Sustainable livestock breeding with a focus on heat stress

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Genetic selection as optimization

- Selection for one trait or an index
- Gains on selected traits
- Losses on correlated antagonistic traits

- Losses in artificial selection
  - Fighting ability (predators and other males), ability to outrun, mating behaviors,…
  - Losses less important because of improved environment/management

- Very poor fitness of domesticated animals when released back into the wild (Frankham, 2008).

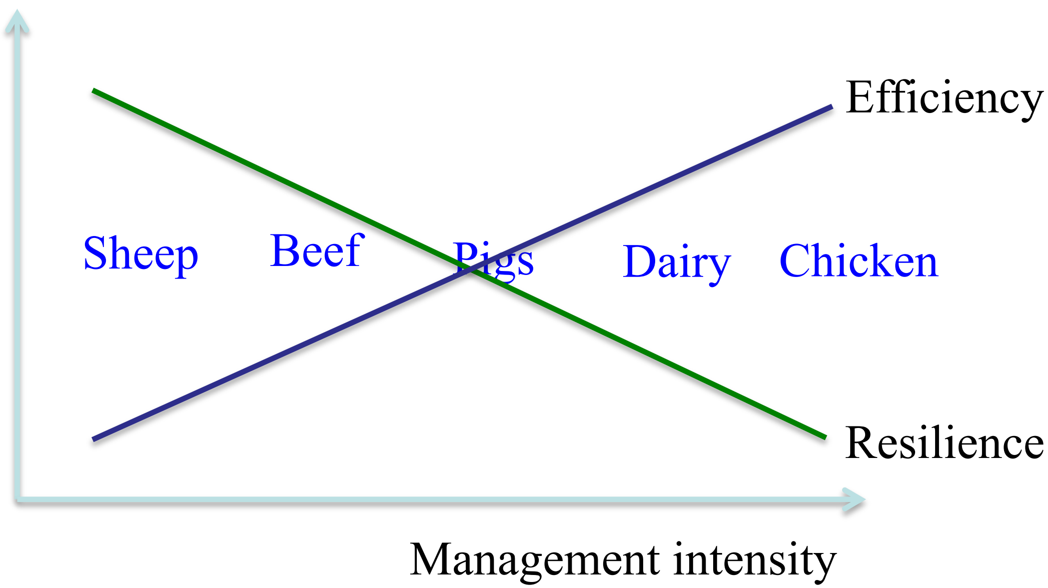
Example – Intensive selection for growth in broiler chicken

- Unlimited appetite / obesity ➔ artificial lightning
- Different maturity rate of males and females ➔ separation of sexes
- Poor survival of males ➔ male supplementation
- Increased susceptibility to diseases ➔ antibiotics
- Low hatchability ➔ alternate heating/cooling of incubators
- …

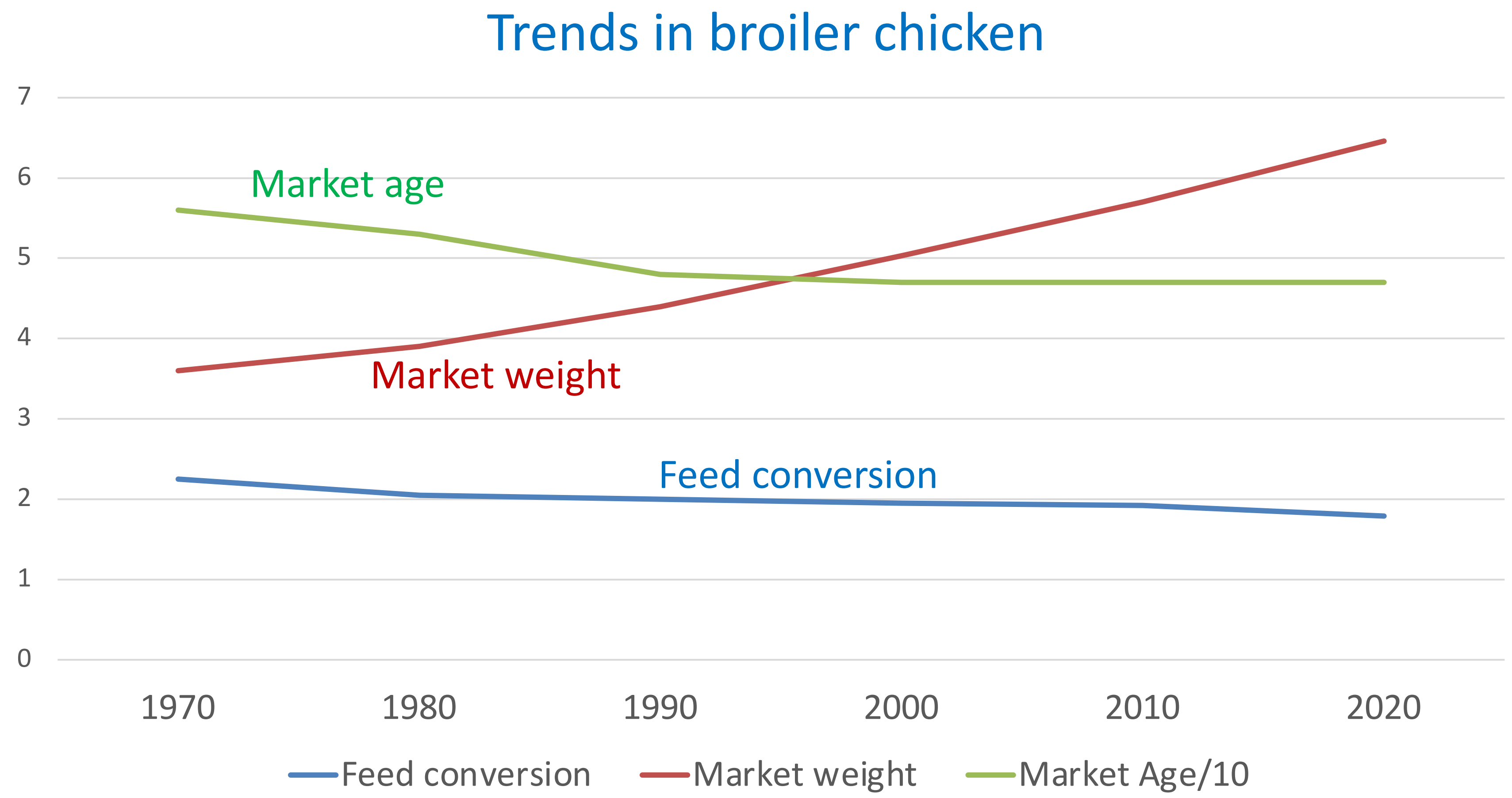
Selection for main traits, improved management for secondary traits

Eitan and Soller, 2014

Resilience/efficiency and management intensity



Fundamental limits of selection



https://www.nationalchickencouncil.org/about-the-industry/statistics/u-s-broiler-performance/

Challenges for efficient improvement

- Which traits to improve by genetics?
- Which traits to improve by management?

- Should G x E be considered or ignored in selection?
  - Geographic
  - Production systems (e.g., extensive and intensive)
  - Purebred and commercial

- Change with genomics
  - Faster selection for lower h^2 traits
  - Widespread use of untested animals
  - QTLs and pleiotropy

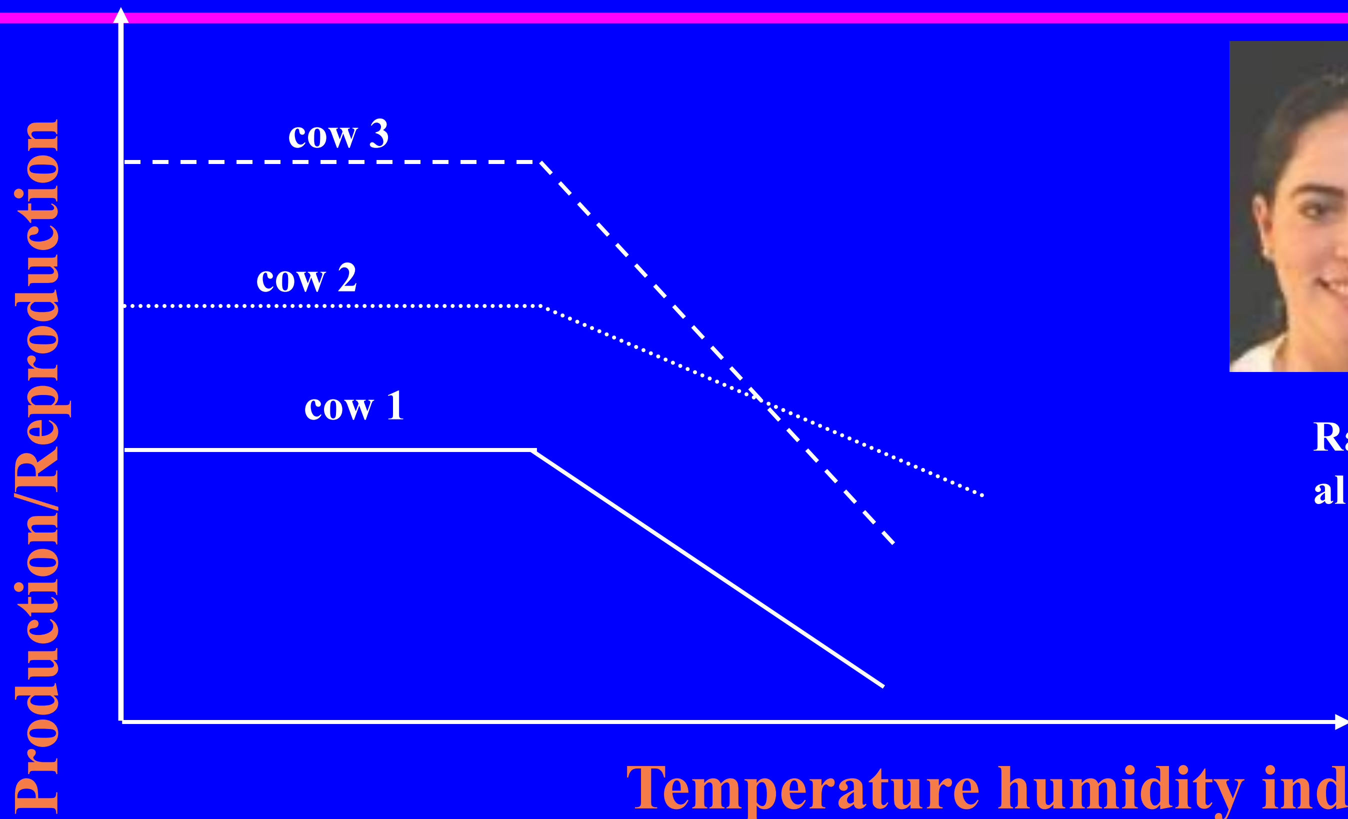
Can we improve heat tolerance – example of a project

- Greater variations of climates
- Hotter

- Losses across during heat stress (St. Pierre, 2003)

- Questions
  - Are animals indirectly selected against heat tolerance
  - Is genetic selection for heat tolerance possible?
    - How to use national data for analyses?
  - Is genetic selection preferable to managemental improvements?

Assumption for heat stress model



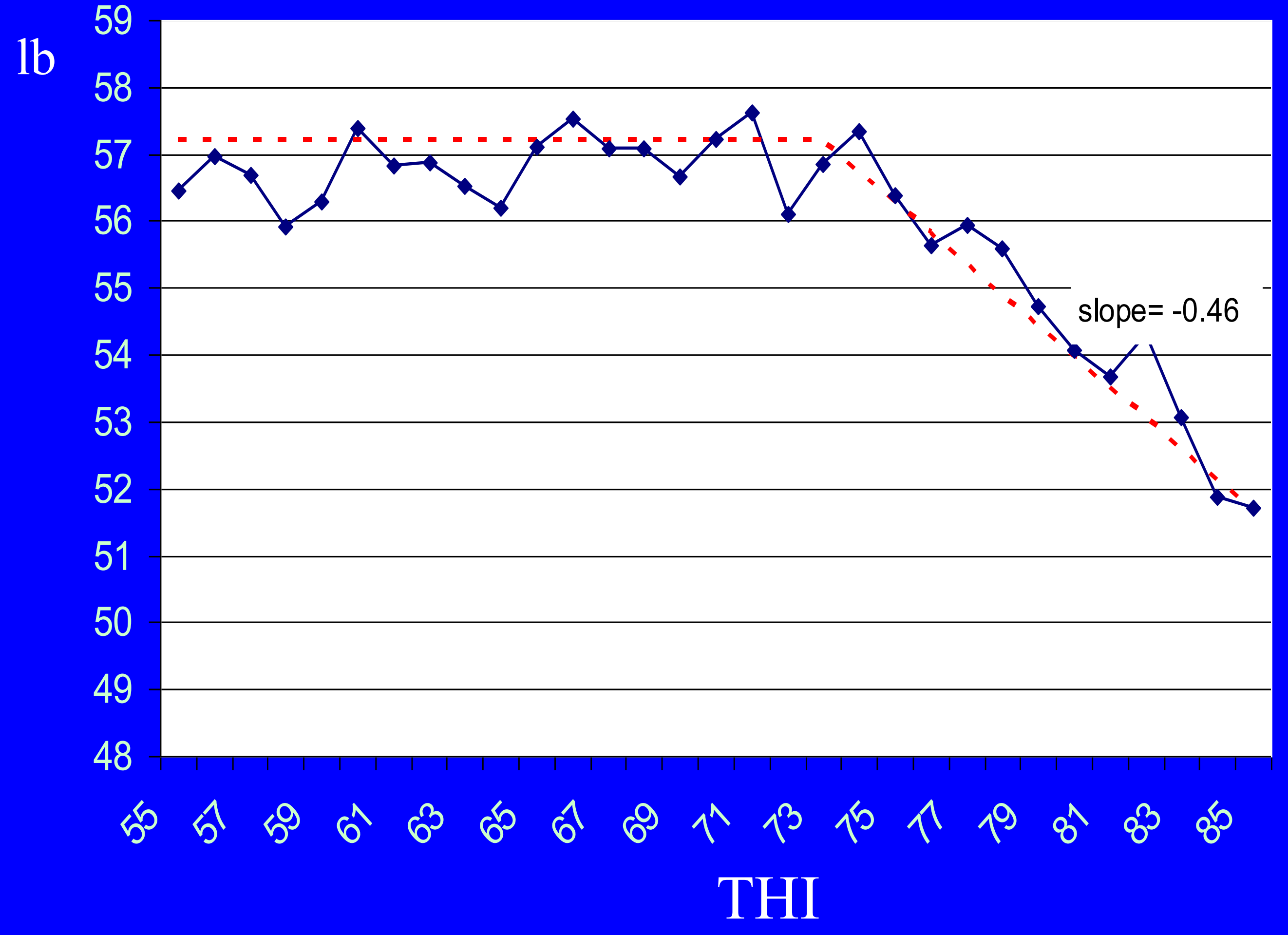
Ravagnolo et al., 2001

Breeding value: BV = a + f(THI)*v

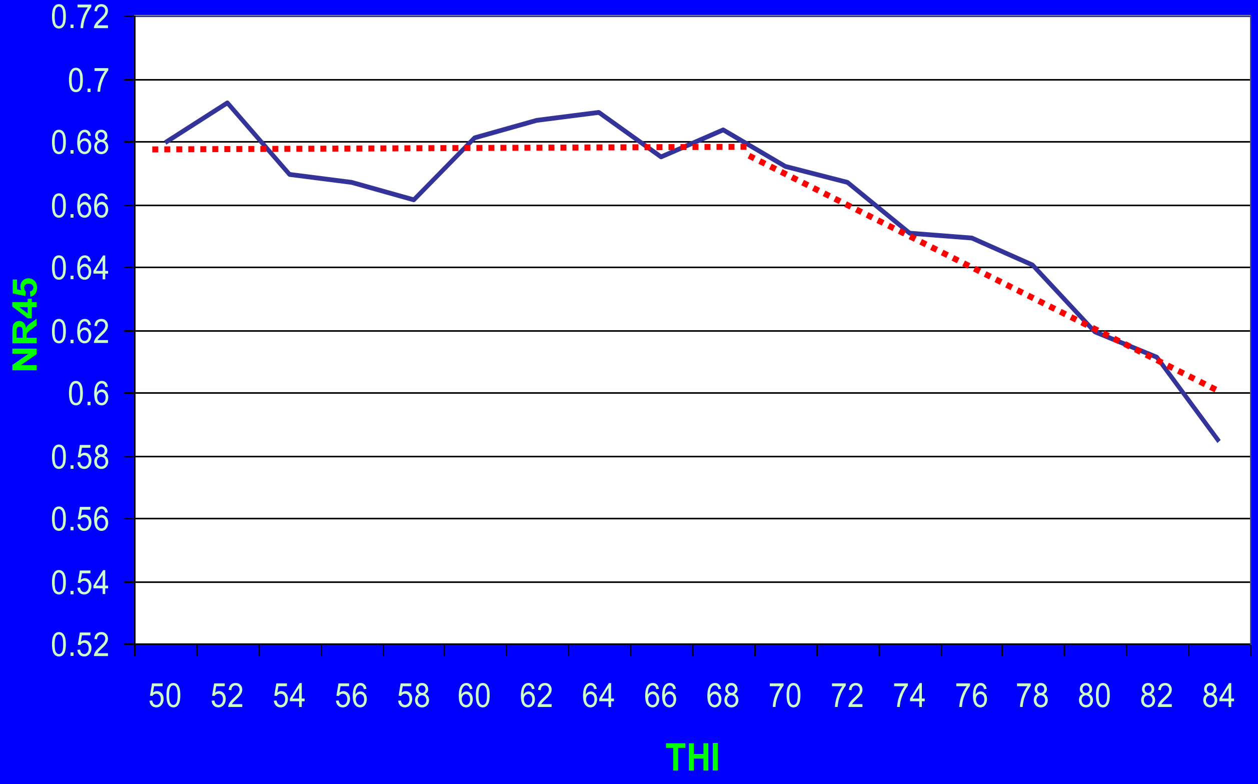
a – regular breeding value v – heat-tolerance breeding value

f(THI) – function of temperature humidity index

Effect of THI on daily milk production



Effect of THI on Non-return rate at 45 days



Genetics results - 2002

- Heat stress begins at about 72F THI (22C at 100% humidity)
- Genetic variability for heat tolerance present but not big
- Relationship between regular and heat tolerance genetics antagonistic at ~ -0.4

Heat stress across USA

- Variation in heat tolerance across USA
- Genetic evaluation for heat stress with national data
  - Do colder regions contribute information about heat stress?
  - Profile of heat tolerant bull
  - Can one identify heat-tolerant sires?
  - What are they?

Bohmanova et al. (2005 and 2006)

Differences between most 100 and least 100 heat tolerant sires

Milk	-1100kg
Fat%	+0.2%
Pro%	+0.1%
Dairy Form	-1.4
Udder	+0.7
Longevity	+0.90
Fertility	+1.6
Index	+36

- Selection for fluid milk detrimental to heat stress
- Low accuracy of active sires for heat stress

Is data from colder states useful for heat tolerance evaluation?

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***Short Communication:* Genotype by Environment Interaction Due to Heat Stress**

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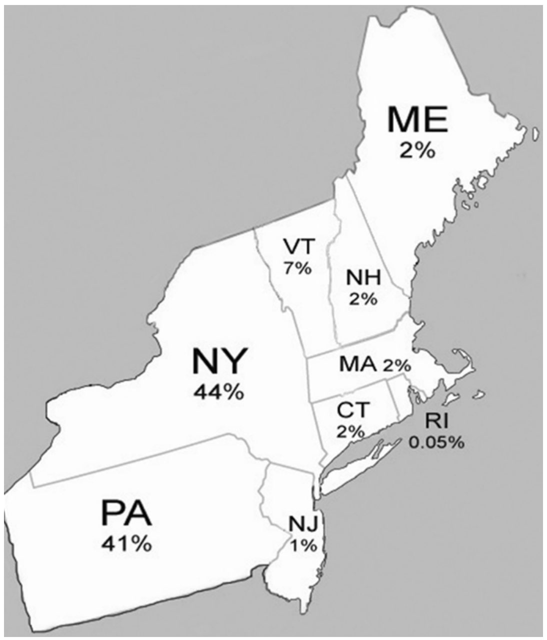
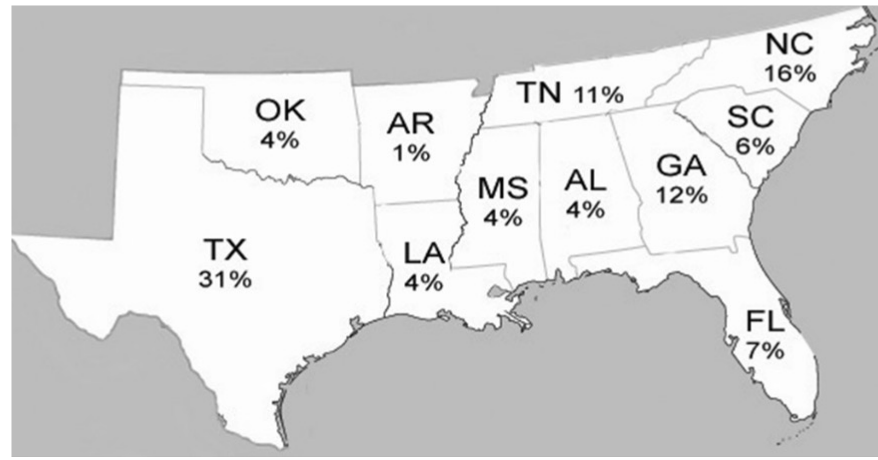


EBV_heat_south



EBV_heat_south

Correlation 0.8 for well proven bulls

Same threshold for all states – modeling details not too important

Optimal THI index?

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Temperature-Humidity Indices as Indicators of Milk Production Losses due to Heat Stress

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~ 700 citations

Different optimal THI in GA and AZ

Heat stress in later parities (Aguilar et al., 2009)

- Holstein U.S. test days
- 3-trait RR and RPT models
- Heat stress effect

- Estimation of parameters
- National evaluation

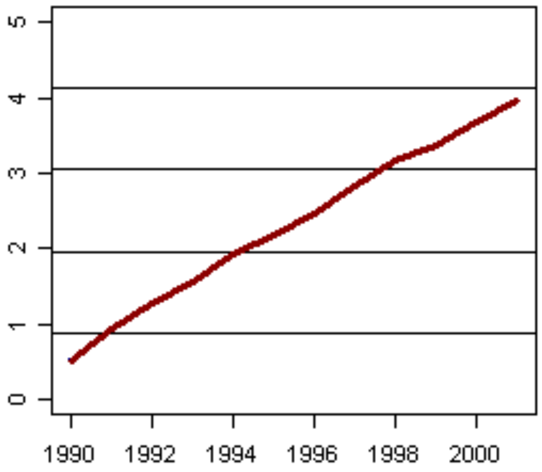
Variances for three-parity test-day repeatability model

	Milk			Fat (kg*100)			Protein (kg*100)		
	1	2	3	1	2	3	1	2	3
Regular	5.6	7.5	6.5	74	94	109	43	57	52.2
Heat(+5^{0}C)	4.0	7.0	9.0	37	75	142	22	48	108
Corr	-0.46	-0.38	-0.47	-0.39	-0.39	-0.30	-0.43	-0.36	-0.50

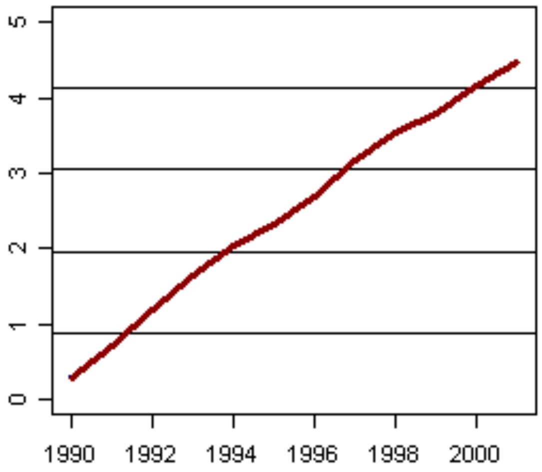
Genetic variance for heat stress increases up to 5 times in third parity

Genetic trends of daily milk yield for 3 parities – regular effect

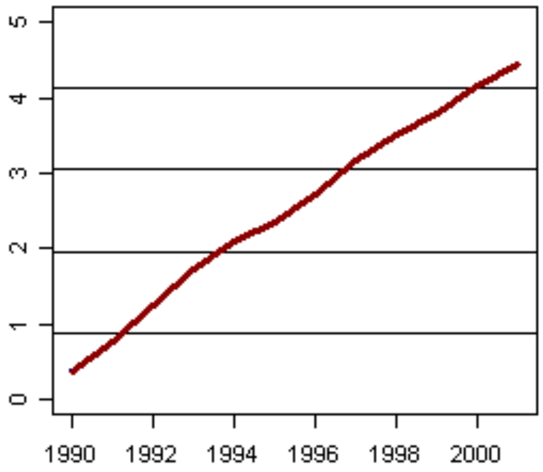
First



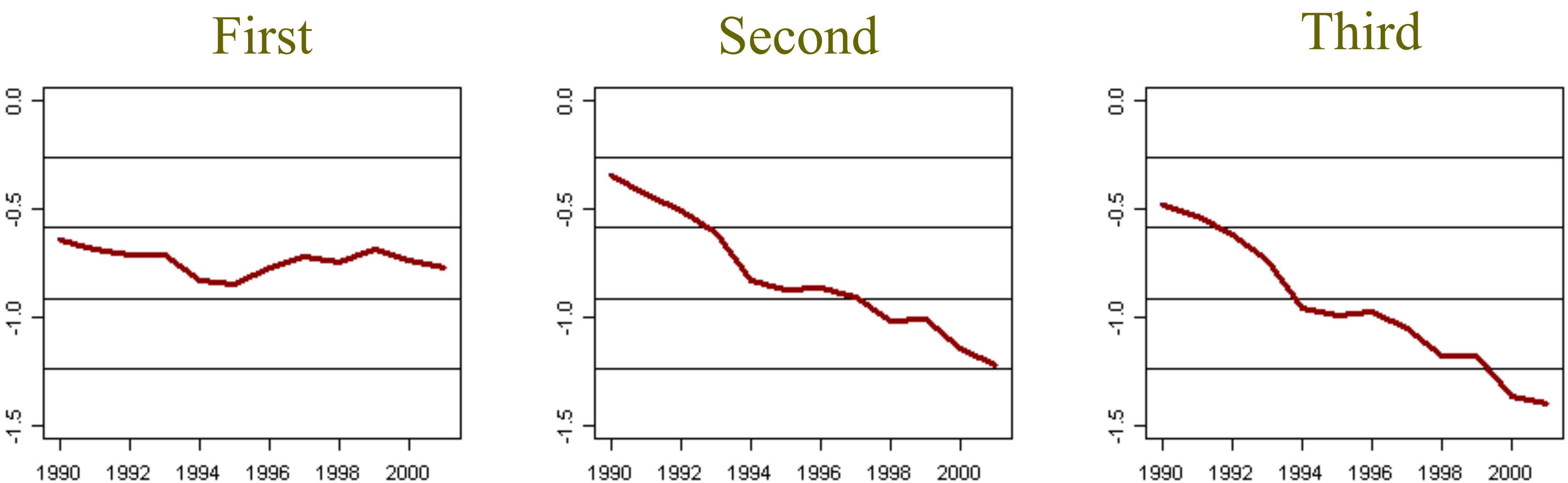
Second



Third



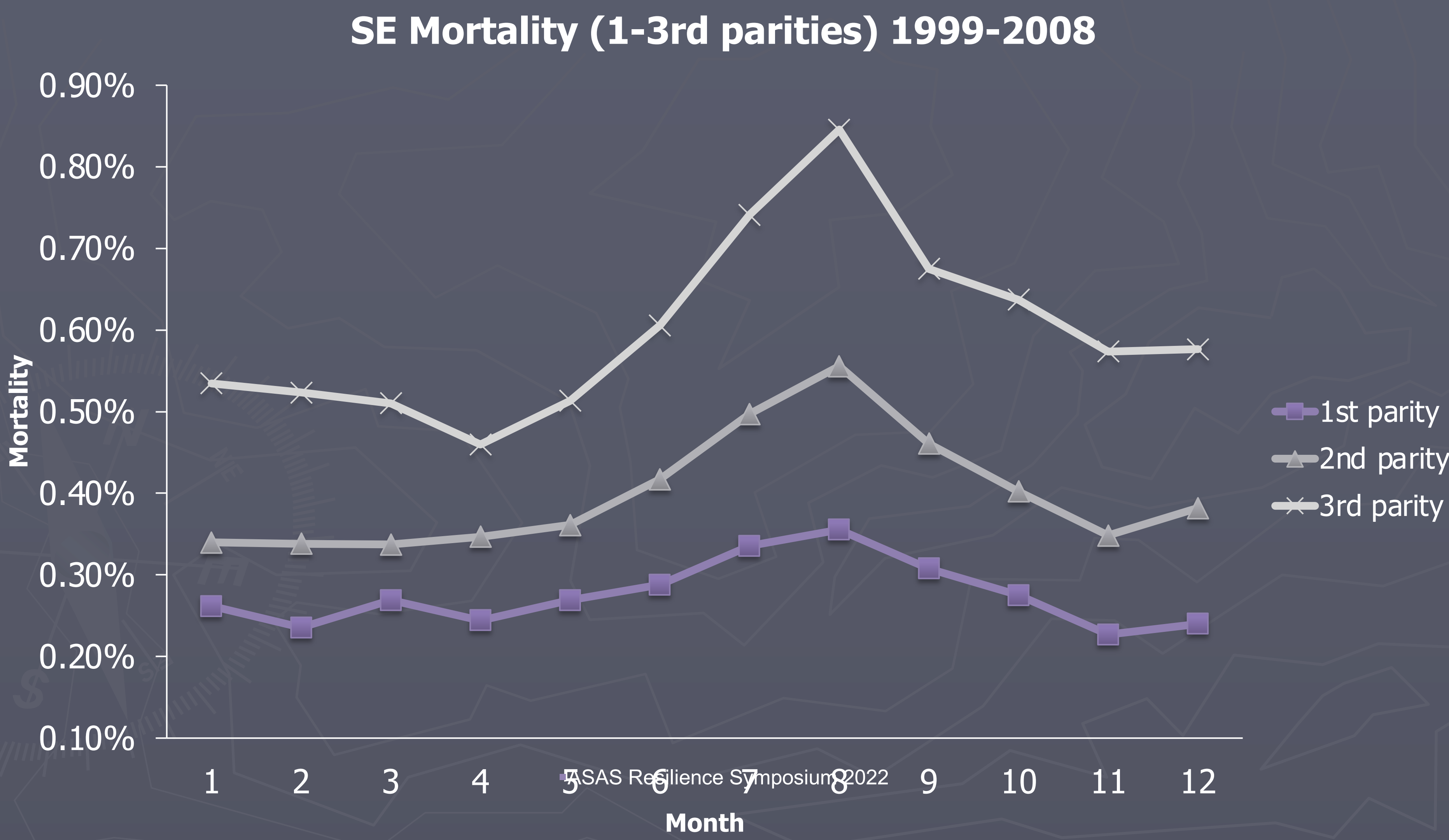
Genetic trends for heat stress effect at 5.5º C over the threshold



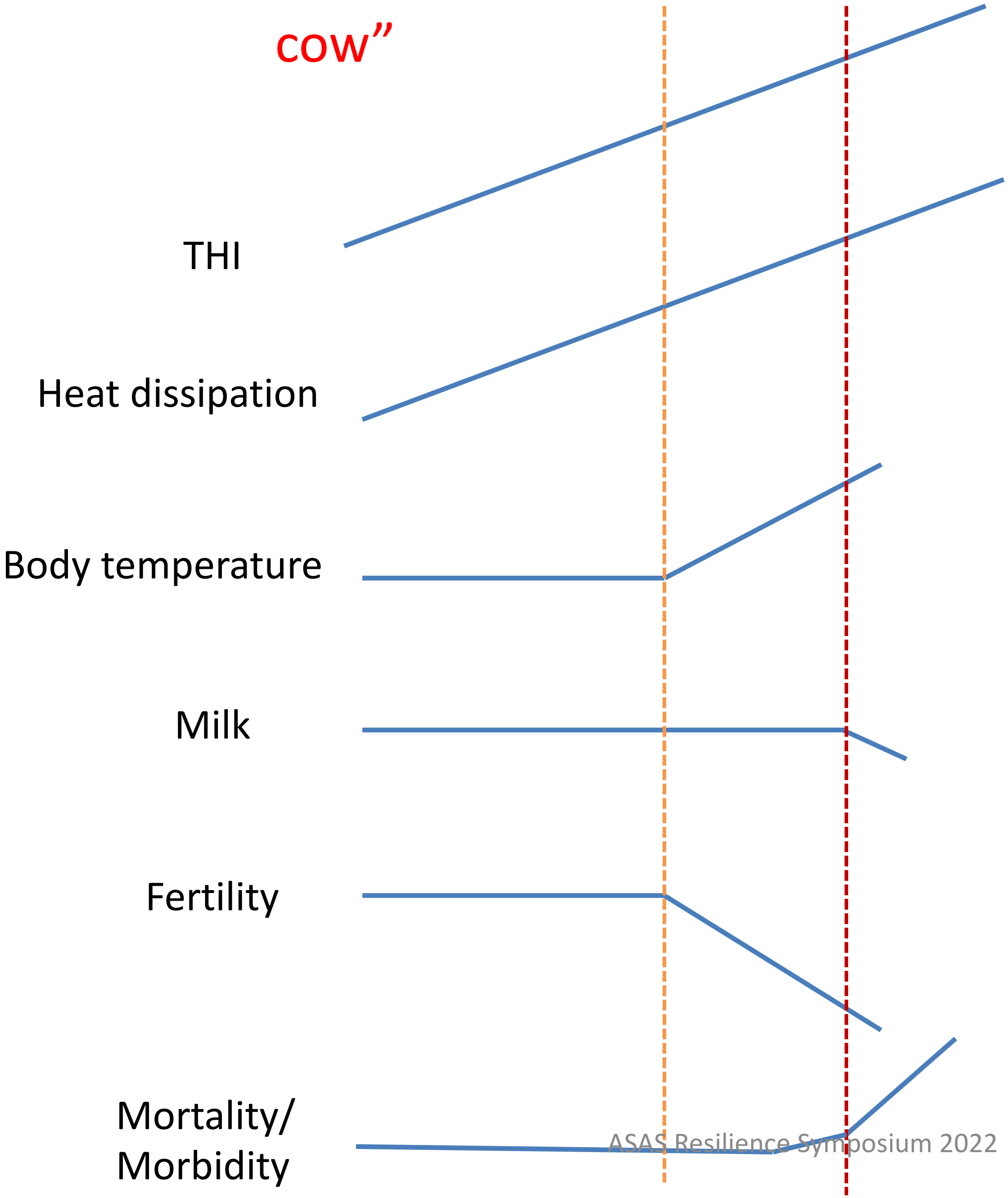
- Improvement higher than deterioration
- Test days capture fraction of heat stress information (Freitas et al., 2005)

Holstein mortality in SouthEast

Tokuhisa et al. (2011)



Profile of a "heat-tolerant cow"



- What is a heat tolerant cow?
  - Milk as long as possible?
  - Reduces production when dangerous?
  - Reduces production early to maintain reproduction
- Thresholds management specific
  - Match genotype to environment

Partially based on Dikmen et al. (2012)

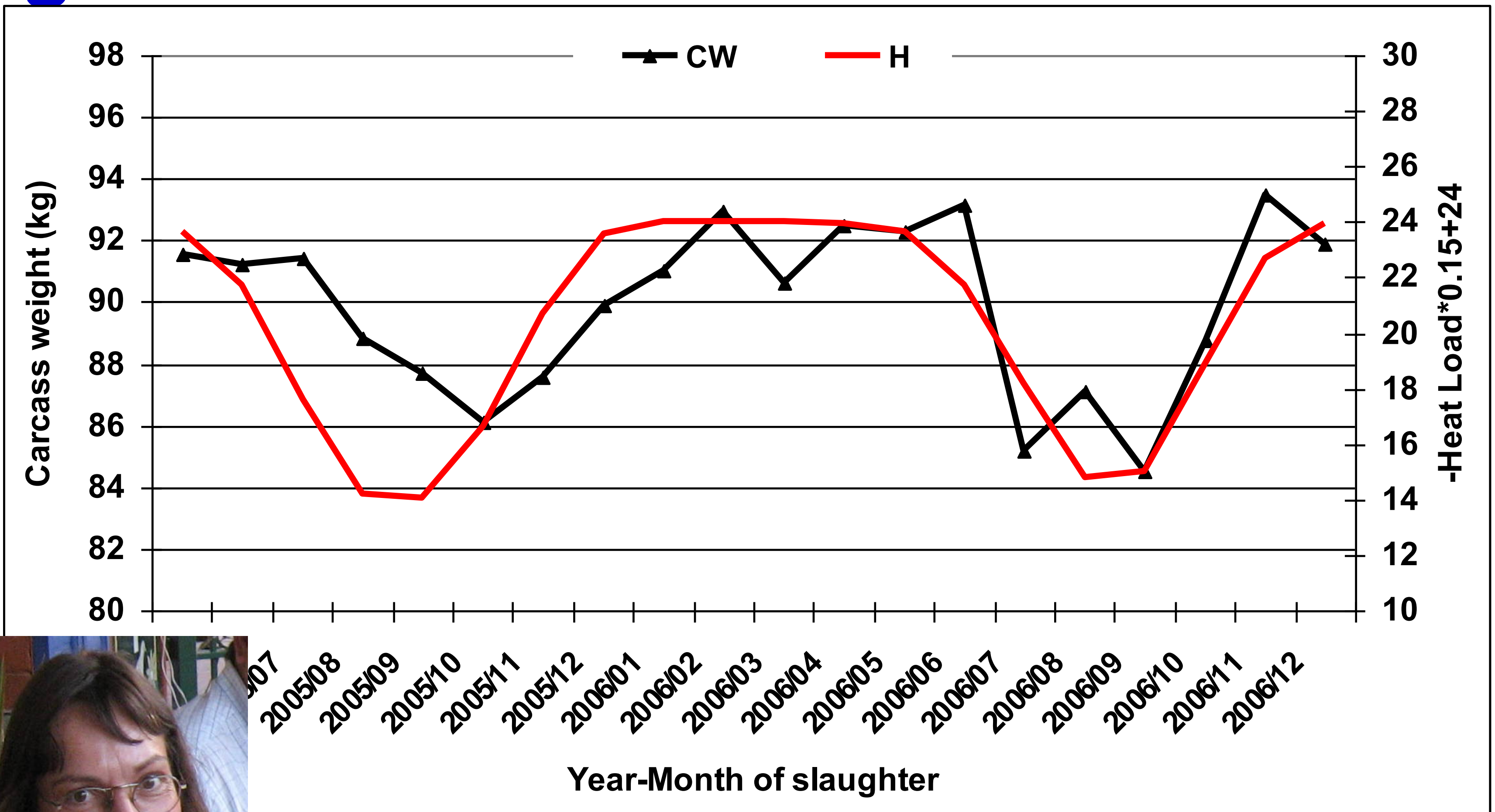
Why no implementation?

- No heat stress in USDA study by Wright et al. (2015)
- Poor milk and fertility → better sprinklers and fans
- Still poor fertility and poor heat detection → timed AI
- Low survival and not enough replacements → sexed semen

New developments

- Heat stress moving north
  - In Canada, threshold of heat stress 57 for protein (Campos et al., 2022)
- With genomics, high reliability even for cows
- Genetic evaluation for heat stress in Australia
- New interest by AI companies, e.g., Select Sires (Taylor et al., 2022), and possibly CDCB

Theoretical and realized heat loads in pigs

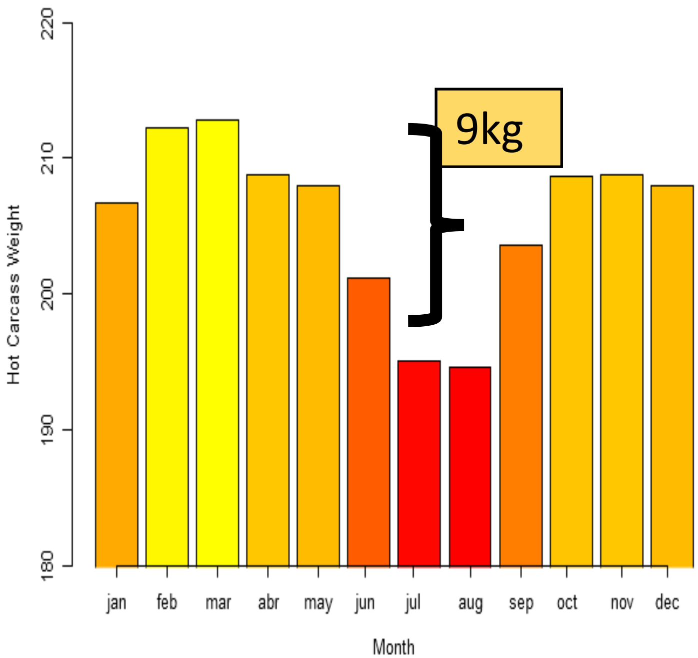


Zumbach et al., 2007

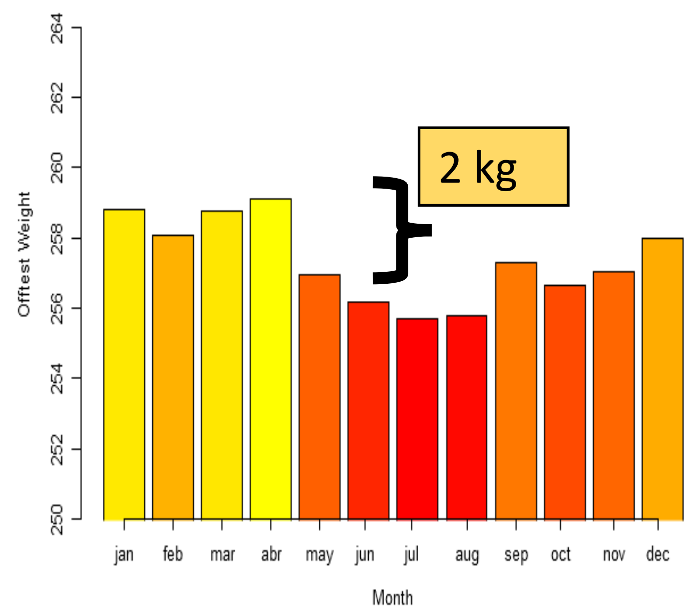
Heat stress in purebred and crossbred pigs

Fragomeni et al., 2016)

Crossbred

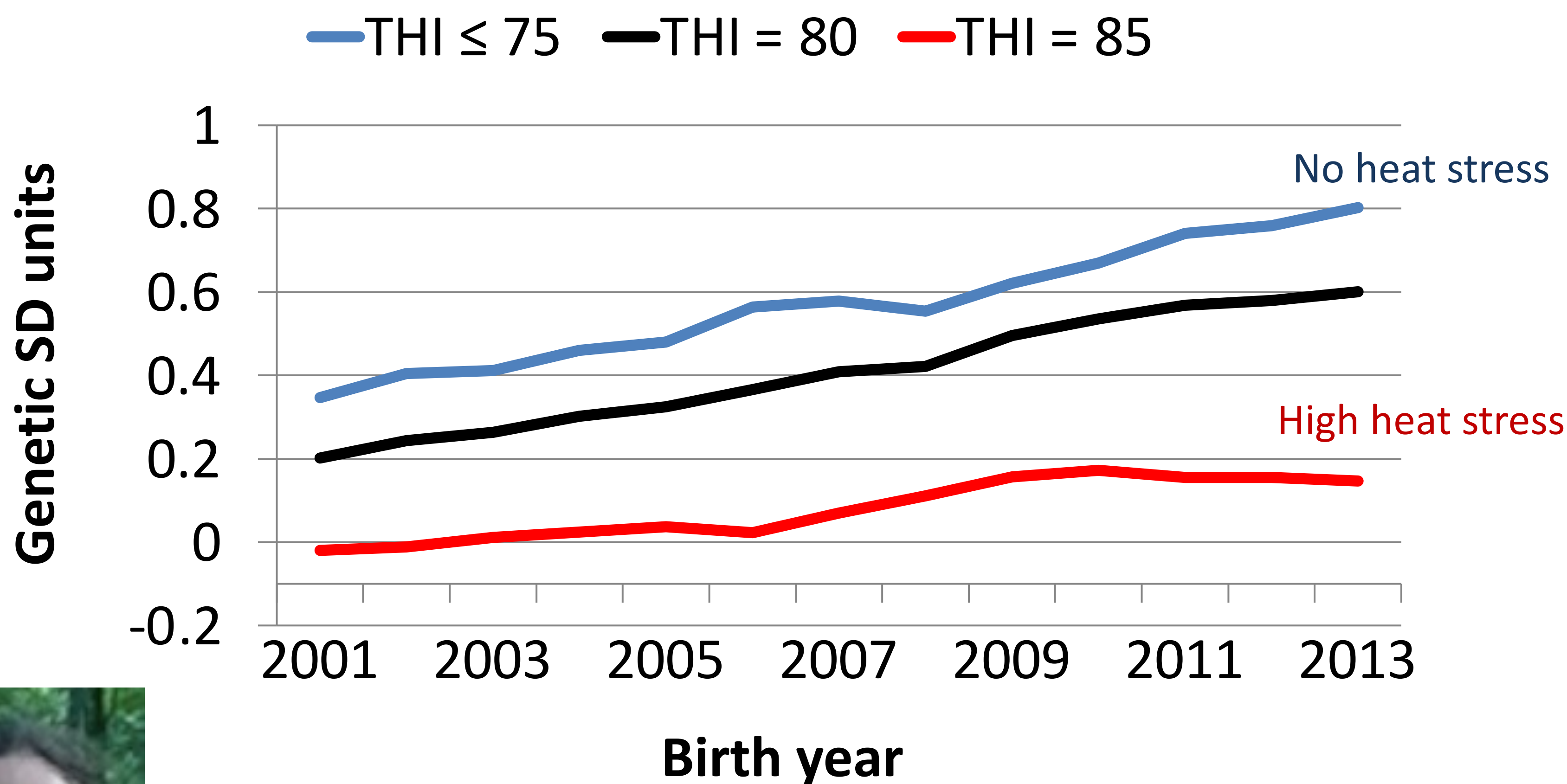


Purebred



Better environment almost eliminates heat stress

WW Direct Genetic Trend for Angus in Southeast



(Bradford et al., 2016)

ASAS Resilience Symposium 2022

J. Dairy Sci. 85:1586–1589

Studies on Genetics of Heat Tolerance in Dairy Cattle with Reduced Weather Information via Cluster Analysis

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Comparison of lactational responses of dairy cows in Georgia and Israel to heat load and photoperiod

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www.elsevier.com/locate/livsci

Utility of on- and off-farm weather records for studies in genetics of heat tolerance

M.S. Freitas [a,b,*], I. Misztal [b], J. Bohmanova [b], J. West [c]

J. Dairy Sci. 94:1592–1596
doi:10.3168/jds.2010-3491

Short communication: Genetic effects of heat stress on days open for Thai Holstein crossbreds

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Genetic components of heat stress in finishing pigs: Parameter estimation

B. Zumbach, I. Misztal, S. Tsuruta, J. P. Sanchez, M. Azain, W. Herring, J. Holl, T. Long and M. Culbertson

J ANIM SCI 2008, 86:2076-2081.
doi: 10.2527/jas.2007-0282 originally published online May 9, 2008

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J. Dairy Sci. 86:3718–3725

Seasonality of Days Open in US Holsteins

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Temperature-Humidity Indices as Indicators of Milk Production Losses due to Heat Stress

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J. Dairy Sci. 92:4689–4696
doi:10.3168/jds.2008-1985

Short communication: Trends for monthly changes in days open in Holsteins

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doi:10.3168/jds.2010-3893

Multiple trait genomic evaluation of conception rate in Holsteins

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RESEARCH ARTICLE
Open Access

Validation of single-step genomic predictions using the linear regression method for milk yield and heat tolerance in a Thai-Holstein population

Piriyaporn Sungkhapreecha[1], Ignacy Misztal[2], Jorge Hidalgo[2], Daniela Lourenco[2], Sayan Buaban[3], Vibuntita Chankitisakul[1,4] and Wuttigrai Boonkum[1,4]

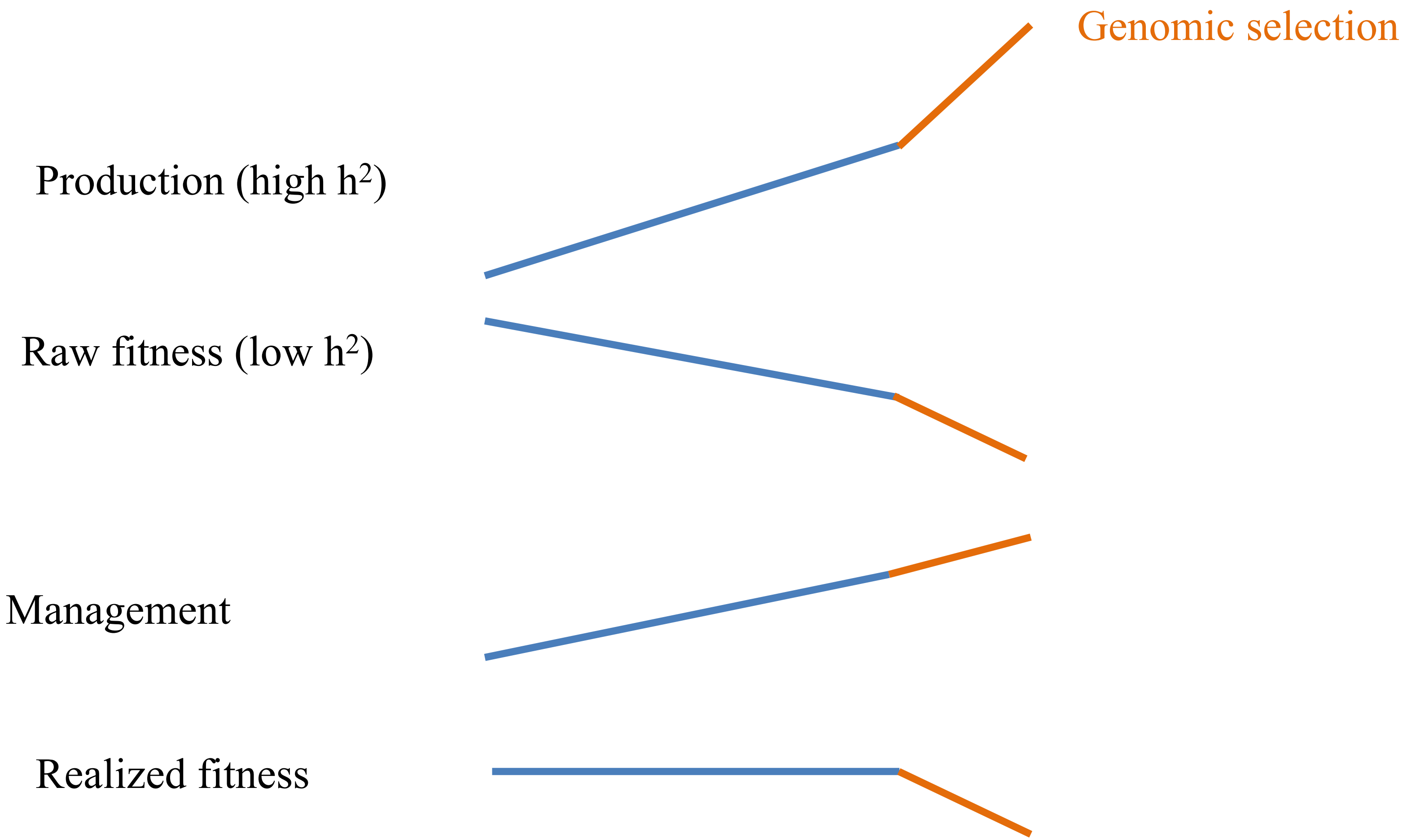
Lessons from heat stress studies

- Traits change over time
  - Indirect selection
  - Changing management

In genomics, use of more than 2 generations not useful (Cesarani et al., 2020)

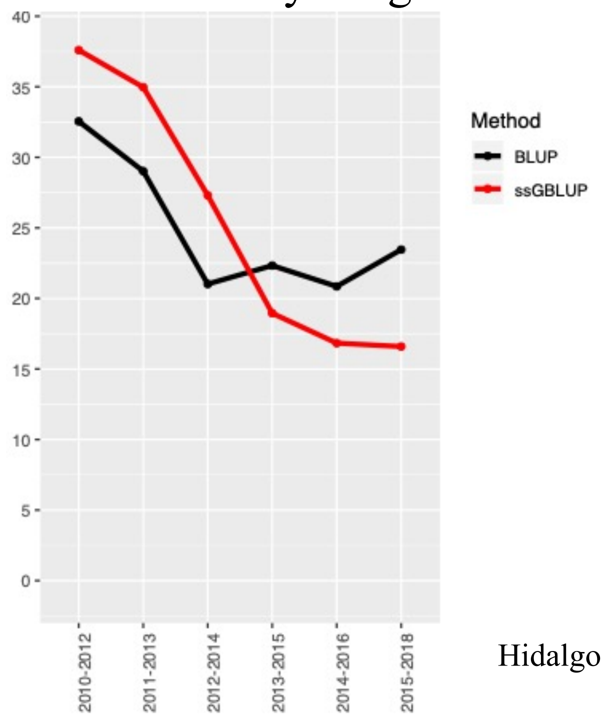
- Know your data, e.g., little heat stress in first parity
- Managements modifications for heat stress successful
- Genomics opens new frontier

Hypothetical trend changes with genomics

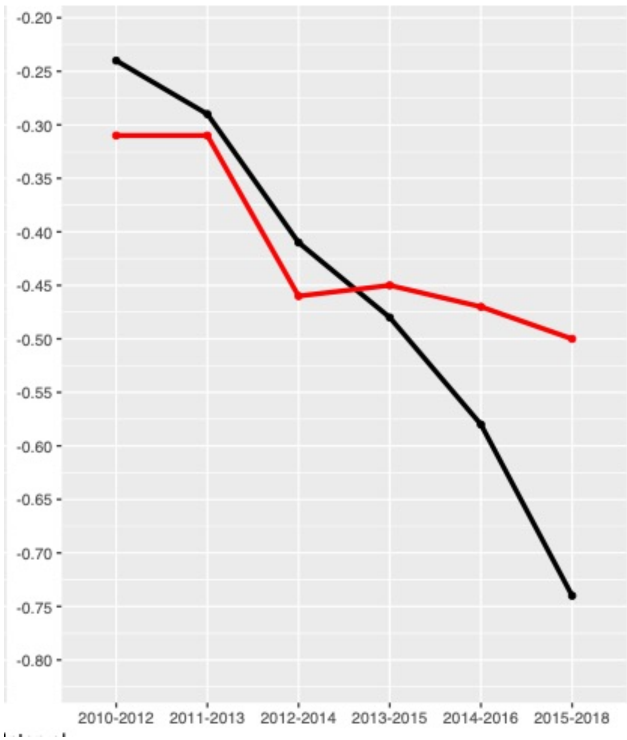


Changes in (co)variances in pigs due to genomic selection

Heritability for growth



Genetic correlation with reproduction



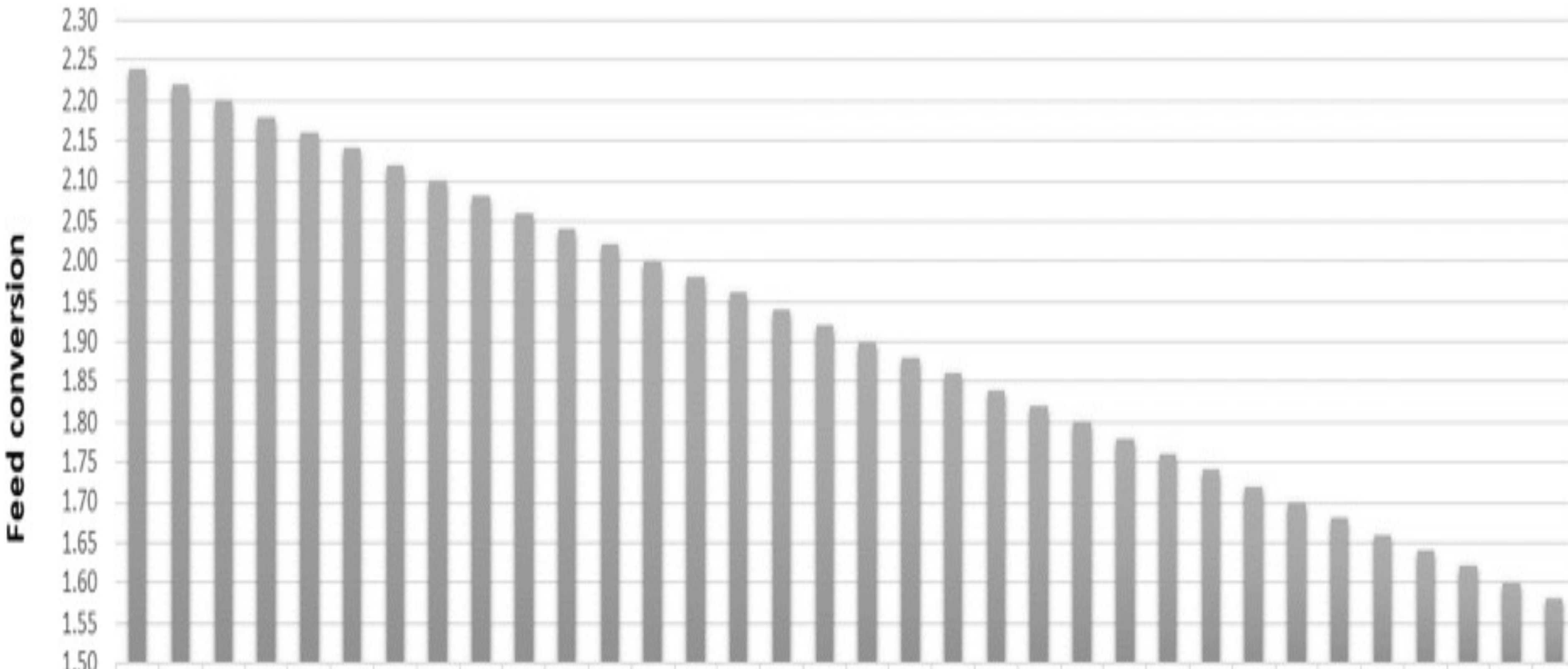
Hidalgo et al. (2019)

Heritability decreases, antagonistic correlations intensify

Is intensive selection for RFI detrimental?

Feed conversion from one company

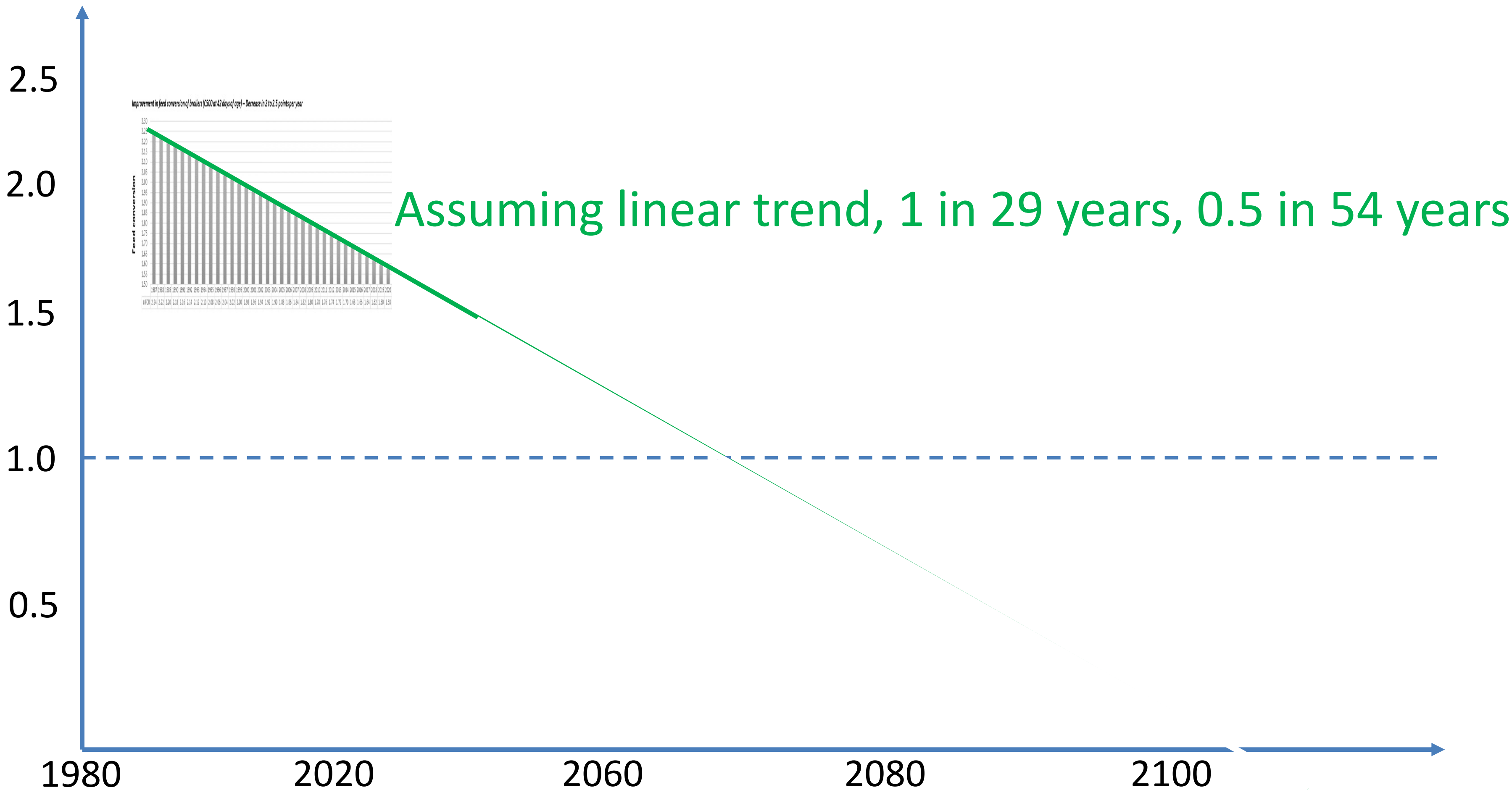
Improvement in feed conversion of broilers (C500 at 42 days of age) – Decrease in 2 to 2.5 points per year



	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
FCR	2.24	2.22	2.20	2.18	2.16	2.14	2.12	2.10	2.08	2.06	2.04	2.02	2.00	1.98	1.96	1.94	1.92	1.90	1.88	1.86	1.84	1.82	1.80	1.78	1.76	1.74	1.72	1.70	1.68	1.66	1.64	1.62	1.60	1.58

2.24 to 1.58 from 1987 to 2020

Feed conversion from one company



Conclusions

- Selection as optimization –winner and loser traits
  - Try to identify losing traits

- Less efficient species more robust

- Interplay between genetics and management improvements

- With genomics, opportunities for recorded traits and danger for unrecorded traits

Acknowledgements

USDA
NIFA
ANGUS THE BUSINESS BREED
AMERICAN ANGUS ASSOCIATION
AGI
zoetis
WAGYU
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U.S. Registered Holsteins
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PFHBiPM