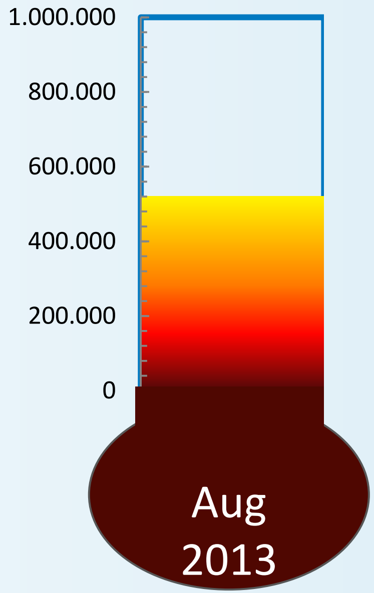
TARGET

DOUBLE OUR DATA

Percentage of herds that have insemination data that qualifies for fertility breeding values





Data, data, data!

Mating data

+

Pregnancy test data

→

Better fertility ABVs

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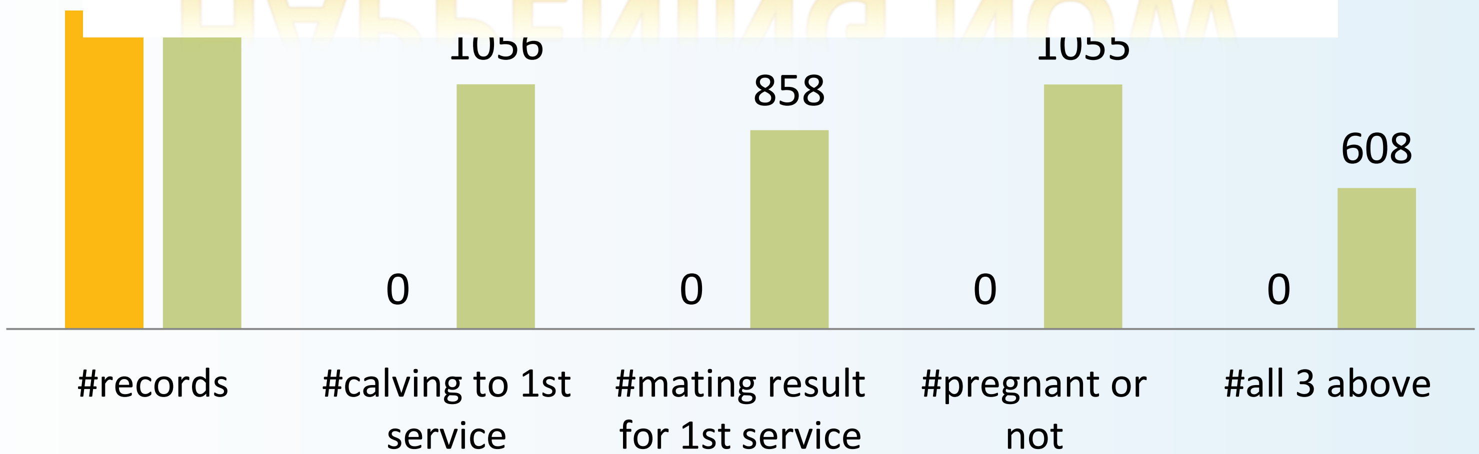
From farm…..

To Data Processing Centre

Example herd, data reaching ADHIS before and after our intervention

AUTOMATION HAPPENING NOW



Action

- – Project underway to increase the amount of fertility data that is captured
- – Increase of 18% cows with fertility data that qualifies for ABV calculation in the same period for data extracted in August 2012 and March 2013
  - Increased awareness milk recording companies
  - Actively going out and getting the data

Other opportunities

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Challenges

– 50K does not capture all genetic variation
– Poor persistence of reliability across generations
– Poor prediction of diverse pedigrees
– Cannot use across breed information

Solution: Whole genome sequence?

Genetic variation captured

Current technology (50K) only captures 60% to 90% of genetic variation (fertility, production)

Whole genome sequence information

- Sequencing still more expensive than SNP chip genotyping

- Alternative strategy
  - *Sequence key ancestors, impute genotypes from sequenced animals into all animals genotyped with SNP chips for genomic prediction*

1000 bull genomes project

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- 16 international partners
- **Run 3.0:** 427 bulls, 2 cow sequences (15 breeds)
  - 29.1 million SNP

- Early discovery: embryonic lethal recessive mutation
  - INRA collaborators
  - *smc2* gene - controls chromosome separation during cell division
  - Mutation phenylalanine -> serine
  - Avoid carrier matings

Name	Fold coverage
Starlite	12.8
Shotime	11.9
Goldsmith	11.8
Gravita	15
Orana	9.5
Beau	12
OVGM	12.3
Goldwyn	22.7
Starbuck	30.3
Rameses	12.4
Donor	15.4
Donante	17.1
Mountain	18.9
Enhancer	16.8
Yukon	19
Gibbon	17
Jocko	15.1
Oman	14.7
Manhattan	17.9
Fatal	16.9
Cash	16.8
Boudewijn	18.5
Sabastian	26.2
Vickai	15.2

Whole genome sequence information

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1000 Bull Genomes Project

29.1 million variants

SNP selection

- Biological information
- Very large data sets
- Pathway information

100,000 variants ??

Implementation

- Genomics Evaluations (ADHIS)

Summary

World phenotypic fertility trends look promising

World genetic trends are variable

In Australia:

- Genomics making a difference to fertility
  - A new genomic information nucleus (Ginfo) established
- A new multi-trait fertility ABV has just been released
- We are working towards getting more mating and pregnancy test data to get the most out of this model!
- Sequencing provides exciting opportunities to improve fertility

Acknowledgements

- ASAS for travel grant to EAAP
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DFCRC sub-program 2.3: Fertility

Data team	Science team (DEPI)	PhD students (DEPI)
Pete Williams (ADHIS)	Mekonnen Haile-Mariam	Hassan Aliloo
Matt Reynolds (DEPI)	Oscar Gonzalez-Recio	Frances Bowley
Thuy Nguyen (DEPI)	Jennie Pryce	
Phil Bowman (DEPI)		
Steve Jagoe and Dave Beggs (Warrnambool Vet Clinic)		

Comparison of European production systems to Australian

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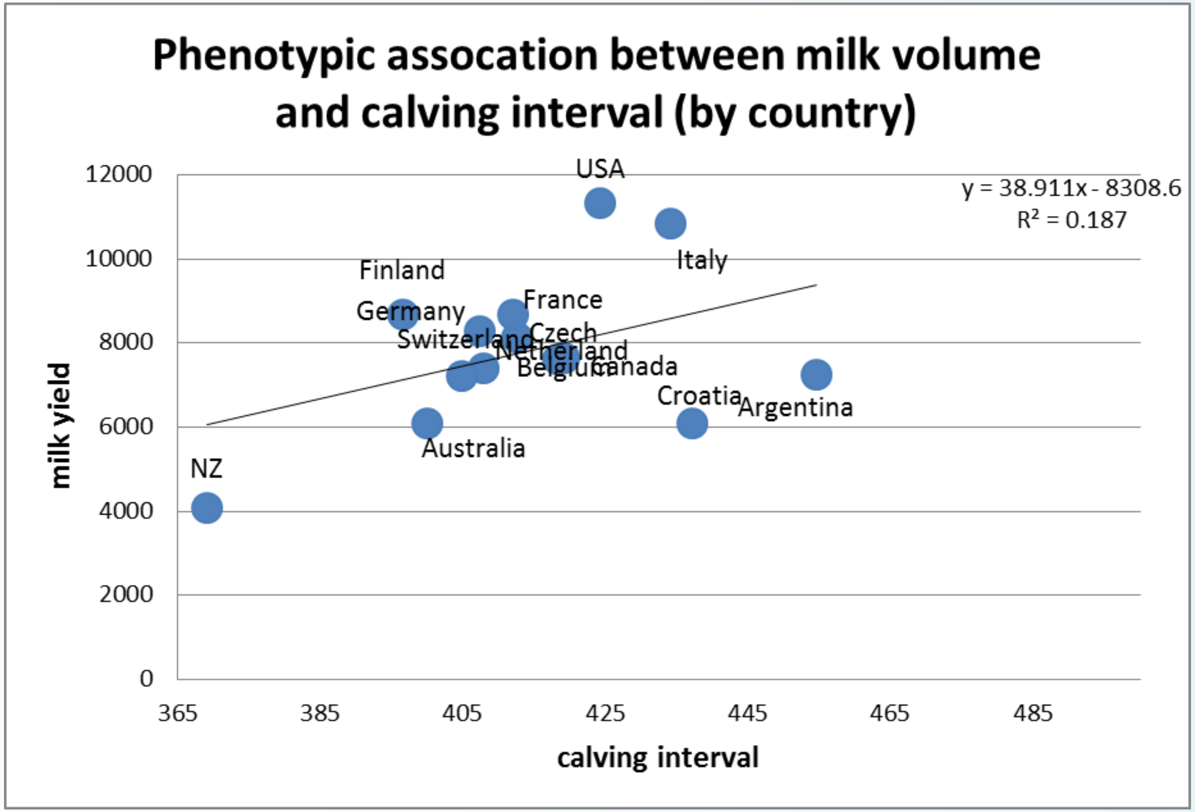
Europe

- Range of systems: Total mixed rations, grass
- Calving all year round (some seasonal: IRL)
- Welfare and sustainable productions systems
- In most countries milk not as important for GDP
- Subsidies….

Australia and NZ

- Pasture (NZ), pasture and TMR in Australia
- Seasonal calving (Spring/Autumn)
- Feed efficiency and productivity
- Milk is a major component of national GDP
- World milk price

World Holstein Friesian Federation



World Holstein Friesian Federation

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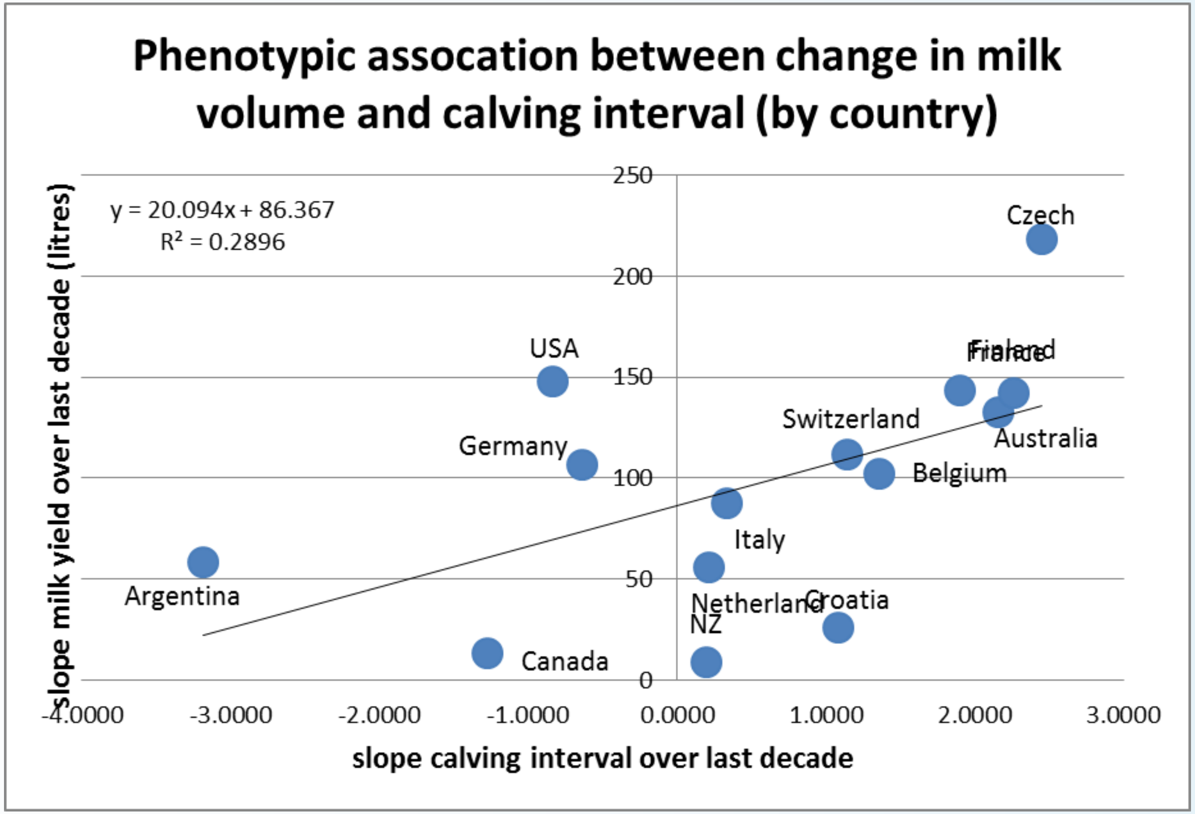

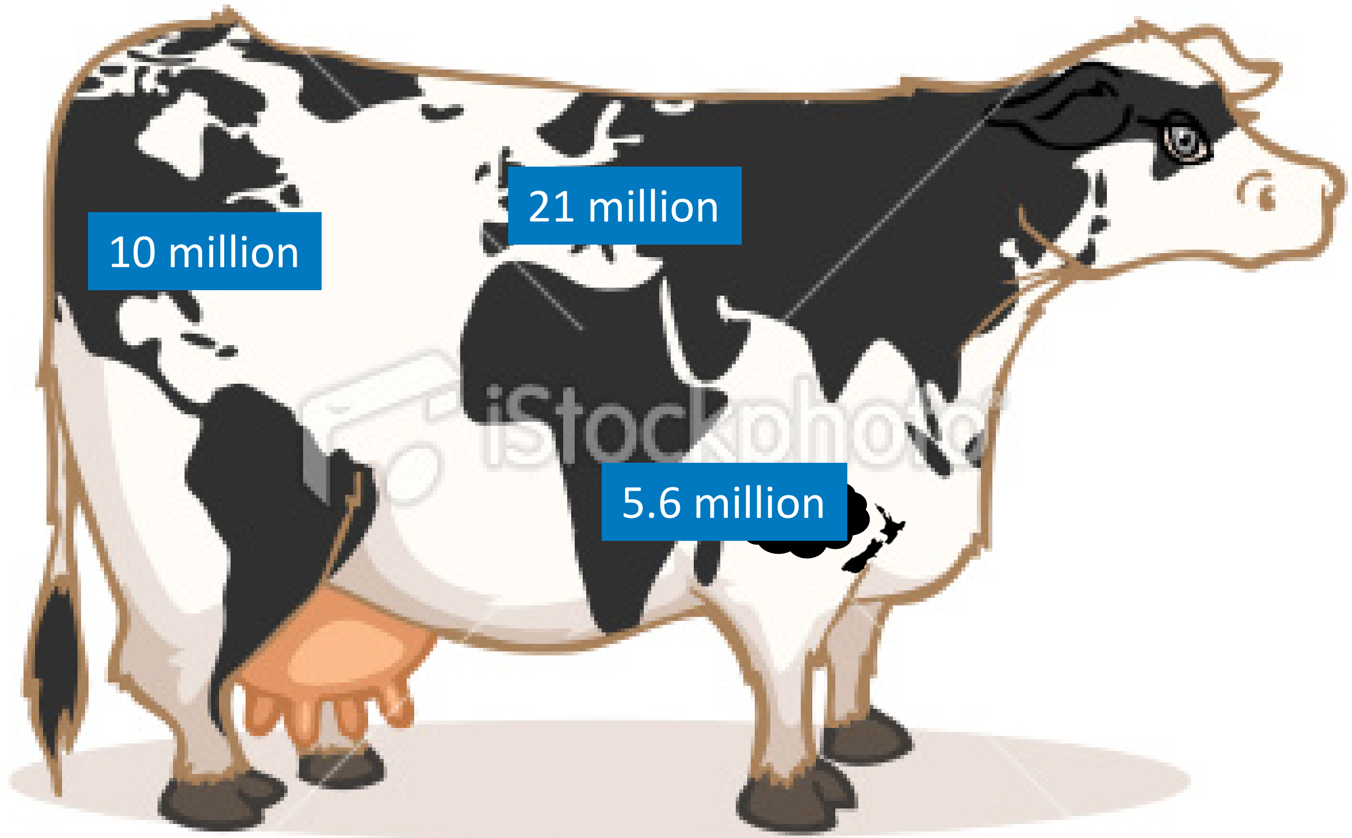
10 million
21 million
5.6 million

$ Annual response to selection (contribution to profit)

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	Economic Index	APR
Milk Yield	-$3.27	-$2.82
Protein Yield	$13.80	$12.09
Fat Yield	$4.04	$3.57
Survival	$7.56	$7.75
Fertility	$0.76	$1.53
SCS (Mastitis Resistance)	$0.61	$0.75
Liveweight	-$0.85	-$1.02
Milking Speed	$0.29	$0.30
Temperament	$0.99	$0.94
TOTAL	$23.92	$23.09

* Difference between optimal vs APR = $0.83